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October 29-31, 2015
at
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Edited by
Eiko Yoshimoto

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National Society for Earthquake Technology- Nepal (NSET), Nepal

&

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PREFACE

On behalf of the Organizing Institutes of the 14th International Symposium on New Technologies for Urban Safety of Mega Cites in Asia (USMCA2015), I express our sincere welcome to all symposium participants and distinguished keynote and plenary speakers.

In the Asia and Pacific-Rim regions, rapid economic development and population growth and concentration has been fast accelerating the pace of urbanization. Unfortunately, the rapid expansion of infrastructure for urbanization is not adequately balanced with appropriate measures for their maintenance and management, and urban disasters have resulted. During the last ten years, there were many big disasters in Asia and the Pacific Rim regions, such as killer cyclones Sidr in Bangladesh (2007), Nargis in Myanmar (2008), and Aila in Bangladesh and India (2009), and Typhoon Ketsna (2009) and Haiyan (2013) in the Philippines, flooding in Mongolia (2009) and Pakistan (2010), the devastating earthquakes in Sichuan, China (2008), Sumatra (2009), Samoa (2009), Canterbury, New Zealand (2011), East-Japan, Japan (2011) and Kathmandu, Nepal (2015), and heat waves in Russia and Japan (2010). The number of fatalities and missing reported due to these disasters was well over 200,000. These unprecedented events illustrate the importance of urban safety.

The International Center for Urban Safety Engineering (ICUS) was established in 2001 at the Institute of Industrial Science (IIS), the University of Tokyo, with the objectives of carrying out research on urban safety towards the realization of safer cities, especially in Asia and the Pacific Rim regions, in the 21st century. For over a decade, ICUS has been actively tackling advanced research, as well as the enhancement of networking, information dissemination and collection in order to fully realize this vision. As a part of its activities, ICUS has been annually co-organizing USMCA since 2002 with its partners in the Asian region. In 2015, ICUS has jointly organized the 14th USMCA in Kathmandu, Nepal, with National Society for Earthquake Technology-Nepal (NSET) after half year since the Kathmandu earthquake.

During the two-day symposium, 87 papers in eight parallel sessions were presented with seven papers by keynote and plenary speakers. We also had research exhibitions in 9 booths. The objective of the symposium is to bring together decision makers, practitioners and researchers involved in the field of urban safety to share their expertise, knowledge and experience in tackling the critical issues for safer cities in Asia and the Pacific Rim regions. It also provides an environment to create and reinforce collaborative networks among experts in the fields relevant to urban safety. The symposium focused on urban safety and disaster mitigation, infrastructure management, and environment informatics.

I would like to thank all the members of the Steering, Technical and Organizing Committees as well as the Symposium Secretariat for their hard work, time and effort in putting this symposium together. I would also like to thank all our sponsors for their generous support and contribution. Thanks are also due to all those who have contributed towards making this symposium successful.

Kimiro MEGURO

Director of ICUS, IIS, The University of Tokyo
(Co-Chairman of Organizing Committee, USMCA2015)

PROGRAM OVERVIEW

Time	*Wednesday, 28 October* (कार्तिक ११, २०७२)
17:30-19:30	*Welcome dinner at Wellness organic club*
21:00-22:00	*Registration at Radisson Hotel*

Time	*Thursday, 29 October* (कार्तिक १२, २०७२)
08:00-08:50	*Registration (Radisson Hotel)*
09:00-09:40	*Opening Ceremony (Nepa Dhuku Hall)* *Chief Guest: Honorable Minister of Ministry of Federal Affairs and Local Development* *Chair: Honorable Vice-Chairman of National Planning Commission* *1. Address (Dr. Amod Mani Dixit, Executive Director of NSET, Nepal)* *2. Address (Prof. Kimiro Meguro - Director of ICUS, IIS, The University of Tokyo, Japan)* *3. Address (H.E. Mr. Masashi Ogawa, Ambassador of Japan to Nepal)* *4. Address (Chief Guest, Honorable Minister, Ministry of Federal Affairs and Local Development)* *5. Address (Mr. Hiroyasu Tonokawa, Senior Representative, JICA Nepal)* *6. Address and Closure of Opening Ceremony (Chair, Honorable Vice-Chairman of National Planning Commission)*
09:40-10:10 *10:10-10:30*	*Keynote in Plenary Session 1 (Nepa Dhuku Hall)* *Chair: Prof. Dr. Jib Raj Pokharel / Ms. Tomoko Matsushita* *Prof. Kimiro Meguro* *Lessons learned from past big earthquake disasters and comprehensive disaster management for implementation of disaster resilient society* *Dr. Amod Mani Dixit* *Two Decades of Earthquake Risk Management Actions Judged against Mw 7.8 Gorkha Earthquake of Nepal April 2015*
10:30-11:10	*Group photo – Coffee break & Exhibitions*

11:10-11:25 *11:25-11:55*	*Keynote in Plenary Session 2 (Nepa Dhuku Hall)* *Chair: Mr. Shiva Bahadur Pradhanang / Ms. Tomoko Matsushita* 1. *Prof. Reiko Kuwano* *Investigation into the multiple sinkholes in Pokhara, Nepal, occurred since November 2013* *Mr. Suresh Prakash Acharya* *Planning for Post-Earthquake Recovery and Rehabilitation*	
11:55-13:30	*Lunch at Radisson*	
	Room A	*Room B*
13:30-15:10	*Session Chair :* *Dr. Somanath Sapkota* *Prof. Kimiro Meguro* *Session 1 :* *Gorkha Earthquake 1*	*Session Chair :* *Dr. Pwint* *Prof. Sudhir Misra* *Session 2 :* *Pre-event countermeasure in Disaster Management 1*
15:10-15:50	*Coffee break & Exhibitions*	

15:50-17:30	*Session Chair :* *Mr. Padma Kumar Mainalee* *Prof. Ansary Mehedi Ahmed* *Session 3 :* *Gorkha Earthquake 2*	*Session Chair :* *Prof. Dr. Prem Nath Maskey* *Dr. Takaaki Kato* *Session 4 :* *Pre-event countermeasure in Disaster Management 2*
18:30-20:00	*Symposium Welcome Reception at Wunjala Moskva Restaurant*	

Time	*Friday, 30 October* (कार्तिक १३, २०७२)	
	Room A	*Room B*
09:00-10:40	*Session Chair :* *Dr. Ramesh Guragain* *Prof. Osamu Murao* *Session 5 :* *Pre-event countermeasure in Disaster Management 3*	*Session Chair :* *Mr. Tuk Lal Adhikari* *Dr. Muneyoshi Numada* *Session 6* *Environment Informatics / Infrastructure Management 1*
10:40-11:10	*Coffee break & Exhibitions*	
	Room A	*Room B*
11:10-13:00	*Session Chair :* *Mr. Yogeshwar K Parajuli* *Dr. Koji Matsumoto* *Session 7 :* *Post-event countermeasure in Disaster Management*	*Session Chair :* *Mr. Suresh Prakash Acharya* *Prof. Tan Kiang Hwee* *Session 8 :* *Environment Informatics / Infrastructure Management 2*
13:00-14:30	*Lunch at Radisson Hotel*	
	Keynote in Plenary Session 3 (Nepa Dhuku Hall) *Chair : Prof. Dr. Gokarna Bahadur Motra*	
14:30-15:00	*Dr. Somanath Sapkota* *Paleoseismology of Nepal Himalaya and its implication in Seismic Hazard Assessment*	
15:00-15:30	*Prof. Kazuki Koketsu* *Integrated research on great earthquakes and disaster mitigation in Nepal Himalaya*	
15:30-16:00	*Dr. Ramesh Guragain* *Building Damage Patterns of Masonry and Non-engineered Reinforced Concrete Buildings during April 25, 2015 Gorkha Earthquake in Nepal*	

16:00-17:00	*Closing Ceremony (Nepa Dhuku Hall)* *Chair : Dr. Yudai Honma* *Young Award Ceremony* *Announcement of USMCA2016* *NSET's Closing Speech* *ICUS's Closing Speech*
18:00-	*Farewell Party*

Time	*Saturday, 31 October* (कार्तिक १४, २०७२)
09:00-18:00	*Excursion (by bus) to the Earthquake Affected area Sankhu and Bhaktapur* *Excursion In-Charge: Mr. Surya Prasad Acharya* *(Interested/Registered International participants only)*

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Session 2

Pre-event countermeasure in Disaster Management 1

Session 3

Gorkha Earthquake 2

Session 4

Pre-event countermeasure in Disaster Management 2

Session 5
Pre-event countermeasure in Disaster Management 3

Session 6

Environment Informatics / Infrastructure Management 1

Session 7

Post-event countermeasure in Disaster Management

Session 8

Environment Informatics / Infrastructure Management 2

Photographs

Symposium Banner

Reception desk at Radisson hotel

Conference room

Opening Ceremony

H.E. Mr. Masashi Ogawa, Ambassador of Japan to Nepal

Mr. Hiroyasu Tonokawa, Senior Representative of JICA

Mr. Som Prasads Pandey, Minister of Industry, The Government of Nepal

Mr. Ganga Lal Tuladhar, Minister of Ministry of Federal Affairs and Local Development

Mr. Shiva Bahadur Pradhanang, President of NSET

Lightening the Nepali traditional lamp to inaugurate the USMCA2015

Keynote Speakers

Prof. Kimiro Meguro, Director of ICUS, IIS, UTokyo

Dr. Amod Mani Dixit, Executive Director of NSET

Prof. Reiko Kuwano, ICUS, IIS, UTokyo

Dr. Soma Nath Sapkota, Deputy Director General, Dept. of Mines and Geology, Government of Nepal

Prof. Kazuki Koketsu, UTokyo

Dr. Ramesh Guragain, NSET

Group photo at Radisson hotel on 29th October

Closing ceremony

Mr. Christopher Rollo, Country Programme Manager
UN-Habitat Philippines

Young-Researcher-Award recipient, Mr. Hideki Yamamoto was shaking hands with Dr. Amod Mani Dixit

Closing speech from NSET

Closing speech from ICUS

Booths

Break, Lunch, Banqet and Farewel Party








Excoursion to the Earthquake Affected area Shankhu and Bhaktapur


Visited to earthquake damage community, Sankhu Bazar and shelter


Visited to Shree Bhagawati Higher Secondary School at Sankhu


Visited to the shelter at Bhaktapur

Extended tour to Pokhara, 1st -3rd November

Group photo at Heritage site of Bhaktapur on 31st October

Visited to Krishnabhir landslide

Visited to the village of Gajuri, Malekhu

Visited to the village of Gajuri Malekhu

Visited the Kharepani Area, where the flashflood happened on 5th May 2012, Pokhara

Visited sinkholes in Armala VDC, Pokhara, the village mayor explained the cause that there were holes.

Rode on local bus around Kharepani Area

Lunch time

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ANNEX 1. INFORMATION ON EXCURSION (BY BUS) TO THE EARTHQUAKE AFFECTED AREA IN SANKHU AND BHAKTAPUR

SCHEDULE

Time	Location	Activity
9:00	Hotel	Start travel to Shankhu
9:00 – 10:15		Travel time to Shankhu
10:15 – 11:15	Sankhu settlement	Visit earthquake damage community, earthquake walk in Shankhu Bazar, observe recovery stage
11:15 – 12:00	Bhagyodaya School Shankhu	Observe disaster impact in School, compare the performance of retrofitted and non-retrofitted school building, interact with school principal and teacher
12:00 – 13:00		Travel to NSET
13:00 – 14:00	NSET Bhainsepati	Lunch
14:00 – 15:00	NSET Bhainsepati	An Interaction on earthquake response and activities of NSET
15:00 – 15:30	Travel to Bhaktapur	
15:30 – 17:00	Bhaktapur	Visit Heritage site of Bhaktapur, observe earthquake impact and recovery and reconstruction status
17:00 – 17:45	Travel back to hotel	
17:45 onwards	Free time	

Note: Entry fee to Bhaktapur for Foreigners: US$ 10.

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ANNEX 2. INFORMATION ON EXTENDED TOUR TO POKHARA

November 1-3, 2015

Schedule

Date	Time	Location	Description
November 1	8.00	Leave the Hotel in Kathmandu	Heading towards Dhading
	10.00 to 11: 00	Gajuri, Malekhu	Building Damage due to Gorkha Earthquake (intensity VII to VIII as of USGS)
	12.00 to 12.30	Krishnabhir landslide	Stabilization of Krishnabhir landslide
	13.00 to 13.45	Lunch	Venue TBC
	14.00	Towards Pokhara	Around 17.00 reach to Phokhara
November 2	8.00	Leave the hotel	Heading towards Kharepani
	9.00 to 11.00	Kharepani Area	Flashflood of on 5th May 2012 caused death of 72 persons and a significant damage to infrastructure and property
	12.00 to 13.00	Armela	Sinkholes are appeared in the entire Thulibesi Phant, Armala village.
	13.30 to 14.00	lunch	Venue: TBC
	14.00 to 17:00	Observation in Phokhara	
November 3	8.00	Leave the hotel	Heading towards Byas Municipality Tanahu
	9.30 to 10.30	Vyas Municipality	Observation of Building Code Implementation program at Municipal level.
	12.00 to 12.45	Lunch	Venue: TBC
	13.00		Heading towards Kathmandu

Keynote& Plenary Session

Lessons learned from past big earthquake disasters and comprehensive disaster management for implementation of disaster resilient society

Kimiro MEGURO[1]

[1] Director/Professor, International Center for Urban Safety Engineering (ICUS), Institute of Industrial Science (IIS), The University of Tokyo (UTokyo), Japan
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ABSTRACT

There have been many big earthquakes causing numerous casualties and large economical loss in the world. Even in the 21st century, there are nine earthquake disasters with more than 5,000 fatalities. For minimizing negative impact due to natural hazard, there is a comprehensive disaster management system, which is composed of seven-phase countermeasures. They are three pre-event measures, 'damage mitigation', 'preparedness', and 'disaster prediction and early warning', and four post-event countermeasures, 'damage assessment', 'emergency disaster response', 'recovery', and 'reconstruction'. There are three players for each countermeasure, individuals and companies for self-help effort, community and/or group for mutual assistance, and national to local governments for public support.

Based on the experiences and lessons learnt from past disasters, I have developed a new system that can support making proper regional disaster management plan and this will be a base for making action plans for each player and each phase of countermeasures considering natural and social conditions of the target regions. With the proposed system, ideal and current situation matrixes of disaster countermeasure can be created and by comparing the two, prioritized specific actions for each player can be indicated.

We cannot prevent earthquake occurrence. Earthquake does not kill people but structures do. It is very difficult to save people by post-event countermeasures, such as search and rescue operations. Today's poor-quality structures will be negative inheritance in next generations and attack their society. Today's poor disaster management system will cause more damage in the future. However we can drastically reduce earthquake damage by creating disaster resilient society which is possible by implementing seven-phase structural and non-structural measures, both of which are locally feasible and acceptable, in a well-balanced manner.

Keywords: disaster resilient society, comprehensive disaster management, pre-event and post-event countermeasure, disaster life cycle

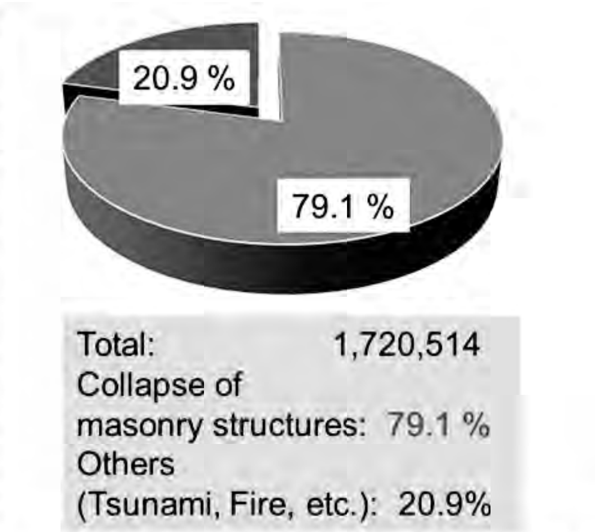
1. INTRODUCTION

There have been many large earthquakes causing many casualties and structural damage in the world. Figure 1 shows 21 catastrophic earthquake disasters with over 5,000 fatalities in the last 100 years including nine disasters happened in the 21st century. Excluding four events, collapse of masonry structures was the major cause of damage and accounted for approximately 80 % of all fatalities. Due to the following three reasons, many more people have been killed by the collapse of masonry structures. First, is the failure behavior of masonry structures is brittle and the occupants cannot get enough evacuation time when it collapses, secondly, it is very difficult to keep survival space as the size of structural members and main materials, i.e. bricks, stones, and blocks is small and survival space is filled with these small pieces of materials, and thirdly, during the collapse of masonry structure, heavy dust is generated and the occupants are suffocated even if they survived the collapse.

In this paper, to reduce earthquake damage and implement earthquake disaster resilient society, I will introduce some important points on what we should do.

Year	Location	Fatalities	Magnitude
1915	● Avezzano (Italy)	32,610	7.0
1920	● Haiyuan (China)	200,000	7.8
1923	✹ Kanto (Japan)	105,000	7.9
1927	● Gansu (China)	40,900	7.6
1934	● Bihar, India-Nepal	10,700	8.1
1939	● Erzincan (Turkey)	32,700	7.8
1948	● Asgabat (Tukemenistan)	110,000	7.3
1970	● Cimbote (Peru)	70,000	7.9
1976	● Tangshan (China)	242,769	7.5
1990	● Western Iran	50,000	7.4
1995	O Kobe (Japan)	6,434	7.3
1999	● Turkey	17,118	7.6
2001	● Gujarat (India)	20,085	7.6
2003	● Bam (Iran)	31,000	6.6
2004	▣ Sumatra (Indonesia)	227,898	9.1
2005	● Kashmir (Pakistan)	86,000	7.6
2006	● Java (Indonesia)	5,749	6.3
2008	● Sichuan (China)	87,587	7.9
2010	● Haiti	316,000	7.0
2011	▣ East-Japan (Japan)	20,896	9.0
2015	● Kathmandu (Nepal)	8,000	7.8

Major cause of damage { ● : Collapse of masonry structures, ✹ : Fires, O : Collapse of wooden structure, ▣ : Tsunami



(Source: http://earthquake.usgs.gov/earthquakes/world/world_deaths.php)

Figure 1 Catastrophic earthquake disasters with over 5,000 fatalities in the last 100 years

2. COMPREHENSIVE DISASTER MANAGEMENT SYSTEM

In order to minimize the negative impact due to natural hazard, there is a comprehensive disaster management system as shown in Figure 2. This management system is composed of seven-phase countermeasures. They are three pre-event measures, ‘damage mitigation’, ‘preparedness’, and ‘disaster prediction and early warning’, and four post-event countermeasures, ‘damage assessment’, ‘emergency disaster response’, ‘recovery’, and ‘reconstruction’. All seven-phase countermeasures (six-phase if recovery and reconstruction are considered as one phase) combined is called “Disaster Life Cycle” and information and communication play important roles at all phases.

Followings are brief explanation of each phase of the countermeasures. 'Damage mitigation' consists of two countermeasures i.e. structural mitigation and land use management mitigation measure, resiliency of the site is improved and damage will be reduced. Structural mitigation measure improves structural performance, such as seismic retrofit of weak structures in case of earthquake disaster and increasing height of embankment and breakwater in case of flood and Tsunami disaster. Land use management mitigation measure is the effort by which people are guided to move from high disaster potential areas, such as bad soil condition area and low land with high flood risk to better conditioned area. The aim of 'Preparedness' is to reduce affected area or velocity of propagation of negative impact by preparing before the hazard attacks, i.e. preparation of organizations for disaster response, pre-disaster recovery and reconstruction plan and disaster manual, and also conducting training and drill. 'Disaster prediction and early warning' is that although earthquake prediction is difficult, practically impossible but in case of typhoons and Tsunami disaster, we can predict disaster and give the information before the hazard attack and then we can drastically reduce damage, especially human casualties. After hazard attack, what we should do first is 'damage assessment' that is to assess the amount and kind of damage and their distribution as soon and accurate as possible. Based on the assessment result, what we should do next is 'emergency disaster response' and the main purpose is prevention of secondary damage and to rescue the people, and it does not include the recovery of the affected area. Therefore, 'recovery', and 'reconstruction' should follow. Considering the fact that disaster happened under the condition of what the affected area was, the aim of 'recovery', and 'reconstruction' is not enough to just recover what it was before hazard attacked. Better conditioned area should be created using the disaster as an important opportunity to improve the affected area. This is called 'Build Back Better' that is an important concept included in the statement by Japanese government at the United Nations' World Disaster Conference held in March 2015 in Sendai, Miyagi Prefecture, Japan.

At all seven phases of disaster management, it is necessary to understand that the government is not only the player in disaster management. There are three players for each countermeasure, individuals and companies for self-help effort (SE), community and/or group for mutual assistance (MA), and national to local governments for public support (PS). Also, it is necessary to act based on the idea that one must protect one's own life.

Figure 2 Comprehensive disaster management system for minimizing negative impact

3. DISASTER COUNTERMEASURE MATRIX AND PROMOTION OF COMPREHENSIVE DISASTER MANAGEMENT

3.1 Disaster Countermeasure Matrix

Disaster Countermeasure Matrix (DCM) shown in Figure 3 represents the idea that in all countermeasure phases, there are tasks for three players for PS, MA, and SE. The countermeasure by three players is often complementary to each other and it must be well-balanced. In other words, if the work is concentrated in only PS part, the cost could be enormous while if each individual and company put an effort and cooperate with each other, it could be much more effective with less cost. Therefore, PS should promote MA and SE rather than enhancing people's dependency to PS. In order to realize this situation, disclosure of information about the disaster risk to the general public becomes important.

Event

		Damage Mitigation	Prepared-ness	Prediction and Early Warning	Damage Assess-ment	Emergency Disaster Response	Recovery and Reconstruction
SE (Self-help effort)	H						
	S						
MA (Mutual assistance)	H						
	S						
PS (Public Support)	H						
	S						

Issue of Disaster Countermeasures Basic Act: Participation of the general public

Figure 3 Disaster Countermeasure Matrix (DCM)

3.2 Method for promoting comprehensive disaster management

In order to efficiently conduct disaster management countermeasures, it is important to make appropriate combinations of regional characteristics, target disaster types, available time and budget at each phase. Figure 4 shows the specific procedure. Local government officials in disaster section should start by filling up the matrix with as many countermeasures as possible. This approach can be applied not only for earthquake and Tsunami but also for all other types of disaster. However, the contents will differ based on the type of hazard and thus DCM for each type of disaster needs to be created and all necessary disaster matrixes should be integrated (Figure 5).

1) Describe specific countermeasures as many as possible for each phase and player with structural (H) and non-structural (S) measures. This is called Ideal Situation Matrix (ISM) to achieve goal (G). Then, next describe specific countermeasures that they have done so far in target area. This is called Current Situation Matrix (CSM) to show the present environment (P) in terms of disaster countermeasures.
2) The difference between the "ISM" and "CSM" (G-P) indicates the Action Item Matrix (AIM) that needs to be conducted with priority.

3) For each countermeasure in the “AIM”, add the responsible division, necessary time & budget and its effect. It is important to work on this section together with site operators because it is not easy for disaster division officials to evaluate time, budget, and effect.
4) Examine available time and budget with the result of 3) and determine realistic countermeasures that can achieve maximum effect within the given condition. It is easy to understand that even for the same action, necessary time and budget can be different depending on the region and its effect can be also different. Based on the evaluation of each measure using AIM, create project plan by picking up best combination of measures that achieve maximum effects.
5) By practicing this process over several years, PDCA management cycle is put into practice and effective progress management is realized as shown in Figure 6.

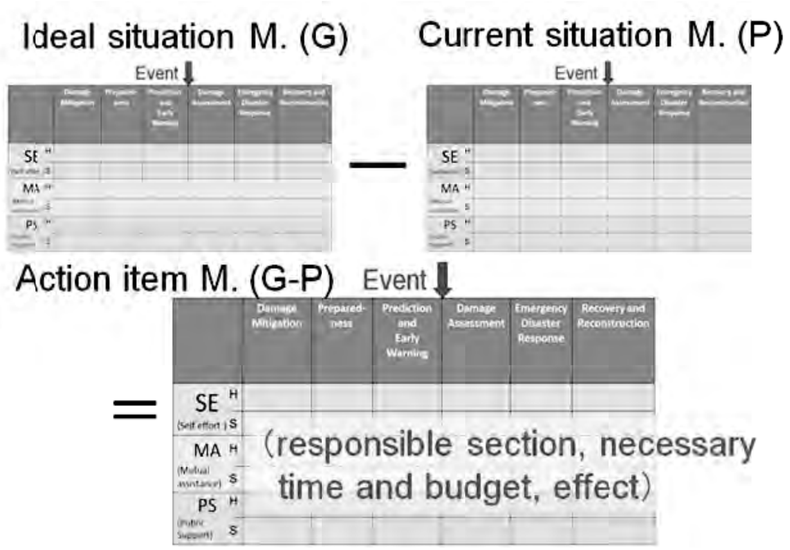


Figure 4 Making of Action Item Matrix (AIM)

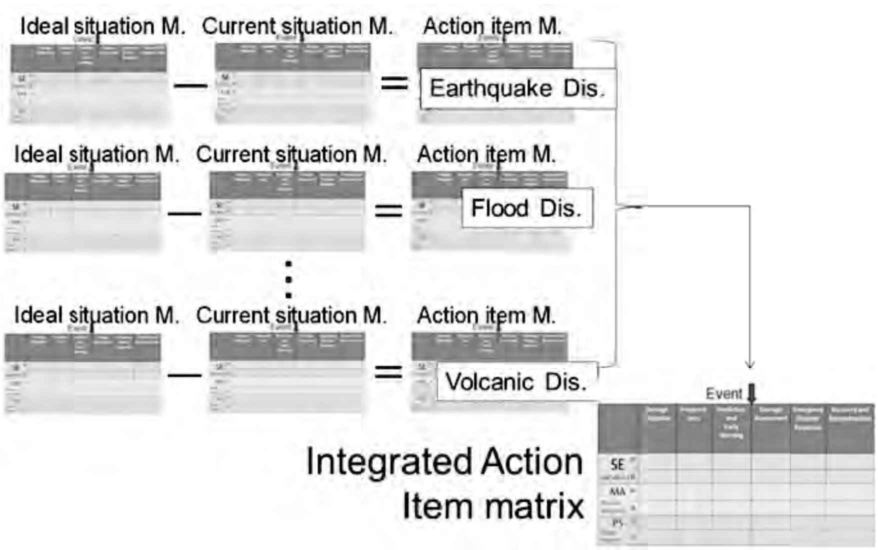


Figure 5 Making of Integrated Action Item Matrix (IAIM)

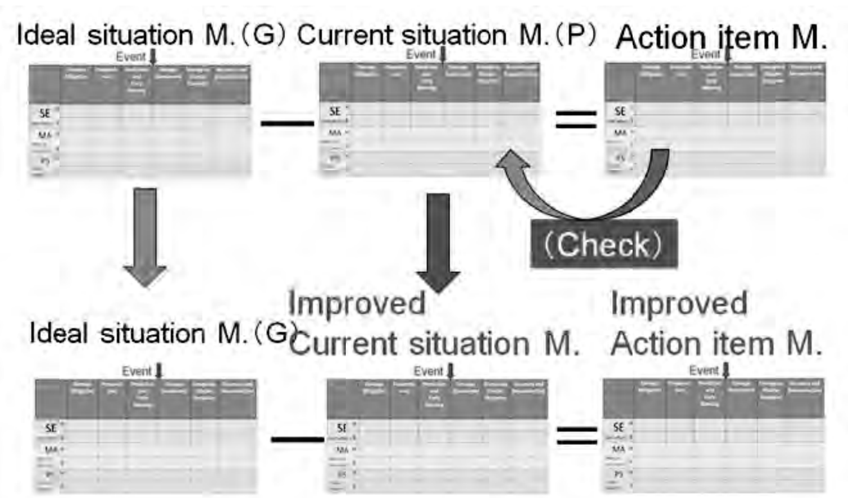


Figure 6 PDCA cycle of making AIM and its implementation

4. REAL SITUATION OF PAST DISASTERS AND INTERNATIONAL PROJECTS FOR DISASTER REDUCTION

4.1 Real Situation of Past Earthquake Disasters

There was M 7.3 earthquake happened near Kobe City, Hyogo Prefecture in Japan at 5:46 (local time) on January 17, 1995. By this earthquake, till today, total of 6,437 people have been killed and are still missing. But, within the first two weeks, approximately 5.5 thousand people were killed in the entire affected areas and about 70 % of them were in Kobe City. Medical examiners in Hyogo Prefecture checked all the dead bodies carefully and examined direct cause and death time. According to their examination results, 83.3 % of total death toll were killed by structural damage, mainly collapse of old timber houses constructed before the final revision of structural code at that time. Among the rest of the fatalities, which was 16.7 % of total death toll, over 90% of them were found in burn areas. That was 15.4 % of total fatalities and it could be divided into two groups, 2.3 % and 12.2 %. Regarding 2.3 % fatalities, they were burn out perfectly and became born chips, therefore, it was impossible even for professional medical examiners to identify the direct cause. Medical examiners could not judge if people were still alive when the fire attacked them or not. However, regarding 12.2 % fatalities, medical examiners could make clear that people were still alive when the fire attacked and killed them. Therefore, it can be said that over 95 % of the fatalities were killed by the structural damage.

Table 1 shows the time of death evaluated by medical examiners and ordinary doctors. According to the medical examiners, accuracy of the data obtained by ordinary doctors were low as they were not trained to examine the death time. Therefore, ordinary doctor often reported that death time was when the dead body was carried to the hospital or the day of the earthquake. When you see the data obtained by medical examiners, you can clearly understand that within the first 14 minutes, approximately 92 % of the total fatalities were killed.

After the Kobe earthquake, many mass media reported that if information of damage could smoothly reach central part of Japan, such as Kasumigaseki and Nagata-cho, if Prime minister could performed better, and if Self-defense force had had a system by which they had been able to decide by themselves to visit affected areas without waiting for request by the local governors, many fatalities could have survived. But these news were not correct. Even if we had established such a system before the Kobe earthquake, it would have been impossible to save them. There was only one way that could save them which was to retrofit or rebuild weak structures that killed them before the earthquake.

Table 1 Time when the fatalities were killed by the 1995 Kobe Earthquake (in Kobe City)

Time of death		No. of Casualties by Medical Examiners		by Ordinary Doctors		Total Number
1/17	~6:00	2,221	2,221 (91.9 %)	719	719 (58.2 %)	2,940 (80.5 %)
	~9:00	16	2,237 (92.6 %)	58	777 (62.9 %)	3,014 (82.6 %)
	~12:00	47	2,284 (94.5 %)	61	838 (67.9 %)	3,122 (85.5 %)
	~23:59	12	2,296 (95.0 %)	212	1,050 (85.0 %)	3,346 (91.6 %)
	unidentified	110	2,406 (99.6 %)	84	1,134 (91.8 %)	3,540 (97.0 %)
1/18		5	2,411 (99.8 %)	62	1,196 (96.8 %)	3,607 (98.8 %)
1/19			2,411 (99.8 %)	13	1,209 (97.9 %)	3,620 (99.2 %)
1/20		2	2,413 (99.9 %)	8	1,217 (98.5 %)	3,630 (99.4 %)
1/21		1	2,414 (99.9 %)	6	1,223 (99.0 %)	3,637 (99.6 %)
1/22		1	2,415 (100.0 %)	1	1,224 (99.1 %)	3,639 (99.7 %)
1/24			2,415 (100.0 %)	1	1,225 (99.2 %)	3,640 (99.7 %)
1/25		1	2,416 (100.0 %)	1	1,226 (99.3 %)	3,642 (99.8 %)
1/26			2,416 (100.0 %)	2	1,228 (99.4 %)	3,644 (99.8 %)
1/27			2,416 (100.0 %)	1	1,229 (99.5 %)	3,645 (99.8 %)
1/28			2,416 (100.0 %)	1	1,230 (99.6 %)	3,646 (99.9 %)
2/4			2,416 (100.0 %)	1	1,231 (99.7 %)	3,647 (99.9 %)
	No record		2,416 (100.0 %)	4	1,235 (100.0 %)	3,651 (100.0 %)
Total Number		2,416		1,235		3,651

(after Hyogo Medical Examiners)

We should recognize that the number of people who can be saved by search and rescue operation is very limited. Since the time of the earthquake to the third day, there were about 45 to 50 thousand people who were trapped under the damaged structures in all affected areas by the 1995 Kobe earthquake. Among them, about 8 thousand people were taken out from damaged structures by public support services, such as police, fire fighters and self-defense force. 27 thousand people were rescued by local people and 10 to 15 thousand people came out from the damaged structures by themselves. Survivors' ratio of people who were rescued by public support services was the lowest. Rescue dogs that came from Switzerland, UK and France, could find totally 13 dead bodies and no survivors.

After the 2015 Gorkha earthquake, Nepal, Japanese government dispatched the Urban Search and Rescue team composed of 70 specialists with advanced equipments and rescue dogs by specially chartered airplane. The team left from Japan on the next day (April 26), but on April 27, the team could not land on Kathmandu international airport because of airport operation problem by the earthquake. The team could start search and rescue activities form April 28 and finished May 8. Japanese government, Ministry of Foreign Affairs reported on their Website that Nepal government and people express their appreciation to the team, but result of their search and rescue activities of about 800 man-day was that they could recue no person and find one dead body. We should recognize how difficult it is to save people who are trapped or buried under the damaged structures by search and rescue activities, especially in case of collapse of masonry structures.

4.2 International Disaster-related Projects Conducted in the World

As mentioned already, it is very difficult to save people by search and rescue activities and not many lives can be saved by post-event countermeasures. However, among all international projects carried out during 1990-2010, in both the number of projects and total budget, projects related to 'emergency response' was the top as shown in Figure 7. When we see the number of projects, 90 % is 'emergency response' projects. Only 10 % is related to 'mitigation and preparedness' and 'recovery and reconstruction'. This is the order of standing out and the number of reports by mass media. Mass media only reported disaster related projects just after a large disaster happened, therefore, the pre-event countermeasure, which is the most important and efficient countermeasure to reduce damage, cannot get attention from the general public and funding organizations.

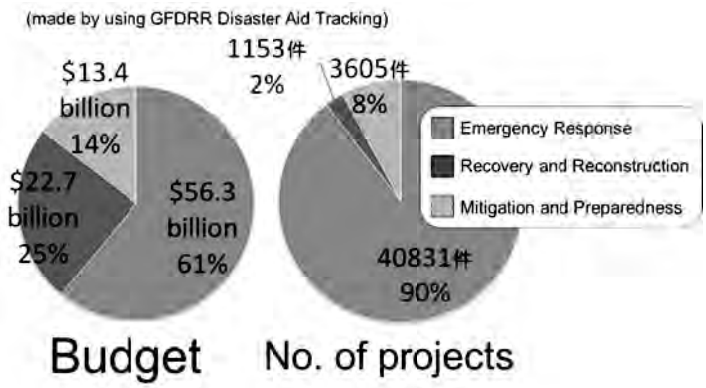


Figure 7 Break down of international projects for disaster reduction (1990-2010)

Among all countries and international organizations, USA is the first and Japan is the 5th top country that have spent the biggest budget for disaster-related projects during 1990-2010 as shown in Figure 8. But between these two countries, there is a big difference. US has spent a lot of money for 'emergency response' and Japan has spent more than half of the total budget for 'mitigation and preparedness' whose percentage 51 % is the world highest value.

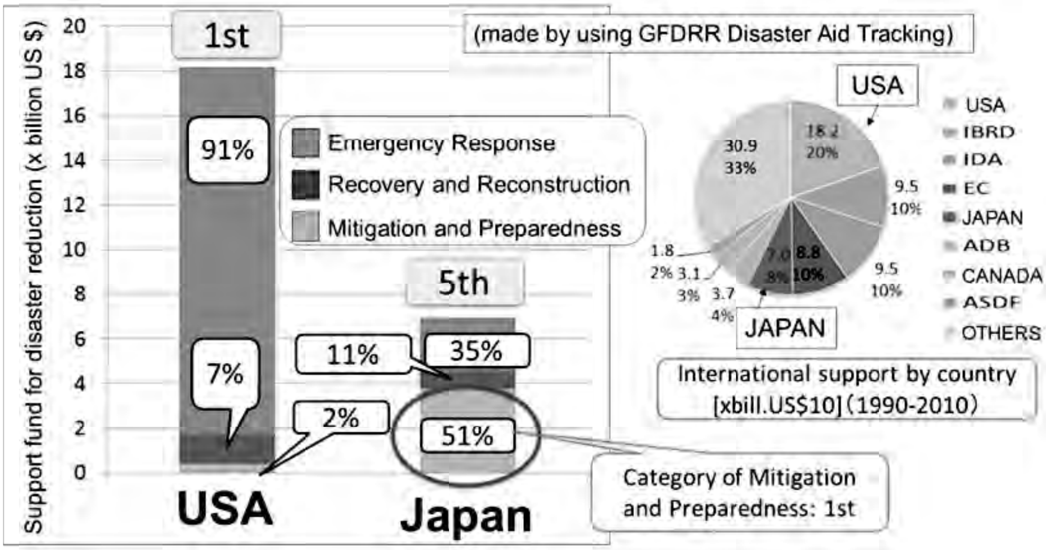


Figure 8 Comparison of budget of USA and Japan for disaster-related projects (1990-2010)

5. IMPLEMENTATION OF DISASTER RESILIENT SOCIETY

There are two important elements to implement disaster resilient society. One is disaster resilient build environment that is guaranteed by resilient infrastructure and buildings, and the other is disaster resilient people with high disaster imagination capability. Regarding resilient structures, especially social infrastructure, revision of seismic code of structure based on the earthquake damage investigation is essential, however, about private buildings and houses, especially in developing countries, revision of seismic code of structure cannot be a solution to the problem because there are many existing and new structures constructed by the local people without any engineering background using locally available materials without following the code. These types of structures are called non-engineered structures. Because of this reason, establishment of quality control system is necessary. This system is a quality check and promotion system by which people are encouraged to retrofit their own houses by proper way.

People who are trained in the engineering field tend to think that engineering issue is the most important to create disaster resilient society, but this is not correct. Engineering issue is important, but that is not all. We should recognize that without integration of technological and social approaches, existing important problems cannot be solved.

5.1 Implementation of Disaster Resilient Structure: Technological Approach and Social Approach

In order to implement earthquake disaster resilient structures, especially non-engineered buildings in developing countries, I have developed several retrofit methods as technological approach. They are all technically feasible and economically affordable methods using PP-band mesh, Bamboo mesh, PET-band mesh, Abacá-rope mesh, FRP+PP-band mesh, and Splint and Bandage+PP-band mesh, etc. PP-band is a polypropylene band, which is normally used for packing. PET band, which is about twice stronger than PP-band, is a recycled material from PET bottle. Abacá is a natural fiber produced from naturally growing plant in tropical regions normally used for making rope.

I have been testing these methods regarding applicability not only for brick and/or adobe single story masonry houses but for other masonry structures, such as shapeless stone masonry and multi-story masonry buildings. Generally speaking, seismic capacity of structures is discussed by three key characteristics of the structure, strength, deformation capability, and energy dissipation capacity. Based on the research results, it has proved that by these methods, deformation capacity and energy dissipation capacity of structures can be improved drastically and by FRP+PP-band mesh and Splint and Bandage+PP-band methods, strength can also be improved. With the PP-band method, retrofitting cost is approximately 30 USD per single-story housing unit with the floor area of 73 m^2 if the house owners retrofit in Pakistan. In case of hiring masons, the cost is no more than 5% of the total building cost.

In the affected area by the 2015 Gorkha earthquake, there is one two-story adobe masonry house with mud mortar, retrofitted by PP-band method by NSET in 2009. There are many severely damaged masonry structures around the retrofitted house and in spite of the fact that adobe masonry house with mud mortar is the world's weakest type structure, damage to this house was very minor. Minor damage was seen at the bottom of the walls showing the effects of PP-band retrofit.

Regarding the social approach for implementation of disaster resilient structures, I have proposed several social promotion systems by which people are encouraged to retrofit their own weak masonry structures. The methods are; 1) Two-step incentive promotion system, 2) Micro earthquake insurance based promotion system, 3) Government micro earthquake reinsurance based promotion system, and 4) Micro-finance based promotion system, etc. With all of these promotion systems, all stakeholders can get benefit by retrofitting weak structures and damage by the future earthquake can be drastically reduced. Due to limitation of the space, I cannot explain the detail of them, but I will introduce them in my lecture.

On the research theme related to seismic retrofit of non-engineered masonry structures and their promotion systems, six PhD students successfully obtained PhD degrees and over 15 Master students got Master degrees under my supervision so far. They carried out from very primitive research to full-scaled dynamic tests using shake table and numerical approaches. Based on their research results, we can say that all of these developed methods can enhance safety of both existing and new masonry buildings. Therefore each method can be one of the optimum solutions for promoting safer building construction in developing countries and contribute earthquake disaster mitigation in future. Now, PP-band retrofit methods are started to be used in Iran, Pakistan, Nepal, Indonesia and China, etc.

5.2 Role of Private Sectors and A New Concept of Disaster Countermeasures from COST to VALUE

As introduced in chapter 2, there are seven phases of disaster management and for each phase, there are three players, individuals and companies for self-help effort (SE), community and/or group for mutual assistance (MA), and national to local governments for public support (PS). For efficient improvement of disaster resilient capacity, strengthening of SE and MA is quite important. Therefore, some social system, which can give strong incentive to the players of SE and MA to promote their disaster management countermeasures, is necessary. As the organizations that establish such a system and make it popular, financial institutions, such as bank and insurance company, and mass media have high potentials.

I would like to introduce a system that my former student working at Development Bank of Japan (DBJ) has established. This is a unique system called BCM (Business Continuity Management) rating project and I have been serving one of the members of its advisory board. Disaster countermeasures have been considered as 'COST' for many years. It is very difficult to keep high level disaster countermeasure when it is considered as 'COST'. And people think that effects of disaster countermeasure can only be appeared when hazard happens. But by some system, if disaster countermeasures can be considered as 'VALUE', it gives incentive to the players of SE and MA to keep high level disaster countermeasure and it gives always benefit to them even without hazard.

With the DBJ BCM rating project, capacity of BCM of client organization is carefully examined by evidence based evaluation method by DBJ and when the score of the evaluation result is high, so that organization is rated as A, highest rate for example. If this organization is a private company, DBJ can consider this company with high BCM rate as reliable business partner that will have less negative impact when some hazard happens. Therefore, DBJ can loan money to the company with lower interest than the other companies with low BCM rate. From the company's viewpoint, continuation of high-level disaster countermeasure will give always benefit even in case that there is no hazard.

6. CONCLUSIONS

For disaster reduction, knowledge on natural science and technological approach are very important. But in many cases, real problems cannot be solved by only knowledge on natural science and technological approach. It is necessary to integrate technological approach based on the knowledge of natural science and social approach based on the knowledge of social science, both of which should be locally feasible and acceptable. Disaster management related issues are typical examples. These problems can be solved by combining both technological and social approaches. We can drastically reduce earthquake damage by seven-phase well-balancing structural and non-structural countermeasures.

Please imagine that you are killed due to an earthquake disaster. What would you like to say to your important persons who could survive? In general, politicians pay attention to the survived victims who can vote, however, this is different from essence of disaster management. Limited resources and energy should be used to reduce the number of people who will be affected before an earthquake rather than to take care of affected people.

We cannot prevent earthquake occurrence. But earthquake does not kill people. Structures kill the people. Among all earthquake disaster measures, 'damage mitigation', structural issue, is the most important and efficient for reducing damage, especially casualties. Today's poor-quality structures will be negative inheritance in next generations and attack their society. And today's poor disaster management system will make that damage worse. But, we can create disaster resilient society by constructing disaster resilient built environment and by educating people of all generations to be disaster resilient with the collaboration of SE, MA, and PS based on understanding that importance of role of private sectors and change of mind on disaster countermeasures from COST to VALUE.

Two Decades of Earthquake Risk Management Actions Judged against Mw 7.8 Gorkha Earthquake of Nepal April 2015

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ABSTRACT

The 1988 M6.6 Udaypur Earthquake was the starting point of national efforts towards earthquake risk management in Nepal. With international support, the government of Nepal developed and in acted one of the most proactive building codes of developing countries in seismic region. This helped trigger better understanding of earthquake hazard and risk faced by the country and the need for developing and implementing organized approaches for earthquake risk management. The National Society for Earthquake Technology – Nepal (NSET) came into being during such national realization of the needs. NSET started a program for earthquake risk management for Kathmandu Valley which taught several fundamental lessons that became subsequently one of the most influencing directions in earthquake risk management in Nepal and the region by initiating several milestone programs such as the school earthquake safety program, annual earthquake safety days, mason training for earthquake resistant construction, program for enhancement of emergency response, community-centered disaster risk management program, municipality earthquake safety program, public private partnership for earthquake risk management, community level disaster preparedness and planning and so on. These works were acknowledged positively nationally and globally.

However, the real test of these methodologies and approaches took place during the devastating M7.8 Gorkha Earthquake of April 25, 2015 that took a toll of more than 8000 human deaths and several thousand injuries, and more than 8 million houses totally damaged in almost a third of Nepal's territory.

The earthquake was the real test for the usefulness and contribution of the policies, regulations, approaches and methodologies as well as the preparedness and mitigation measures undertaken by NSET and also by other stakeholders in the past two decades in aspects of earthquake risk management in Nepal. The efficacy of the approaches were demonstrated in organization of the emergency response by the government and by the people, in the results of damage assessment which showed that all school buildings retrofitted following a standard process of design, quality control and construction not only didn't get damaged but also served as temporary although a majority of the school buildings was non-engineering stone or brick masonry. The earthquake demonstrated the efficacy of earthquake awareness, earthquake preparedness works in the school, non-structural mitigation works I hospitals and community buildings and individual households, the use of light search and rescue capacity and the simple tools in helping the victims and also the formal responders, the contribution of the formal emergency response capacities in medical response and collapsed structure search and rescue. The damage assessment guideline which was prepared a priori and dues for training engineers were handy to immediately start the damage assessment and for the formulation of the PDNA.

The earthquake also identified areas of gaps and areas for further improvements. The paper will provide evidence based cases on the implementation of global, national and local level policies and strategies for disaster risk management at nominal costs in Nepal.

Keywords: Earthquake Risk Reduction, School Safety, Building Code Implementation, Program for Enhancement of Emergency Response

Investigation into the multiple sinkholes in Pokhara, Nepal, occurred since November 2013

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ABSTRACT

Since November 2013, numerous sinkholes have been forming in the Armala area of Pokhara Valley, Central Nepal, posing serious threat to local residents.

In order to provide countermeasures for reducing sinkhole risk, detailed investigations into the cause and the formation mechanism of the sinkholes are crucial. Preliminary surveys were conducted in June 2014 and November 2014. Comparison of photos, taken in the two surveys, clearly indicates not only the formation of new sinkholes, but also the re-activation of filled sinkholes. By means of dynamic cone penetration tests and surface wave investigations, qualitative characterization of the soil profile was attained, and shallow weak soil layers which are believed to be the location for future sinkholes could be identified. On the basis of the preliminary field investigation, possible sinkhole formation mechanisms are considered.

Furthermore, no major apparent effect of the earthquake was observed in the sinkhole damaged area due to the 2015 Gorkha Nepal Earthquake. But risk of sinkhole does not seem to disappear as white turbid water continuously springs. It indicates that the internal erosion of white clayey silt layer is still in progress.

In August 2015, a boring was carried out beside one of the largest sinkholes. The overall structure of ground layers was first revealed and a 2.5m high cavity at 7.5-10m deep from the ground surface was found within a thick white clayey silt layer. Further ground investigations including boring, surface wave exploration, ground water survey and others will be conducted in December 2015.

Planning for Post Earthquake Recovery and Rehabilitation

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ABSTRACT

The 7.6 magnitude earthquake of 25th April 2015, 7.3 magnitude aftershock of 12th May and continuous aftershocks (more than 300) have caused heavy loss of shelters and physical/social infrastructures in the hilly region of central and western Nepal. With a loss of lives of more than 8000 people and injuries to more than 22000 people, this catastrophe has shaken the Nepalese society posing a great challenge of recovery and rehabilitation to affected population. The destruction was widespread covering residential and government buildings, heritage sites, schools and health posts, trekking routes and many physical/social infrastructures specially in rural hilly areas of central and western region. Since a recovery programme involves implementing a large number of activities in a relatively short period of time requiring enormous effort in the preparation of institutional, financial and logistical support, we need to go forward in a unique Nepali way on the basis of previous experiences and our own legal framework. The guiding principle for recovery planning needs to include a transparent working system to address all the affected community with a focus on single women, children who have lost their parents, disabled and elderly people without any discrimination on the basis of caste, religion, race or political belief. Keeping in mind the enormous loss of settlement, the rehabilitation planning will focus on achieving a goal of safe and efficient settlement with adequate basic services.

Keywords: physical /social infrastructures, challenges, recovery and rehabilitation programme, guiding principle

1. INTRODUCTION

Disaster Risk Management: Disaster causes major disruption in the life of people causing death or injuries to the persons and or damage to the physical property. For example the primary effect of Earthquake is massive destruction by ground shaking, and secondary effects include liquefaction, land slides, ground ruptures, uplifts and subsistence etc. Disaster risk management can be termed as use of administrative directives, organizations and operational skills and capacities to lessen the adverse impacts of hazards and possibility of disaster. It may consists of various management steps such as mitigation, preparedness, response, recovery and reconstruction. The various steps of DRM varies as per stages of disaster such as pre disaster, during disaster and post disaster. Thus we need to understand clearly the stage of disaster and then the steps and list of activities we need to perform in each step.

- **Pre Disaster Stage**: Mitigation and Preparedness are the two major steps comprising of various activities. Mitigation Plan can be defined as taking actions to reduce the effects of a hazard before it happens and it may consists of various activities such as hazard assessment, vulnerability analysis, risk assessment, risk evaluation, strategies for vulnerability reduction, integration of disaster risk reduction activities in all development works etc.

  Earthquake Mitigation can be done in two ways, structural mitigation can be achieved by implementation of National Building Code and also by retrofitting of existing structures. Non structural mitigation can be achieved by resilient land use and settlement planning, preparation of microzonation map, enforcement of policy, regulation and act. Similarly preparedness plan can be defined as several activities related to prediction, forecasting, early warning, public awareness, training and capacity building. Thus preparedness is more related to capacity building of the community and the disaster volunteers and officials so that they can immediately get activated during disaster event.

- **During Disaster Stage**: Response and rescue is the main step to be taken into consideration. The effectiveness of response lies in quick mobilization of response and rescue team in the effected area. Immediately after that, damage assessment has to be made and requirement analysis is needed for future action. Similarly rescue and evacuation along with emergency health assistance are the major activities to be done during the time of disaster. The effectiveness of response depends upon the capacity and availability of skilled human resource as well as equipments and logistics during the time of disaster.

- **Post Disaster Stage**: The post disaster operation will run efficiently if the state is well equipped and prepared with trained personnel, provisions in annual budget as well as well defined legal institution to carry out rescue and evacuation efforts. Immediate actions to bring back public life to normalcy has to be given first priority by providing food, emergency shelter, and immediate health support in early recovery stage. Then after post disaster need assessment, recovery works should be started without any delay with participatory approach and giving priority to recovery of livelihood. Schools need to be reopened as soon as possible. Recovery means effort to improve the lives of the victims of the disaster. Short term, mid term and long term plan for reconstruction and rehabilitation should be prepared in close participation with the disaster victim people.

2. RECOVERY PROCESS

Early recovery is a multidimensional process of recovery that begins in a humanitarian setting. It is guided by development principles that seek to build on humanitarian programmes and to catalyse sustainable development opportunities. It aims to generate self sustaining, nationally owned, resilient processes for post-crisis recovery. It encompasses the restoration of basic services, livelihoods, shelter, governance, security and rule of law, environment and social dimensions, including the reintegration of displaced populations. (Extract from Guidance Note on Early Recovery, CWGER, April 2008). The international Strategy for Disaster Reduction (ISDR) defines recovery as the decision and actions taken after a disaster with a view to restoring or improving the pre disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risks. Early Recovery can be started while humanitarian response activities are ongoing.

2.1 Key Considerations in Recovery Process

Developing Disaster Recovery Frameworks, Sendai Conference Version, March 2015 recommends following considerations in the Recovery Process:

- **Institutional Arrangements**: A lead recovery agency should be designated early into the recovery process. It should have a clear mandate and that it should be backed by effective political and technical leadership.

- **Vision and Guiding Principle**: Early setting of the vision and guiding principles for recovery is important to ensure effective transition from the immediate humanitarian response to the medium to long term recovery.

- **Programmatic Approach**: The lead recovery agency may help the government develop a framework that takes a programmatic approach to identify priority sectors that are critical for restoring livelihood.

- **Financing the Recovery**: Recovery may be funded through government funds, international aid, private sector financing and community contribution. The government need to have an effective fund tracking mechanism for both on- budget and off-budget funds. This will enhance donor confidence and help in mobilizing additional funds for recovery.

- **Simplified Procurement**: Simplified procurement procedures can provide a robust mechanism for the timely purchase of goods and services.

- **Communication**: The government need to have a consolidated communication system that conveys the progress of recovery and address the expectations of the effected communities.

2.2 Disaster Recovery Framework

Developing Disaster Recovery Frameworks, Sendai Conference Version, March 2015 recommends following Framework in the Recovery Process. Disaster Recovery Framework is arranged in six modules or units. These modules follow the sequence of steps required to develop and implement a framework.

- **Module 1 - Conducting Post Disaster Damage and Need Assessment**: A Post Disaster Needs Assessment (PDNA) is a pre requisite for developing a Disaster Recovery Framework (DRF). The government must ensure participation and consultation by relevant government departments (both horizontally and vertically), civil societies, the private sector and face to face with people in the affected communities.

- **Module 2 - Policy and Strategy setting for Recovery**: This module describes the vision, guiding principles, and appropriate strategies needed to achieve integrated, cross sectoral disaster recovery

- **Module 3 - Institutional Framework for Recovery**: How institutions are set up is critical for a successful recovery. A collective effort across government, NGOs, the private sector and communities promotes a successful recovery process.

- **Module 4 - Financing for Recovery**: In post disaster recovery, there are four major financing challenges. They are to quickly quantify the economic cost of the disaster, develop recovery and reconstruction budgets, identify sources of financing and set up the mechanisms to mange and track funds.

- **Module 5 - Implementation Arrangements and Recovery Management**: Coordination brings together a larger number of partners and stakeholders to support the recovery program. Existing project approval and procurement, reporting and staffing procedures need to be simplified to meet the pressing demand of the recovery process.

- **Module 6 - Strengthening Recovery System in National and Local Governments**: It refers to enhancing governmental capacity to help country and its people recover from disaster. The government needs to incorporate disaster risk management (DRM) in its development planning.

3. PLANNING FOR RECOVERY AND REHABILITATION (Nepalese Context)

3.1 Post Disaster Need Assessment

Just after disaster, rescue and relief works are activated immediately. At this stage Humanitarian aid agencies along with the army and security persons are activated for rescue and relief works. Before the activities for Recovery start, Post Disaster Need Assessment is done to ensure the level of damage and loss and also to get all the stake holders including government agencies, NGOs, INGOs, development aid agencies etc work together to understand the extent and type of damage due to the disaster. The main steps to be followed for assessment can be listed as follows:

- **Develop Baseline for Assessment**: To assess the damage, stock of physical assets in the affected area prior to disaster need to be identified and to assess the loss, the data of expected production and sales in the affected area need to be collected.

- **Estimate Post Disaster Situation**: To have clear understanding of the post disaster situation, the government must identify damage and loss on sector by sector fashion and then an estimate can be made about the total values of damage and loss. Damage to physical assets can be determined through field survey and or aerial photo analysis. An estimation can be made dividing the whole scenario into four major sectors such as social , infrastructure, productive and cross cutting sectors.

- **Estimate Disaster Impact**: Such impact has to be estimated for macro economic level such as GDP, BOP (Balance of Payment), and Fiscal Budget. Such impact need to be calculated for affected population as well as personal and household level.

- **Recovery and Reconstruction Need**: Estimates on recovery and reconstruction needs must be based on solid, quantitative analysis, take into account the affected country's recovery and reconstruction policy and strategy, include necessary risk reduction measures, "Building Back Better" concept, needs for reconstruction of destroyed assets derived from the value of damage

In Nepal, the catastrophic earthquake of 25th April 2015 (7.6 magnitude) followed by more than 300 aftershock (big one on 7th June) caused tremendous physical loss with casualty of 8790 people, more than 22000 injuries and affected almost one third of population of Nepal. The destruction was widespread covering residential and government buildings, heritage sites, schools, health posts, rural roads, bridges, water supply systems, hydropower plants etc. The PDNA covers 31 districts affected by the earthquakes, of which 14 districts are the worst affected. This assessment was led by National Planning Commission covering **23 thematic areas** as follows:

- **Social Sectors**: Housing, Health and Population, Nutrition, Education and Cultural Heritage

- **Productive Sectors**: Agriculture, Irrigation, Commerce and Industry, Tourism and Financial Sectors

- **Infrastructure Sectors**: Electricity, Communications, Community Infrastructures, Transport and Water Sanitation

- **Cross Cutting Sectors**: Governance, Disaster Risk reduction, Environment and Forestry, Employment and Livelyhood, Social Protection, Gender Equity and Social Inclusion, Poverty and Human Development and Macro economic Impact Assessment

PDNA report on Nepal Earthquake has concludes that the total value of disaster effects including damage and loss is US$ 7.065 Billion including US$ 5.404 Billion as private property loss, 1.661 as Public loss and US$ 171 million as losses in personal income. Social sector bears the biggest loss as 58% where as productive sector 25%, infrastructure as 10% and cross cutting as 7% . In this way it gives a clear indication that social sector which include Housing and Human Settlements, Health, Education and Cultural Heritage bears the biggest damage and Housing and Human Settlements has suffered the highest damage amounting US$ 3.036 Billion which is almost 43% of the total damage. PDNA Report prepared by NPC mentions that the earthquakes will end up pushing an additional 2.5 to 3.5 % Nepalese into poverty in 2015-2016 which translates into at least 700000 additional poor.

3.2 Guiding Principle

The main objective of the recovery and rehabilitation lies in guiding principle which is derived from PDNA report output. Keeping in mind the April earthquake , following principles have been proposed :

- Centralised Policy, Decentralised Programme Formulation
- Build back better
- Appropriate Technology based on indigenous knowledge has to be optimally utilized with appropriate improvement
- Improved Settlement planning in the old place to be prioritized and the tradition and cultural values to be protected if resettlement done in new place
- All the stake holders including political parties, NGOs, INGOs, Professional Societies, Donor agencies, Social organizations etc must follow the policy endorsed by the government
- All type of relief packages and supports must be uniform and standardized as per government rules, no discrimination on the basis of cast or race or geographical pocket should be made
- The policy and programme applied in earthquake affected area need to be replicated in other part of the country
- The government should give priority to get support from neighboring countries in addition to others globally.
- Social Sector must be given priority keeping in mind the biggest amount of loss in this sector and also largest public demand as well.

3.3 Strategy for Recovery

Based on the report of PDNA, the strategy for recovery and rehabilitation for April 2015 Earthquake in Nepal can be written as following major areas:

3.3.1 Reconstruction, repair and rehabilitation of Housing and Public Building:

When a heading comes at the bottom of a page please try to adjust the length of preceding paragraphs, by slight rewriting, so that the title appears at the top of the next page; it is often possible to shorten a paragraph with only one word on the final line. You might also be able to resize a figure. Otherwise, add extra line spacing above headings.

- Owner Built approach is suitable for private building repair or reconstruction using locally available construction materials with improved indigenous skill and techniques.

- The mass training campaign for local masons and junior technicians has to be organized by the government. To make it implemented several NGOs and skill development institutions could be mobilized at local level.

- Retrofitting campaign for those private buildings which are not damaged by the last earthquake has to be made based on technical assessment by the experts.

- For reconstruction of Public Buildings, priority will be given to school and health post building and integrated public building construction will be practiced to save the precious land and cost of maintenance and quality control in construction.

- All short of building construction will be strictly guided to make them compatible to the provisions of National Building Code.

3.3.2 Resettlement Planning and Improvement of settlement Pattern and infrastructures:

- The government must focus on restoration of services as soon as possible and facilitate return of internally displaced people (IDPs) back to their homes and villages of origin.

- The damaged settlement needs to be improved so that every settlement will have open space which could be used as rescue place (preferably equivalent helipad) during the time of disaster and playground during normal times

- Resettlement will be promoted only if the existing place is found to be highly vulnerable from technical investigations and use of land readjustment technique will be widely used for resettlement.

- The settlements will be connected to vehicular road network as far as possible and the internal roads inside the settlement will be planned for vehicular purpose as far as possible.

- Repair and maintenance as well as new construction of physical infrastructures in affected areas should be given sufficient budget for making the life comfortable e.g. roads, bridges, hydropower plants, office buildings, communication systems, schools, hospitals etc. and this development needs to be tied up with settlement development.

3.3.3 Restoration and Conservation of historic and archaeological areas:

- Various modalities of execution of regeneration of historic core areas has to be discussed with the affected public before going for implementation.

- Restoration and conservation of damaged world heritage sites can be implemented with consultation of experts from different international organizations.

- House Pooling could be done for regeneration of historic core settlements to make them disaster resilient without loosing their historic identity.

3.3.4 Support for earthquake affected family and renovation of economic infrastructures:

- Special programme for employment generation and skill development for ultra poor and most vulnerable family.

- Special activities of saving and credit cooperatives and micro finance activities among such families.

- Improved varieties of seed and fertilizers to be made easily available to the affected farmers.

- Commercial Banks to be mobilized in affected rural areas to make easy access of loan for affected family.

3.4 Institutional Arrangement

How institutions are set up is critical for a successful recovery. A collective effort across government, NGOs, the private sector and communities promotes a successful recovery process. To effectively manage the contributions of various stakeholders in the recovery, it is important to clarify their roles and responsibilities. Three different options for the structure of lead agency for recovery could be as follows:

- Recovery programme can be done by making a coordination mechanism of existing line ministries involved in reconstruction work

- Creating a new empowered new authority for managing recovery activities

- Hybrid model by establishing a new institution which could coordinate with all the concerned stakeholders involved in recovery activities

The proposed bill for Post Earthquake Reconstruction work in Nepal has envisioned provision of an Reconstruction Authority under the chairmanship of Rt. Hon. Prime Minister with four ministers, chief executive officer, vice chairman of NPC, Chief Secretary and three experts as members. This Reconstruction Authority will be fully responsible for all the related works for recovery and reconstruction at post earthquake stage which can be listed as follows:

- Assessment of damage and declaration of earthquake affected area according to the extent of damage and loss

- Prioritise the sectors for reconstruction

- Approve the policy, planning, budget and programmes for earthquake affected area

- Keeping coordination with various stakeholders government, non government, UN agencies and development partners involved in reconstruction work and guiding them for their work and responsibility

- Planning for resettlement and facilitate in acquiring land wherever needed

- Managing the required budget for reconstruction

- Monitoring the reconstruction work and keeping quality control

3.5 Miscellaneous Sectors to be addressed

In addition to the normal activities to be done during the recovery and reconstruction stage, some cross cutting issues need to be taken into consideration such as:

- Involvement of media group and artists:
- Education, Research and Development of Earthquake Science and Technology
- Facilitating supply of construction materials
- Construction of Earthquake memorials at worst affected areas
- Strict Supervision and Monitoring of Reconstruction Works
- Honoring best practices in Rescue, Response and Recovery Activities
- Amendments of related existing acts, rules, regulations and directives for facilitating recovery and rehabilitation

4. CONCLUSION AND RECOMMENDATION

The various available reports and studies predict that Nepal could face even bigger catastrophic loss of human life and destruction of property in major earthquake of future. The recent April 25, 2015 earthquake in central Nepal with hundreds of after shocks have really shaken Nepalese people and they have realized the importance of preparedness. All the machinery of government must be mainstreamed about such mega natural disaster and appropriate budget needs to be allocated for preparedness. In addition to the earthquake, Nepal have been facing series of other natural disasters such as flood and land slides during rainy season, events of household and forest fire during dry season, and in a high risk of earthquake any time. In addition to these, Nepal experiences substantial amount of casualty by lightning, epidemics and road accident every year. Recommendations can be summarized as follows:

4.1 Safety of Infrastructure

Building safety is major concern in Nepal because recent earthquake has clearly given the message that most of the rural housing are seismically unsafe. Thus strict implementation of National Building Code is recommended not only in urban but also in rural area. Some amendments in NBC is very much essential in inclusion of seismic retrofit code for buildings and infrastructure, national fire code , electrical, plumbing and mechanical code, approval of NBC compliance system, monitoring and quality control etc In addition to Building there are many other infrastructure sectors which need to be taken into consideration such as Roads and Bridges Safety, Airport and Helipad Safety, Water Supply and Sanitation Safety, Hydropower Production and electrical Transmission Safety, Irrigation System Safety, and Factory Building and Mechanical Safety etc.

4.2 Medical and Public Health Safety

There is an urgent necessity to train emergency rescue personnel, emergency health workers, doctors, public health professionals and volunteers for getting them ready all the time for providing their service in case of disaster. Equally important is making the essential logistics items and equipment available, including ambulances, temporary medical treatment facility, medical supplies, temporary health camp facilities and portable emergency communication facilities. For this purpose, a strong public private partnership as well as strong coordination mechanism with international volunteer organization is needed.

4.3 Communication System

Most of the Nepal's commercial communications infrastructure has been found to be non functional during earthquake and people get panic trying to know the status of their close ones. The rescue team gets undecided how to move and where to move without knowing the real status of event. Even the Emergency Operation Center becomes non functional if the communication system does not work. Thus proper functioning of communication system become so vital during disaster. At the same time the mass communication media must broadcast the messages which are fact and real otherwise a false message may create another disaster among the community.

4.4 Post Earthquake Preparedness

The importance of preparedness can be realized from the statement "It is estimated that for every $ 1 of investment in Disaster Risk Reduction saves as much as $100 in recovery". The biggest challenge lies in coordinating and mobilizing the nationally and internationally available resources properly and effectively. Effective preparedness help to mobilize the heavy machinery and equipment for rescue and immediate repair of essential facilities and transportation system.

4.5 Dedicated and Strong Institution

Existence of dedicated and well defined institution for Disaster Management is of extremely high importance for country like Nepal where natural disaster is a regular phenomenon.

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Paleoseismology of Nepal Himalaya and its implication in Seismic Hazard Assessment

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[3]Earth Observatory of Singapore

ABSTRACT

Department of Mines and Geology in collaboration with Department Analyse Surveillance Environment (DASE) France and Earth Observatory of Singapore (EOS) is conducting many basics and applied researches to understand the process of earthquake nucleation in Himalaya and return period of great earthquake in this region. Many fundamental question regarding the seismotectonic model, seismic cycle, interseismic slip deficit and behavior of Main Himalayan Thrust is understood as an outcome of this collaboration. Most of the epicenter of the Himalayan earthquake follow a belt of seismicity, at a depth of 10-20 km, follows approximately the front of the higher Himalaya along the 3000-3500m topographical contours. Past earthquake of the Himalayan region were also nucleated and their epicenter were located in this region. This midcrustal seismic cluster is well mapped at the surface by high uplift rate inferred from geodetic measurements and high conductive zone which might be due to fluid circulation at the midcrustal depth. A network of 29 continuous GPS stations within the territory of Nepal Himalaya complement the seismic network since 2002, monitoring the convergence rate between northward moving Indian plate and the Tibetan plateau. Result from this network shows that the Main Himalyan Thrust fault (MHT) is currently locked between the higher Himalaya and the Main Frontal Thrust, 100 km southward, and accumulates a slip deficit in this part of the Himalaya at a rate of approximately 1.8cm/yr, this slip is responsible for nucleation of big earthquake in this region.

Himalayan region has been shocked by 6 great earthquakes in the past century including recent April 25, 2015 Mw 7.8 Gorkha Earthquake: 2005 Muzzafarabad Pakistan (Mw 7.6), 1905 Kangra (Mw 7.8), 1934 Bihar Nepal (Mw 8.4), 1987 Shillong (Mw 8.3) and 1950 Assam (Mw 8.6) earthquakes. The region between 1905 Kangra Earthquake and 1934 Bihar Nepal Earthquake between 78°E and 84°E has not produced any major earthquake since more than four centuries and stands for being a large seismic gap in the Himalayan region. The high seismogenic potential of this locked fault zone exposes the North-Western Himalaya and the densely populated region of nearby Ganges basin in India to a high level of seismic risk. Better understanding the future seismic behavior within this seismic gap is one of the major challenges to be taken up by the scientific community in the region. This paper will focus on the present understanding of the seismicity of the Himalaya and impending seismic hazard of the region.

To Assess the seismic history of the region, we should have complete history of past earthquake this paper will describe the surface ruptures discovered and studied in Nepal. It will try to answer some fundamental questions such as; How complete is the historic record for M>8 earthquake in the region ? What structures generate these very large earthquakes? and do they rupture to the surface or they stopped before reaching the surface as 2015 Gorkha Earthquake? To address these questions will confront the historical records with the results of geomorphic and paleoseismic studies conducted along the MFT in Nepal. The MFT has been chosen as a main target because deformed river terraces show that late Pleistocene and Holocene deformation across the Nepal Himalaya is expressed on the frontal fold above the MFT. The surface trace of the MFT therefore provides an opportunity to document whether large earthquake in the MFT rupture the surface, and if so, to determine there size and recurrence as demonstrated by the first report by Sapkota et al., 2013 of the surface ruptures on the same MFT segment of two of the largest historical earthquakes that occurred in central eastern Nepal (AD 1934 (M8.4) and AD 1255 (M>8)). For the strict purpose of accurate seismic hazard assessment in Nepal, it is also important to know whether great earthquakes produce surface ruptures, because this has strong implications on the kind of regional damage expected. The design or retrofitting of major infrastructures directly depends on such information. Nepal should put its step forward in this direction to find out the return period of great earthquake and segmentation of Himalayan arc in relation to its length and width.

Integrated research on great earthquakes and disaster mitigation in Nepal Himalaya

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ABSTRACT

This project is now at the preparatory stage of making detailed research plans, and will be carried out for five years from 2016 under the Science and Technology Research Partnership for Sustainable Development (SATREPS) program of the Japan Science Technology Agency (JST) and the Japan International Cooperation Agency (JICA). Its overall goal is to mitigate future earthquake disasters in Nepal and the project will realize this overall goal in association with the risk assessment project of JICA. Therefore, the project will contribute to the overall goal through research activities on seismic potential evaluation, ground motion prediction, seismic hazard assessment, earthquake information delivery, and education and policies. 1. We evaluate the seismic potential of the Central Seismic Gap along the Main Frontal Thrust and construct the source models of future great earthquakes. 2. We model the velocity structure in the Kathmandu Valley and perform scenario ground motion predictions using the constructed source and velocity structure models. 3. We assess the seismic hazards in the Kathmandu Valley due to the future great earthquakes. 4. We build a monitoring system for the future great earthquakes to enhance the existing observation network and information system. 5. We educate graduate students and experts on seismology and earthquake engineering, and recommend policies to Nepal.

Keywords: SATREPS project, seismic potential evaluation, ground motion prediction, seismic hazard assessment, education and policies

1. INTRODUCTION

Nepal is an earthquake disaster-prone country because of its tectonic setting. The Indian plate is moving northward at a rate of 5 cm/year. However, its continental lithosphere is too buoyant to subduct, so that it is colliding with the Eurasian plate generating large earthquakes and forming steep mountains in the Himalayan region including Nepal. Urban areas in Nepal are mostly located in a few basins such as Kathmandu Valley. Since basin sediments and steep topography in basins' outskirts can amplify and lengthen seismic ground motions, it is important for hazard estimates and disaster mitigation to explore not only earthquake sources but also the subsurface structures and topographies of the basins. Moreover, the urban areas are highly vulnerable to earthquakes due to almost entirely non-engineered/very weak houses with root causes of weak law enforcement of building codes, unplanned settlements and low economic conditions. Even though under the conditions mentioned above, there are only few experts in seismology, which is a geophysical discipline for earthquake studies. Consequently, Nepal is one of the highest risk countries in the world against earthquakes, and it is urgent for Nepal to perform an integrated research on earthquake disaster mitigation in collaboration with Japanese researchers.

2. RESEARCH PLAN

2.1 Research areas

We focus on large future earthquakes in the "Central Seismic Gap" as the greatest seismic threat to Nepal (*e.g*., Avouac, 2007). Research sites to be targeted are:

Area 1 Around the Central Seismic Gap along the Main Frontal Thrust where a large future earthquake is expected, for the source modeling and seismic and geodetic monitoring.

Area 2 Kathmandu Valley and its surrounding areas for the modeling of velocity structures and seismic hazard assessments.

2.2 Research components

Our overall goal is to mitigate future earthquake disasters in Nepal and the project will realize this overall goal in association with "The Project for Assessment of Earthquake Disaster Risk for the Kathmandu Valley" of JICA. The project will contribute to the overall goal through the five research components: 1. Earthquake potential evaluation, 2. Ground motion prediction, 3. Seismic hazard assessment, 4. Earthquake information delivery, and 5. Education and Policies, as shown in Figure 1.

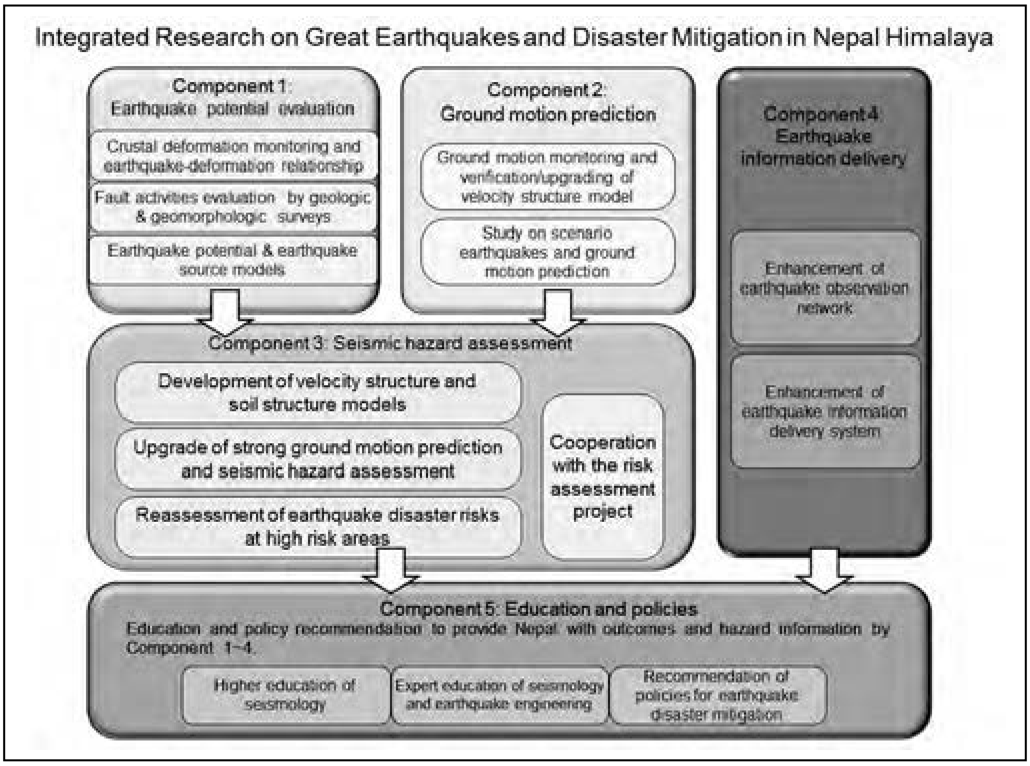

Figure 1: Master plan of the project

3. RESEARCH ACTIVITIES

3.1 Earthquake potential evaluation

It is proposed to (a) deploy a continuous GPS array in the Central Seismic Gap to precisely monitor current crustal deformation field, (b) acquire past earthquake and crustal deformation records along the Main Frontal Thrust and others through geological surveys, and (c) integrate geodetic and geological data together with seismic data for developing earthquake source models. To carry out these objectives, three research subjects are proposed as follows:

1-1 Crustal deformation monitoring and evaluation of relationship between earthquakes and crustal deformations
1-2 Evaluation of fault activities by geological and geomorphological surveys
1-3 Evaluation of earthquake potential and development of earthquake source models.

3.2 Ground motion prediction

We build an array of strong motion seismometers. We then verify and upgrade the three-dimensional (3-D) velocity structure model from Component 3 for Kathmandu Valley, using strong motion records obtained by the array. We also use the strong motion records of the Gorkha earthquake and its aftershocks. We conduct ground motion prediction in Kathmandu Valley for scenario earthquakes, using the upgraded 3-D velocity structure model. To carry out these objectives, two research subjects are proposed as follows:

2-1 Strong motion observation and verification and upgrade of velocity structure model
2-2 Study on scenario earthquakes and ground motion prediction.

3.3 Seismic hazard assessment

We collect geological information and results of boring, and conduct reflection or refraction, gravity, and microtremor surveys. Using the results of the collection and surveys, we construct velocity structure and soil structure models for the deep and shallow parts of the Kathmandu Valley basin, respectively. Based on the earthquake source models of Component 1 and the results of the ground motion prediction performed by Component 2 using the structure models above, we make seismic hazard maps of Kathmandu Valley and reevaluate seismic risks at high risk areas introducing the tools and parameters developed by the risk assessment project of JICA. The consequences of the Gorkha earthquake are used as actual data for making seismic hazard maps. To carry out these objectives, three research subjects are proposed as follows:

3-1 Development of velocity structure and soil structure models
3-2 Upgrade of ground motion prediction and seismic hazard assessment
3-3 Reassessment of earthquake disaster risk at high risk areas.

3.4 Earthquake information delivery

We build an earthquake observation network, which can be enhancement of the existing network. We then build an earthquake information delivery system, which can also be enhancement of the existing system. This is ready to deliver rapid earthquake information. If considerable aftershocks of the Gorkha earthquake still occur at the completion of a prototype of the system, we will examine to apply it to rapid

information delivery for the aftershocks. To carry out these objectives, two research subjects are proposed as follows:
4-1 Enhancement of earthquake observation network
4-2 Enhancement of earthquake information delivery system

3.5 Education and policies

We provide opportunities of higher education in seismology for Nepalese graduate students and those of expert education in seismology and earthquake engineering for Nepalese researchers. From the standpoint of science and technology research, we make policy proposals based on the latest findings of our research project using state of art scientific approaches mentioned above. During the project, we make the most use of the people’s experiences during the 2015 Gorkha earthquake. To carry out these objectives, four research subjects are proposed as follows:
5-1 Higher education of seismology
5-2 Expert education of seismology and earthquake engineering
5-4 Recommendation of policies for earthquake disaster mitigation

4. Discussion

We are now carrying out the one-year J-Rapid project called “Investigation of ground-motion to damage relationship in the Kathmandu Valley from aftershock and microtremor observations.” We will make full use of its results in the SATREPS project from 2016.

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Building Damage Patterns of Masonry and Non-engineered Reinforced Concrete Buildings during April 25, 2015 Gorkha Earthquake in Nepal

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ABSTRACT

The April 25, 2015 Gorkha Earthquake of Magnitude 7.8 in Nepal damaged about seven-hundred thousand buildings. The main typology of buildings in the affected area are stone masonry with mud mortar, some buildings with stone and brick masonry with cement/sand mortar and few reinforced concrete buildings with masonry infill. Among the damaged buildings, about 96% of the buildings were masonry and about 4% reinforced concrete buildings with masonry infill.

This study conducted detail damage assessment of over one hundred fifty thousand buildings of different type of Masonry and Reinforced Concrete (RC) buildings in Nepal. First, the buildings were classified to different structural types like adobe, stone in mud, brick in mud, stone in cement, brick in cement, wood, bamboo, RC and others. Other important parameters like type of floors and roofs and occupancy of the buildings were noted before starting the detail damage assessment in structural elements.

Damage to overall building as well as to different structural/non-structural elements were categorized into four different categories mainly overall hazard, structural hazard, non-structural hazard and geotechnical hazard. The damage level to different structural/non-structural elements was assigned from insignificant damage to extreme damage in three categories considering the severity of damage like crack widths, delamination, tilting etc. In addition to the severity of damage, extent of damage to that particular element of different severity was also noted. Each type of damage with different severity was estimated in terms of extent like less than 1/3rd of the total area, 1/3rd to 2/3rd and more than 2/3rd. Considering the damage severity and extent, overall damage grade to the building was assigned. Finally, based on the damage grade and extent of damage recommendation to the building either to demolish, repair and retrofit or just repair was recommended.

This study further analyze the main type of damage to different categories of the buildings and finds out critical factors to be considered for making them earthquake resistant. Existing traditional earthquake resistant elements like wooden bands and their effectiveness on earthquake safety of masonry buildings are further studied. It is found that, corner separation, diagonal cracking, out of plane failure, in-plane flexural failure and delamination are the main type of damage to masonry buildings while soft-story damage, joint failure, lap splice, columns shear failure, beam failure and infill walls failure are the main types of damages to non-engineered RC buildings.

Keywords: Low strength masonry, Non-engineered buildings, Damage Patterns

Oral Sessions

Integrated Safer Settlements: GIS (Geographical Information System) as a technological aid for its conceptualization

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ABSTRACT

In Nepal, the hill settlements are largely characterized by low-density scattered settlements. Several of these are situated in steep slopes with low accessibility. They are also remotely located. In many instances, these settlements are found to be in the flood plains of rivers. Since Nepal being located in an active seismic zone, these settlements are therefore exposed to risk of multiple hazards such as earthquake, landslides, and floods. The recent Gorkha earthquake of April 25, 2015 is an evidence to the prevalent vulnerability, as multitudes of settlements—just not the isolated buildings—succumbed to devastation including ground rupture and mounting threat of impending landslides. This has necessitated examining location vulnerability of settlements closely. In this regard, spatial analysis of existing datasets such as land-cover, terrain topography, slope and geological data provide key insight into identifying the possible hazard/risk prone areas. Only by ensuring location safety of settlements, enforcement of earthquake resistant building design will ensure safety of precious human lives and physical assets.

Emerging from this background, this paper takes GIS (Geographical Information System) as a technological aid for conceptualizing the integrated safer settlements. The published reports and experiential knowledge are further combined for conceptualization. The paper takes on Sindhupalchowk district as a case. It relies primarily on the census for the socio-economic data, while spatial and geological analysis has been carried out using data from the Survey Department and Department of Mines and Geology. Using GIS based analysis; this paper systematically examines the natural hazard factors which are associated with the incidence of earthquake, landslides and floods. These factors include (a) slopes (b) coverage of natural resource areas such as water bodies (the forest area is also identified as this is unin-habitable area) and (c) geological fault zones. These factors tend to primarily inhibit safety of settlements in the hill region. By excluding coverage and proximity of these areas, habitable area of the district is determined. Such habitable area has a potential of lower risk of natural hazards. Further, by incorporating the recent (freely available) satellite imagery of the district, mismatches between the existing settlements and habitable area of the district are examined and settlements exposed to higher risk are determined. The damage pattern of the recent earthquake reveals that the settlements which encountered greater devastation or such threat fall in higher risk zone. Based on this analysis, this paper further goes on to recommend reasonable norms and standards for the policy makers to ensure safer settlement practices.

Keywords: *spatial analysis, location vulnerability, hazard factors, location safety, safer settlements, norms and standards*

An introduction to disaster information sharing system and its possible utilization in the aftermath of 2015 Gorkha Earthquake

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ABSTRACT

An earthquake with a magnitude of 7.8 (MW) struck central Nepal at 11:56 NST (local time) on 25 April 2015, with its epicenter in the central part of Nepal (Gorkha). The National Research Institute for Earth Science and Disaster Prevention (NIED) organized interviews to assess the utilization status of disaster information such as damage situation and response situation. In order to understand the overall picture of disaster information during and after the disaster, interviews were conducted involving various people, Central government staff, tent life victims, NPO staff assisting the victims, the United Nations staff and so on. As a result, we found that there is no system of information collection and sharing in place at the local government level. This is affecting the whole information sharing network and the effective response to the disaster.

NIED has been doing research and development of a rapid and smooth disaster information sharing system at the local government level that is highly likely to be suitable for Nepal. In this paper, we review the interview results on the status of utilization of disaster information. We will also introduce an overview and future efforts of the disaster information sharing system, which is under research and development by NIED and its possible use in Nepal.

Keywords: *Gorkha Earthquake, web-system, disaster information, disaster response, disaster management*

1. INTRODUCTION

An earthquake with a magnitude of 7.8 (MW) having its epicenter in the central part of the Federal Democratic Republic of Nepal (hereinafter Nepal) struck the central area of the country at 11:56 NST (local time) on 25 April, 2015, and created widespread damage such as the collapse of brick constructions in a wide area around the capital of Kathmandu.

The National Research Institute for Earth Science and Disaster Prevention (NIED) integrates disaster information provided by various institutions, provides centralized control over such information, and studies mechanisms to enable secondary use of the information. From the viewpoint of the utilization of disaster information with respect to the recent Nepal earthquake, an interview survey was conducted as a basic investigation to understand the status quo of the sharing and utilization of disaster information and to make improvements. This paper, while providing an overview of the results of the interview survey, introduces an approach using the public-private disaster-control cloud system researched and developed by NIED for the sharing of disaster information among local governments and the enhancement of its utilization.

2. Interview Survey

2.1 Outline of Interview Survey

The interview survey was conducted from 26 May to 1 June, 2015, about a month after the occurrence of the earthquake. The subjects of the survey were people in various position including central government clerks, disaster victims living in tents, Japanese people living in Nepal, and researchers at research institutes or officials of national associations. The intended purpose was to gain a brief overview of how the disaster information was shared across society. Table 1 shows the list of interviewees.

In addition to the central part of Kathmandu, people were also interviewed in Sankhu, where the worst damage was observed within the Kathmandu Valley, and Dolakha district, where the largest aftershock occurred on 12 May.

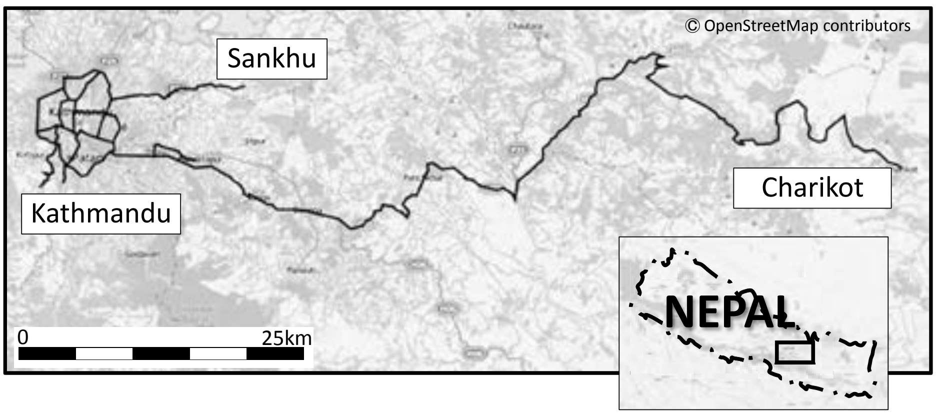

Figure 1: Overview of the survey area

The interview survey concentrated mainly on the basic items listed below, but also focused on collecting the opinions of interviewees without limitation, therefore a semi-structured interview technique was adopted.

■ Basic Items

○ Checking basic attribution (organization, department, position, name, gender, age)

○ Whereabouts at the time of the earthquake

[Approach as an organization]

○ Was disaster information before the earthquake (such as hazard maps) well organized? In addition, were you aware of the hazards?
○ How did you obtain general disaster information (such as on damage and supporting circumstances)?
○ Is disaster information shared? Is any utilization system provided?
○ What information did you obtain immediately after the earthquake? How did you handle such information?
○ Please detail the damage to buildings, lifelines, establishment of safe shelters, and provision of relief supplies.
[Personal Opinion]
○ What are the current challenges to utilizing disaster information? What are the issues related to equipment for utilizing the information and operation of the information system?
○ From among the various pieces of disaster information, what is the one that “must be notified at all costs”?
○ How did schools or other institutions teach people about the risks of an earthquake equivalent in size to the latest case and other aspects related to disaster response?

2.2 Results of Interviews

The results of the interview survey were summarized into survey slips. Please refer to Ise (2015) for individual survey slips. Here, the results of the interview are sorted into the following categories, and problems in disaster information utilization in Nepal are described.

2.3 Sorting of Issues regarding Disaster Information Utilization

2.3.1 Education before Disaster Occurrence

Through an initiative of the National Society for Earthquake Technology-Nepal (NSET) and other organizations, disaster prevention education is provided and the effect is partially observed. However, among the general public of Nepal, hazard maps are not well recognized and the level of understanding of the correct response to protect oneself at the time of an earthquake is low, so disaster prevention education cannot be said to be very effective.

2.3.2 Communication Environment after Disaster

As in Japan, mobile phones are the communication means most popular among the general public of Nepal. In the central area of Kathmandu, some interviewees said that mobile phone communication was available for 20 minutes after the disaster in some areas. Communications started becoming congested 30 minutes after the disaster and recovered about a half day later (5 to 6 hours). However, even around Kathmandu Valley, it took about three weeks for the restoration of service in some areas.

Internet services in the central part of Kathmandu recovered in a few hours, and no significant damage was observed. However, use of smartphones or personal computers was restricted due to electricity outages.

Table 1: List of Interviewees

	Date	Division	Affiliation
1	26, May	Government	JICA NEPAL OFFICE
2	26, May	Research institute	Tribhuvan University Institute of Engineering
3	26, May	Research institute	National Society for Earthquake Technology-Nepal (NSET)
4	27, May	Japanese resident	Maharjan International Pvt. Ltd. Sales, PR & Marketing
5	27, May	Japanese resident	Monta Dio Consulting
6	27, May	Electricity Authority	Chief Nepal Electricity Authority, Community and Rural Electrification Department
7	27, May	Electricity Authority	Director Nepal Electricity Authority Kathmandu Regional Office
8	27, May	Electricity Authority	Chief Nepal Electricity Authority Ratnapark Distribution Center
9	27, May	General public	Quantity Survey Engineer GEOCE Consultants Pvt. Ltd.
10	28, May	General public	Victim in Tundekhel Shelter
11	28, May	NPO	World Vision (NPO)
12	28, May	International agencies	Nepal Risk Reduction Consortium (NRRC)[7)]
13	28, May	Research institute	Nepal Health Research Council (NHRC)
14	28, May	General public	Freelance Engineer
15	28, May	International agencies	JPANESE RED CROSS SOCIETY
16	29, May	General public	Grocery stores management in Charikot, Dolakha
17	29, May	Medical institution	Sindhu Sadabahar Hospital in Khadichaur, Sindhupalchok
18	30, May	Government	JICA NEPAL OFFICE, Nepal Electricity Authority, JICA Expert
19	30, May	Research institute	—
20	30, May	General public	Victim in Sankhu, Kathmandu
21	30, May	Japanese resident	NPO, Tibetan children’s Project
22	30, May	Japanese resident	—
23	31, May	Local government	Senior Engineer Lalitpur Sub-Metropolitan City Office
24	31, May	Local government	Disaster Management Section Kathmandu Metropolitan City
25	31, May	Local government	Assistant Chief District Officer Ministry of Home Affairs District Administration Office
26	31, May	Government	JICA NEPAL OFFICE
27	1, June	News media	IT Officer Sagarmata Television Pvt. Ltd.
28	1, June	Research institute	Sineor Divisional Department of Water Induced Disaster Prevention
29	1, June	Religious groups	Boudhnath
30	1, June	Mountaineer	—

2.3.3 Basic System of Response to Disaster

In the event of a large-scale disaster such as the 25 April earthquake, the Nepal Emergency Operation Center (NEOC) of the Ministry of Home Affairs is officially tasked with conducting overall risk management. However, due to the unstable political situation that has pertained for a prolonged period, NEOC is not functioning effectively and thus disaster response is in fact carried out with the help of the United Nations and governmental institutions of countries providing aid.

2.3.4 Collection and Sharing of Knowledge Regarding Damage (among central governments)

Information sharing among central governments, such as between the Nepal government and governmental institutions of various countries, is conducted relying on the CLUSTER SYSTEM, which was developed through an initiative of the U.N. Office for the Coordination of Humanitarian Affairs (OCHA). However, given the limited capability of the Nepal government, the actual operation is conducted by the United Nations.

The CLUSTER SYSTEM is used to summarize the activities of governmental departments, and the information on deaths and injuries collected from the hospital network overseen by the Ministry of Health and Population functioned relatively well. Having the national hospital as the Hub-Hospital, damage in respective regions are summarized and reported.

2.3.5 Collection and Sharing of Damage Information (among local governments)

Information sharing at the level of local governments between the site of a disaster and the central government is realized mainly via mobile phones.

In Kathmandu City, 71 engineers are engaged in the task in 35 districts, in Lalitpur City, and 17 engineers engaged in the task for 30 districts to understand the damage to constructions. The information gathered by them is reported to their respective district administration offices.

2.3.6 Provision of Information to Disaster Victims

With the support of the United Nations, central governments of various countries are taking action, but due to the limited capability of local governments affected by the political situation, which has been unstable for a long time, support for disaster victims is not comprehensive enough. The information provided by the government is inadequate and, for the psychological ease of residents, more information is need.

In the city of Kathmandu, a system was launched whereby ID cards are distributed to disaster victims to control distribution of supplies, etc.

2.3.7 Others

One of the largest characteristics of the damage caused by the 25 April earthquake is that many Nepalese people choose to sleep outdoors for more than a month as they were afraid of damage to buildings caused by aftershocks. This generated anxieties over property loss and damage to health.

2.4 Summary of Issues in Utilization of Disaster Information

For information sharing among central governments, such as information linkage between the Nepal government and governmental institution of various countries, a mechanism to share information of damage and responding situations using the information sharing system called the CLUSTER SYSTEM is functioning with the support of the United Nations.

The CLUSTER SYSTEM, which was developed as a platform for humanitarian relief operations by OCHA, is a system that has been used in a number of countries and was effectively applied to handle the 25 April Nepal earthquake situation. The interviewees of this survey including staff of the Nepal Health Research Council (NHRC), which is a research institute of MoHP; the JICA Nepal Office (Survey No. 26); and the National Society of Earthquake Technology (NSET), which is a major earthquake research institute in Nepal (Survey No. 2), said the CLUSTER SYSTEM was the main mechanism used to share disaster information.

In particular, the health cluster (health section) seems to have worked very well. In the health cluster, a hospital network having its core at the Health Emergency Operation Center (HEOC) and Hub-Hospital is formed, and information on sick or injured people is summarized by this hospital network. Not only the Nepal Health Research Council (NHRC) (Survey No. 13), but also the JICA Nepal Office (Survey No. 26) praised the health cluster.

However, disaster information gathering from the disaster site to the district department level is mainly done orally via mobile phones, and thus currently, information categories that should be communicated or the development of the format is not advancing. In fact, with respect to the information summarized by the aforementioned health cluster, a local private hospital testified that it has not provided information through the Hub-Hospital (according to the testimony in Survey No. 17), and others pointed out the inadequacy of information sharing by the Ministry of Health and Population and the District-Health Office (according to the testimony in Survey No. 15).

3. Approach toward Introduction of a Disaster Information System

At the local government level where the damage situation is ascertained and reported to a superior institute, and where disaster measures suitable to the damage situation are taken, NIED has long studied and developed a disaster information sharing system (public-private risk-control cloud system) for use as a system to support the smooth utilization of disaster information.

The disaster information sharing system is a mechanism based on Web-GIS for sharing geospatial information indicating disaster situations and corresponding statuses via the Internet.

This disaster information sharing system enables the visual organization and presentation of disaster information, including to neighboring autonomous communities as geospatial information.

In addition, as a characteristic of the system interface, two-layered tabs and menu buttons enable the organization of disaster corresponding operations and guide the flow of procedures. Accordingly, the disaster information sharing system has an aspect of a disaster corresponding system that supports the elimination of manuals on disaster correspondence.

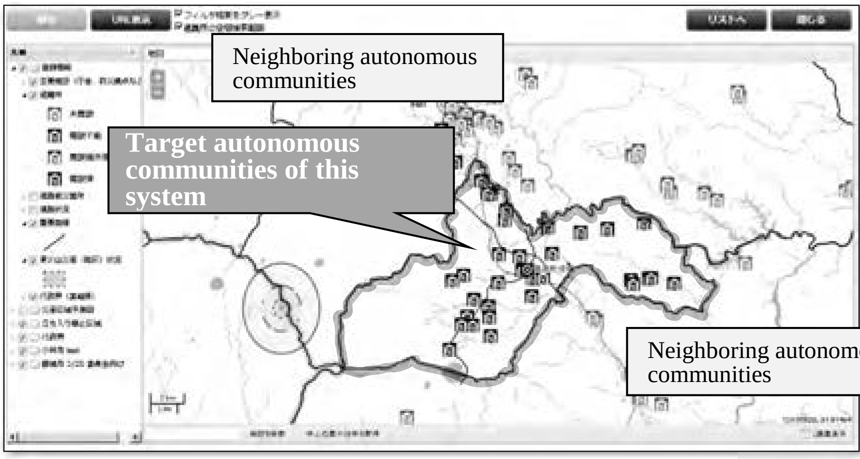

Figure 2: Image of information sharing with neighboring autonomous communities

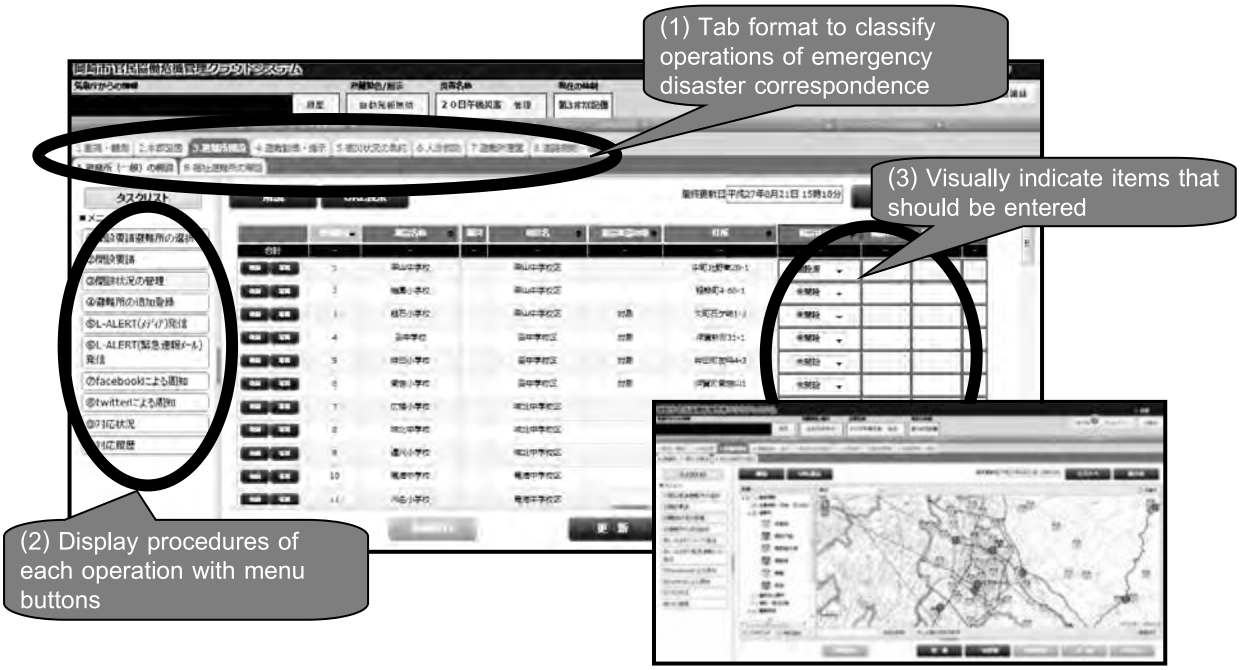

Figure 3: Image of two-layered tabs and menu buttons

3.1 System Briefing Session

Including the cities of Kathmandu and Lalitpur, where this interview survey was conducted, it is planned to establish a trial public-private risk-control cloud system aiming at information linkage among four cities and one county.

In order to develop such a system, it is necessary to provide information about disaster correspondence facilities, etc. to concerned autonomous communities and thus a briefing session on public-private risk-control cloud system is scheduled to be held on 1 November in Kathmandu City.

Table 2: Explanatory meeting Overview

	Content
Date	Date: 1, Nov, 2015 Time: undecided
Place	Undecided (Kathmandu)
Participant	Kathmandu City Lalitpur City Baktpur City Thimi City Baktpur District Development Committee

3.2 Session for Operation Experience and Opinion Exchange

After checking the intention of participant organizations at the briefing session, a session for hands on experience of the system and opinion exchange is planned to be held in January next year.

At the practical operation session, data such as a map of the area around Kathmandu, important road maps and planned safety shelter maps will be made available to let staff from each community experience the operation to enter damage information or corresponding situations using a model disaster scenario of a flood.

4. Summary

This document, using the results of an interview survey conducted in May 2015, about one month after the occurrence of a major earthquake, summarized the problems of disaster information sharing and utilization in Nepal and presented several approaches toward the introduction of a disaster information sharing system to overcome current problems. In the future, through the approaches described herein and by listening to the opinions of personnel in different communities, a development and implementation method of a practical and effective disaster information sharing system needs to be discussed.

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Assessment of Urban Seismic Hazard due to 2015 Gorkha Seismic Sequence

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ABSTRACT

On April 25, 2015 at 11:56 am (local time) an earthquake of magnitude Mw 7.8 struck the central Nepal. The epicenter was located near the Barpak village of Gorkha district about 77 km NW of Kathmandu. The focus of the earthquake was about 15 km. The main shock was followed by two major aftershocks; first Mw 6.7 epicenter in Sindhupalchowk district some 69 km NE of Kathmandu and the second one with magnitude 7.3 Mw was located in the boundary between Sindhupalchowk and Dolakha districts. This continuous seismic sequence in the central Himalaya was the biggest series of events after the 1934 Great earthquake that was located NE of Kathmandu Valley.

The Gorkha seismic sequence has caused massive damages in the form human, socio-economic and environmental losses. Till date, at least 8787 people are reported to be killed and another 22,304 injured. The earthquake has damaged at least 469,539 houses partly or completely. Six districts of central Nepal were severely affected. More than 3600 landslides of small to mega scales were induced in central Nepal causing enormous environmental loss. During the field observation, it was found that the main reasons for extensive damages to the houses were local geology and local seismic site effects along with the construction quality. In this contribution, it is therefore, aimed to focus on urban seismic hazard assessment in the Kathmandu Metropolitan City.

Keywords: Gorkha earthquake,Uurban seismic hazard, Kathmandu Metropolitan City

1. INTRODUCTION

Study of urban seismic hazard is not adequate in Nepal. Only few studies regarding seismic site effects analyses and microzonation have been done for Kathmandu valley, Nepal. Though several constraints like, database and exact modelling of soil behaviour have questioned the representative findings from such studies. Past studies by Maskey and Dutta (2004), Paudyal et al. (2012), Chamlagain and Gautam (2015), Chaulagain et al. (2015), and Gautam and Chamlagain (2015), have attempted to delineate the underlying seismic hazard in Kathmandu valley. After the uneven and more localized nature of damage distribution during MW 7.8 Gorkha earthquake, the urban seismic hazard assessment is more pronounced. The north-eastern parts of Kathmandu valley observed severe damage in reinforced concrete and unreinforced masonry structures however many other areas remained intact being similar in workmanship, construction technology and types of structures. This localized and uneven damage scenario has further highlighted the urban seismic hazard assessment for densely populated Kathmandu valley. During many past events like 1255, 1408, 1681, 1803, 1810, 1833, 1866, 1934, 1988 the damage concentration is more intense in Kathmandu valley both due to building concentration, their deficiencies as well as the stratigraphy (Chitrakar and Pandey, 1986; Gupta, 1988; Bilham et al., 1995; Pandey et al., 1995). Many heritage sites, urban centres, administrative centres, critical facilities, among others are concentrated in Kathmandu valley. Thus, future earthquakes may be more devastating than past events because of higher population concentration and haphazard urbanization. The occurrence of big to great earthquake is also underpinned by the continuous convergence of Indian plate beneath the Eurasian plate at the rate of 35-38mm/year (Chen et al., 2000; Holt et al., 2000; Paul et al., 2001; Sella et al., 2002; Jouanne, et al., 2004). Thus preliminary attempt has been done in this contribution so as to delineate the first order urban seismic hazard assessment in terms of seismic site effects for the Kathmandu Metropolitan City (KMC).

2. STUDY AREA

Kathmandu metropolitan city (KMC) is chosen for performing the urban seismic hazard assessment. KMC has the largest fraction of urban population (24.3%) housing 1,003,285 individuals, whereas total urban population in Nepal is 4,530,820 (17% of total population) only (CBS, 2012). Majority of the medium to high rise constructions, urban centres, commercial complexes, hospitals, airport, administrative centres, historic and heritage sites along with traditional settlements are the common housing units within KMC. During 2015 Gorkha earthquake, the Kathmandu durbar square was severely affected and the northern parts of KMC like Sitapaila and Gongabu observed massive destructions in medium to high rise reinforced concrete (RC) structures.

Geologically, Kathmandu valley is located in the Lesser Himalayan zone. The intermontane basin with young fluvio-lacustrine sediments of Pliocene to Quaternary age has thickness up to 500 m (Yoshida and Igarashi, 1984). The Kathmandu valley is surrounded by mountains, the Shivapuri in the north and Phulchoki in the south. The basement rock in Kathmandu valley consists of Phulchoki Group and Bhimphedi Group of the Kathmandu Complex (Stocklin and Bhattarai, 1977). The valley is filled up by the fluvio-lacustrine unconsolidated sediments; moreover the distribution of sediments across Kathmandu valley is not uniform. The southern part of the valley consists of hill terraces formed during late Pliocene to middle Pleistocene (Yoshida and Igarashi, 1984), with the sediment exposure along the terraces. In general, northern part of the Kathmndu Valley has sand dominated soft sediments while southern part is of clay dominated (Fig. 1). KMC covers partly both clay and sand dominated units.

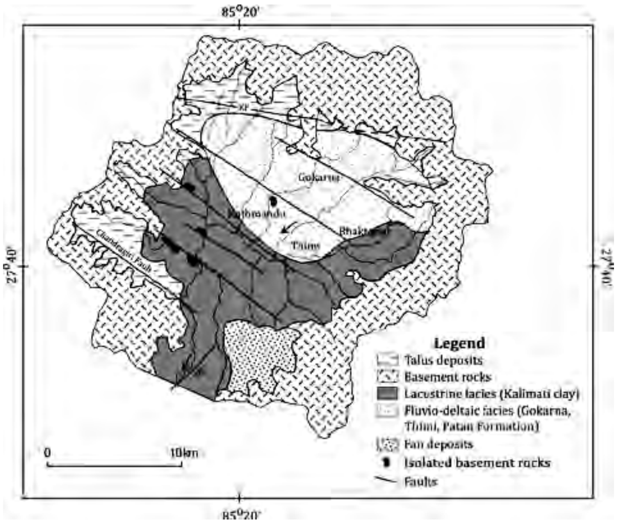

Figure 1: Geological map of Kathmandu valley (After Sakai 2001)

Geotechnically, KMC is characterized by the soft fluvio-lacustrine sediments with thickness variation from place to place. Moribayashi and Maruo (1980) estimated sediment thickness up to 650 m in the central part. In addition, Katel et al. (1996), based on drilling data has shwn more than 300 m thick muddy and sandy sequence. At the central part of the KMC, Bhrikutimandap, a drillhole reaches the basement rock at a depth of 550m. Based on the observed shear wave velocity in some bore holes and N-values of Standard Penetration Test, the average shear wave velocity has been found to be varying from 148 m/s to 297m/s (Chamlagain and Gautam, 2015). As there is no data on the dynamic properties of the soil of Kathmandu valley, for the modelling purpose, we used experimental soil curves given by Vucetic and Dobry (1991) for different PI values.

1. METHODOLOGY

Equivalent linear site response analysis has been performed within KMC choosing 37 borehole logs running up to engineering bedrock level. EERA-Equivalent Linear Earthquake Site Response Analysis (Bardet et al., 2000) is used as an analysis tool. Input motion is chosen from a component of 2015 Gorkha (Nepal) earthquake with a peak ground acceleration of 0.26g (Fig. 2a). The corresponding response spectra at 5% damping shows peak spectral acceleration about 0.98g at 0.25 sec (2b).

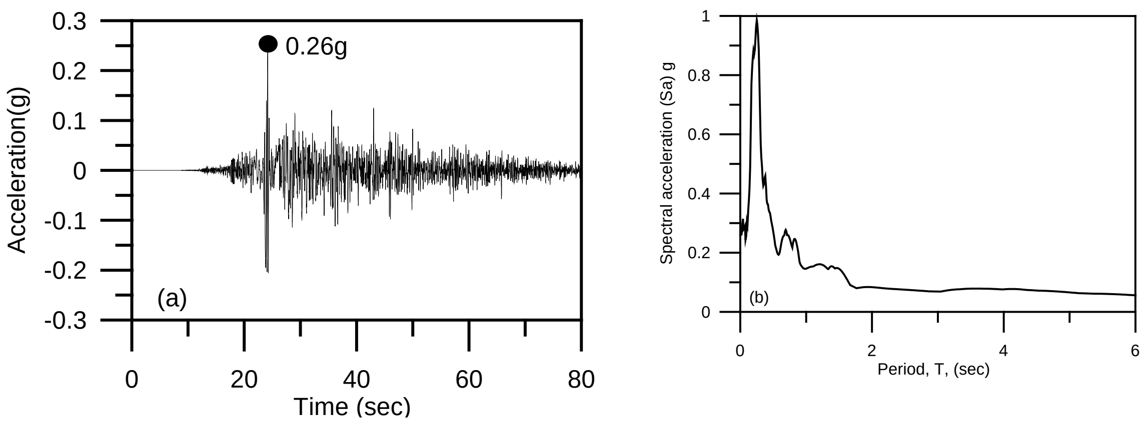

Figure 2: (a) Acceleration time history (b) Corresponding response spectra at 5% damping.

2. RESULTS AND DISCUSSION

Analysis of geotechnical observation logs from KMC is analyzed using EERA code and the results of the analysis are presented and discussed hereafter. Parameters like soil fundamental period, peak ground acceleration (PGA), response spectra and soil amplification are discussed.

3.1. Soil fundamental period

Soil fundamental in study area is observed to be varying from 0.40 sec to 0.70 sec (Fig. 3). While accounting the vibration resonance, the building period could be approximately calculated as 0.1 times the number of stories, this suggests in KMC, the buildings of 4 to 7 stories need higher seismic demand. Meanwhile, majority of the structures in KMC are of this type, so higher attention towards designing and monitoring of constructions for the buildings of 4 to 7 stories are to be paid.

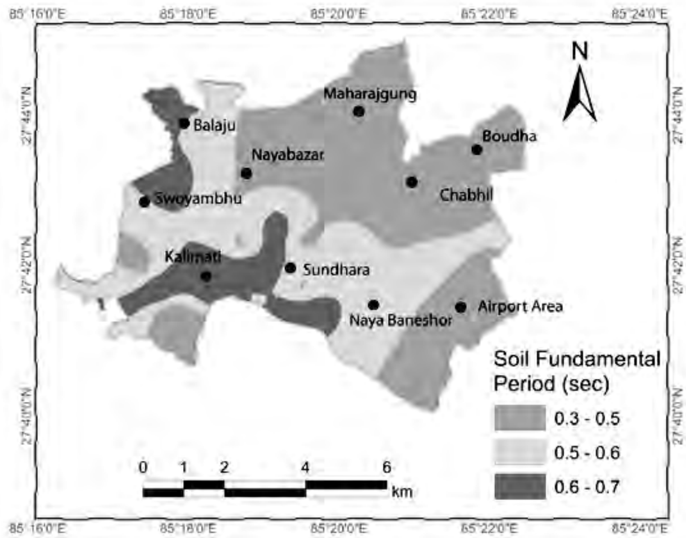

Figure 3: Distribution of soil fundamental period in KMC.

3.2. Peak ground acceleration (PGA)

The PGA in KMC is estimated in between 0.11g to 0.46g (Fig. 4). The upper limit of this estimation is well within the USGS shake map maximum PGA (0.8g) estimation however lower limit is lesser than that of the USGS estimation (0.28g). The maximum value of PGA (0.46g) is obtained for Singh Durbar and least PGA (0.11g) is estimated at New Road. Majority of the studied logs have been observing the PGA in the range of 0.11g to 0.25g and all except Singh Durbar lie between 0.26g to 0.33g. Areas like Gongabu, Sitapaila, Dhapasi which observed severe damage during 2015 Gorkha earthquake are estimated with higher PGA values of 0.31g, 0.28g and 0.28g respectively. Conversely, the low PGA values in majority of the locations are also consistent with the undamaged areas in many areas.

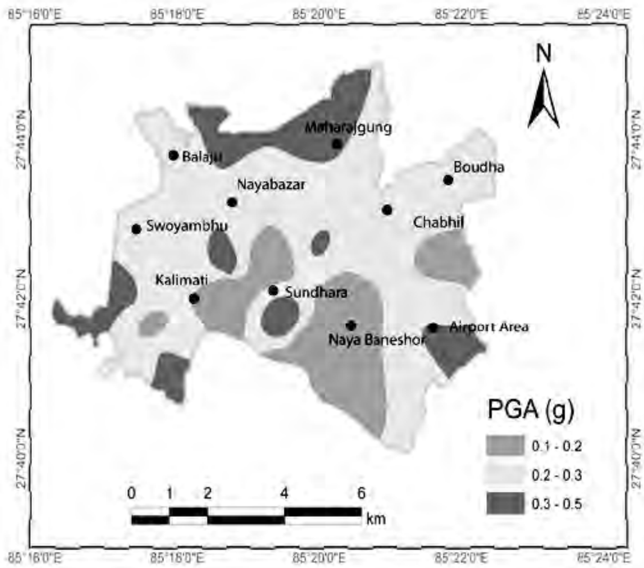

Figure 4: Distribution of Peak Ground Acceleration in KMC.

3.3. Response spectra

The response spectrum for each site for the input motion is computed. The trend of response spectra is plotted in figure 5a. Leaving the outlier at Singh Durbar, the maximum value of spectral acceleration lies in the range of 0.26g to 1.1g (Figs. 5 and 6), however for Singh Durbar it is estimated as 1.67g.

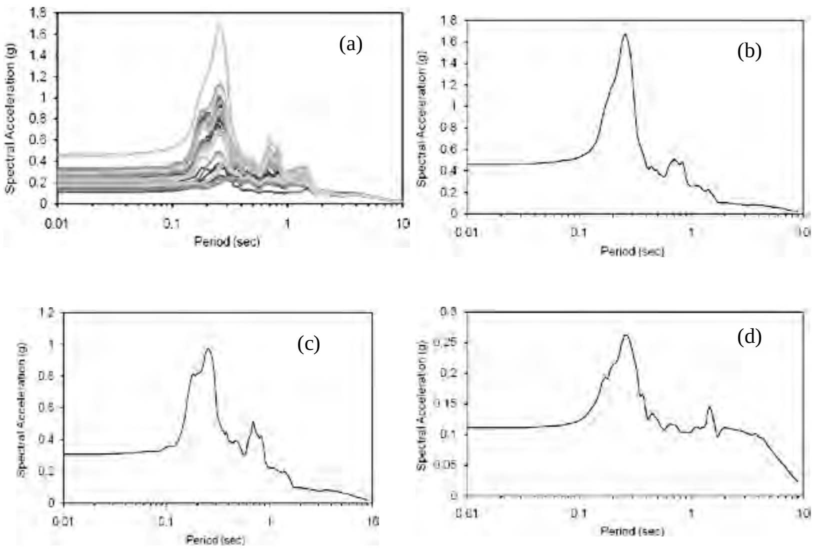

Fig. 5: Response spectra for (a) overall trend in KMC (b) Singh Durbar (c) Gongabu and (d) New Road.

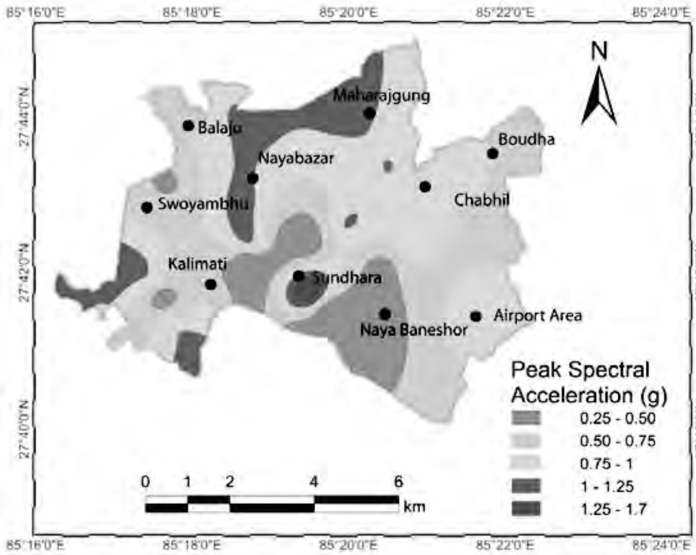

Figure 6: Distribution of peak spectral acceleration in KMC.

3.4. Seismic wave amplification

Among 37 borehole locations, 22 are found to be observing soil de-amplification and rest of the areas are estimated to be amplified up to 8.5 times. The spectral amplification/de-amplification trend is presented in figure 7. The soil de-amplification within KMC strongly correlates with the soil nonlinearity. Thus soil nonlinearity should be well accounted in order to predict the soil behaviour exactly in KMC.

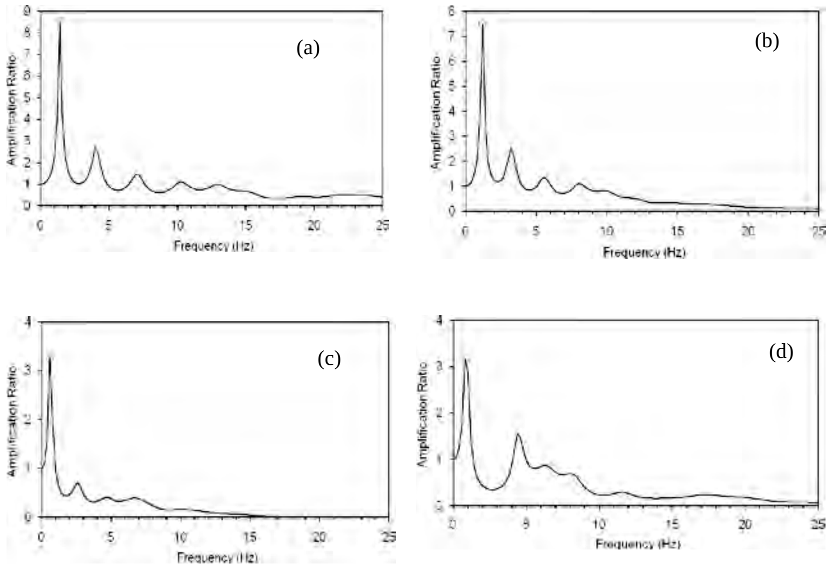

Figure 7: (a) amplification pattern in Baphal (b) amplification pattern in Sitapaila (c) de-amplification pattern in Kamaladi and (d) de-amplification pattern in New Baneshwor

3. CONCLUSION

Analysis of 37 spatially selected geotechnical logs running up to 30m is performed for the only metropolitan city of Nepal. As per the more localized trend of damage distribution, this study coincides with localized soil behaviour in terms of soil-amplification/de-amplification, PGA, spectral acceleration and soil amplification/de-amplification. The soil fundamental period in KMC ranges from 0.4sec to 0.70 sec suggesting larger seismic demand to structures of 4 to 7 stories. Likewise, the PGA variation in study area is found to be 0.11g to 0.46g. This is, in many extents, consistent with the recorded database inside Kathmandu valley. The wider variation of PGA, soil fundamental period, soil amplification/de-amplification within small areas suggests the urgency of microzonation study. Beside this, site specific design spectra are more suitable for such soil nonlinearity led variation in soil behaviour. Due to concentration of medium to high rise structures, large population concentration, critical facilities, urban centres, administrative areas, heritage sites, among others, KMC may observe severe devastation in case of future earthquakes.

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Ecological approach to post disaster settlement planning: a case of a traditional settlement Sankhu

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ABSTRACT

The increasing trend of urbanization is one of the salient features of the twenty first century. With growing number of people residing in urban areas, the stresses on the ecological systems of the earth have been increasing and as a consequence climate change and its impacts are being realized on a global scale. Human settlement planning can no longer be carried out in isolation without considering the ecological consequences of the development efforts in the present context. The development approaches in the past seems to have undermined the fact that human beings are part of the ecological cycle and the planning initiatives focused mainly on physical, social and economic development. It is only recently that various planning initiatives have been propagated by planners such as eco city, sustainable city and so on to create cities in balance with nature and this paradigm shift in planning cities have gained a lot of significance. While planning ecologically sustainable cities is eminent for the survival of human species, it is equally important to plan settlements that are resilient to natural and manmade disasters especially in the disaster prone areas across the globe.

In the context of Kathmandu valley it has been seen that most of the traditional settlements were planned in such a manner that the natural ecosystem is maintained to a great extent and this has been inculcated in the socio economic and cultural practices. The traditional settlements of the Valley especially Sankhu, Chapagaun, Kirtipur, Tokha, Khokana can be considered as good examples of settlements that are in balance with nature and are disaster resilient. However the recent earthquake on 25 April 2015 has impacted most of the traditional settlements in the valley. This paper focuses on the impacts of earthquake disaster in one of the traditional settlements, Sankhu of Kathmandu valley and seeks to explain the consequences. The results of the paper indicate that although the traditional settlements of Kathmandu valley have been planned to be ecologically sustainable and resilient to disasters, there are significant lessons to be learnt from the recent experience. It further elaborates that an ecological approach linked with disaster resilience is the key to post disaster planning.

Keywords: traditional settlements, disaster resilience, ecological approach

1. INTRODUCTION

Planned and involuntary resettlement after natural disasters has been a major policy in post disaster reconstruction in developing countries over the past few decades. Studies show that resettlement can result in significant adverse impacts on the resettled population. Conversely, a well-planned and managed resettlement process can produce positive long-term development outcomes. (S. Ali Badri, 2006). Recovery is not considered complete until the domestic life has regained its pre-disaster state, and that the affected people should be the ones to determine whether domestic life has been restored. Building damage levels have a great impact on domestic life recovery times. The more serious the damage, the longer the recovery time will be. In addition, government policy intervention also has important effects on the recovery process. Post disaster recovery is a long process. Because affected families have different needs during different recovery periods, accurate and meticulous studies of recovery processes will provide important decision-making support, assisting the government in developing efficient recovery policies. (Wang, Li, Chen, & Zou, 2014). Disaster recovery operations that do not account for environmental sustainability (ES) risk exacerbating the impact of the disaster and hindering long-term recovery efforts. (Abrahams, 2014).

The traditional settlements of Kathmandu valley have been among the worst affected areas in the earthquake that hit the nation on 25 April 2015. The impact of the earthquake as in the other traditional settlements of the Kathmandu valley has been felt in terms of destruction most of the buildings that were old from the medieval periods leaving a general impression that the traditional buildings are neither resilient nor are sustainable. However on a closer look this might not be true. An analysis of the philosophy behind the design of the built form and provision of infrastructure in the traditional settlements can provide meaningful insights to the issue of sustainability and disaster resilience of the traditional settlements for which Sankhu has been taken as a case study.

Fig: location map of Sankhu (google maps)

Sankhu is one of the traditional settlements of Kathmandu valley dating back to the ancient period (licchavi period) in the history of Nepal which flourished due to its strategic location in the trade route to Tibet. Located at the foothills of Manichud mountain range, 16 km towards North East of Kathmandu, this settlement has a unique identity being a typical newar settlement with a rich socio cultural environment. Sankhu, also known as Sankharapur for its famous ancient Sankha-shaped town structure, was formerly divided into 3 Village Development Committee namely Pukhulachhi, Suntol and Bajrayogini. Recently the town of Sankhu has been declared as Sankharapur Municipality merging 3 above mentioned VDCs and other neighbouring VDCs. Sankhu region is bordered by Chhaaling and Nagarkot VDCs of bhaktapur district in the south, Lapsephedi and Nanglebhare VDCs in north-east and Indrayani and Gagalphedi VDCs in west. With a total population of 2277 in the area of 14.25 sq.km. The core settlement of Sankhu has been severely affected with more than 95% of the buildings being damaged and resulting in 115 casualties (Sankhu reconstruction committee).

2. THE BUILT FORM AND OPEN SPACES

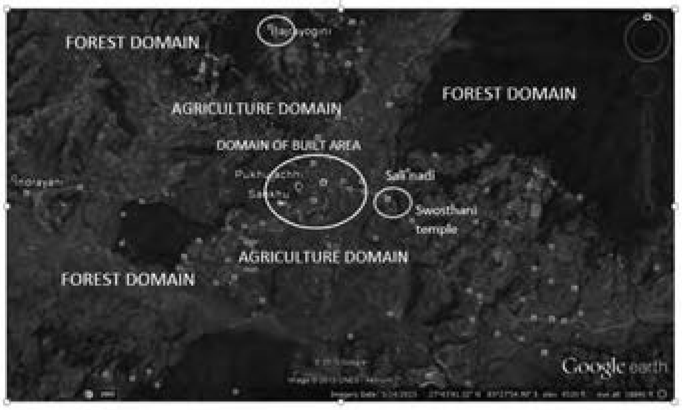

Fig: Landuse pattern of Sankhu

Like other traditional settlements within the valley the planning is based upon vedic and cosmic principles. There are several legends and stories related to the establishment of the Sankhu that was built in the shape of a conc which is considered to be auspicious according to Hindu mythology. The land use and settlement pattern of the traditional towns reflects the fact that nature was considered as an integral part of the daily life and was treated with respect. The residential settlements were mostly located on elevated tar land and was a compact one. The domain of the built area was surrounded by the agriculture domain and further away towards the periphery was the domain of natural resources like forest.

The tangible and intangible cultural heritage played a key role in maintaining the built form and in preserving the natural resources. The natural resources like forest and water bodies were thus given due reverence with the placement of temples and idols of gods which were considered to protect these elements. The location of Bajrayogini temple in the forest premises in the outskirts of Sankhu and the Madhav Narayan temple and other deities on the banks of the Sali river are examples of treating the forest and river as objects of respect. In a way the cultural traditions and belief systems acted as an unwritten doctrine towards maintaining what we consider as sustainable settlements.

Fig: Bajrayogini for forest preservation

Fig: Temples at Sali nadi (River)

The traditional towns of Kathmandu valley are “abodes of gods with various forms, characters and qualities. Wonderfully, the gods do not always live their lives inside their temples; once in a while they come out to renew their relations with humans, just as humans, as believers, visit the gods in their temples”. (Tiwari, 2002)

The built form in these towns were guided by cosmic entities and gods and power places put in places and “streets laid out as if their function was to facilitate the passage of gods rather than that of man”. The settlements were thus compact as the towns grew “ through the process of in-fill, thereby keeping the ritual infrastructure static and unchanged" and were " walled in towns, with a clear definition of the inside (dune in newari) and outside (pine in newari), neither was able to transgress upon the other." (Tiwari, 2002) In the more ancient of the indigenous towns, the ritual structure consisted of a dyoche, or house of god, in the town and pith, or aniconic power of place, outside the settlement limits in the domain of nature. (Tiwari, 2002). Such characteristics can still be seen in Sankhu which is a walled town delimited by the gates serving as the entry and exit points in the settlement.

Fig: Festival route of Bajrayogini jatra

Fig: asta matrikas

It is interesting to see that some of these gates are still seen in Sankhu which are still being used for various purposes like Dyo Dhwakha for Lord Bajrayogini during Bajrayogini festival, Bhau Dhwakha, for welcoming the bride during marriage ceremony, Mhyaymach Dhwakha for seeing off the daughter when married, Magh Dhwakha for the entry of god Mahadev Narayan during Magh Bajrayogini festival, Si Dhwakha, for taking funeral procession to the rivers during the last right which is also known as Mahadev Dhwakha.

Fig: Gates depicting the boundary of the settlement

The urban form which was inclusive of public and private open spaces formed an important element of the traditional settlements which gave it a unique identity. These open spaces usually in the form of squares, Chowks, Courtyards, Bahals, Bahils, Lachhi, khyos, dabalis are the key elements of urban settlements that define the urban fabric and which act as the focal point of social interaction, that knits the communities together. The potential of the urban spaces in the contribution of sustainable urban development and also in the growth of the economy is quite significant. While parks (khyo) can foster the green environment and support the urban ecosystem, various activities like evening markets, outside seating areas for restaurants and pubs, street performances, occasional festival markets and so on not only enliven the urban spaces but contribute towards strengthening the economy as well. Both the public and private residential courtyard open spaces have been meticulously designed in the traditional settlements not only to improve the micro climate in the dense residential areas but also as spaces that are ecologically significant and which enhanced disaster resilience within the settlement. Streets have also been important open spaces where a myriad of activities happen and the fact the streets paving as well as that of the open spaces were done with open jointed bricks meant that people in those times were aware of the much needed water recharging in the urban areas. The water bodies like ponds, hitis, wells, stone spouts etc were important elements in these open spaces which contributed to water recharging as well. The open spaces also served the purpose of safe zones in case of earthquake disasters.

Fig: open spaces in Saknhu

The effective land use pattern, the compact built form with its open spaces as seen in Sankhu and other traditional settlements of the valley are the elements that are considered to be desirable in ecological cities in the modern context. Based upon these and other aspects such as the socio cultural traditions and belief systems it can be stated that the traditional settlements of Kathmandu valley have been planned for sustainability and disaster resilience. However the extent of destruction of the buildings in the present earthquake can be attributed to the fact that there was lack of proper maintenance. In fact the building technology of the traditional settlement can be considered as sustainable as well looking at it from the point of disposability and reuse of materials

Fig: open spaces in Saknhu

which are of much significance. The building materials mostly used are bricks on mud mortar, with wooden doors and windows and tile roofing which are mostly natural materials that do not contribute to global warming. The buildings built in the traditional period were meant to have a certain lifetime depending upon the life period of the materials that were used and without maintenance these are bound to deteriorate. It has to be noted that disposability and perishability is also a significant aspect of sustainability and the traditional building materials unlike the materials of the contemporary times could be disposed off without much stress on nature as such. In fact due to the use of mud mortar the recycling potential of bricks were much higher.

Fig: Blocked roads and buildings in need of demolition

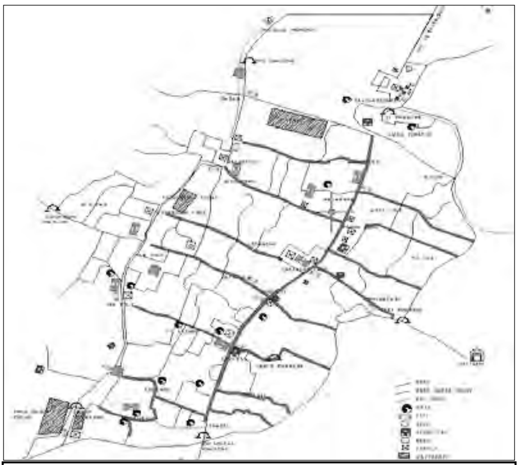

Fig: Internal roads blocked with debris

3. WATER SENSITIVE URBAN DESIGN AND THE TRADITIONAL SETTLEMENTS

Water has always been at the core of human civilization and settlements were historically located around water sources. With industrialization and development especially the western countries have been using the nonrenewable natural resources like water, fuel etc in an unsustainable manner. Water resources on which the modern society depends not only for daily needs but also for various other purposes does not seem to have received much priority in planning, resulting in water shortages, pollution of water bodies, flooding etc which is increasing at an alarming rate. “Conventional methods for water management fail to help the city to promote the importance of water resources. Under natural conditions, water operates in a cycle of precipitation, infiltration, surface runoff, and evaporation. However, in urban areas, this cycle is disturbed and cannot run its course. Urban water is polluted, cannot infiltrate the ground due to paved surfaces and is rapidly collected and discharged to the public draining systems leaving no time for evaporation. Finally, this negatively impacts groundwater recharge, water supplies, the qualitative and quantitative state of receiving rivers, and urban climate ” (Hoyer, Dickhaut, & Kronowitt, 2011). With the paradigm shift in the planning sustainable cities like the ecocities, green cities and so on, concerns have been raised regarding the sustainable water and waste management and water sensitive urban design and other concepts have started to gain significance. The objective of Water Sensitive Urban Design is to combine the demands of sustainable stormwater management with the demands of urban planning, and thus bringing the urban water cycle closer to a natural one (Hoyer, Dickhaut, & Kronowitt, 2011). The Green Water Defense (GWD) has been developed as an extension of the 'Green Growth' concept in the water sector. GWD is an adaptive management philosophy and approach which seeks to spatially integrate natural forces and human interventions, and to balance incentive-based and supply-driven measures, with minimum footprints and externalities in sustainably providing water services and managing related climate risks. (Li, Turner, & Liping, 2012).The traditional societies especially in the East have been practicing this sustainable water management practices since the ancient times. Most of the traditional settlements in Kathmnadu have a very well managed and sustainable water supply system. The townships of the Lichchhavies located in the ridges and other high lands of the valley were away from the hill sources and at the same time the subsurface ground water table was also fairly low for the technology of that time. This led to the development of ponds with deep wells or fed by canals brought over long distances or in some cases, fed by naturally available water veins, as reservoirs and depressed pit conduits for water supply (Tiwari, 2001).

Fig: Raj kulo network of Sankhu

Fig: Ponds of Sankhu

Sankhu is one of the traditional settlements in Kathmandu valley where the water system was well developed and sustainable management practices were inbuilt in the culture and traditions of the society. It is said that each and every household of Sankhu was connected to water supply canals which were fed by the network of Raj kulo (irrigation canal). The intricate network of rajkulo and ponds along with the deep wells and hitis form the water supply network of Sankhu. The ponds and wells and hitis were designed so as to recharge the aquifer in the ground which provided the source of water for the supply at lower levels. Various rituals and cultural traditions related to the ponds, wells and hitis were associated with maintaining the water quality. There were annual festivals like sithi nakha where all the water bodies were cleaned. The communal water supply points like stone water spouts, hitis etc were considered to be a sacred place which was supposed to be clean and were usually decorated with deities and idols of snakes at these areas which were worshipped. On a deeper level we can assume that the role of biodiversity preservation was well understood by the traditional societies and the role of snakes in opening the clogged water conduits was well recognized. The element of sustainability in managing the water supply system is worth preserving and revitalizing in the modern context.

4. CONCLUSION

The world commission on Environment and Development recognized how much industrialized cultures have to learn from traditional people and at the same time how vulnerable the latter are to encroachment by the former (WCED 1987). The belief and behavior pattern of the people, dictated by the native world views of the cultures have been supportive in sustainable patterns of resource use and management.

The post disaster settlement planning of the traditional settlements including Sankhu needs to focus not only on the reconstruction of the buildings and infrastructure but should be based on a wholistic approach considering the strengths and weaknesses of the traditional planning practices that are both sustainable and disaster resilient. The analysis of the traditional settlement planning of Sankhu shows that the settlements have been well planned both form the ecological sustainability and disaster resilience perspectives and that these are the basic parameters that are key to most of the planning concepts of the twenty first century like the eco city, green city etc. The philosophy behind the planning of traditional settlements can be adapted to suit the modern context so that the traditional settlements can be regenerated rather than reconstructed.

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Investigation of damage to buildings and ground truth verification for satellite data in Kathmandu Valley due to the 2015 Gorkha Earthquake

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ABSTRACT

An earthquake with a magnitude of 7.8 (M_W) occurred at 11:56 NST (local time) on 25 April 2015, in the central part of Nepal (Gorkha). The National Research Institute for Earth Science and Disaster Prevention (NIED) organized a damage survey team and dispatched it to the affected area for several periods following the earthquake (26 May to 3 June, 17 to 24 June and 16 to 21 August) to investigate the damage and collect data. This report outlines the findings of this investigation into various aspects of the earthquake disaster in the Kathmandu valley. We also carried out a first-hand building damage survey in selected areas. The primary purposes of the first and second surveys were to collect timely statistical information on the damage to brick and stone masonry buildings and to confirm the availability of data and their sources for subsequent surveys. The motivation for the thread survey was to obtain ground truth data to calibrate.

Keywords: *Gorkha Nepal Earthquake, Kathmandu, masonry, ground truth*

1. INTRODUCTION

An earthquake with a magnitude of 7.8 (M_w) occurred at 11:56 NST (local time) on 25 April 2015 in the central part of Nepal (Gorkha). The epicenter was east-southeast of Lamjung, 77 km southwest of Kathmandu, at 28.15°N, 84.71°E, and at a depth of 15 km (USGS). According to Nepal Police statistics, the number of deaths, as of 22 June, was 8,660 with 21,952 injured in the main shock and 172 deaths with 3,470 injured in the aftershocks. It was also reported that more than 5 million buildings were damaged, with about half of them experiencing collapse. This earthquake is officially referred to as the 2015 Gorkha Nepal earthquake because the hypocenter was located in the Gorkha region.

A major aftershock with a moment magnitude of 7.3 (M_w) occurred at 12:51 NST on 12 May 2015. The epicenter was 75 km northeast of Kathmandu, near the Chinese border, at 27.82°N, 86.08°E, and at a depth of 19 km (USGS).

The National Research Institute for Earth Science and Disaster Prevention (NIED) organized a damage survey team and dispatched it to the affected area for three periods following the earthquake (26 May to 3 June, 17 to 24 June and 16 to 21 August) to investigate the damage and collect information and data. This report outlines the findings of this investigation into various aspects of the earthquake disaster in the Kathmandu valley (**Figure 1**) and compares vulnerability analyses for “The study on earthquake disaster mitigation in the Kathmandu Valley (JICA, 2002)”.

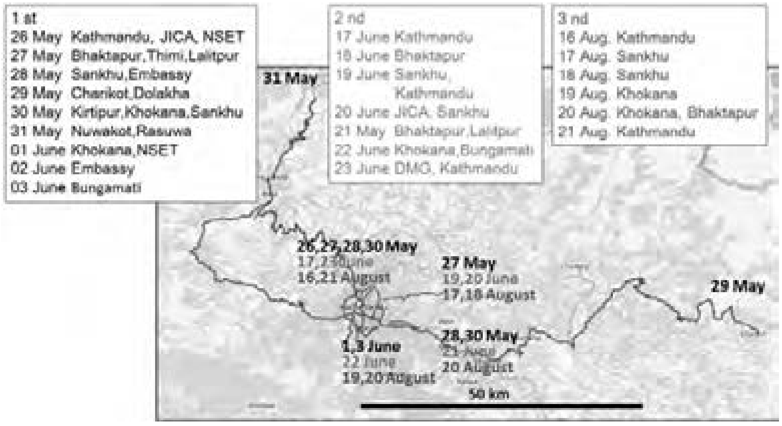

Figure 1: Survey Roots (OpenStreetMap https://www.openstreetmap.org/)

2. SEISMO-TECTONICS AND EARTHQUAKE GROUND MOTION

2.1 The Earthquake as Recorded in Kanti Path (KATNP), central Kathmandu

The strong-motion data set from the USGS Center for Engineering Strong Motion Data (CESMD: http://strongmotioncenter.org/cgi-bin/CESMD/iqr1.pl) includes stations from Nepal that continued to function during the main shock and several subsequent strong aftershocks of the 2015 earthquake series.

Figure 2.1 shows the three components of acceleration and velocity recorded by the CESMD station at the US Embassy in Kathmandu, which recorded the M_w 7.8 main shock (06:11:26 UTC, 28.15°N 84.71°E, 15.0 km deep). **Figure 2.2** shows the three components of the tripartite response spectrum of the main shock and aftershocks. The dominant periods in the Fourier spectra were approximately in the range of 4 to 5 s for magnitude 7 class events. However, for magnitude 5 class events, the dominant periods of the Fourier spectra were about 0.5 s. The response spectrum of the pseudo velocity exceeds the 400 cm/s level of the response spectra in the case of the main shock.

In **Figure 2.1,** the vertical velocity motion waveform has two pulse-like ground motions. The main parts of the velocity waveform can be seen centered at two points: 45.08 and 53.07 s. The difference between the rupture start time and arrival time for the S-wave is 8 s. The dominant period of the body wave is about 4 s.

These sizes can be estimated for each strong motion generation area (SMGA) by direct interpretation of body waves.

The method followed is shown below;

$$R = T_p \times V_r \tag{1}$$

$$V_r = 0.72\ V_s \tag{2}$$

where R: Circular strong motion generation area

T_p: Pulse period

V_r: Rupture velocity

V_s: Share-wave velocity

Thus, two SMGA might exist near the city of Kathmandu.

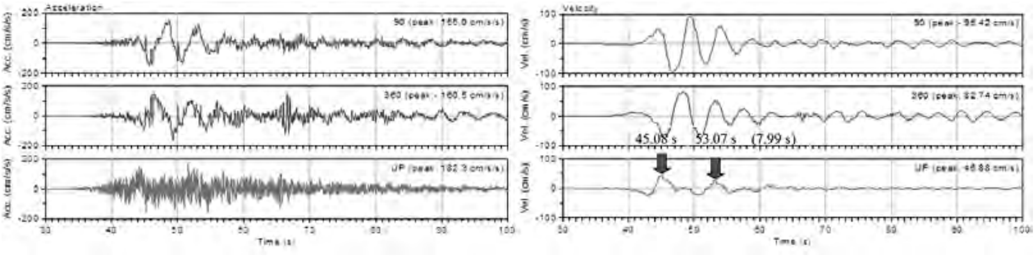

Figure 2.1: Acceleration (left) and Velocity (light) Record of M_w 7.8 main shock

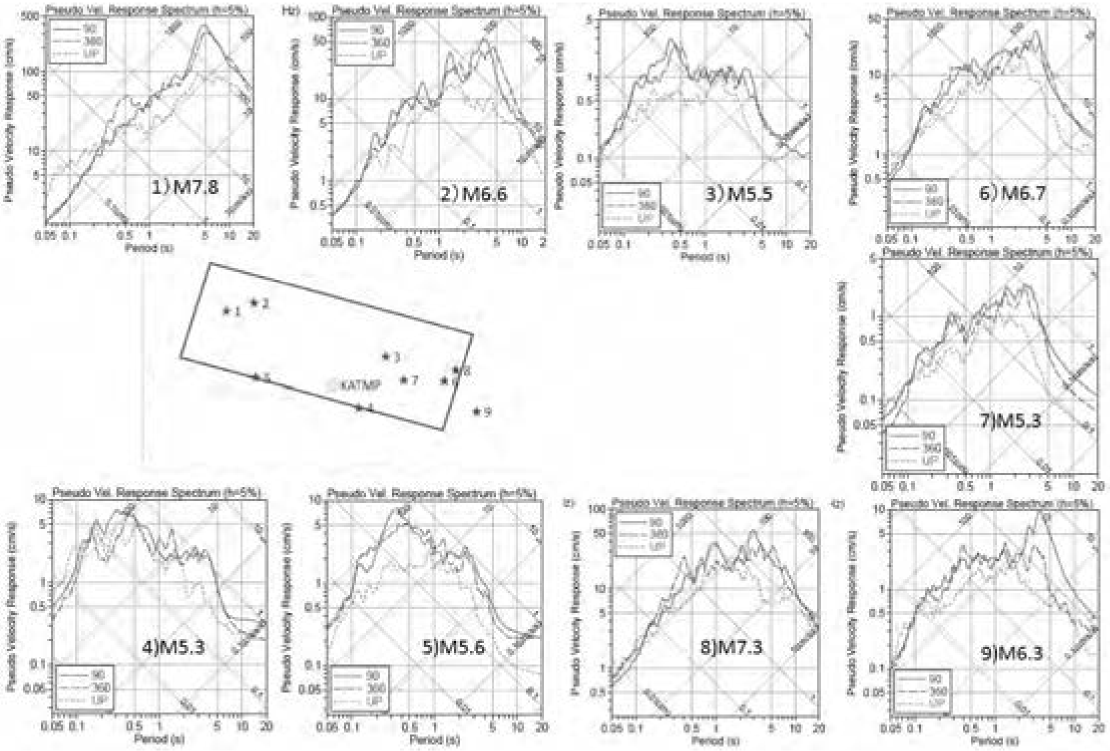

Figure 2.2: Response Spectrum of main shock and Aftershocks.

3. DYNASTIES, HISTORICAL PALACES AND BUILDINGS IN SANKHU

During the Malla dynasties, prior to 1768, there were three kings in the Kathmandu valley. Their palaces were in Kathmandu, Bhaktapur, and Lalitpur/ Patan.

3.1 Bhaktapur

"*Bhakta*" means Devotee in Sanskrit, and pur means city. Thus, "*Bhaktapur*" is the city of devotees. The central areas of these palaces are referred to as "*Durbar Squares*". Bhaktapur's Durbar Square is a conglomeration of pagodas, and during the earthquake series, many Sikhara style temples in Bhaktapur's Durbar Square were severely damaged (**Figure 3.1**).

Figure 3.1: Bhaktapur before / after the earthquake (Photo. by T. Ohsumi), before / after the 1934 earthquake in Bhaktapur (Courtesy of MoHA)

3.2 Lalitpur/ Patan

The Patan Royal Palace complex (Patan in Sanskrit, or "*Yela*" in Newari) is found in the city of Lalitpur, which means the city of beauty. The Patan palace was renovated in 2013 with assistance from the Kathmandu Valley Preservation Trust (KVPT) and the Sumitomo Foundation.
Thus, the palace had only partial damage during the earthquake at the top of structural parts of the buildings (Gajur and Baymvah) (**Figure 3.2**).

Figure 3.2: In Patan, after the earthquake, this place (*a*) had partial damage at top of structure parts (Gajur and Baymvah) (*b*) (Photo. by T. Ohsumi).

3.3 Kathmandu

The old palace structures in Kathmandu's Durbar Square, which had not undergone renovations, had severe damage during the earthquakes (**Figure 3.3**). In the photo on the left, the white structure is about 150 years old, built during the Rana Dynasty. In the photo on the right side, the four-tiered brown temple is about 300 years old, constructed during the Gorkha Dynasty.

Figure 3.3: Kathmandu Durbar Square after the earthquake (*a*), before the earthquake (*b*) (Photo. by T. Ohsumi)

3.4 Sankhu

Houses damaged by the earthquake have been demolished with the support of Canadian Forces relief operations in Sankhu. Heavy equipment was brought for this purpose from Canada. In general, RC buildings were partially damaged, whereas masonry buildings were severely damaged.
The difference in damage as a result of building type was remarkable. Damage in Sankhu was extensive. Brick and cement mortar houses without RC columns experienced a lot of damage. In contrast, the damage to RC structures – particularly those erected in recent years – was generally minor. These structures were mainly five

to six story buildings. In contrast, many of the non-engineered masonry structures that experienced complete collapse or partial damage were two to four story buildings in Sankhu (**Figure 3.4:**left). Damage in non-engineered masonry structures was initiated by vertical cracks in the corners of the buildings (**Figure 3.4:***a*), which contained no RC columns (**Figure 3.4:***b*). The outer wall structures of such buildings was generally burned brick with cement mortar joints to withstand rain. In several cases, the inner walls of buildings are adobe bricks with mud mortar.

Figure 3.4: The damage to RC structures was generally minor.These structures were mainly five to six story buildings. Many of the non-engineered masonry structures that experienced complete collapse or partial damage were two to four story buildings in Sankhu (left). Damage in non-engineered masonry structures was initiated by vertical cracks in the corners of the buildings (*a*), which contained no RC columns (*b*).
(Photo. by T. Ohsumi)

4. LANDSLIDES

A numerous number of huge slope failures which occurred in the mountainous area buried villages and valleys, and resulted in the loss of many lives. We visited a landslide zone in Ramche, and it is located in the northwest of Kathmandu city in a mountainous area. Many of fallen rocks were on the roads, also we encountered a bus that hit by falling rocks (**Figure 4.1**). Thick talus is deposited in the landslide area in Ramche, in Rasuwa district (**Figure 4.2**). The town is located at an altitude of 2,068 m. There are houses that had been caught in a landslide, but the damage was limited. However, the whole scope of the slope failures is not clear at the present time, because any detailed and total survey in the mountainous area has not been carried out. Thus, causalities will in-crease as they are found.

Figure 4.1: Bus was hit in falling rocks in Dhikure,on Baglung Rajmara High way. (Photo. by T. Ohsumi)

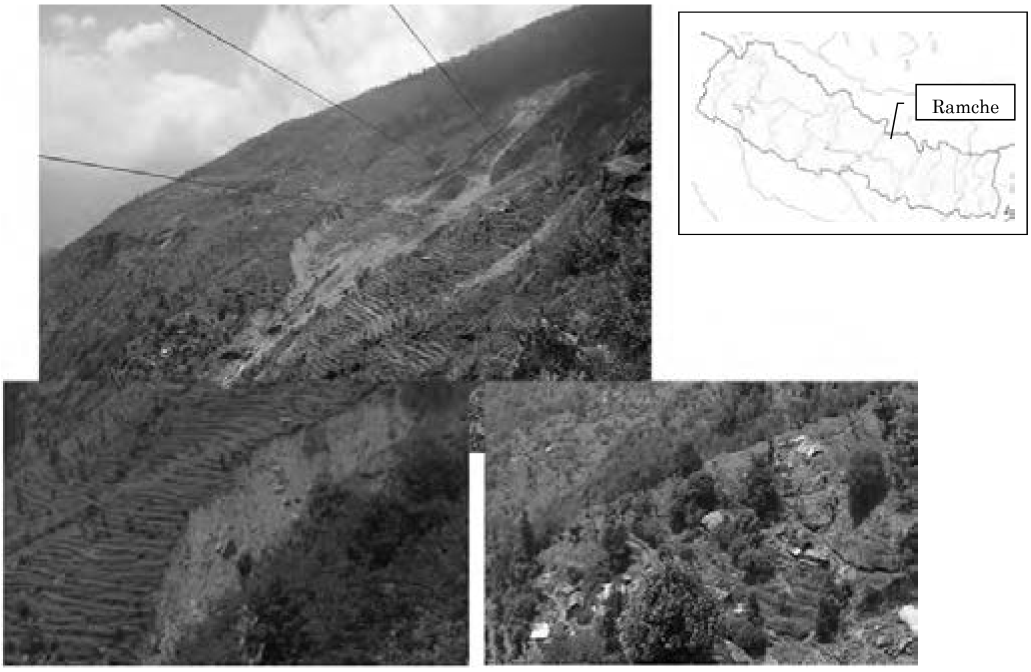

Figure 4.2: Thick talus is deposited in the landslide area in Ramche. (Photo. by T. Ohsumi)

5. SUBURBANS AND RURAL AREAS

The number of casualties was concentrated to the northeast of the Kathmandu Sindhupalchowk district. We visited Charikot, in the Bhimeshwar Municipality, roughly 50 km east of Dhulikhel. The town is located at an altitude of 1,554 m. The name of the district Dolakha came from Dolakha Town, which is situated northeast of the capital Charikot. These areas had many casualties. According to the locals, the large aftershock felt stronger than the main shock. This is understandable as the aftershock's hypocenter is located just below this area. Many houses collapsed in the aftershock.
Urban and rural housing is significantly different. In the suburban and rural areas where there are many stone houses, a lot of damage occurred. The collapse of heavy stones used in house construction, resulted directly in deaths and property destruction.
In Dolakha district, adobe style houses collapsed. Primarily, adobe houses collapsed as a result of cracks in the gables and corner foundations as a result of ground motion. Many adobe style houses were broken at their gables. Stone houses could also collapse as a result of delamination (**Figure 5**).

Figure 5: Adobe style houses (*left*) and Stone style house (*right*) in Charikot, (Photo. by T. Ohsumi)

6. DISCUSSION

According to Nepal Police statistics as of 22 June 2015, the number of deaths was 8,660 and injuries were 21,952 for the main shock. A total of 172 deaths and 3,470 injuries were associated with the aftershocks. It was also reported that more than 5 million buildings and houses were damaged – and about half of those collapsed; that number is now increasing (**Figure 6**).

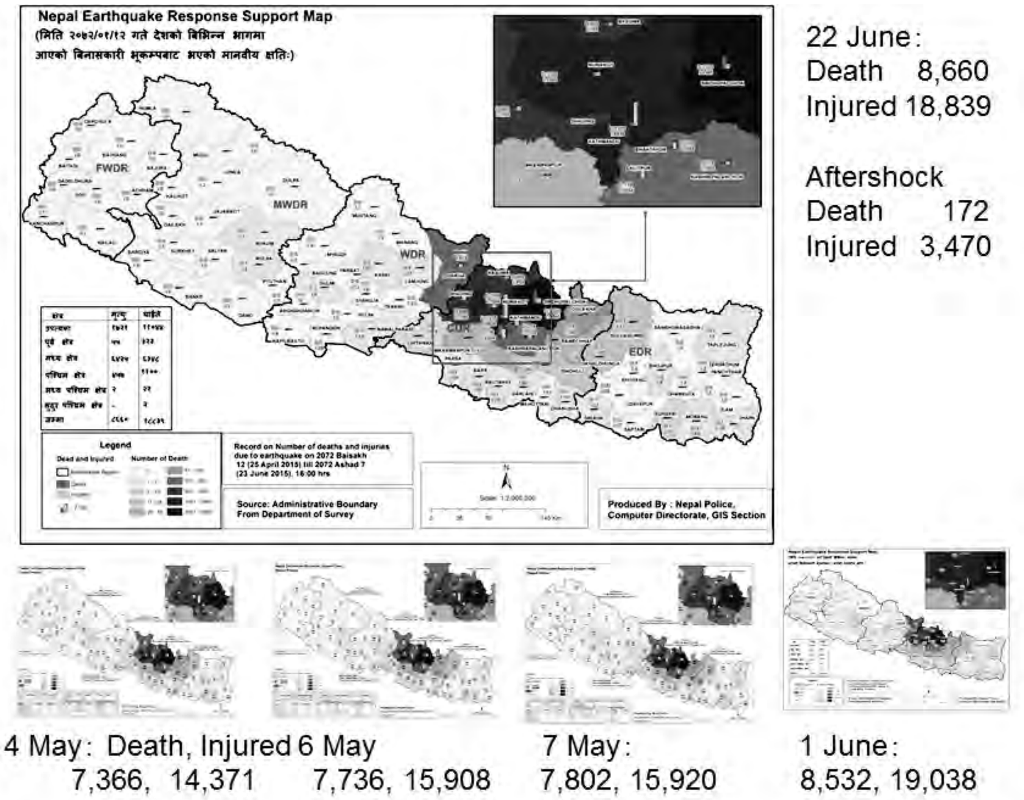

Figure 6: Casualties and injured people by Nepal Police.

Why did this area have concentrated casualties?

First, the dominant rural housing style in the area consists mainly of stone masonry. The collapse of heavy stone buildings killed many. The damage to houses in the mountainous region was typically concentrated in non-engineered structures. In rural areas, unreinforced masonry, sourced from regionally available materials, was the main construction material. Regardless of the masonry material used, serious damage occurred with houses as a result of masonry cemented with mud mortar. This housing construction method also exists in urban areas, primarily for constructions undertaken more than 30 years ago. In the rural areas, this type of housing is still the most popular method of housing construction. Thus, the retrofitting of low-cost earthquake-damaged housing without the consideration of engineering standards is a key issue.

Second, this earthquake involved major high-frequency (1 Hz) seismic energy that can be observed in the earthquake waveforms (Yagi and Okuwaki (2015)). The area is north of the Kathmandu Valley and located near the North Bagmati scenario earthquake model.

The major high-frequency (1 Hz) seismic radiation area was used for the hybrid back-projection analysis of Yagi and Okuwaki (2015). The area is north of Kathmandu Valley, in the vicinity of the North Bagmati scenario earthquake model. This high-frequency seismic radiation caused much of the damage to buildings in the Kathmandu Valley.

7. CONCLUSION

1) Although RC buildings were partially damaged, the difference in damage between buildings with and without RC appears remarkable. Brick and cement mortar houses without RC columns generally had a lot of damage. Structures having no RC columns in the corners generally experienced vertical cracking in the brick masonry walls.
2) The casualties resulting from the earthquake were concentrated in the northeast of Kathmandu in the Sindhupalchok district. Many houses here collapsed in the aftershocks. The casualties were compounded by significant differences in urban and rural housing. In suburban and rural areas, there are many stone houses that were badly damaged. The collapse of heavy stones used in house construction took many lives.
3) The three royal palace complexes in the Kathmandu valley (Kathmandu, Bhaktapur, and Lalitpur / Patan) had undergone significantly different renovation works over the last few decades (although not for the historic structures within the old royal palaces). This enables a means to assess how particular renovations can strengthen historical structures.
4) In rural areas, stone masonry is used as a current building technique. Retrofitting such low-cost non-engineered housing is a key issue.
5) The dominant periods observed in the Fourier spectra of magnitude 7 class events are approximately 4 to 5 s. However, for magnitude 5 class events, the dominant periods are much shorter 0.5 s. These differences in shaking periods / frequencies can have a significant effect on the resulting damage.
7) The major high-frequency (1 Hz) seismic radiation caused much of the damage to buildings and housing on the north side of the Kathmandu Valley.

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Estimation of Seismic Intensity at Lalitpur, Nepal

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ABSTRACT

An attempt has been made to estimate seismic hazard at rock level in terms of peak horizontal acceleration (PHA) at two sites of Lalitpur district using probabilistic seismic hazard analysis (PSHA). Earthquake data base for the site was prepared merging the various data bases. Magnitude frequency relationship was developed to represent the earthquake recurrences in the region. Then using Young's et al 1997 attenuation relation and with help of CRISS 2007 software peak ground acceleration was estimated and probabilistic spectra for the two sites is obtained. The results show the higher level of seismic risk at the sites which suggest the existing guideline of earthquake resistant design considerations.

Keywords: peak ground acceleration, spectral acceleration, PSHA

1. INTRODUCTION

Lalitpur is one of the three districts of Kathmandu valley. The Kathmandu valley has been reported to have experienced many earthquakes in the past. Records of past destructive earthquakes date back up to 1255 AD (Chitrakar and Pandey, 1986). The significant earthquakes around Nepal (NDGC, 2015) are shown in table 1. The earthquakes on 1255, 1833 and 1934 have badly destroyed the Kathmandu valley (Pant, 2000, Rana 1935). A strong earthquake occurred and damaged eastern side of Nepal in 1988 (ISC, 2015). The recent M7.8 earthquake in Barpak, Gorkha following M7.3 after shock in Dolakha in 2015 severely damaged along 80 kilometer stretch of the Himalayan which lies just north side of Kathmandu valley. The study area falls in the western extremity of the source region that produced the 1934 great earthquake. It is believed that this region has to wait for some 5 hundreds of years before it gets matured to produce great earthquake (M>8.0) again, but we should not ignore the possibility that this region has collected some energy in the last about 80 years (after the 1934 Bihar-Nepal Earthquake) and this energy might be equivalent to one ~M7.0 earthquake at the present.

The recent, Barpak M7.8 earthquake developed 240gal acceleration at Kathmandu. Another very important aspect it has very long duration -56 seconds with period 4 - 5 seconds. Thousands of buildings were damaged, soil is liquefied in many places, ground failure occurred and 8922 people (NDGC, 2015) died and 23000 people injured (Sherchand, 2015). Looking at history recurrence history of major earthquakes (magnitude greater than 7.5) has occurred in the interval of 80-100 years period. It is quite large and show big seismic risk in the region. From similar studies for other places, it had been emphasized by many researchers (Maskey, 2004, Parajuli et al 2008, JICA 2003) which have proved urgent need to revise the seismic risk and make the decision as per updated risk scenario.

Table 1 Significant Nepal earthquakes

Source:https://en.wikipedia.org/wiki/List_of_earthquakes_in_Nepal#cite_note-DPNET-Nepal-2

Date	Place	Latitude	Longitude	Fatalities	Magnitude	Remark
1255	Kathmandu	27.70	85.30	2,200	7.8	
1260	Sagarmatha	27.10	86.80	100	7.1	
1344	Mechi	27.50	87.50	100	7.9	
1408	Bagmati	27.90	86.00	2,500	8.2	
1505	Mustang	29.50	83.00	6,000	8.2	Mw
1681	Koshi	27.60	87.10	4,500	8.0	
1767	Bagmati	28.00	85.50	4,000	7.9	
1833	Gosaikunda	27.90	85.50	6,500	8.0	Ms
1869	Kathmandu	27.70	85.30	750	6.5	M_s
1916	Nepal/Tibet	30.00	81.00	3,500	7.7	M_s
1934	Sagarmatha	26.77	86.76	8,519	8.4	Mw
1966	Nepal/India border	29.55	80.85	80	6.3	M_s
1980	Pithauragarh	29.60	81.09	200	6.5	M_s
1988	Udayapur	26.78	86.62	1,091	6.6	M_s
2011	Sikkim, India	27.33	88.62	111	6.9	M_s
2015	Gorkha	28.15	84.71	8,922	7.8	M_w
2015	Dolakha	27.97	85.96	213	7.3	M_w

2. EARTHQUAKE CATALOGUE

The earthquake catalogue for this area was prepared by combining and consolidating the available information from different sources and covers the period 1255-2014 AD. The earthquake data were collected from different sources, i.e., United States Geological Survey (USGS), Department of Mines and Geology (DMG), International Seismological Centre (ISC). In addition to that, a few more data were collected from the catalogues published by different researchers. Uniformity of data base was prepared using Scordilis, 2006, Pant 2000. Catalogue was completed considering both- Historical Catalogue and Seismicity (1255 – 1910 A.D.) and Instrumental Catalogue and Seismicity (1911-2014 A.D.)

2.1 Declustering

In order to avoid repetition of dependent events such as fore and aftershocks were removed by declustering. Declustering is the method of filtering the overlap events. As the available earthquake data include fore shocks, main shocks and aftershocks, it is difficult to identify main shock or background or dependent events. Hence, after converting reported magnitude (Ms or Mb) and intensity into moment magnitude (Mw), all the dependent events (fore shock and aftershock) were removed by the windowing procedure based on algorithm given by Gardner and Knopoff (1974).

2.2 Catalogue Completeness

The collected earthquake data consists of different magnitude scales and intensities which are finally converted into moment magnitude in order to keep uniformity in completeness by using the empirical relationships given by Johnston, 1996 and Scordilis, 2006. Residual catalogue obtained after declustering the dependent events, containing independent earthquakes is finally prepared. Earthquake catalogue is prepared neglecting magnitude less than M5 because an earthquake with magnitude less than 5 contributes very less in seismic hazard assessment. In this work a total of 1900 unclustered main shocks were collected for the period of 1255 to 2014 A.D. After making completeness of the earthquake data, magnitude frequency relationship was developed for all sources.

2.3 Seismic Source Zone

The first step of seismic analyses is the definition of the earthquake sources that could most probably affect the site of interest at which the seismic hazard will be calculated. In fact, the characterization of seismic source zones depends on the interpretation of the geological, geophysical and seismological data obtained by many tools such as tectonic theory, seismicity, surface geological investigations and subsurface geophysical techniques. The discontinuity in the tectonic boundary of the study area has been divided into a total of 25 quadratic and polygon shaped- areal sources.

2.4 Gutenberg – Richter Coefficients (a, b):

After characterizing the earthquake sources, logarithmic value of the rate of exceedance of earthquakes falling in the particular sources are plotted against the earthquake magnitude in order to find out the Gutenberg-Richter parameters. The slope of the plotted curve represents the “b” value while the rate of earthquake exceeding magnitudes represents the “a” value (Stepp, 1972).

3. PSHA FORMULATION

The Probabilistic Seismic Hazard Assessment (PSHA) refers to the estimation of some measure of the strong earthquake ground motion expected to occur at a selected site. The PSHA is formulated following the procedure mentions in the Cornell 1968, Kramer 1996, Parajuli et al 2008. The seismicity is specified by a recurrence relationship indicating the average rate at which an earthquake of a particular size will be exceeded. The standard Gutenberg–Richter recurrence law is used for this purpose, that is,

$$\lambda_m = 10^{a-bM} = \exp(\alpha - \beta M) \tag{1}$$

Here, λ_m denotes the average return period of the earthquake of magnitude m. If earthquakes lower than a threshold value m_0 are eliminated, then the expression for λ_m is modified as:

$$\lambda_m = \nu \exp[-\beta(m - m_0)] \tag{2}$$

Where, $\nu = \exp(\alpha - \beta m_0), m > m_0$,

$\alpha = 2.303a$, $\beta = 2.303b$

Similarly, if both the upper and lower limits are incorporated, then λ_m is given by:

$$\lambda_m = \frac{\nu \exp[-\beta(m - m_0)] - \exp[-\beta(m_{\max} - m_0)]}{1 - \exp[-\beta(m_{\max} - m_0)]} \tag{3}$$

The CDF (cumulative distribution function) and PDF (probability density function) of the magnitude of earthquake for each source zone can be determined from this recurrence relationship as:

$$f_M(m) = \frac{\beta \exp[-\beta(m - m_{\min})]}{1 - \exp[-\beta(m_{\max} - m_{\min})]} \tag{4}$$

The uncertainties in earthquake location, earthquake size, and ground motion parameter prediction are combined to obtain the probability that the ground motion parameter will be exceeded during a particular time period. This combination is accomplished through the following standard equation (Kramer, 1996, McGuire, 2004).

$$\nu_{y^*} = \sum_{i=1}^{N_s} \nu_{i_{M\,min}} \int\int P\left[Y > y^* \mid m,r\right] f_{Mi}(m) f_{Ri}(r) dmdr \tag{5}$$

$$\nu_{y^*} = \sum_{i=1}^{N_s}\sum_{j=1}^{N_r}\sum_{k=1}^{N_m} \nu_{i_{M\,min}} \rho_i P\left[Y > y^* \mid m,r\right] P[M = m] P[R = r] \Delta m \Delta r \tag{6}$$

Where, N_s is number of sources in the region, $\nu_{iM\,min} = exp(\alpha - \beta_i m_{min})$ is total rate of exceedences of threshold magnitude (M=5.0 is taken in this study). $P\left[Y > y^* \mid m,r\right]$ is conditional probability that chosen acceleration exceeded for a given magnitude (M) and distance (R), and $f_{Mi}(m)$ and $f_{Ri}(r)$ are probability density functions for magnitude and distance respectively. Here, M and m are used as random variable and specific value for magnitude respectively. The first term within the integral considers the prediction uncertainty, the second term considers the uncertainty in earthquake size, and the third term considers the uncertainty in location of the earthquake. The above uncertainties for all source zones are considered by way of the double integration summation. A seismic hazard curve is then constructed by plotting the rate of exceedance of the seismic parameter for different levels of the seismic parameter and calculated by using CRISIS 2007.

4. ATTENUATION EQUATION

Though there are hundreds of attenuation laws developed for various region of the world, no earthquake attenuation relations have been developed for the Himalayan region specially. Because of unavailability of sufficient data, here, instead of developing new equation for the region, attenuation equations among already developed equations for subduction zone Crouse 1991, Fukushima and Tanaka 1990, Molas and Yamazaki 1995, Young et al. 1997, Gregor et al. 2002, Atkinson and Boore 2003, Kanno et al.

2008, Zhao et al. 2006 which supports the tectonics, geology and faulting system were studied. Most of the earthquakes occurring in Nepal are considered to be interface events due to subduction of Indian plate beneath the Eurasian plate. Hence, in this research work attenuation relationship suitable for subduction zone proposed by Youngs et. al. (1997) is used.

From the probability distribution of particular ground motion parameter, the probability that this parameter Y exceeds a certain value, y*, for an earthquake of a given magnitude, m, occurring at a distance, r, is given by:

$$P[Y > y^* \mid m,r] = 1 - F_y(y^*) \tag{7}$$

Where, $F_Y(y)$ is the value of the cumulative distribution function of Y at m and r. The value of $F_Y(y)$ depends on the probability distribution used to represent Y. In general, ground motion parameters are usually assumed to be log normally distributed (the logarithm of the parameter is normally distributed).

3. RESULTS

Following the procedure explained preceding sections, uniform hazard spectrum (UHS) and PSHA of Tikathali area and Lubhu were estimated and the results are shown in the Figures 1-4. Probabilistic spectra for 10% probability of exceedence in 50 years which 475 years return period (RP) and 2% probability of exceedence in 50 years which 2475 years return period (RP) are obtained using CRISIS software. The obtained results are shown in the respective figures. The results the higher level of seismicity at the two sites. It helps the planner and designers to act or higher level of safety.

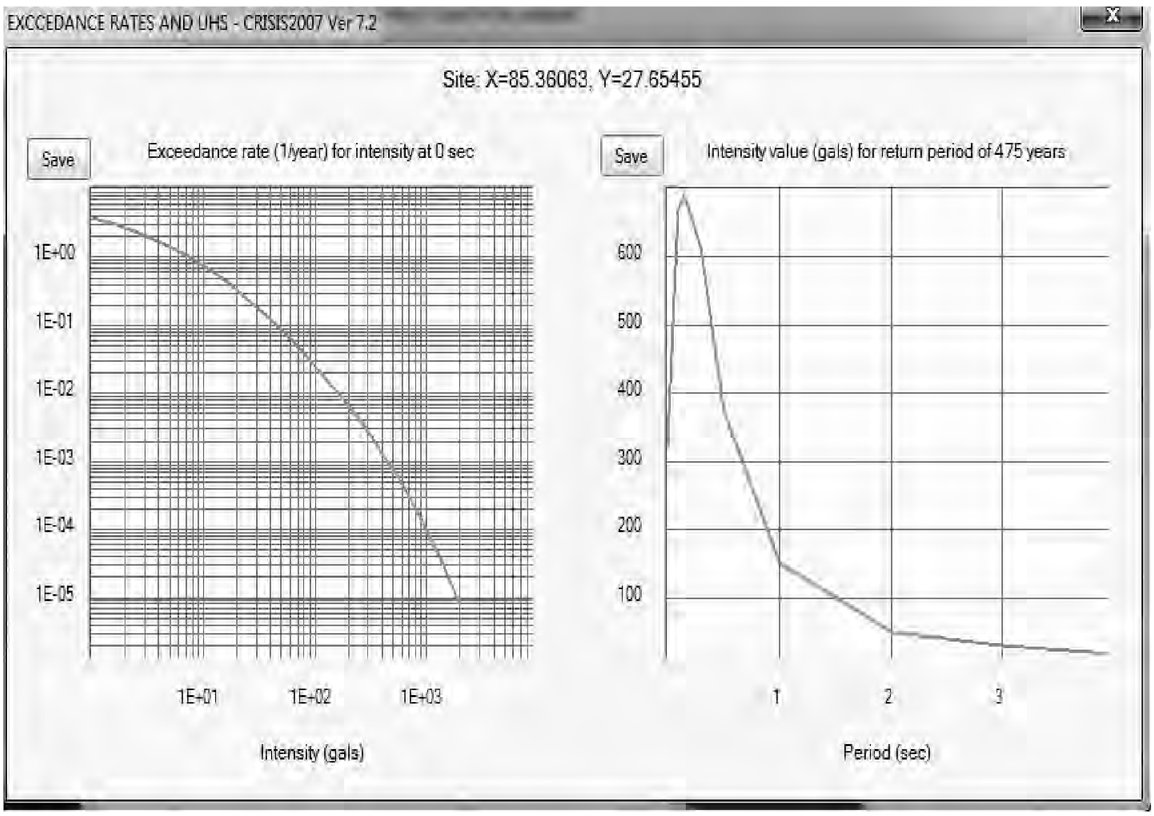

Figure 1: Tikathali PGA of .30g showing Hazard Map and UHS Map, RP=475 yrs

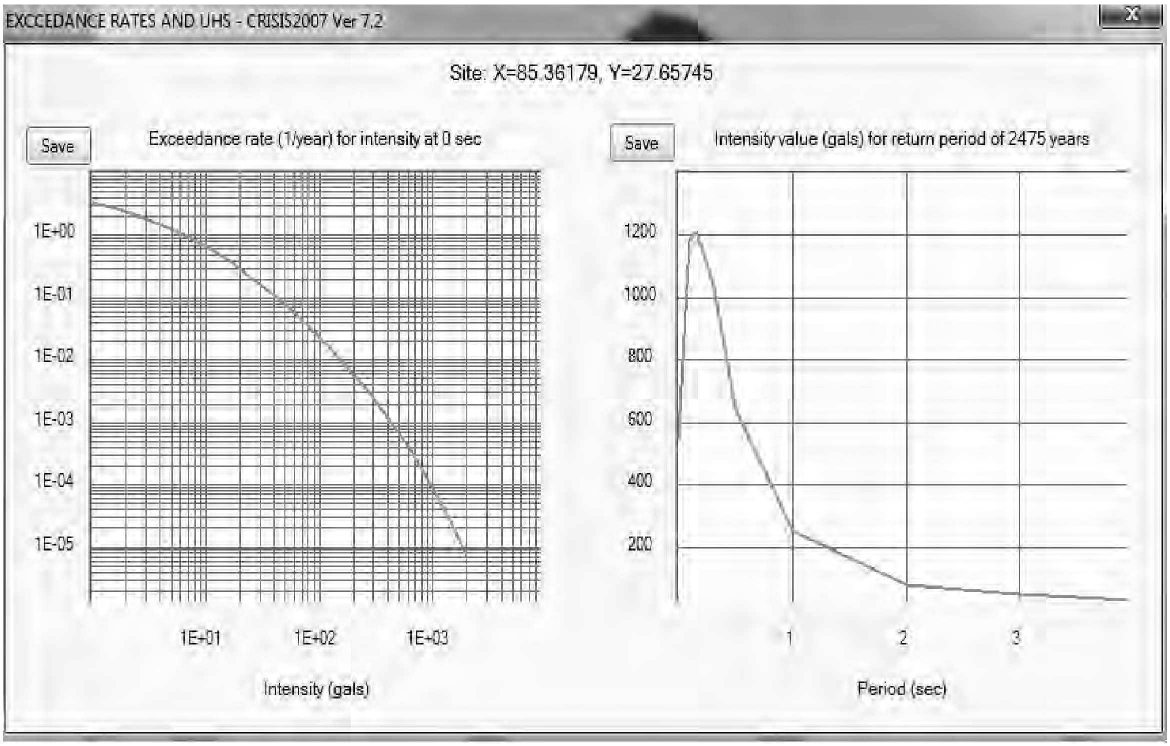

Figure 2: Tikathali PGA of .58g showing Hazard Map and UHS Map, RP=2475 yrs

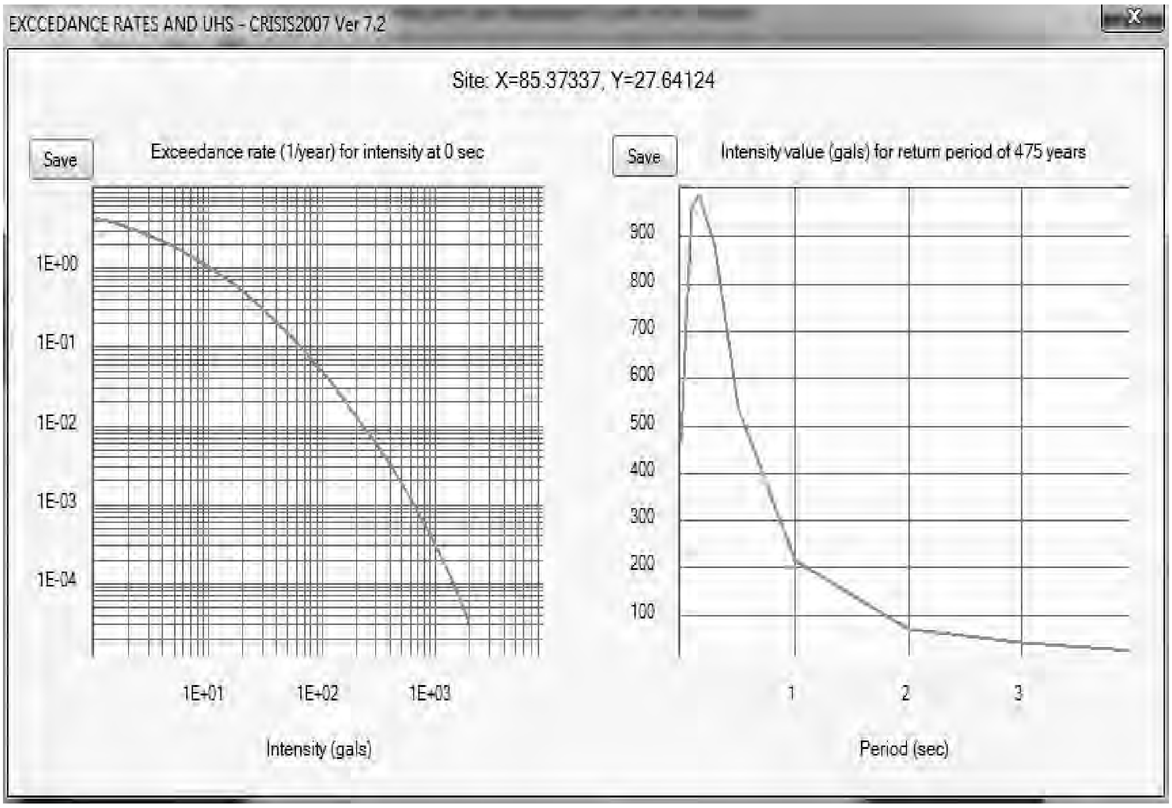

Figure 3: Lubhu PGA. 39g showing Hazard Map and UHS Map, RP=475 years.

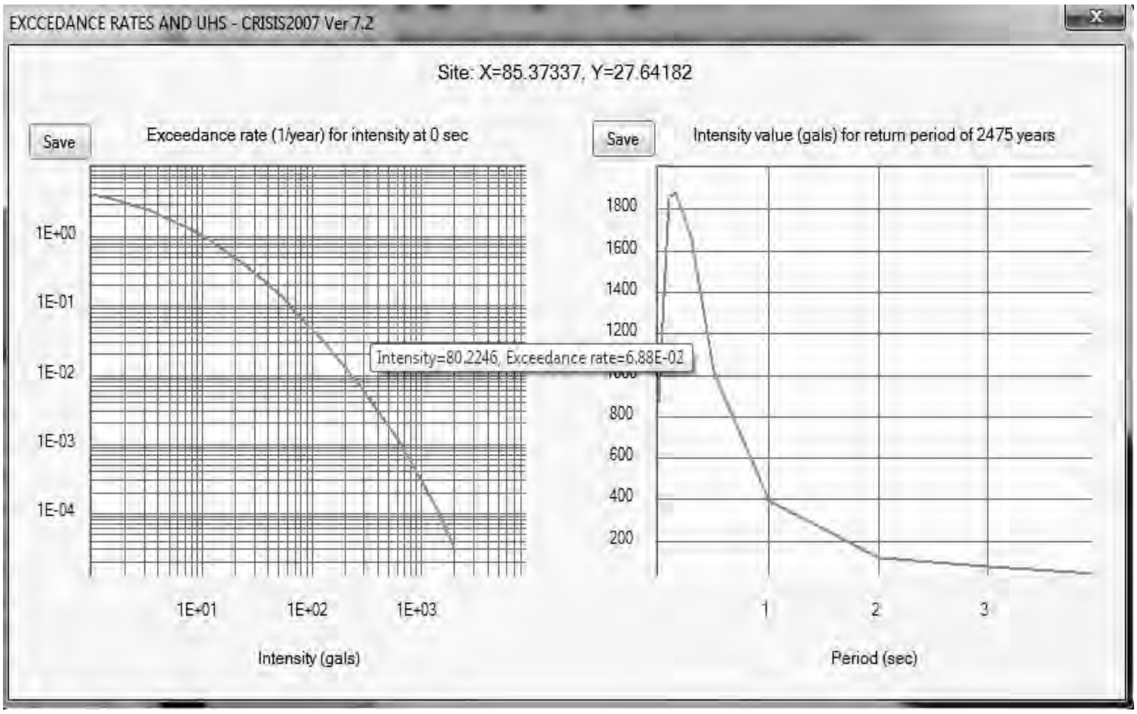

Figure 4: Lubhu PGA. 39g showing Hazard Map and UHS Map, RP=475 years.

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Damage scenario of reinforced concrete buildings in the 2015 Nepal earthquakes

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ABSTRACT

The Gorkha earthquake of April 25, 2015 and its aftershocks caused extensive damage to hundreds of thousands of building structures in Nepal. A reconnaissance survey was carried out in the most affected areas to assess the damage to buildings due to the earthquakes. It was found that many old as well as modern reinforced concrete buildings including residential, school and high-rise apartments sustained minor to major damage including collapse. Most of the well-designed reinforced concrete buildings sustained minor or non-structural damage. From the field observation, some of the main reasons of such a vast damage to building structures are found to be the lack of maintenance of old structures, negligence of building codes, and poor design and construction practices. This paper summarizes the damage to reinforced concrete buildings with specific focus on the causes and types of damage due to the earthquakes. Most of the collapsed reinforced concrete buildings were seen to have soft-first story failure mechanism. Non-structural damage mainly included heavy damage to the brick masonry infill walls. Suggestions and research needs are also identified to improve the seismic performance of reinforced concrete buildings in Nepal.

Keywords: earthquake reconnaissance survey, reinforced concrete buildings, seismic damage, 2015 Nepal earthquake

1. INTRODUCTION

A magnitude 7.8 earthquake occurred in the central region of Nepal on April 25, 2015 at 11:56 AM (Nepal Standard Time). The epicenter (28.147°N, 84.708°E) of the earthquake was located in the village of Barpak, Gorkha district which is approximately 77 km north-west of the capital city Kathmandu (Figure 1) and its focal depth was 15 km (USGS, 2015). The earthquake resulted in a maximum Mercalli Intensity of IX (Violent) and more than 8,700 deaths and over 22,300 injuries were reported. Some casualties were also reported in the adjoining areas of India, China, and Bangladesh. Over 350 aftershocks with magnitude greater than 4.0 have occurred, with some significant ones having a magnitude of 6.7 on April 26 and 7.3 on May 12 (Figure 1). More than 500,000 houses were totally collapsed and over 200,000 houses were partially damaged leaving over two million people homeless. Although Kathmandu and Sindhupalchowk districts were far away from the epicenter, severe damages were observed in these areas.

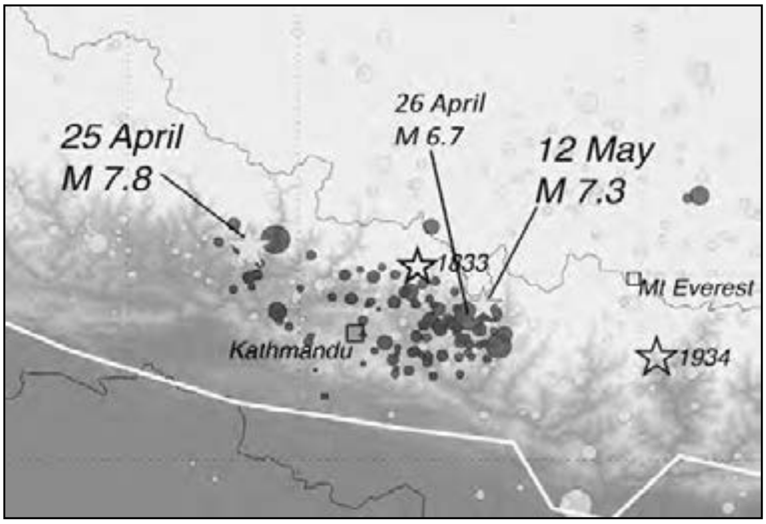

Figure 1: Locations of the mainshock and major aftershocks. (Source: USGS)

Reconnaissance survey of the heavily affected regions (Kathmandu valley and Sindhupalchowk district) were conducted by a team from Tokyo Institute of Technology, Japan to assess the extent and nature of damage to building structures caused by the earthquakes (Wijeyewickrema *et al.*, 2015).
This paper summarizes the cause and nature of the structural damage to RC buildings due to the earthquakes. Some suggestions for improving the performance and future research needs in the area of seismic design and construction practice of RC buildings in Nepal are also presented. Since, the investigation was based on the visual inspection without the information on actual design and construction details, there is a possibility that the interpretation of the failure mechanism might not be accurate.

2. SEISMIC DESIGN AND CONSTRUCTION PRACTICE IN NEPAL

In recent years, reinforced concrete framed structures are common construction practice in Nepal (JICA, 2002). Low-rise reinforced concrete buildings are designed using the seismic design code NBC-105 (DUDBC, 1994) whereas high-rise buildings are designed following the guidelines provided by the Indian seismic code IS1893 (BIS, 2002). Detailing for ductility is based on Indian standard IS 13920 (BIS, 1993). Although various guidelines are prevailing for the seismic design of buildings in Nepal, most of the low-rise structures do not follow the design codes. Owners themselves compromise with the quality of construction materials, design and construction process due to economic reasons. The construction practice in most of the cases is based on thumb rules and the masons are not well trained. Due to the increasing urbanization and skyrocketing population in the Kathmandu valley, the owners opted for addition of stories in the old construction, which were not well designed. These are some of the weaknesses of the current building design and construction practice in Nepal. Chaulagain *et al.* (2013) studied the seismic vulnerability of common RC buildings in Nepal and found that the buildings constructed using current construction practice and designed with Nepal Building Codes (NBC) are highly vulnerable to earthquakes.

3. DAMAGE TO REINFORCED CONCRETE STRUCTURES

Reinforced concrete moment-resisting frame buildings performed poorly in the 2015 Gorkha earthquakes. Many low-rise reinforced concrete buildings in the affected area were either collapsed or sustained heavy damage. Most of the poorly designed buildings not confirming to design standards suffered severe damage. But well-designed reinforced concrete buildings suffered only minor non-structural damage. The damaged reinforced concrete buildings included mostly residential buildings as well as school and high-rise apartment buildings. Most of the high-rise apartment buildings were subjected only to damage in the non-structural elements and are livable after repairing.

3.1 Damage to residential buildings

Many poorly designed residential buildings collapsed or suffered heavy damage due to the earthquakes. All the reinforced concrete framed constructions in Nepal have heavy brick masonry infill walls increasing the seismic weight of the buildings. Typical damage scenario of reinforced concrete residential buildings in the Kathmandu valley and Sindhupalchowk district are reported here.
Photo 1 shows a completely collapsed RC building. The failure is due to the insufficient size and poor detailing of columns, beams and structural joints resulting in a pancake failure.

Photo 1: Collapsed residential RC frame building in Sitapaila, Kathmandu.

Photo 2: Pancake failure of buildings in Gongabu, Kathmandu.

The buildings in Photo 2 lost their lower 2 stories and 4 stories due to the soft story pancake failure. The heavy load of brick masonry infill walls and the cantilever projection as seen caused the failure of columns. Photo 3 shows the pounding damage between two adjacent building ‘A’ and ‘B’. Photo 4 shows the collapsed building with fractured reinforcement of the columns, which is due to the poor ductile detailing. The first story columns of the 3 storied building (Photo 5) failed in shear in which the upper 2 stories were added recently on top of the original single story building.

Photo 3: Pounding damage between two adjacent building ‘A’ and ‘B’ in Lamosanghu, Sindhupalchowk.

Photo 4: Collapse of a 3 storied RC building in Lamosanghu, Sindhupalchowk. Note that all the longitudinal reinforcing bars of the column shown have fractured.

Photo 5: Damage to the first story of the 3 storied building in Chautara, Sindhupalchowk, in which upper 2 stories are added recently.

3.2 Damage to school buildings

More than 8,000 school buildings were destroyed due to the earthquake and its aftershocks. Fortunately, the schools were closed on the day when main shock and its major aftershocks occurred. Temporary shelters have been constructed to conduct classes in the Kathmandu valley as well as in remote areas. The damage to one of the reinforced concrete school building in Sindhupalchowk district is reported here.

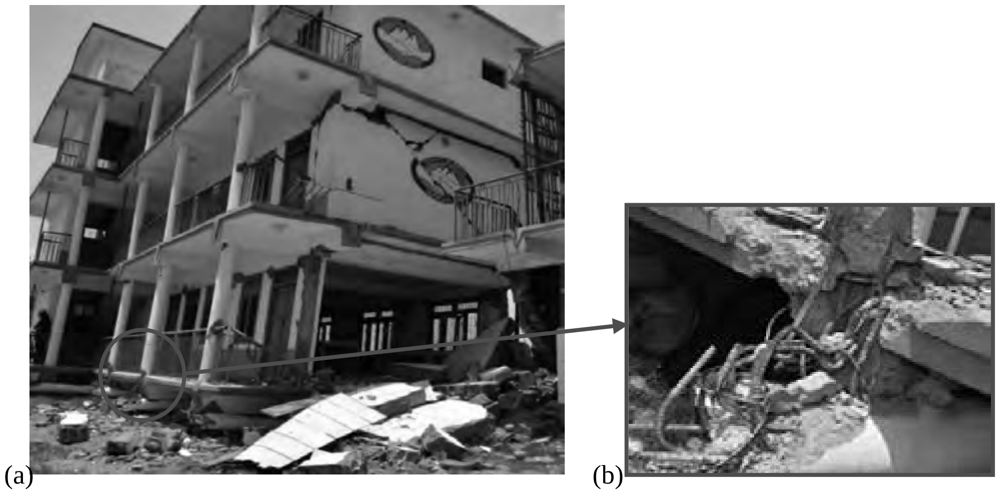

Photo 6: (a) Collapsed building of the Shree Jana Jagriti Higher Secondary School, Sangachowk, Sindhupalchowk and (b) Shear failure of columns.

Photo 6 shows a school building damaged heavily due to the earthquakes. Circular columns in this 3-story building had 300 mm diameter with 6 no. of 16 mm main bars, while square columns had 300 mm x 300 mm size with 4 no. of 16 mm and 4 no. of 12 mm bars as longitudinal reinforcements. Both circular and square columns had 5 mm stirrup with 150 mm spacing which is not sufficient (Photo 6(b)).

Photo 7: Heavily damaged brick masonry infill wall.

3.3 Damage to high-rise apartment buildings

Many high-rise apartment buildings in Kathmandu valley suffered mostly non-structural damage. Only minor structural damage was observed in some buildings. None of the high-rise apartment buildings collapsed and almost all are usable after repairing. Damage to one of the apartment buildings (Sunrise Apartment) at Nakkhu in Kathmandu valley is shown in Photos 8 and 9.

Photo 8: Diagonal cracks in the masonry infill walls.

Photo 9: Diagonal shear failure of a beam at the basement leading to seepage of water.

4. CONCLUSIONS AND RECOMMENDATIONS

As reported in this paper, many reinforced concrete buildings in the affected areas suffered either collapse or severe damage due to the 2015 Gorkha earthquakes. Most of the collapsed buildings suffered soft-first story failure. Similarly, the non-structural damage mainly included the heavy damage to brick masonry infill walls. Besides some of the exceptional cases in which the earthquake effects exceeded the design limits due to geological, site effects etc., the primary reasons of such a vast damage to reinforced concrete buildings are negligence of seismic design codes and poor construction practices. As observed by the authors, insufficient member size, inadequate shear reinforcement, poor ductile detailing, strong-beam weak-column combination, weak beam-column joints, large cantilever projections, heavy masonry infill walls were among the most common reasons for such a massive damage to reinforced concrete structures.

There are many factors to be considered for improving the seismic performance of reinforced concrete buildings in Nepal. The first and foremost step is to strictly implement the building codes for the seismic design. The owners, contractors, engineers, workers must be educated about the earthquake resistant constructions. The seismic design code of Nepal is to be revised to include current practices and developments in earthquake resistant constructions around the world. Lightweight construction should be preferred. Use of reinforced concrete shear walls should be promoted for better seismic resistance. Seismic strengthening and retrofitting works should be implemented to old and partially damaged constructions.

Future research work is needed to improve the frame-infill wall connection to reduce the non-structural damage as well as the replacement of masonry infill walls with lightweight materials. Seismic resistance of stone masonry walls should be studied as these are economical construction materials in developing countries.

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Post-earthquake assessment of buildings using Mobile Technology and Google Imaginary plus GIS visualization

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ABSTRACT

The aim of this article is to present a computer-aided comprehensive strategy for the detailed damage assessment of the buildings and the optimal prioritization of strengthening and remedial actions that are necessary after a major earthquake event. Based on the visual screening procedures a building inventory was first compiled; then a vulnerability ranking procedure was specifically tailored to the prevailing construction practice implemented into a multi-functional, georeferenced computer tool, that accommodates the management, evaluation, processing and archiving of the data stock gathered during the post-earthquake assessment process, and the visualization of its spatial distribution. The methodology proposed and the computer system developed was then applied to the Municipality of Chautara, Sindhupalchok, Nepal, city which was strongly damaged during the overwhelming 2015 Gorkha earthquake.

Keywords: *building damage assessment, GIS, mobile data transmission, Gorkha earthquake, Nepal*

1. INTRODUCTION

Nepal was shaken by magnitude Mw7.8 (ML 7.6, in terms of local magnitude, Department of Mine and Geology (DMG)) Gorkha Earthquake on 25th April 2015 at 11:56 AM local time with the epicenter at Barpak, Gorkha, 80km North West of Kathmandu Valley. This Gorkha Earthquake was followed by thousands of aftershock including M6.6 and M6.7 within 24 hours and Mw 7.3 (ML 6.7, DMG) on 12th May 2015 which caused additional damage and casualties. The spatial distribution of aftershocks occurred before 15 June 2015 is shown in Figure 1. According to official reports the worst affected districts include Sindulpalchowk, Kavre, Nuwakot, Rasuwa, Dolakha in the Central Region and Kaski, Gorkha, Lamjung in the Western Region. The impacts caused by this event included 8,969 people killed, 22,321 injured and, many more displaced (MOHA, 2015). In addition, significant damage to buildings, infrastructure and other critical services were well observed.

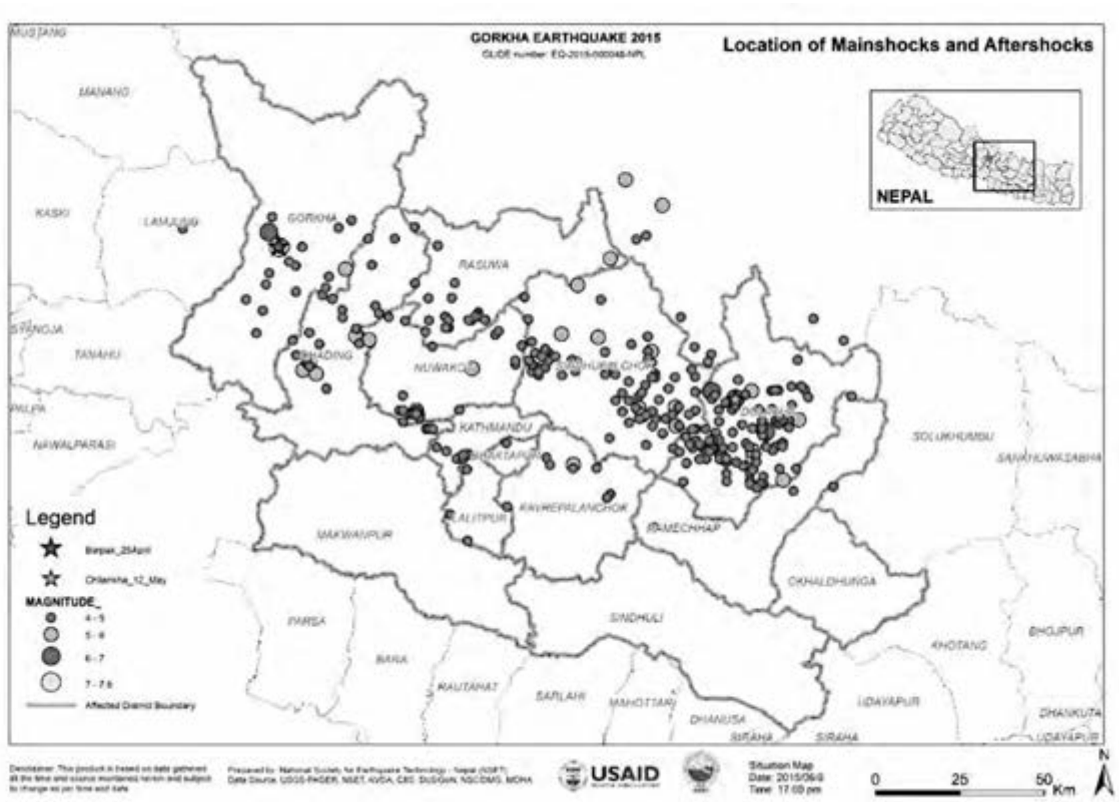

Figure 1 Spatial distribution of Aftershocks

Geoinformation technologies offer an opportunity to enhance real time situation management, disaster response and subsequent post event (Gusella. L. et. al). To help improve the usefulness of geoinformation in a post disaster context, information should be freely available, up-to-date and provide in georefrenced format. Data requirements have traditionally been met through ground based damage survey during the days and weeks following the events. However the integrations of remote sensing (google earth imaginary) data and georefrenced damage information collected in the field can effectively streamline, accelerate and increase the volume and diversity of data captured during post disaster reconnaissance. Remote sensing (Google Imaginary) plays a valuable role to play when integrated within and used in conjunction with mobile mapping technology which enable the collection of digital data of each house in the field.

This paper aims to give detailed explanation of Chautara Municiplity of Sindhupalchok District which have 9 wards, how technology (mobile and Google earth) inspired and alliance were used to speedily assess the amount of damage caused by Gorkha earthquake. In less than a minute, devastating earthquake demolished approximately 90 percent of the buildings in Sindhupalchok killing 3,557 people; numerous injuries; and leaving 63,885 homeless (drrrportal, Nepal). Almost from the very onset of the disaster, high-resolution satellite imagery was available through Google earth to provide the first insight of the devastation caused by Gorkha earthquake. Google Earth imaginary can form a base layer for buildings within the system, guiding the team to recognize each damaged building and proving the direction-finding support. The whole system is integrated with mobile mapping ground based perspective to develop and validate Google GIS imaginary based building damage scales, and to access the accuracy of damage assessment results.

2. PAST WORKS

The frequency and magnitude of natural hazard and its occurrence is growing rapidly in the country. The impact of disasters even small scale has left negative impacts at local level. Municipalities have been spending significant amount of money for recovering those losses from disasters. Advanced disaster management technology could provide a critical support system for emergency authorities during crises. Such a technology can also provide important inputs for any disaster management plan of action in modern times (Mileti, 1999). There are growing recognition that a mobile disaster management system could help minimizing the fatalities of human lives when natural disasters occur. Because of this recognition, countries such as Australia, Czech Republic, France, England, Hong Kong, Japan, Singapore, and others, have increased their efforts in developing disaster management applications which use mobile technology to enhance their response capabilities during a disaster (Cimellaro et al 2014). For correct decision-making at any stage of natural disasters, from prediction to reconstruction and rehabilitation, a considerable amount of data and information is necessary. The most important procedures relating information from disasters are monitoring, recording, processing, sharing, and dissemination. Experience from Italy and Japan have proved that information technology simplifies the receiving, classifying, analyzing, and dissemination of information for appropriate decision-making (Sextos, A 2008). A critical component of any successful rescue operation is time. Prior knowledge of the precise location of landmarks, streets, buildings, emergency service resources, and disaster relief sites saves time and saves lives. Literature shows that mobile-based information systems can be a greatest key to benefit responders in different ways. Implementation of new information technologies in emergency response can potentially improve communication and coordination (Comfort, 1999; Comfort and Kapucu, 2006). A more robust information network with greater distribution will further improve communication and coordination in major disasters (Comfort and Kapucu, 2006; Graber, 2003). The possibility of using mobile technologies and the Web to build and substitute response systems would aid communities' disaster management cycle, uploading and distributing information, and coordinating the responses.

3. METHODOLOGY

Traditional method of damage assessment comprise of walking survey, where damage indicators together with the overall damage state, are logged on damage assessment form in paper format. But for this study, questionnaire Survey of each buildings is developed in odk android Mobile environment following documents of Guideline on Seismic Vulnerability Evaluation Guideline for Private and Public Buildings which was prepared by NSET, 2009.

The study area was divided into a grid (figure 2) of 200*200m square cells field paper which consists base map of Google Imaginary. Surveyor locate each building and provide the ID of every building in field paper. And using mobile application they input the damage information for buildings.

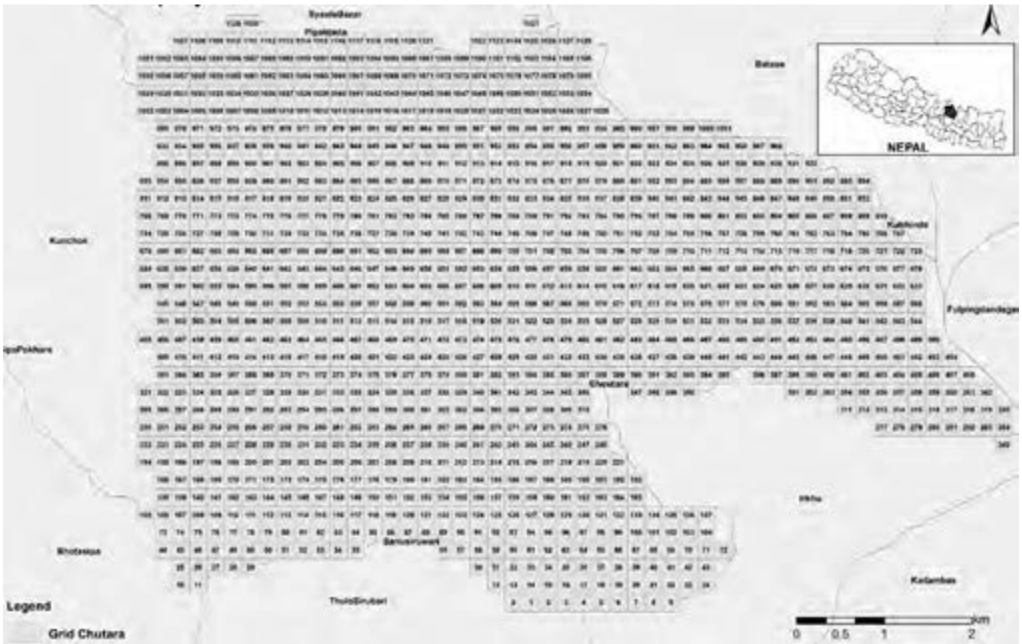

Figure 2 Grids of the Chautara Municipality

Mobile inspection form consists of five Section (figure 2). Section A contains building identification data (id, city, address, ownership, no of resident etc.), Section B contains building technical characteristic (no of stories, age of building, primary occupancy etc.), Section C contains geotechnical hazard, Section D contains data related to the structural type and Section E contains Damage grade, recommendations and building Photographs.

Figure 3 Digitization of the building in the google Earth

After completing of Buildings survey in one girds, surveyors handover the paper to the GIS mapper so that they digitize each building as of filed paper in the Google earth environment (figure 3). In the intranet server, all the information collected form each Mobile device is uploaded and digital database is prepared. Later on, all information of the building that are collected from the mobile devices were join with each building digitized by GIS mapper in GIS Environment for the visualization of the assessment results using QGIS software. Reason for choosing Google Earth as the platform for the image analysis is because it is freely available across the globe and people are familiar with it and have readily available pre-event imagery archive for selected area in Nepal and can incorporate imagery captured at multiple dates.

4. RESULTS

It is observed that Chutara Municipality have 83% of Stone in Mud type building where only 14% RCFrame structure considering Figure 4a and 4b.

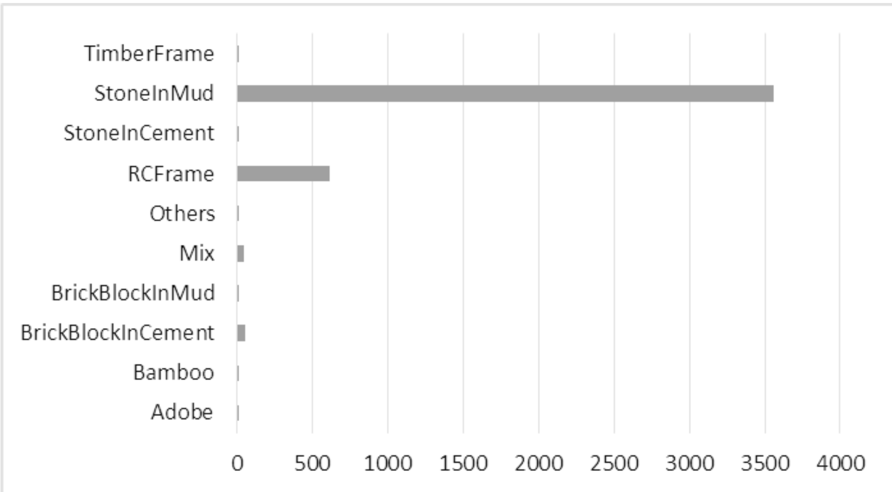

Figure 4 a Building Typology vs Number of Buildings

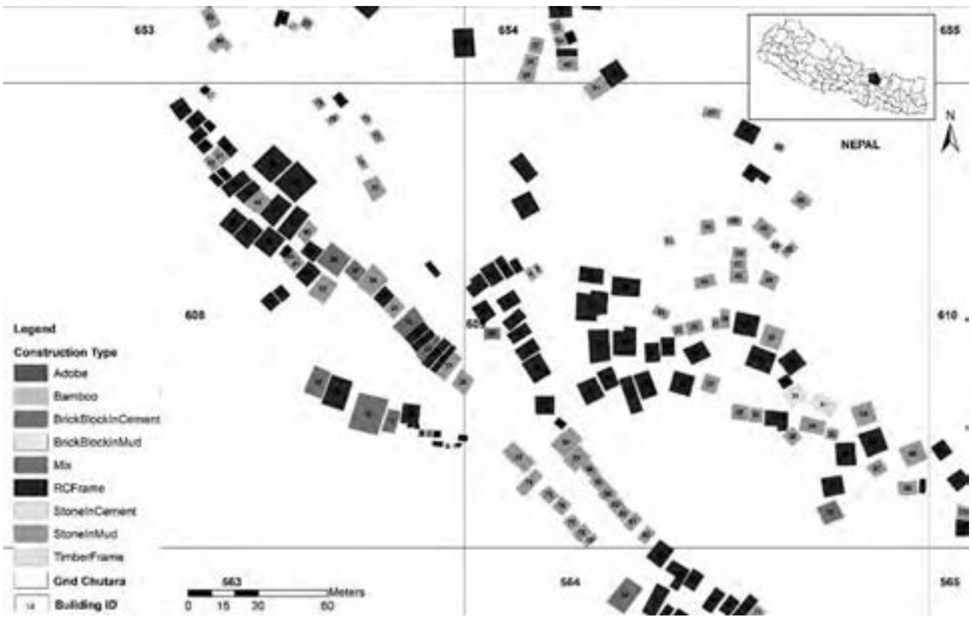

Figure 4b Map Showing Construction type

Also, 70% of buildings have been categorized under Grade5 whereas 15% falls under Grade4 .Also, Grade1, Grade2 and Grade3 corresponds to 5%, 8%, 2% of sum chronologically referring to figure 5a and 5b

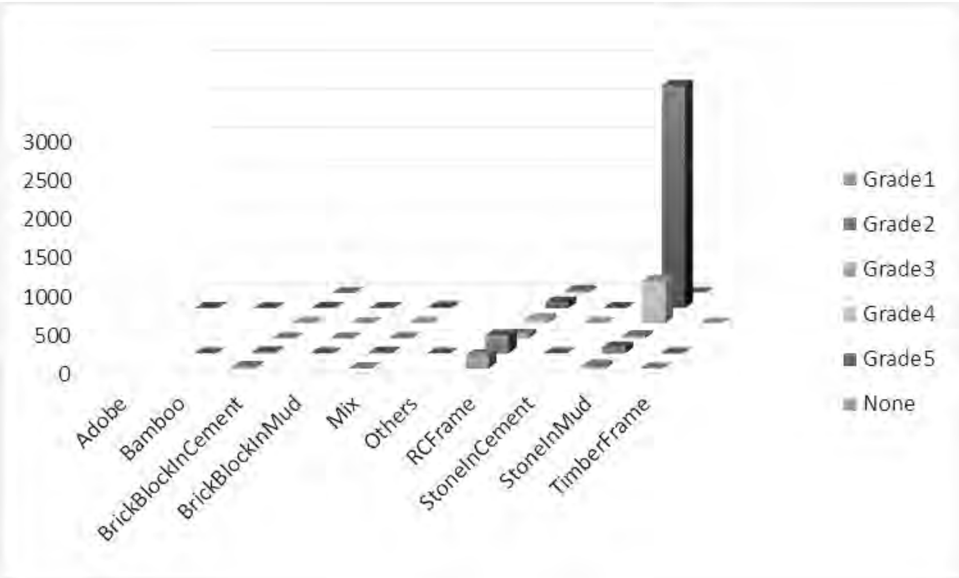

Figure 5a Building Typology vs Damage Grade

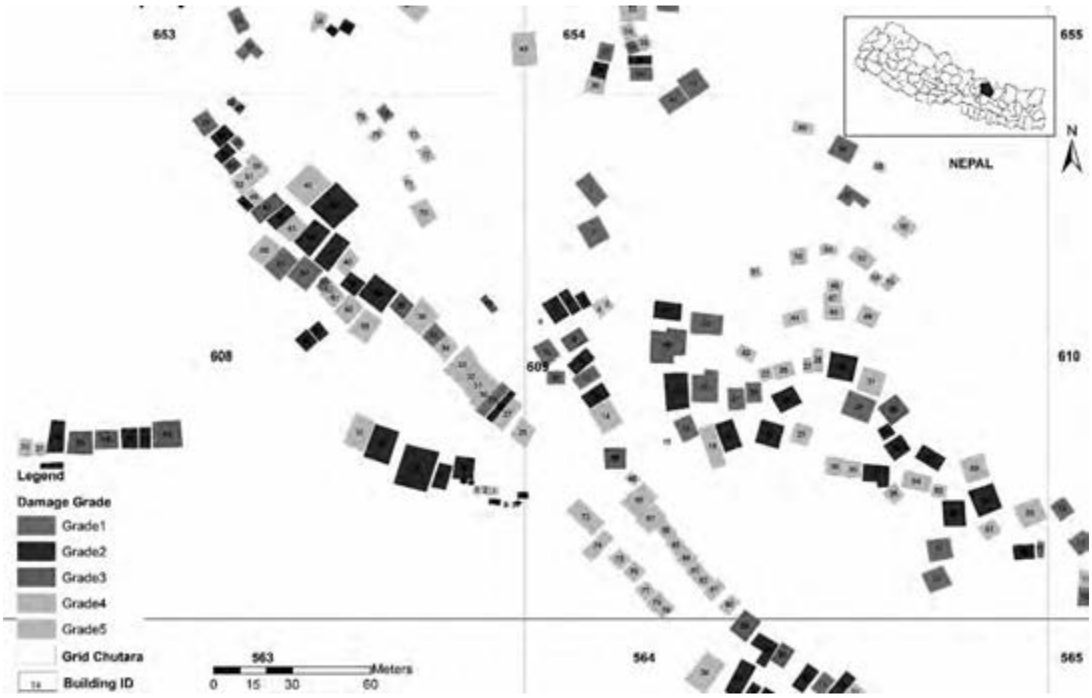

Figure 5b Map showing Damage Grade

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Table 1: Recommendation for different ward

	WARD									
Recommendation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
None		1	12	16	3	1	11		5	49
Repair	11	24	231	66	39	7	142	18	20	558
Retrofit	7	7	26	16	3		50	15	16	140
Demolish	405	490	237	311	507	386	322	335	560	3553
Further Evaluation			2				5	1		8
Grand Total	**423**	**522**	**508**	**409**	**552**	**394**	**530**	**369**	**601**	**4308**

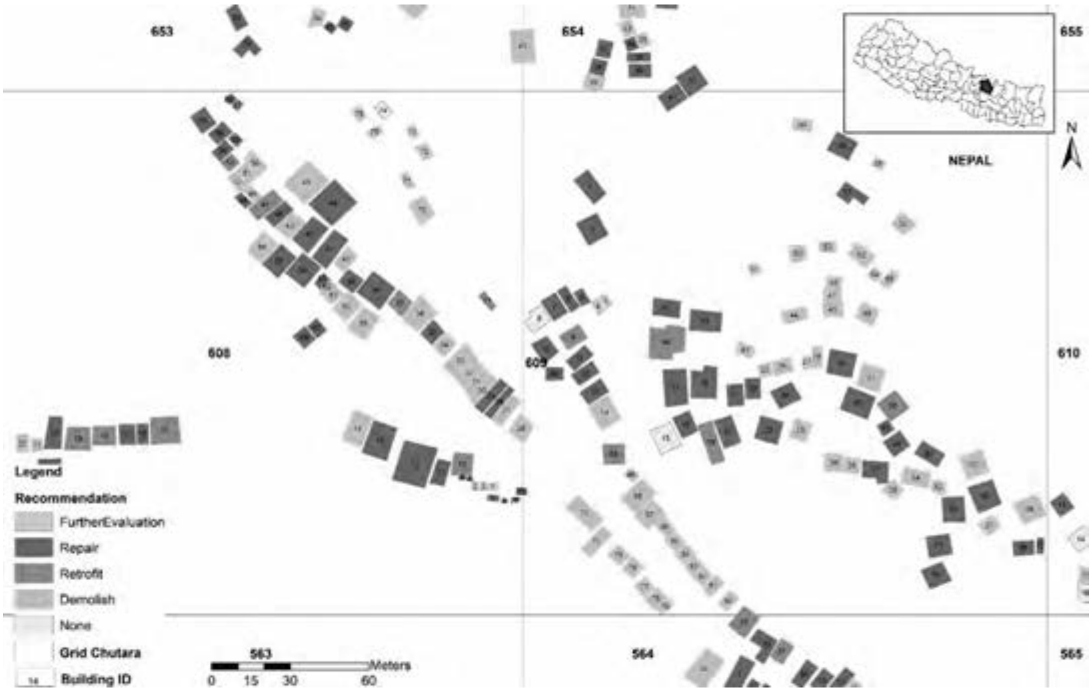

Figure 6 Map showing Recommendation type

With regard to the above assessment and analysis Table 1 and Figure 6, 83% of totally surveyed buildings are suggested to be demolished. Repairing is most for 13% of left part. Only 3% of buildings are recommended to get retrofitted.

5. CONCLUSION

Natural Disasters are not certain, could occur anytime and seriously disrupts the functioning of a community causing huge losses. However, during the time of crisis the collection and dissemination of damaged data are crucial. This study positively support the government to developed reconstruction strategy plan. Apart from it, this study will monitor Chautara Municipality to differentiate the building which are possible to repair/ retrofit and which needs demolition. Hence, GIS tools if properly utilized, saves time, labor and improve efficiency of work. Prompt data collection and its analysis results over time could prepare agencies to better response for future disasters. Thus, paper illustrates the utilization of technologies (mobile and google earth) to collect post-disaster damage information within short span of time.

ACKNOWLEDGEMENTS

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PEER Impact on Gorkha Earthquake National Response

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ABSTRACT

Nepal, one of the most vulnerable country to seismic hazard in South Asia was rocked by a 7.8Ms earthquake in April 25, 2015. The tremblor wasn't a surprise because Nepal straddles highly active tectonic plates. Compounding the country's vulnerability to natural hazards are socio-political weaknesses and poor infrastructures. On the other hand, Nepal has been preparing for any emergencies through capacity building of emergency responders through the Program for Enhancement of Emergency Response (PEER) since 1998. PEER is a regional training program introduced in Asia and funded by the United States Agency for International Development / Office of U.S. Foreign Disaster Assistance. PEER's main focus is to develop highly qualified instructors who will cascade the knowledge and skills to train skilled emergency responders. PEER began in Nepal several years prior to the crafting of a national emergency response strategy. The national program partners have acknowledged that PEER has been instrumental in shaping Nepal's emergency response system. In 1998, PEER introduced the Medical First Responder (MFR) and Collapsed Structure Search and Rescue (CSSR) courses, which addresses the response needs in the event of an earthquake, especially in densely populated areas. Nepal pressed on to developing instructors amid the program challenges of rapid human resource turnover, diaspora and varying priorities or lack of commitment of program partners. PEER partners responded to the increasing need of capacity building in emergency response and have made PEER curricula part of their own training prospectuses. Over a period of time, PEER trained professionals do not only deliver and facilitate trainings but were also catalysts in the establishment of Disaster Management units in their respective organizations. Seventeen years after Nepal's induction into PEER, the country's emergency response capacity was put to test during the recent earthquake. A strategic training program for emergency responders is key to timely and effective response.

Keywords: *capacity building, emergency response, disaster management*

1. INTRODUCTION

Earthquake is a sudden-onset natural hazard that when it takes place in a densely populated area with infrastructure and other social vulnerabilities, would likely have a devastating impact on lives, properties, economy and development. For cyclones, early warning systems are more commonly in place and widely used by countries that are in the line of cyclone path, to further intensify information dissemination and prepare the population ahead of a possible landfall. The coming of typhoon is more predictable and with advanced technology for forecasting and tracking a cyclone path, people have sufficient time to collect items for emergency use and evacuate to a safer place, as necessary. Earthquakes alone do not kill; people in poorly built structures may become trapped, or catch fire in immediate post-earthquake consequences. In such situations, there is very little or rarely time to evacuate and seek shelter in a safer area. Availability and accuracy or such near-accuracy of historical chronicles can shed light on the extent of damage, date and place of occurrence. Despite some notable exceptions, early warning system is rarely effective for earthquakes (UNISDR, 2015). Earthquake risk reduction and preparedness efforts rely heavily on available historical records of past earthquake occurrences.

Nepal lies above two converging tectonic plates - the India and Eurasian plates. This location puts the country to high earthquake risks. Based on recorded Nepal's earthquake history, records have shown that Nepal can expect two earthquakes of magnitude 7.5 to 8 on the Richter scale every forty years and one earthquake of magnitude of 8+ in Richter scale every 80 years. The country has witnessed major earthquakes in the 20th century: Bihar-Nepal earthquake (1934), Bajhang earthquake (1980) and Udayapur earthquake (1988). With all these past earthquakes, the April 25, 2015 Gorkha Earthquake was not an entirely new experience for Nepal.

This paper presents the impact of the Program for Enhancement of Emergency Response (PEER) in the 2015 Gorkha Earthquake. While the country is being fraught with socio-political strains and disaster risk reduction may be competing in the priorities of the government, PEER has been implemented in Nepal since 1998. Since then, the Ministry of Home Affairs-Government of Nepal, the apex body of the government for disaster risk reduction activities in the country, played a pivotal role as PEER nodal agency in Nepal. The objective of this report is to dissect how PEER has influenced the emergency response system of the country and how the program contributed during the recent earthquake response.

This paper has referenced its findings from PEER program reports, country meetings, personal accounts from April 2015 Gorkha earthquake response operations experience of PEER trained professionals shared to NSET.

2. Nepal National Disaster Response Framework

The Government of Nepal has formulated the National Strategic Action Plan on Search and Rescue (SAR) Capacity in 2013 based on recommendations from the series of scoping missions on emergency preparedness and response in Nepal and also in line with the National Strategy on Disaster Risk Management (NSDRM) and Nepal Risk Reduction Consortium (NRRC). The National Strategic Action Plan on Search and

Rescue Capacity is a useful guide towards strengthening the country's overall disaster and preparedness and response system, specifically supporting the capacity building of emergency responders at all levels. The foundation of the action plan is based on the Urban Search and Rescue (USAR) Response Framework of the INSARAG Guidelines, i.e. first responders in an emergency are the community level then followed by the local emergency services; these will be supplemented by national level rescue teams, which are considered the professional responders. If the SAR needs are beyond the national capacity, international SAR teams will support the national rescue efforts.

3. Program for Enhancement for Emergency Response (PEER)

Approximately 15 years prior to crafting of Nepal government's national policies and plans on disaster risk management, some national or local NGOs in Nepal have begun initiatives on emergency preparedness and response.

The Program for Enhancement of Emergency Response (PEER) is a regional training program that assists program beneficiary countries to enhance their emergency response capacities thereby reducing mortality rates from emergencies and disasters. The United States Agency for International Development / Office of U.S. Foreign Disaster Assistance introduced PEER in Asia in 1998 and is providing the funding support since then. The first phase of PEER (1998-2003), was implemented by Asian Disaster Preparedness Center (ADPC), targeted four earthquake-prone countries in the region – India, Nepal, Indonesia and the Philippines. PEER Phase 1 established linkages with national governments, identified and initiated partnerships with key emergency response organizations; and developed regional instructors. PEER Phase 2 (2003-2009) was implemented by the National Society for Earthquake Technology – Nepal (NSET) in the same four original PEER countries, adding Bangladesh and Pakistan into the program coverage. Program nationalization and institutionalization; and development of national instructors, coordinators and monitors were the main focus of PEER Stage 2. USAID/OFDA awarded PEER Stage 3 (2009-2014) to ADPC and NSET. ADPC managed the implementation of Community Action for Disaster Response (CADRE) and Hospital Preparedness for Emergencies (HOPE) in the six older PEER countries, with expansion to selected countries in Southeast Asia, namely, Cambodia, Lao PDR, Vietnam and Thailand. NSET managed the implementation of Medical First Responder (MFR) and Collapsed Structure Search and Rescue (CSSR). PEER Stage 3 continued the successes and efforts initiated from previous PEER stages.

PEER Stage 4 (2014-2019) is being implemented by NSET in selected South Asian countries, namely, Bangladesh, India, Pakistan and Nepal, all of which are highly vulnerable to earthquakes and other natural and human-induced hazards. PEER Stage 4 objectives are to enhance emergency response capacity of South Asian countries by providing training on MFR, CSSR, CADRE, HOPE and Swift Water Rescue (SWR) courses and by providing networking and collaboration among relevant individuals and institutions in the region.

NSET, in collaboration with the Ministry of Home Affairs – Government of Nepal (MoHA-GoN), has trained numbers of emergency response personnel in MFR and CSSR in the country. Since 1998, there are more than 1,100 PEER MFR-CSSR trained professional responders in Asia, approximately 245 are from Nepalese Army, Nepal Police, Nepal Armed Police Force and the Nepal Red Cross Society; all mandated with emergency first response tasks. Most of the PEER graduates/instructors belong to emergency response agencies, became catalysts in promoting PEER, designed similar training curricula for their organizations and have delivered similar emergency response trainings for their response personnel.

Since the induction of Nepal into the PEER program in 1998, the MoHA-GoN designated Nepal Police/Nepal Police Academy as the focal partner training institute for the implementation of MFR and CSSR courses in Nepal. To this extent, NSET, through PEER support, has distributed sets of CSSR equipment were distributed to Nepal Police-Central Police Disaster Response Squadron, to complement the institutionalization of CSSR course. NSET and PEER partner organizations labored much on how to make PEER program best fit the country's context. In 2014, NSET in collaboration with senior PEER instructors from Nepalese Army, Nepal Police, Armed Police Force and Nepal Red Cross Society, designed and developed the MFR-CSSR curriculum for training of end users. This initiative came at the right time when Nepal's security forces established their respective Disaster Management units and started to train emergency response teams.

NSET, a premier national non-government organization, whose mandate is on earthquake engineering and earthquake risk management, has expanded its initiatives in disaster risk reduction since the organization's establishment in 1994. In addition to PEER implementation in the region, NSET is also at present carrying out emergency preparedness and response trainings for institutional and community levels. NSET has taken every possible step to inculcate a culture of preparedness and build earthquake safer communities in Nepal.

4. PEER Reflections in Gorkha Earthquake

On mid-day of April 25, 2015, a 7.8 magnitude earthquake rocked Nepal, with epicenter at Lamjung District, 77 km west of Kathmandu. The earthquake's energy caused widespread destruction of residences, government and private buildings schools, heritage sites, health facilities, rural roads, bridges, water supply systems, and trekking routes. The tremor has prompted the Government of Nepal to declare a state of emergency, activated a massive SAR operations and has appealed for international assistance. More than 90% of the security forces were mobilized for SAR. (World Bank, 2015).

The more than 15 years of PEER investment in Asia has been put to test during this challenging episode in Nepal's history. Nepal PEER partner organizations were on full alert and have mobilized response teams for SAR, contributing to the national government's efforts to address the most critical needs. Trained and skilled emergency response volunteers were also tapped to provide additional support to the already overwhelmed national search and rescue teams on ground zero. Regardless of the magnitude of an emergency, local and national responders are the country's first line of defense, the first ones to save their own before any external help arrives.

PEER-trained professionals were mobilized by their respective organizations to respond in the earthquake search and rescue operations. Primary PEER partners in Nepal, namely, Nepalese Army, Nepal Police, Armed Police Force, Nepal Red Cross Society and NSET were all in full force in earthquake response. Through PEER implementation in Nepal, the program has helped embed the basic SAR skills in local and national responders; because of this foundation, national responders were able to assist and work side by side with international USAR teams and understood the same guidelines and techniques in SAR operations, with the same goal of searching, rescuing victims using the safest techniques and eventually saving lives. Apparently, the main difference among national and international SAR teams is the use of heavy-duty and more sophisticated SAR equipment by the international teams. Some national response teams worked independently on-site and also assisted the international USAR teams as the former had the local understanding.

Based on reports received by NSET, response teams were deployed by Nepal Police-Central Police Disaster Response Squadron in Kathmandu. It was observed that during the recent SAR operations, PEER-trained staff were assigned to lead their local SAR teams. In a team of 15 – 20 responders, Nepal Police had made an arrangement to make sure the involvement of at least two to three PEER certified responders, and most of the time the PEER responders led the team.

Armed Police Force (APF) dispatched a total of 45 emergency response teams for SAR in Kathmandu and in affected areas outside the valley, namely, Bhakthapur, Lalitpur, Gorkha, Sindhupalchok, Nuwakot and Dolakha . According to APF, there were a total of 35 PEER graduates from APF who were deployed and mobilized for coordination and response within and outside Kathmandu Valley. APF has immediately responded to the affected sites of Kathmandu Valley and other districts and saved 345 lives; jointly recovered 340 dead bodies jointly with other national and international search and rescue teams (APF Report, June 2015). In addition to search and rescue efforts, APF provided shelters within its premises for earthquake victims, distributed relief items, cleared debris, retrieved historical artifacts of world heritage sites and now on the process of demolishing collapsed houses.

The Nepalese Army has reported that remaining PEER graduates still in active military service were deployed during SAR operations in different locations in Kathmandu Valley and also assigned its MFR graduates in Army Hospital and other field hospitals established. Nepalese Army being a primary responder to disasters, its trained personnel were deployed from the very first day of earthquake SAR operations within and outside Kathmandu Valley. CSSR trained personnel were deployed in different locations where there was need of heavy cutting and breaching equipment. Nepalese Army has extracted 1,336 live personnel and 357 dead bodies in earthquake affected areas. (Nepalese Army, June 2015)

PEER's main goal is to reduce the number of mortalities during disasters or emergencies in the beneficiary countries. In Nepal, NSET also works in partnership with Institute of Medicine (IOM) for Hospital Preparedness for Emergencies (HOPE) course and with Nepal Red Cross Society (NRCS) for Community Action for Disaster Response (CADRE) course. Through HOPE Course, hospitals are prepared to respond and remain functional after a devastating natural disaster, such as after a huge earthquake injuring high numbers of victims, during major epidemics or during any mass casualty incidents. Until date, there are a total of 415 HOPE graduates in Nepal since 2003. In addition to HOPE Course, NSET provided additional technical assistance to some hospitals in Kathmandu by way of securing non-structural elements of the healthcare facilities. The

Tribhuvan University Teaching Hospital (TUTH) has significantly put into practice hospital preparedness and has a functional disaster preparedness plan. Hence, during the Gorkha Earthquake, TUTH has functioned effectively post-earthquake and coped with the increased number of patients from the disaster.

CADRE is a new PEER course introduced in 2009, targeting participants at the community level. CADRE fills-in the gap in emergency response prior to the arrival on-site of professional responders. Until date, Nepal has a total of 164 PEER-certified CADRE graduates. NRCS has conducted a number of CADRE courses in Nepal outside of PEER support. Nepal Red Cross Society reported that 678 CADRE national volunteers were mobilized in view of the Gorkha earthquake response.

5. Achievements and gaps/failures

The power of media, from television, radio, print, web/social networking sites, have captured overflowing images of search and rescue efforts by local and international response teams. There may still be a long way until the country reaches the benchmark of an efficient emergency response system, but this recent earthquake showed that Nepal's local responders have nailed it. It is very much worthy to note that the skills applied in searching and safely extricating the trapped living and dead bodies, complemented by effectively using modern search and rescue equipment, are attributed to the years of embedding the MFR and CSSR skills in PEER partner organizations in Nepal. It was also evident that non-PEER certified responders followed the same skills/life saving procedures that are delivered in PEER courses as they have used same standards and curricula for their in-house training courses, facilitated by PEER-certified instructors, such as in the case of Armed Police Force Disaster Management Training Center which has adapted MFR and CSSR courses from PEER.

PEER training equipment, in principle, are primarily used for training purposes only to facilitate maximum hands-on experience by the trainees. However, in view of the pressing need for searching and safely extricating trapped victims, NSET is aware that PEER training equipment were also utilized by local response teams during their operations. In view of PEER institutionalization, NSET through PEER, has distributed sets of equipment to Nepal Police and Armed Police Force, which were heavily used during the SAR operations in different locations in Kathmandu Valley. NSET observed and received verbal feedback that these were definitely helpful for the teams and have been utilized in safely extricating live victims by Nepal Police and Armed Police Force. One very important observation by the responders is that the present CSSR equipment is still appropriate (especially for small residential areas) but should be supplemented by heavier and more advanced equipment to be used in increasingly bigger structures in developing cities like Kathmandu. Heavier and more modern SAR equipment can spell a big difference for local responders to search for victims, breach and break structures safely and more swiftly. With this experience, NSET also realized that there is an apparent need for more professional emergency responders and community volunteers to be trained and equipped.

6. Lessons learned

While the road to recovery doesn't stop at successful rescue stories, we must take advantage of the catastrophe, keep a tab on the lessons learned and continue raising the bar of emergency response in Nepal. The following are some of the lessons learned and recommendations noted by NSET:

- PEER serves part of the national strategy on emergency response. Accordingly, there is an apparent need to scale up PEER trainings and expand to more response organizations, districts, municipalities and communities in Nepal. The cost of training for heavy teams, acquiring and maintaining a number of heavy and high level SAR equipment can be costly and may not be practical for Nepal economic situation. Therefore, training more light to medium-level emergency response teams is more realistic and doable, considering the present capacities and limitations of the country.

- Continue upgrading of knowledge and skills in emergency response; including modernizing SAR equipment appropriate for megacities like Kathmandu. Developing, training and developing SAR teams with modern equipment may apply to a limited number of organizations identified by the Government of Nepal, such as the Nepalese Army to develop heavy teams; and Nepal Police and Armed Police Force to develop medium teams.

- Strategically preposition trained and equipped response teams in different parts of the country. Light to medium search and rescue teams need to be developed to respond in identified most vulnerable areas. During the early phase of post-earthquake emergency response, the search and rescue efforts were focused mostly in Kathmandu, with response to other heavily affected areas being delayed. Rapid search and rescue is very critical in the minutes and hours immediately following a big earthquake, especially if it is affecting a highly populated area.

- Further intensify hospital preparedness to cope with the demand and remain functional during disasters or mass casualty events. Reports show that hospitals within and outside Kathmandu Valley were functional, although most were partially damaged. The hospitals were overcrowded with patients, but had sufficient staff. The hospitals in the affected areas needed additional support on medicines, equipment and other medical supplies, including body bags. Secondary to hospital preparedness is psychosocial intervention to support and care for disaster victims and responders alike.

PEER efforts in Nepal cannot be underestimated. The photos, reports and informal sharing from the responders reflect the great impact PEER has entrenched among the responders trained under the program. The immense damage of this recent earthquake, actual experience of responders and lessons learned from this catastrophe, will substantiate the increasingly continuous need to escalate public awareness, enforcement of risk reduction measures, to include scaling up of trainings on emergency preparedness and response to empower the national and community levels.

Nepalese people are ceaselessly grateful to all international and national responders, medical professionals and volunteers; salute to the national responders for they may also have become homeless or had missing loved ones but chose to perform their duties as police, soldiers, doctors/nurses/medics, and volunteers in this time of great need by the country.

7. CONCLUSIONS

If Gorkha Earthquake occurred say a decade ago, the scenario of SAR operations may have been grim with more lives lost, and most likely less capable national level responders.

Between 1980 and 2012, 42 million life years were lost in internationally reported disasters each year. (The concept of “human life years” provides a better representation of disaster impact, as it provides a metric describing the time required to produce economic development and social progress.) (UNISDR, 2015). Therefore, disaster risk reduction, with efficient emergency preparedness and response measures must be considered in reducing mortalities from disasters.

Capacity building of local or national responders is crucial in timely and efficient response. It is not only because the locals are the first responders in an emergency. It is, in part, connected to the rise of the global risk reduction agenda, which asserts that humanitarian action must be better linked to building the resilience and preparedness of people, institutions and places affected by hazards. Even beyond this, there is a growing feeling that strengthening the role of local actors may finally help to redress some of the perennial challenges of humanitarian aid, such as shrinking access, fragmentation and incoherency in operations, and the gaps between response, recovery and development. (IFRC, 2015).

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Response of tall buildings to 2015 Gorkha Earthquake as seen from natural frequency perspective

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ABSTRACT

On 25 April 2015 (11:56AM), the Gorkha Earthquake (M_L: 7.8, Depth: 15 km) particularly damaged old brick-mud built low-height buildings, brick masonry historical monuments, poorly designed/constructed brick masonry-infill reinforced concrete buildings, and comparatively newly built mass housing apartment type 10 or higher story reinforced concrete buildings in the Kathmandu valley, about 80 km away from the epicenter. Earthquake motion data recorded at various locations in the valley indicate that the valley ground was shaken with low frequency cycles of 0.2 to 0.3 Hz, which are equivalent to 5 to 3 seconds of natural period of the ground points of data acquisition. Due to thick layers of soft sediments composed mainly of clayey and silty soil layers, especially in the valley center, where the sediment depth is estimated to be more than 500 meters, the natural period of the central sediment is estimated to be comparatively long, which is probably well demonstrated by the recent earthquake motion data. As a basic principle of frequency resonance, long period objects such as tall buildings, towered structures, long bridges, slender objects, comparatively flexible structures, etc. built on a long period ground may sustain heavier damage than the short period objects. So, in this paper we discuss the relation between the location of the damaged tall apartment buildings in Kathmandu valley and the frequency-based ground shaking map of the valley we have prepared out of a wide area ambient ground vibration survey back in 2012. Our analysis demonstrates that most of the damaged tall apartment buildings lie in longer period zones. Moreover, for crosscheck purpose, we measure the natural frequency of some of the damaged tall buildings in the valley and find that the similar frequencies of the buildings and the corresponding ground locations are similar, which probably resulted in resonance effect during the Gorkha Earthquake.

Keywords: Gorkha Earthquake, Kathmandu valley, Tall buildings, Frequency resonance effect, ambient vibration survey

Subject No.:
First priority: 1. Urban Safety and Disaster Mitigation
Second option: 4. Special session

Middle Floor Slab Support Replacement beneath an Operating Subway Line used in the Large-Scale Improvement of the Yurakucho Line between Kotake-mukaihara and Senkawa

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ABSTRACT

The Tokyo Metro Yurakucho Line connects Wakoshi in Saitama Prefecture to Shin-kiba in Tokyo. It splits at Kotake-mukaihara Station from the Fukutoshin Line, which travels through Ikebukuro, Shinjuku, and Shibuya Stations, and also provides through service to the Seibu Yurakucho Line. The section of the Fukutoshin Line between Kotake-mukaihara and Ikebukuro opened in 1994, and service over the entire line to Shibuya began in 2008. The number of cars on each train was increased, and the level junctions between Kotake-mukaihara and Senkawa Stations often slowed trains and significantly disrupted schedules.
Tokyo Metro began construction to remove the level junctions in 2010 and completed the Shin-kiba bound A Line connection by the time the through service between the Fukutoshin Line and the Tokyu Toyoko Line began in March 2012. We decided to wait until the connection was put into operation to install middle pillars in the open-cut section on the Wakoshi side, and installed PC steel bars as temporary supports for the middle floor slab to see this work through to completion.
We chose this support replacement method to enable workers to remove inner walls and reinforce side walls and floor slabs within three-hour overnight periods to ensure that the Yurakucho Line could continue to serve nearly 1.5 million passengers per day. This report explains the steps taken to use the support replacement method in a large-scale improvement project beneath an operating subway line, and the measurement control results of the work.

Keywords: hanger construction, prestressed concrete steel bar, displacement, tensile force

1. INTRODUCTION

In 2010 Tokyo Metro began construction of a connection line to remove the level junctions between Kotake-mukaihara and Senkawa Stations on the Yurakucho and Fukutoshin Lines and ensure consistent passenger transportation. The Shin-kiba bound A Line connection was completed and put into service by the time the through service between the Fukutoshin Line and the Tokyu Toyoko Line began in March 2012. Figure 1 is an overview of the construction work.

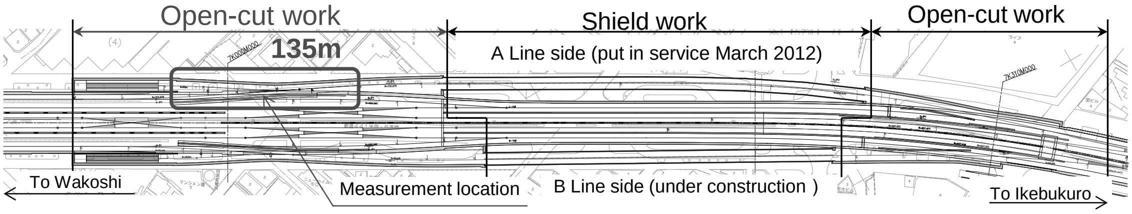


Figure 1: Work Overview

The construction zone was a total of 425 meters long. The shield method was used for a 175-meter section in the middle of the zone, and the open-cut method was used for the end sections, which totaled 250 meters. The priority task in the 135-meter end section on the Wakoshi side was to add a third span to the two-layer, two-span structure and put it into operation to allow through service to begin via a connection line. Therefore, we decided to wait until the connection was put into operation to install middle pillars in this section, and used steel bars to temporarily replace the supports on the middle floor slabs ("middle floor slab hanger construction") to see this work through to completion. This report describes the procedure, details and measurement control results of this hanger construction.

2. WORK OVERVIEW AND GROUND CONDITIONS

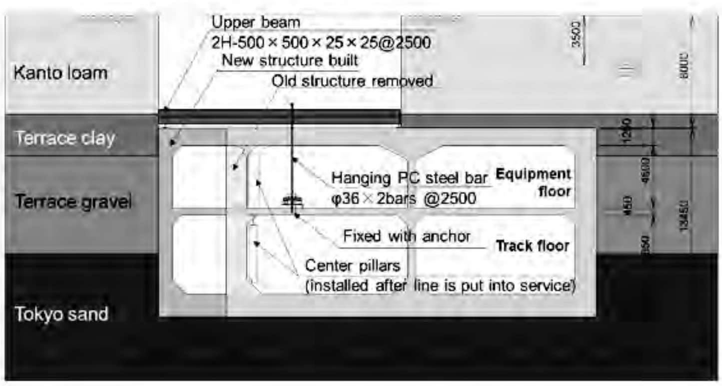


Figure 2: Work Conditions

Figure 2 is an overview of the construction work and ground conditions. The existing frame in the work area is a two-layer, two-span structure with the B1 floor as the facilities floor with various facilities installed on it, and the B2 floor as the track floor. The figure shows that only the left side has been excavated. This is because construction on the A Line side was the priority; the right side will be excavated for work on the B Line side.

Ground conditions are as follows: Kanto loam from the surface to a depth of around 7 meters, terrace clay from 7 to 10 meters, terrace gravel from 10 to 17 meters and Tokyo sand from 17 to 26 meters. Groundwater is present around 3.5 meters below the surface. The earth covering over the frame is about eight meters.

3. OVERVIEW OF MIDDLE FLOOR SLAB HANGER CONSTRUCTION

The following figures show various information about middle floor slab hanger construction: Figure 3 shows procedures on order, Figure 4 is a cross-sectional view, Figure 5 shows details and measurement locations, and Figure 6 is a floor plan.

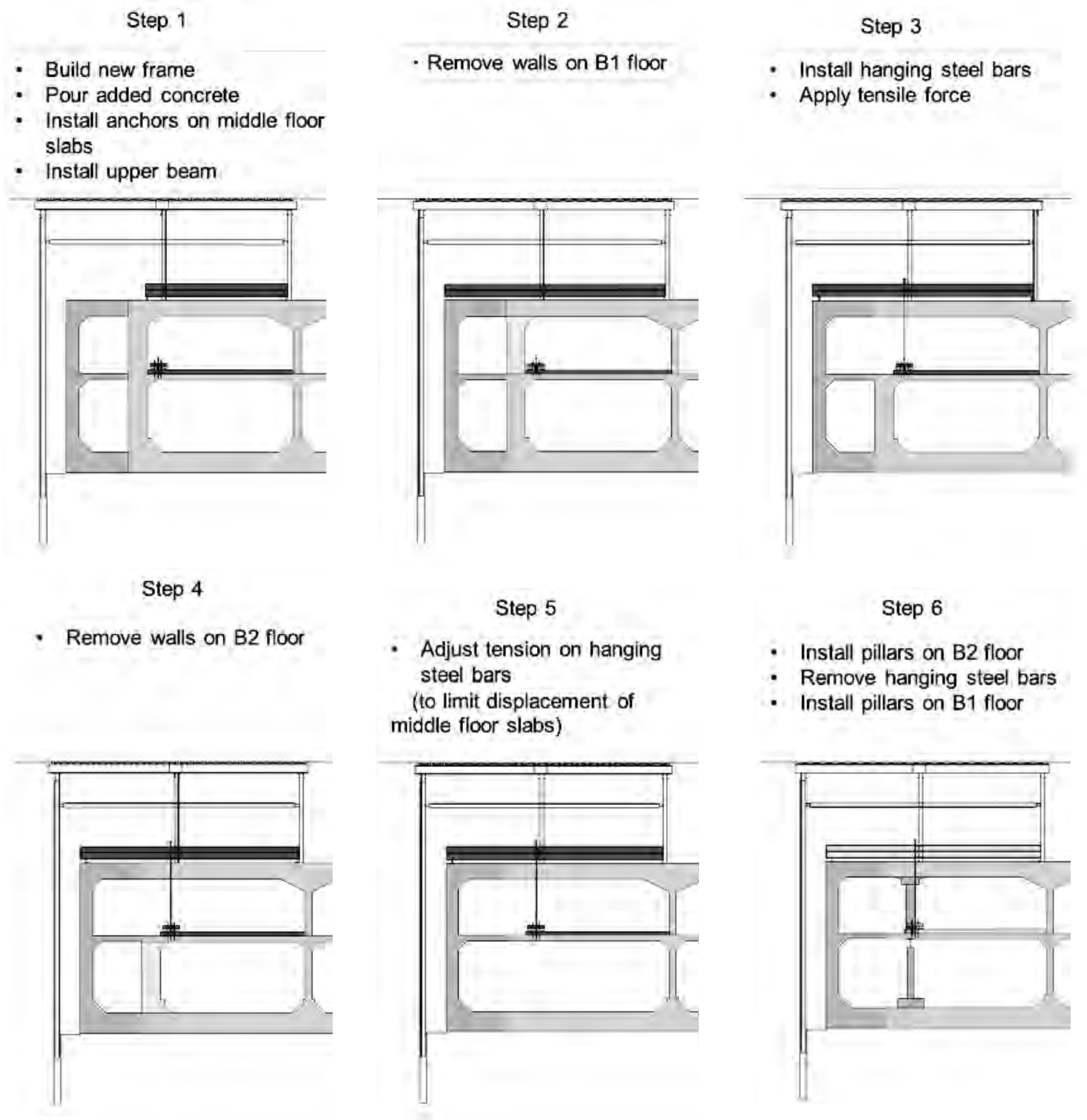


Figure 3: Procedures for Middle Floor Slab Hanger Construction

As shown in Figure 4, the middle floor slabs are suspended from the upper beam (2 x H-500 x 500) installed atop the upper floor by ϕ 36-mm hanging PC steel bars, and the anchored parts are secured with anchor plates embedded in the reinforced concrete poured on top of the middle floor slabs. We chose this method because of the hard overhead lines installed just 10-20 cm below the underside of the middle floor slabs on the track floor (the operating line); for this kind of work PC steel bars are often run through middle floor slabs, whose undersides are supported by steel channel or the like.

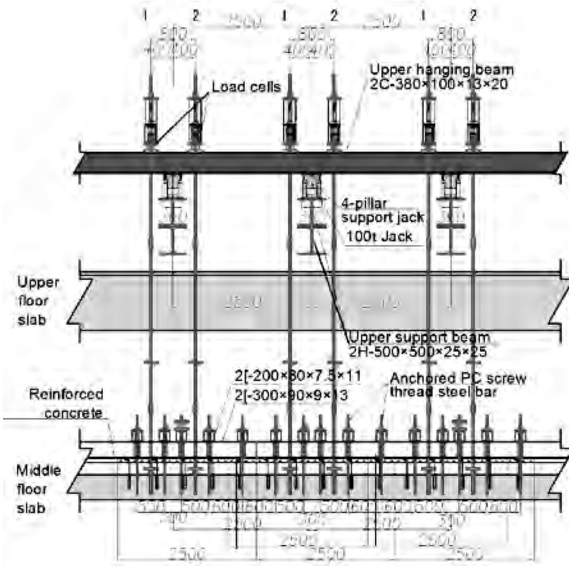


Figure 4: Cross-Sectional View of Middle Floor Slab Hanger Construction

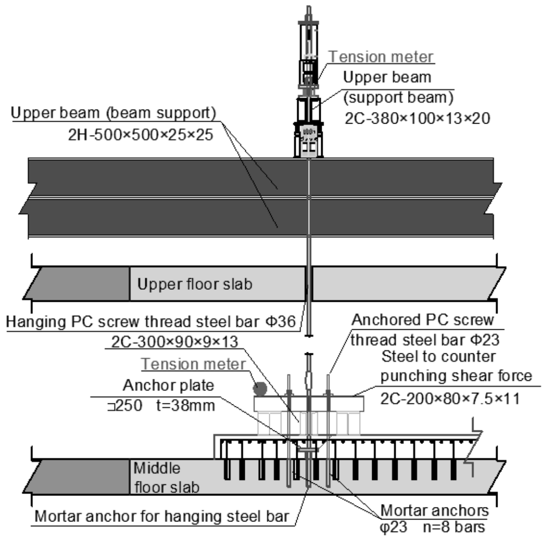


Figure 5: Detailed Drawing of Measurement Location and Middle Floor Slab

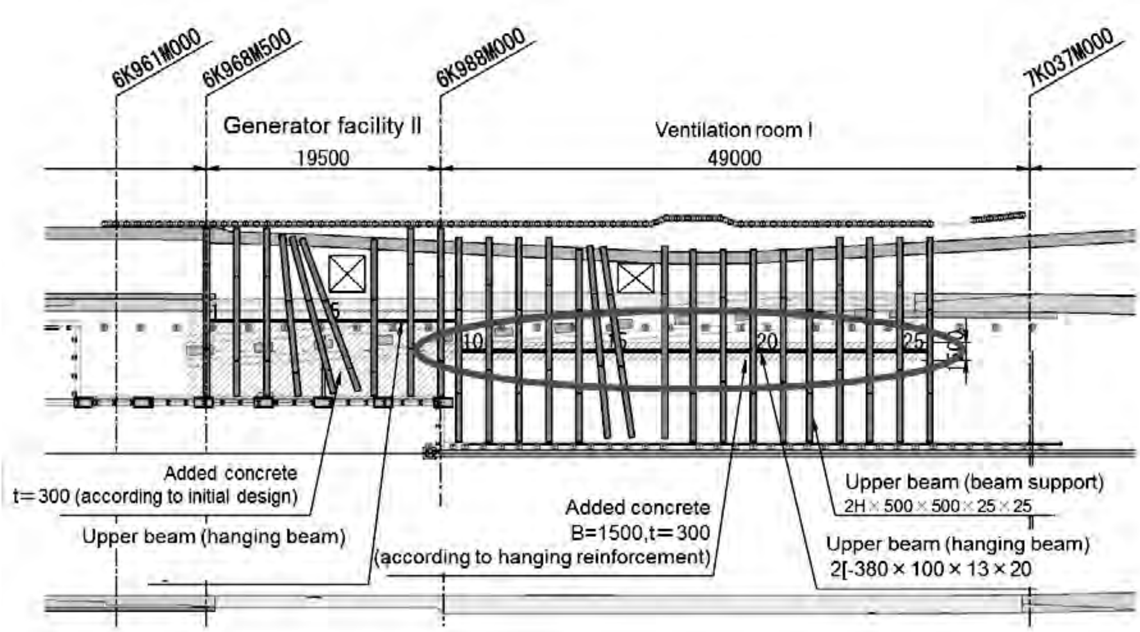


Figure 6: Floor Plan for Middle Floor Slab Hanger Construction

In addition, we inserted a steel channel between the anchored parts of hanging PC steel bars and used ϕ 23-mm anchored PC steel bars to join the reinforced concrete to the middle floor slabs to limit sudden deformation in case the anchored parts suffered punching shear failure (Figure 4). This doubled as a robust safety measure by allowing the hanging PC steel bars to function as anchors against middle floor slabs for later work[1)].

Picture 1: Middle Floor Slab Hanger Construction Conditions within Figure 6 Area

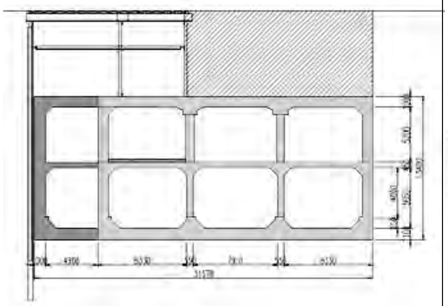
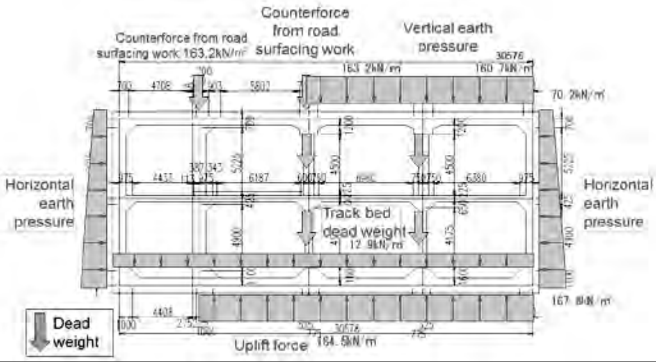
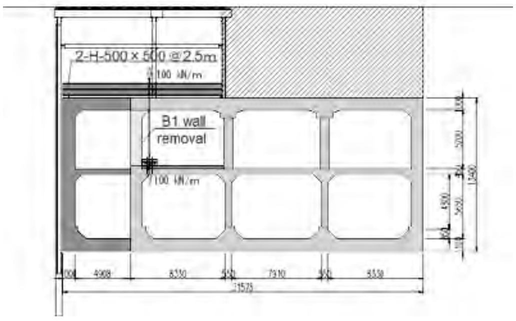
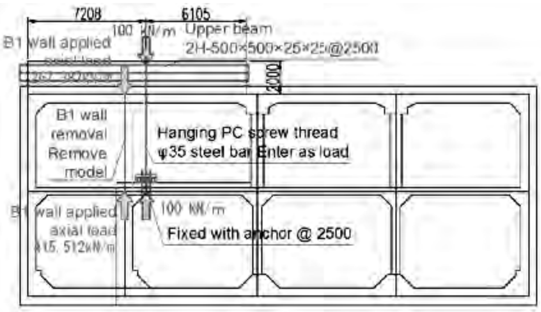
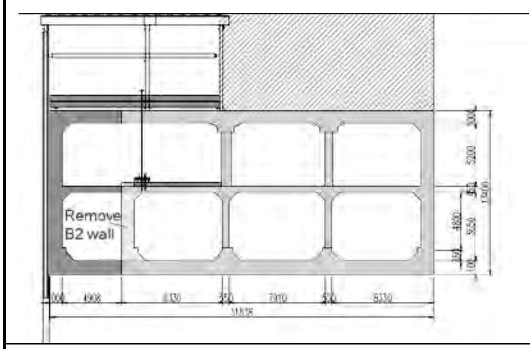
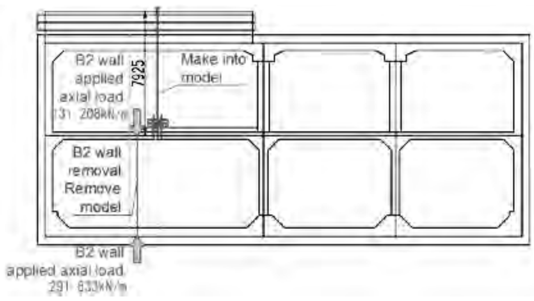
<table>
<tr><th colspan="2">(1) At new frame completion</th></tr>
<tr><th>Work procedure</th><th>Analytical procedure</th></tr>
<tr><td></td><td>
</td></tr>
<tr><td colspan="2">・ External forces and dead weight applied.</td></tr>
<tr><th colspan="2">(2) At middle floor slab reinforcement after B1 wall removal</th></tr>
<tr><th>Work procedure</th><th>Analytical procedure</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">・ Remove the B1 wall model.
・ Apply axial forces from the upper and lower edges of the B1 wall as calculated in analysis of (1) to the place the B1 wall will be installed.
・ Apply the tension to the hanging reinforcement of the middle floor slabs.</td></tr>
<tr><th colspan="2">(3) At removal of B2 wall</th></tr>
<tr><th>Work procedure</th><th>Analytical procedure</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">・ Remove the B2 wall model.
・ Apply axial forces from the upper and lower edges of the B2 wall as calculated in analysis of (1) and (2) to the place the B2 wall will be installed.
・ Make a model of hanging steel bars.</td></tr>
</table>

Figure 7: Step Calculation Procedure

4. PREDICTIVE ANALYSIS

As the middle floor slab hanger construction took place within the structure of an operating subway line, it was critical to ensure the safety of the structure as well as the required space on the track floor as not to interrupt subway operation. Thus, as we drafted measurement control plans for this work we needed to predict the behavior of the frame around the middle floor slabs and displacement of the hanging PC steel bars for each stage of frame expansion and removal. To do so, we performed the two-dimensional structural analysis ("step calculations") that illustrated work procedures as shown in Figure 7, and used it as a guideline for determining the appropriateness of the work.

Step calculations express changes in behavior at each work stage through structural changes and changes in loads exerted due to frame expansion and removal, and focus on the effects of vertical displacement of the middle floor slabs (middle floor slab displacement).

Specifically, the first step is to analyze the initial frame at the time of completion in terms of external forces, dead weight and the like. Load changes replace structural changes in Steps 2 and 3 and are applied to structural models. Thus, deformation at any given step is the cumulative result of deformation in previous stages. In other words, the deformation in Step 3 is the sum of the results from Steps 1, 2 and 3. Figure 8 shows middle floor slab displacement at each step. We calculated the displacement of middle floor slabs at each step exclusive of subsidence and listing of the entire frame by setting the displacement at Step 1 to 0 mm.

Based on these results, we determined that middle floor slab displacement of ±5 mm would not negatively affect the various facilities on the operating line, and set the initial tension of the PC steel bars to keep the frame within that range of displacement. We compared the stress levels of the materials and verified that stress levels encountered were within the allowable range.

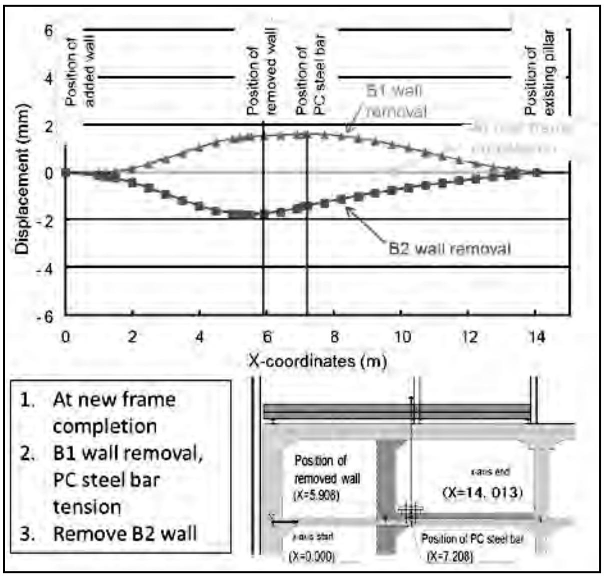


Figure 8: Distribution of Middle Floor Slab Displacement (Predictive Values)

5. MEASUREMENT CONTROL

5.1 Measurement method

The step calculations showed that limiting the displacement of middle floor slabs ensured the safety of the frame and operating subway line, thus we decided to measure and control the displacement and the tension of the PC steel bars. Table 1 shows measurement items and evaluation criteria.

We used a system for measuring displacement through images to measure the displacement of middle floor slabs[2)]. Specifically, we installed targets at reference points and survey points within the ranges of the images, and camera units outside the ±5-mm range of displacement impact collimated on each target to detect the relative displacement of survey points from the reference points in order to measure vertical and horizontal displacement.

The main idea was to detect the location of the target images, determine their coordinates and use scaling factors, distance and other positional information to calculate the vertical and horizontal displacement to a margin of error of ±0.5 mm at a distance of 50 m.

If the measured displacement temporarily exceeded the control value of ±4.0 mm, an email alert would be sent to the mobile phones of relevant personnel.

We used center-hole load cells to measure the tensions of both the hanging and anchored PC steel bars. To be specific, we used waterproof, differential-transformer load cells that have performed well in measuring loads on earth anchors and other measures used in earth retention and landslide prevention work, and in measuring earth pressure and other forces acting in tunnel falsework and similar projects.

Table 1: Measurement Items and Evaluation Criteria

Focal point	**Specifications**	**No. of locations**	**Measurement frequency**	**Evaluation criteria**
Middle floor slab displacement	System for measuring displacement through images	25	Every 5 minutes	Initial control value: ±4.0 mm; Limit: ±5.0 mm
Tension of hanging steel bars	Center-hole load cells (for 100t)	49	Every 5 minutes	Maximum tension: 228 kN Sudden increases in tension indicate a problem
Tension of anchored steel bars	Center-hole load cells (for 100t)	13	Every 5 minutes	Maximum tension: 144kN Sudden increases in tension indicate a problem
Upper floor slab temperature	Attach to center-hole load cells	3	Every 5 minutes	-
Middle floor slab temperature	Attach to center-hole load cells	1	Every 5 minutes	-
Cracks in reinforced concrete	Visual inspection	49	Measure width of cracks at each inspection, twice per week	Sudden increases in the width or number of cracks indicate a problem

5.2 Measurement results

Figure 9 shows the results of measuring displacement and tension. The horizontal axis is time shown as dates. Part A is displacement from the removal of existing walls, where the instruments measured 3.0 mm of displacement compared to actual measured displacement of 1.8 mm. Part B is displacement from changes to overhead loads, where the instruments measured 1.3 mm compared to actual measured displacement of 0.4 mm.

Subsidence progressed gradually over the long periods following Part B, and we estimate this was due to decreasing ambient temperatures, concrete creep and relaxation of the steel [3].

Despite a lack of extraordinary events during Part C, we observed changes too large to ignore. Since this coincided with a sudden drop in ambient temperature, we magnified Figure 9 and examined it as shown in Figure 10, and determined that the changes were due to the change in ambient temperature. Similarly, we observed an increase in Part D without extraordinary event, and we attributed the increase to the sudden change in ambient temperature.

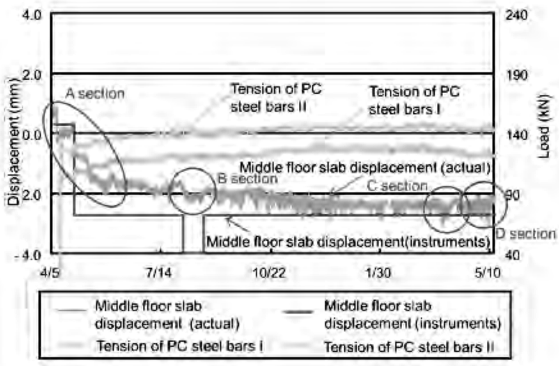


Figure 9: Change in Middle Floor Slab Displacement and PC Steel Bar Tension over Time

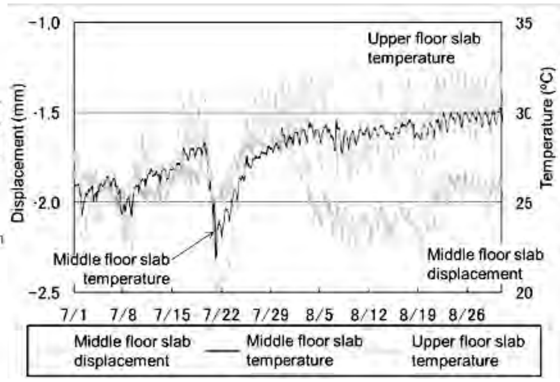


Figure 10: Middle Floor Slab Displacement and Temperature (Part C, Expanded View)

6. CONCLUSION

Our measurements of middle floor slab displacement were smaller than the displacement determined from step calculations. Thus, we believe the support replacement work is progressing smoothly. We will use the methods explained in this report to draft plans for construction work and measurement control for the upcoming work on the B Line side, and expect to use the knowledge we gained from these measurements to carry out the work even more safely.

Our method is unprecedented, but effective in widening open-excavated tunnels in service and other large-scale improvement projects. Thus, we plan to use the various measurement results obtained from this work to validate analysis of future designs and work.

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Open-spaces inventory and analysis in planning for safe evacuation sites in earthquake emergencies for in Kathmandu Valley

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ABSTRACT

An essential piece of earthquake preparedness is ensuring safe and accessible open spaces for emergency response. With the high rate of urban development in Kathmandu Valley, open spaces are gradually decreasing. An effort, by the government and community groups, is crucial to preserve the remaining open spaces in Kathmandu Valley. In this regard, an inventory of open-spaces in Kathmandu Valley is an initiative taken by National Society for Earthquake Technology – Nepal (NSET) as a part of Risk Mapping for Shelter Response Project. This study is focused on mapping and analysis of available public open spaces in Kathmandu Valley for possible use of temporary shelter and other facilities. There is a need of large open spaces considering possible displaces people during emergencies while as the amount of open spaces is decreasing because of several reasons. Recognizing that all open spaces do not show equal potential for use in post-disaster emergency, possible use of different open spaces for emergency was analyzed. The study was carried out with site visit and field verification including several attributes as observed and discussed with local authorities and people including use as parking, playground for children community use, drying food grains, fruit and vegetable vendors etc. Hence, preserving such public open spaces is essentially protecting the culture also. Realizing the importance of preserving these available open spaces, the Kathmandu Valley Development Authority (KVDA) and NSET has published an inventory of open spaces in the form of this Atlas. The main objectives of this atlas are: to help develop emergency response plans for a large earthquake disaster; and to help preserve the public open spaces. This paper presents the findings and challenges with suggestion for protection and development of open-spaces for better emergency response.

Keywords: open-spaces, Kathmandu Valley, earthquake preparedness, atlas

1. INTRODUCTION

This inventory and analysis of open spaces in Kathmandu Valley was carried out with the purpose of assessing available open spaces for shelter requirement in emergencies. This inventory was originally carried out as part of Risk Mapping for Shelter Response Project implemented with the support from UN Habitat, Global Risk Identification

Program (GRIP) of UNDP/BCPR, IFRC and ProVention Consortium; under the Global Emergency Shelter Cluster of the UN/IASC context.

This study seeks to document and describe public open spaces available within Kathmandu Valley. Rapid urban growth in one hand increases the need for more open space (a larger displaced population requires more shelter space), and on the other - reduces its supply (through development) – this is clearly an imbalanced equation. Recognizing that all open spaces do not show equal potential for use in post-disaster emergency, we have specifically targeted public lands, as private lands are both logistically difficult to use, and they are quickly disappearing due to development.

Many of the sites visited were filled with people actively engaged in those spaces. During the field visit, we observed various daily uses of the open spaces such as vehicle parking, playground for children, meeting and chatting place for adults and retired persons, drying food grains, fruit and vegetable vendors etc. Hence, preserving such public open spaces is essentially protecting the culture also.

An essential piece of earthquake preparedness is ensuring safe and accessible open spaces for emergency response. With the high rate of urban development in Kathmandu Valley, open spaces are gradually decreasing. A concerted effort, by the government and community groups, is needed to preserve the remaining open spaces in Kathmandu Valley. Realizing the importance of preserving these available open spaces, this inventory was carried out. The main objectives of inventory were to help prepare emergency response plans to be useful for a large earthquake disaster while preserving public open spaces.

2. METHODOLOGY

There have been some works in the past for identification of large open spaces in Kathmandu Valley. Those earlier works largely based on the documents, satellite image or available maps, with least physical verification. However, the condition and actual usable size of open spaces are different than as seen in the formal documents, maps and images. Hence, a thorough verification of such sites at field is crucial for making them really applicable during the disaster situations. The previous work a) Study on Seismic Vulnerability of Drinking Water Supply System in Kathmandu Valley (NSET, 2003), b) Disaster Preparedness and Response Plan Framework (DPRF) in Lalitpur Sub-Metropolitan City (NSET/UNICEF, 2007) and c) Identification of Open Spaces for Humanitarian Purposes in Kathmandu Valley (IOM, 2008) were focused on the evacuation sites identification for emergency purposes. These works give an idea on its background which emphasize on identification of open spaces to be used in emergencies.

2.1 Field preparation and surveys

Prior to the field visit, preliminary maps were prepared collected from different secondary sources. Preliminary screening of potential open spaces was carried out using such maps and images including cadastral maps, and Google Earth. Satellite images from the Google maps were further captured for wider use for field purpose. A survey form was developed for collecting information from the field. Major information of the each site was collected are shown in the following table (Table 1) with explanation.

Table 1 : Key information and attributes included in the survey of open spaces.

SN	Attributes	Explanation
1	Name of site	Local Name of the area (including with survey code - each survey site was given unique identification code for further processing of data in GIS)
2	Geographic location	Latitude and Longitude, Altitude of the site (using GPS equipment)
3	Total area	Reported (in ropani) vs. calculated, (1 Ana = 342.25 sq. feet (31.8 sq. meter), 16 Ana= 1 Ropani)
4	Ownership	While all lands surveyed were public lands, not all were state or municipal properties. Many of the open spaces surveyed were owned and managed by smaller community groups.
5	Contact person (name, phone number)	If a community group owns the land, a representative will be contacted in the event of an earthquake to discuss shelter site implementation.
6	Master plan	If a community group has a master plan for the development of the site, when will development begin? How long with this land be open and available for use as a potential shelter site?
7	Existing uses	Park, Courtyard, Roadside. Land use specifics of the site. Certain existing uses are undesirable (e.g., garbage dumping).
8	Physical environment	Slope of land, and drainage.
9	Potential hazards	Fire: Due to proximity to fire pumps, gas depots, factories, or high-voltage power lines. Most of the areas surveyed in the denser parts of valley had a large number of high-voltage power lines, some of which were unprotected. Great caution must be taken when establishing shelter sites in these locations. Landslide risk (especially along the river side as danger of under-cutting by river and slope) Flood risk (along the river, urban flood prone areas). Pollution (River, Sewage, Soil, Garbage, Noise).
10	Infrastructure	Major Connecting Roads: Proximity to a major road is tremendously important for emergency vehicle access, aid delivery, and removal of waste and rubble. Water Supply System: brand, type, distance, and capacity. Stone taps and wells were also observed, and could potentially be damaged and put out of use in the event of an earthquake. We've prioritized sites with clean and earthquake safe water supply systems. Electricity: Availability and capacity of generators, in the event of power failure.
11	Proximity to other facilities (type, number available in proximity, distance, capacity)	Hospitals (Number of available beds, medical specialty Schools: Education must continue after disaster. Ideal school sites will have large open spaces for sheltering students and faculty. Other Large Open Areas near Site: If small area does not work, people can be moved to larger areas.
12	Security (type, count, distance, capacity)	Police Station: Police are needed for both evacuation assistance and protection of those in the camp. Fire Brigade: Fire brigade services are extremely limited in Kathmandu Valley; an appropriate camp plan should be designed accordingly.

SN	Attributes	Explanation
		Ambulance Service Availability: Where are ambulances stationed, which is the nearest station to the site. Fencing around site: Many of the open spaces within the denser parts of cities are surrounded on all sides by large buildings, but on the city's periphery, fencing may be useful in securing the shelter area.
13	Implementation issues	What other issues may help or hinder the implementation of a post-disaster shelter site in this location? Are their potential governmental or political issues that could be in conflict with a plan for using a site for shelter purposes?

Before conducting survey, an extensive training on data collection and field verification was provided to field surveyors. This includes process for conducting consultation with local government officers, local people, and other local stakeholders; steps for mapping and several other practical techniques required for the field survey. The university students from the background in geography were chosen having prior knowledge on mapping and surveys. The entire process was guided and monitored by NSET.

2.2 Field survey and verification

Field survey was carried out during three months period (in November 2010 – March 2011). Each team visited local government offices (VDC/Ward offices) and open space sites as assigned prior. The field approach was taken as: a) meeting with local government officials – VDC and Ward officers, especially the secretaries were identified to be the ideal informants for obtaining information about the sites. Therefore, these key informants were met prior to survey of the actual open space. Surveyors brought 24''x36'' satellite images of the ward areas, printed from Google Earth. The ward officers were then requested to identify open spaces and draw the associated boundary of the open spaces identified. Further information about the available open space (e.g., public or private, site conditions, surroundings) were also provided by these ward officers. Most of the ward officials are local residents; this provided added benefit and ease in doing the survey. If the ward officers were not-available, assistance was taken from other local residents around. The preference was given in group discussion for such inventories; and b) ground-truthing processes – after meeting with the ward officers, and other local community members, the survey team physically visited each site for ground-truthing. The survey form was used to collect information from the field. For the ground-truthing and collecting field information, representatives of the community organization in-charge of the land were targeted; however, when they were not available, nearest shopkeepers or local residents were interviewed. The satellite images often attracted large crowds of local people, who further helped in providing information more accurately about the site. Community members were asked to provide information regarding a wide range of site-specific information, some of which can be used to prioritize shelter site locations: For each open space a single survey form was completed.

Open spaces available in all VDC/Municipalities Valley were surveyed with the aim of determining potential sites for post-earthquake evacuation camps. So, the characteristics of each site- population holding capacity, ownership (excluding private land), water availability, sanitary conditions, and accessibility (proximity to major roads and health) was collected. In addition, while collecting data in the field, the surveyors had the opportunity to discuss about earthquake risk and preparedness with both government officers and members of the general public (see Table 1 for detail taken in to consideration). People were found to be concerned and eager to help.

Figure 1 : Determining site boundaries and identifying open spaces with ward officials (left) and on-site discussion on site-features with community members (right).

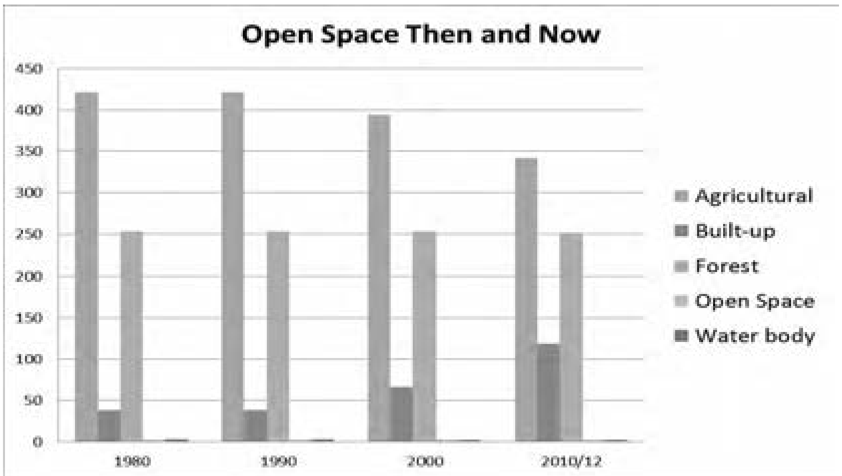
2.3 Data verification and mapping

Collected information were checked again after the field visit. The collected data was verified with the pre-field visit data. The identification number was recorded on both the survey form and on the corresponding location on the satellite image. This allowed for easily connecting the open site in the image with the data recorded. Then boundary of the particular open space was drawn in map with some verification.

Based on the defined boundary of the sites, each site was digitized using Google Earth, because of the quality of map. After digitization of each site in Google Earth, this data was exported into GIS for further processing and analysis. The location (coordinates – obtained from a handheld GPS device) of each site was also recorded on survey forms.

All the information of open spaces were presented in the form of maps. These maps are overlaid on the topographic maps prepared and produced by Department of Survey/Government of Nepal (DoS/GoN). Since the open space database has been stored in GIS formats, the maps thus prepared can be shared and it can be used with other databases compatible with the most common databases. These maps are highly useful for further awareness-raising of common people on evacuation site and most importantly for the planning purposes for preparedness and risk reduction. Since all maps are prepared in GIS environment, these could be easily updated in the future.

All surveys were conducted on foot, in neighborhoods with narrow, mazelike streets. Locating ward offices and open spaces, was sometimes very time intensive. There is likely little way around this due to the architecture of the street system and the lack of street signage in Core city areas. Our experiences navigating the streets in core areas furthered our worries regarding the difficulties of post-disaster navigation, when many roads may be out of service.



Source: Joshi et al (2013)

Figure 2 : Open spaces in Kathmandu Valley then and now 1980-2012 period.

The community members who were interviewed were met spontaneously, and the quality of information provided varied greatly. Some interviewees were very knowledgeable of the site and its surroundings, while others were less. If possible, where the data is available, GIS could be used to confirm surface area and proximity to hospitals, schools, police departments, water sources, etc

3. SUMMARY OF FINDINGS

3.1 Characteristics of available open spaces

The type of open spaces surveyed were: playgrounds, road right-of-ways, community courtyards, temple areas, schoolyards, parks, river banks, pond margins, parking grounds, historic sites, gardens, and government office premises. One of the most common types of sites surveyed was the courtyard type settlement, called ‘Bahaa’ in Newari, or ‘Bahaal’ in Nepali which are basically community courtyards, often surrounding a temple or stupa at the middle, houses in the surrounding and large space in between. The neighborhood manages these grounds, and the funds for the upkeep are often provided by agricultural lands on the outskirts of the city. Thus bahaa represent two separate open spaces – the urban courtyard and its associated rural agricultural land. In the event of a major earthquake, the narrow access ways to many of these bahaa may be blocked by debris or fallen buildings. The access component of the survey form are especially relevant for these sites. It may be worth recording which agricultural lands are connected with which bahaa, so that if the bahaa is unsuitable for a shelter site, the community could shelter on their rural lands.

Apart from the typical newari bahaa especially in city core area and in the old settlements of Kathmandu Valley, there are several types of public open spaces were found during the survey. They are: open spaces used by religious purposes, i.e. temples, guthi, church, bihar etc. The other type is the land occupied by other public entities such as Red Cross, public schools, ward offices. Land being used by government offices are also holding significant amount of open spaces within the valley. In the survey, some larger open spaces were also found which are unused in the present time; however, they were separated for the public purposes in the past. Open space of oxidation pond and Tribhuvan University compound in Kirtipur still remain larger open spaces within the valley. A summary of main types of public open spaces and their key characteristics are presented in Table 3.

Table 2 : Different types of open spaces and their key characteristics

Type of open space	**Key characteristics**
Courtyard Settlements (Bahaa, Bahaal)	Mainly community courtyard located amongst Newar communities. The major significance of this type of open spaces can be taken as a primary collection point.
Playgrounds	Playgrounds can be found in many places in Kathmandu varying in size and ownership.
Institutional Areas	Institutional areas are mainly owned by Government offices, educational institutions etc. These are found as major areas can be used to establish emergency shelters. The size varies.

3.2 Distribution of open spaces

Total 887 public open spaces were identified and mapped within Kathmandu Valley. Total area mapped was 15.5 square kilometers (sqkm) of open spaces of different sizes ranging from small to large. The majority of open spaces found in Kathmandu District (numbers 488), followed by Lalitpur District (numbers. 346) and Bhaktapur District (numbers 53). The total usable area is 9 sqkm, which is about 58 % of the total open spaces mapped.

The open spaces are categorized according to the size/area, ownership, present use, purpose of open space etc.

3.2.1 Open spaces by size

According to the size, open spaces are categorized into 3 categories. These are a) Large open spaces area with more than 10,000 sq meter; b) medium size open spaces - area with 5000 - 10000 sq meters; and c) small size open spaces area with less than 5000 sq meters.

Figure 3 : Open spaces distribution in Kathmandu Valley.

Table 3 : Summary of open spaces in terms of size.

Size of open spaces by District / Municipalities		**No. of open spaces**	**Total area (sq.mt.)**	**Usable area (sq.mt.)**
Kathmandu District		488	10,576,269	5,938,820
Kirtipur Municipality (19 Wards)		13	2,307,612	1,325,994
	> 10000	4	2,282,236	1,308,730
	5000 - 10000	1	8,131	6,505
	< 5000	8	17,245	10,759
Kathmandu Metropolitan City (35 Wards)		266	5,737,268	2,962,287
	> 10000	48	4,576,185	2,427,525
	5000 - 10000	36	553,718	256,386
	< 5000	182	607,366	278,377
VDCs (56 VDCs)		209	2,531,389	1,650,538
	> 10000	27	1,731,134	1,167,410
	5000 - 10000	27	280,390	183,313

Size of open spaces by District / Municipalities		No. of open spaces	Total area (sq.mt.)	Usable area (sq.mt.)
	< 5000	155	519,865	299,815
Lalitpur District		346	3,486,077	2,092,636
Lalitpur Sub-metropolitan City (22 Wards)		137	1,850,728	1,221,890
	> 10000	23	1,468,261	1,000,420
	5000 - 10000	14	180,893	96,207
	< 5000	100	201,575	125,263
VDCs (26 VDCs)		209	1,635,349	870,746
	> 10000	20	940,417	535,044
	5000 - 10000	17	228,369	116,318
	< 5000	172	466,563	219,384
Bhaktapur District		53	1,473,459	998,819
Bhaktapur Municipality (17 Wards)		17	631,283	454,492
	> 10000	6	562,569	411,299
	5000 - 10000	3	34,157	23,915
	< 5000	8	34,558	19,278
Madhyapur Thimi Municipality (17 Wards)		13	560,194	378,572
	> 10000	5	511,310	350,048
	5000 - 10000	3	36,852	20,470
	< 5000	5	12,033	8,053
VDCs (16 Wards)		23	281,982	165,756
	> 10000	3	217,245	123,890
	5000 - 10000	3	26,058	20,127
	< 5000	17	38,679	21,739
Total		887	15,535,804	9,030,275

Source: Field survey 2010.

3.2.2 Open spaces by land ownership

Land ownership of the open spaces are categorized as a) Institutional, b) Nepal Government Offices, c) Private in Lease, d) Educational (schools and colleges), e) Religious Institutions (eg. guthi, temple, bihar, church etc), f) Hospitals or Health Institutions etc. The following table shows the summary by ownership in different districts and according to total area as well as usable area.

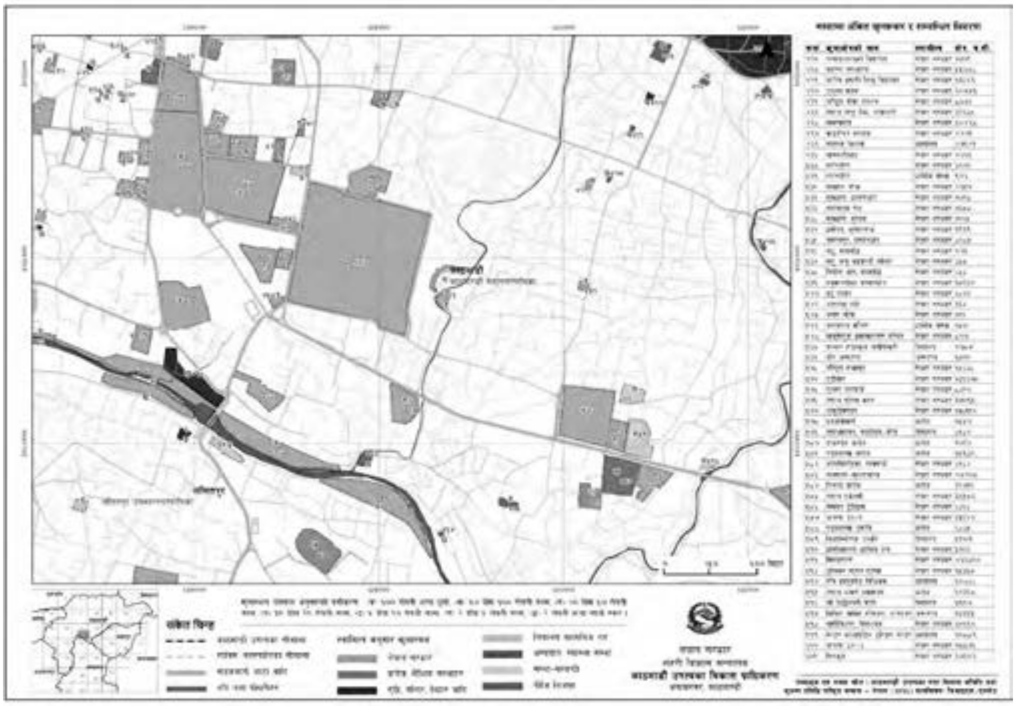


Figure 5 : Distribution of open spaces in core city areas of Kathmandu of different sizes.

Table 4 : Summary by ownership of identified open spaces.

	Ownership by District / Municipalities	No. of open spaces	Total area (sq.mt.)	Usable area (sq.mt.)
Kathmandu District		488	10576268.7	5938819.5
Kirtipur Municipality (19 Wards)		13	2307611.8	1325993.9
	Institutional	1	96550.4	28965.1
	Nepal Government	10	2141353.2	1275690.1
	Private in lease	1	65445.4	19633.6
	School	1	4262.7	1705.1
Kathmandu Metropolitan City (35 Wards)		266	5737268.1	2962287.4
	College	8	82238.8	39244.9
	Guthi/Temple/Bihar/Church	14	753226.9	454390.7
	Hospital	2	45201.5	20446
	Institutional	27	339063.4	140268
	Nepal Government	157	4388078.5	2238706.3
	Private in lease	44	69849.1	35865
	School	14	59609.9	33366.5
VDCs (56 VDcs)		209	2531388.9	1650538.2
	College	1	2522.9	1261.4
	Guthi/Temple/Bihar/Church	9	102152.6	61923.6
	Hospital	2	14351.6	6123.7
	Institutional	8	287470.6	169033.1
	Nepal Government	130	1786078.7	1183271.5

	Ownership by District / Municipalities	No. of open spaces	Total area (sq.mt.)	Usable area (sq.mt.)
	Private in lease	40	184381.3	119189.9
	School	19	154431.3	109735.1
Lalitpur District		346	3486076.9	2092636
Lalitpur Sub-metrop. City (22 Wards)		137	1850728.2	1221890
	College	3	58353.4	44712.9
	Guthi/Temple/Bihar/Church	17	44245.1	28442.7
	Institutional	18	864936.5	618073.4
	Nepal Government	83	784002.4	474869.7
	Private in lease	4	5683.1	3042.7
	School	12	93507.6	52748.5
VDCs (26 VDCs)		209	1635348.7	870746
	College	2	29849.4	21145.8
	Guthi/Temple/Bihar/Church	12	190962.9	133192.4
	Institutional	11	108139.8	66624.9
	Nepal Government	124	775852.2	395753.5
	Private in lease	24	342022.8	133683.2
	School	36	188521.7	120346.2
Bhaktapur District		53	1473458.8	998819.2
Bhaktapur Municipality (17 Wards)		17	631282.9	454491.6
	College	1	29038.8	23231
	Institutional	2	394968.8	275489.7
	Nepal Government	12	200343.3	152025.7
	School	2	6932	3745.1
Madhyapur Thimi Municipality (17 Wards)		13	560193.8	378571.5
	College	2	113312	87794.3
	Nepal Government	8	432352.8	281550.8
	Private in lease	1	9820.9	6383.6
	School	2	4708.3	2842.9
VDCs (16 VDCs)		23	281982	165756.1
	Nepal Government	19	275002.4	161150.8
	School	4	6979.6	4605.3
Total		887	15535804.4	9030274.7

Source: Field Survey

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Kathmandu Valley is the most populated region in the country. Population growth has now reached 2.5 million, with nine to twelve percent new construction in the urban area yearly. Rapid urban growth can be easily seen rapid change in the farmland, riverbank and cultural sites too. The numbers of houses is in increase, but the amount of land is limited. Infrastructural facilities in the valley are in a pathetic state. Hence, the open spaces in the Kathmandu valley are decreasing very rapidly. We will barely be able to find an open space in the valley, if this trend is continues.

Nepal is notoriously prone to earthquakes. If the large scale natural disasters occur in Kathmandu valley (approximately 1.5 - 2.0 million displace population) might be major challenge for the government and other humanitarian agency with the resulting significant shelter need.

Through this process, many potential risk of the built environment were observed. The need for stronger land use planning, and earthquake safe building code enforcement is of extreme importance. The safety of the city's residents is under great threat, and the steps to address it should be prioritized. Preservation for open spaces could in fact be used as a means of bringing greater cooperation into the political process.

Most of the community groups surveyed were happy to have their lands available for emergency purpose; however, some showed concern regarding potential crowding and the possible social impacts of such use.

4.2 Recommendations

The following specific recommendations are made to promote emergency planning and shelter management for the post-earthquake situation in the Kathmandu valley.

i. The importance of open-spaces during the time of disaster is highly realized throughout the world, it should integrate in local level planning and awareness among local level authorities is highly needed. The community is equally important in this awareness of the importance and use of open-spaces.
ii. Detail investigation of open spaces in Kathmandu is still not finished, and the regular update of the information is quite important. So regular update of information is required, suggested every year.
iii. Comprehensive study is needed for the open spaces in Kathmandu as a continuous process rather than onetime collection of data (repository).
iv. Open-space cannot sustain alone. It requires basic infrastructure in the site. Detail assessment of such open spaces should be carried out in terms of basic infrastructure available around. Detail inventory of other facilities such as nearest hospital, drinking water facilities, road-accessibility etc. around such open-spaces is needed.
v. Coordination among government partners and other institutions, associations, NGOs, INGOs and private sector to impart proper knowledge on open spaces is important.
vi. MoU between stakeholders and Government can be one of the best way to keep those places available during the post-disaster operation.
vii. Legal grounds for local government (VDC or Municipalities) to use in emergencies should be established. Cooperative partnership between local government and owner of the land (if other than local government) and other partners should be established prior.
viii. For the care and maintenance of potential local evacuation sites, local CBOs can be a part of this. Community Based Open Space Planning Management could be an approach.

ix. Community awareness programs on the need of open-spaces around the community should be carried, so that local people can preserve the open spaces around them.
x. Improve the condition of open spaces wherever required
xi. Prepare plans on how the open spaces can actually be implemented during situations, especially if the community disaster preparedness plan is prepared, take consider of the locally available open spaces.
xii. Preposition minimum required supplies in the open spaces for evacuation and emergency food and some non-food items.
xiii. Conduct periodic drills at local level.

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New response reduction system for bridges using rotating inertia mass devices

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ABSTRACT

The new vibration control system for bridges using rotating inertia mass devices has been developed in order to reduce both the deformation of bearings and damage to columns. The seismic performance can be improved by using this mechanism without reinforcement of columns and piles, which would require a significant time and cost such as for access control or excavation of the bridge's neighboring area. This compact device consists of a ball screw mechanism including a flywheel and has significant mass damping effects, even if the mass of the flywheel is small.
Time history response analysis was conducted to decide the specifications of the vibration control system and to investigate the response reduction effect for bridge structures. Dynamic loading tests of the rotating mass devices were carried out to clarify the inertial mass and the damping ratio. In addition, we conducted an analytical study of the dynamic tests to establish the design procedure of the rotating mass devices. It has been proved that the devices have sufficient performance. The analytical results show very good agreement with the dynamic test results regardless of vibration frequency.

Keywords: vibration control, rotating inertia mass device, response reduction, dynamic test, time history response analysis

1. INTRODUCTION

In the last few decades, various kinds of vibration control devices for tall buildings like viscous dampers and non-linear hysteretic dampers have been developed and widely used in Japan. A few compact devices with inertia effect have been developed for the vibration control of structures [1],[2],[3]. Inertial mass dampers generate an inertial force thousands of times their mass weight, by utilizing the inertial mass effect determined by the outer diameter of the flywheel and the rotating ball screw lead. The damper reduces the response that would be caused by having the inertial force act on the structure. The authors have developed the new vibration control system for bridges using rotating inertia mass devices to simultaneously reduce both the deformation of

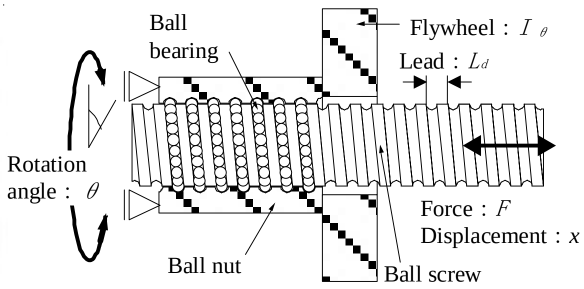


Figure 1. Damper Installation

Figure 2. Inertia Mass Damper

bearings and damage to columns. The inertia mass damper is installed between a bridge girder and bridge as shown in Figure 1.

The seismic performance can be improved by using this mechanism without reinforcement of the column and the pile, which would require a significant time and cost such as for access control or excavation of the bridge's neighboring area. Time history response analysis was conducted to investigate the dynamic parameters for the damage control devices and response reduction effects. Moreover, we fabricated the inertia mass damper prototype and carried out the dynamic tests to ensure the performance of the response reduction system. This paper describes the results of both analysis and experimental work.

2. MECHANISM OF INERTIA MASS DEVICE

The mechanism of the rotary mass device is illustrated in Figure 2. The device is composed of a ball screw, a ball nut, and a flywheel. The axial inertial force is generated through the moment of inertia of the flywheel. The torque of the rotating mass, T, and the axial inertial force, F, are calculated from the following equations by neglecting the friction force:

$$T = I_\theta \ddot{\theta} = \left(\frac{2\pi}{L_d}\right) I_\theta \ddot{x} = \frac{\pi}{4L_d}\left(D_1^{\,2} + D_2^{\,2}\right) m\ddot{x} \tag{1}$$

$$F = \left(\frac{2\pi}{L_d}\right) T = \frac{\pi^2\left(D_1^{\,2} + D_2^{\,2}\right)}{2L_d^{\,2}} m\ddot{x} = \psi \ddot{x} \tag{2}$$

where F denotes the axial force; x, axial displacement; I_θ, rotational inertia; L_d, lead of ball screw; D_1, external diameter of the flywheel; D_2, internal diameter of the flywheel; and m, mass of the flywheel, and Ψ in Eq.(2) corresponds to the induced axial inertial mass. Equation (2) indicates that the value of Ψ can be greatly enlarged by the mechanism. Since this mechanism can generate inertial mass hundreds to thousands of times as large as the real mass of the flywheel, the device is considered to be very effective as a response control system of an actual bridge structure. The inertia mass damper can follow the expansion or shrinkage of the superstructure subject to changes of temperature with almost no reaction.

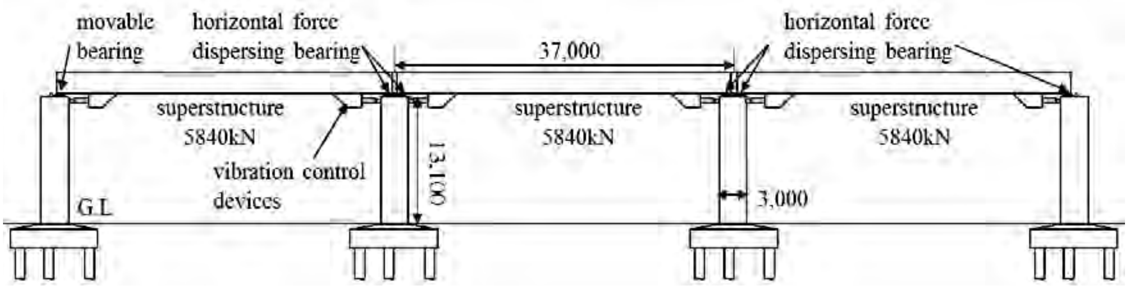


Figure 3. Bridge Specification

3. ANALYSIS FOR ENSURING THE PERFORMANCE OF THE RESPONSE REDUCTION SYSTEM

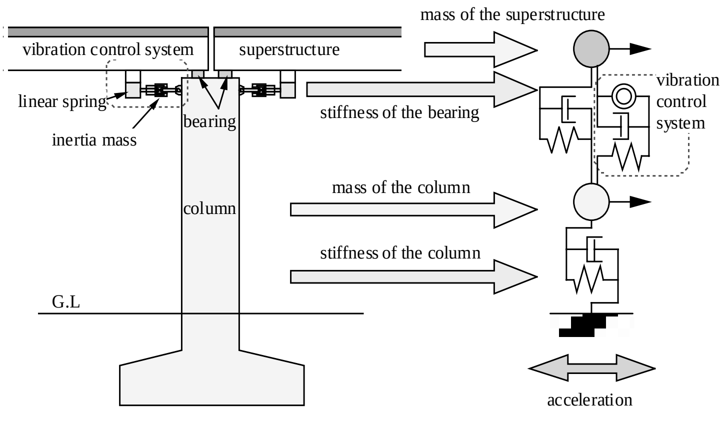


Figure 4. Analysis Model

3.1 Bridge Specifications

Figure 3 shows the outline of the bridge. This bridge has a continuous girder structure formed of three simple girder bridges. The span length is 37 meters and the weight of the bridge girder is 5,840 kN. The column is reinforced by steel plate lining. The diameter of the column is 3.0 meters, and its height is 13.1 meters. The natural period of the longitudinal direction is 0.92 sec.

3.2 Outline of the Study

The vibration control system consists of the inertia mass damper and damping elements in parallel, and the linear spring elements aligned in series (Figure 4). The inertia mass is assumed to conduct a parametric study as well as to determine the tuning ratio γ and damping ratio h of the optimum damping unit for the target bridge. These specifications are used to verify the response reduction effects by analyzing the bridge with a non-linear model.

3.3 Result of the Study

3.3.1 Settings of Inertia Mass

The natural period of the vibration control system is decided according to inertia mass and serial spring. The vibration control system is designed to be tuned to the primary natural period of the target bridge. The analysis model of the vibration control system is shown in Figure 4. The authors studied various combinations of damping coefficient and spring stiffness for 8-28% of inertia mass ratio, in order to have the response ratio of the bearing displacement achieve an almost equivalent bimodal around the natural frequency level. Figure 5 shows an example of the transfer function of the bearing displacement against the design seismic motion. The result of the linear analysis, using

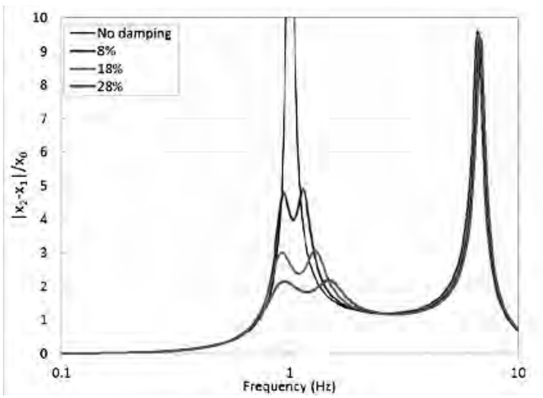


Figure 5. Transfer Function of Bearing Displacement

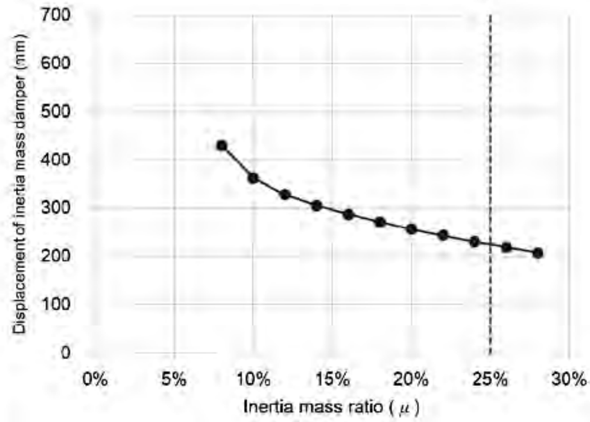
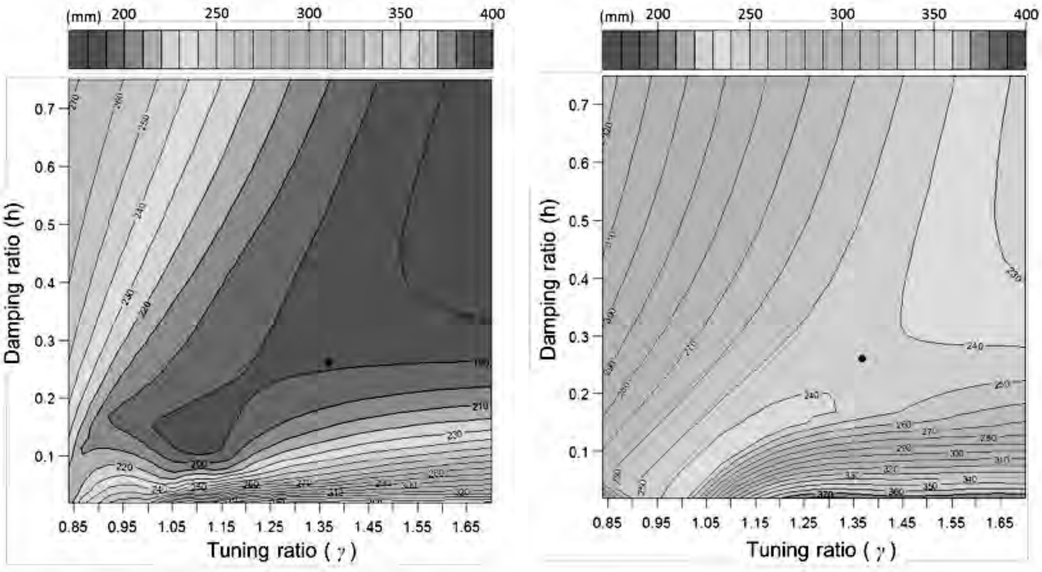


Figure 6. Displacement of Inertia Mass Damper Displacement



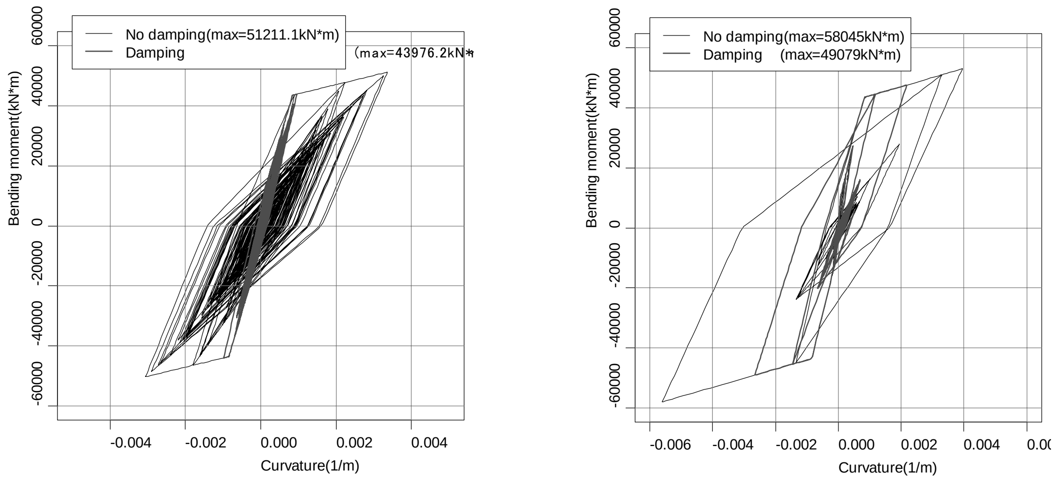
(a) Type I Seismic Movement (I-III-1) (b) Type II seismic wave (II-III-2)

Figure 7. Reduction Effect of Bearing Displacement

the inertia mass ratio as the parameter, is as shown in Figure 6. It results in larger inertia mass and smaller damper displacement. According to the results, the inertia mass ratio is determined as 25%.

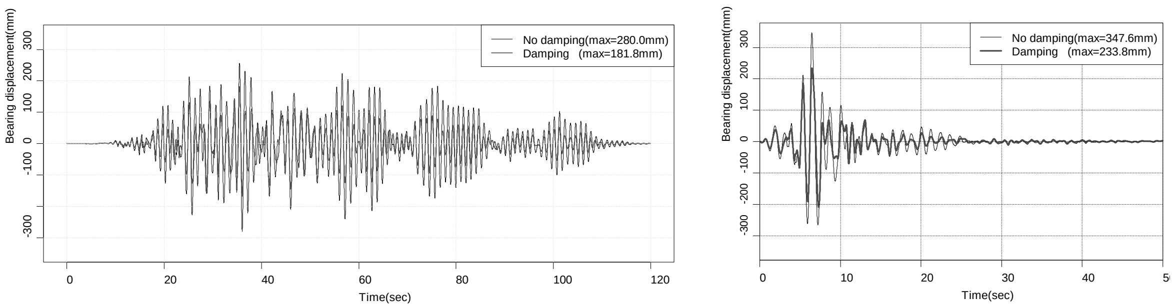
3.3.2 Parametric Study for Specifications of the Damping Unit

The features of the vibration control system are to reduce the displacement and moment of column at the same time. However, it is not practical to define the optimum value for multiple required performances since the optimum values for responses such as bearing displacement and moment of column would vary. Moreover, the optimum value should change against the input seismic motion. Therefore, we have conducted the detailed parametric study with various spring stiffness and damping values against the six types of input seismic waves [4]. The maximum values of the spring displacement and inertia mass displacement, which should impact on the size of the damping units, are preset as the parameter.



(a) Type I Seismic Movement (I-III-1) (b) Type II seismic wave (II-III-2)

Figure 8. Non-linear Response History of the Bridge Base



(a) Type I Seismic Movement (I-III-1) (b) Type II seismic wave (II-III-2)

Figure 9. Response Wave of Bearing Displacement

With the upper limits as 200mm and 300mm for each, the authors explored the combinations of the specifications to reduce bearing displacement and bridge moment. Figure 7 shows the contours for the maximum values of the reduction of the bearing displacement. Each axis of the figure is organized with the parameters as shown in Equations (3), (4). The subscript *d* refers to the damping unit, and *s* is a parameter for structures.

$$\gamma = f_d / f_s = \omega_d / 2\pi f_s = \sqrt{k_d / \psi_d} \Big/ 2\pi f_s \tag{3}$$

$$h = c_d \Big/ 2\sqrt{\psi_d k_d} \tag{4}$$

Here, γ : tuning ratio, h : damping ratio, f : natural vibration, ω : natural angular frequency

The values of the contour show the maximum bearing displacement of a parameter. The maximum bearing displacement decreases toward red in the color bar chart. According to the result of the bearing displacement and moment of bridge to six different types of input seismic motions, the value of the black dot in Figure 7 (γ =1.37, h=0.26) is considered to be the optimum value.

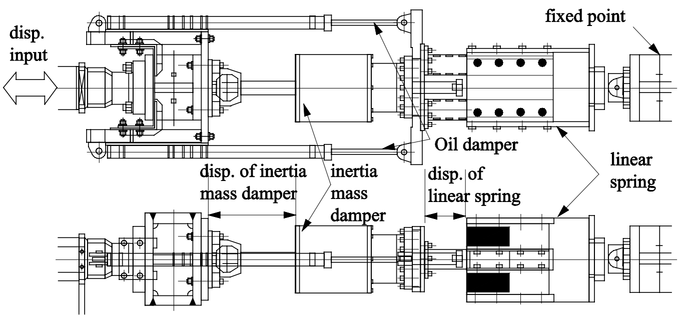


Figure 10. Test Device

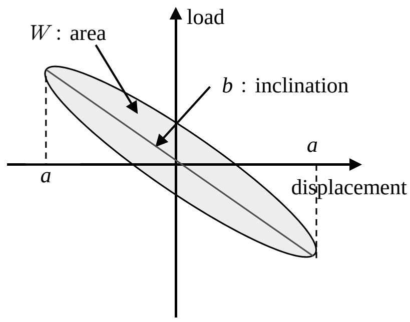


Figure 11. Evaluation Method

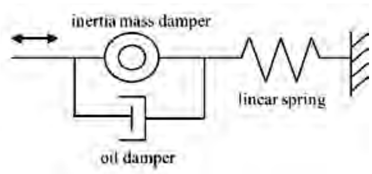


Figure 12. Analysis Model

3.3. 3 Verification of Response Reducing Effect

The results of the non-linear analysis are shown in Figures 8 and 9. It reveals that the maximum plastic deformation of the column decreased to almost the elastic range level with Type I seismic motion (plate boundary earthquake), to almost half the value with Type II seismic motion (inland earthquake). And it shows about 30% decrease of the maximum displacement of the bearing regardless of the seismic waves of Type I or II compared to the non-damping .

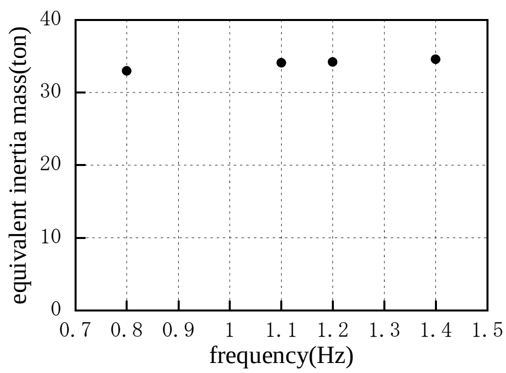


Figure 13. Equivalent Inertia Mass

4. Dynamic Test of Inertia Mass Damper Prototype

4.1 Outline of the Test and Evaluation Method

According to the analysis above, we designed a prototype with the target specification per one unit of the inertia mass damper as the equivalent inertia mass 35(ton), the damping ratio 0.26. The inertia mass damper is placed in parallel to the oil damper, which is then connected to the spring device in series (Figure 10). The total lengths of the inertia mass damper and spring are 1,280mm and 770mm, respectively. The end of the spring device is fixed and the damper devices are installed into the 2,000kN hydraulic test unit to carry out the sinusoidal vibration. The test was conducted at the frequency around the resonance point (1.2Hz), combining the inertia mass and the spring unit. The combinations of the excitation frequency and the amplitude are: 0.8Hz-100mm, 1.1Hz-60mm, 1.2Hz-60mm and 1.4Hz-60mm. The axis displacement of the inertia mass damper and spring is measured using the laser displacement sensor. The input load to the testing device is measured with the load cell.

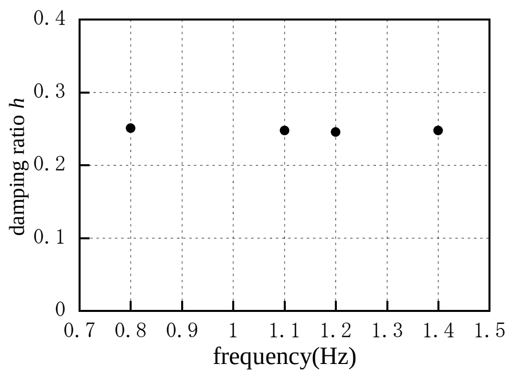


Figure 14. Damping Ratio

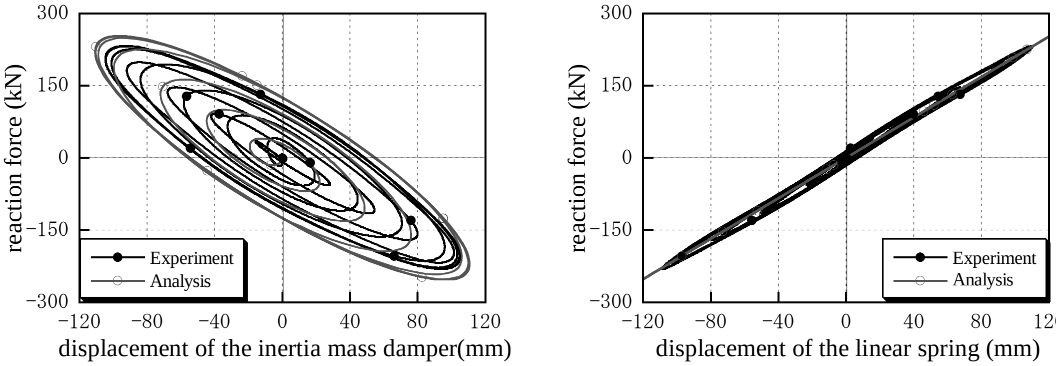


Figure 15. Inertia Mass Damper Displacement (left) and Spring Displacement (right) at 1.2Hz-amplitude 60mm

For calculation of the inertia mass , inclination *b* of Figure 11 and the value are calculated from Equation (5).
For the equivalent damping coefficient, the values led by *W* of Figure 11 and Equation (6) are used.

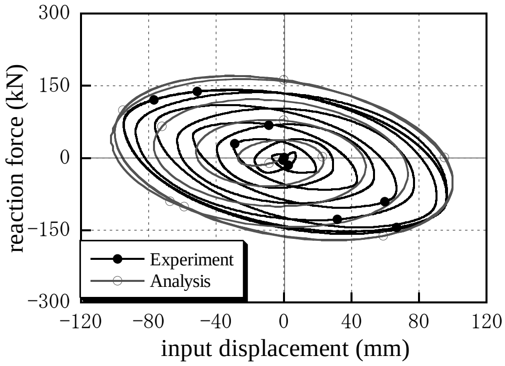
$$\psi = \frac{F}{\ddot{x}} = -\frac{F}{(2\cdot\pi\cdot f)^2\cdot x} = \frac{b}{(2\cdot\pi\cdot f)^2} \qquad (5)$$

$$C_{eq} = \frac{W}{2\cdot(\pi\cdot a)^2\cdot f} \qquad (6)$$

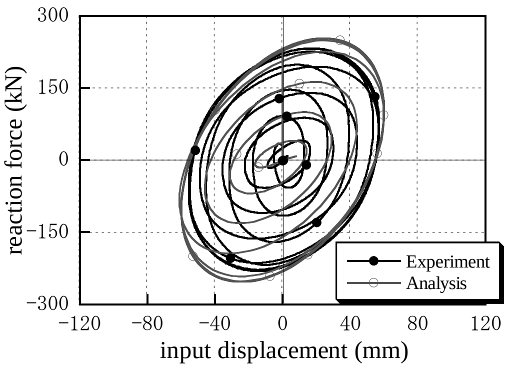
In order to validate the analysis model, we compared the results of the tests and the analyses using the model shown in Figure 12.

4.2 Test Result

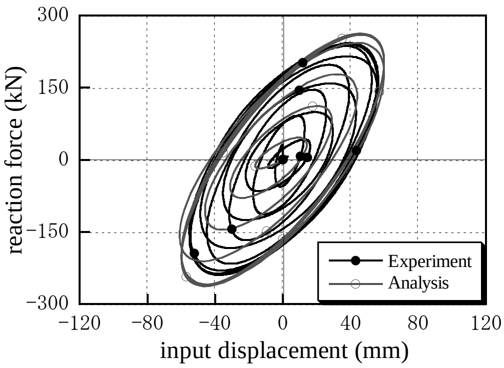
The test results related to the equivalent inertia mass and the damping ratio are shown in Figure 13 and Figure 14. The average values of the equivalent inertia mass and the damping ratio were 34.0 (ton) and 0.25 respectively, which were almost the same as the target values, and not much affected by excitation frequency or amplitude. Figure 15 shows the result of comparison of the testing and analysis for the reaction force, inertia mass damper displacement and spring displacement as excitation frequency 1.2Hz and amplitude 60mm as an example. While the damper or spring displacement increased,



(a) 0.8Hz-100mm



(b) 1.2Hz-60mm



(c) 1.4Hz-60mm

Figure 16. Reacting Force – Input

compared to the input displacement, the analysis shows very good agreement with the behavior of the inertia mass damper and spring. Figure 16 shows the comparison of the testing and analysis on the relation of the reaction force and input displacement. The total inertia mass damper displacement and spring displacement is referred to as the input displacement. With lower frequency than the excitation frequency, the inertia mass damper displacement become larger than the spring displacement. With a higher frequency than the excitation frequency, the inertia mass damper displacement becomes smaller than the spring displacement. The inclination of the reaction force and input displacement change at the border to the excitation frequency. The analysis was validated to show the various behaviors of the structure subject to the excitation frequency.

5. Conclusions

The new vibration control system for bridge using rotating inertia mass devices in order to reduce both the deformation of bearings and the damage to columns was proposed in this paper.
We decided the specifications of the vibration control devices and confirmed the response reduction effect for bridge structures using time history response analysis. We fabricated the inertia mass damper prototype and conducted both experimental and analytical study of the devices. It has been proved that the devices have sufficient performance in regards to the equivalent inertia mass and the damping ratio. The analytical results show very good agreement with the dynamic test results regardless of vibration frequency.
We have a plan to conduct the shaking table test that modelled the bridge superstructures, columns and bearings to investigate the response reduction effect for both the deformation of bearings and damage to columns.

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Efforts on institutionalization of school earthquake safety in Nepal: Experiences and achievements

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ABSTRACT

Making schools safer means developing and implementing the technical curriculum, financial curriculum, management curriculum and governance curriculum with participation of many stakeholders for ultimate achievement for making schools safer against seismic hazards in the high seismic prone countries like Nepal.

The concept of school earthquake safety was initiated by NSET in 1999. As a result of decade long efforts of NSET in piloting School Earthquake Safety Program (SESP), in 2010, Government of Nepal and the development partners including financial Institutions identified school DRR program as one of the five flagship programs of Nepal Risk Reduction Consortium (NRRC) which is led by the Ministry of Education/ Department of Education and coordinated by the Asian Development Bank. The school safety of flagship is focus on the seismic vulnerability reduction of schools and institutional capacity building of different stake holders of the department of education (DEO) such as engineers, technicians, masons and teachers on earthquake vulnerability reduction and preparedness.

Government of Nepal with the support from ADB through NSET developed and endorsed an action plan for retrofitting of 260 buildings along with developing capacity of stakeholders like engineers, masons, teachers and school management committee. ADB and Government of Australia provided financial support to the Government of Nepal to implement the Action Plan by July 2015. The Government has incorporated SESP in the National Plans and programs with adequate budget since 2012 and is being implemented in different 23 districts of Nepal.

This paper aims to discuss the experiences of the implementation of SESP through institutionalization, achievement, lessons, challenges faced and way forward. This paper also highlights on the contribution of SESP in demonstration of best practices for technology transfer and earthquake risk reduction in the country

Key words: Institutionalization, Earthquake risk, Earthquake safety, Vulnerability, Risk Reduction

Exploration of different retrofitting options for rc frame buildings in Kathmandu

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ABSTRACT

Various study reports on the seismic vulnerability of Nepal have revealed that more than 60% of the buildings in Kathmandu valley are unsafe and extremely vulnerable to the large impending earthquake (IX MMI intensity). National Society for Earthquake Technology-Nepal (NSET) has been involved in earthquake vulnerability assessment of hundreds of private and public buildings in Nepal for the past two decades which shows that most masonry buildings and more than 36% of RC frame buildings are non-compliant to construction standards with seismic consideration.
Recent Gorkha Earthquake 2015 has already shown the vulnerability of existing buildings in Kathmandu valley. Many buildings got severely damaged even at MMI VI intensity Earthquake or below. Since reconstruction of all unsafe buildings is not possible economically, retrofitting of these buildings could be better option to make them seismically safe. NSET has been doing retrofitting of many masonry and RC Frame type school, residential and commercial buildings. This paper mainly focus on retrofitting of RC Frame buildings. It presents different retrofitting techniques explored and implemented along with their feasibility for retrofitting of RC Frame buildings such as RC jacketing of frame; Steel profile jacketing of frame; Addition of reinforced masonry wing walls; Strengthening of infill masonry.

Keywords: Vulnerability assessment, retrofit, RC Frame Buildings, Kathmandu, jacketing

1. INTRODUCTION

Past seismic records of Nepal show that many destructive earthquakes have occurred throughout the country, claiming thousands of lives and property. In 1934AD, a strong earthquake shook the Kathmandu Valley, destroying 20 percent and damaging 40 percent of the buildings in the valley. Many earthquakes have since followed causing further damage to the buildings of Kathmandu Valley, warranting the fact that future destructive earthquakes are unavoidable. (KVERMP, 1998)
Through development and rapid urbanization, the seismic vulnerability of Kathmandu valley has increased a great deal over the past century. With an increase in population to

about 1 1/2 million, construction of new buildings and infrastructure has increased at an extremely fast rate. The majority of this new infrastructure especially that with buildings of poor construction, does not meet basic seismic requirements hence increasing the seismic vulnerability of Kathmandu. If an earthquake of similar intensity to that of 1934AD (IX MMI Intensity) were to occur in modern day Kathmandu Valley, the lost estimate study of the valley reveals that as many as 60 percent of all buildings in the Valley are likely to be damaged heavily, many beyond repair. (KVERMP, 1998)

National Society for Earthquake Technology-Nepal (NSET) has been involved in earthquake vulnerability assessment of hundreds of private and public buildings in Nepal for the past two decades. Assessment results show that most masonry buildings and more than 36% of RC frame buildings assessed were also found non-compliant. The problem lies with the configuration of the building as well as lack in strength and ductility.

Recent Gorkha Earthquake 2015 has already shown the vulnerability of existing buildings in Kathmandu valley. Many buildings got severely damaged even at MMI VI intensity Earthquake or below claiming thousands of life and huge property loss. Since reconstruction of all unsafe buildings is not possible economically, retrofitting of these buildings could be better option to make them seismically safe.

NSET has been doing retrofitting of many school buildings under different projects; and many residential buildings and commercial buildings upon request of clients. Though retrofitting of both masonry and RC Frame buildings have been done, this paper mainly focus on retrofitting of RC Frame buildings. This paper presents different retrofitting techniques explored and implemented for retrofitting of RC Frame buildings. RC jacketing of frame; Steel profile jacketing of frame; Addition of reinforced masonry wing walls; Strengthening of infill masonry walls are the most common methods of retrofitting used to retrofit of RC Frame buildings along with their feasibility.

2. SEISMIC RETROFIT

Seismic retrofit of a structure is the correction of the major weakness in the structure relating to seismic performance. It refers to a process of enhancing the structural capacities such as strength, stiffness, ductility, stability and integrity of a building to mitigate the effect of future earthquakes. The need of seismic retrofitting of building arises under two circumstances: (i) earthquake damaged buildings and (ii) earthquake vulnerable buildings that have not yet experienced severe earthquakes. Due to the lack of standards and guidelines for retrofit design, problems in designing and implementation of retrofitting works are faced by engineers.

Seismic behaviour of a structure can be enhanced by adopting different retrofitting strategies. The choice of the optimal retrofitting strategy depends on good understanding of the dynamic behavior of the building, cost of the chosen retrofit strategy and also on the future use of the building.

In structures where many of its members do not have adequate strength and ductility, an effective way to retrofit the structure would be to add new lateral load resisting elements. Additions of infill walls, shear walls and braces are examples of global retrofit strategies. Improving regularity and mass reduction can also be categorized under global retrofit strategy.

In structures where only few members lack adequate strength or ductility and the structure has got sufficient level of strength or ductility at the global level, local retrofit

strategy is adopted. Strengthening of individual beams, columns, joints and walls are examples of local level retrofit strategy.
Seven strategies have been identified to retrofit building. They are: Improving regularity, Strengthening, Increasing ductility, Softening, Damping, Mass reduction and Change in use.

3. RETROFIT DESIGN OF RC FRAME BUILDINGS

For purpose of strengthening RC Frame Building, at first the deficient frame members and joints are identified during the detailed evaluation of the building. Depending upon the deficiencies identified, retrofitting strategies either to increase strength, ductility or a proper combination of both is employed.

3.1 Strengthening Options

Various options are available for retrofitting of the deficient RC building. RC Jacketing of Columns and Beams, Steel Profile Jacketing of beams and columns, Addition of Infill wall, Addition of Shear Wall, Addition of Wing walls, Strengthening of infill masonry walls, Addition of Steel Braces, Retrofitting of Shear Walls, Addition of Frames, Fiber Reinforced Polymer Wrapping, Reduction of Irregularities, Reduction of mass, Energy dissipation devices and base isolation techniques Addition of Buckling restraint braces are the most common methods.
NSET has retrofitted a large number of school buildings, some residential buildings and few commercial buildings. Even though many retrofitting techniques are available, only few of them are feasible for retrofitting of residential buildings considering technical difficulties and socio-economic condition and of Nepal.
Among the different retrofit options, mostly used four retrofit options are presented here: RC Jacketing of Columns and Beams, Steel Profile Jacketing of beams and columns, Addition of Wing walls and Strengthening of infill masonry walls.

3.2.1 RC Jacketing of Columns and Beams

RC Jacketing involves placement of new reinforcement and concrete overlay around the existing beam and column member. It increases the flexural strength, shear strength as well as ductility of the column. Size of columns, size of beams, quantity of longitudinal reinforcement, transverse reinforcement can be increased in deficient columns and beams as per design requirement.
After RC jacketing of beams and columns, their size increase, minimum 100mm from all faces. This retrofitting technique is suitable only for medium rise school buildings and commercial buildings. It is not feasible for low rise residential building where there is space limitation. Such size increased columns and beams also reduces the aesthetic value of the residential buildings. NSET has retrofitted few School buildings using this technique.

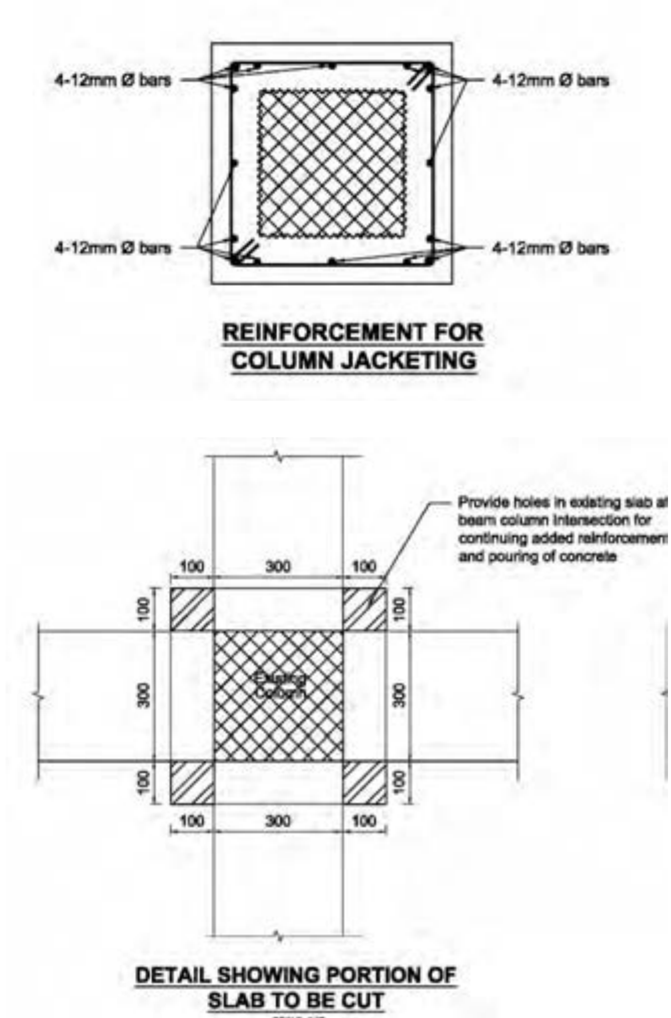

Figure 1: Different typical sectional details of RC column jacketing

Photo 1: RC Column jacketing

3.2.2 Steel Profile Jacketing of beams and column

Steel profile jacketing of beams and columns is the process of encasing these members with steel plates. It is basically used for remedy of inadequate shear strength and also to provide passive confinement to frame members. As the steel plates cannot be made continuous through the floor slab and frame members, it cannot be used for enhancement of flexural strength of the columns in which the beams are of same size of columns or beams are flushed with columns. Steel jacketing can also be used to strengthen the region of faulty splicing of longitudinal bars.
Considering the space limitation in residential building, this method is more feasible than RC column jacketing as there is no much increase in column and beam sizes and their stiffness. NSET has used this technique to retrofit residential buildings.

Photo 2: Steel profile jacketing to increase flexural strength in column

3.3.3 Addition of Wing Wall

The lateral strength of existing columns can also be increased by adding walls segments on each side of the column and reinforcing them or reinforcing the existing walls surrounding the column. These walls are called wing walls. Wing walls generally have thickness considerably less than the width of adjacent column. While designing wing walls, adequate connection to existing structure needs to be ensured. Wing walls should be anchored to all beams and at foundation level also. The wing wall will shorten the clear span of the beam creating large reversal moment in the beam at the face of the wing wall. If the beam is not detailed for the reversible moment at that location, strengthening of the beam or make other provision is required to ensure that beam does not fail.
In RC and Steel profile jacketing of columns, walls surrounding the columns needs to be demolished to carry out the retrofitting work. But this method includes less interventions compared to RC and Steel profile jacketing of columns since walls need not to be demolished to carry out retrofitting work.

Photo 3: Strengthening of wing wall in RC Frame Building

3.3.4 Strengthening of infill masonry walls

In RC building, specially non-engineered residential buildings built 10-15 years ago, columns are very lean and non-ductile. Longitudinal reinforcements provided are highly insufficient and stirrups are provided are large spacing about 600mm- 800mm c/c. In such condition, the contribution of RC Frame is very less. But 230mm infill masonry are provided around most of the columns. Such buildings can be retrofitted using the contribution of infill masonry. The existing RC columns and beams will act as masonry wall confining elements. Reinforcing the unreinforced masonry walls through Splint and Bandage method or Full Jacketing method as per requirement are the better options for such types of buildings. Another advantage of this retrofitting technique is that it not only strengthen the RC Frame, but also ties all the masonry walls to RC frame, hence preventing it's out of plane failure as well.

Splint & Bandage: In this method, steel reinforcing bars are provided at critical locations of the wall. The reinforcing bars along with 40 mm thick micro-concrete overlay are provided in the form of vertical and horizontal elements. Vertical elements are known as splints and horizontal elements are known as bandage. Splints are provided at wall corners, wall junctions and adjacent to openings of the wall. Splints resists in plane forces. Bandages are run all around the walls a plinth, sill, lintel, floor and roof levels of the building. Bandages integrate various walls together and prevent out-of-plane collapse of walls. Splint & bandages are provided on both faces of the wall. Splint and Bandages at inner and outer walls are tied together at places by steel wires (G.I. wires) at 450mm interval and anchor bars at 450mm alternatively

Jacketing of walls: Steel reinforcement mesh of vertical and horizontal bars are applied on both faces of the wall surface. The mesh is tied at places by steel wires (G.I. wires) at 450mm interval and anchor bars at 450mm alternatively. 40 mm thick layer of micro-concrete overlay is applied on to the wall. The jacketing is designed to resist both in-plane and out-of-plane forces. Jacketing helps to basket the walls and thereby increasing integrity and ductility.

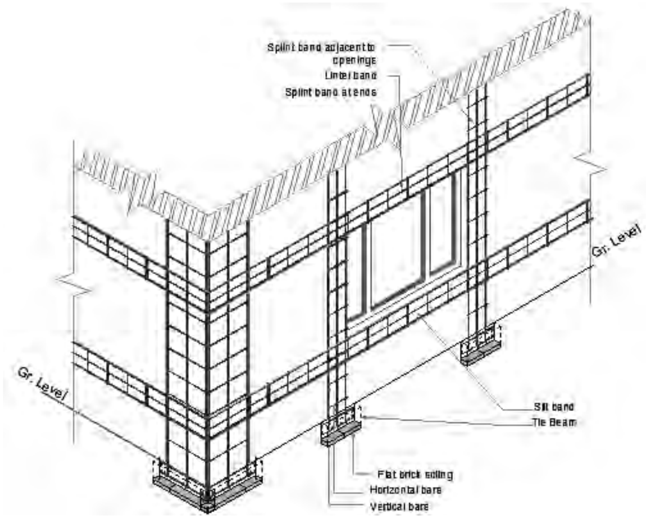

Figure 2: Splint and Bandage technique

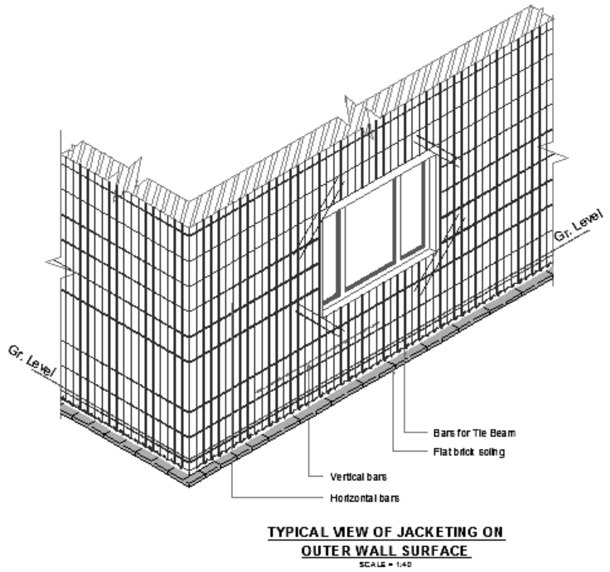

Figure 3: Jacketing on both faces

Photo 4: Strengthening of infill masonry wall through Splint and Bandage method

4. CONCLUSION

For retrofit of RC Frame buildings, RC Jacketing of Columns and Beams, Steel Profile Jacketing of beams and columns, Addition of Wing walls and Strengthening of infill masonry walls have been found to be most feasible options technically and economically.

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A pragmatic Proposal for Award of Credit to Qualify as a Green building for effective Building code implementa tion in Nepal

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ABSTRACT

Of late construction industry is undergoing a lot of change and eco-friendly materials are slowly replacing the conventional construction materials in an attempt to protecting the environment and human health and recent earthquake in Nepal also have indicated the need of updating in the building code. The trend of man overuse and abuse of natural components and unaware about the forthcoming catastrophic calamities and our deeds and construction techniques in accordance with the environment and consideration of calamities and acting accordingly is also widely understood as Green Building concept. However due to lack of awareness and misconception about the green building, the use green building technology has remained mainly within the domain of developed countries and has not been very widely received in the developing world. It is imperative that the concept is spread in developing countries too because in these the rate of development is currently going on at a fast rate. To make this happen Governments in developing countries should take the lead in educating the masses, and should make basic grounds rules so people can start embracing the technology. It is important that government defines rules and protocols for certification/registration of buildings at a basic level which we term as a building code but the recent earthquake and the effectiveness of the building code also have seen the necessities for the upgrading and regular monitoring for future flexibility. Some of these basic levels could be as simple as Sustainable site development, Water saving, Energy efficiency, use of locally available material, Indoor Environmental quality and eco-friendly designs, etc. This paper forwards the concept of green buildings and basic categories which can be promoted by governments of developing countries like Nepal to start the Green building concept in a bid to save the environment and future earthquake's effect in the building. This paper also forward the basic steps and protocol that can be followed to take up the concept not only within a rich people but also within a domain of poor people

Keywords: *Nepal's Earthquake, Green Building, Building code, Energy efficiency, Environment protection*

Strengthening Risk-Governance & Accountability

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ABSTRACT

Cities are the engines of national growth. However, they are overwhelmed by rapid population increases and unplanned development. Rising impacts of climate change and increase in frequency of disasters make our cities more vulnerable. Significant progress has been made in mobilizing communities for Disaster Risk Management (DRM), with visible signs of improved preparedness. Still, this has often occurred on fragmented and short-term basis and the underlying vulnerabilities persist.

Presently, a chasm prevails between local initiatives and national policy. The reasons for limited progress are manifold, significantly being weak or unclear institutional mandates, limited capacity and resources for DRM at the intermediary scales. Non binding and lack of enforcement mechanisms calls for stronger accountability processes and advocacy strategies to ensure governments to act to fulfill their commitments. Hence, further increased attention to partnerships and longevity of efforts are required.

The research attempts to explain how to enhance risk - governance and accountability in urban areas for building resilient communities. The research looks at progress made so far in maintaining accountability process i.e. at upwards and downward level emphasizing on the involvement of community. Further, the paper explores ways to enhance and strengthen risk- governance and accountability to reduce impacts of disasters in urban areas of Asia

Keywords: Risk-Governance, accountability, urban planning, participation, transparency, disaster management, mitigation, disaster safety

1. INTRODUCTION

Asia is going through an unprecedented wave of urbanization. Secondary and tertiary cities are seeing the most rapid changes in land-use and ownership, social structures, and values as peri-urban and agricultural land become part of metropolitan cityscapes. The key factors that enhance disaster risks are fast population growth, urbanization, expansion of economic activities in hazard prone areas and environmental degradation. All the while, climate change and its variability - is an emerging risk in the region and making many of these fast growing cities more vulnerable to disasters.

Urban areas need separate consideration because their very character – the concentration of population, homes and other buildings, transport infrastructure and industry – presents both problems and opportunities for disaster risk reduction (DRR) and humanitarian assistance. In low-income and most middle-income nations, there is also more ‘government’ in urban than in rural areas, as urban populations and enterprises are subject to more rules and regulations, and state institutions are more likely to be present. Such government activities should reduce disaster risk but in reality, they may often exacerbate it. Thus, the rapid pace of development across South Asia requires greater commitments and efforts to increase resilience to disasters and climate change[1].

2. WHAT IS RISK-GOVERNANCE & ACCOUNTABILITY?

There is a growing cry among the development policymakers to build urban “resilience”. HFA implementation since 2005 has advanced Disaster Risk Management (DRM) understanding that disasters are intrinsically linked to development choices, which either can increase or decrease people or communities’ vulnerability to hazards. Significant progress has been made in mobilizing urban communities for DRM, with improved preparedness, building an extensive knowledge base about what contributes to risk reduction in different settings. However, this has occurred on fragmented and short-term basis and the underlying vulnerabilities persist. Governance is the umbrella under which DRR takes place. Hence, mainstreaming of DRM is a governance process enabling the systematic integration of DRM concerns into all relevant development spheres.

Risk Governance is the way in which national and sub national actors are coordinating their actions to manage and reduce disaster and climate related risks. These actors involve public authorities, civil servants, media, private sector and civil society organizations.

There are good laws, regulations, and people in place, but they are too constrained by the fact that cannot effectively and fairly reconcile competing needs and interests. Many cities already struggle to maintain core systems and services like water, energy, and transportation. Preparation for natural disasters is difficult as single sector government departments are unable or unwilling to work with one another, making citywide solutions difficult.[2]The gap between initiatives and policies is further corroborated by weak or unclear institutional mandates, limited capacity and resources for DRM at the intermediary scales. Hence, further increased attention to multi-sectoral coordination, partnerships and longevity of efforts are required.

Progress so far…

National legal frameworks for improved accountability with strong enabling environments can be found in India, Indonesia and Philippines. Indonesia’s legislation makes official authorities directly responsible for disaster losses. In the Philippines, the DRR and Management Act of 2010 call for greater responsibility and resources to be provided for stakeholders’ involvement. New risk focused legislation is currently under discussion in Bhutan, Cambodia, Nepal and Viet Nam (IFRC, 2011). Throughout

[1] http://saarc-sdmc.nic.in/pdf/hfa-2%202014.pdf

[2] http://www.newsecuritybeat.org/2014/07/dont-forget-governance-risk-tunnel-vision-pursuing-resilience-asias-cities/

Indonesia, more than 337 local community and 33 provincial platforms have been established with the involvement of multiple stakeholders. Following the Wenchuan earthquake centered in Sichuan, China in 2008, an unique partnership model was devised for “twinning” affected counties and cities with those in other Chinese provinces specifically to assist affected areas with additional resources and personnel for monitoring the recovery process (Hoyer, 2009).[3] The summary report of the 2009 Global Assessment Report on DRR highlighted that governance arrangements for DRM in many countries do not facilitate the integration of risk considerations into development. Further the initiation of the mid-term review of the HFA at the Global Platform for DRR (hosted by the United Nations International Strategy for disaster Reduction (UNISDR) in June 2009 also identified areas of limited progress particularly in mainstreaming DRM into development and tackling underlying drivers of poverty and vulnerability. The reasons for limited progress are manifold, but significantly it was found that the HFA is voluntary and non-binding and therefore lacks an enforcement mechanism.

Need to shift from Response to integrated DRM…

To achieve cultural and practice shifts from disaster response and relief to integrated DRM in a changing climate, work needs to take place across various scales. Establishment of different forms participation can help citizens to fully engage with the process and claim their spaces for expressing their views and needs that relate to risk reduction. Enactment of implementation of relevant legislation provides institutional mechanisms, ensuring more responsive state for DRM delivery. Besides, building capacities of claimants through access to information, awareness of rights and standards relating to risk reduction and holding government institutions accountable for their actions. These three interrelated components will help in ensuring better transparency in development planning, and greater compliance and responsiveness amongst governments to obligations to ensure the safety and resilience of communities. Accountability is ‘answerability’ and ‘enforceability’ of actors in power. It occurs when an individual’s actions come under review, and when that person receives a higher or lower degree of sanction if their performance does not come up to standard. Transparency is considered a tool of accountability because its presence enables the public to be informed of the results of certain actions. This includes both procedures and finance.

Accountable, Participatory and Efficient governance structures create the environment where DRM can be institutionalized

A central criterion of good governance for effective DRM and sustainable disaster recovery should essentially ensure that the voices of the weakest and the poorest are heard in decisions about the allocation of resources affecting them. Besides, generating public awareness to recognize and address risk along with political will, policy backing and allocation of resources, is the key to efficient DRM governance. [4]

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[3] UNESCAP, UNISDR; Reducing Vulnerability and Exposure to Disasters ; The Asia Pacific Disaster Report 2012

[4] http://www.undp.org/content/dam/undp/library/crisis%20prevention/disaster/4Disaster%20Risk%20Reduction%20-%20Governance.pdf

The need for Community Involvement…

Development policies are made by the respective organs of the state which can cope with as well as create new risk geographies. Most of the disasters appear to be the collateral damage of growth-driven development approaches persuaded by successive governments.[5] Despite this, we found there is often implicit assumption by development policy makers that urban governance is representative and accountable. This is simply not true in many Asian cities and intervening in the name of resilience- particularly by providing finance and support for infrastructure development has the potential to do significant harm in many places.

Research demonstrates that community engagement is important because it can lead to better local ownership, uptake, and improved programme outcomes. Downward accountability by the government means including the community in the policy design and implementation process in some way: either by sharing information with them at various stages in the process or by working with the community to determine its priorities in order to shape programming[6].The affairs of local governments are normally run through ad hoc measures and local bureaucracy which normally consider themselves answerable or accountable to higher tiers of government, instead of citizens they are meant to serve.[7]Hence, there is a general deficit in local government accountability to the communities they serve. Participation is one of the cornerstones of our democracy and has equal benefits for politicians, officials and civil society. Mayor & Councillors can only claim to be accountable if they have regular interactions with the people they represent and if they consult and report back on key council decisions. Government cannot address all the development needs on its own and partnerships are needed with communities, civil society and business to improve service delivery and development.[8]

3. COMPONENTS OF ACCOUNTABILITY & RISK GOVERNANCE IN URBAN CONTEXT

Devolved Structures that enable participation: There is a need to build stronger linkages between national and local governments including the alignment of national policies with local needs. Efforts should be made for effective decentralization of responsibilities and resources to local government.[9] Establishing genuine forms of participation is fundamental for citizens for taking a proactive role in engaging and claiming spaces and developing meaningful forms of representation. This pertains to the setting of democratic space like local forums for citizen-led initiatives. Freedom of association allows collective action that increases the chances that participation can be

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[5] Bhatti 2012; Decentralized Disaster Risk Governance: Case studies of Indonesia and Pakistan ;Background paper , UNISDR

[6] Johnson C and Janoch E, Aug 2011:The Partnerships for Child Development; Engaging Communities, Evaluating Social Accountability in school Feeding Programmes

[7] Sindhu A. S., Risk Governance and Accountability; Lessons from South Asia and Recommendations for New Global Framework for Disaster Risk Reduction HFA2,A background paper(Draft) by Duryog Nivaran

[8] http://www.etu.org.za/toolbox/docs/localgov/account.html

[9] UNISDR: Synthesis Report: Consultations on a Post 2015 Framework on Disaster Risk Reduction (HFA2) April 2013

citizen-led.[10] Further, there is a need to integrate mechanisms training sessions on DRM as part of official training programmes for senior and middle level officials of national and provincial governments and agencies.[11] Learning networks need to be nurtured for city authorities, urban professionals and citizen groups

Access to Information: Clearer and more consistent dissemination of Disaster Risk information, including national policy decisions that impact local level decision making is crucial. In many countries legislations mandates access to information by the community for example, The Right to Information Act in India grants powers to citizens to learn about decisions taken by government departments about development activities. The Lebanon Citizens' Charter has proven to be a useful instrument to pursue accountability issues related to the delivery of public services at local levels. There is growing interest in some quarters to consider drafting a citizens' charter for DRM in the expectation that it could become effective in forging more beneficial partnerships between governments and civil society in local communities.[12]

Public participation & Communication strategy: Maximizing (and expanding) opportunities for participation in DRM and capacity building of the citizens to hold government institutions accountable for their actions is necessary. Public awareness campaigns specific to citizen needs and are locally owned or managed should be launched. Local media can play a significant role, publicizing various strategies and how they would be implemented at the local level. Awareness could also be generated as to how the local communities can question and hold the service providers accountable for their actions.

Inclusion of Vulnerable groups in Decision making:
Deeply rooted and deeply problematic urban governance issues mean that even mechanisms designed to reach the most marginalized are often easily subverted, allowing elite capture of resources, legitimized by rubber stamped regulation and decision- making processes. Studies carried out reveal that there is differential impact of disasters on women and men. Therefore, it is necessary to take specific measures to facilitate the inclusion of women and girls in local level decision making.

Listening to people's voices: A number of countries have called to enhance monitoring systems for an HFA2. Monitoring at local level was also raised. Social accountability can be defined as an approach towards building accountability that relies on civic engagement, i.e., in which it is ordinary citizens and/or civil society organizations who participate directly or indirectly in extracting accountability. Mechanisms of social accountability can be initiated and supported by the state, citizens or both, but very often they are demand-driven and operate from the bottom-up.

High level of volunteerism for DRM: The training of communities and volunteers would significantly strengthen the country's capacity to prepare for relief and recovery efforts. By carrying out community and volunteer training programmes, we are

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[10] Polack E., Luna E.M., Bercilla J.D. 2010; Accountability for Disaster Risk Reduction; Lessons from the Philippines, CDG working paper

[11] http://www.undp.org/content/dam/undp/library/crisis%20prevention/disaster/4Disaster%20Risk%20Reduction%20-%20Governance.pdf

[12] UNESCAP, UNISDR; Reducing Vulnerability and Exposure to Disasters; the Asia Pacific Disaster Report 2012

EDUCATING, ENGAGING AND EMPOWERING individuals and communities to maximize their response to future disasters and to increase their knowledge and awareness of DRR (Japan CSO coalition for 2015 WCDRR – contribution towards AMCDRR for key area 3, December 2013)

Strengthening Regulatory Framework: Effective regulatory frameworks are needed to enforce laws, and can provide key instruments for DRM implementation in public spending such as disaster risk assessment protocols, building codes, municipal regulations, zoning, land use regulation, emergency procurement policies, and minimum standards and checklists for development and humanitarian relief. To implement national disaster risk reduction legislation, a government agency must be accountable for providing regulations on how legislation will be implemented. These will set minimum requirements for the public and the authorities to meet, specifying penalties for lack of enforcement

Capacity and skill sets: the pervasiveness of urban governments lacking authority, funding, knowledge and capacities limit the success of urban governance as long as national organisations/government do not participate. Thus, while an urban governance network may be appealing and seem more "manageable," it cannot reach its potential and reduce risk if stakeholders do not have decision-making powers and adequate funding.

4. TOOL FOR INCREASING RISK GOVERNANCE & ACCOUNTABILITY

Citizens Forum

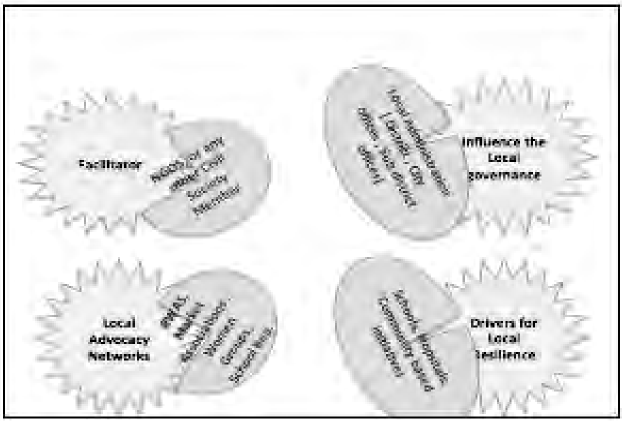

Fig 1: Figure Depicting the Mechanism of the Forum

The concept of "Citizens 'Forum" is evolved to ensure that heterogeneous communities are represented by their local leaders, who ensure that the gap between policy and practice is reduced, by making the local government more accountable and ensuring that the resources are leveraged at its best to reduce the day to day stress of these communities. The primary group of the forum is the citizens group represented by the resident welfare societies, ward members, market associations, school representatives, hospital representatives and others who are the local advocacy networks, who would act as major influence to the local government such as local administrators such as City offices or offices at the district offices. The facilitators to the local advocacy networks are the Local Ngos and the Civil Society members. Their role is to sensitize the participants of the local advocacy network to ensure that DRR is embedded in the development schemes, thereby helping them to reduce the day-to-day stresses. The facilitators also at the same time crystalize and analyze the factors creating vulnerabilities for the communities and thereby present them in the manner, which the local advocacy network groups understand and provoke them to present with substantial evidence to the local government. The initiatives such as school safety, community based disaster risk reduction and climate change adaptation, taken jointly by the local government and the citizens and facilitated by the ngos becomes the drivers for the local resilience. The local advocacy networks can further be devolved to creating the network of volunteers to generate awareness amongst the neighborhoods and set in the planning and implementing processes of the disaster risk preparedness.

Citizens' Forums are in particular effective in urban environment, where the communities are located in the defined administrative units of wards and represented by groups of residents, associations such as markets, unions, elected ward members or small local based civil society or Ngos. Moreover, these citizens utilize the same resources such as schools and hospitals and other essential services. The collective platform such as "Citizens' Forum" acts as an informed group to take collective actions to ensure effective implementation of the development schemes, such that it integrates risk reduction features and also ensure continuously maintaining accountability of the local governance. The issues such as solid waste management, open drainages, lack of disaster preparedness in the public places, lack of implementation of the building codes, lack of proper sanitation and drinking water facilities and many such vital issues can be advocated by these citizens' forums to the local government and thereby force these local government bodies to take necessary steps and actions to provide adequate services.

Purvi Delhi Apada Prehri [PDAP], East Delhi District:

Purvi Delhi Apda Prehri, which primarily means East Delhi Disaster Vigilantes, are the group of active citizenry of East Delhi District. East Delhi is prone to frequent floods, fire and earthquake. East Delhi District is faced with number of problems such as slum developments in the low lying area, un engineered construction of buildings,narrow lanes, road encroachments, lack of solid waste management unplanned development, water storage and contamination, lack of proper sanitation facilities in the slum areas and other problems related to rapid urbanization. The District forum is the platform, which has created network of the volunteers in the district to sensitize and generate awareness on risk reduction through road shows, rallies and community fairs. Moreover, the district has trainers these volunteers on First Aid, Fire Safety and Search & Rescue and have made them part of civil defense team. District government works closely with this forum to address the issues of risks and try to take proactive action on reducing risks. The Forum jointly with the District government takes up joint activities to sensitize and bring awareness amongst the local citizens on Disaster Risk Reduction. The forum also has initiated with pilot projects to set an example for solid waste management. PDAP is recognized by the local government as a citizens' group and are

5. CHALLENGES

In the urban areas complex layers of governance exists involving multiple agencies. As a result of which the efficiency and accountability is reduced considerably amongst these institutions. The planning, delivery and maintenance are with different departments and therefore there is no way that the efficiency and the quality of services can be measured. There is rapid growth in the urban periphery. It is important to create a dialogue between the local government and the community, to ensure that both of them are equally accountable and the resources are utilized effectively to minimize the risks. There is no disaster management department within the city government. For effective city disaster management plan, it is imperative, that the government involves community in developing plan and taking actions towards reducing risks. Hence, the grass root level disaster management platform formation acts as an effective body to ensure disaster safety.

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Process-based disaster management system "BOSS"

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ABSTRACT

This research defined the standard response process for the local governments and developed IT disaster management system based on the standard disaster response process. Developed IT system in this research was named BOSS (BOSai System, Bosai means the disaster management in Japanese). BOSS can show the total disaster process with database of historical disaster knowledge. About 500 processes are defined by the interview for staffs in Yabuki town in Fukushima prefecture and Ishinomaki city in Miyagi prefecture where was heavily damaged by the 2011 Tohoku disaster. And the database of people, houses, industry, law, land etc. are defined the relationship to the disaster responses. In post disaster phase, BOSS can be used the simulation of disaster responses to show the critical path and bottle neck response according to different cases of input conditions. Then stakeholders can understand all disaster processes with priority, difficulty or level for the effective human resources management.
For the verification of this system, the staffs of Ishinomaki city have used this system. The results show that the analyzed responses can clearly explain the role of each stakeholder in the emergency and recovery phase.
Over the whole Japan, as most local governments are small population (53% of local governments have less than 30,000 population), this small local governments don't have enough budget and knowledge to develop and manage their original IT system. Therefore, BOSS has huge potential to apply small local governments with the past knowledge in Japan.

Keywords: disaster process, knowledge, database, IT system

1. INTRODUCTION

Japan has suffered from many different kinds of natural disasters. And now the country has entered a seismically active period, damage mitigation is addressed as the major national issue. The 2011 Great East Japan Earthquake disaster has taught us the value of safety and sustaining the quality of life.
As one of the solutions to minimize damage, we suggest a total disaster response cycle featuring measures on the following: pre-disaster damage prevention, damage reduction, disaster prediction, alert system, damage assessment, emergency response according to damage assessment, and smooth recovery/reconstruction. Current efforts by regions and

organizations should be reviewed in terms of hard/software and disaster response, while different kinds of hazard and its levels (in terms of intensity, extension and frequency) should also be taken into consideration. Weak points in a region are analyzed after a regional survey. Extracted problems are improved under the limitations of time and budget. This process is the most effective and efficient way to solve the problems what they need to be in the future".

Our research aims to develop a process based “sustainable disaster/ emergency management system” to accomplish the above-mentioned process. By following this system, problems will be solved accurately, improvements made at ordinary times, alert will be heightened before urgent situation, damage precisely assessed after disaster, and damage response conducted appropriately according to the assessments. It realizes “seamless transfer from ordinary times to emergency situations”.
The biggest challenge lying ahead is to develop a "model which accurately estimates spatio-temporal disaster transition". Because no such model exists in Japan, many disaster management stakeholders have no idea what they should actually do or how their activities contribute to disaster reduction. When they all become aware of the meaning of their roles, effective disaster management cycle would be put into practice. The key factor in developing the spatio-temporal disaster transition model is to make accurate estimation ahead of time even from limited information, and then making the best response. Needless to say, no matter how well we grasp the spatio-temporal transition, it is essential that each stakeholder has the correct understanding of his/her assignment, or else appropriate disaster response will never be possible.
Effective initial responses in crisis management are important to reduce or minimize the impact of large-scale disasters such as the 2011 Great East Japan Earthquake for the prevention of secondary disasters and rescue.
However, it is difficult to operate initial disaster responses effectively for the disaster response headquarters just after the disasters under the condition of the limitation of human and product resources. In order to solve these problems, there are the current researches such as standardization and system of disaster responses[1,2)].

This research defined the standard response process for the local governments and developed IT disaster management system based on the standard disaster response process. Developed IT system in this research was named BOSS (BOSai System, Bosai means the disaster management in Japanese, Business Operation Support System). BOSS can show the total disaster process with database of historical disaster knowledge. About 500 processes are defined by the interview for staffs in Yabuki town of Fukushima prefecture and in Ishinomaki city of Miyagi prefecture where was heavily damaged by the 2011 Tohoku disaster. And the database of people, houses, industry, law, land etc. are defined the relationship to the disaster responses. In post disaster phase, BOSS can be used the simulation of disaster responses to show the critical path and bottle neck response according to different cases of input conditions. Then stakeholders can understand all disaster processes with priority, difficulty or level for the effective human resources management.

2. Analysis of Initial response during the 2011 Great East Japan Earthquake disaster

To develop the BOSS, the balance of workload during initial responses needs to be analyzed. This paper provides the case study that the initial responses of Yabuki town in Fukushima prefecture are analyzed during the 5days after the Tohoku earthquake to achieve the effective disaster system. The analysis data in this paper is obtained from the staffs who worked for the disaster response immediately after the earthquake from 11th to 15th March 2011 for 5 days in Yabuki town of Fukushima prefecture.
The analysis data is obtained from staffs which are divided into six time sections for one day as the early morning, morning, daytime, afternoon, evening, night.
The around half numbers of staffs answered to that with the exception of the staffs who could not engage in disaster responses at the time and who have already left or retired after the earthquake. If the staffs transferred to the new department from the department at the disaster, we collected the data as that staffs belongs to previous department.
Table 1 shows the change of the time history of disaster emergency responses. The number inside of this table is the total number of working staffs during the time division. The vertical line is ordered from the higher total numbers of working staffs for a response category item.
According to this result, "food supply", "water supply", "damage investigation" and "evacuation management" are frequent in the order during the five days. 33 staffs worked for the damage investigation on March 11. Many staffs worked for the food supply from March 11.
The number of staffs gradually increased for the water supply and the most of the staffs worked for that on March 14. Because the water in the water tank on the roof of the government building was used up immediately after the disaster, it was necessary to supply water to the people. The water supply was carried out by the truck with water tank at the entrance of the government building.
For evacuation centers, in addition to the distribution of goods, the staffs walked around the all evacuation places to check the number of evacuee.
Due to the damage of JR (Japan railways), some passengers could not move on March 12. Yabuki town received the people who could not go home, and Yabuki town transferred the people to the Shinshirakwa station by the bus of town on the next day of the earthquake
We analyzed the disaster responses for the each department of the town. Table 2 shows that all numbers of working staffs for the each department during 5 days totally. The number in the table describes the working load in each department that the total working people times the total working hours (people × working hours) assumed as three hours for each time sections.

For the project management division, "food supply (138 [people × time])" is the highest, "water supply (90 [human × time])" followed by it. As the management of "Conference" is the one of the role of the disaster response headquarters, this was controlled by the project management division. The "meeting" by the school education division means that they discussed about how to response to the students and restart the classes.
The project management division takes a role of the wide-area supports from the municipalities located in outside of damaged area (9 [human × time]) as well. Yabuki town were received the supports from Mitaka city, Towada city, Kawaminami city and the others.

Table 1: Time history of disaster response (unit: number of people)

Response items	2013/3/11				2013/3/12						2013/3/13						2013/3/14						2013/3/15						Sum
	Immediately	Evening	Night	Midnight	Early morning	morning	Daytime	afternoon	Evening	Night	Early morning	morning	Daytime	afternoon	Evening	Night	Early morning	morning	Daytime	afternoon	Evening	Night	Early morning	morning	Daytime	afternoon	Evening	Night	
Food supply		6	8	8	13	6	9	8	9	9	12	1	14	1	12	8	13	1	16	12	14	11	7	11	13	13	13	9	284
Water supply		1	1		3	6	3	7	12	3	6	12	9	16	11	7	9	2	17	18	16	14	8	16	14	14	11	7	261
Damage investigation	33	13	8	6	4	16	17	11	7	5	2	6	6	3	4	5	2	4	9	9	5	7	5	8	4	7	5	3	214
Evacuation	1	7	11	5	4	6	3	5	4	8	4	11	9	9	4	2	5	7	4	5	5	5	5	6	5	6	6	9	161
Information collecting	4	1	8	7	5	2	4	5	3	4	4	2	1	2	2	3	5	4	3	2	2	4	4	2	5	4	4	4	109
Goods supply		2	2		2	2	4	3	2			2	3	3	1		1	3	4	4	3	3	2	3	5	6	5	1	66
Emergency safety check of house		1	1		2	3	3	3	3	1	2	3	3	3	3	2		2	2	2	2	2	2	3	3	3	3	1	58
Meeting		1	1	2	3	2			5	1	4	2	2	1	8	1	3	1		1	7	1	2	4	1	1	2	1	57
Staying at home			6	1	5	4	3	2	4	4	2	4	4	4	5	4	1						1	1				2	57
Restoration		2			1	1	3	3	2	1	2	2	2	3	2	1	1	2	1	2	2	2	1	4	4	4	4	3	55
Others	5	2	3	2	3	3	2	1	2	4	4	1	1	2	1	2	4	1		1			2	1		1		2	50
Safety check	1	2	2		6	5	7	6	3	1	3	2	3	1	1		1		1				1		1				47
Office counter work	2										1	2	1	1			1	3	2	3	3	3	2	3	3	3	2		35
Traffic control	2	5	4	1	1	1	1	1	1	1	1	1	1	1	1		2	1	1	1	1		1	1	1	1	1		34
Disaster wireless system	1	1	1		2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	28
Clearing up		1			1	2	2	4	3			4	2	2				1		1	1	1		1					26
A child's delivery	6	8	2																										16
Fire-fighting round		1	1		1	1	1	1	1	1	1	1	1	1	1	1													14
Disaster waste							1	1	1	1	1	1	1				1	1	1				1	1	1				13
Suffering certificate														1	1	1				1	1	1				1	1	1	9
Temporary house						1	1							1			1		1	1	1								7
Liaison and adjustment			1	1		2																			1	1	1		7
Acceptance wide-area support																				2	2	1		1					6
Evacuation guidance	4	1	1																										6
Parliamentary correspondence	1	1				1												2											5
Support disabled persons	1				1						1							1					1						5
Volunteer					1															1	1	1							4
Supply of food for school children								1	1						1			1											4
Information arrangement						1	1	1	1																				4
Installation of a temporary lavatory														1						1						1			3
Check a school road							1	1				1																	3
Victim unable to return home					1	1																							2
Defense				1																					1				2

Table 2: disaster response and division (unit: people times hours)

Division	Food supply	Water supply	Damage investigation	Evacuation	Information collecting	Goods supply	Emergency safety check of house	Meeting	Restoration	Safety check	Office counter work	Traffic control	Disaster wireless system	A child's delivery	Fire-fighting round	Disaster waste	Suffering certificate	Temporary house	Liaison and adjustment	Acceptance wide-area support	Evacuation guidance	Parliamentary correspondence	Support disabled persons	Volunteer	Supply of food for school children	Information arrangement	Installation of a temporary lavatory	Check a school road	Victim unable to return home	Defense	Sum
Project management	138	90	15	27	9	15	0	33	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	12	0	0	0	3	351
General Affairs	3	96	30	42	6	90	0	0	93	0	0	6	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	6	0	375
Tax	75	186	24	99	9	33	0	0	3	0	0	3	0	0	42	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	477
Residential life	81	6	6	0	3	0	36	0	0	0	30	3	84	0	0	39	27	0	6	0	0	0	0	0	0	0	0	0	0	0	321
Health and Welfare	39	45	3	129	6	21	0	3	0	6	48	0	0	0	0	0	0	0	15	0	3	0	15	9	0	0	0	0	0	0	342
Industrial development	21	123	84	24	24	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	297
Urban construction	0	0	183	0	0	0	138	0	18	6	0	72	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	438
School education	99	36	222	90	150	0	0	120	18	15	0	0	0	15	0	0	0	0	0	0	0	3	0	0	12	0	0	9	0	0	789
Lifelong learning	42	111	66	36	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	291
Kindergarten	234	75	9	36	84	39	0	9	3	114	3	0	0	33	0	0	0	0	0	9	12	0	0	0	0	0	9	0	0	0	669
Parliamentary office work	0	15	0	0	0	0	0	6	30	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	63
Teller's cage	120	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144

The General Affairs Division mainly worked for "water supply", "goods supply", "Recovery". In addition, the operation of evacuation centers and the understanding of the number of the evacuees are managed. The Tax Division mainly worked for water supply, operation of evacuation centers and food supply. The evacuation guidance shows that the division induced the people who came to the governmental building just after the earthquake. The residential life division mainly worked for the community wireless system, food supply, building inspection survey, disposal of wastes, issuances of a victim's certificate. With regard to the community wireless system, three kinds of those systems those of Yabuki town, volunteer fire group and Fukushima prefecture were used.
On March 11, information was provided to the people in every one hour, and then on March 12 the frequency of information was provided in every two hours.
Immediately after the disaster, information about severed road was send to the government from a volunteer fire group, and then the staff in the room of the community wireless system sends its information to the urban construction division. The room of the community wireless system played the role of the information hub in the town. The Health and Welfare Division worked for care of evacuees and provide food in evacuation centers. The Industrial Promotion Division conducted a damage survey and water supply mainly. For damage investigation, they checked the function of agricultural related facilities. The Urban construction division conducted a damaged survey of infrastructures, recovery of infrastructures. The School Education Division conducted a damage survey of school facilities, food supply, and operation of evacuation center.

3. Overview of Process-based disaster management system “BOSS”

To analyze what kinds of disaster responses are experienced or not experienced is important for effective disaster responses. It is necessary to build the regional disaster prevention plans according to the experiences.
The standard response process for the local governments is defined following to the interview for staffs in Yabuki town of Fukushima prefecture and in Ishinomaki city of Miyagi prefecture.
We found that many officials worked for the responses (food supply, water supply, and etc.) most of those are available not only government people.
Then, we can apply the responses in accordance with the characteristics.
In this paper, the disaster responses are divided into four types.
(1) the responses by everyone can work immediately after disaster such as such as management of the Volunteer Center etc., (2) the responses by government staff at first stage of disaster but gradually shifting to the other people such as food supply, water supply etc. (3) the responses by every government staff such as residents support, issuance of certificate, etc., (4) the responses by government staff with a special skills such as restoration of infrastructure and lifelines, health issues etc.
It is important to make a category for each disaster response according to these kinds of types in a regional disaster prevention plan. Then we can understand what kinds of disaster responses are necessary by staffs with special skills or without those, and manage the limited resources effectively.

The database of people, houses, industry, law, land etc. are defined the relationship to the disaster responses. In post disaster phase, BOSS can be used the simulation of disaster responses to show the critical path and bottle neck response according to different cases of input conditions. BOSS can show (1) Evaluation of amount of work (work load), (2) Effective distribution of human resources with skill level and work load and (3) Management of response schedule. Figure 1 shows the web based BOSS system. After the hazard level is estimated, the damage level is calculated by the hazard level. Then, the work load, time schedule of staffs and the flow of responses are shown by BOSS. Then stakeholders can understand all disaster processes with priority, difficulty or level for the effective human resources management.

Table 3 explains the effects of BOSS in the points of quality, cost and duration/deliver. Quality can be achieved in (1) Prioritizing responses and (2) Difficulty of responses (required qualification and skill). Cost can be reduced by (1) Response that requires large human resource (2) Spending on Equipment purchases, support for residents to recover from disaster. Duration can be described with (1) Duration of response, (2) Retention time between processes and (3) Gap between supply and demand.

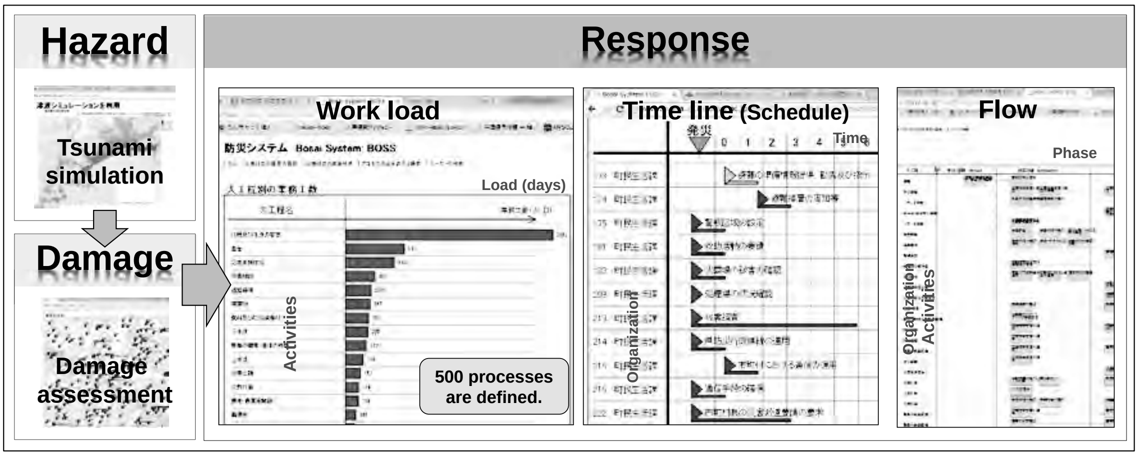

Figure 1: Web based BOSS system

Table 3: Effects of BOSS system

QCD	SUMMARY
Q quality	(1) Prioritizing responses (2) Difficulty of responses (required qualification and skill) Effective and necessary support for residents can be achieved by effective deployment of staff by this system. Considering support staff from other municipalities, prioritizing responses and level of difficulties, this system is used for efficient human resource allocation.
C cost	(1) Response that requires large human resource (2) Spending on Equipment purchases, support for residents to recover from disaster Activities like disaster risk assessments of buildings, post disaster damage evaluation etc. responses with large human resources. Securing financial resources through government expenditure (not for

	personal fee). Also, implementing mitigations for proper evaluation of these cost-effective measures.
D duration	(1) Duration of response (2) Retention time between processes (3) Gap between supply and demand The completion of responses in a shorter period of time depends on the improvement of time during the bottlenecked work schedule. Supply/demand variation is the difference in occurrence time of demand and the actual supply time to completely meet the demand. It is a situation where the changing need of goods are not met by the left over goods.

4. CONCLUSIONS

Our research aims to develop a “sustainable disaster/emergency management system” to accomplish the above-mentioned process. By following this system, problems will be sorted out accurately, improvements made at ordinary times, alert will be heightened before urgent danger, damage precisely assessed after disaster, and damage response conducted appropriately according to the assessments. It realizes “seamless transfer from ordinary times to emergency situations”.
This study analyze the patterning the kinds of disaster response, defining its flow and evaluating its amount of volume which are expected in advance to build effective the spatio-temporal disaster responses model. By understand these operations for each different actors, it will be possible to carry out disaster responses4immediately under the condition of confused disaster phase.
Over the whole Japan, as most local governments are small population (53% of local governments have less than 30,000 population), this small local governments don’t have enough budget and knowledge to develop and manage their original IT system. Therefore, BOSS has huge potential to apply small local governments with the past knowledge in Japan.

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Considerations Concerning "How Should the Central and Local Government Respond in Emergency Situations Such as Natural Disasters"

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Abstract

In Japan, at the times of natural disasters such as the Ise Bay Typhoon many years back in 1959 and the Great Hanshin Awaji Earthquake in 1995, the national emergency response system was not adequate that the government agencies failed to cooperate as one entity in establishing a disaster response system, initial response system, supervision structure for on-site disaster relief teams and the central government, cooperation system between rescue teams, information gathering and aggregation structure, and in accepting foreign rescue teams immediately after the occurrences of disasters.
Based on the lessons learned from the past disasters, Japan has improved the practices each time disaster strikes in order to enhance the emergency response system, including an initial response system, in which the government agencies cooperate as one entity, and an emergency response system has also been established in each central government agency and local authority. The accumulation of these efforts functioned to a great extent in the Great East Japan Earthquake.
It has been observed in the recent earthquake in Nepal that the government and local authorities had no adequate emergency response systems just as what Japan used to be, interfering disaster expansion prevention, rescue of disaster victims, and acceptance of foreign rescue teams.
This paper therefore presents the view on establishing a crisis management system in anticipation of possible emergency situations that may arise in Nepal by considering Japan's experiences to derive what are necessary and what are important in general when establishing an emergency response system, capable of responding to disasters appropriately, in the central government and local authorities in Nepal.

1. Introduction

In order to enhance government's crisis management system, it is required to analyze how the actual crisis situations in the past were responded to clarify problems and challenges, and to make efforts to overcome such challenges. In Japan, disaster response situations have been evaluated each time disaster struck. The causes of failures found in the evaluation are analyzed to reflect the result in the aspect of organizational structure of the central government and local authorities, to prepare necessary equipment and materials, and to facilitate legislation. In the meanwhile further evaluation on the effects of improvements of systems has been conducted in the actual occurrences of subsequent disasters.

As a result, the emergency response system of the central government and local authorities at the times of disasters has been enhanced over the years, allowing emergency response operations to be performed appropriately in order in the actual major disasters. These experiences of Japan clarify principles common to all regions and at any time with regard to the role of initial response operations that the central government and local authorities should conduct in the event of disasters.

For this reason, the principles derived from lessons learned through experiences may not only be applied in Japan, but also to central governments and local authorities of any country in the world. According to the present writer's experiences in responding to natural disasters and even other various crisis and emergency situations as the Deputy Chief Cabinet Secretary for Crisis Management within the Cabinet Secretariat, the principles may also be applied to various incidents, accidents, and life-threatening emergency situations other than natural disasters.

This paper describes, basing on Japan's experiences, disaster response systems that central governments and local authorities should adopt, the significance of setting up of facilities and provision of equipment and materials in anticipation of disasters, and considers the role of governments common to disaster response in any country.

1. Actions That the Government Should Take in Emergency Situations Such as Disasters

In general, actions that government should take in terms of crisis management when an emergency situation such as a disaster arises include rescue of disaster victims, prevention of damage expansion, and maintenance of governance. To achieve these objectives, it is required for government to function as one entity to respond to situations by providing human and material resources of the country, yet the following actions are required at all times regardless of type and scale of emergency situations.

- Establishment of a system where the government functions as one entity
- Assessment of situations by prompt information-gathering
- Prompt initial response operations
- Decision-making by the government
- Emergency response operations
- Accurate crisis communication

In order to undertake these operations promptly and accurately, and to carry out the government's responsibility to protect the lives, bodies and properties of the citizens, it is important for government to make its organizational structure prepared to respond to possible emergency situations such as disasters in advance.

Although not mentioned in this paper, it is needless to say that government should always engage in national land planning that is resistant to disasters including soil and water conservation, and construction of earthquake resistant buildings.

I. Organizational Structure of the Government in Emergency Situations

What is most important for government in responding to emergency situations is to function as one entity to perform meticulous operations without omissions or redundancy rather than central and local government administrative agencies respond to situations separately.

Additionally, in order for government to perform operations as one entity it is important that the information is concentrated to the highest official of the government, and orders and instructions are issued in an integrated manner to ensure a structure where no contradicting or duplicate orders are issued to the scenes of response operations.

Naturally, this structure is completely different from the structure to carry out usual routine work and members of an emergency headquarters of the government will be temporary. Also, a flat and simple organization is required for information sharing. When emergency situations occur, it is important that the highest official and all the staff who works under the highest official assemble to share information reported and orders issued there.

Needless to say, a structure and legislation that allow delegation of full authority to the highest official of the government are essential to clarify where responsibility lies and to allow prompt decision-making by the government. There should also be legislation that allows issuance of orders to local governments from central government in emergency.

In Japan, the Headquarters for Emergency Disaster Control based on Disaster Countermeasure Basic Act set in time of disaster serves as such structure. The members are comprised of prime minister, cabinet ministers and the Deputy Chief Cabinet Secretary for Crisis Management, and they assemble together with staff from ministries at the Prime Minister's Official Residence to make prompt decisions and implement prompt emergency measures.

Needless to say, a prior establishment of legislation that facilitates building of such structure and creation of a structure that actually functions are required.

II. Assessment of Situations by Prompt Information Gathering

It is not straightforward for government to assess what is actually happening immediately after the occurrence of emergency situations. This is especially true for situations where affected sites are in a state of confusion and reporting arrangements are not functioning properly. Government is therefore required to develop arrangements to gather information promptly at any time of the day or night and report to the highest official of the government in advance of emergency situations. Often these reporting arrangements do not function due to severity of emergency situations, and therefore, it is important to develop twofold or even threefold redundant reporting arrangements. Besides development of information lines, provision of communication equipment in anticipation of a power failure and damage to communication networks becomes important. In case of emergency, inadequate information delivered quickly is valued more than detail information delivered slowly. It is important to develop and train reporting arrangements that force to report even unconfirmed or inaccurate information.

In Japan, the Crisis Management Center has been set up at the underground floor of the Prime Minister's Official Residence from where all sorts of information are gathered 24 hours a day on a daily basis while connections of communication lines with ministries and agencies allow centralized information gathering through TV, wireless and wired networks, and data communication.

III. Prompt Initial Response Operation

What is crucial when an emergency situation is identified is a prompt initial response operation. In order to gain control over the situation, to calm down the situation and to rescue victims as quickly as possible before it becomes worse, it is necessary for government to have built a structure which can promptly assemble government personnel for responding to situations in advance.

Securing of communication means between personnel and readiness of personnel are important, and it is necessary for the government to promptly conduct initial response operation including first reporting from the personnel to the relevant parties including the highest official, calling of additional personnel, gathering of additional information, development of initial response system, and issuing of orders to emergency relief teams to be ready for mobilization. Moreover, an operation room equipped with equipment and materials required to conduct these activities is needed.

As a consequence, there is a need to set up facilities for performing operations concurrently with securing personnel for emergency response at the center of central government, and facilities that serve as accommodation, resting and waiting places where equipment and materials, and personnel can be gathered promptly. The similar structure is also needed in local governments.

In Japan, crisis management personnel is on duty 24 hours a day at the Crisis Management Center located at the Prime Minister's Official Residence, and accommodation equipped with communication equipment for crisis management personnel is prepared within the periphery of the official residence, allowing all the crisis management personnel to assemble at the Prime Minister's Official Residence where the Crisis Management Centre is located within half an hour. Similar standby and emergency assembly plans of crisis management personnel are adopted in the local governments.

IV. Decision-Making of the Government

In emergency situations, government has to perform decision-making on how to deal with the situation. In starting response activities including information gathering and establishment of initial response system, it is important for government to decide response guidelines that set objectives of situation response and to inform the guidelines to the public and organizations within the government. The response guidelines should be decided by the highest decision-making organization of the government such as the headquarters led by the highest official of the government. In this case, the government usually has the full responsibility over emergency response and parliaments normally do not involve.

It is desirable to specify the purpose of activities, immediate objective, measures, plan and order of priority in the emergency response guidelines. These serve as guidelines for relevant parties of the central government, local authorities and relevant agencies in charge of situation response while these serve as a message to the nation.

In Japan, various disaster drills including rehearsals of development of the government's response guidelines and press conference by the prime minister are carried out each year and several of drills are with the prime minister in presence.

V. Emergency Response Operation

In the event of emergency situations such as disasters, central government together with local police, fire authority, military, and agencies of medical and welfare, national land planning and food aid should immediately respond to the situations. However, there is a need for a central control to assign and coordinate tasks to each agency depending on the nature of situations and changing conditions.

In addition, the role of coordinating acceptance of and assigning tasks to foreign agencies and international support organizations, and coordinating tasks between domestic agencies is necessary.

In Japan, top officials of each central government agency assemble at the Crisis Management Center located at the Prime Minister's Official Residence to gather information, assign and coordinate tasks, and issue orders while disaster headquarters located at local prefectural offices perform the same information gathering and task assignment and coordination.

In the event of emergency situations, the occurrence is sudden and unpredictable, and the damage situation is serious. Therefore, decisions and handling of the situation should be performed in a short time while there are enormous tasks to handle.

Although the emergency response system becomes temporary and large-scale compared to the usual routine work, the main role and system are almost same in any emergency situations with only difference in a part of members depending on the nature of situations. It can be said that patterns of crisis management are similar in any types of crisis.

On the other hand, the party in charge of responding to emergency situations is the on-the-scene operational team. The team responds to the situation onsite based on task assignment by emergency headquarters and the central government. In this case, it is important to establish a coordination mechanism and a center onsite to prevent redundancy and omissions of onsite operations by government agencies.

VI. Accurate Crisis Communication

In the event of a national emergency situation, it is essential for government to explain the public what is currently happening, what the government is going to do and what the government requires the public of.

It is vital for government to explain accurately and straightforwardly what the government has been doing and will do, and for this to happen, government should communicate with the public frequently and in detail from ordinary times.

Particularly, it is important to inform all sorts of information gathered with regard to emergency situations, to disclose prospects on situations, to address actions expected of the public, and to provide information that may help the public remove the fear associated with the occurrence of emergency situation.

In Japan, information is provided to the public through press conferences by the Chief Cabinet Secretary and technical press conferences by the Japan Meteorological Agency in case of case of natural disasters.

What is important in this regard is to conduct crisis communication as quickly as possible to make efforts not to cause public’s anxiety and dissatisfaction due to lack of information.

In addition, addressing of actions expected of the public is essential for the sake of prevention of further damage.

2. Conclusion

In order for government to conduct right response in the event of emergency situations such as disasters, it is important for government to function as on entity to respond to the situation promptly. To enable this to happen, prompt and accurate information gathering and prompt onsite actions of agencies and relief parties, in other words, prompt initial response, are required. What becomes important here is to develop a mechanism to aggregate information under supervision of the government’s highest official, to issue orders based on decisions made, and for government agencies including local agencies to perform prompt and efficient emergency response operations.

For the realization of this plan, there is no way other than to make efforts in establishing systems including government’s emergency legislation, setting up facilities, providing equipment and materials, and to go over drills many times, hence increasing the consciousness and practical proficiency of government agencies including local agencies and emergency response personnel.

Furthermore, all these efforts begin by not disregarding but valuing the importance of regrets and lessons learned from hard experiences including disasters over the years.

Tokyo Metro earthquake countermeasures

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ABSTRACT

Tokyo Metro has 9 lines, with a total length of 195.1 kilometers. The total tunnel length is 166.5km, which is about 85% of all the lines. Each day, 6.84 million passengers use our lines. To keep the passengers feeling safe and secure, Tokyo Metro gives high priority to structure maintenance and disaster measures.
In Tokyo Metro, earthquake-proof measures were carried forward based on a notification by the former Ministry of Transport in 1995, and measures against the structures that are the target of reinforcement were completed. In addition, earthquake-proof measures are carried forward based on a major earthquake which will hit the Tokyo metropolitan area. In regard to judging the necessity for reinforcement, an examination of fracture morphology and damage level was performed.
This paper describes our earthquake countermeasure activity. Specific contents of the paper are the view of this judgment, seismic reinforcement which were already partly finished, seismic wave scenarios of an earthquake which has an epicenter directly below Tokyo and earthquake risk maps of our structures.

Keywords: subway, RC rigid-frame viaduct, earthquake countermeasure, earthquake risk map, seismic reinforcement

1. INTRODUCTION

Many railway structures were greatly damaged by the Great Hanshin Earthquake in January 1995, for example, reinforced concrete viaducts were damaged and a cut & cover tunnel in Daikai station collapsed due to shear failure of the center pillar. With this as a starting point, the former Ministry of Transport put out a notification for emergency seismic reinforcement methods to railway companies[1)]. It showed a policy to perform urgent seismic reinforcement regarding existing railway structures, as a step for that time until establishment of a new seismic designing method, hereinafter referred to as emergency seismic reinforcement. The notification showed that subject line sections of emergency seismic reinforcement are high priority line sections considering effects on human life, basic activities of residents living in the area, the regional economy and restoration due to a big earthquake. Subject structures of the emergency seismic reinforcement shown are shear failure precedence type-RC structures, namely RC rigid-frame viaducts, rigid-frame abutments and the center pillars of cut & cover tunnels, as well as devices to prevent bridges from falling.

Tokyo Metro Co., Ltd., (hereinafter, Tokyo Metro), proceeded with seismic reinforcement[2)] that were subject to the notification of the Ministry of RC pillars of rigid-frame viaducts (hereinafter, RC pillars), RC center pillars of cut & cover tunnels and instillation of devices to prevent bridges from falling[2)]. At present, the seismic reinforcements for all our structures that were the target of reinforcement were already completed. In addition, now, Tokyo Metro is advancing with further seismic reinforcement based on a major earthquake which will hit the Tokyo metropolitan area.

The subject structures of seismic diagnosis are RC pillars which were judged to not need seismic reinforcements in 1995[3)]. Seismic Diagnosis is basically carried out based on the current design standard of railway seismic design and considers early restoration after a large-scale earthquake and measurement of shear failure after flexural yielding.

Moreover, we have made risk maps which show the priority of places that need seismic reinforcement, because of policy formulation of future seismic reinforcement.

This paper describes our earthquake countermeasure activity, namely an outline of a further seismic reinforcement method for RC pillars and the seismic reinforcement work which is already finished, as well as risk maps.

2. OUTLINE OF SEISMIC DIAGNOSIS

2.1 Seismic Diagnosis Procedures

The procedures of seismic diagnoses regarding RC pillars, which were carried out in 1995 and recently, are described in this section. Figure 1 (a) shows a flowchart in 1995 and Figure 1 (b) shows it this time. The subject structures are RC pillars which were judged to not need seismic reinforcement in 1995. Thereafter, checking of the damage level for subject pillars was carried out by fracture morphology analysis and a non-linear spectrum method.

2.2 Fracture Morphology Analysis

Initially, fracture morphologies were judged by a simple judgment method with applying corresponding judgment results of seismic reinforcement necessity in 1995, because there were too many subject pillars to check in detail. The procedure of the simple judgment is shown below.

A) Select typical cross sections of RC pillars from 1200 RC pillars which were judged not to need seismic reinforcement in 1995. 21 cross sections were selected this time.
B) Calculate the shear capacity ratio in a current standard, Vyd/Vmu, of the selected RC pillars.

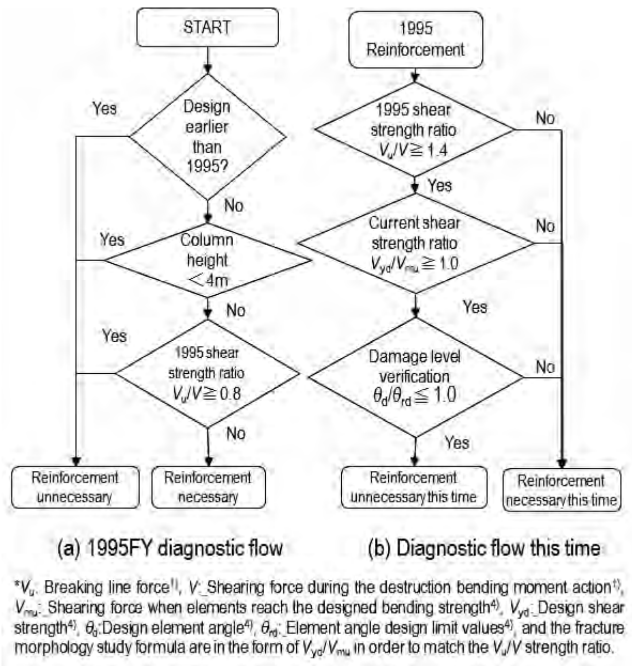

Figure 1: RC column seismic diagnosis flow

C) Compare the value of the Vyd/Vmu in B) and Vu/V that was already calculated, and lead a conditional expression of Vu/V which is satisfied with Vyd/Vmu$\geqq$1.0, the current standard.

D) Judge that the pillar needs reinforcement, when the pillar does not meet the conditional expression of Vu/V obtained in C). Calculate Vyd/Vmu, when the pillar satisfies the conditional expression in the next flow.

We could reduce the cost and required time to calculate Vyd/Vmu in the current seismic measure design standard of all RC pillars due to seismic diagnosis with the flow, shown in A) - D).

Figure 2 shows the results of the comparison with the shear capacity ratio Vu/V for the standard of emergency seismic reinforcement in 1995 and this in the current standard, Vyd/Vmu. The lateral axis shows a shear capacity ratio Vu/V and vertical axis shows Vyd/Vmu. Through the figure, it is clear that Vu/V becomes 1.4 when Vyd/Vmu is 1.0. Therefore, we set a threshold to 1.4. It is also judged that a pillar needs reinforcement when Vu/V is greater than 1.4. When Vu/V is less than or equal to 1.4, we judged this by the equation Vyd/Vmu $\geqq$1.0, shown in Figure 1(b).

Moreover, seismic performance was checked by the non-linear spectrum method, when a structure satisfied checks of these fracture morphologies.

3. SEISMIC DIAGNOSIS RESULTS

3.1 Fracture morphology analysis results

RC pillars, which were judged to not need reinforcement, consist of only 60 of the 1200 subject pillars, as a result of fracture morphology analysis. The cause is considered that the volume of tiehoops is insufficient, because almost all of the structures were designed before 1983, using an old design standard. In addition, structures which satisfy the fracture morphology analysis are the viaducts which were designed after 1995 [4].

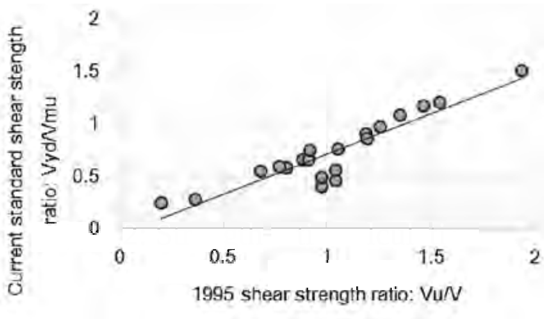

Figure 2: Strength ratio calculation formula comparison

3.2 Damage Level Check Results

A check of the damage level was carried out on about 60 RC pillars which satisfied the fracture morphology check. From the results, it was clear that all 60 of the pillars did not satisfy necessary conditions and needed seismic reinforcement.

Figure 3 shows an example of an RC pillar which needs seismic reinforcement. The subject structure is an RC rigid framed viaduct with one story and three spans, and with a single pillar for a perpendicular to a bridge axis. The subject ground consists of mainly soft, clayey soil and is G5 class in the Japanese seismic measure design standard. Cast-in-place piles and footings are connected by underground beams in the direction of the bridge axis.

Table 1 shows the response in a perpendicular direction to the bridge axis, and the results of the seismic performance check against the RC pillar, on the a-a cross-section in Figure 3. The fracture morphology was flexural failure type. However, it did not satisfy the damage level check, because the damage level of the viaduct is 4 against its limit value of 3.

From the above, it became necessary to carry out seismic reinforcement which improves deformation performance and satisfies the damage level.

Table 1: Seismic performance evaluation results

Direction		Bridge axis perpendicular direction
Ground Conditions		G5 ground
Response value	T_{eq}(sec)	1.623
	δ_y	305
	k_{hy}	0.463
	μ	2.29
	δ_{max}(mm)	698
Element/place		Pillar lower end
Fracture morphology study	V_{mu}/V_{yd}	0.48
	Decision	Flexural failure type
Damage level verification	θ_d(rad)	0.07259
	$\gamma_i \cdot \theta_d / \theta_{yd}$	26.39
	$\gamma_i \cdot \theta_d / \theta_{md}$	3.59
	$\gamma_i \cdot \theta_d / \theta_{md}$	2.18
	Damage level	4
	Damage level limit value	3
	Reinforcement necessity	The main reinforcement

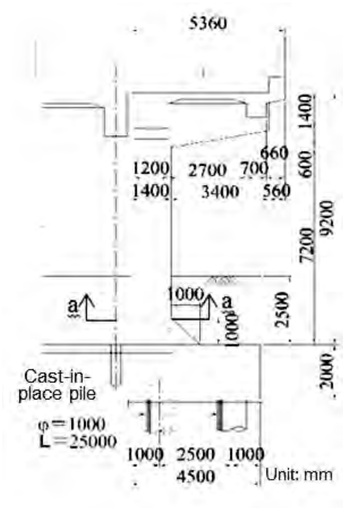

Figure 3: General shape of the structure

4. OUTLINE OF SEISMIC REINFORCEMENT WORK FOR RC PILLARS

4.1 Construction Outline

This section describes the outline of the finished seismic reinforcement work in places where some reinforcement work was finished, within RC pillars that were diagnosed to need reinforcement through seismic diagnosis

Steel plate reinforcement on all four sides was basically applied for improving the toughness ratio. However, in some cases, the method was

changed due to problems in the surrounding environment or features of the pillar. It was very difficult to advance the seismic reinforcement work due to several obstacles. In particular, about 800 subject pillars are in station offices or commercial stores under viaducts. In such cases, we negotiated with facility users, consulted with suspension of business in stores, removed pieces of equipment or the interior before seismic reinforcement work, and restored everything after the work. Photos 1, 2, and 3 show the removal of the interior, seismic reinforcement, and restoration of a store, respectively.

Photo 1: Before removal of interior

Photo 2: Seismic reinforcement

Photo 3: After restoration of store

Figure 4 shows the construction process of steel plate reinforcement on the all four sides method.

4.2 Quality control

Quality control items of the seismic reinforcement are described below.

1) Material inspection of reinforcement steel
- Since reinforcement steel was processed in a factory, only plates which passed factory inspection are shipped.
- Acceptance inspection is carried out at the site when the steel plate is carried in. Thickness, size, and the mill sheet are confirmed.

2) Steel plate welding
- Plates are welded by qualified persons, skill tests are performed in advance, and construction is implemented through items that have passed the tests.
- The quality of the steel plate welding is checked by an ultra-sonic test and penetration test (color check).

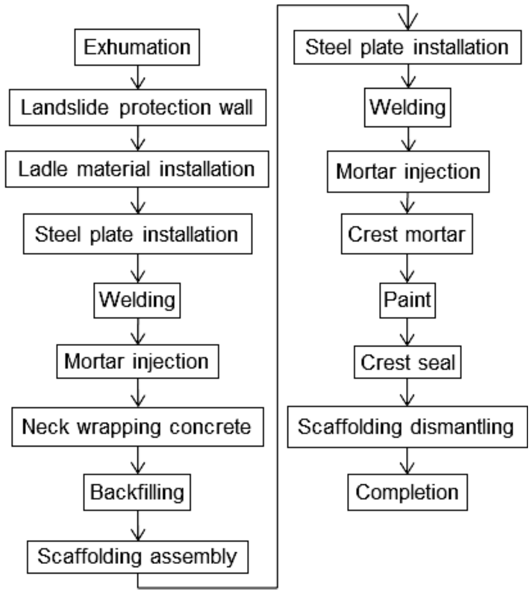

Figure 4: 4-side reinforced steel plate construction flow

3) Infilling of highly workable mortar

For mortar infilling, premix type mortar is applied, and it is kneaded and mixed on site. For this reason, we confirm the quality of the mortar through a bleeding test, mortar flow-down test and compressive strength test. Table 2 shows specifications and control values of the bleeding test and compressive strength test.

Table 2: Test specifications and management values

Management items	Specifications	Management values
Bridging experiment	3h,20h	0%
Compressive strength test	σ_{28}	24N/mm^2

4) Coating

Steel plates are coated 4 times. In other words, under coating in the factory, under coating on site, intermediate coating on site and top coating on site are carried out. The thickness of the coat is confirmed by coating thickness gauges.

4.3 Other methods

Pillars which are not suitable for steel plate reinforcement on all four sides due to work conditions are reinforced by the following methods.

1) Concrete jacketing method

It is difficult to apply steel plate reinforcement on all four sides of pillars that are in a river, like the one in Figure 5,

Figure 5: Concrete jacketing method

due to the constraints of construction and quality assurance. For this reason, the concrete jacketing method shown in Figure 5 would be applied.

2) Steel plate reinforcement with the one side method

When subject pillars are in the building or close to the building, as shown in Figure 6, construction of steel plate reinforcement on all four sides requires the demolishing or removal of a building. If the method with four sides is impossible, steel plate reinforcement on one side is applied.

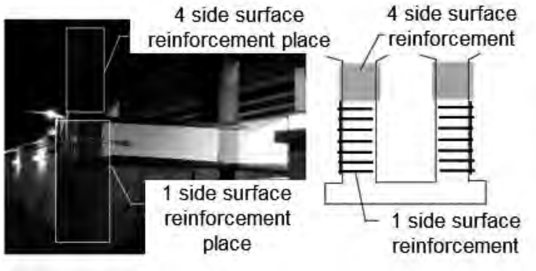

Figure 6: 1 side + 4 side surface reinforcement construction method

However, because steel plate reinforcement of one side requires drilling holes with a diameter of about 40mm in a subject pillar, there is a high possibility that the holes interfere with the reinforcing bars of the pillar. This is especially the case with reinforcing bars that are dense in the under part of the top haunch. Therefore, the steel plate reinforcement hybrid method that incorporates 1-side and 4-side reinforcement is shown in Figure 6.

5. APPROACH FOR FUTURE SEISMIC MEASUREMENT

5.1 Risk map outline

It is considered that the risk of structural collapse due to earthquake has now been drastically reduced as seismic measurements against structures of the Tokyo Metro, which were subject by the notification of the Ministry of Land, Infrastructure and Transport in 1995 were completed.

In addition, Tokyo Metro is now advancing further approaches for seismic reinforcement based on a major earthquake which will hit the Tokyo metropolitan area. Viewpoints of the approach are shown in the following.

1) For structures which were reinforced or judged that seismic reinforcement was unnecessary, how large of an earthquake can they withstand?

2) Is there no overlooked weak point in any place that should have been preferentially reinforced?

The degree of damage to structures in all of the Tokyo Metro lines due to a certain earthquake can be assessed in order to discuss and verify the viewpoints, and by organizing all the lines in places that seem to be empirically dangerous due to knowledge of past earthquakes, this is considered to be good to have an overhead view of how much risk remains against earthquakes.

Therefore, we have created a risk map as shown below for all of the Tokyo Metro lines as a decision support tool for determining the future of earthquake resistance measures, or to understand if there are no places where seismic performance is insufficient or whether there are any weak points for earthquakes in the structure of Tokyo Metro.

I) Map based on numerical analysis
The map shown in a macro suggests the magnitude of seismic motion in Tokyo Metro lines area and structural damage against seismic motion.

II) Map based on experience
The map shows the results of places that fall under special conditions, such as a map based on numerical analysis that cannot be covered and is empirically suspected to be dangerous.

5.2 Outline of forming risk maps

The section describes the outline of making: I) a map based on numerical analysis; and, II) a map based on experience.

5.2.1 Map based on numerical analysis
Seismic performance evaluation (fragility evaluation) was carried out in the target structure and in magnitudes of earthquakes that might occur in the future (hazard evaluation), damage assessment of the structures was performed by superimposing the results, and the results were mapped. Viaducts, bridges, and cut & cover tunnels were selected as structure to be evaluated in the map based on numerical analysis, and we created the following two types of maps for these structures.

I) Seismic performance map
Extract suspicious places that are considered to relatively lack seismic performance by evaluating the damage level of the subject structure in a macro-viewpoint due to uniform seismic motion of all points of the subject location.

2) Scenario earthquake map
As seismic motions are different at each location during an actual earthquake, we performed per-location evaluations of the damage level of subject structures based on the largest imaginable seismic motion. Suspicion locations, based on macro assessments of how much damage will occur in a subject area in which damage from actual earthquakes is expected to be large, were extracted.

5.2.2 Map based on experience
We selected places under special conditions and structure types which are empirically suspected to be dangerous due to earthquakes. Moreover, we extracted these places and made a map by organizing existing documents and drawings.
For making the map based on numerical analysis, we evaluated the hazard of seismic motion, and selected minimum seismic motion for evaluation of the seismic performance map and the seismic motion for evaluation of the scenario seismic map. The minimum seismic motion was set at the seismic motion which arrived when an earthquake of magnitude 6.5 occurred directly underneath that place. An earthquake with magnitude 7 occurred in the southern Kanto area, which is considered to have the biggest rise in acceleration in the Tokyo Metro lines area and was targeted on the seismic motion for evaluation of the scenario seismic map. After that, the ground motion intensity on the surface was set by evaluating the magnification degree of seismic motion due to the ground, which is based on ground motion intensity on the surface on seismic design and the natural period of the ground due to nearby boring data.

The maps which were made by the procedure above are effective as a decision support tool to judge future seismic reinforcement measures.

6. CONCLUSION

We carried out seismic diagnosis of unreinforced viaducts as a further advancement of seismic reinforcement based on a major earthquake which will hit the Tokyo metropolitan area in future. The seismic diagnosis was carried out by a check with fracture morphology analysis and a detailed check with static non-linear analysis in reference to current standard.
As the structures which had satisfied the fracture morphology check could not pass the detailed check, all structures were judged to need seismic reinforcement.
Seismic reinforcement work has progressed to the structures, mainly through steel plate reinforcement of all four sides. When subject pillars are in a river or close to a building, construction of steel plate reinforcement on all four sides is impossible to apply. In such a case, the concrete jacking method, or steel plate reinforcement hybrid method that incorporates 1-side and 4-side reinforcement would be applied.
Moreover, risk maps were made as a decision support tools to comprehensively make future seismic reinforcement plans against large scale earthquakes, such as an earthquake which has an epicenter directly below Tokyo.
From now on, we intend to implement measures continuously by prioritizing those places which need seismic reinforcement due to risk analysis based on the risk maps.

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Damage Mapping of 2015 Gorkha Earthquake by Low-altitude Aerial Photos

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ABSTRACT

We are mapping earthquake damage by the Mw 7.8 Nepal Gorkha Earthquake, 25 April, 2015 using low-altitude aerial photographs. We planned to take aerial photos of residential areas in Kathmandu Valley and surrounding districts affected by the earthquake using a small Styrofoam fixed-wing UAV (Unmanned Aerial Vehicle, or drone), which is a safe and efficient way of taking high-resolution image from 50-150m ground altitude in the sky. We could not use the UAV soon after the earthquake because authorization of using drone was not given by the Nepalese Government. While we were waiting for permission, we flew a real helicopter for the same purpose before losing information of the earthquake damage as much as possible. The first flight was made on August 20th, four months after the earthquake, above the central areas of the cities of Sankhu and Chautara. Sankhu is one of the most affected cities in Kathmandu Valley, partly because of the concentration of old buildings with traditional architecture. Chautara is the capital of the Singdhupalchok, the most damaged district by the earthquake, located in a mountain area outside Kathmandu Valley. The aircraft flew over the core areas of each city at about 150m above the ground. We took few hundred photos from both sides of the craft by handheld cameras at 1 or 2 seconds of shutter intervals. Data are processed by a SfM/MVS software to make orthomosaic photos for mapping purpose, and 3D models for building database. The high resolution oblique photos are most useful for assessing the damage of individual buildings, which can resolve a single piece of brick. We plan to conduct the aerial photo survey in other areas in few more months, either in selected areas by a helicopter, or wider areas by UAV, depending on when UAV permission will be given.

Keywords: *Gorkha Earthquake, Building Damage, Mapping, Aerial Photo, UAV*

1. INTRODUCTION

We propose UAV photogrammetry survey in Kathmandu Valley and surrounding areas to map the buildings and damages caused by the April, 2015 Nepal Earthquake. NIED and NSET will work with Kathmandu Valley Development Authority (KVDA), and local governments outside the valley to provide the data for damage assessment for this earthquake, and for risk sensitive land-use planning for the future earthquakes and other disasters. NIED and NSET will use the data for research on building damage distribution, calibration of satellite imagery by the ground-truth data, and more detailed risk assessment of the cities and rural communities.

2. Equipment

We fly a small, battery powered plane with on-board digital camera in auto-pilot mode to take aerial photos from 50m to 150m above the ground. The plane cruises at a speed of about 60 km/h for about 20 minute flight time to cover an area of two square kilometers in one flight. Pictures are processed by photogrammetry software to create orthomosaic photos for mapping. 3D digital surface models of buildings will be created to measure building heights and shapes. The raw photos with oblique views can be used to investigate more detailed damage and the structures.

Safety of the flights and compliance to the regulations are of primary importance. Our fixed wing foam plane is much safer than popular multi-rotor drones. It will not injure people when it crashes because 1) fuselage is made of soft Styrofoam, 2) propeller is facing rear, and 3) it can glide when it falls. Another big advantage of fixed wing drone is long-range flight. It can fly in 60km/h cruise speed for 40 minutes maximum and 20 minutes on the safe side, i.e., 20km distance range, which is several times longer than multicopters. Autopilot flight can be programmed to avoid prohibited zones and above the height limit directed by Civil Aviation Authority.

Figure 1: Fix wing drone(right) and catch net(left) we use in this study

3. Original Plan

We first planned to carry out a pilot survey in Bhainsepati, Lalitpur near NSET office, followed by a full-spec survey for the Kathmandu Valley. An area of 100 square kilometers in central part of the valley can be photographed by fifty flights in about ten non-rainy days. We thought we might be able to start the survey in middle of June at earliest because applications of flight permission from KVDA to the authorities (CAAN and MoIC) were in process. Taking into account the weather conditions in monsoon season from June through September, we would be able to finish photographing of the central area of Kathmandu Valley by the end of August, and provide orthomosaic photos on GIS system by the end of September.

After the central flat part of the Kathmandu Valley, we continue to map hilly areas in the valley, and selected mountain areas in the districts of Nuwakot, Rasuwa and Sindhupalchok after the monsoon season. We also propose an alliance with other groups who have similar UAV mapping initiatives in Nepal.

Ministry of Home Affairs of Nepal (MoHA), however, banned to fly UAV of any purpose, by anybody, of any size, after the earthquake because of the security, safety, and privacy problems.

4. Helicopter Survey

By August 2015, we had no good prospect of obtaining the flight permission. We then carried out an alternative survey using a manned helicopter. Our first target was Chautara, the capitol city of Sindhupalchok District located north east of Kathmandu Valley. We chose the city firstly because the Sindhupalchok district had large and extensive damage of buildings and hoses among other districts, and closest from Kathmandu. We also targeted Sankhu, which is one of the most heavily damaged areas in Kathmandu Valley and on the way to Chautara, so that we can take aerial photos of the city by making few turns above it.

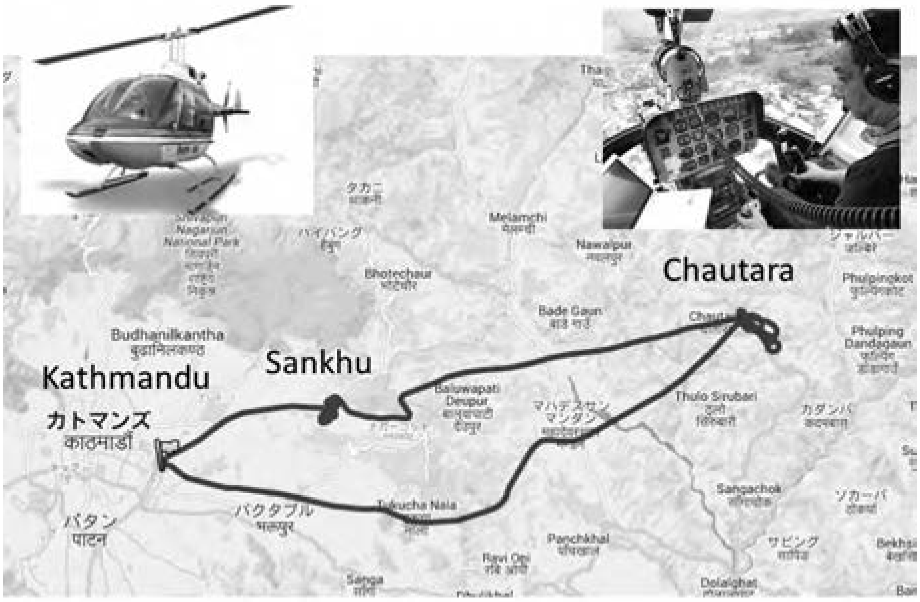

Figure 2: Flight path from Kathmandu, Sankhu, Chautara and Kathmandu of the helicopter (top left). The pilot (top right) follow the waypoint we shoed on PC display.

Figure 3 Flight path above Sankhu

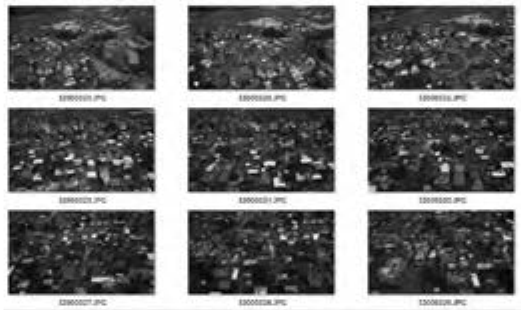

Figure 5 Oblique aerial photos of Sankhu

We made few turns above Sankhu at around 150m ground altitude (Fig 3). Fig 5 shows some of the few hundred photos taken from both sides of the passenger window in time-lapse mode at 1 second interval using Ricoh GR, a compact and high resolution fixed focus camera suitable for UAV mapping.

Figure 6 Orthomosaic photo of Sankhu

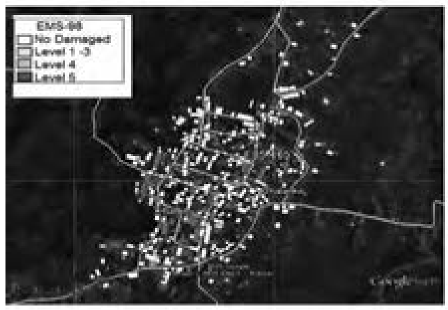

Figure 7 Damage mapping using satellite, UAV and ground survey (Ohsumi et al. 2015)

The photos were processed using PhotoScan™, an SfM/MVS 3D modeling software to produce orthomosaic photo for mapping. The coordinates of GCP (Ground Control Points) were taken from existing GoogleEarth model. Precise measurements using RTK GPS is not necessary for the damage mapping purpose.

Building damages cannot observed by the orthomosaic photos, firstly because the damage is not always visible from the top, and secondly, the processed and stitched photos are considerably deformed in small scale which is difficult to distinguish from the deformation caused by the earthquake. We instead use original oblique photos for the purpose. Fig.7 shows a building damage map by Ohsumi, et al., obtained by ground survey, satellite image processing, and UAV photos.

Figure 8 Flight path above Chautara, Sindhuplchok.

Figure 9 Collapsed building in Chautara.

Fig.8 shows a flight path above Chautara, the district capitol of Singdupalchok. Fig 9 is one of hundreds of oblique photos showing the detailed damage of the buildings. 3D model of the area is given in Fig.10.

Figure 10 3D model of central part of Chautara, Sindhuplchok.

5. Updated plan

Ministry of Home Affairs set up the policy of regulation, application and permission at the end of September 2015 and we applied the detailed flight plan for Bhainsepati, Kokhana, Bungmati of Lalitpur and the city center of Bhaktapur. Our new plan is making UAV aerial photo survey in Kathmandu Valley by December, process the data to map the building by February, and analyze the original images of the photos to map the earthquake damages. We carry out further studies of regional characteristics of the damage by April 2016.

Six months have passed after the earthquake and many damaged buildings were already demolished. The meaning of the damage survey has been largely reduced, but we pursue the project because we will still be able to do meaningful surveys, and we have another purpose, mapping buildings for the future land-use planning and urban developments.

We also have to transfer the UAV operation technology to the counterpart NSET and other government agencies of Nepal to be prepared for the use for emergency responses and for more rapid damage assessment for natural disasters.

Urban safety through the eyes of cultural heritage

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ABSTRACT

All developing countries are facing the phenomenon of urbanization. From the 1970s onward, Nepal has observed one of the highest rates of urbanization in Asia and the Pacific. Historically, Kathmandu Valley has enjoyed sustainable development practice and maintained an ecological balance of urban development through various physical features; cultural practices as well as sustainable opportunities for economic development. The valley reflects its long history through a variety of cultural heritage sites comprising of settlements, monuments, religious sites and traditional infrastructures. The cultural practice of worships and processions are embedded into the people's lives. Looking from the disaster risks viewpoint, cultural and natural properties are increasingly affected by the events. At times of stress, the significant role of heritage in contributing to social cohesion and sustainable development has stressed the importance of its safety. Open spaces of various scale, size and geometry were integral parts of traditional settlements in Kathmandu Valley. This paper tries to review on utilization of cultural heritage, especially traditional open spaces in risk reduction and disaster mitigation.

Keywords: *culture, heritage, urban safety, disaster mitigation*

1. INTRODUCTION

All developing countries are facing the phenomenon of urbanization. From the 1970s onward, Nepal has observed one of the highest rates of urbanization in Asia and the Pacific. Historically, Kathmandu Valley has followed a sustainable development practice and maintained an ecological balance of urban development through various physical features (e.g. mixed-use urban settlement pattern, indigenous architectural styles and construction techniques); cultural practices as well sustainable opportunities for economic development (Adhikari, 2012; IUCN, 1999).

Kathmandu Valley presents a rich history of city planning and space making. As far as recorded in the history, the Kiratis are mentioned to be the early settlers of the Valley from around the 7th century BC till the 2nd century AD. Even in those early times, the Valley appears to have reached a relatively advanced stage of urban culture, with the line of settlements probably following the Bagmati River. From the 3rd century onwards, four ruling dynasties – the Lichhavis, Mallas, Shahs and Ranas have set a trend of their own building trail in Kathmandu Valley. The Lichhavi period and the Malla period are supposedly the eras of city establishments. The ancient art, culture and traditional customs have flourished and enhanced during their reign (Pruscha, 1969). Over the years, this primary gateway for major economic opportunities in the country has experienced haphazard urban development, rapidly increasing population and environmental threats in the absence of a clear and comprehensive planning and land use policy (Haack & Rafter, 2006). Moreover, the valley is highly vulnerable to natural hazards, such as earthquake, flood and landslide (NDR, 2011). Rapid urbanization, haphazard construction, lack of emergency facilities and lack of effective policy implementation further add to the vulnerability mainly in the city core area (Bhattarai & Conway, 2010).

Since many years, Kathmandu Valley has been claimed to be highly prone to earthquakes by various national and international studies. Most of the infrastructure and buildings in the Valley are not strong enough to resist a high magnitude quake. To address the issue, a joint assessment was conducted by Ministry of Home Affairs (MOHA) and the International Organization for Migration (IOM) with the support from United States Agency for International Development (USAID)/ Office of Foreign Disaster Assistance (OFDA) and identified 83 open spaces suitable for Shelter, Aid and Medical Help in the Valley. These open spaces are designed to provide the initial response framework for rescue and relief to those in immediate need by the Government and partner agencies (Shrestha P. , 2015).

While Nepal was anticipating for another big earthquake after the one of 1934 Nepal-Bihar earthquake (ML 8.4), a M 7.8 earthquake occurred at 11:56 NPT with its epicenter about 80 km west of Kathmandu near Barpak, Gorkha, at the depth of 15 km on April 25th 2015. A total number of 1,735 people died and 13,102 people were injured in Kathmandu Valley alone (Nepal Disaster Risk Reduction Portal, 2015).

2. OPEN SPACES IN KATHMANDU VALLEY

In all ancient cities of Kathmandu Valley, it can be seen that the settlement is located on an elevated land. Usually a town in the valley would be a high density compact planned settlement with natural buffer zone created of field/ forest or river. These settlements highly encouraged walking and the use of public open spaces. Traditionally, open spaces of various scale, size and geometry ranging from street scale to courtyard scale and even urban squares have been endowed as integral parts of designated urban spaces. The concept of garden/ green space inside the settlement is rarely located. Instead, one finds open spaces in the form of paved courtyards, street squares or water bodies (Rai R. , 2011). Provisions of large open spaces (*khyo*) for public benefit were also made at town peripheries. These dynamic and functional spaces regulated and shaped urban forms as well as catered to socio-cultural activities (Sharma, 2013).

2.1 Types of traditional open spaces

It can be perceived that the traditional architectural spaces in the Valley were designed with the purpose of holding feasts, festivals, and rituals. Basically every temple and shrine has some open space within and around it, along with *patis*[1] and other attached buildings (Rijal).

Public open spaces in the Valley are more defined as social spaces that follow traditional and cultural trends. Some exist due to the natural design whereas others are delineated by architectural design predating the modern urban design. Following are the types of open spaces found in traditional towns of Kathmandu Valley (Sharma, 2013):

- Street Network
- Closed courtyards (Bahal/ Bahil)
- Neighborhood squares (Nani/ Chowk)
- Palace Squares
- Open space at town periphery (Khyo)

Figure 1: Examples of Closed courtyards (Bahals):
Tebahal, Kathmandu at left and Nagbahal, Lalitpur at right
(Source: www.pinsta.me and www.panoramio.com)

Figure 2: Example of neighborhood square: Pottery Square at Bhaktapur
(Source: www.panoramio.com)

Figure 3: Example of palace square: Patan Durbar Square
(Source: www.nepalonetours.com)

The major backbone of a traditional town is the street network which connects all the closed courtyards (bahal / bahil), open courtyards (chowk or nani) and public squares.

[1] Public rest house

All these spaces are the focus of social settings used for multipurpose activities in daily life as well as during festival seasons. They were also utilized as a place to gather in an event of any natural or man-made disasters such as earthquake and fire (Shrestha B. K., 2011). There also used to be public agricultural land belonging to various community groups or temples and monasteries called guthi lands. The incomes generated from these lands were used for festivals and maintenance of temples and monasteries (Bhandari & Okada, 2009). The space called “khyo” were a type of architectural requirement of the Malla era. They were vast open spaces located near to any densely populated settlement so as to mark the boundary and space for performing larger social and cultural events. For example, Tundikhel alone remained open even when the rest of the Kathmandu city expanded to accommodate new settlements (Rai H. , 2002). Its use has ranged from holding feasts, place for making public announcements, performance of festivals like Ghode jatra and it has even been designated as one of the major spot for evacuation during disaster emergencies.

Thus the composition of these narrow streets, house blocks, numerous courtyards and plazas along with bordering open spaces of our traditional towns modeled sociable, cooperative, safe and secure neighborhoods of ancient times (Shrestha B. K., 2011).

2.2 Traditional open spaces and cultural practices for disaster risk mitigation

The concept of traditional compact settlement planning with settlement boundaries helped to preserve agricultural land that protected primary occupational base of the locals. This way the inhabitants were self-sustained in food products and could survive in the event of natural disaster for a longer period (Bhandari & Okada, 2009).

As per a research done in Kathmandu Valley by Nepal Engineering College (NEC) and Center for Disaster Management Informatics Research, Ehime University, Japan in June 2006, 70% of the respondents affirmed about having knowledge of a safer place in their community in case of a disaster event. This has been credited to the fact that traditional houses in Kathmandu Valley were built with large open spaces surrounded on all sides by residential buildings (Shaw, Srinivas, & Anshu, 2009). The rituals and festivals practiced throughout the traditional cities in the Valley also make local inhabitants familiar to the open spaces around them. Either they pull chariots for various *jatras*[2] or gather for feasts and festivals, people get a chance of making observational learning of city routes and spaces that are useful for life saving during disasters like earthquake (Bhandari & Okada, 2009).

In addition, the traditional houses were built with earthquake resistance measures such as symmetrical windows, double framing of windows, as well as the use of timber wedges called *chuku* that helped in creating earthquake resilience (Tiwari, 1998). Pradhan (n.d.) has pointed out that traditional residential buildings built with brick, mud mortar and timber were rather constructed with much rational thoughts put to withstand earthquakes. In comparison to brick and timber, mud is very weak in strength but the mud mortar cracks easily in case of greater thrust and helps to displace the wall thus absorbing the thrust. This causes only partial collapse of the building preventing it from falling down completely and hence giving time to residents to evacuate. It has also been

[2] Traditional procession of deities

stated that traditional building practice of Kathmandu Valley reflects “local cultural values, reduce the threat of seismic risk to lives of people and address the specific needs of the population” (Bhandari & Okada, 2009, p. 147).

Furthermore, the open spaces in the traditional settlements are well endowed with good infrastructures such as resthouses (patis) and water supply (stone water spouts – hitis). The large size of the open spaces and their proximity from neighboring households made them functionally appropriate as evacuation spaces. One can find a correlation between the intangible cultural practices and the network of open spaces too. Local residents are obliged to be informed about and manage their surrounding spaces due to the repeated communication and active participation while performing the ritual activities. This space cognition ultimately helps in building community coping capacity against disaster events like earthquake (Shaw, Srinivas, & Anshu, 2009; Bhandari & Okada, 2009).

3. USE OF OPEN SPACES IN CASE OF DISASTER

Open spaces in urban areas primarily serve as breathing space for the citizen. Necessity of urban open space for recreational facilities is universally agreed. Alongside various recreational and social uses of open spaces, their importance in the disaster preparedness is increasingly being recognized. Open spaces are required to provide emergency and basic services on the aftermath of disasters.

Kathmandu Valley was exposed to the outside world after the construction of modern highway in late 1950s, coupled with the fast development of communication, rapid population growth and improvement in the economic condition. Rapid demographic change in Kathmandu’s old city core has resulted in the apparent loss of traditional social networks that encouraged the provisions of mutual support during any kind of disaster. In the past, neighborhoods were homogenous with families and relatives living near to each other. The citizens of core city have either shifted outside the city in the modern style buildings or started interfering the traditional architecture and urban spaces. The core settlements have been replaced by renters and more diverse ethnic groups. There have also been massive physical changes in the city center. The former chowks or courtyards, and even the neighborhood squares have been encroached by modern commodities and buildings. Practices of adding new floors or projections to the traditional houses without proper enforcement of building codes and diminution of open spaces have led to lack of light and ventilation on the streets and adjacent open spaces as well as added to the likelihood of casualties and injuries in case of earthquake (Shrestha B. K., 2011; Bajracharya B. N., 2013).

The news that followed the recent Gorkha earthquake and the blogs from various sources shows how traditional open spaces were utilized as shelter space after the disaster. A round sample survey done in those spaces illustrated that the ones who needed to take shelter due to collapse of their homes were not the original dwellers of the core city areas. The rich have left the core for residing in sprawled but still unsafe conglomerates, creating other vulnerable zones, in so called modern dwelling, personally abandoning the buildings to poor and working class floating migrants. The new dwellers do not have any understanding or attachment to traditional cultural values/practices and this has made heritage preservation advocacy more difficult in the Valley.

Many inhabitants in the Valley, both locals and outsiders, have started understanding the significance of the indigenous concept of chowk (courtyard) after the April 25 quake. The chowk offered the residents of the surrounding houses open space to escape the disaster or any danger (Bajracharya G. B., 2015; Leve, 2015).

Figure 4: People taking shelter in a pati in Ason Tole, after April 25 Quake (Source: proof.nationalgeographic.com)

Figure 5: People taking shelter in Yetkha Bahal, following April 25 Quake (Source: www.anthropology-news.org)

The large open spaces such as Tundikhel served as a major evacuation space. It was one of the 83 gazetted open spaces marked for evacuation and refuge in case of disaster. It provided refuge to thousands of people after the recent Gorkha earthquake and is still providing shelters to many families who have lost their homes due to the earthquake.

Figure 6: Tent houses in Tundikhel
(Source: earthquake-report.com)

These spaces also brought the society and neighboring communities together at one place so that they can help each other. From building makeshift shelters to collecting necessary supplies, people came together at one place and helped each other. Thus these traditional open spaces also helped in building social and cultural resilience. The recent quake has reawakened the value of provision of open spaces for various daily uses and cultural practices. The provision of multi-purpose spaces used by communities is not limited to serving only for mundane daily activities. They act as refuge area in case of disasters such as earthquakes and fires. This has been proven during earthquakes that hit the Valley time and again.

4. CONCLUSION

This paper discussed on the traditional open spaces of Kathmandu Valley and their usage in case of disaster such as earthquake. With a rich history of city planning and space making, the Valley boasts a variety of open spaces that caters to specific needs of the population. These open spaces have helped in providing the much needed physical space for evacuation and refuge during disasters. Furthermore, the daily use as well as cultural practices and rituals have made the locals familiar to these places. As a result, people know where to evacuate when there is a threat to their homes. The cultural practices have also brought the communities together and helped in building socio-cultural cohesiveness and resilience towards disasters.

Rapid population growth and haphazard urbanization have put these spaces at danger. These spaces are being encroached upon and decreasing very quickly. Despite their diminution, the still present traditional open spaces provided shelter to many in the case of the recent Gorkha earthquake event. People have started again to value their design and existence. It is high time to preserve whatever is left of these spaces and create new spaces learning from the old city design experience. It is imperative to preserve the open spaces not only for retaining our identity but also to create urban safety and continue our heritage based economy. Both national and international commitment for conservation of our heritage spaces is the prime need of the hour.

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Role of open space in strengthening communities' resilience towards disaster: Case of Nandi Keshwor Bagaicha

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ABSTRACT

Open spaces not only contribute in improving the quality of everyday urban life, in megacities but also increase communities' resilience in case of disaster if properly integrated in urban design and planning. This paper examined the case of Nandi Keshwor Bagaicha, a pilot project for open space revitalization through public-private partnership approach. While appreciably contributing to urban ecosystem based adaptation and cultural significance, the project led to development of the space as highly beneficial for disaster recovery, particularly after the Gorkha earthquake (7.8 magnitude). The paper documented major historic changes in daily usage of the space and analyzed how the revitalized open space proved successful in providing post-disaster facilities, including shelter and first aid, to more than 7000 inhabitants in a day through the active participation of local community. It further discussed the lessons learnt from the earthquake response to stimulate inter-disciplinary discussion regarding the critical role of open space that might encourage communities and government participation in the development of ample and adaptable number of such spaces. The paper, thus, highlighted the crucial role of multi-purpose open spaces as essential post-disaster recovery support in disaster prone megacities, while promoting urban safety through the development of dynamic public space that acts as a catalyst for civic engagement and revenue generation.

Keywords: *open space, disaster recovery, Public Private Partnership, Gorkha earthquake, emergency response*

1. INTRODUCTION

Increasing population and haphazard urban development has led to poorly managed open spaces in Kathmandu Valley, the primary gateway for major economic opportunities in the country. Historically, the Valley has followed a sustainable development practice and maintained an ecological balance of urban development through its abundant open spaces, mixed-use urban settlement pattern, indigenous construction techniques cultural practices as well sustainable opportunities for economic development (Adhikari N. , 2012; IUCN, 1999). However, with the rise in urban sprawl over the years, open spaces are being heavily encroached by built up areas, thereby, compromising with the community's need for open spaces. This notion has highlighted the need to conserve, develop, protect and rehabilitate open spaces- not only to enhance environmental and socio-cultural values of the area but also to strengthen communities' resilience in case of disaster. In order to emphasize on the importance of open spaces, the Kathmandu Valley Development Authority (KVDA) has been working on facilitating the development of multi-purpose open spaces, which could be utilized in case of disaster and for leisure purpose as well.

The importance of preservation of open spaces has been stated in the Policies and Programs of the Government of Nepal for Fiscal Year 2014-15 (GoN, 2015) as

> Pt. 43: "*…. Based on the notion of open and clean Kathmandu, parks and playgrounds will be constructed in different places of the Kathmandu valley".*

This was followed by the Budget Speech for Fiscal Year 2071-72 (2014-15) stating in its point no. 103 that

> *"…. Agency wise responsibilities will be clarified for preservation of government, public and Guthi lands. No local agencies can provide public lands for private or any other uses without having a certain plan and cost benefit analysis.*"[1]

The Environment Conservation Committee of the Parliament had also given direction to KVDA on June 29, 2014 about identification, conservation and management of parks and gardens. In accordance to all these statements, the 7th Management Committee meeting of KVDA had passed the Nandi Keshwor Bagaicha Revival Project on Jan 10, 2014 as a major multi-purpose open space for recreation and emergency response.

In this context, this paper examines the case of Nandi Keshwor Bagaicha, one of the 83 identified open spaces identified by the Government of Nepal for emergency response site in case of disaster. The area has been developed as a pilot project for open space revitalization through public-private partnership approach. This paper, thus, analyzes its highly significant role in post- disaster recovery support during the Gorkha Earthquake (7.8 magnitude) on 25 April, 2015 and the subsequent aftershocks, which could further be an impetus for the development of more multi-purpose open spaces and help to build community resilience to disaster.

2. NANDI KESHWOR BAGAICHA

2.1 Location

Nandi Keshwor Bagaicha is an open space, located in Naxal, the heart of Kathmandu Valley. Nandi Keshwor is a temple of Lord Shiva and Bagaicha in Nepali means a garden. So it is a garden dedicated for flowers to worship Lord Shiva. The space covers about

[1] (Ministry of Finance, 2014, p. 22)

10,266 sq. m. of land area. The area is surrounded by historical Narayanhiti Palace Museum, Nagpokhari Pond, Shankha Kirti Mahavihar, Nepal Police Headquarters, educational institutions, residential buildings and apartments, along with major corporate offices and financial institutions. Due to the diversity of land use around the area, the locality remains mobile most of the time.

2.2 Historical Background

Historically, Nandi Keshwor Bagaicha (Nandi Keshwor Garden) held a significant value as an important part of the Nandi Keshwor Bahal. The Bahal consists of 'Nandi Keshwar Temple' of Lord Shiva, built in 1801 AD by then queen Subarna Prabha Devi, along with residential buildings, resthouses and garden areas. As per the scriptures in the Temple area, the queen used to worship the deity using the flowers from the garden, which was named as the Nandi Keshwor Bagaicha (NCSC, 2013; SP, 2013). In 1947 AD, the entire Bahal was brought to use as a school, after which the garden space was heavily neglected. Until 2012 AD, the space was mainly used as a solid waste dumping site, and frequently as a playground and parking lot, thus negatively affecting the environment and outlook of the area.

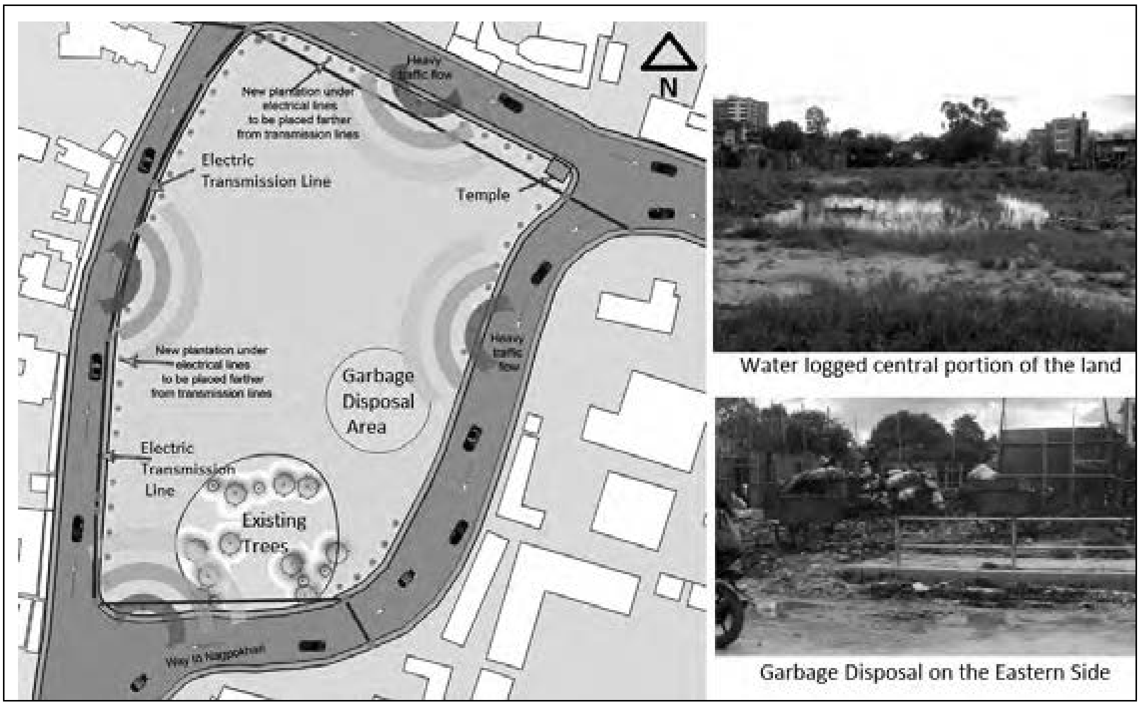

Figure 1 Site Condition before Project Development

2.3 Efforts to preserve the Nandi Keshwor Bagaicha

Considering the socio-cultural value of the open space and the depleting environmental condition of the area, various efforts had been made to preserve the entire temple surroundings, including the open space. However, the efforts until 2012 AD had been less appreciated in the past mainly due to ineffective participation of major stakeholders (NCSC, 2013). Thus, a social organization, Community Service Center Naxal, led the preservation efforts in collaboration with KVDA, local community and the community police. The initiatives were kept in line with the efforts to deal with the problem of pollution and building community resilience to disasters through community beautification and development. The continual efforts over the years not only started to rescue the deserted space, but also acted as an impetus to make positive changes in the society by setting an example of cooperation, coordination and responsibility towards community through Public-Private Partnership, which would be an example for the preservation of such neglected space in other parts of the Kathmandu Valley as well.

As an initial step, collaborative efforts were made to raise the need for the preservation of the open space for enhancing the environment of the area and mainly for its utilization in case of disaster, considering the increasing vulnerability of Kathmandu Valley with respect to natural hazards like earthquake. Interaction with major stakeholders and government bodies, utilization of local media, hoarding boards display and tree plantation campaigns were fruitful in raising awareness. Regular clean up campaigns were organized to eliminate the piles of garbage. Involvement of youth was encouraged through interaction programs, painting competitions to make them aware of the importance of preserving such unattended spaces to create a green park that enhances the environment and supports the community during emergency. The regular interactions with major stakeholders clearly emphasized on the need for careful planning of the open space. Hence, the KVDA initiated the Nandi Keshwor Bagaicha Revival Project to establish the open space as a multi-purpose park that further strengthens the community's resilience to cope with disaster.

3. REVIVAL OF NANDI KESHWOR BAGAICHA FOR URBAN RESILIENCE

3.1 The Nandi Keshwor Bagaicha Revival Project

The Nandi Keshwor Bagaicha Revival Project has been initiated by Kathmandu Valley Development Authority using Public- Private- Community partnership model. The park exists within a densely populated mixed use zone that consists of numerous residential areas and important properties of public concern within its 1 km radius; these include 4 Hospitals, 15 education centers and 4 Police Stations, along with numerous financial institutions, corporate houses and foreign diplomatic offices. Hence, there is a huge potential to develop the area as a multi-purpose open space. The project gained momentum from 2012 AD and eventually developed into a beautiful garden by the end of 2014 AD (Smrit, 2015).

Objectives

The project has been designed with the following major objectives:

- Incorporate the park as Disaster Risk Management zone, equipped with facilities required for post-disaster related activities
- Provide a dynamic public space that fosters socio-cultural interactions and promotes citizen's engagement in preserving cultural heritage
- Cater the need of people from different age groups: such as playground for children, recreational area for youth and resting space for elderly
- Develop the area as a multi-purpose Health park
- Make it a unique example of a Minimum Maintenance Park

- Maintain a Positive Environmental Impact in the area with respect to surrounding development through incorporation of urban EbA (Ecology based Adaptation) Concepts

Community Involvement in the Process

The revival project has been designed with considering the outcome of a series consultation meetings with local communities along with other stakeholders. Such meetings helped to understand the major challenges faced by the area. These include the need for a dynamic public space for all ages, issues of environmental and noise pollution within the area and the potential for ground water recharge system that could be utilized in case of emergency. These requirements have been addressed using suitable landscape design for the area.

Considerations and Components of Design

The central area of the space has been left open as green space for multipurpose use as well as for post disaster recovery. Sitting areas have been created for children and elderly. A walkway has been constructed around and connected with four access point at north, south, east and west. The park is especially designed to help ground water recharge, promote rain water harvesting and decrease air pollution. As the one of the first emergency rescue spaces in the Kathmandu Valley, the space includes the construction of recharge well, grease chamber, rapid sand filter, and soak pit that could be highly useful in case of emergency.

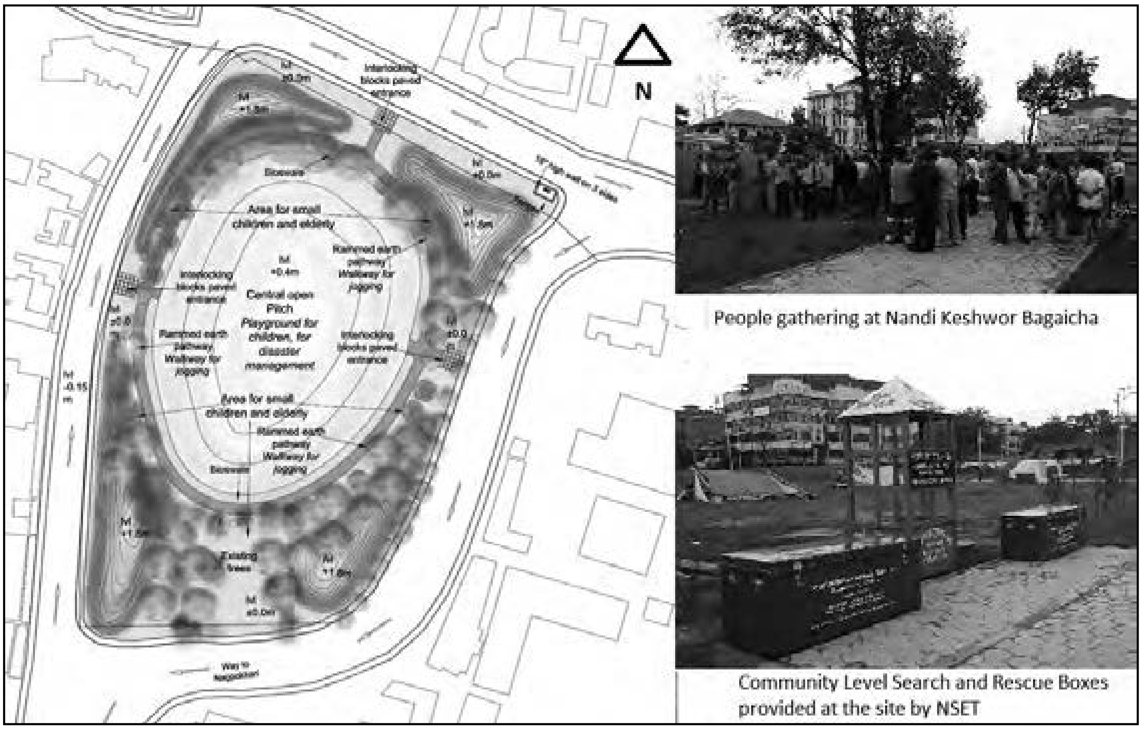

Figure 2: Conceptual plan and Present state of the area

Recharge wells are constructed in Nandi Keshwor Bagaicha to conserve and use the excess water runoff in order to recharge the ground water table using underground storage. To facilitate accessibility, 3.5 m wide footpaths, with trees on both sides, have been constructed in and around the site using interlocking concrete block. For differently abled population, altogether 8 ramps, two on each gate (size 2.5m x 1m x 0.45m), have been constructed. In addition, railings have been erected along the outer boundary walls of the park, with the provision of entry points at four corners. The concept of railings was not fully accepted initially considering the usage of the space as emergency evacuation zone. However, its construction was considered important mainly to safeguard the park from unattended animals, and illegal usage of the area for commercial purpose. Additionally, to reduce acoustic disturbance from surroundings using landscape design, mounds of approximate height 1.8 m have been built at the four corners of the garden; and trees are planted along the periphery of the space, which further act as visual barrier and facilitate vehicular noise diversion.

As one of the 83 emergency evacuation sites designated by the Government of Nepal, the design for the park also integrates the key elements for post- disaster need. In collaboration with National Society for Earthquake Technology- Nepal (NSET), the park has been provided with Community Level Search and Rescue (CSLR) boxes to be used for post disaster situation. Local youths were provided with trainings on local level disaster management and operation of equipment stored in the box. Moreover, solar lights shall be installed in cooperation with Alternative Energy Promotion Center (AEPC) and Nepal Electricity Authority (NEA), being facilitated by KVDA.

Hence, Nandi Keshwor Bagaicha has been developed as one of the first parks with multiple uses - as a beautiful green park for general public, playground for children and most importantly as an emergency shelter during a large earthquake disaster, which in turn aids in building community resilience to disasters.

3.2 Challenges and Further Improvements

Following are some of the issues and challenges faced during the park development and construction:

- As the site was being used as a mini-transfer station to dump solid waste by informal sectors, the related groups were against the construction of garden because the site was used as a medium for easy access to dump waste.
- The source of funding was also major challenge in the initial phase.
- Local community also raised questions about the security due to the construction of mounds at four corners. Representatives from KVDA and the community police convinced local people about the security system, such as establishment of surveillance cameras at strategic locations and deployment of community police at the park and explained the salient features of those mounds.

4. NANDI KESHWOR BAGAICHA IN POST GORKHA EARTHQUAKE

The revitalization project of Nandi Keshwor Bagaicha is an outcome of the continual support from various stakeholders ranging from local communities to central Government bodies. The developed park was handed over to the Community Service Centre on 6 July, 2015. Since its operation, the park has been offering respite to its users as a major recreational space and health park. The park has already served as one of the evacuation spaces during Gorkha Earthquake that hit Nepal on 25 April, 2015. Immediately after the earthquake, the space was used as an evacuation zone for more than 7 thousand people, including locals and tourists. The Community Service Center Naxal along with Nepal

Police and local youth made full utilization of the recently refurbished open land. Supports from various agencies were also witnessed in supplying tarpaulins, tents, food and water to the population. Since the earthquake, the Community Service Center and the Community Police established a community command post within the site area in order to address the issues related to shelter, water supply, waste management, food supply and psychological recovery from the shock. Being one of the first pioneer projects on park revitalization for the purpose of emergency rescue during a disaster, the objectives of the project were fully met. Provisions of community disaster tool box were made and trainings on local level disaster management and operation of equipment stored in the tool box were given to the community there. This project has led way to identification and planning of other similar spaces in Kathmandu Valley. Table 1 provides timeline of the post disaster activities at the site.

Figure 3 People taking Shelter at Nandi Keshwor Bagaicha after the Gorkha Earthquake

Table 1. Time line of activities at the area after the April 25 Earthquake

Date	Time	Activities
25 April 2015	11.56 AM	A 7.8 Magnitude earthquake hit the Kathmandu Valley, with epicenter at Barpark, Gorkha at the depth of 15 km.
	1:00 PM	Around 7000 local population, including 24 foreigners use the park as an evacuation zone and shelter space
	1:30 PM	Medical facilities provided at the site through the collaborative effort of Community Service Center, Satya Sai Center and Local youths
		Considering the climatic condition, Catering tents provided at the site by local catering service
	7.30 PM	Free Food supplied at the site from the catering service
	8:00 PM	Generator used at the site for electricity supply
	Night	Security at the site for nighttime provided by Metropolitan Police Force and Armed Police Force Nepal

26 April 2015	5:00 AM	Community Service Center contacted various agencies to support organized shelter space in the park area
		Water supply at the park managed by Nepal Police and KUKL
		Free food supply provided for the entire day at the site by Community Service Center
	1: 00 PM	Tarpaulin sheets provided in the area for shelter: Metropolitan Police: 25 sets; Nepal Red Cross : 53 sets; Community Service Center: 8 sets; Save the Children : 10 sets
		Temporary shelter constructed using local bamboo
27 April 2015	10: 30 AM	Meeting held with Secretary, Ministry of Cooperatives and Poverty Alleviation; Secretary, Nepal Trust; Joint Secretary, Ministry of Urban Development to manage the shelter space
May 11	9.30 AM	10 set of tents provided at the site by tourist from Argentina Ms.Maria Alejandra Ulehla, CEDISUR S.A
May 12	12.50 PM	7.3 Magnitude hit the Kathmandu Valley
		48 sets of Tarpaulin sheets provided at the site by NRN
May 20	6.20 AM	Cleaning campaigns conducted at the site by locals
	10 AM to 3 PM	Assessment conducted regarding the condition of the people at the shelter along with Recreational programs for children
May 22	5.30 AM	Yoga classes conducted for the people in the temporary shelters
	7:00 AM	Cleaning campaign at the site
		Assessment of condition of 104 children and 10 pregnant ladies by community police; Sanitary pads and Soaps distributed at the site
May 23	7:00 AM	Cleaning campaign at the site
	4:30 PM	Reconstruction of temporary sheds damaged by the heavy rainfall and storm
May 24	5.30 AM	Yoga classes conducted for the people in the temporary shelters
	7:00 AM	Cleaning campaign at the site
	10: 00 AM	Art, Play Program organized at the site to provide psychological comfort for the people in the area, targeting small children
May 25	5.30 AM	Yoga classes held at the site
	7:00 AM	Cleaning campaign conducted at the site
	10: 00 AM	Art, Play Program organized at the site to provide psychological comfort for the people in the area, targeting small children
May 26 and 27	7:00 PM	Removal of unattended tents at the site by Community police and local youth
May 28	11:00 AM	3 boxes of Sanitary Napkins and 6 boxes of Masks provided for the people at the park
	11.30 AM	Representatives from Community Police and Maiti Nepal, NGO helping victims of sex trafficking, visited the site to assess the living condition of the people in the park. The condition of the people in the area was normal
May 26 – May 30	4:00 PM	Musical program organized at the site to provide psychological comfort for the people in the area, targeting small children
May 30	10:00 AM	One day Self Defense Training program conducted for 35 female of age group 16 to 35

5. CONCLUSION

Rapid urbanization and haphazard sprawl has put a lot of stress on the existing open spaces in Kathmandu Valley. Considering the need of such spaces for recreational purpose and emergency response site as evident during the April 25 Gorkha earthquake, their revitalization is seen as a prioritized task for the safe and organized development of the Valley. The revival of Nandi Keshwor Bagaicha Park had a highly significant value as a post-disaster recovery support that highlighted the need for preservation of more open spaces for future, while promoting urban safety through the development of dynamic public space. Thus, the success of Nandi Keshwor Bagaicha park revival project and its satisfactory usage is an initial step taken by KVDA that would pave way to preserve the old and develop new multi-purpose spaces mainly for essential post-disaster recovery support in disaster prone megacities. It is clearly understood that collaboration of all stakeholders is necessary to implement such projects even in the future. Thus, the lessons learnt from the project would help to stimulate inter-disciplinary discussion regarding the critical role of open space that might encourage communities and government participation in the development of ample and adaptable number of such spaces. This might further act as a catalyst for civic engagement and revenue generation that are crucial for sustainable maintenance of the park. The project was initially designed as a revenue efficient model and this will be possible only if the community plays a proactive role in sustainable maintenance of the park. Simultaneously, KVDA looks forward to replicate such projects so that more breathing spaces are provided to the Valley residents.

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Building damage estimation at Kathmandu using UAV photos and satellite imageries

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ABSTRACT

In this research, the feasibilities of several types of remote sensing technologies to earthquake disaster have been investigated in the case of the 2015 Nepal-Gorkha earthquake. First, the city center Kathmandu were observed using several types of remote sensing sensors; optical sensor and synthetic aperture radar of satellites, and optical sensor at Unmanned Aerial Vehicle. First, the quick damage estimation was conducted with pre- and post-event ALOS-2/PALSAR-2 data. Next, the result of damage estimation was compared with the result of the visual interpretation of pre- and post-event high-resolution optical satellite images provided by Google earth. Some parts of the Kathmandu cities were investigated with the Unmanned Aerial Vehicle. Finally, feasibilities of the damage estimation by several types of sensors were studied in the case of the 2015 Nepal-Gorkha earthquake. L-band SAR data obtained by ALOS-2/PALSAR-2 sensor was useful to comprehend the building damage in the affected areas, but might not be enough sensitive to find the moderate damage, even the time for processing is short. Visual interpretation of the optical satellite image was good to interpret the collapsed buildings, but not sufficient to know the slight damage. UAV photos could be good to interpret the slight or moderate damage.

Keywords: *remote sensing, Unmanned Aerial Vehicle, the 2015 Nepal-Gorkha earthquake*

1. INTRODUCTION

On April 25, 2015, a Mw 7.8 earthquake attacked the Kathmandu valley. After that, the affected areas were observed by several types of sensors equipped on satellites, or Unmanned Aerial Vehicle (UAV). These results are useful to comprehend the building

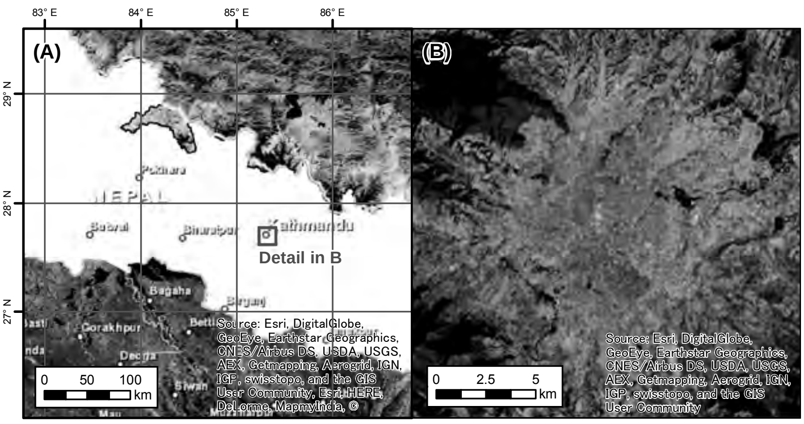

Fig. 1 Study area (Kathmandu valley, Nepal)

damage in the affected area. To utilize these platforms for the earthquake disaster, it is necessary to understand the advantages of these respective platforms.

Several types of method to detect building damage in the areas affected by natural disaster based on the several types of platforms (Miura et al.,2005, Liu et al., 2012). However, few studies have been conducted to discuss the advantage and disadvantage of these approaches by comparing to each other at the same location.

The objective of this study is to investigate the feasibilities of three types of remote sensing platforms to detect building damage in the areas affected by the earthquake, in case of the 2015 Nepal-Gorkha earthquake.

2. Data set and study area

The study areas encompassed Kathmandu valley and the surrounding region as shown in **Fig. 1**. The affected areas were observed by three types of approaches; satellite imageries observed by Synthetic Aperture Radar or optical sensor, and aerial photos captured by UAV. The satellite images include pre- and post-event high-resolution optical satellite images that were provided on Google earth, and pre- and post-event L-band Synthetic Aperture Radar (ALOS-2/PALSAR-2). The set of optical images were captured on 2 November 2014, and 3 May 2015. The ALOS-2/PALSAR-2 data were captured on 21 February 2015 and 2 May 2015. An example of optical satellite image, SAR data, and a UAV photo is shown in **Fig. 2**. To identify the building outline, Open Street Map was used (Open Street Map, 2015).

3. Method

3.1 Comparison of three types of imageries captured by satellites and UAV

Destroyed buildings at Bhakutapur in Kathmandu valley were observed by Pre- and post-event optical satellite image, pre- and post-event SAR data and a UAV photo as shown in **Fig. 3**. These imageries were compared to each other by focusing on the same building that was destroyed by the earthquake.

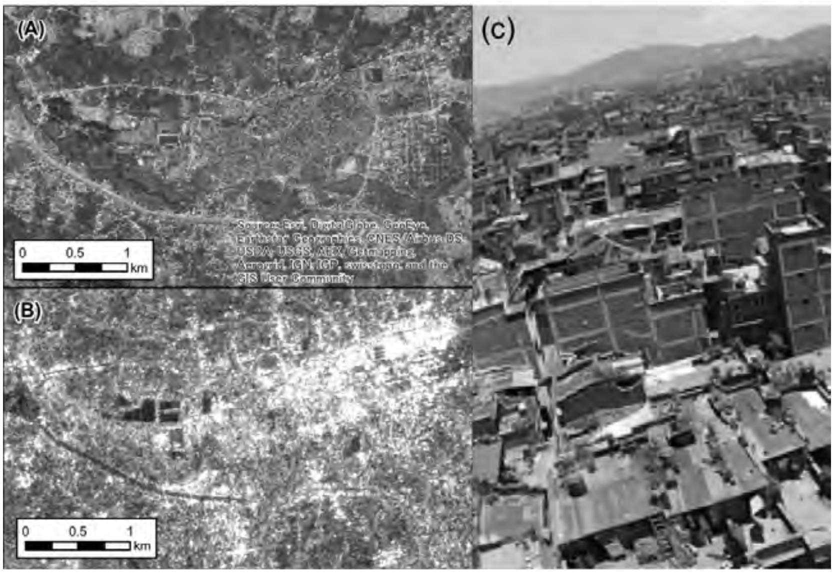

Fig. 2 An example of (A) Optical satellite image, (B) ALOS-2/PALSAR-2 data, and (C) UAV photo.

The pre- and post-event optical satellite images show the clearly differences between pre- and post-event (**Fig. 3 (A), (B)**). The spatial resolution is quite high, which is up to 50 cm, and it could be easy to classify the collapsed and survived buildings. With regard to the ALOS-2/PALSAR-2 data, it was more difficult to interpret. However, the same building on pre- and post-event SAR showed the small differences in the pixel value, which is circled by red line (**Fig. 3 (C), (D)**). The UAV photo showed a good quality to identify the building damage clearly, as shown in **Fig. 3 (E)**. Based on the UAV photo, it could be found that, it is possible to identify the building damage in more detailed and accurate manner.

3.2 Building damage estimation by using SAR data

Building damage was estimated using pre- and post-event ALOS-2/PALSAR-2 data, based on the method proposed by Gokon et al.(2015). Originally, the method was developed to estimate the damage ratio of buildings that were washed away by the tsunami. Therefore, the applicability of this method to earthquake disaster was investigated in this research.

This is based on the relationship between the building damage ratio and the mean value of correlation coefficient of pre- and post-event pixel values on L-band SAR data. First, pre-processing was applied to these data, including calibration, speckle noise filtering, and co-registration. Next, change detection of pre- and post-event ALOS-2/PALSAR-2 data was conducted by calculating correlation coefficient. Then, built-up areas were identified by making envelopes around building footprint data, which was obtained from Open Street Map. Next, object-oriented image processing was applied to the correlation coefficient image within the built-up areas, to estimate the local homogeneities in terms of building damage. Finally, the damage ratio in terms of

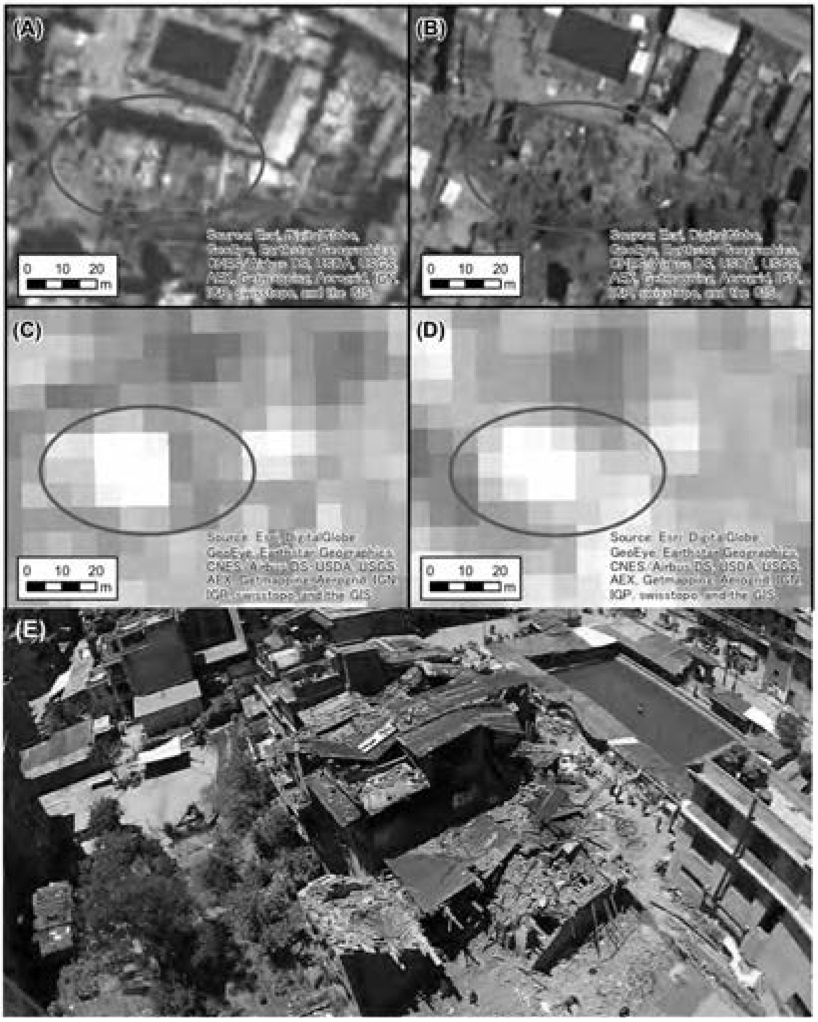

Fig. 3 An example of building damage at the same location; (A) Pre-event optical satellite image, (B) Post-event optical satellite image, (C) Pre-event SAR data, (D) Post-event SAR data, (E) UAV photo.

collapsed buildings was estimated by applying damage function proposed by Gokon et al.(2015), that shows the relationship of the mean values of correlation coefficient and damage probability of destroyed buildings. An example of building damage ratio estimated by SAR data is shown in “**Fig.4 (B)**”.

3.3 Visual interpretation of building damage using optical satellite images

To identify the building damage at a building unit scale, visual inspection of high-resolution optical satellite images was conducted. The pre- and post-event satellite images were extracted from Google earth. These layers were displayed at the same coordinate system on GIS. The vector data of building outline was created by hand based on the pre-event satellite image. Then, pre- and post-event buildings were compared one by one, and the building damage were categorized into two classes as “collapsed” and “survived”. The damage class was given to each building as an attribute on GIS data. The example of building damage interpretation is shown in “**Fig. 4 (C)**”.

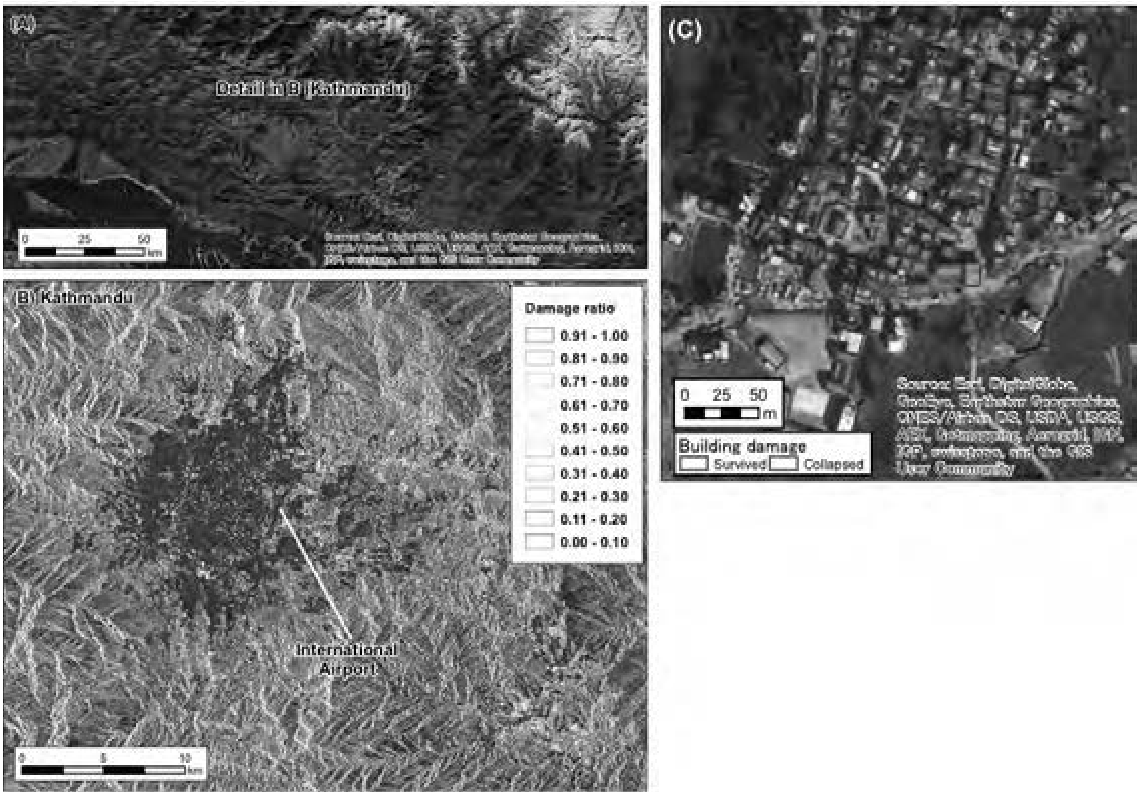

Fig. 4 An example of building damage estimated/interpreted by (B) pre- and post-event SAR data, and (C) high-resolution optical satellite image.

4. Results and discussion

Three types of sensors were tested to identify the building damage, and compared to each other to investigate the advantage and disadvantage.
The high-resolution optical satellite images were useful to identify the collapsed buildings at a building unit scale. And, it would be inferred that the accurate result could be obtained in case of the buildings that were completely collapsed and the shape of the roof was changed. However, a building with the small change at roof might be difficult to classify the damage category. In addition, it is not possible to classify more detailed building damage. Furthermore, it is difficult to interpret the building damage due to the reason of weather condition, observation angle of the image, and the color of the roof.

The ALOS-2/PALSAR-2 data might be useful to comprehend the building damage in a extensive area with a short time. The result of damage estimation as shown in **Fig.4 (B)**, showed the slight damage in the Kathmandu valley. The validation of the damage estimation based on the ground truth data could not be conducted, yet. This study applied a method to estimate the regional damage ratio, therefore the result showed relatively lower damage ratio at Kathmandu valley. To identify the built-up areas, Open Street Map was used, and the method was applied only to the built-up areas. Therefore, if the building data was not created on the map, the building damage could not be identified properly. This might be one of the problems to be solved.

The UAV photos showed the detailed damage situation, the slight damage or moderate damage could be investigated, that could not be identified by using satellite imageries. Not only the damage level, but also more detailed damage situation could be confirmed with high accuracy. It could be inferred that, the data has almost same quality as the data obtained in the field survey by foot.

4. Conclusion

Feasibilities of the damage estimation by several types of sensors were studied in the case of the 2015 Nepal-Gorkha earthquake. The summaries of this study are as follow; L-band SAR data obtained by ALOS-2/PALSAR-2 sensor might be useful to comprehend the building damage in the affected areas, however, might not be enough sensitive to find the moderate damage, even the time for processing is short. Visual interpretation of the optical satellite image was good to interpret the collapsed buildings, but not sufficient to know the slight damage. UAV photos could be good to interpret the slight or moderate damage.

Acknowledgement

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Lessons from Response Activities during April 25, 2015 Gorkha Earthquake, Nepal

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ABSTRACT

The Gorkha Earthquake of M7.8 hit Nepal on April 25, 2015. The epicenter of this earthquake was Barpak, Gorkha, 80 km northwest of Kathmandu Valley. The main shock was followed by hundreds of aftershocks including M6.6 and M6.7 within 48 hours and M7.3 on May 12, 2015. According to the Government of Nepal, a total of 8,686 people lost their lives, 16,808 people injured, over 500,000 buildings completely collapsed and more than 250,000 building partially damaged.

The National Society for Earthquake Technology – Nepal (NSET), a not-for-profit civil society organization that has been focused on earthquake risk reduction in Nepal for past 21 years, conducted various activities to support people and the government in responding to the earthquake disaster. The activities included: i) assisting people and critical facility institutions to conduct rapid visual building damage assessment including the training; ii) information campaign to provide proper information regarding earthquake safety; iii) support rescue organizations on search and rescue operations; iv) support local organizations in coordinating and managing relief supplies; and v) provide technical support to common people on repair, retrofit of damaged houses. NSET is also involved in carrying out studies related to earthquake damage, geotechnical problems, and causes of building damages. Additionally, NSET has done post-earthquake detail damage assessment of buildings throughout the affected areas.

Prior to the earthquake, NSET has been working with several institutions to improve seismic performance of school buildings, private residential houses, and other critical structures. Such activities implemented during the past decade have shown the effectiveness of risk reduction. Retrofitted school buildings performed very well during the earthquake. Preparedness activities implemented at community levels have helped communities to respond immediately and save lives. Higher level of earthquake awareness achieved including safe behavior, better understanding of building code, and improvement of skills towards safer construction, helped in saving lives and assets, and also helped to understand better the gaps and shortcomings.

The Gorkha earthquake provided an opportunity to test the effectiveness and impact of the response activities carried out in the backdrop of the preparedness and mitigation actions implemented during the past several years by NSET and many other organizations. Many important lessons have been learned which will be helpful in paving further course of action for the future.

This paper will discuss key response activities, achievements, lessons learned, and optimal directions for future activities.

Keywords: Awareness, Response activities, resilience

Performance of a ten-story reinforced concrete building damaged in the 2015 Nepal Gorkha Earthquake

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ABSTRACT

An earthquake of moment magnitude M_w = 7.8 occurred in Gorkha district, Nepal on April 25, 2015 followed by an aftershock of *M_w = 7.3 in Dolakha district on May 12, 2015. The earthquake resulted in damage to more than 700,000 houses leaving over two million people homeless. A majority of the buildings in the affected regions were either load bearing masonry or reinforced concrete frame structures. In this paper, a ten-story reinforced concrete residential building that sustained damage in the 2015 Gorkha Earthquake is considered as a case study. The building comprises of moment resisting frames with core walls for the elevator shafts. The structural members suffered minor flexural and shear cracks, while the non-structural brick walls suffered multiple shear cracks. The building was investigated by the authors one month after the earthquake and information on damage was collected. A three-dimensional finite element model of the building was created and pushover analysis and nonlinear response history analysis under bidirectional seismic excitation were carried out. Although, the building was designed following the Indian Standards, the seismic resistant capacity of the building was found to be inadequate from the analysis.*

Keywords: *bidirectional seismic excitation, lateral load carrying capacity, pushover analysis, reinforced concrete building, 2015 Nepal Gorkha Earthquake*

1. INTRODUCTION

Reinforced concrete (RC) buildings are the most common type of medium- to high-rise construction in urban areas of Nepal. Moment frames in the RC structures serve as the primary lateral load resisting system as they provide sufficient stiffness and strength. In addition to the moment frames, use of shear walls and core walls provide additional lateral force resistance to the buildings. Some of the RC buildings in Nepal are constructed following the Indian Standards (IS 13920:1993, IS 1893:2002), while many buildings are not designed to resist seismic loads. A detailed review of the design and construction practice of RC buildings in Nepal can be found in Chaulagain et al. (2013). During the 2015 Nepal Gorkha Earthquake, many RC buildings were severely damaged while some of them sustained minor damage. Some of the high-rise apartment buildings suffered minor damage, leading to a reduction of the residual strength of the structure.

In this paper, a high-rise apartment building that sustained minor damage during the earthquake is considered as a case study. The building was designed following the IS 13920:1993 and IS 1893:2002. Three-dimensional nonlinear static analysis (i.e. pushover) and nonlinear response history analysis of the building are performed to evaluate the capacity of the building and to study the seismic performance.

2. BUILDING DESCRIPTION

The building considered in this study is located in Lalitpur sub-metropolitan city. It is a 3-bay by 4-bay, 10-story RC building with a uniform floor height of 10 ft (3.048 m) with varying bay width (Figures 1a and 1b). The building has a reinforced concrete moment resisting frame and two elevator shafts as shown in the figures. In addition to 10 stories, the building has a small room having a height of 13 ft (3.962 m) to house the elevator machinery on the roof. The building has two floors of basement assumed to behave as a rigid body, which are not considered during the analysis. The basements and first floor of the building are used for parking and the second and higher floors are used for residential purposes. From the available data, the design compressive strength of the concrete is 30 MPa and the nominal yield strength of reinforcement is 500 MPa. Dead load consists of member self-weight, loads due to partitions, infill clay brick walls, and floor finish. Live load on the floor and roof slabs were 2.0 kN/m^2 and 1.5 kN/m^2, respectively. Total seismic weight of the building was 62,108 kN and the design base shear in *X*- and *Y*- direction were 5,936.3 kN and 5,542.7 kN, respectively. The base shear was calculated based on the provision of IS 1893:2002, which is extensively used for the design of buildings in Nepal. The periods of the building for the first three modes are 1.22 s, 1.20 s, 1.04 s.

3. FIELD INVESTIGATION

The field investigation of the building was conducted by the authors and the remaining of seismic performance index R was obtained in the field, following the guidelines of The Japan Building Disaster Prevention Association (2002). It is to be noted that this calculation was done based on observations of the first floor only. The residual capacity of the building was found to be 90% of the original strength, which suggests that the superstructure had undergone some damage to its structural members at the first floor level. The calculation sheets are shown in Figures 1b and 2. Schmidt hammer test of the concrete was performed in the field and the compressive strength of the concrete was found to be around 45 MPa but the design value was considered during the numerical analysis.

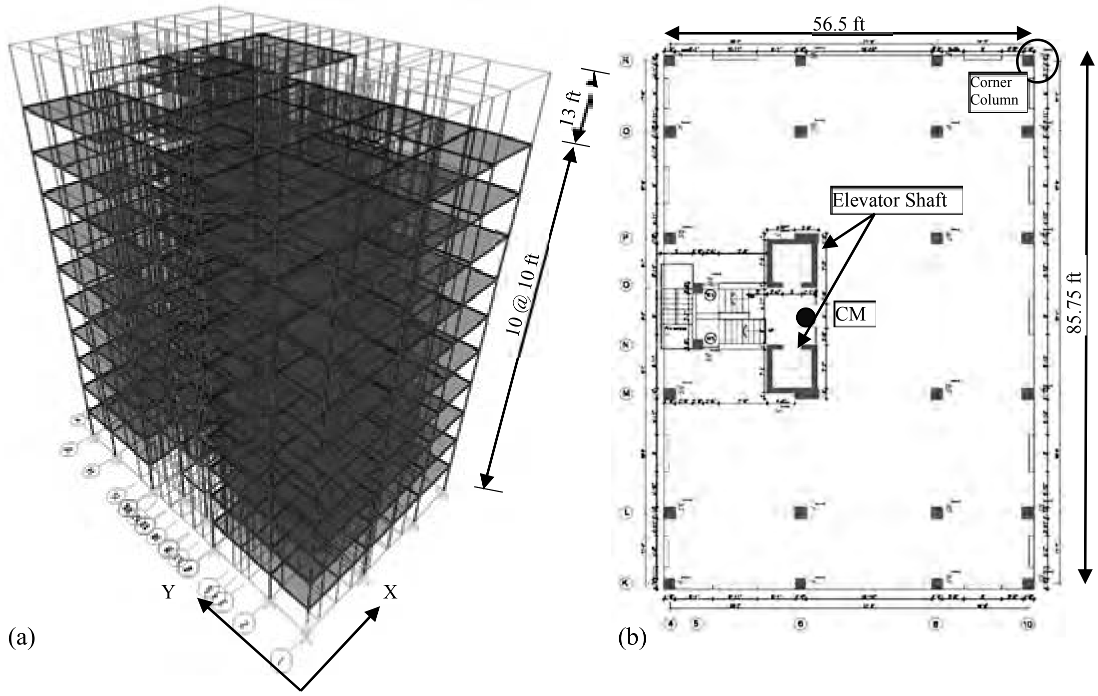
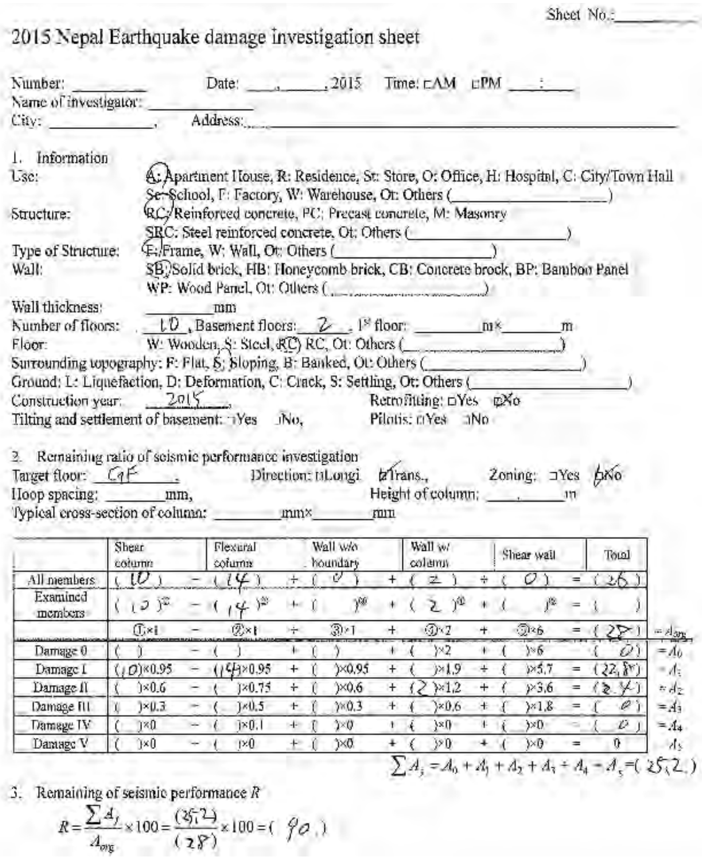


Figure 1: Ten-story RC building: (a) three-dimensional model (b) first floor plan. (Note: Types of crack observed in structural elements of first floor during field observation are shown).



Sheet No.:________

2015 Nepal Earthquake damage investigation sheet

Number: ________ Date: ___, _____, 2015 Time: □AM □PM ___:___
Name of investigator: __________
City: __________, Address: ______________________________

1. Information
Use: A: Apartment House, R: Residence, St: Store, O: Office, H: Hospital, C: City/Town Hall
Sc: School, F: Factory, W: Warehouse, Ot: Others (______________)
Structure: RC: Reinforced concrete, PC: Precast concrete, M: Masonry
SRC: Steel reinforced concrete, Ot: Others (______________)
Type of Structure: F: Frame, W: Wall, Ot: Others (______________)
Wall: SB: Solid brick, HB: Honeycomb brick, CB: Concrete brock, BP: Bamboo Panel
WP: Wood Panel, Ot: Others (______________)
Wall thickness: ________mm
Number of floors: 10, Basement floors: 2, 1st floor: ______m× ______m
Floor: W: Wooden, S: Steel, RC: RC, Ot: Others (______________)
Surrounding topography: F: Flat, S: Sloping, B: Banked, Ot: Others (______________)
Ground: L: Liquefaction, D: Deformation, C: Crack, S: Settling, Ot: Others (______________)
Construction year: 2015, Retrofitting: □Yes ☒No
Tilting and settlement of basement: □Yes □No, Pilotis: □Yes □No

2. Remaining ratio of seismic performance investigation
Target floor: GF Direction: □Longi ☑Trans., Zoning: □Yes ☑No
Hoop spacing: ______mm, Height of column: ______m
Typical cross-section of column: ______mm× ______mm

	Shear column		Flexural column		Wall w/o boundary		Wall w/ column		Shear wall		Total	
All members	(10)	+	(14)	+	(0)	+	(2)	+	(0)	=	(26)	
Examined members	(10)①	+	(14)②	+	( )③	+	(2)④	+	( )⑤	=	( )	
	①×1	+	②×1	+	③×1	+	④×2	+	⑤×6	=	(28)	$=A_{org}$
Damage 0	( )	+	( )	+	( )	+	( )×2	+	( )×6		(0)	$=A_0$
Damage I	(10)×0.95	+	(14)×0.95	+	( )×0.95	+	( )×1.9	+	( )×5.7	=	(22.8)	$=A_1$
Damage II	( )×0.6	+	( )×0.75	+	( )×0.6	+	(2)×1.2	+	( )×3.6	=	(2.4)	$=A_2$
Damage III	( )×0.3	+	( )×0.5	+	( )×0.3	+	( )×0.6	+	( )×1.8	=	(0)	$=A_3$
Damage IV	( )×0	+	( )×0.1	+	( )×0	+	( )×0	+	( )×0	=	(0)	$=A_4$
Damage V	( )×0	+	( )×0	+	( )×0	+	( )×0	+	( )×0	=	0	A_5

$\sum A_j = A_0 + A_1 + A_2 + A_3 + A_4 + A_5 = (25.2)$

3. Remaining of seismic performance R

$$R = \frac{\sum A_j}{A_{org}} \times 100 = \frac{(25.2)}{(28)} \times 100 = (90)$$

Figure 2: Field observation sheet.

4. MODELING OF THE BUILDING

Modeling and analysis of the building was done using SAP2000 V15 (CSI 2013). The beams and columns were modeled using rectangular frame elements (rectangular sections), while the core walls of the elevator shafts were modeled using a frame element (box section) representing equivalent wall sections. Similar techniques have been adopted in many studies to model shear walls (Rana et al. 2004, Rahman et al. 2012). To maintain the connectivity of the walls with the frame, it was connected at the floor level with rigid links. For all the beams and columns, a cracked section was assumed with an effective stiffness equal to 50% of the gross section. In-plane rigidity of the floors was considered by a rigid diaphragm action. The gravity loads from the infill walls and staircase were applied to the beams, hence, explicit modeling of these components were not conducted.

In order to model the nonlinear behavior in the structural components, nonlinear hinges were assigned to each frame element. The default hinge properties available in SAP2000 which is based on FEMA 356 (FEMA 2000) is used. The PMM hinges that combine axial force and biaxial bending (i.e. axial force-moment interaction) was assigned to both ends in all the columns, while M3 hinges (representing the out-of-plane bending) were assigned to the beam ends. For the walls, PMM hinges were applied only at the first floor as plastic hinges are expected to be formed at the base level.

5. NUMERICAL ANALYSIS AND RESULTS

A three-dimensional model of the building was created and pushover analysis and nonlinear response history analysis (NLRHA) under bidirectional seismic excitation were performed. The ground motion considered for the NLRHA is the record of Kantipath (KATNP) station in Kathmandu available from the USGS (USGS 2015) strong motion center database. Time history plots of the records are shown in Figure 3. For the analysis, the EW and NS components were applied in X- and Y-directions, respectively, while the vertical component was not considered in this study. The PGA at the station was $0.158g$, and $0.164g$ in EW and NS directions, respectively, which is thought to be amplified at other locations where heavy damage was observed. The building was re-analyzed using the same ground motions with a scale factor of 1.5, hereafter referred as 1.5KATNP, to investigate the behavior under the increased intensity.

5.1 Pushover analysis

Pushover analysis in the X- and Y-directions considering the P-delta effect was carried out for the building using an inverted triangle load pattern (tri) and uniform load pattern (uni). The pushover curve of the building is shown in Figure 4, where the base shear coefficient V/W is plotted against the roof drift ratio. Here, V is the base shear force and W is the seismic weight of the building. After the plastic hinge formation in the wall elements were observed, a drop in the pushover curves can be seen as indicated in the figure. The drop in the pushover curve corresponds to the point C shown in Figure 4. Uniform load pattern resulted in larger base shear compared to that of inverted triangular pattern.

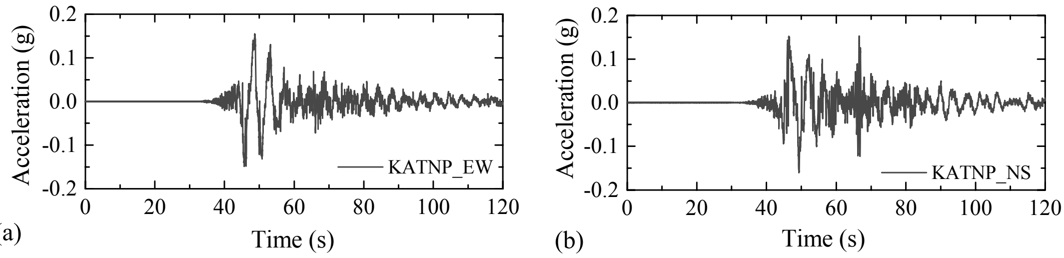


Figure 3: Acceleration time history recorded at Kantipath station, Kathmandu: (a) EW-direction and (b) NS- direction. (Source: http://www.strongmotioncenter.org/).

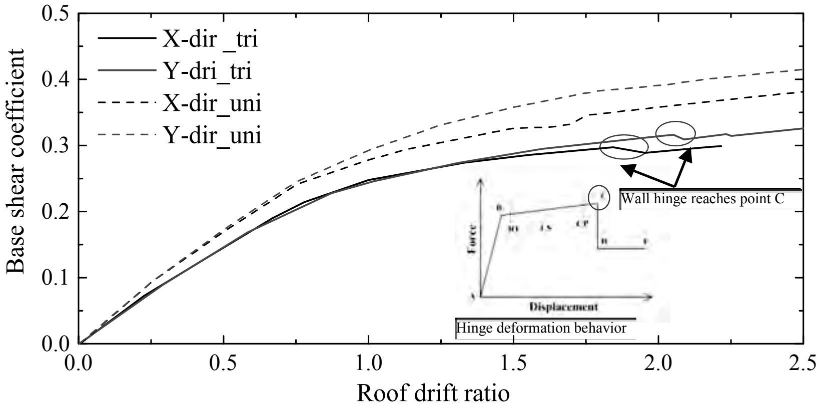


Figure 4: Pushover curves for the building.

5.2 Nonlinear response history analysis

Figure 5 presents the results for peak inter-story drift ratio, peak floor displacement, peak normalized story shear force and peak absolute floor accelerations under KATNP ground motion. Peak inter-story drift ratio, peak floor displacement, and peak absolute floor accelerations are shown at the center of mass (CM) and one of the corner columns (see Figure 1b for the location of CM and the corner column). Maximum inter-story drift ratio along the height of the building is 1.0% at CM whereas it is about 1.15% at the corner column (Figure 5a), signifying the effect of torsion in the building. Since, the building was subjected to twisting action as observed in the numerical analysis, this could be a reason for a few cracks in the walls and some columns that were observed during the field investigation. The displacements for the CM and corner columns are shown in Figure 5b. The floor displacements in X- and Y-directions at CM and corner column are nearly the same. The maximum value of the normalized story shear force at the base in X-direction is about $0.29W$ (Figure 5c). The base shear corresponding to the roof drift (obtained from response history analysis) is well predicted when a uniform load pattern is considered during the pushover analysis. Although the results from numerical analysis show the base shear reaching its ultimate capacity, the field observation did not represent such a damage state. This could be due to the ground motion considered, which is not scaled to represent the site condition. Besides this, the strength of the concrete obtained by Schmidt hammer test was about 1.5 times the value considered during the analysis and the modeling assumptions where the basement was neglected and the boundary conditions considered for the analysis could have led to such a large demand in the building. The acceleration in the floor level varied from $0.15g$ at the base to a maximum value of about $0.3g$ at higher floor levels (Figure 5d). There is only a slight variation in the value of peak floor acceleration at the CM and the corner column.

Under 1.5KATNP ground motion record, there was significant variation in the results of inter-story drift ratio for X- and Y-direction as well as at CM and corner column (Figure 6a). Maximum inter-story drift ratio of the building in the X-direction increased up to 1.9% indicating that there can be severe damage in the building. The maximum difference between the value of inter-story drift ratio between CM and corner column is significant as seen in Figure 6a, signifying that the building could twist leading to failure of the lateral load resisting system. The displacement in the X-direction at CM and corner column increased significantly (Figure 6b) compared to the case of KATNP ground motion. The base shear of the building reached about $0.45W$ indicating that the capacity is exceeded and severe damage can occur. The peak floor acceleration in the Y-direction increases drastically up to $0.7g$ for the corner column while it is about $0.45g$ in the X-direction. At the CM, the acceleration at the base and roof for both the X- and Y-directions are almost the same while some variations can be seen along the floor levels. The distribution of acceleration along the floor indicates the higher mode effects in the building.

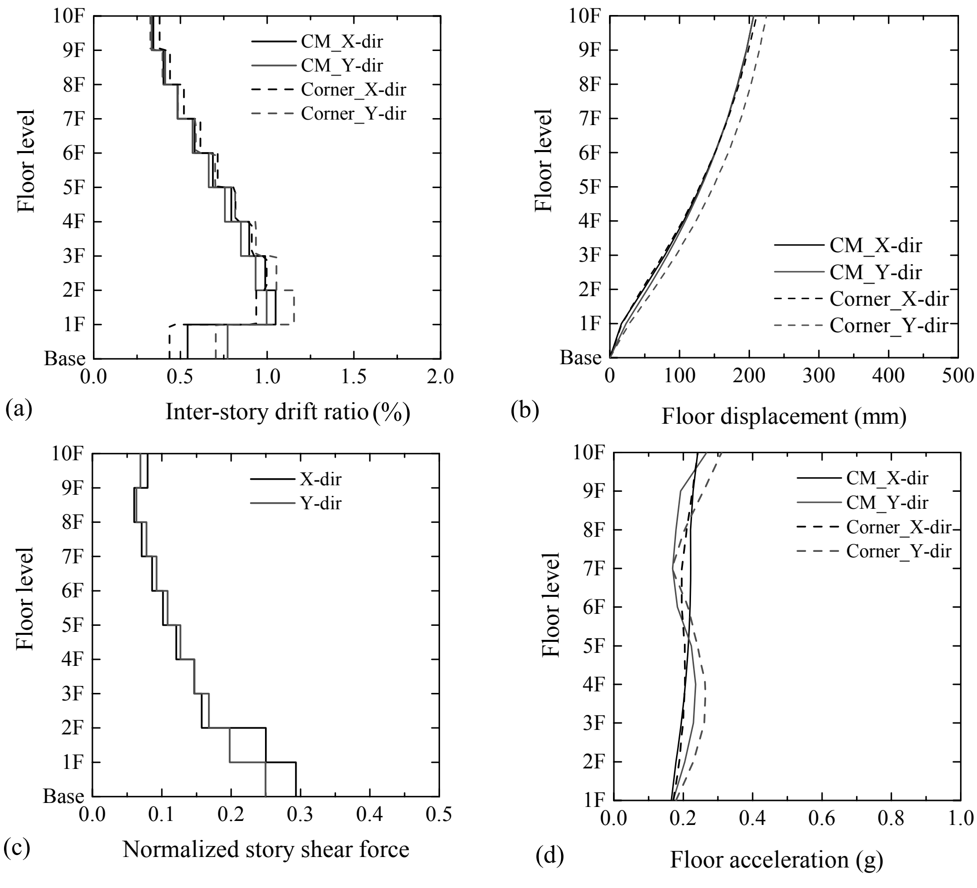


Figure 5: Peak response of superstructure under KATNP ground motion record: (a) inter-story drift ratio, (b) floor displacement, (c) normalized story shear force, (d) floor acceleration.

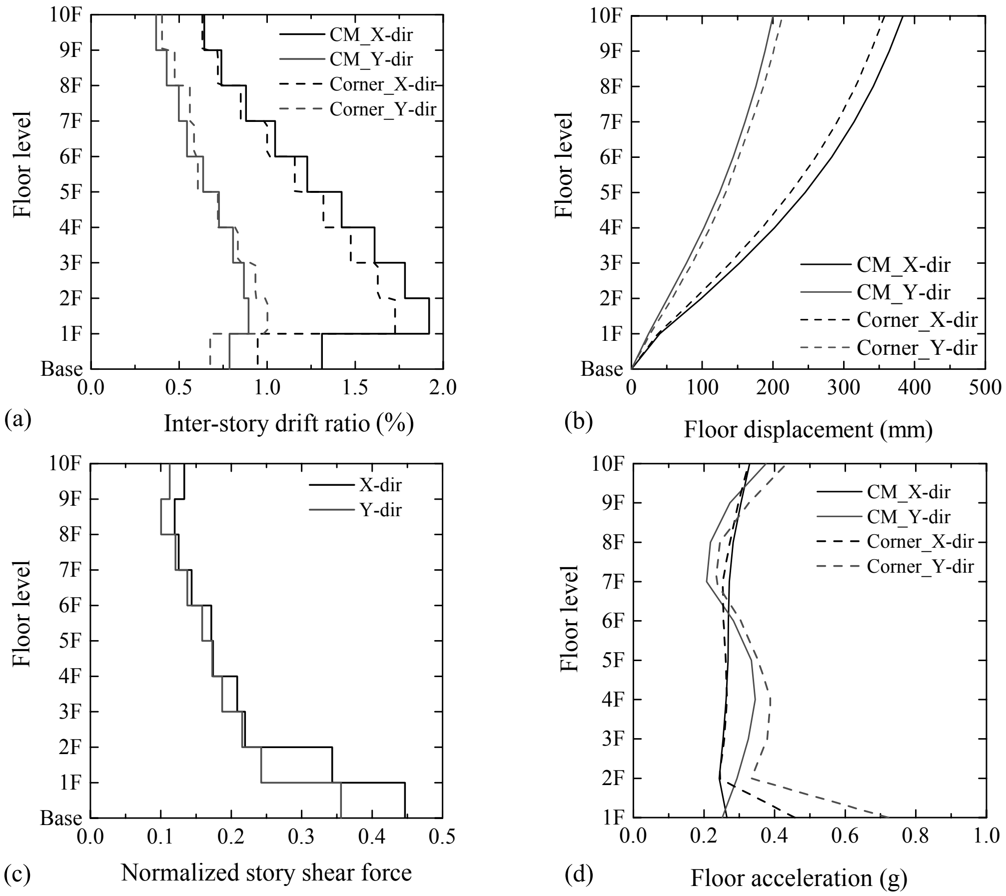


Figure 6: Peak response of superstructure under 1.5KATNP ground motion record: (a) inter-story drift ratio, (b) floor displacement, (c) normalized story shear force, (d) floor acceleration.

6. CONCLUSIONS

The seismic performance of a 10-story building which is typical type of high-rise RC buildings constructed in Nepal is studied. The building is evaluated using nonlinear static and nonlinear response history analysis. Based on the results of the nonlinear analysis, the following conclusions can be drawn:

- Although the base shear capacity of the building is significantly larger than the design value, the earthquake induced base shear is large enough to cause damage. But the damage observed in the field was very less which could be due to the site effect, use of nominal strengths of concrete and steel rather than the expected values.
- Torsional behavior of the building could be observed as there were notable differences in the inter-story drift ratio at the CM and corner column, when the ground motion without any scale factor was considered.
- The maximum inter-story drift ratio of the building under the earthquake was 1.2% and this value reached 1.9% when a scale factor of 1.5 for the ground motion was used, indicating that the building may not be able to sustain higher seismic demands.
- On increasing the scale factor of the ground motion record by 1.5, the displacement in the *X*-direction increases drastically compared to that of the *Y*-direction.

Hence, it can be stated that although the building is designed following the Indian Standards, the resistance to seismic demands is inadequate. To enhance the performance of the building, and to avoid torsional behavior the stiffness should be increased by adding shear walls to the flexible side. The authors also recommend the use of instruments to monitor the behavior of the buildings which can be the basis for the construction of new buildings in the vicinity.

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Observed Damage Patterns on Buildings during 2015 Gorkha (Nepal) Earthquake

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ABSTRACT

This paper outlines the common observed failure patterns in the buildings of Nepal after M7.8 Gorkha (Nepal) earthquake. Several types of damage patterns were observed for reinforced concrete buildings, as well as for unreinforced masonry and adobe houses during the reconnaissance survey performed immediately after the earthquake of 25 April 2015. Several field visits in the affected districts have been performed and associated failure/damage patterns have been reported and analyzed. This paper also covers damage patterns in non-engineered buildings, middle and high-risebuildings, commercial complexes, administrative buildings, schools and other critical facilities from Kathmandu valley as well as other affected districts. The construction and structural deficiencies are identified as the major causes of failure, however local soil amplification, foundation problems, liquefaction associated damages and local settlement related damages are also significantly observed during this earthquake and reported in the present paper. In the end, the lessons learned from the field survey are resumed in order to give some guidelines for future construction practices.

Keywords: *Gorkha earthquake, building damage, reinforced concrete structures, unreinforced masonry buildings, adobe houses*

1. INTRODUCTION

On 25 April 2015 a strong earthquake of M7.8 hit central Nepal and its vicinity (USGS, 2015) causing 8787 casualties and 20000 injuries. Around 500000 buildings, 4000 government offices and 8200 school buildings are damaged due to this earthquake. The hypocentral depth was about 15km and it was immediately followed by strong aftershocks of M6.9 and M6.7. The earthquake was located at Gorkha district of central

Nepal near the Barpak village around 77 km NW of Kathmandu. A strong aftershock of M7.3 also jolted central Nepal on 12 May, which further enhanced the damage and casualties. Total of 8 million population was affected by this earthquake and several thousands of aftershocks everyday for around three months. Six of the fourteen districts in Nepal were severely damaged causing enormous property and infrastructural damage. People remained outside their house under tarpaulins/tents for around a month due to frequent aftershocks and also prevailing minor to severe damages.
A general description of Nepalese building construction frameworks and associated deficiencies in terms of structural as well as construction scenario has been discussed in this paper. Furthermore, this paper attempts to correlate the building damage pattern associated with structural and construction deficiencies. Moreover, the failure types and identified causes are presented drawing conclusions from extensive field reconnaissance in 11 districts in central Nepal.

2. BRIEF HISTORY OF BUILDING CONSTRUCTION IN NEPAL

Building construction in Nepal dates back to several thousand years, though the reminiscent of bricks from Buddha's period are the most reliable sources. It could be said that before 2500 years, there used to be masonry construction system in Nepal. Most of the traditional settlements of Kathmandu valley are of around 13th century and the history of villages dates back to similar time. The adobe construction and random rubble masonry constructions are more popular in villages of Nepal, however most of the urban and suburbs constitute majority fraction of masonry buildings with around 20% of reinforced concrete (RC) construction. So, it is obvious that 80% of the buildings are non-engineered construction; however majority fraction of RC construction is also covered by non-engineered or pre-engineered construction as owner built houses (CBS, 2012). Past studies have shown the vulnerability of buildings to be very high and predicted a severe damage (JICA, 2002; Chaulagain et al., 2014; Chaulagain et al. 2015**).** After 1980, the trend of RC construction was evolved in Nepal and most of the RC buildings are of 2-6 stories with exception of a few 7 to 11 stories buildings. The trend of RC construction is being more popular than any other construction types though economic constraints, availability of construction materials and technology, lack of optimized design, lack in enforcement of building regulations are some of the loopholes that are degrading the quality of construction ultimately increasing vulnerability of buildings. Regarding other types of structures, it is obvious that older and non-engineered constructions are enhancing the vulnerability. With exception to some severe but localized damages in RC buildings, most of the damage was concentrated in masonry, random rubble and adobe constructions during 2015 Gorkha Nepal earthquake. This earthquake also correlates with the severe damage of unreinforced masonry (URM) structures during 1934 earthquake (Rana, 1935**)** and also the damage patterns are similar for many urban fabrics and outskirts.

3. MATERIALS AND METHODS

Immediately after the earthquake of 25 April, many field observations were carried out within and outside the Kathmandu valley. Affected districts namely; Kathmandu, Lalitpur, Bhaktapur, Kavrepalanchowk, Sindhupalchowk, Dolakha, Nuwakot, Gorkha, Dhading, Solukhumbu, Makwanpur, Tanahun and Kaski were covered in field visits at different times. The damaged buildings were analyzed in terms of construction history, structural adequacy, building components, binding materials and adopted technology for construction. Non-structured interviews were conducted during reconnaissance and associated failure types were pictured. The pictures were analyzed for identifying the causes of failure. The reconnaissance covered mainly four types of building; RC, URM, random rubble construction and adobe. As completely wooden constructions were not identified during reconnaissance, performance of those four types of buildings was judged under the basis of common earthquake resistant construction bases.

4. STRUCTURAL AND CONSTRUCTION DEFICIENCIES AND ASSOCIATED DAMAGES IN BUILDINGS DURING 2015 GORKHA EARTHQUAKE

4.1. Construction and structural deficiencies and associated damages in RC buildings

About 20% of buildings in Nepal are RC buildings (CBS, 2012). The construction of RC buildings only started after 1970, though the mushrooming number of RC construction was started only after 1990. Even though the RC construction was started in 1970s, engineered construction was only felt after enforcement of building codes in 2006 and almost 70% of existing RC buildings are either owner built constructions with the help of contractors or constructed as per the mandatory rules of thumbs (MRT). Smaller fraction of buildings are structurally analyzed, designed and constructed. After more localized concentration of RC building damage during 2015 Gorkha earthquake, several field visits and case studies have reflected many of the deficiencies associated with construction or structural aspects have been highlighted in recent dates.

4.1.1. Soft storey

During the fieldwork performed immediately after the 2015 Gorkha earthquake, it has been observed that soft storey failure in RC construction is dominant over any other type of structural deficiencies. The common type of building framing is moment resisting with monolithic slab casting in beams and columns. The foundation type usually adheres as isolated footing in residential level. The ground floor in almost 90% RC buildings is used for commercial purpose and provided with shutters (Fig. 1(a)). The upper stories of such houses are provided with infill brick masonry walls. Similarly, in case of high-rise constructions, the ground floor is left open for parking or even sometimes basement parking is provided without infill walls (Fig. 1(b)). Such practices have led the soft storey failure during 2015 earthquake in most of the damaged RC buildings (Fig. 1(c)). Due to lack of infill wall on ground floor, the increased flexibility has clearly led the increased displacement in first floor thus majority of the cracks or minor damages are found to be concentrated therein during reconnaissance.

4.1.2. Horizontal and vertical re-bars

The vertical rebar are mostly limited to 12mm diameter to 16mm diameter and usually in four in number (Fig. 1(d)). In most of the collapsed buildings, the vertical rebar were usually four in number, however majority of the building columns were found to be constructed with six rebar in vertical direction. The intense damage was significantly governed by the horizontal rebar (Fig. 2(a)). The horizontal rebar were found to be 6mm diameter bars usually gaped in regular interval of 0.15m or more. The horizontal rebar in infill walls are not found to be provided in residential constructions with exception to some apartments. More significantly, the connection between various structural components was also found to be poor. In some cases, it has been observed that people preferred welding for connection of vertical reinforcements rather than anchoring thus failures were observed in those columns.

Fig. 1(a) Ground floor of residential buildings without infill walls (b) Ground floor of an apartment building without infill wall (c) Soft storey failure of buildings and (d) exposed detailing showing insufficient rebar

4.1.3. Floating columns

In order to cover up maximum area, upper stories are constructed more in balconies. In such practices, floating columns from first storey are commonly observed in residential construction within as well as outside Kathmandu valley (Fig. 2(d)). Due to lack of continuous load path during earthquakes, the lateral forces are not effectively transferred to the foundation. The overturning forces developed lead to buckle the columns of ground floor and subsequent damage was noticed in some buildings.

4.1.4. Soil investigation and foundation site selection

Soil investigation before construction is seldom performed for residential buildings in Nepal. Even metropolitan cities, sub-metros and municipalities are not able to enforce mandatory geotechnical investigation before construction. The severely damaged areas of Sitapaila and Gongabu have soil bearing capacities of 52 KN/m^2 and 106 KN/m^2 respectively. As per Nepal building code these sites are classified as weak to soft foundation types (NBC, 1994) though effective remedies weren't incorporated for building constructions. Instead of foundation improvement, additional stories were constructed in weak columns of 0.23*0.23m.

Due to lack of microzonation and site-specific design spectrum, construction practices are similar for all over Nepal. Though MRT is mandatory in many urban areas, most of the recently declared municipalities lack the basic earthquake resistant features in residential level. The effect of topographic amplification, ridge effect and local site effects are clearly identified due to the more localized nature of damage during 2015 Gorkha earthquake.

Fig. 2: (a) Damage due to large gap between stirrups (b) beam-column joint defect (c) collapsed column due to welded stirrups and (d) floating column failure

4.1.5. Other damages and causes

- Building asymmetry
- Load accumulation in upper stories
- Building proximity
- Non-structural element failure (staircases, water tanks and parapet walls, etc.)
- Inclined and stepped foundation
- Construction material and workmanship deficiencies (Fig. 2(b) and 2(c))

4.2. Construction and structural deficiencies and associated damages in URM buildings

Most of the urban center in Kathmandu valley and older settlements outside Kathmandu valley consists larger fraction of unreinforced masonry buildings constructed from burnt-clay bricks.

4.1.6. Structural integrity

Almost all, except some URM buildings do not consist bands at various levels like; sill, lintel or gable. Due to lack of proper bonding in masonry load bearing wall, out of plane collapse was more commonly observed in Kathmandu valley and other settlements abundance of URM buildings (Fig. 3(a), 3(b)). In most of the URM building, the orthogonal walls were found to be behaving differently due to lack of proper tie between such walls. Also due to lack of integration of several members within the structural components, out of plane failures were more intense than any other type of failure.

Fig. 3(a) Out of plane collapse of brick masonry building due to lack of structural integrity (b) out of plane collapse of dressed stone masonry building due to lack of structural integrity at Solukhumbu (c) Failure of masonry units due to lack of proper binding and (d) Mud mortar used for reconstruction of URM building destroyed during 2015 Gorkha earthquake at Bhaktapur

4.1.7. Binding materials

The structural integrity depends also on monolithic and homogenous behavior of masonry structures; however the mud mortar used for binding the brick/stone units were found to detached already and brick/stone units were found to be behaving separately (Fig. 3(c)). This binding problem led the severe devastation during 2015 Gorkha earthquake in the historic settlements of Kathmandu, Lalitpur, Bhaktapur, Sankhu, Harisiddi, Barpak, among others. Even after the earthquake damage people were found to be using the same binding material for reconstruction (Fig. 3(d)). This could be detrimental in future events.

4.2.3. Load path discontinuity

The reentrant corners and diaphragm discontinuities are also noticed in masonry construction practices in Nepal. Masonry buildings up to six stories have been found inside Kathmandu valley and outside Kathmandu, the number of stories for masonry buildings is limited to four. Sometimes in upper stories, projections were noticed and the load transfer mechanism was not made continuous. Struts in some masonry buildings performed the work of transferring the load into structural wall, but in majority of buildings do not constitute struts.

4.2.5. Other damages and causes

- Shared walls and wall thickness
- Inclined foundation and soil problems
- Heavy roofs (roof tiles)
- Age of buildings
- Pounding and progressive failures

4.3. Construction and Structural deficiencies and associated damages in random rubble masonry buildings

This building type in Nepal constitutes majority of buildings fraction in Nepal. These are non-engineered constructions without following any earthquake resistant construction guideline. The rural construction is either guided by adobe or random rubble masonry construction in terms of dry stone masonry buildings. Though rural constructions are isolated type building units with lower height, preferably from one to three stories yet deficiencies in terms of structural composition and construction technology are widely noticed during field reconnaissance. Heavy wall of rubble stones with irregular shape and size up to 0.53m thick was observed. Beside the irregular stones, in majority of houses, there was no cornerstone so out of plane failure in all orthogonal walls was commonly observed. Timber bands were seldom noticed in most of the damaged houses in all reconnaissance sites, however the heavy roof like in the epicentral area of Barpak constructed from stone was also responsible for causing severe damage. Smaller chips to heavy stone pieces were found to be used to construct walls, sometimes such arrangement itself was found to be triggering the pancake destruction houses due to lack of structural integrity. Those houses with timber elements were found to be less damaged than the homogenously constructed stone houses.

4.4.Construction and Structural deficiencies and associated damages in adobe buildings

Adobe buildings are also non-engineered constructions prevalent in many urban fabrics as well as in suburbs and villages in Nepal. Most of the adobe constructions constitute either non-burnt clay brick walls or even sometimes clay units of irregular shapes. The roofing may be of tiles, thatched or sometimes stones as well. The structural integrity is not justified in adobe houses due to poor binding and non-homogenous construction. Somehow, the brick units behave separately rather than combined action against the earthquake motion. The roof if provided with tiles is also heavy thus damages were frequent in such houses during 2015 Gorkha earthquake. Adobe constructions are also found to be one to three storied and houses with more heights were affected more than the single storied adobe houses.

5. CONCLUSION

The Gorkha earthquake of 25 April 2015 reflected the performance of various types of buildings. After field reconnaissance in buildings of various types, many types of construction as well as structural deficiencies were identified. The RC, URM, random rubble construction and adobe construction were found to be the dominant construction systems of Nepal. The majority fraction of damage was found to be consisted by damage in URM, random rubble and adobe buildings of central Nepal. Moreover, RC damage is found to be localized so many reasons except structural and construction deficiencies like liquefaction, local site effects, and ground amplification, among others may have contributed in building damage. The common types of failures in RC construction were identified as the soft storey, pounding, shear failure, and other failures associated with construction as well as structural deficiencies like building symmetry, detailing and others. Moreover, for URM constructions, the structural integrity, heavy load accumulation, age, lack of bracing and pounding were the major cause of complete collapse or out of plane failure. Similarly, binding and structural integrity, lack of tying members, heavy gable and roof construction were the leading cause of damage in random rubble construction and adobe constructions.

About 95% damage is shared by URM, random rubble and adobe buildings, so this earthquake was more devastating towards such buildings in comparison to the performance of RC buildings in affected districts. All the damage was noticeably concentrated into non-engineered or pre-engineered buildings with major flaws in construction or structural components so it could be inferred that engineered constructions should be plausible solution for seismically active regions like Nepal.

ACKNOWLEDGEMENT

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Field Investigation in affected area due to the 2015 Nepal Earthquake by AIJ reconnaissance team: Outline of damage and damage classification result of high-rise apartment buildings

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ABSTRACT

During the 2015 Mw 7.8 and Mw 7.3 Nepal earthquakes, R/C and masonry buildings were significantly damaged. After the event, Architectural Institute of Japan (AIJ) dispatched several reconnaissance teams to the affected area to conduct field investigation. In this paper, discussion is concentrated on the damage of the high-rise apartment buildings, which have 9 to 18 stories. Eleven apartment complexes, which have 36 apartment buildings, were investigated. Most of all buildings suffered slight or very minor damage. Non-structural brick walls were, however, severely damaged and some portion fallen down, which is crucial to residents. The outline of their damage will be presented. Damage level of 5 apartment buildings were classified according to the Japanese Damage Classification Method. The method classifies all members into 5 damage levels, then calculates the ratio of residual seismic capacity to the original one. The ratios of the buildings were 96%, 90%, 94%, 97%, and 98%, respectively. Three of them were classified as "slight damage", and two of them were done as "minor damage". It can be said that the structural damage level of the high-rise apartment buildings was low.

Keywords: reinforced concrete, high-rise apartment buildings, earthquake damage, damage classification

1. INTRODUCTION

The earthquake of Mw7.8 occurred at 80km north-west from Kathmandu city at 11:56, April 25th, 2015. After that, anther earthquake occurred at north east of Kathmandu city at 12:51, April 12, 2015. It was reported by Nepalese government that number of casualty was 8,460 and more than 20,000 people were injured due to earthquakes (as of May 15th).

Facing this catastrophic events, the research committee on earthquake disaster of Architectural Institute of Japan (AIJ) started to gather information on the disaster, and summoned an emergent meeting. During the meeting, it was decided to dispatch a disaster reconnaissance team to the affected area led by Dr. Kusunoki (Earthquake Research Institute, the University of Tokyo). The reconnaissance team had three groups. This paper introduce outline of the AIJ reconnaissance team and presents the investigation result of team A, of which target was the damage investigation of high-rise apartment building.

2. OUTLINE OF AIJ RECONNAISSANCE TEAM

Table 1 shows the member list of the AIJ reconnaissance team. Fifteen researchers joined the team. Field investigation of main team was conducted during May 23rd to May 31st. Ground motion team conducted field survey during May 1st to 10th. The objectives of the AIJ reconnaissance team were to investigate the followings;

1. The damage of middle- to high-rise buildings
2. The damage of the buildings outside of Kathmandu City
3. The damage of historical and monumental buildings/structures
4. The damage of the buildings inside of Kathmandu City
5. The damage ratio in a specific area inside Kathmandu City
6. The strong motion records

Table 1. Member list

Leader, Team A Leader	Koichi KUSUONKI	ERI, Univ. of Tokyo
	Susumu KONO	Tokyo Tech. Institute
	Seitaro TAJIRI	Univ. of Tokyo
	Hisatoshi KASHIWA	BRI
Team B Leader	Yasushi SANADA	Osaka Univ.
	Yuebing Li	Osaka Univ.
	Yukiko NAKAMURA	Chiba Univ.
	Takaya NAKAMURA	Niigata Univ.
	Ayako MAESHIMA	Meikai Univ.
	Takeyuki OKUBO	Ritsumeikan Univ.
Team C Leader	Yo HIBINO	Hiroshima Univ.
	Akihiro NAKAMURA	Nagoya Univ.
	Naoki ONISHI	Hokkaido Univ.
	Yusuke MAIDA	Chiba Univ.
Ground motion	Nobuo TAKAI	Hokkaido Univ.

In order to achieve the objectives, the main team was divided into three teams, Team A, Team B, and Team C. Team A investigated damage of high-rise apartment buildings. In total, 13 complexes (38 buildings) were investigated. Architectural/structural drawings, calculation documents, and soil test reports of 4 complexes (13 buildings) were obtained. Damage classification was conducted for 5 buildings according to Japanese standard (JBDPA, 2001). This paper introduce the investigation results of Team A.

Team B investigated damage of seven world heritages and two historical districts in Kathmandu City. Masonry buildings and R/C frame structure with brick infilled wall buildings were mainly investigated in 4 districts outside of Kathmandu city. Some school buildings were retrofitted before the earthquakes. The effectiveness of the retrofitting was also investigated. Damage ratio of the buildings in 4 world heritages was also measured.

Team C investigated damages of R/C and masonry buildings in Kathmandu city (Gongabu district). Twenty-one severely damaged buildings were investigated in details and damage classification method was applied for one of these buildings. Damage levels of all buildings in five 500m×350m blocks in Gongabu district were classified according to EMS-98 method. The total number of classified buildings was about 1,200.

3. Damage outline of investigated high-rise apartment buildings

3.1 Outline of the investigated buildings

Table 2 shows the investigated building list by Team A. Figure 1 shows the locations of the investigated buildings. Thirteen complexes with 38 buildings, of which number of stories was 8- to 17-story, were investigated. All buildings are in Kathmandu city. They are R/C frame structures with continuous shear wall mainly around elevator shaft. Non-structural brick walls are used as partition walls and exterior walls, which are not fixed to surrounding structural members. Architectural/structural drawings, calculation documents, and soil test reports of 4 complexes (13 buildings) were obtained. Damage classification was conducted for five buildings according to Japanese standard (JBDPA, 2001). The structural damage levels of the buildings without damage classification were classified according to the visual investigation. The damage of non-structural brick walls was not taken into account. As shown in Table 2, the most damage levels of the investigated buildings were slight to light except Building E. It can be said that most of all investigated buildings have enough seismic capacity to the occurred earthquakes. Non-

Table 2. Investigated building list

Building	Number of Buildings Number of Stories	Structural Damage level
Building A	3, 13-story	Slight
Building B*1	3, 15-story	Slight
Building C*1	2, 15-story	Slight
Building D	1, 11-story	Slight
Building E	5, 15-story and 16-story	Light to Moderate
Building F	3, 15-story	Slight
Building G	1, 8-story	Slight
Building H	1, 9-story	Slight
Building I	4, 8-story, 11-story, and 13-story	Slight
Building J*1, *2	4, 10-story, 12-story, and 13-story	2: Slight, 2: Light
Building K	4, 11-story, 13-story, and 16-story	Slight to Light
Building L*1, *2	2, 14-story	Slight
Building M	5, 17-story	Slight

*1: Building information such as structural/architectural drawings, calculation documents and/or soil test reports are available.
*2: Damage classification was conducted

structural brick walls were, however, severely damaged as shown in Figure 2. The damage of brick walls was observed in the all investigated buildings.

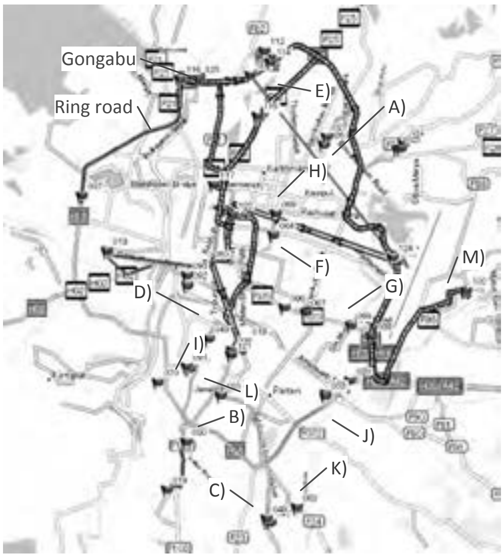

Figure 1: Location of the investigated buildings

Figure 2: Damage of non-structural brick walls

4. Damage classification

4.1 Calculation method

According to the Japanese Standard (JBDPA, 2001), the damage level of building is evaluated using the residual seismic performance ratio, η, which is calculated according to damage level of vertical structural members and the failure mode of members. At first, the damage of vertical members are classified according to Table 3. The standard does not consider the damage of beams, since beams of Japanese old buildings tend to be stronger than columns. In this study, damage of beams are also classified with Table 3. If the damage class of beam is severer than that of connecting column, the damage class of beam is applied for that of connecting column. The damage of non-structural brick walls was ignored in the calculation.

The residual seismic capacity ratio, R, is calculated with considering the effect of damage according to its class. In order to consider the effect of damage, flexural and shear strengths are reduced by multiplying the seismic capacity reduction factor, η, which is defined according to their damage classes. Seismic capacity reduction factor for brittle column and shear wall are shown in Table 4. Seismic capacity reduction factors for other failure modes are defined in the standard (JBDPA, 2001).

Table 3: Damage class of columns and walls

Damage Class	Description of Damage
I	- Visible narrow cracks on concrete surface (Crack width is less than 0.2 mm)
II	- Visible clear cracks on concrete surface (Crack width is about 0.2 -1.0 mm)
III	- Local crush of concrete cover - Remarkable wide cracks (Crack width is about 1.0 - 2.0 mm)
IV	- Remarkable crush of concrete with exposed reinforcing bars - Spalling off of concrete cover (Crack width is more than 2.0 mm)
V	- Buckling of reinforcing bars - Cracks in core concrete - Visible vertical and/or lateral deformation in columns and/or walls

Table 4 Seismic capacity reduction factor, η, for brittle column and shear wall

Damage Class	Brittle column		Shear wall	
	Damaged	After repair	Damaged	After repair
I	0.95	0.95	0.95	0.95
II	0.6	0.95 (crack grouted)	0.6	0.95 (crack grouted)
III	0.3	0.9 (crack grouted)	0.3	0.9 (crack grouted)
IV	0	0.8 (concrete jacketing)	0	0.8 (replaced by new wall)
V	0	0.7 (concrete jacketing)	0	0.7 (replaced by new wall)

The damage class of the building is defined as follows according to the calculated R;

Slight $95\ \% \leq R$
Light $80\ \% \leq R < 95\ \%$
Moderate $60\ \% \leq R < 80\ \%$
Heavy $R < 60\ \%$
Collapse deemed to have $R \approx 0$ due to overall/partial collapse

4.2 Damage classification for Building J

Damage level of Building J was classified according to the Japanese Standard (JBDPA, 2001). The Building J has 4 towers, Tower A to D. They have 12-story+2-BF, 10-story+2BF, 13-story+2BF, and 13-story+2BF, respectively. Basement floors are for parking space and they are all connected. Since most of all members in the first story did not have finishing, the damage classification was conducted for the first story. The damage class of all members in the first story are shown in Figure 3 to Figure 6. The Roman number shows the damage level of each member as shown in Table 3. The subscripts of "F", "S", and "B" mean "flexural damage", "shear damage", and "classified by the damage level of connecting beam", respectively. The calculated R indexes were 93%, 90%, 94%, and 98%, respectively. Although classified damage levels of

Tower A, B, and C are “Light”, the R values are close to border of 95%, and it can be said that the damage is not serious.

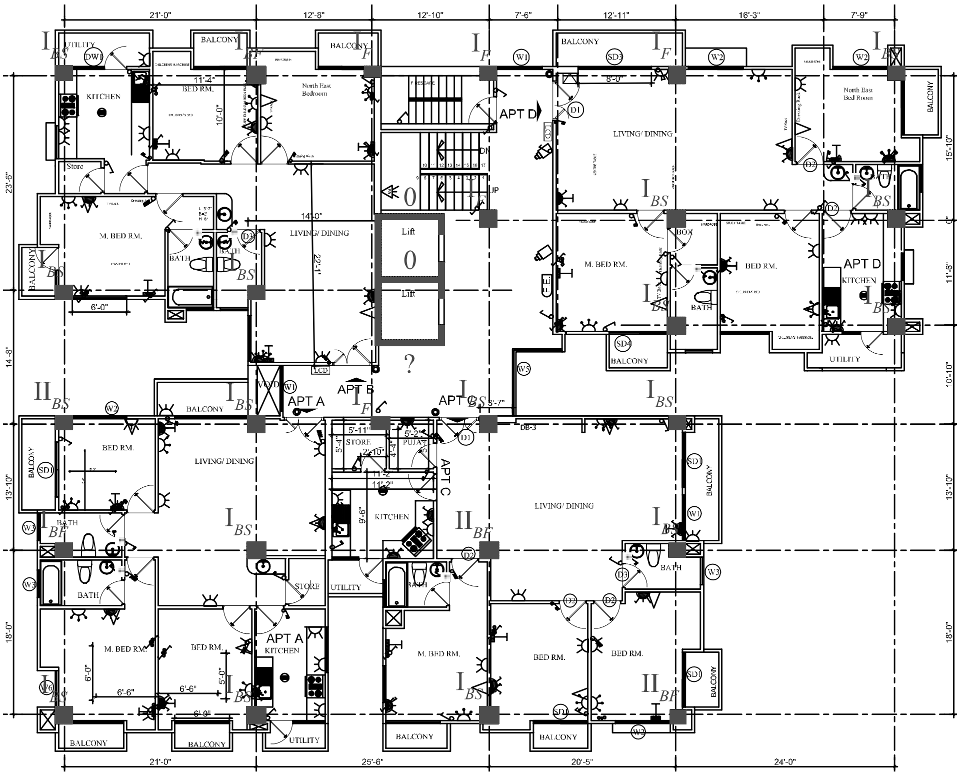

Figure 3: Damage classification result of Tower A

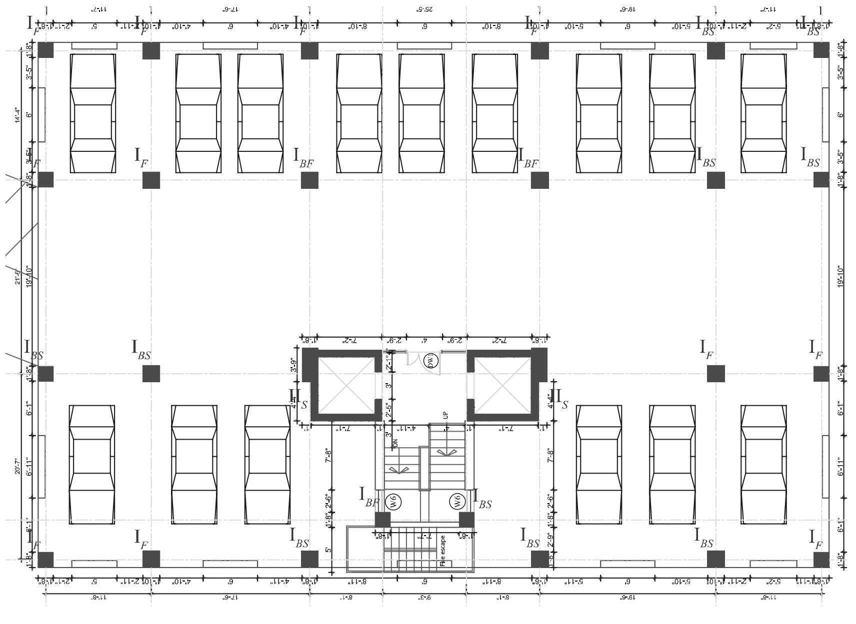

Figure 4: Damage classification result of Tower B

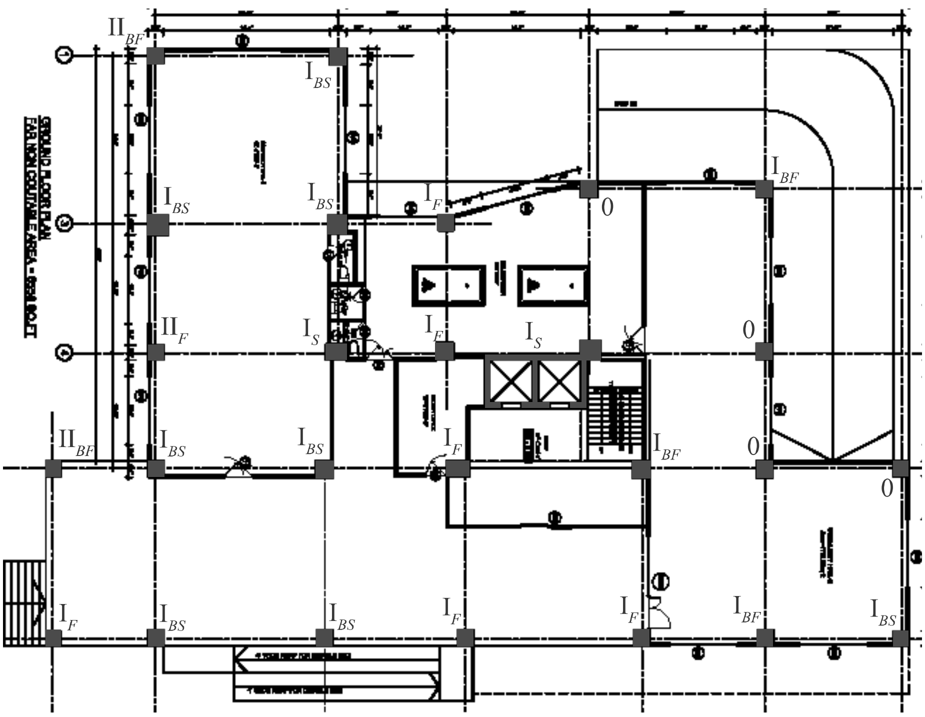

Figure 5: Damage classification result of Tower C

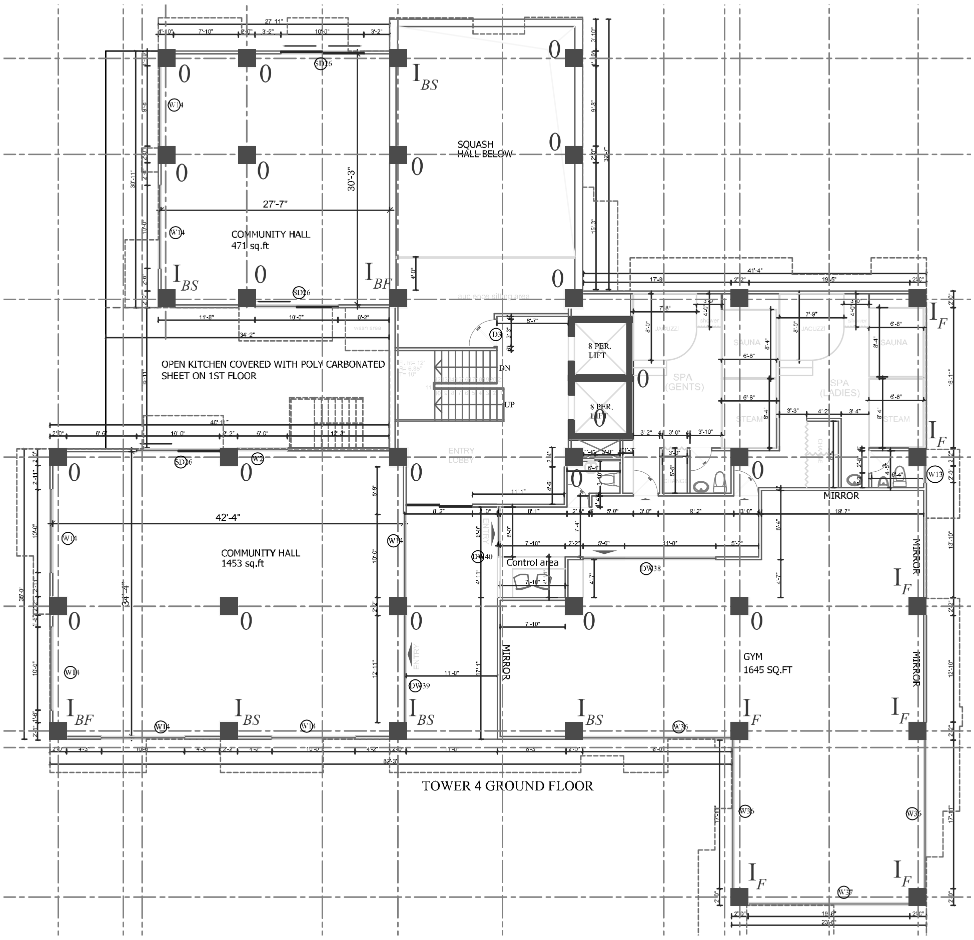

Figure 6: Damage classification result of Tower D

Figure 7 shows the damage of non-structural brick walls. Although the damage level of the structure was slight, the non-structural brick walls were severely damaged and some bricks fell down to floor or even streets. No anchor was observed to fix the brick wall to the surrounding R/C structural members. From the reparability viewpoint, development of retrofitting technique for the brick walls is urgent. Severe damage of non-structural brick walls was observed in the all investigated buildings.

Figure 7: Damage of non-structural walls

7. CONCLUDING REMARKS

Damage of 13 high-rise apartment complexes (38 buildings) due to 2015 Nepal Earthquake was reported in this paper. Structural damage of most buildings were slight to light, which means that the buildings have enough seismic capacity against the occurred earthquakes. The damage of non-structural brick walls were, however, severe, and some of them fell down to the streets, since they were not fixed to the surrounding structural members. Prompt measure to prevent collapse of non-structural brick wall is urgent.

SYMPATHY NOTE AND ACKNOWLEDGEMENT

The investigation members would like to express deepest sympathy to all victims. The investigation was organized by Architectural Institute of Japan. We appreciate Prof. Kabeyasawa, the chair of research committee on earthquake disaster for his arrangements. The Japan Building Disaster Prevention Association also financially supported the investigation. Dr. Prakirna Tuladhar, Senior Divisional Engineer, Department of Urban Development and Building and Dr. Krishna, Tribhuvan University with his colleagues kindly contributed our onsite investigation.

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Field investigation in affected area due to the 2015 Nepal earthquake by AIJ reconnaissance team: Wall-to-floor area ratios of masonry school buildings

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ABSTRACT

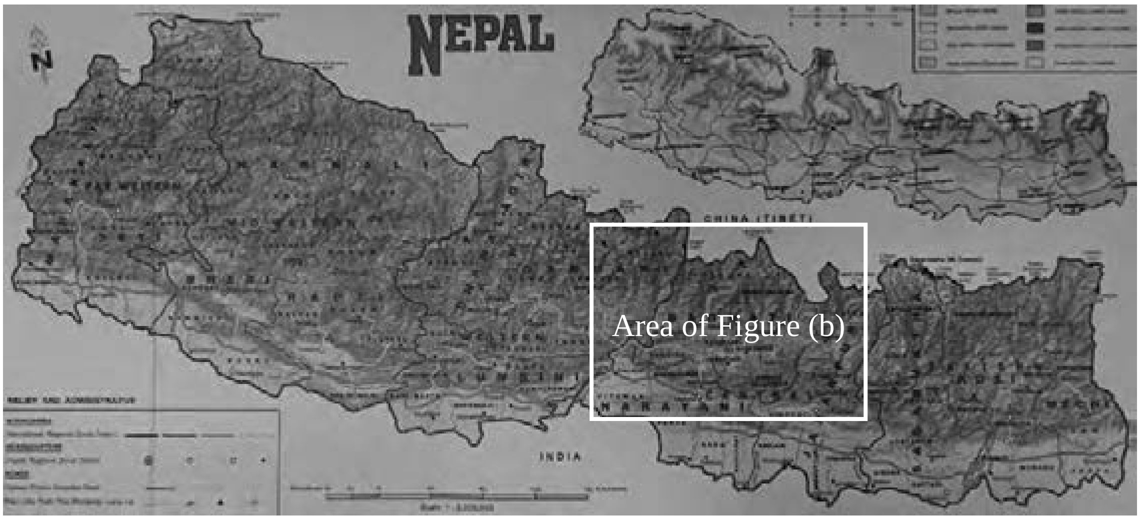
During the 2015 Mw 7.8 and Mw 7.3 Nepal earthquakes, R/C and masonry buildings were significantly damaged. After the event, Architectural Institute of Japan (AIJ) dispatched several reconnaissance teams to the affected area to conduct field investigation.
The authors' post-earthquake field investigation was conducted in the end of May 2015 to obtain specific data on buildings damaged by the earthquakes. The investigation covered Kathmandu, Bhaktapur, Dhading, Lalitpur, Nuwakot, Sindhupalchok districts. This paper reports the investigation results on earthquake damage to masonry school buildings in the above affected area. Severe damage was observed to masonry school buildings constructed by vulnerable materials—namely, stone masonry with mud mortar. Moreover, the paper summarizes the Japanese seismic performance evaluation method for screening seismically vulnerable buildings based on an index of wall-to-total floor area ratio (wall ratio). Therefore, focusing on severely damaged buildings, the wall ratios were evaluated for several types of masonry school buildings. The upper bounds of the wall ratios are feasible for prospective application to a simple screening method for seismically vulnerable school masonry buildings in Nepal.

Keywords: building structure, earthquake damage, EMS, masonry construction, seismic vulnerability assessment

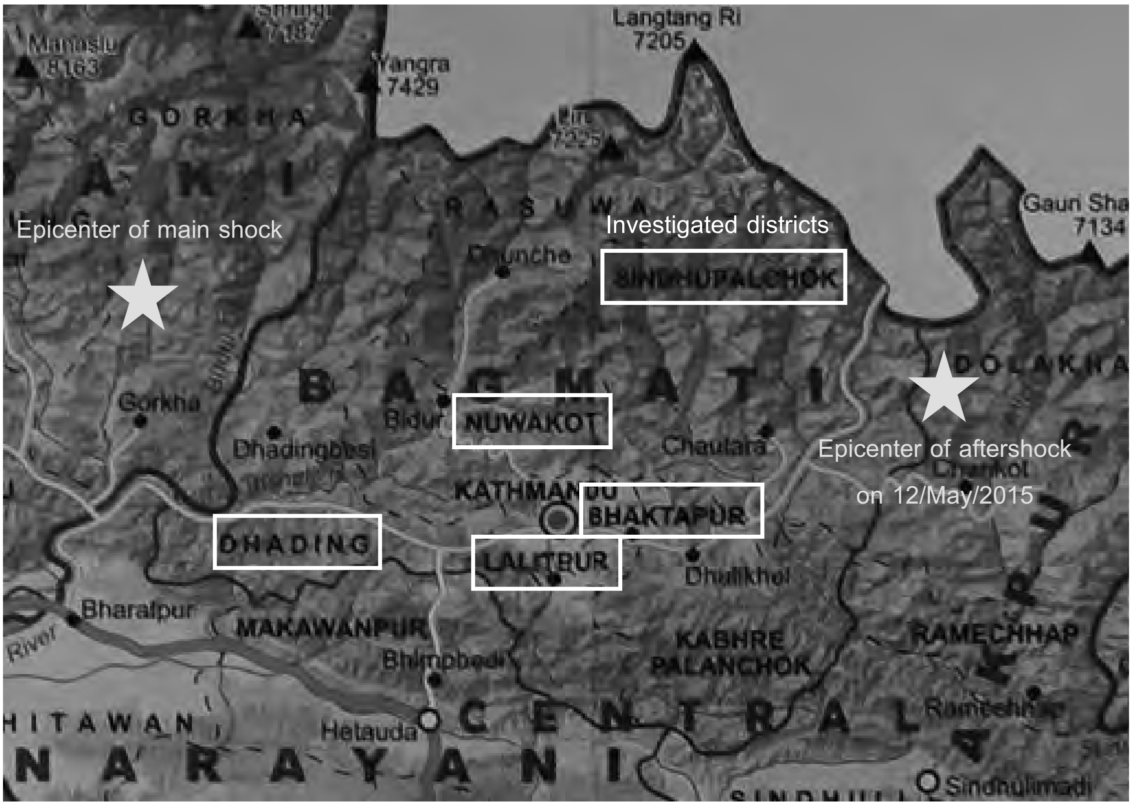
1. INTRODUCTION

During the 2015 Mw 7.8 and Mw 7.3 Nepal earthquakes, R/C and masonry buildings were significantly damaged. After the event, Architectural Institute of Japan (AIJ) dispatched several reconnaissance teams to the affected area to conduct field investigation.

The authors' post-earthquake field investigation was conducted in the end of May 2015 to obtain specific data on buildings damaged by the earthquakes. The investigation covered Kathmandu, Bhaktapur, Dhading, Lalitpur, Nuwakot, Sindhupalchok districts, as shown in Figure 1. This paper reports the investigation results on earthquake damage to masonry school buildings in the above affected area. Figure 2 shows the route map of the investigation.

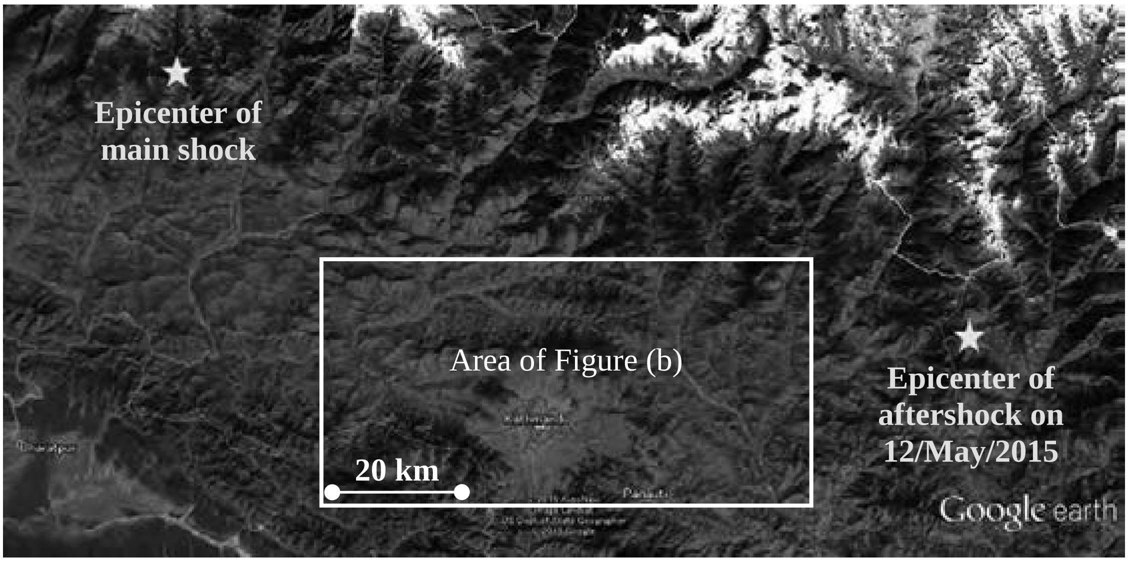


(a) Map of Nepal

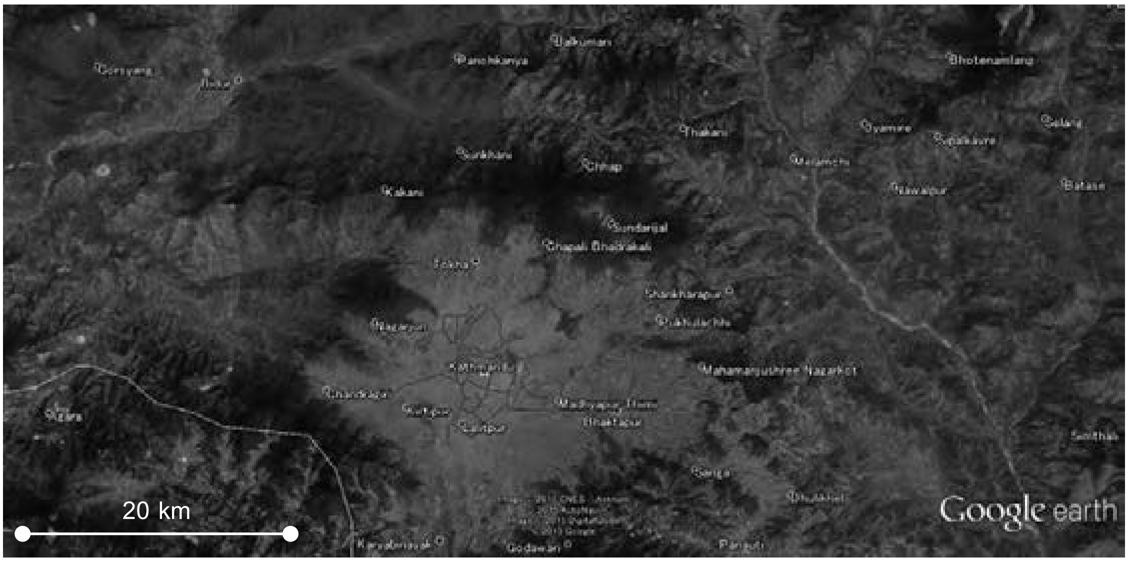


(b) Investigated districts on map

Figure 1: Investigated districts



(a) Map with the epicenters



(b) Route map

Figure 2: Investigated route

The objectives of the authors' investigation were

1) to obtain data on building characteristics and damage in the suburbs of Kathmandu, where the epicenters of the main shock or aftershock on 12/May/2015 were closer than Kathmandu, and
2) to compare the intensity of ground motions based on damage to similar buildings in the investigated area.

In particular, the investigation was performed focusing on school buildings to complete the second objective, by

1) collecting structural drawings of school buildings (standard design and retrofit design) from the local boards of education of the investigated districts,

2) evaluating quantitative data on e.g. wall ratio (introduced below)-damage relationship based on onsite investigation results on structural characteristics and damage of school buildings, and
3) performing inventory surveys to obtain damage ratios at some limited areas around the investigated schools.

In this paper, the investigation results focusing on the second item above are mainly summarized as follows.

2. WALL-TO-TOTAL FLOOR AREA RATIO

The Japanese seismic evaluation standard (JBDPA, 2005) provides a rapid screening method to judge seismically safer (or more vulnerable) reinforced concrete (RC) existing buildings with sufficient (or insufficient) amounts of walls as well as columns. A threshold for the judgement was given based on the statistical data from the past earthquake disasters in Japan. The basic concept had been originally proposed by Shiga (1969) presenting an application of wall-to-total floor area ratio (hereafter, wall ratio), Aw/ΣAf, where Aw is the wall area in the first story (cm^2) and ΣAf is the total floor area above the first story (m^2), to estimating seismic resistances of earthquake-damaged RC buildings.
The above index of Aw/ΣAf is simple and effective for screening seismically vulnerable RC buildings. Therefore, the authors evaluated wall ratios in several masonry school buildings to apply the index to masonry buildings in Nepal in the future.

3. EARTHQUAKE DAMAGE TO MASONRY SCHOOL BUILDINGS

Ten masonry school buildings were investigated in detail during the limited period of the onsite investigation, as listed in Table 1.
The damage grades were classified into five grades according to European Macroseismic Scale 1998 (EMS98) (1998), as illustrated in Figure 3. Figure 4 shows the distribution of the damage grades obtained as above. 80% of the investigated buildings completely or partially collapsed.
Moreover, the wall ratios for several severely damaged buildings are calculated and presented in Table 1, however, where the calculated values are shown in percentage terms. Consequently, the maximum wall ratios for severely damaged buildings were 12.5% and 26.6% for Brick-Mud and Stone-Mud buildings, respectively.
Typical damage to masonry school buildings are summarized in the following.

3.1 Complete collapse

Several masonry school buildings had completely collapsed, which corresponded to Grade 5 in Figure 3. Figure 5(a) exemplifies a typical collapsed building. The complete collapses of the investigated buildings seemed to be caused following brittle out-of-plane failure of masonry walls mentioned below.

3.2 Out-of-plane failure

Out-of-plane failure was observed to masonry walls in completely or partially collapsed buildings, as shown in Figure 5(b). Poor seismic resistances in the out-of-plane direction seemed to aggravate damage to masonry buildings. It sometimes resulted in loss of roof supports, as shown in the figure.

3.3 Vertical crack opening at corner

Vertical cracks were also observed at the corners of the investigated buildings, as shown in Figure 5(c), which might be an initial stage to the out-of-plane failure. Traditional strengthening material installed at corner between orthogonal masonry walls which is applied to historical buildings such as Newalese architecture, as shown in Figure 6, can be effective to prevent/reduce this type of damage, then the out-of-plane failure.

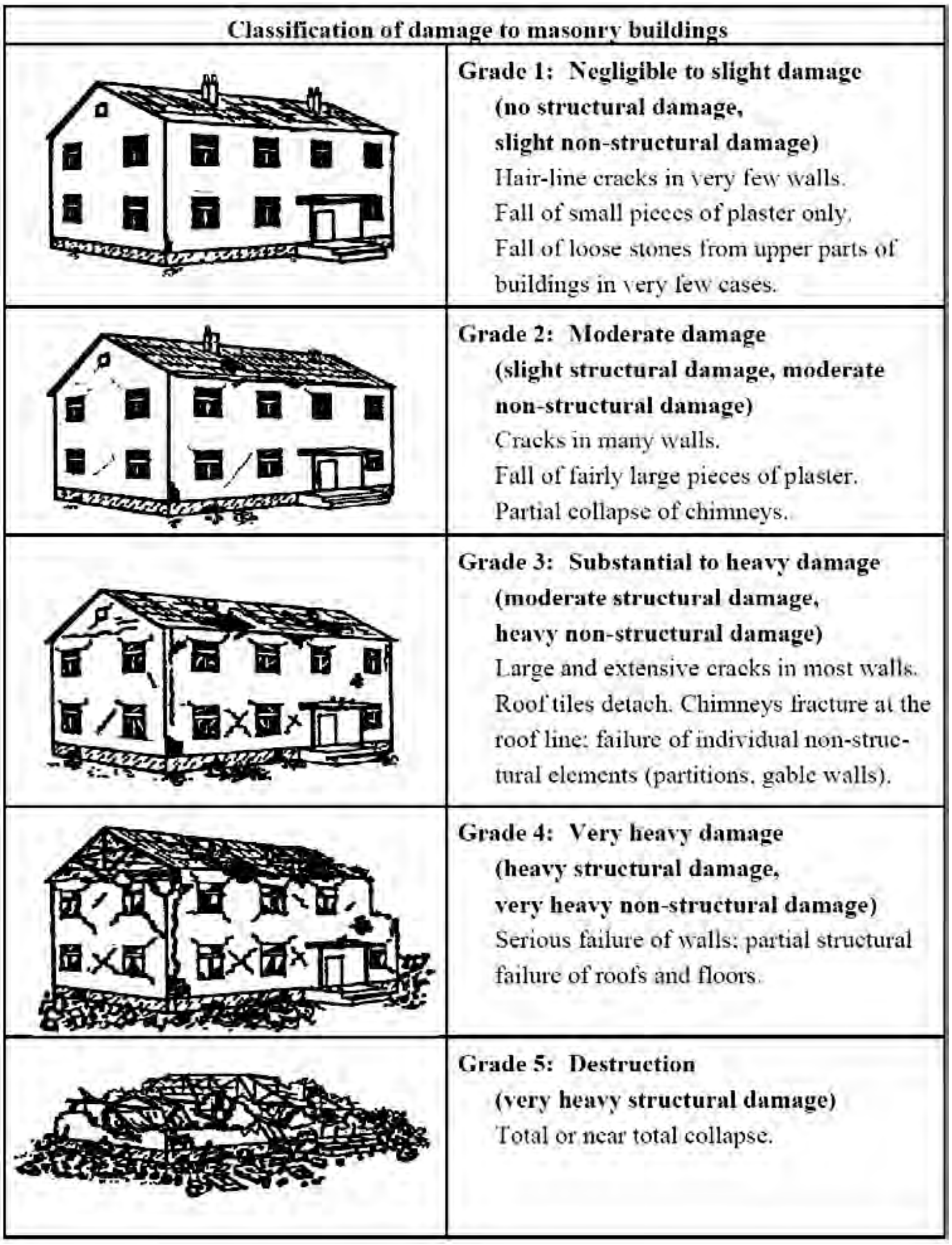
3.4 Shear crack

Shear cracks on masonry walls in the diagonal direction were also typical damage, which indicated that the walls resisted seismic forces in the in-plane direction. Therefore, masonry walls may be a lateral force-resisting element if the out-of-plane failure can be prevented.

Table 1: Investigated masonry school buildings

Name	Location	Number of story	Type of wall construction*1	Damage grade	Wall ratio*3 (%)
A school	27.67°N 85.43°E	3	Brick-Mortar	4	—
B school (1)	27.67°N 85.43°E	2	Brick-Surki*2	4	—
B school (2)	27.67°N 85.43°E	1	Brick-Mortar	1	—
B school (3)	27.67°N 85.43°E	1	Brick-Mortar	1	—
C school	27.69°N 85.39°E	3	Brick-Unkown	4	—
D school	27.69°N 85.41°E	1	Brick-Mud	5	L: 12.5 S: 7.8
E school	27.78°N 85.71°E	1	Stone-Mud	5	L: 26.6 S: 18.1
F school	27.77°N 85.72°E	3	Stone-Mud	5	L: 2.7 S: 2.9
G school	27.78°N 85.02°E	1	Stone-Mud	4	L: 11.1 S: 11.5
H school	27.85°N 85.04°E	1	Stone-Mud	5	L: 12.2 S: 12.7

*1 The former and latter materials indicate masonry unit and joint, respectively.
*2 Surki is a mixture of brick powder, lime, and rice husk.
*3 L and S mean the longitudinal and span directions of the buildings.



Classification of damage to masonry buildings	
	Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage) Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
	Grade 2: Moderate damage (slight structural damage, moderate non-structural damage) Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
	Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
	Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Serious failure of walls; partial structural failure of roofs and floors.
	Grade 5: Destruction (very heavy structural damage) Total or near total collapse.

Figure 3: EMS98

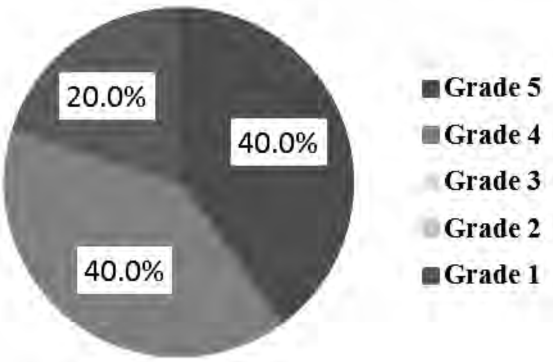
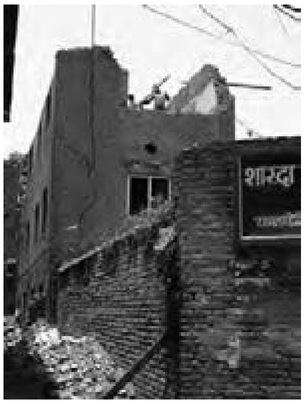


Figure 4: Distribution of classified damage grades

(a) Complete collapse

(b) Out-of-plane failure

(c) Vertical crack opening at corner



(d) Shear cracks

Figure 5: Typical damage observed to the investigated masonry school buildings

Figure 6: Strengthening material used for historical buildings

4. CONCLUDING REMARKS

This paper summarizes the authors' post-earthquake field investigation results performed in the suburbs of Kathmandu, and reports major findings on earthquake-damage to masonry school buildings from the investigation, as follows:

- Completely and partially collapsed masonry school buildings occupied 80% of ten investigated buildings.

- Typical failure patterns observed to the investigated buildings were complete collapse, out-of-plane failure of walls, vertical cracking at corner, and shear cracking. The first three damage patterns seemed to be caused by seismic forces in the out-of-plane direction. Traditional strengthening material provided at corner between orthogonal masonry walls for historical buildings can contribute to prevent/reduce these failure patterns. On the other hand, the last pattern resulted from in-plane forces, which indicates that masonry walls can contribute to resist seismic forces if the out-of-plane failure is prevented.
- The maximum wall area-to-total floor area ratios, $A_w/\Sigma A_f$ calculated for several completely or partially collapsed buildings were 12.5% and 26.6% for Brick-Mud and Stone-Mud buildings, respectively. Collecting more data may provide a threshold for rapidly screening seismically vulnerable masonry buildings in Nepal.

SYMPATHY NOTE AND ACKNOWLEDGEMENT

The investigation members would like to express deepest sympathy to all victims. The investigation was organized by Architectural Institute of Japan. We appreciate Prof. Toshimi Kabeyasawa, the chair of research committee on earthquake disaster for his arrangements. The Japan Building Disaster Prevention Association also financially supported the investigation. Dr. Prakirna Tuladhar, Senior Divisional Engineer, Department of Urban Development and Building and Dr. Krishna Bhetwal, Assistant Professor, Tribhuvan University with his colleagues kindly contributed our onsite investigation.

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Field Investigation in affected area due to the 2015 Nepal Earthquake by AIJ reconnaissance team: Damage assessment and seismic capacity evaluation of buildings in Gongabu, Kathmandu

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ABSTRACT

During the 2015 Mw 7.8 and Mw 7.3 Nepal earthquakes, reinforced concrete and masonry buildings were significantly damaged. After the event, Architectural Institute of Japan (AIJ) dispatched several reconnaissance teams to the affected area to conduct field investigation. The team of authors conducted field investigation in Gongabu, Kathmandu to collect information with respect to damage of buildings in Nepal to assess the damage of buildings and to predict seismic capacity of buildings in Nepal. Most of the severely damaged buildings, have similar structural details: reinforcement arrangements; anchorage; and joint, except difference of number of floors, dimensions and use application, were collapsed due to soft first story mechanism formed. According to damage classification of buildings, severely damaged buildings were concentrated in some small areas. The mechanism of soft first story in one of five story reinforced concrete buildings with non-structural brick walls was investigated by structural strength considering failure mechanism with Japanese structural calculation method and inelastic response analysis of members. The predicted failure mechanism was almost agreed with observation and seismic capacity of the building was predicted.

Keywords: Seismic capacity, Reinforced concrete buildings, Masonry buildings, Damage evaluation, Failure mechanism

1. INTRODUCTION

On 25 April 2015, Mw 7.8 earthquake occurred in the central region of Nepal and Mw 7.3 aftershock occurred on 12 May. During the earthquakes, more than eight thousand people were killed, 20 thousand people were injured, and damaged buildings spreaded throughout widespread areas around Kathmandu.
After the event, a reconnaissance team organized by the Architectural Institute of Japan (AIJ) was dispatched to the affected areas to conduct field investigation. The team consisted of some professors and the team was divided into some groups according to their objectives. They specialize in reinforced concrete, masonry structures, earthquakes and ground, and these investigations were conducted under the support of many professors, local government officials and engineers in Nepal.

The team of authors conducted field investigation in Kathmandu to collect information, which helps understanding of the cause of damage to reinforced concrete buildings in Kathmandu due to the earthquakes. The objective of this study is to evaluate seismic performance of damaged buildings and find the cause of damage to buildings.

2. DAMAGE TO REINFORCED CONCRETE AND MASONRY BUILDINGS

2.1 Investigation and the area

The authors investigated buildings in Gongabu, which is in the northwestern part of Kathmandu to collect information about damage to reinforced concrete and masonry buildings built with the local construction methods. In this area, most of low-rise buildings and houses did not suffer damage, nevertheless several mid-rise reinforced concrete and masonry buildings collapsed and suffered severe damage. Figure 1 shows map of Gongabu area. There are many buildings in the north area of the Ring Road and almost all of the buildings were non-structurally joined with each other. The red symbols indicate locations of damaged buildings which detailed structure was investigated.

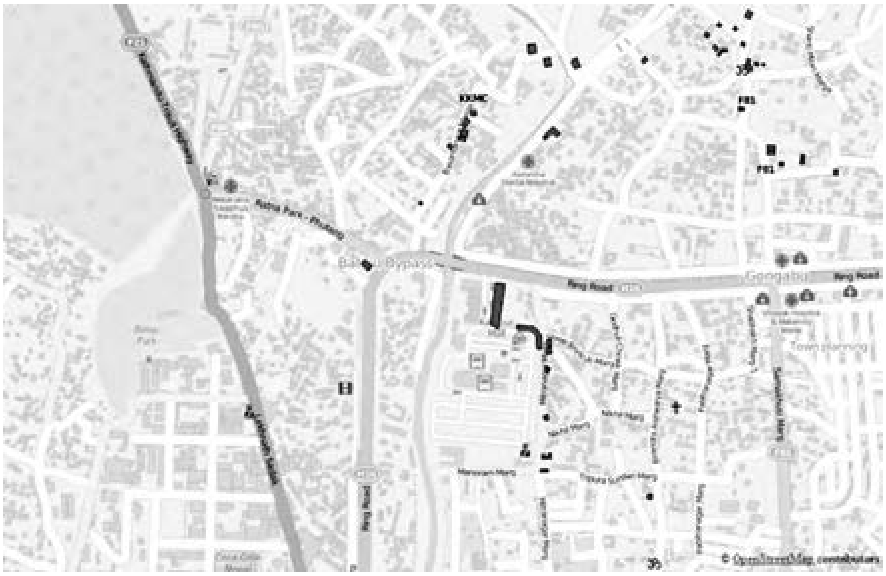

Figure 1: Investigated area and buildings in Gogabu

2.2 Structural details of damaged reinforced concrete buildings

Figure 2 shows typical damage to reinforced concrete buildings in Gongabu. Damage pattern of suffered buildings were very similar and moreover, almost all of collapsed reinforced concrete buildings formed the soft first story mechanism. These buildings had similar stories: four and five stories, structural details in geometry of member, reinforcement arrangement, anchorage, and beam-column joint. The cross-sectional geometry of column was 9 in. (225 mm) x 12 in. (300 mm), the eight longitudinal deformed steel bars enclosed by hoops with 150 mm pitch spacing were placed. Longitudinal reinforcements of beam were not anchored in the core of the cross section of column at beam-column joint as shown in Figure 3, which may yield beam-column joint failure.

Figure 2: Collapsed building

Figure 3: Damage of beam-column joint

3. DAMAGE CLASSIFICATION

In this investigation, damage classification based on European Macroseismic Scale (EMS-98) (Grünthal, 1998) were carried out for more than a thousand (1289) buildings in Gongabu. Damage to reinforced concrete and masonry buildings were classified into five levels according to this method. The investigated buildings and the damage grade were shown in Figure 4. The grades were defined according to damage level as shown in Figure 4. It appeared that the location of buildings which grade is more than Grade 3 (G3) concentrated in some small areas, which may indicate the effect of difference of ground characteristics. Figure 5 shows the ratio for reinforced concrete and masonry buildings. Total of the number of Grade 2 (G2) to Grade 5 (G5) for masonry buildings reaches 13 % of all the buildings (See Figure 5(a)), whereas for reinforced concrete buildings total of the number of those reaches 7 % (See Figure 5(b)). This means that the number of damaged reinforced concrete buildings is not small in relation to that of masonry buildings.

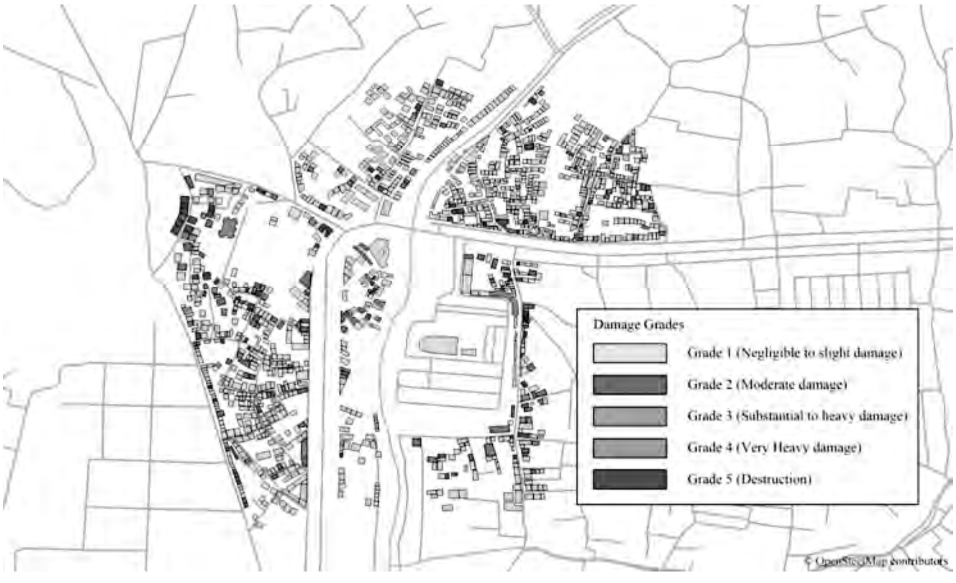

Figure 4: Investigated buildings and damage level

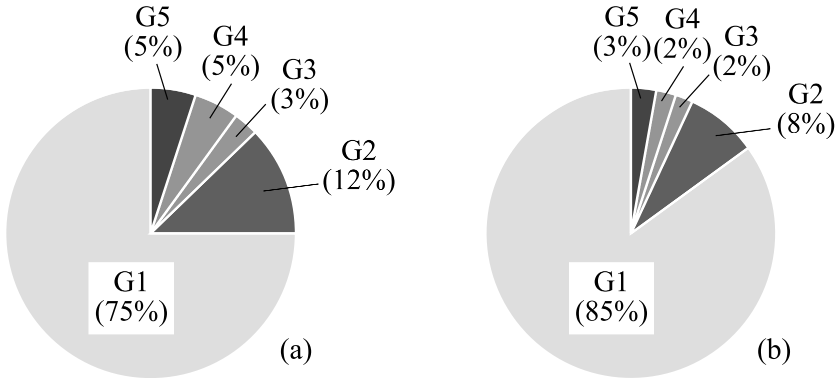

Figure 5: Damage classification of buildings: (a) Masonry; (b) Reinforced concrete

4. DETAILED INVESTIGATION

4.1 Seismic capacity

A reinforced concrete building, which had five and a half story forming the soft first story mechanism as shown in Figure 6, was selected to examine the seismic capacity and the cause of the failure mechanism. Figure 7 shows damage inside of the first floor, where the columns at the front of the building and two columns failed in shear due to be shortened by walls as shown in Figure 7. All the other columns on the first floor shows flexural yielding. Wide horizontal crack was observed on non-structural brick walls in the longitudinal direction on the first floor, however, diagonal cracks were observed on that in transverse direction, which indicates that response in the transverse direction dominated. The failure mode of columns was predicted by the ultimate strength with Japanese structural calculation method (JBDPA, 2005) using investigated structural properties and the mode agreed with observation. Additionally, base shear coefficient of was predicted as 0.25 assuming unit weight of 12 kN/m^2 on each floor, concrete strength of 40 MPa obtained by rebound hammer test and yield strength of steel of 415 MPa.

Figure 6: Investigated building

Figure 7: Damage of the first floor

Figure 8: Shear failure of shortened column

4.2 Damage assessment

The damage level of building was assessed according to the Japanese Damage Classification Method (JBDPA, 1991). The method classifies all columns into five damage levels, then calculates the ratio of residual seismic capacity to the original one. Figure 9 shows the damage level of each column on the first floor for both directions. Very heavy damaged columns which label is “V” are observed on the west and north east corner on the floor. The ratio of residual seismic capacity was calculated as 37.5 % and 38.9 % in the longitudinal and transverse direction, respectively, and damage of this building was classified as “destruction” for both directions, which almost agreed with observation.

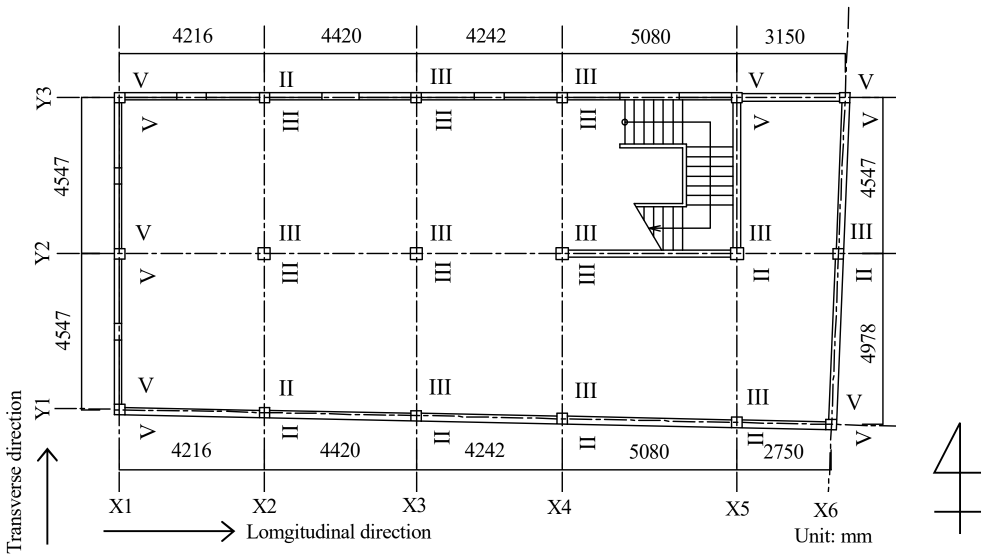

Figure 9: Damage level of columns on the first floor

4.3 Analytical investigation

To investigate collapse mechanism of aforementioned building, nonlinear static and dynamic response analyses were carried out. Three-dimensional frame constituted by beam element with rotational boundary springs, multi-spring model of column and three vertical line element wall model were used. Behavior of spandrel and breast walls on response of building were represented by shortening of column length. The hysteretic models of both beam and column springs and non-structural brick wall were assumed by Takeda model (Takeda, 1970) and bilinear with slip model (Sanada, 2009), respectively. Tangent stiffness-proportional damping of 3 % was assumed. The material properties was set to follow test results as discussed but the yield strength of steel of 490 MPa were used due to limitations of analytical software. Total weight of the building was assumed as 21267 kN assuming relative density of non-structural brick walls of 1.66.

Figure 10(a) shows relationships between story shear and interstory drift by pushover analysis, which terminated when the interstory drift reaches 2 %. The first and second floor's drifts dominate and the maximum base shear coefficient is 0.2. The base shear coefficient is smaller than the predicted value by assuming ultimate strength of columns but the soft story mechanism agreed with observation. Figure 10(b) shows story drifts obtained by dynamic response analysis for each direction with record at Kanti Path station (CESMD, 2015). It is observed that the story drift of the first story in the north-south (NS) direction is dominant. Figure 11 shows failure mode of members obtained by dynamic response analysis under NS record. Most of columns suffered flexural failure at the top and bottom on the first floor and the failure mode and the locations almost agreed with investigated result.

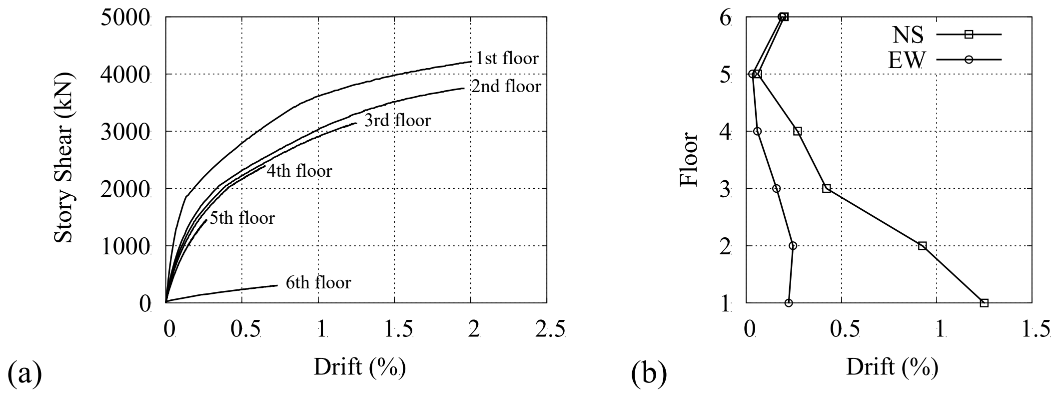

Figure 10: Pushover and dynamic analysis result: (a) Relationship story shear verses interstory drift; (b) Interstory drift distribution

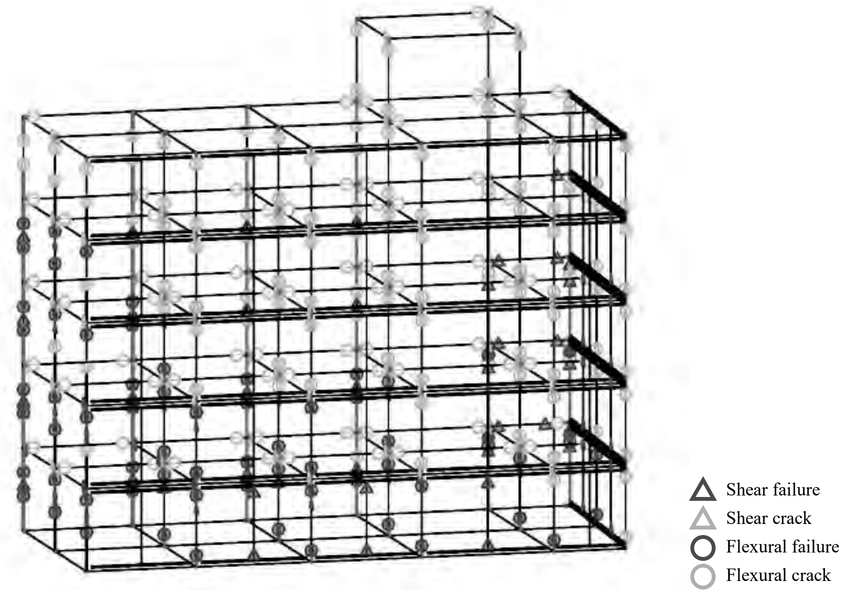

Figure 11: Failure mode of members

5. CONCLUSIONS

The field investigation by AIJ reconnaissance team to assess damage of reinforced concrete and masonry buildings in Gongabu, Kathmandu was conducted. Damage classification and assessment for buildings were carried out. The main findings are summarized as follows: 1) number of the damaged buildings was investigated and the number for all buildings for reinforced concrete buildings was not smaller than that of masonry buildings; 2) base shear coefficient of five and a half story reinforced concrete building forming the soft first story mechanism was assumed as 0.25; 3) the ratio of residual seismic capacity became about 40 %, which classified as “collapse” and agreed with the observation; 3) analytical results almost agreed with observation in terms of base shear coefficient, failure mode of members, and failure mechanism of investigated building.

SYMPATHY NOTE AND ACKNOWLEDGEMENT

The investigation members would like to express deepest sympathy to all victims. The investigation was organized by Architectural Institute of Japan. We appreciate Prof. Toshimi Kabeyasawa, the chair of research committee on earthquake disaster for his arrangements. The Japan Building Disaster Prevention Association also financially supported the investigation. Dr. Prakirna Tuladhar, Senior Divisional Engineer, Department of Urban Development and Building and Dr. Krishna Bhetwal, Assistant Professor, Tribhuvan University with his colleagues kindly contributed our onsite investigation.

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Characterization of soil profile of Dhaka city using electrical resistivity tomography (ert)

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ABSTRACT

Over the past 45 years, Dhaka city has experienced a rapid growth of urban population and it will continue in the future due to several unavoidable reasons. As a result, different new areas are being reclaimed inside and near Dhaka city. In most cases, the dredged material is silty sand with high fines content and since Dhaka city exists in seismic Zone-II(BNBC1993) of Bangladesh, this silty sand layer may liquefy if an earthquake of sufficient magnitude occurs. The main aim of the study is to characterize the sub soil profile based on resistivity. Three reclaimed locations and one original soil location within Dhaka city have been selected as the study area. The Electrical Resistivity Tomography (ERT) method have been undertaken with several different electrode spacing. Wenner–Schlumberger array has been used as electrodes array. Measurement has been performed with electrodes positioned on the surface. Primary data have been processed through a 2-D inverse method, using the program Res2DInv. The data have been processed by creating a pseudo-section of the apparent resistivity values using RES2DINV software. Computer iterations have been then carried out and two dimensional (2-D) resistivity contour maps have been created. For the three reclaimed locations, three distinct soil layers have been identified namely Filling Sand, Clay and Sand Mixture and a Sand layer. Sometimes an additional clay layer has been observed. The original ground is underlain by mainly by clay layers and below that a sand layer exists.

Keywords: *electrodes, iterations, pseudo-section, resistivity, soil profile.*

1. INTRODUCTION

Ground Resistivity survey methods have been widely used in order to solve engineering, archeology, environmental and geological problems in the last decades. Subsurface resistivity distributions are measured by applying electrical current into the ground by using two current electrodes. The potential differences caused by the flow of current between any two points in linear line with the current electrodes are then measured by a pair of potential electrodes. From the measured voltage (V) and current (I) values, the resistance at the specified point in the subsurface can be determined.

Electrical geophysical methods have proven to be fairly effective in delineating inorganic contaminants in the subsurface. The mechanism and responses are fairly well understood. Their application for mapping organic contaminants in the subsurface, in particular non-aqueous phase liquids is not as well accepted nor the mechanisms as well understood. Various surveys have reported results conducted over subsurface organic contamination; however the actual anomaly associated with the organic contamination has been difficult to ascertain over other factors caused by variations in the porosity, degree of saturation, mineralogy, and structure (Pitchford et al., 1989).

Electronic conduction, which is conduction through the rock's mineral compositions, occurs mainly through metallic ore minerals, providing that these minerals exist in dense enough concentration. However, most conducting minerals rarely exist in sufficient quantity in a rock composition, especially granite, to have considerable effect on the electrical properties of host rock. This conduction is controlled by matrix properties (semi conduction, lattice defects, and conductive accessories) which often resulted in very high resistivity values (Parkhomenko, 1967).

For 2D resistivity imaging, it is important to have a large set of data recorded along a survey line to effectively map the complex resistivity distribution of subsurface structure. The most practical way to acquire such large amount of data is by using automated multi-electrode data acquisition system. In the interpretation of ground resistivity survey, it is important to differentiate between apparent resistivity and true resistivity. Apparent resistivity can be defined as the volumetric average of a heterogeneous half-space, except that the averaging is not done arithmetically but by a complex weighing function dependent on electrode's configurations (Dahlin, 2001)

2. BACKGROUND OF THE STUDY

In practice, there are a lot of factors that can affect resistivity pseudo section imaging. Apparent resistivity is measured instead of true resistivity due to unknown near surface strata with different resistivity. This affects the conduction of current through earth material and thus affects the resistivity measurement. Most of field resistivity surveys conducted by geophysicist are not always validated by laboratory measurement. The difficulty in obtaining the core sample, where the drilling works should be preceded by resistivity survey has made it difficult for geophysicist to analyze samples in laboratory (Nguyen and Garambois, 2005).

The electrical resistivity method allows the calculation of the resistivity present in soil. The calculation of resistivity makes it possible to obtain information about the subsoil nature and structure. Applying a potential difference (ΔV) to the two poles of a conductor, in it will pass a current of intensity (I) which is related to the potential difference from Ohm's law:

$R = \Delta V/I$

Where,

R= electrical resistance that depends on the nature and geometric characteristics of the conductor.

ΔV = difference of potential measured between M and N [V]

I = current injected into soil [A]

For each acquisition performed in the selected spreading, the following formula is generally applied:

$\rho = (\Delta V/I).\ K$

Where,
ρ = apparent resistivity [Ω m]
ΔV = difference of potential measured between M and N [V]
I = current injected into soil [A]
K = geometric coefficient related to the sounding being used
ρ (spell it 'rho') is known as resistivity, is measured in Ω*m and provides useful elements for identifying the nature of the rock types investigated.

2.1 Electrode array

Common array types are-

- Wenner array
- Wenner-Schlumberger array
- Dipole-dipole array
- Pole-dipole
- Multiple gradient array

Figure 1 show the Wenner- Schlumberger array which has been used in this study.

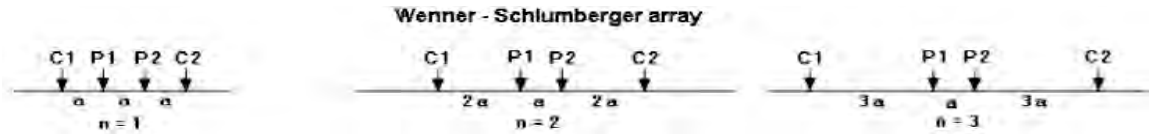

Figure 1: Wenner- Schlumberger array (www.geoelectrical.com)

2.2 Types of surveys and models

In geophysical inversion, the finding is a model that gives a response that is similar to the actual measured data. The models used can be classified as 1-D, 2-D and 3-D.

2-D electrical imaging survey: A 2-D imaging survey is usually carried out with a computer controlled resistivity meter system connected to a multi-electrode cable system. The control software automatically selects the appropriate four electrodes for each measurement to give 2-D coverage of the subsurface. Figure 2 below shows the Sequence of measurements to build up a pseudo-section using a computer controlled multi-electrode survey setup.

2.3 The software RES2DINV

RES2DINV is a computer program that will automatically determine a two-dimensional (2-D) resistivity model for the subsurface for the data obtained from electrical imaging surveys (Griffiths and Barker, 1993). This program is designed to invert large data sets (with about 200 to 21000 data points) collected with a system with a large number of electrodes (about 25 to 16000 electrodes). The 2-D model used by the inversion program which consists of a number of rectangular blocks. A forward modeling subroutine is used to calculate the apparent resistivity values, and a non-linear least-squares optimization technique is used for the inversion routine (deGroot-Hedlin and Constable, 1990; Loke and Barker, 1996).

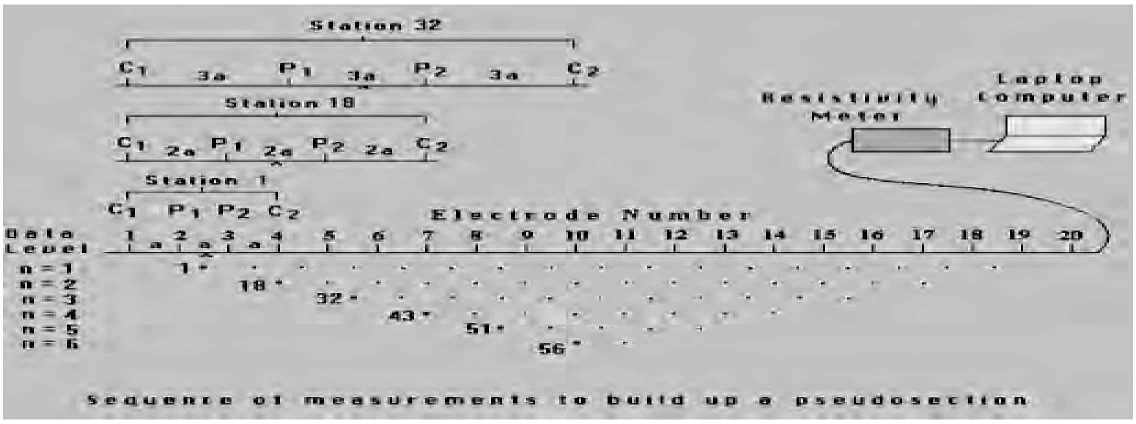

Figure 2: Sequence of measurements to build up a pseudo-section using a computer controlled multi-electrode survey setup (source: PASI –2014)

3 METHODOLOGY OF THE STUDY

The research has been conducted with the following methodology:

3.1 Study Area

Four different points of Dhaka city is selected as the study area. Table 1 presents the name, dates and location names of the survey points and Figure 3 shows the points (red star marked) of the study area of Dhaka city.

Table 1: Details of the study area

Sl. no	Date	Name of the point of study area	Location		City
			Latitude	Longitude	
01	13/10/2014	Kamrangir Char	23°42’34” N	90°22’04” E	Dhaka
02	16/11/2014	Bosila	23°44’32” N	90°21’10” E	Dhaka
03	17/11/2014	Aftab Nagor	23°45’38” N	90°27’02” E	Dhaka
04	18/11/2014	BUET Play Ground	23°43’19” N	90°23’48” E	Dhaka

3.2 Data collection

The Electrical Resistivity Tomography data have been gathered through electrodes of length equal to 50 cm, partially driven into the ground. The electrodes were then connected through multichannel cables, adopting the Wenner-Schlumberger array configuration.

Figure 3: shows the points (red star marked) of the study area of Dhaka city.

The details of the data collection points are discussed below.

Kamrangir Char

- Low land area which is situated at a distance of about 500m-600m from the Buriganga River.
- Number of Electrodes used = 32
- Electrode spacing = 1m
- Three data acquisitions were made, two parallel acquisitions @ 5m apart and one cross acquisition across the center of the parallel acquisitions.

Bosila

- Number of electrodes used = 32
- Two data acquisitions were made, one parallel acquisition and one cross acquisition across the center of the parallel acquisition.
- Spacing between electrodes of parallel acquisition is 2m and spacing between electrodes of cross acquisition is 1.5m

Aftab Nagor

- Semi-submerged land during rainy season
- Number of electrodes used = 31
- Electrode spacing = 3m
- Two data acquisitions were made, one parallel acquisition and one cross acquisition across the center of the parallel acquisition.

BUET Play Ground

- Number of electrodes used = 32
- Electrode spacing = 3m
- Four data acquisitions were made, two parallel acquisitions @ 5m apart and two cross acquisitions @ 5m apart across the center of the parallel acquisition.

3.3 Data processing and analysis

The data collected from the survey have been analyzed with the software RES2DINV. RES2DINV is a computer program that automatically determines a two-dimensional (2-D) resistivity model for the subsurface for the data obtained from electrical imaging surveys.

4 RESULTS AND ANALYSIS

Primary data were processed through a 2-D inverse method, using the program Res2DINV. The presented figures are the results of smoothness-constrained inversion; these outputs best fit the situation observed in the sites. The validity of these results is supported by the low RMS error. Table 2 presents reference resistivity values for various materials.

Table 2: Reference resistivity values for various materials

Type of soil or water	Typical Resistivity (Ωm)	Usual limit (Ωm)
Sea water	2	0.1-10
Clay	40	8-70
Ground well and spring water	50	10-150
Clay and sand mixtures	100	4-300
Shale, Slate, Sandstone etc.	120	10-100
Peat, Loam and Mud	150	5-250
Lake and brook water	250	100-400
Sand	2000	200-3000
Moraine gravel	3000	40-10000
Ridge gravel	15000	30-30000
Solid granite	25000	10000-50000
Ice	100000	10000-100000

1) Kamrangir Char

The soil profile of the Kamrangir Char is shown in the Table 3 along with analysed resistivity values. Figure 4 and Figure 5 show the model resistivity of ERT at Kamrangir Char for parallel acquisition and cross acquisition respectively.

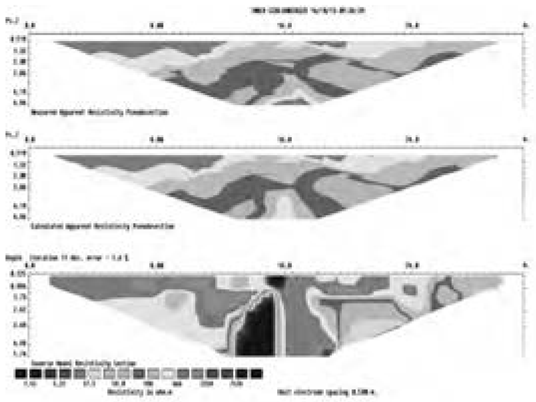

Figure 4: Model resistivity of ERT at Kamrangir Char Parallel acquisition

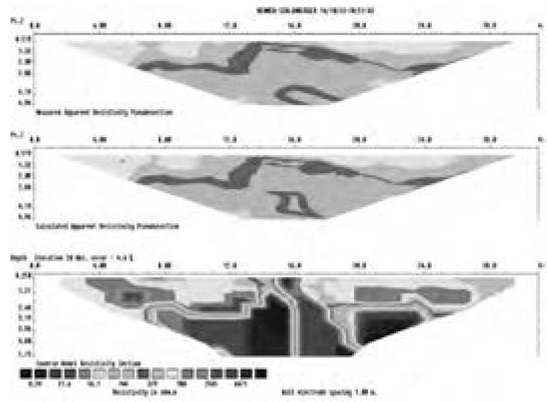

Figure 5: Model resistivity of ERT at Kamrangir Char Cross acquisition

Table 3: Electrical Resistivity Tomography (ERT) result at Kamrangir Char

Depth (meter)	Soil Description	Resistivity ranges (Ω m)
0 to 2.62	Filling Sand	200-666
2.62 to 4.99	Clay and Sand mixture	10-200
4.99 to 5.76	Sand	198-2239

2) Bosila

The soil profile of the Bosila is shown in the Table 4 along with analysed resistivity values. Figure 6 and Figure 7 show the model resistivity of ERT at Bosila of parallel acquisition and cross acquisition respectively.

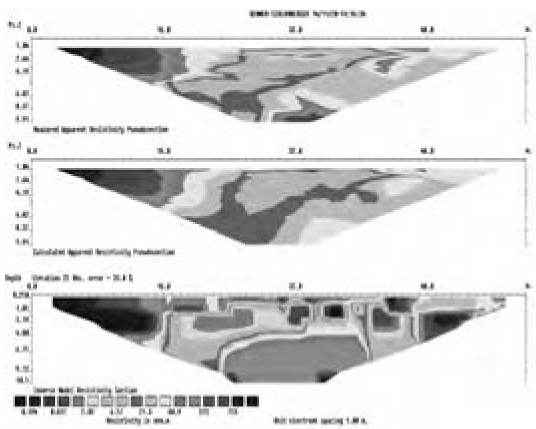

Figure 6: Model resistivity of ERT at Bosila, Parallel acquisition

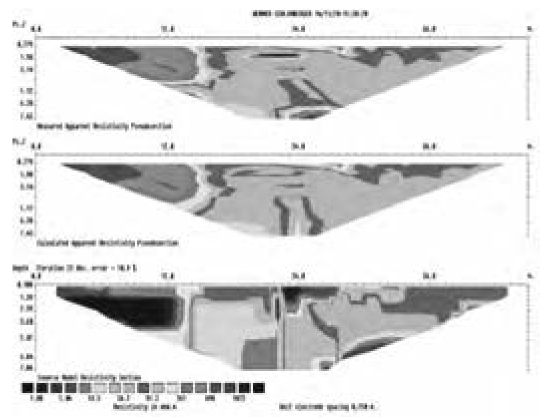

Figure 7: Model resistivity of ERT at Bosila, Cross acquisition

Table 4: Electrical Resistivity Tomography (ERT) result at Bosila

Depth (meter)	Soil Description	Resistivity ranges (Ω m)
0 to 2	Filling Sand	68.9-223
2 to 4.88	Clay	1-68.9
4.88 to 6.75	Clay and Sand mixture	68.9-273
6.75 to 10.5	Sand	273-723

3) Aftabnagar

The soil profile of the Aftabnagar is shown in the Table 5 along with analysed resistivity values. Figure 8 and Figure 9 show the model resistivity of ERT at Aftabnagar of parallel acquisition and cross acquisition respectively.

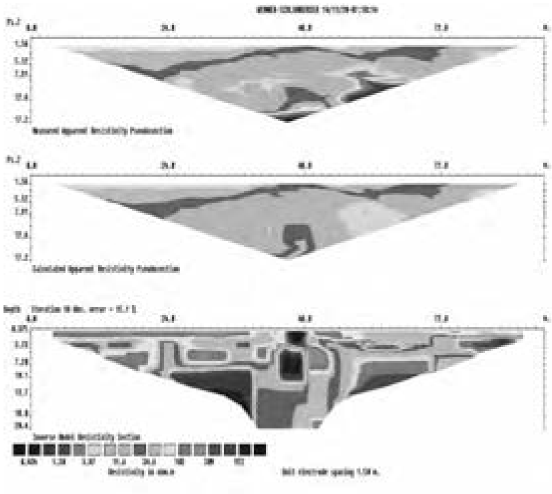

Figure 8: Model resistivity of ERT at Aftabnagar, Parallel acquisition

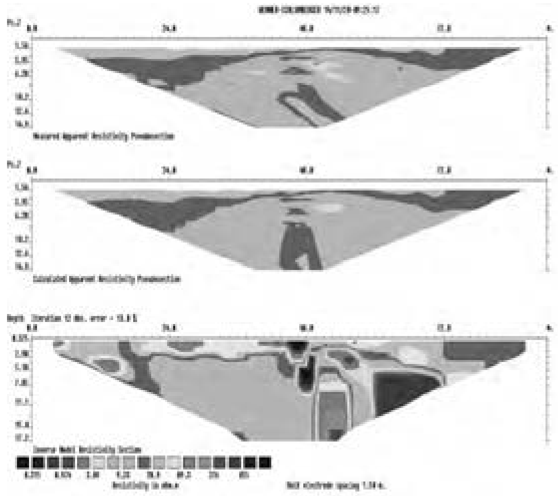

Figure 9: Model resistivity of ERT at Aftabnagar, Cross acquisition

Table 5: Electrical Resistivity Tomography (ERT) result at Aftabnagar

Depth (meter)	Soil Description	Resistivity ranges (Ω m)
0 to 2.98	Filling Sand	100-309
2.98 to 7.28	Clay	10-70
7.28 to 10.1	Clay and Sand mixture	10-309
10.1 to 20.4	Sand	309-922

4) BUET Play Ground

The soil profile of the BUET Play Ground is shown in the Table 6 along with analysed resistivity values. Figure 10 and Figure 11 show the model resistivity of ERT at BUET Play Ground of parallel acquisition and cross acquisition respectively.

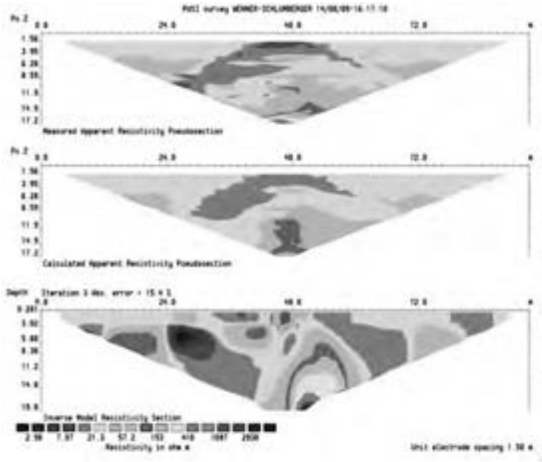

Figure 10: Model resistivity of ERT at BUET Play Ground, Parallel acquisition

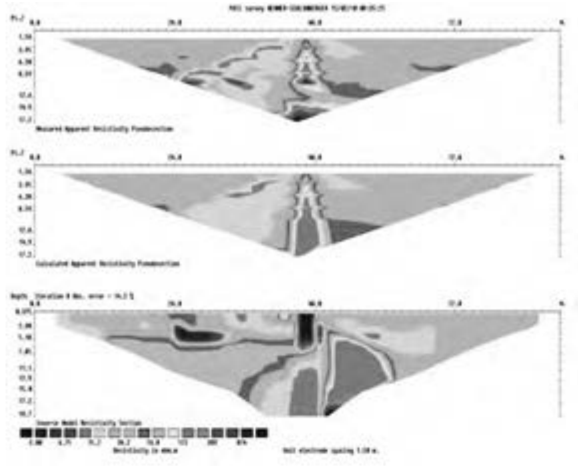

Figure 11: Model resistivity of ERT at BUET Play Ground, cross acquisition

Table 6: Electrical Resistivity Tomography (ERT) result at BUET Play Ground

Depth (meter)	Soil Description	Resistivity ranges (Ω m)
0 to 5.18	Clayey silt	3-74
5.18 to 7.85	Clay	34.2-76.8
7.85 to 15.8	Clay and Sand mixture	76.8-389
15.8 to 19.7	Sand	389-1097

5 Conclusions

Four locations are selected within Dhaka city to characterize local soil profile using Electrical Resistivity Tomography (ERT). Out of those four, three are reclaimed land and one is original soil. The data have initially been processed by creating a pseudo-section of the apparent resistivity values using RES2DINV software. Computer iterations have then carried out and two dimensional (2-D) resistivity contour maps have been created. For the three reclaimed locations, three distinct soil layers have been identified namely Filling Sand, Clay and Sand Mixture and a Sand layers. Sometimes an additional clay layer has been observed. The original ground is underlain by mainly by clay layers and below that a sand layer exists.

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Seismic Vulnerability Assessment and Retrofit Design of Heritage Buildings of Kathmandu Valley

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ABSTRACT

There are many cultural heritage buildings in Nepal made of burnt clay brick in mud mortar dated more than 100 years of age. Considering the high seismic hazard of Nepal preservation of its architectural and archeological values is very important. This paper focuses on seismic vulnerability assessment and retrofit design of one of such historic buildings Keisar Mahal carried by NSET just few months before the Gorkha Earthquake.

Although the principles for evaluating the historic structures are similar to those for other buildings, the comprehensive assessment plan was prepared to study the special condition and considerations that existed in historic buildings of Rana period in Nepal. Different detailed non- destructive and intrusive tests were carried out in the building to find the condition and properties of materials used. Detail structural analysis shows that the critical vulnerable factor is large out-of-plane moments at higher intensities of shaking. Out of various alternatives of seismic strengthening, adding of some cross walls and buttresses and increasing the rigidity of floors by means of bracing are effective means to reduce out-of-plane moments. Similarly, steel plates are suggested to resist in-plane stresses: at critical locations near jambs of door/window openings and corners with spacing limiting to 1m-1.2m.

Keywords: *historic building, Rana building, seismic assessment, retrofitting*

1 DESCRIPTION OF HERITAGE BUILDING UNDER STUDY

Kaiser Mahal is a Rana Palace in Kathmandu built in 1895 by Chandra Shamsher Jung Bahadur Rana for his son Kaiser Shamsher Jung Bahadur Rana. It is one of the historic durbars of Kathmandu with Neoclassical architecture. Such Rana palaces are made of burnt brick in mud mortar with lime plaster and arresting French windows. They have Grecian columns and four wings with a large courtyard in middle for religious and ceremonial purposes, so is Kaiser Mahal. It has a courtyard in the middle with projected wings at the South-East and South-West portion. The building is three stories at East, South and North portion, the original structure and four storey at West portion which was added later. Wall thicknesses are in the range of 900mm, 850 mm, 650 mm, 600 mm, 550 mm, 500 mm, 450 mm, 350 mm and 250 mm, mostly thick walls in first three stories. Floor/roof structures are made of Jack Arch and timber flooring.

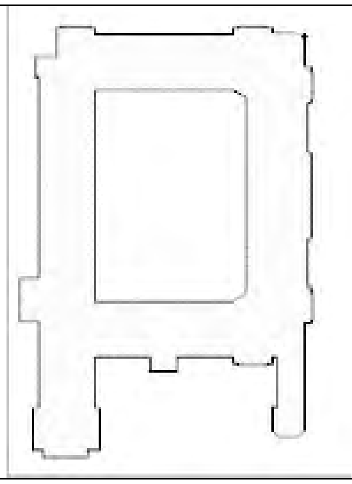

Fig 1: Front View of the Building	Fig 2: Building Foot Print

2 VISIBLE PHYSICAL CONDITION OF THE BUILDING BEFORE GORKHA EARTHQUAKE

From the inspection of the building, visible cracks were found on the walls of the building at many locations. Near the North-West and North-East corners of the building there were large vertical cracks throughout the walls and floors initiated from the ground floor walls to the roof level of the building. However, there was no crack seen in plinth level of the building and below. Crack width increases from average of 1.0 mm at ground floor level to 5-10 mm and more at roof level. The nature of crack indicates it may be due to settlement. The settlement could have been occurred as a result of improper drainage and leakage leading to foundation erosion and subsequent crack in upper parts of the building which is further aggravated due to vibration in the building. Similarly, there were several vertical and diagonal minor cracks above the door/window openings. This is more likely due to the difficulty in load transfer on the wall due to the presence of openings and degradation of material strength with time. In addition, there were leakages in the building from toilets and water and sanitary pipelines, which made the wall damp resulting in decay of wood structures and growth of lichen and trees on the walls.

3 FIELD INVESTIGATIONS AND OBSERVATIONS

Field investigation was carried to verify the details at site and to determine the actual condition and strength of different structural elements. This was done by visual observation, non-destructive and intrusive tests such as foundation exploration, making inspection holes on walls, in situ in-plane shear test, micro tremor test, wood decay test and flat jack test.

3.1 Inspection Hole on Walls

Brick lay pattern is an important parameter to determine the integrity of brick masonry wall. An opening of size 450mm x 450mm x450mm were created at two places, and observed the brick lay pattern. It was found that walls are constructed using burnt clay brick in mud mortar. Average thickness of mortar is 10 mm. All bricks are laid properly with offset along the length and breadth of the wall as in English bond

3.2 In Situ In-plane Shear Test

It provides a direct measurement of the shear resistance of mortar joints in masonry. The test locations were prepared by removing the brick, including the mortar, on one side of the brick to be tested. The head joint on the opposite side of the brick to be tested was also removed. With care that the mortar joint above or below the brick to be tested was not damaged. The hydraulic ram was inserted in the space where the brick was removed. A steel loading block was placed between the ram and the brick to be tested so that the ram will distribute its load over the end face of the brick. The dial gauge was inserted in the space. The brick was then loaded with the ram until the first indication of cracking or movement of the brick. The ram force and associated deflection on the dial gage were recorded. Twenty Six test locations, at least one location at each wing each floor, were selected based on different wall thickness, internal and external locations. The test was carried out at 13 locations at ground floor, 7 locations at first floor and six locations at second floor. From the observation, final corrected shear strength of brick masonry is obtained as per ASTM standard and IITK- GSDMA Guideline and the corrected shear strength obtained are 0.0718N/mm^2 and 0.042 N/mm^2 respectively. The difference in these values from two standards, ASTM and IITK-GSDMA Guideline, is due to the coefficient of friction between the brick and mortar that is assumed as per the site condition. Lower value 0.042 N/mm2 is used for design purpose.

Fig 3: Inspection Hole on Wall

Fig 4: In-situ In-Plane Shear Test

3.3 Micro-tremor Test

Micro Tremor measurements were taken to calibrate the numerical computer analysis. The Micro Tremor measurements were obtained at 18 locations in second floor and 1 location in first floor. As far as possible, measurements were taken at four corners and near CG of second floor of all four wings of courtyard building. The average fundamental frequency in East-West (X) direction was found to be 2.56 Hz, while in North-South (Y) direction was 2.74 Hz. The fundamental time period at X and Y-directions was found to be 0.39 sec and 0.36 sec respectively. Despite their thick walls, the fundamental time period is slightly higher, this may due to the cracks on walls, flexibility of floors or insufficient bracing of walls.

3.4 Wood Decay Test

Timber is extensively used in different forms in the building. Its current condition is very important parameter during the assessment of the building. Besides inspecting the surface visually, the condition of wooden members: beams, girders, rafters, posts, windows, doors, etc were tested with the help of decay detection instrument, IML PD Series.
During the test, a drilling needle with a diameter of 1.5mm and 3 mm cutting tip is inserted into wood under constant drive. While drilling, the resistance was measured as a function of drilling depth of the needle. The data was plotted on a scale 1:1 simultaneously. The high amplitude graphs represent the higher intact of wood. The test was carried out only on the exposed wood surface at 86 different locations. From the observation, except few beams most of the wooden members are of good quality.

	
Fig 5: Microtremor Test	Fig 6: Wood Decay Test

3.5 Flat Jack Test

Flat jack testing is the direct and in-situ testing method to determine the local compressive and stress-strain behavior of the masonry and requires only the removal of portion of mortar from the bed joints. This test is intrusive since the damage is temporary and can be easily repaired after testing. Flat jack testing was carried as per ASTM Standards (ASTM C1196 and ASTM C1197) by using two flat jack plates of size R-6-16 (0.15” X 6” X 16”). Two slots of size 6.5” x 17” were prepared at 18.5” apart (5 layers of brick) and gauge point pairs were selected to measure the deflection of the masonry units. Flat jacks were then introduced into both slots, and the initial distance between gauge points were measured. By pressuring the flat jacks, loads applied to the wall specimen. With a pressure increase in the flat jacks, the distance between gauge point pairs decreased. By gradually increasing the pressure, the pressure and deformation were recorded and stress-strain curve was developed. The pressure was increased till there was failure in the masonry specimen. From the three different flat jack tests the average value of Modulus of Elasticity of Masonry and Compressive Strength of Masonry was found to be 943.8 N/mm^2 and 1.21 N/mm^2 respectively.

3.6 Brick Test

Three brick samples were taken from the building wall, compressive strength and water absorption test was carried out at Central Material Testing Laboratory, Institute of Engineering, Nepal. The average breaking strength of brick was found to be 10.68 N//cm^2 and water absorption of three samples are 14.29%, 15.62% and 18.76%.

	
Fig 7: Flat Jack Test	Fig 8: Brick Test

4 DETAIL STRUCTURAL ANALYSIS

Finite Element Modeling of the Kaiser Mahal building was done using structural analysis and design software program, SAP 2000 Advanced 14.2.2. For simplicity, only the west portion of the courtyard was modeled (red rectangular mark on building plan). Load bearing brick masonry walls were modeled as single layered shell elements. Since the flooring of the building is made of brick and mud with timber girders, only the main timber girders were modeled.

Seismic coefficient method was used to analyze the building. Indian Seismic Code IS 1893:2002 was used for lateral load calculation and seismic coefficient value was also compared with the Nepal National Building Code NBC 105:1994. 3D view of the SAP model is shown below.

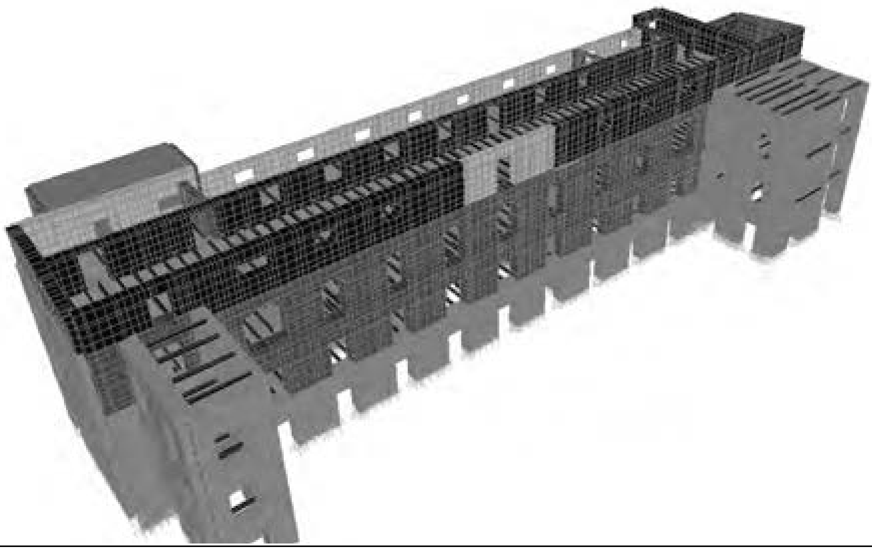

Fig 9: 3D model of West Portion of the Kaiser Mahal Building in SAP2000

In-plane and out-of-plane stresses are studied. From the analysis, large amount of out of plane bending moments are produced on the walls due to the large span of wall, height of the building and flexible floor diaphragm. While in-plane stresses are also not to be ignored.

5 CONCEPTUAL RETROFIT STRATEGY

Since the building is a national heritage, preservation of architectural and archeological value is vital. The main strategy of seismic strengthening is to intervene as less as possible. The proposed strategy to bring the building performance within the acceptable level of life safety are i)Addition of internal buttresses and cross walls to reduce the span of the wall, ii) Increase floor rigidity and iii) Addition of tension resisting members on the piers

Some cross walls and buttresses are added on second and third floor of the building to reduce the out-of-plane moments of load bearing walls. Similarly, floor bracings are added to improve the rigidity of floor diaphragm. Modified building plan significantly reduces out-of-plane bending in walls both horizontally and vertically and also the building deformation (See fig 10). Further to improve the integrity and ductility in the building and also to resist tension force in the wall panels vertical tension resisting elements, Splints of steel straps are introduced at corners and junction of walls and at jambs of door/window openings; Horizontal bands of tension resisting element of steel straps, are provided at lintel and floor levels. Schematic sketch is shown below (Fig 11 & 12):

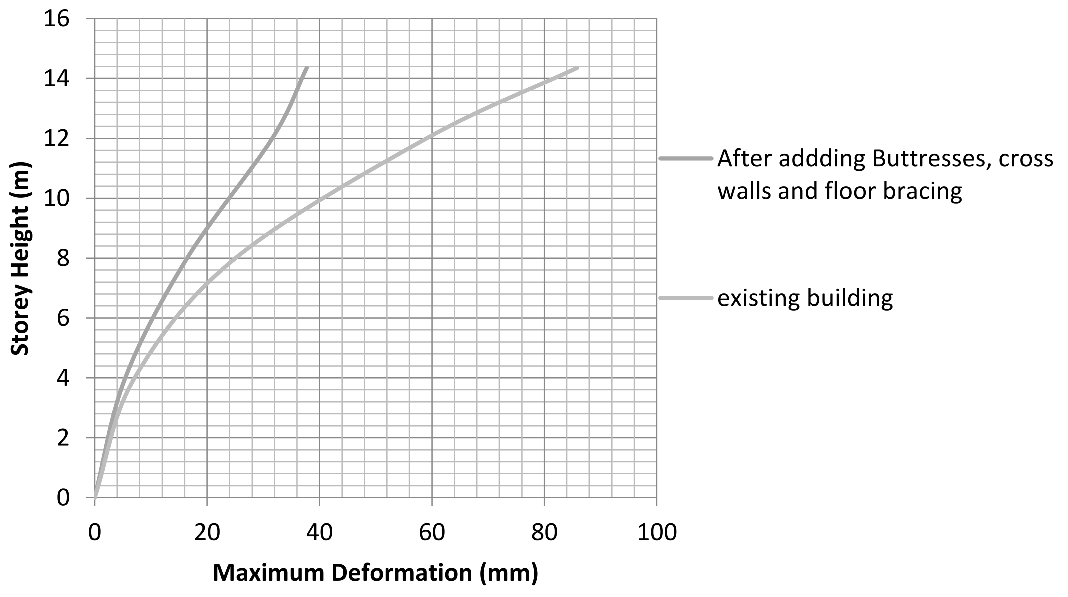

Fig 10: Comparison of Out-of-plane Deformation of the West Portion due to Earthquake Loading

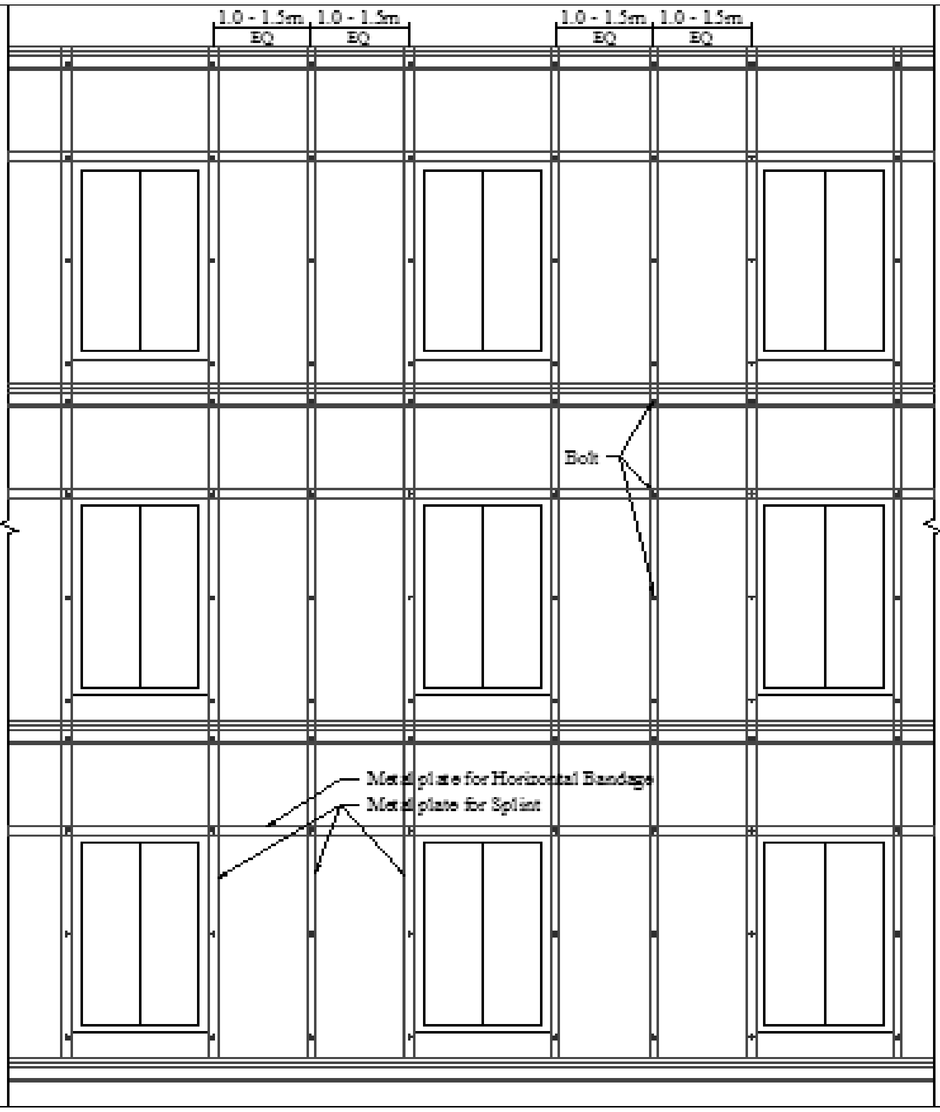

Fig 11:Wall Elevation showing Metal Plates used as Vertical Splints and Horizontal Bands

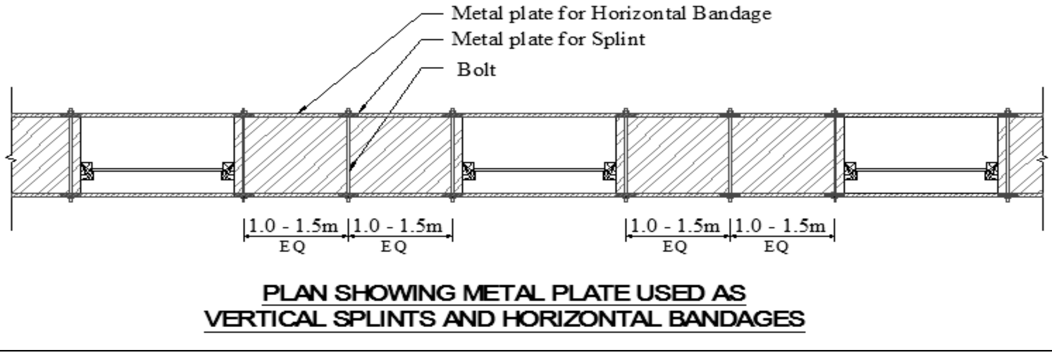

Fig 12: Wall Plan with Metal Plate as Vertical Splints and Horizontal Bandages

6 DAMAGE TO THE BUILDING IN GORKHA EARTHQUAKE 2015 AND WAY FORWARD

The detail damage assessment and retrofit design of the building was done just before the Gorkha Earthquake 2015 and implementation was yet to be taken. The building is further damaged due to the Gorkha earthquake 2015. Rapid visual damage assessment indicates the building has suffered moderate structural damage with minor and major shear and flexural cracks at many locations which would require more repair works. The building having historical and cultural value, it is very necessary to maintain and strengthen the building structure to preserve the value of its time though the cost of intervention is slightly high. For this, a detail damage assessment along with the appropriate retrofit scheme is necessary to safeguard the building with national importance.

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Urban regeneration as post disaster rehabilitation / reconstruction of historic core city and settlements

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ABSTRACT

The impacts of recent earthquake of 25 April 2015 are devastating and widespread in the historic core city and settlements of Kathmandu valley. Because of the historical, archaeological, artistic, cultural and touristic value of core city structures and settlements, a fundamental principle of its reconstruction and redevelopment should be the conservation of its unique character and earthquake risk management. In post earthquake scenario the National Society for Earthquake Technology Nepal (NSET) has been implementing post earthquake damage assessment of these settlements, safe shelter planning and design and earthquake risk reduction initiatives such as Urban Regeneration of Historic core city and settlements. It is a model for sustainable redevelopment of historic urban areas, pilot program in a small block within dense settlement. This is a continuation of feasibility study conducted in 2012-2014 in core city of Kathmandu. This feasibility study is being carried out by NSET as a part of Public Private Partnership for Earthquake Risk Management with core funding from the office of Foreign Disaster Assistance of USAID.

Keywords: Earthquake, Historic core city and settlements, Earthquake Risk Management, Urban Regeneration, Conservation

1 BACKGROUND

On 25th April, 2015, at 11:56 local time, a massive 7.8 magnitude earthquake struck Nepal, with the epicenter in Gorkha District north-west of Kathmandu and south of the China boarder. Dozens of aftershocks followed, including a 6.7 magnitude earthquake on 26th April 2015 at 12:54 local time. The earthquake has been found with a maximum Modified Mercalli Intensity (MMI) of IX (Violent). Epicenter of main shock is approximately 34 km (21 mi) east-southeast of Lamjung, Nepal, and its hypocenter at the depth of approximately 15 km (9.3 mi). It is the most powerful disaster to strike Nepal since the 1934 Nepal-Bihar Earthquake.

The impacts are devastating and widespread. Among the most affected areas are densely populated city core areas, historical settlements of Kathmandu valley and also remote villages perched on hilly areas. As of June 19, the Government reports 1,733 deaths and 13,103 injured people in Kathmandu Valley. Major chunks of this casualty belongs to the earthquake devastated historic core city areas of Kathmandu, Lalitpur and Bhaktapur and traditional settlements like Sankhu, Bungamati, Chapagaon, Khokana, Harishidi, Lubhu, Sunakothi, Tokha, Sitapaila Thankot, etc. Centuries of Kathmandu's architectural heritage was destroyed in 80 seconds Saturday on 25th April, 2015. In Kathmandu Valley only around 73000 buildings are collapsed and 67000 buildings are partially damaged.

The existing urban structure in Kathmandu Valley is characterized by two salient features: existence of old historic parts full of unparalleled artwork and architecture, which are being threatened by haphazard and unplanned modern development in the historic city core and unplanned sprawl development in urban fringe areas and orientation of the urban life towards urban fringes. And if we look at our tightly packed street pattern and tall, slender buildings which are being constructed without following building codes, the potential threat here is massive. Due to the recent big quake of 25 April, 2015 there have been significant loss of lives, buildings and a large part of the city are on the ground in rubble mostly in the historic core city and settlements . The historic core city and settlements, which has an extraordinary culture and extraordinary history, the source of great philosophy, great thought and great architecture is at risk of haphazard demolition, rebuilding and replacement with modern concrete structure. This valley, which is unique, is at risk because we are not planning to protect ourselves, the culture and the buildings. Kathmandu Valley's risk has increased significantly since the recent big quake. It is clear that a large earthquake near the Kathmandu Valley today would cause significantly greater human loss, physical damage, and economic crisis than caused by the recent big quake.

The main issues of Kathmandu Valley historical core city and settlements are:

- Dense settlement
- Highly vulnerable buildings without or limited possibility of seismic retrofitting
- Poor accessibility, especially for emergency services
- Inadequate Infrastructure and urban service
- Underutilized tourism and economic potentials
- Historic Heritage at high risk due to natural and manmade hazards, and also due to the current trend of building repair & replacement
- Vernacular Architecture is in the verge of disappearance due to the current trend of building demolition & replacement

2 URBAN REGENERATION AS A TOOL FOR POST EARTHQUAKE REHABILITATION AND RECONSTRUCTION

The cities in which we are living need safe housing and a better infrastructure plan altogether; our houses are very vulnerable to fire and earthquake risk, our built heritages are encroached upon and are dilapidated, the roads are very narrow, there is no scope of further improvement at all, and there are cities which are badly managed altogether. Here comes urban regeneration into scene.

More ever, we have to reconstruct the recent earthquake devastated historic settlements and core city areas. The reconstruction activities should include safe housing and a better infrastructure plan altogether. If we don't build back better our houses and settlements as we did in the past, our buildings, settlements and infrastructure will be very vulnerable to fire and earthquake risk. If we don't take care of our built heritages which are damaged, encroached upon and dilapidated, they will be lost forever. In this situation urban regeneration comes into scene.

Urban regeneration is a land redevelopment in moderate to high density urban land use to improve city's infrastructure, to create more economic activities, to transform old earthquake-vulnerable building stock into earthquake-resistant neighborhood, to improved quality of life, to preserve historic & architectural heritages and to ensure social inclusion and cohesion. In many countries it is taken as Pre-disaster shelter planning (Urban Seismic Risk Management) of historic city core as well as post –disaster reconstruction planning.

The purpose of urban regeneration is to take into consideration the complexity of urban dynamics. It is applied through horizontal approaches which comprise several fundamental rules:

- It is location-specific, as it dispenses with the difficulties specific to all urban factors. But it aims at reducing disparities, within the global vision of a more homogeneous social environment.
- It covers different time frames, as it responds to the social needs at present, and then those of long-term sustainability, aimed at predicting the future change. It likewise includes the lessons of the past, since in most Kathmandu Valley cities today; consensus is mostly in favor of the preservation of urban heritage following a period of destruction to cater to modernization, in the 1970s onwards.
- It is multidimensional, as it is used by many different public and individual stakeholders. Urban regeneration must serve to overcome contradictions, through negotiation, and priority of the targets. Priorities depend on the alignment between national policies and local schemes.
- Urban regeneration strategies are implemented in one sector and cause positive effects elsewhere.

2.1 Objective

Priority objectives of urban regeneration should be:

- Economics: to attract investors, create employment, renew the urban economy
- Social: to enlarge the supply of safe urban housing and develop local infrastructure.
- Environmental: to improve living conditions, combat pollution, while taking into accounts the values and preferences of society and each social group
- Cultural: to enhance the architectural heritage of historic urban areas and urban tourism,

Urban regeneration has been examined and enforced in the most advanced and developing countries and may be the solution to the burning issues like post earthquake damage assessment and the reconstruction of earthquake devastated historic core city and settlements. The analysis and assessment of the problems faced by these core city and settlements before and after the quake highlight the ways and means favorable to the generalized implementation of urban regeneration in our urban development system, while respecting historical and institutional characteristics, as considerably as the uniqueness of each case and locality.

2.2 Trends

Cities are potential engines of economic growth, as well as celebrations of collective human hope, imagination and efforts. While cities in the developed world are readjusting to post-industrial economies and shrinking populations at this time in history, cities in the developing world like Nepalese cities are swelling with rural-urban migrations, slum and squatter areas alongside rising prosperity.

At either end of the spectrum, there is pressure for cities to engage in the global economy just as new information and communication technologies make it increasingly easy to do so. Cities now compete for financial investments, multinational companies and talented human resources, all of which that are becoming increasingly mobile across the global stage. Urban regeneration and economic development, those related to urban environmental sustainability and social inclusion are the longest lasting in their impact.

2.3 People's Perception

It is too early to reckon that regeneration is possible in Nepal. Before the earthquake of 25 April 2015, the government and local authorities as well as the people living in the historical urban areas do not seem too bothered about it. The attitude to shout around for change prevails only after a disaster and not before it. Until then everyone seems to enjoy and carry on at the expense of social, cultural or environmental resources and most importantly safety & wellbeing of the entire community. But after the recent devastating earthquake peoples, community, local authority and concerned government agencies have shown interest in urban regeneration. Local communities of Khokana of Karya Vinayak municipality, Panga of Kirtipur municipality and Dambu chowk, Kilagal,of KMC have requested NSET to provide technical assistance on urban regeneration. Ministry of Urban Development (MOUD), Kathmandu Valley Development Authority (KVDA) have declared urban regeneration programs in their recently announced post earthquake rehabilitation and reconstruction plan. Thus, until we change we can't see any change.

2.4 Lesson learned from past studies

Nothing is impossible, even it is be read as "I'm-possible", but yes it would require brain storming and fore thought with meticulous planning, keeping in view the changing socio-economic developments and future requirements of at least next 50 years. At this juncture it will be better to share the lessons learned by NSET while carrying out feasibility study of urban regeneration of a part of the Kathmandu Core City. They are:

2.4.1 Lesson 1

One has to identify the historic urban areas and settlements and have strong proposal of regeneration keeping in the mind without a loss of any ones interest. For this to happen we need to have a Community Habitat Forum or Community discussion Forum. Local Authorities as a Local Planning and Development Authority should plan to establish such forum. Community Habitats Forum is a public awareness platform in partnership with core city community leaders, local municipal authority, Kathmandu Valley Development Authority (KVDA), Department of Urban Development and Building Construction (DUDBC), Department of Archaeology (DOA), Academia, Civil Societies and designed as a collaborative network of multidisciplinary thinkers and change-makers to push for innovation in shaping and saving the historical settlements of Kathmandu Valley. The forum aims to mobilize action through intelligent discourse, impactful research and result-driven advocacy.

2.4.2 Lesson 2

The City government (Municipal Board) should pass a resolution declaring Core City areas and historic settlements as historic conservation areas under the provisions of special purpose zones and should be delineated in land use map of municipalities. They should establish a Neighborhood Management Program as part of City Core Management (CCM) in historic settlements with special problems of safety and development requirements. Specific tasks characterizing the neighborhood management program are:

- Networking and coordination between various interest groups in the area;
- Motivation and organization of residents, to make them more actively involved;

- Initiation of projects aiming at the social, environmental, economic and cultural stabilization of the neighborhood;
- Monitoring and evaluation of these different projects

2.4.3 Lesson 3

International experiences of urban regeneration plan implementation demonstrate that a clear understanding of institutional responsibilities along with supportive legal provisions is crucial for the effective implementation of urban regeneration activities.

3. WAY FORWARD

Because of the historical, archaeological, artistic, cultural and touristic value of structures and settlements within the preserved historic area, a fundamental principle of its regeneration and redevelopment will be the preservation of its unique character in terms of style, scale, building materials and activities. Considering the potential seismic risk another important aspects are to ensure the earthquake safety of all manmade structure and to stabilize economy of the settlements. Based on the lessons learned from domestic experience and international practices on reconstruction and rehabilitation, Government of Nepal, specifically High Powered Nepal Reconstruction Authority, National Planning Commission, Ministry of Urban Development, Ministry of Federal Affairs and Local Development, Department of Urban Development and Building Construction, Department of Archaeology, Kathmandu Valley Development Authority and municipalities should have policy, plans and programs on urban regeneration as a tool for post earthquake rehabilitation and reconstruction of these historic urban core areas and settlements.

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Building Code Implementation: Way to Stronger Nepal

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ABSTRACT

Nepal National Building Code, prepared in 1994, announced for implemented in 2003, was introduced in Damak Municipality in 2012. In these two years of period, Damak did significant work and progress in implementing building code.
During the implementation, the road up to here was not so easy but the approaches adopted for the implementation helped the municipality to mark this success. The initial work was the identification of stakeholders. The main four stakeholders for the implementing process are Municipality, House owners, Mason groups and Technical society. The first and most challenging work is to increase the level of understanding of these stakeholders to the same level and maintain that equilibrium state during the entire process. So, after identification of stakeholder, three level of work was done, first is increase awareness level of the people of municipality, second capacity building trainings for masons, technical groups and most importantly house owners, and third institutionalization of the process by municipality. The strong monitoring and guiding system of the municipality and equal responsibility distribution between the stakeholders for this process was key of the success.
In around two years of period, Damak transformed itself from a municipality without any building code provisions in building permit system to an example municipality to effectively implement the building code. As a result, most of the newly constructed buildings in Damak are compliant to building code. But, still there are challenges to keep this momentum for long period.
From Damak municipality, other municipality of Nepal can understand that building code implementation process is difficult but not impossible.

Keywords: implementation, stakeholders, awareness, trainings, institutionalization

1. AN INTRODUCTION TO BUILDING CODE IMPLEMENTATION

Building Code is a technical document with minimum standard which guides the construction of structures. And the code is prepared by any country as per identified hazards, and economical acceptance of the individual country. In Nepal, National Building Code regulates the construction of all the buildings to be constructed in Nepal which specially guides the structures to an improved seismic performance level. It was prepared in 1994, after the feel of need after 1988 earthquake as Nepal lies in an earthquake prone zone, which consists of four levels as per type of structures to be constructed:

1. **International State of Art**: It is for those buildings/structures, designed using the building codes of other countries. Nepalese Engineers and international consultants can use the code but structure should maintain minimum Nepalese standards.

2. **Professionally Engineered Buildings**: It is the code which can be used by qualified Engineers for the design of buildings. And this is a minimum standard for designing any structures in Nepal.

3. **Mandatory Rule of Thumb**: In Nepal, there is limited access of professional engineers to design all the buildings and it is practically not possible to design all buildings by a professional Engineer. Mandatory Rule of Thumb is a ready to use code which covers those residential buildings with limited height, span, and no. of storey, and floor area but can be constructed both RC frame and Masonry load bearing structures. This part of building code covers most of the residential buildings of Nepal. The explanatory documents are such that an experienced junior engineer is able to understand them and present sufficient details at the time of permit application and construction process.

4. **Guideline for remote rural Buildings**: This guideline focuses on those changes that should be made to current practices to improve the seismic resistant of rural buildings which are not subject to modern quantitative analysis and rational design consideration. These structures are normally of earthen construction (unfired masonry, mud mortar, rubble, dry stone etc.).

And this mandatory rule of thumb part and guidelines for remote rural building covers more than 80% buildings of Nepal.

After the decision of government to implement the building code in Nepal in 2003, Damak municipality decided to implement it in 2012 with the continuous guidance and technical support from NSET through Building Code Implementation Program in Municipalities of Nepal (BCIPN). With the reference to the experience of NSET on implementation of building code in different municipality projects like Municipal Earthquake Risk Management Project suggests that the Building Code itself is a technical document but when it comes to the time of implementation it is more social issue than technical.

2. APPROACHES ADOPTED

The proper coordination between all the stakeholders is the key to success in building code implementation. Municipality had decided that following should be mandatory to be sure for proper implementation of building code practically:

a) There should be appropriate design of building as per National Building Code. Also the maps which comes under building permit process must be as per NBC.
b) Quality construction at field as per permitted map.
c) Use of quality materials at field with good workmanship.

To get the expected success in the implementation proper strategy is necessary. As this building code implementation part is a function of all the stakeholders, if any variables of this function turns negative building code implementation is impossible. So, following is the strategy adopted:

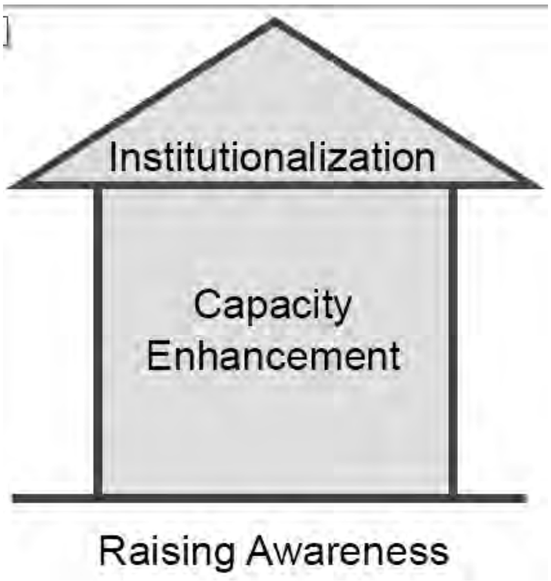

Figure. 1 Strategy for effective building code implementation

Building code implementation is a process which can be compared to a building as shown in Figure.1. For proper and successful implementation of building code every element of above building should be strong enough.
Four main stakeholders identified by Damak municipality which may influence the building code implementation are as follows:

1. Technical Society
2. Masons and Petty contractors
3. House Owners
4. Municipality

Other stakeholders which may act as catalyst; positive catalysts when used properly and negative catalysts if not used properly are:

5. Media
6. Political Society
7. Community

2.1 Raising Awareness

In a building, foundation is most important part, without strong foundation no any superstructure can perform well. Just like that in the process of building code implementation raising awareness is the base of the entire process. But it is necessary to find out the proper stakeholders to be oriented for this. It contains not only what to do, it must contain why to do. This answer is given in the awareness programs. The main purpose of this part is to create a desire to construct earthquake resistant building as per building code. There may be additional stakeholders to be oriented but from the experience of Damak basic stakeholders to be oriented are as follows:

2.1.1 Political Leaders

Political leaders can play a pivotal role in any of the social decisions. Without the realization by political leaders, the importance of the implementation of building code, it is not even possible to announce the implementation of building code. There is need of intensive interaction between political leaders and municipality, and create a same positive perception to implement the building code for easy implementation of the building code.

2.1.2 House Owners

For effective implementation of the building code self-realization by the house-owners to construct earthquake resistant building is necessary. Everybody want to build their house safe, stronger and earthquake resistant. The only thing that leads house owners not to build the earthquake resistant building is due to the fear of cost. But, in Damak and in most of the Nepal, just 5-10% addition in the cost of normally constructed buildings results the earthquake resistant building. If the design, materials, and manpower are carefully managed than it may cost even less. So, there is necessity of creating a situation of craving for earthquake resistant buildings from the house owners. This can be created by orienting them on how to construct such buildings, why to construct, and how much it costs. These kind of orientation is must because during implementation of building code, if a house owner wants to build an earthquake resistant building than no one is there to restrict him on constructing safer building but if this group stands against the implementation than it would be very difficult to implement. A house owner is the one which is most important stakeholder in building construction but the most immature one, because a house owner constructs a building in his lifetime and believes his/her nearest one, his/her hired masons, technical personnel. So, if they are oriented to the better direction before they go to wrong one then building code implementation also goes in right direction. The right time to orient them is just after they come to building permit process.

The only purpose of these kind of orientations is to make the house-owners understand and accept the importance of the safety of the buildings in which they are investing, make prepare them to pay a little extra for safety and suggest them to hire qualified and experienced designers and trained masons or contractors.

2.1.3 Social Mobilizers, Tole leaders

These groups are the secondary stakeholders but can influence the primary stakeholders. People believe what they say, people copy what they do, and people follow their footsteps in most of the case. If this group spread a good vibes about the building code in the community can create demand of building code implementation.

2.1.4 Media

Media can reach the every people around. If it passes the right message effectively, then it can create a good environment. But it is necessary to orient this group during the implementation process such that they pass right message to the audience. Also, municipality can spread some messages related to building code implementation, also messages regarding safer building constructions which may influence the public. Right use of the media will be a positive catalyst for the implementation process.

2.1.5 Community Awareness

Unless all people of the community are not aware to the safer construction, building code implementation is difficult. As neighbor of any house owner can influence most than any other to build a building safer or not. Because anyone believes his/her relatives, neighbors more than any other and if that relatives and neighbors who are not aware to the building code may affect negatively to the house owners resulting ineffectiveness of building code implementation.

Other alternatives for raising the awareness level of the community used by municipality are:

1. **Mobile clinic**: The concept of "Mobile Clinic" is to provide onsite consultation in aspects of earthquake- resistant building construction. A team of Engineers

from municipality, consultants visit different locations / building construction sites in specific areas and provide technical advice. The aim of the clinic is to improve seismic performance of buildings being constructed by the untrained masons.

2. **Earthquake Safety Day Awareness Programs**: Government of Nepal has declared Magh 2, January 15 (or 16) as the Earthquake Safety Day of Nepal. Using this day as a day for raising awareness, municipality does different activities like Rally covering municipalities, distribution of informative publications, symposium between stakeholders, talk programs related to earthquake safety and Shake table demonstration.
3. **Informative visual display in municipality office**: Municipality has installed TV for the information sharing about the municipality news, which also covers the information regarding building code and other tips regarding earthquake resistant building construction.
4. **PSA through TV and Radio:** Regular informations through TV and Radio regarding building code implementation help to reach the community.

2.2 Capacity Enhancement

This is like the superstructure of the building which is most needed and visible requirement by everyone. As building code is a technical document, so for proper implementation most of the implementing agencies and people needs their capacity enhancement. First work was to identify the stakeholders who needs the capacity enhancement trainings. It was identified the following as the potential stakeholders to be trained:

1. Masons
2. Petty contractors
3. Municipal Engineers
4. Consultant Engineers

NSET focused on capacity enhancement of local champions and municipality staff for sustainable long run of the implementation process. NSET provide technical assistance to the municipality throughout this process.

2.2.1 Masons/ Petty Contractors

More than 90 % buildings in Damak municipality constructed by the owner at the guidance and involvement of petty contractors and masons who lacks any modern knowledge on earthquake resistant construction. Most of the buildings constructed in the municipality area constructed can be covered by mandatory rule of thumb (MRT) part of the building code but unfortunately they were all constructed only with the help of untrained masons and contractors resulting unsafe construction. It shows that, after the announcement of building code implementation, without the special consideration of this group more than 90% buildings cannot be constructed earthquake resistant. So, this is one of the main stakeholder for building code implementation.

But, the real scenario is that this group which governs 90% of the building construction have got no any formal education for earthquake resistant building construction. They have only learned to construct buildings through their seniors, they have learned what their seniors taught them. But, the thing is that the seniors who taught them are also unaware of earthquake resistant building construction. So, more and more trainings on earthquake resistant building construction for masons and contractors is necessary to make those buildings safe. These trainings are for the masons who are already masons but constructing buildings in their own traditional

way.
Municipality of Damak decided as mandatory to be at least one mason who is trained on earthquake resistant building construction. Such that, the trained mason can guide other untrained masons in the field. Damak municipality trained more than 50% of the masons in different series of trainings.
The trainings are basically in form of interaction, photographs display, site visit and practical model exercises on key elements of seismic safe construction for different building types.

2.2.2 Municipal and Consultant Engineers

As Building Code itself is a technical document, so role of technical manpower in its implementation is primary. In case of Damak and also in most of the municipality of Nepal, understanding the building code itself technically by the consultant engineers and self-realization of importance of its implementation by them is the first step to the journey of implementing the building code. As in Damak municipality, where building permit was mandatory before the announcement of implementation of building code, the role of Engineers and Technicians was to make a plan of Buildings and clear the building permit process. In that time, building permit systems only concern was to make sure of compliance of building By-Laws. After announcement of the Building Code, structural design of the building and its structural drawing with addition of architectural drawing requirement is to be done as per the Nepal National building code and this most initial work of implementing building code is entirely technical part and it goes under the arm of the technical society.
The buildings should be properly designed first of all such that to build the building earthquake resistant in the field also. The faulty design leads to a faulty construction, so it is necessary to train the engineers who designs and draws the buildings and it is also necessary to train the engineers within the municipality for the checking of submitted designs and drawings of the buildings. Damak municipality decided to give the trainings to the consultants and municipal engineers firstly on basic course on earthquake resistant building design and construction, which course contains the basic things that must be considered during designing the buildings and focuses mostly on buildings which lies under mandatory rules of thumb. Because, according to municipality, more than 80% of building constructed inside the municipality lies under this category.
It is also necessary to design the buildings through consultancies which are registered in the municipality. And the building construction supervision also should be done through the consultant engineers. Municipal Engineers assures the every stage of the building permit process is going as per the building code.

2.3 Institutionalization

As much the roofing of the building is important to protect the superstructure, institutionalization of the whole building code implementation process is necessary for the effective implementation for the long term.
Most of the responsibility for the institutionalization of this process falls under the arm of municipality. The entire work for the proper institutionalization of the building code implementation by the municipality are as follows:

Announcement of Building Code Implementation:

- The very first work is to announce the building code implementation after the proper background development. Before the announcement intensive interaction with political leaders, technical society, and other intellectual groups is necessary.

- During the same time awareness programs to the stakeholders and capacity enhancement trainings for masons and engineers are to be coordinated by the municipality.

Incorporation of Building Code and Building By-laws In the Same Building Permit System:

- Incorporation of building code in building permit process is the most important and critical work. As municipality already have the building permit process which contains mostly the by-laws, it is felt necessary to incorporate the building code also within the permit process and municipality was successful for that.

Masons and Consultants Regulation System:

- It is necessary to bring all the main stakeholders of the implementation of the building code under the same umbrella.

To assure that, municipality needs to register and license the trained masons within the municipality and give them the appropriate responsibility. Damak had licensed the trained masons and at least one trained mason in one building construction site was maintained. It was ensured by taking the responsibility signatory by the trained mason in the building permit process and also regular field monitoring by the municipality. Also, there must be the rules and regulations to regulate the masons such that they will not do any works against the building code.

Another group is the group of consultant engineers who designs the buildings. Municipality needs to register the consultancies who can design the buildings within the municipality area. Municipality also confirms the capacity of the consultants and provides capacity enhancement trainings if needed. Damak has decided that every new building designs and maps must come through these registered consultancy such that they will be responsible for any consequences. Also there must be availability of consultants during the construction for the supervision but it need not to be the consultant who designed the building.

Hiring the masons, consultants and complete the entire building permit process through the municipality, this responsibility lies under house owner. Municipality is now planning for contracting house-owners, masons and technical consultant with their responsibility to make each of them more responsible.

Monitoring by Municipality in Field

- Under the municipality, creation of a section which checks the map and assures the design to be correct is necessary. Also, it also confirms the construction of the building is running as per the design and drawing or not in every stages of construction. In Damak, mainly three times the buildings are monitored by municipal engineers: 1. At the time of layout 2. Before the start of superstructure 3. After the completion of superstructure. This monitoring system also ensures the quality of the construction.

Supporting Groups for Building Code Implementation

- Development of building code implementation supporting groups is the one that other municipality can learn from Damak. There are building code implementation supporting group of masons and technical cell of consultant engineers, whose main purpose is to support municipality during this entire process.

And this is the strength of Damak municipality to be so successful in short period of time. These groups lies under the umbrella of the municipality.

Role of supporting organization

- During the implementation process collaboration with the organizations like National Society for Earthquake Technology –Nepal (NSET) for the technical support to train the masons and consultant engineers, orient different stakeholders, develop strategies throughout the process of implementation ease the implementation process through its Building Code Implementation Program in Municipalities of Nepal (BCIPN). As NSET had already work for effective building code implementation in other municipalities with same socio-economic status, the strategies developed by NSET for effective implementation of Building Code through BCIPN guide Damak to the road of success in building code implementation.

NSET did support municipality in almost all of the municipal activities; awareness, capacity enhancement, and institutionalization process during this period.

3. LESSON LEARNT AND CHALLENGES

From the learnings of the Damak, it is proved that building code implementation process obviously is difficult but not unachievable. Building Code Implementation in Damak municipality is running smoothly now. But still there are more challenges to resolve and works to do:

1. Technical community, masons, municipality, house owners, political leaders, media and community are the main stakeholders for the building code implementation process. The synergetic cooperation between all stakeholders is key to success of building code implementation and it is required to maintain the equilibrium state between all the stakeholders for long run. Controlling the building construction by enforcing the building code through strict rules and regulations is important thing but capacity enhancement of technical community and masons and convincing other stakeholders for safer construction should be promoted for sustainable implementation.
2. An auto running mechanism within the municipality for the implementation of building code is necessary. Incorporation of building code within the building permit system, make the stakeholders more responsible by creating supporting groups like technical cells and masons group of Damak, regulation of technical manpower and masons through licensing, strict field monitoring system, are some of the works that can be learnt from Damak municipality.
3. Approaches must be in a sequence of not increasing the earthquake risk by constructing new buildings safe and then decreasing the earthquake risk by retrofitting the old vulnerable buildings. According to Damak municipality, more than 75% of the buildings which are newly constructed are according to building code but still there are old building which are constructed before the implementation of building code and are very vulnerable to the earthquake. There is challenge to make them safe and Damak is focusing on retrofitting of such buildings.
4. High priority must be given to local manpower and resources in order to ensure sustainable implementation. Till now, NSET or DUDBC is supporting for the capacity enhancement and awareness program but for the sustainable long run, development of local champions for conducting such trainings is felt necessary.

For this, NSET has developed some of the trainers inside and outside municipal office also but is not sufficient and needs to develop more of them for sustainable long run of the implementation.Still there are more masons and contractors who are to be trained on earthquake resistant building construction. And this training process is a regular task which needs to be continued for a long time.

5. House owners are the key for the safer building construction, so orientation on earthquake resistant building construction for the house-owner should be regular. They should be oriented in such way that they not only be convinced to the safer construction, they can also supervise and monitor the construction.
6. Program like Building Code Implementation in Municipalities in Nepal (BCIPN) of NSET should be continued. The approaches adopted in Damak municipality by BCIPN is successful in Damak and its impact is replicated in the nearby VDCs and municipalities as well.

4. IMPLICATIONS

Obviously, Building Code implementation process is difficult but it is still achievable. It is a process which cannot be achieved over a night but if there is strong monitoring and guiding system of the municipality and equal responsibility distribution between the stakeholders, it is possible. From Damak municipality, other municipalities of Nepal can learn and replicate it for easy implementation of building code.

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Seismic retrofitting of a garments factory building in Bangladesh

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ABSTRACT

Seismic assessment and retrofitting methods are not properly addressed in Bangladesh National Building Code (BNBC 1993 and draft of BNBC 2015), although they are strongly needed. After the "Rana Plaza" collapse, owners of many garments factory wanted technical assistance for structural evaluation of their factory buildings. Existing Japanese seismic assessment and retrofitting method was applied to one such factory building, DK Knitwear Ltd with necessary modifications considering local building construction conditions and codal requirements. This Japanese method was selected for simplicity of calculation. After seismic assessment, the selected four storied garments building revealed deficiency in seismic performance in both directions at ground and first floor level. Later retrofitting was done using steel frame bracing at Ground and first floor level. The steel bracings were supported over R.C.C. shear wall at foundation level. Application of the method showed improvement of the seismic behavior. This paper shares the Bangladesh experience in retrofitting works.

Keywords: seismic assessment, reinforced concrete, existing building, retrofitting design.

1. INTRODUCTION AND BACKGROUND

After the "Rana Plaza" collapse in 2013, JICA was keen to help garment factory owners in Bangladesh by sanctioning very soft loans for retrofitting vulnerable R.C.C. factory buildings. The two ongoing JICA funded projects with Government of Bangladesh 1)CNCRP- a technical co-operation project concerning seismic retrofitting techniques with Public Works Department and 2) FSPDSME-a financial co-operation project with Bangladesh Bank were engaged to support the factory owners. A lot of factory owners showed interest to take the technical and financial help. To make a priority list for immediate attention a simplified evaluation method proposed by Seki (2015) was used. The simplified method was derived from existing Japanese seismic assessment and retrofitting method taking into considerations of local construction conditions and characteristics of buildings. The selected building is a four storied R.C.C frame structure garments building with a floor area of 1811 m^2. Its performance against vertical loading was acceptable but performance under seismic loading was questionable. After detailed evaluation it was found that, concrete core strength was considerably lower than the design strength. As a result retrofitting was the ultimate solution to ensure BNBC requirement.

2. JAPANESE SEISMIC EVALUATION METHOD

Japanese seismic evaluation method was used to evaluate a few existing R.C.C. buildings in Bangladesh with some modification considering local seismicity and building characteristics according to Manual for Seismic Retrofit Design of Existing Reinforced Concrete Buildings draft version 2015. The method recognizes the strength and ductility of a building, sequence of failure of less ductile to more ductile members. The earthquake resisting capacity must be compared with an index to characterize the earthquake damaging power (Otani, 2000). Generally, seismic Index of structure I_s shows its seismic performance level. There are three levels of seismic screening method for seismic evaluation of a building. First level is preliminary method used only geometric section ignoring the reinforcement contribution. Second level screening uses detailed investigation where strong beam and weak column failure is considered. Third level is more rigorous and requires tedious calculations. Seismic Evaluation using second level is more appropriate for Bangladesh buildings where narrow column and small volume of beam-column space is common. This will eventually result in failure of column before beam failure which resembles fundamental assumption of second level screening method and is appropriate for Bangladeshi buildings.

2.1 Methodology

The seismic index of structure I_s shall be calculated by following equation which was developed by The Japan Building Disaster Prevention Association in, 1997. It is calculated at each story and in each principal horizontal direction of a building.

$$I_S = E_0 \cdot S_D \cdot T \tag{1}$$

Where: E_o= Basic seismic index of structure.
S_D= Irregularity index.
T= Time index.

Seismic demand index of structure I_{so}, for a building is defined as a product of E_S, Z, G and U. Where E_S, stands for basic seismic demand index of structure, Z for zone index, G for ground index of soil and U is for usage pattern. Seismic index of structure I_s is compared with seismic demand index of structure I_{so}. If $I_s \geq I_{so}$ then the seismic performance of the building is satisfactory.

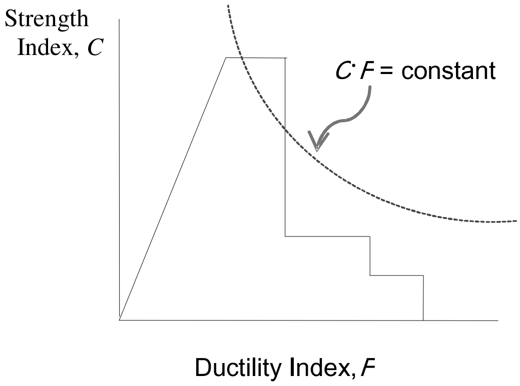

Figure 1: Strength index and Ductility index

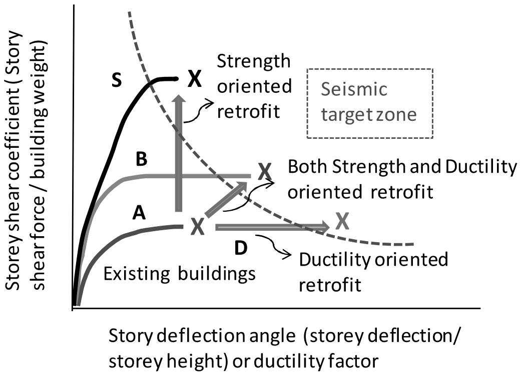

Figure 2: Load and Deflection Curves and Concept of Retrofit

When it is not satisfied structural strengthening elements such as column jacketing, R.C.C wing wall, R.C.C shear wall, steel brace frame and others are provided so that I_s after retrofit exceeds I_{so}. I_s is proportional to C·F [strength index (C) × ductility index (F)]. Strength and ductility is evaluated for each vertical member. Then C·F relation expressed by multi-linear lines a floor in each direction can be prepared through the summation of all vertical members of that floor. In case of seismic evaluation and retrofit design, simplified multi-linear lines express the performance of a building shown in Figure 1. Vertical axis C and horizontal axis F is non-dimensional.

2.2 Seismic Retrofitting

The concept of retrofit design of an existing RC building is shown in Figure 2. Vertical axis is horizontal strength at ground floor divided by building weight, which is base shear coefficient. Horizontal axis is story deflection angle (ductility factor), which is story deflection divided by story height. The curve A of the Figure 2 is a typical existing R.C.C. building where strength and ductility is not enough. There are three retrofit methods strength oriented (curve S), ductility oriented (curve D) and both strength and ductility retrofit method (curve B). Right upper side of hyperbolic curve of the Figure is expressed as “Seismic target Zone”. In case the curve of a building reaches the target zone, it is judged that the building is acceptable.

2.3 Comparison of shear strength between BNBC and Japanese standard

In CNCRP project relationship between the codes was studied before applying the Japanese standard for seismic evaluation and retrofitting for Bangladesh buildings. In the study it was found that BNBC formula can be used to calculate shear strength where following points need to be considered according to Manual for Seismic Assessment of Existing Reinforced Concrete Buildings draft version 2015.

BNBC formula provides safer results compared to both experimental and evaluation formula of Japan. On the contrary, in case of high axial force ration and low strength of concrete it need to be careful for using BNBC formula because in some cases it provides lesser value than the Japanese evaluation formula. Similarly, for high shear reinforcement ration same cautions should be considered for applying BNBC.

3. EXAMPLE OF DK GARMENTS BUILDING RETROFITTING

The selected building was capable of carrying vertical load only according to the BNBC 1993. However, considering earthquake loading its performance was questionable. Therefore, seismic performance was assessed following seismic assessment of Japanese method and eventually retrofitting was done following Japanese method.

3.1 Description of the factory building

The building is a four story R.C.C garment factory constructed in 2002. One of the characteristics of the building is the presence of a double height space at one side of the building. The height of building at ground floor is large compared to other floors.

Table 1: Building Data

Name	D.K Knit Wear Ltd.
Usage	Garments Factory
Story	4
Building height	15,292mm
Story height	3,658mm(Typical) 4,878mm (GF to 1F)
Structural type	R.C.C Framed Structure
Foundation	Individual footing
Building area	1,811m^2
Total floor area	6,038.7m^2
Year of design	2002 (approved)

Figure 3: Front view of D.K. Knit Wear Ltd

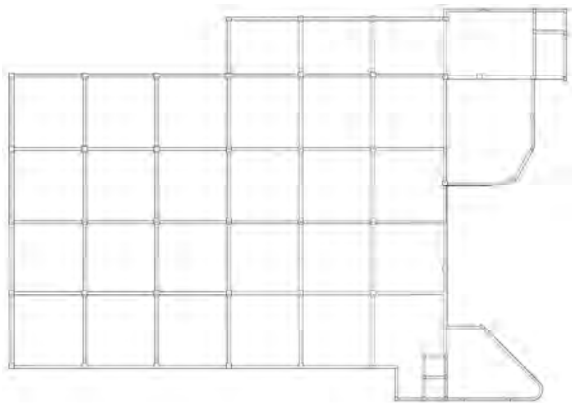

Figure 4: Framing plan of GF and Typical floor.

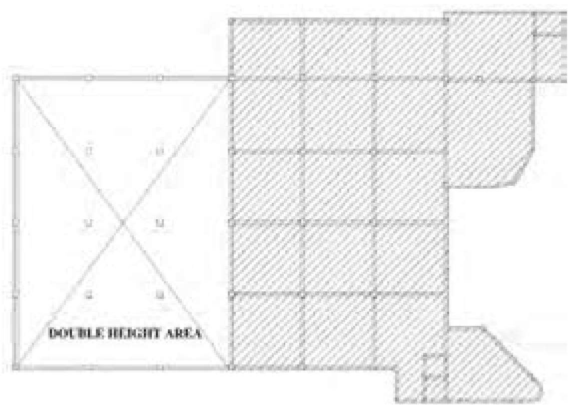

Figure 5: Framing plan of 1st Floor of the building.

3.2 Structural Assessment

Concrete strength, Fc=10.7N/mm^2 and re-bar yield strength 400kN/mm^2 was found according to test report of cores and sample re-bars which were collected from site. Proposed seismic demand index of structure, I_{so}= 0.30 is selected for buildings of Dhaka considering importance factor =1, according to Manual for Seismic Retrofit Design of Existing Reinforced Concrete Buildings draft version 2015.
The strength and deformation capacities of structural members are calculated on the basis of structural dimensions and material properties investigated at site. Ductility index, F=1.50(=1/100) is calculated at ground floor level for most of the columns manually considering structural data. In this evaluation, F = 1.27(=1/150) at ground floor level was used due to high axial force ratio. This conservative adjustment will reduce the damage of brick walls and non-structural elements. During the assessment irregularity index S_D is found 0.76 at GF for both direction (X and Y direction), which is relatively large. Time Index, T is estimated following standard table, and T = 1.0 is used for further calculation. Result of seismic evaluation shows I_s value at level 1 and level 2 are lower than I_{so} (= 0.30) which suggests for retrofitting. Calculated F is higher than 1.5 at level 3 and level 4, but F =1.5 was used for assessment considering "low strength concrete" according to Japan Concrete Institute in February 2009.

Table 2: Result of Seismic Evaluation

Story	**(n+1) / (n+i)**	**X- direction**				**Y- direction**			
		C	**F**	**E_o**	**I_s**	**C**	**F**	**E_o**	**I_s**
4	0.63	0.63	1.50	0.59	0.56	0.59	1.50	0.56	0.53
3	0.71	0.33	1.50	0.35	0.33	0.32	1.50	0.34	0.33
2	0.83	0.18	1.27	0.19	0.18	0.16	1.27	0.17	0.15
1	1.00	0.12	1.27	0.15	0.11	0.10	1.27	0.16	0.12

3.3 Retrofit design

Retrofit elements are provided at outside of perimeter column. This will reduce disturbances during execution of construction work and production will go on smoothly. Among the different retrofitting options steel framed brace is preferred which will allow windows and other openings of perimeter walls to function properly. However, in-filled R.C.C. walls are provided under the steel framed brace up to the existing foundation footing to transfer the strength of steel framed brace at GF. It contributed for the improvement irregularity both in plan and vertical direction. Required number of steel framed brace can be calculated by following standard equations.

Table 3: Required numbers of Steel Framed Brace

Story	ΣW, Weight (kN), Un factored load	$\frac{n+i}{n+1}$	Design shear coefficient, $\frac{n+i}{n+1}\times\frac{0.30}{F\times0.95\times1.0}$ I_{so} = 0.30, S_D = 0.95 (after retrofit)	Design shear strength Q, after retrofit, $\frac{n+i}{n+1}\times\frac{0.30}{F\times0.95\times1.0}\times\Sigma W_i$ (1)	Original strength, C (at F)× ΣW_i, (2)		Required additional strength, Q (1)- (2) (kN)
					Q (kN)	C	Q(kN)
4	15,065	1.6	0.33 (F =1.5)	5,077 in case F =1.5	x 9,481	0.63	---

					y	8,955	0.59	---
3	33,178	1.4	0.29 (F =1.5)	9,788 in case F =1.5	x	10,892	0.32	---
					y	10,646	0.32	---
2	51,803	1.2	0.29 (F =1.27)	15,437	x	9,512	0.18	5,925
					y	8,606	0.16	6,831
1	66,391	1.0	0.24 (F =1.27)	16,531	x	7,909	0.12	8,622
					y	7,013	0.11	9,518

Following combination of steel framed brace is proposed. Well balanced layout of steel brace is planned to improve the irregularity. Irregularity index of each floor is 0.95. In X-direction four numbers of steel frame bracing at GF and four numbers at 1st floor is required. Similarly, in Y-direction four numbers at GF and four numbers at 1st floor is suggested.

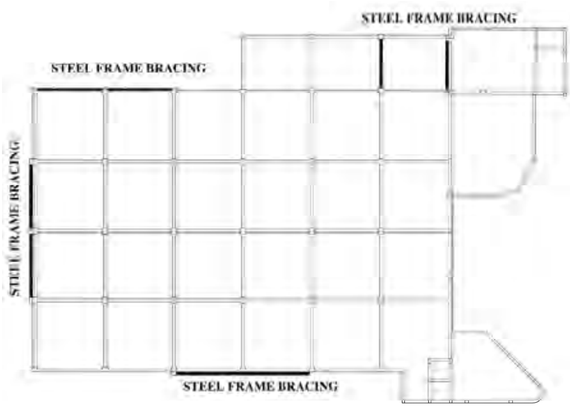

Figure 6: Retrofitting plan at GF

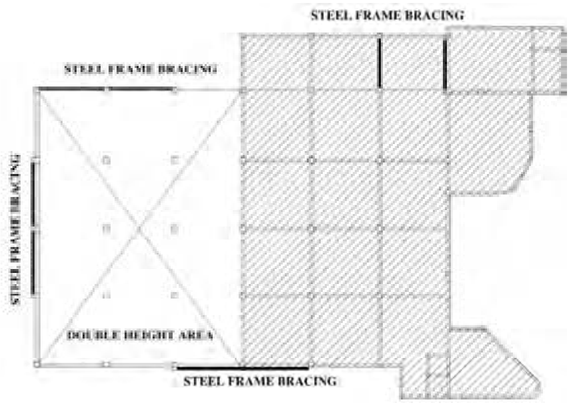

Figure 7: Retrofitting plan at 1st Foor

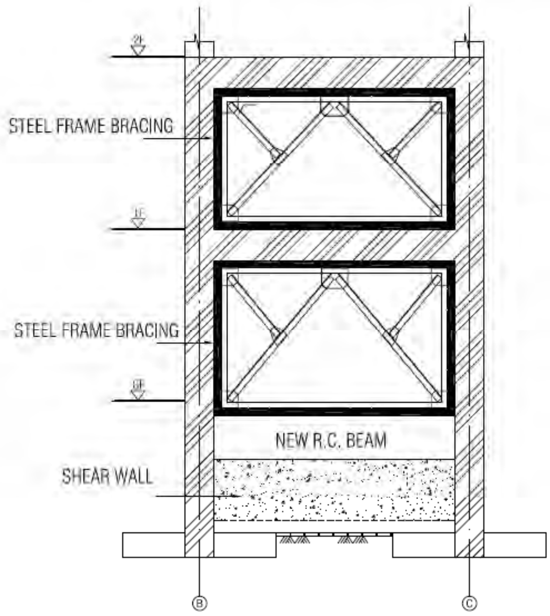

Figure 8: Typical sectional elevation of a retrofitted frame.

4. RESULT OF SEISMIC RETROFIT DESIGN

Seismic index of structure, I_s at level 1 and level 2 are more than I_{so} (= 0.30) and are satisfactory. Irregularity Index, S_{D2}, is 0.95 after retrofit

Table 4: Result after Retrofit

Story	$\frac{n+1}{n+i}$	X-direction				Y-direction			
		C	F	E_o	I_s	C	F	E_o	I_s
4	0.63	0.62	1.50	0.59	0.56	0.57	1.50	0.56	0.53
3	0.71	0.32	1.50	0.34	0.32	0.32	1.50	0.34	0.32
2	0.83	0.14 + 0.17 = 0.32	1.27	0.34	0.32	0.16 + 0.14 = 0.30	1.27	0.32	0.30
1	1.0	0.12 + 0.16 = 0.28	1.27	0.35	0.33	0.11 + 0.14 = 0.25	1.27	0.32	0.30

Figure 9 indicates the performance after retrofitting 1st floor X-direction. The X axis indicates the F (ductility index) and the Y axis C (strength index). C (strength index) *F* (ductility index) relation at each floor before and after retrofit can be shown in similar way. Right upper side of the hyperbolic curve shows the target area of seismic performance. Before retrofit the performance remains below the line and after retrofit the performance line matches with the line ensuring building performance. This hyperbolic curve shows target E_o or I_{so} expressed by,

$$C \cdot F = \frac{n+i}{n+1} \times \frac{I_{So}}{S_D \times T} \qquad (2)$$

Where I_{so}=0.3, S_D=0.95 and T=1.0.

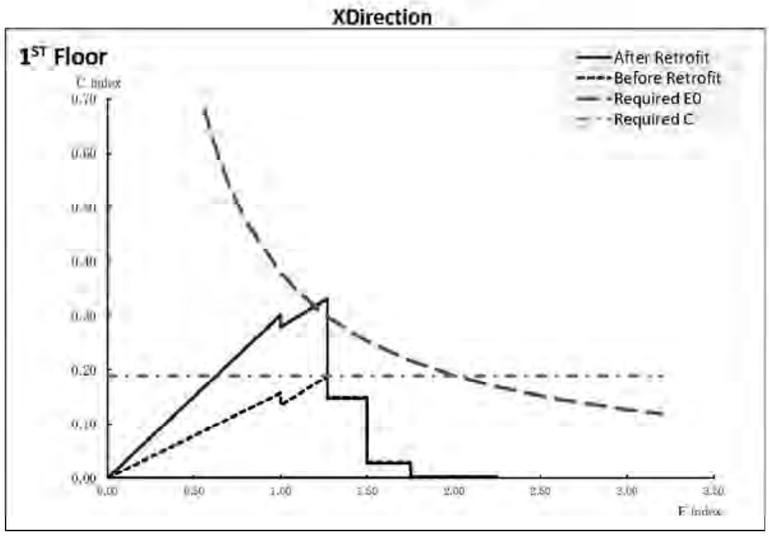

Figure 9: Performance of Building after retrofit (1st floor X direction)

5. CONCLUSION

The application of Japanese method can be used for the buildings of Bangladesh. However, reliability of the procedure needs to be examined with respect to the damage in buildings (Otani, 2000). This can be achieved by scale down model test in simulator or other suitable methods as Bangladesh does not have ample earthquake damage data of buildings. In this regard new research should be encouraged to come up with appropriate solutions considering Bangladesh building characteristics and availability of local construction materials.

6. ACKNOWLEDGEMENT

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Emergence of Alternative Construction Technologies: towards a safer Dhaka

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ABSTRACT

The Urban center of Bangladesh, Dhaka, being the mega city offers diverse livelihood opportunities. Amalgamation of large amount of population in this city is thus foreseeable. Higher standard for living is completely centralized within Dhaka; it attracts people from all over the country with bright lights of hope, employment opportunities, better living condition, educational and health facilities. Despite this pull factors, natural disaster, environmental degradation, insecure livelihood and housing facilities push people towards the city with opportunities. Though they thrive for an amelioration of their livelihood, they eventually end up engaged in informal sector and reside in informal settlements. This results in uncontrolled increase in informal sectors devoid of basic living standards. However Dhaka cannot offer a support mechanism that allows citizens to avail all the facilities of a megacity. Housing is a vital measure for standard living; it is considered as an all-inclusive system of finance, livelihood, affordability and Infrastructure. In megacities the system becomes more crucial because it faces a dichotomous scenario of formal and informal living. This paper attempts to address housing as an important factor for economic, social and environmental development of this megacity. The emergence of affordable and environment friendly alternate construction technologies and building materials are being considered to ensure housing for the privileged and under- privileged. Regarding impact of urban hazard, sustainable building technologies can play an important role towards resilience. The persisting damage to our environment can be reduced for instance by introducing non-burnt construction elements. The application of these technologies in rural housing as well will mitigate its vulnerability against disaster risks and ensure secured livelihood; consequently the rate of rural-urban migration will be demised. In Dhaka while rapid urbanization, centralization and massive pressure of population prevails, making the megacity safer becomes an agenda that this paper addresses in relation to sustainable construction technology.

Keywords: Dhaka, megacity, housing, construction, building material

1. INTRODUCTION

Dhaka, the only mega city of Bangladesh is among the six South Asian cities with at least 15 million inhabitants and included as one of the twenty mega cities of the world (UN HABITAT 2008). More than 60% of urban population lives in four main cities in Bangladesh and Dhaka alone accommodates one third of it (Parvin et al, 2013). With this rate capital Dhaka is projected to become the 4th largest city with 22 million populations by 2025 due to urban migration (Rashid, 2013).

The level of urbanization in Bangladesh is 28.4% (Islam, 2015) and the growth rate is 3.5% per year (Parvin, 2013). Rural urban migration causes 40% of increase in urban population and in some cities of Bangladesh this figure is as high as 70% (Parvin et al, 2013). After migrating to cities these migrant people arrange their accommodations in marginal settlements with substandard housing, limited infrastructure and services. As a result cities are being congested by squatters and slums and at present there about 4,966 slums alone in Dhaka city (CUS, 2005). The fast paced growth has resulted in widespread urban poverty. Unplanned and uncontrolled urbanization is exacerbating environmental problems and disaster risks. All these issues are directing Dhaka to be one of the most unplanned urban centers giving rise to the need of efficient management of limited resources. The provision of adequate shelter is an important parameter of urban safety which is certainly a major concern in the face of such rapid increase in city population.

This paper therefore focuses on the unplanned growth of population in the city and its area of concern is secure living and housing. Four factors have been addressed to analyze urban safety with respect to adequate shelter for Dhaka city population, which are interrelated and acting both as cause and effect. First, we are discussing on the betterment of the substandard living of the informal sectors by introducing new affordable technologies; considering the fact that in a mega city which provides standard livelihood opportunities, such settlements are devoid of minimum living quality. Secondly, we are addressing the urban hazard issue and its relation to housing. The more the population- more is the impact of disaster. Disaster resilient housing can ensure safer Dhaka city. Thirdly, we are pointing out the negative impact of building materials on environment and discuss the advantages of alternatives to it. Utilization of wastes is also high lightened ensuring a less polluted city. Safe environment in long term will ensure a safer Dhaka city. Finally we are addressing the insecure housing condition in rural areas as one of the major causes of migration to cities which in turn increases city population and informal settlements. We therefore emphasize on secure rural living and betterment of rural housing with sustainable technologies as well. This in long term will control the rural-urban migration resulting in population control in the city and thus will limit the growth of informal settlements. The less the population the less is the risk of disaster and higher percentage of people will be living a standard life.

2. AFFORDABLE TECHNOLOGY AND URBAN SAFETY

Center for Urban Studies, Bangladesh 2005 census of low income settlements finds that, a large proportion of slum residents in the city corporation towns had migrated from other districts or their rural hinterlands. Right now 37.4% of the total population of Dhaka is occupied in informal sector. To accommodate this increasing pressure of huge population, it is a must to provide or extend civic facilities and services like housing, transportation etc. Though concerned authorities are offering its urbanites a number of basic services but housing facilities are far from being adequate in terms of both quantity and quality. The result is, all the urban people feel the consequences of inadequately planned and managed urbanization, but it is the poorest are more vulnerable to any kind of risk of urban hazards. For instance 11 people including five women were killed as a two-story makeshift house caved in the swampy soil by the Jheelpar in Rampura, Dhaka. A devastating fire destroyed more than 150 makeshift houses in a crammed Shyamoli area slum in Dhaka. About 100 houses were destroyed in the fire hazard occurred in a slum at Mohakhali.

Fig 1: Building collapse and fire hazard incidents in Rampura and Rai Shaheb Bazar, Dhaka

Betterment of the substandard living of the informal sectors can be achieved by introducing affordable technologies which in turn can provide secure housing, minimum standard living and disaster resilience. Some examples of cost effective technology could be ferrocement and compressed earth block. The production cost of this block is found to be 25% lesser than normal brick, whereas ferrocement channel can be 25-30% cost effective than traditional RCC slab. These cost effective technologies can help to reshape the informal settlements in terms of durability and resilience.

3. DISASTER RISK REDUCTION THROUGH SAFE HOUSING

Cities with high population density naturally have high risks of mortality and number of people affected by any disaster, which eventually lead to higher level of economic losses (Parvin et al. 2013).Similar to the most other bustling cities in Asia, cities in Bangladesh are growing along the river bank, low lying marshy lands, mining or industrial hubs and steep slopes. Inevitably these cities are emerging as hub of disaster risks (Parvin et al. 2013). While Dhaka city is said to be one of the worst affected city by impact of climate change, human habitat and physical infrastructure remains a key challenge to address (Mallick 2013).

3.1 Earthquake Resilient housing

An emerging threat today is the risk of earthquake. There goes a saying that it is the building that kills people, not the earthquake. Comprehensive Disaster Management Program (CDMP) study reveals that out of 326,000 buildings in Dhaka city 125000 will suffer no damage, 43000 slight, 53000 moderate, 33000 extensive and 72000 complete damages considering worst scenario earthquake. Our traditional building technology, lack of awareness of proper construction is reason behind this vulnerability.
One of the considerations to way forward can be selection of material. It is most important to consider the inherent energy and absorption capacity of a material. The materials must have the ability to undergo large processes of plastic deformations. Brick and concrete for example are not good materials in this regard due to their low ductility;

they absorb very little energy. The closely-spaced and uniformly-distributed reinforcement in ferrocement, transforms the otherwise brittle material into a superior ductile composite (Sadeque, 2015).
Another concern is the building mass; the more the mass of a building the more the seismic induced force. This force can be reduced by application of lightweight materials (Sadeque, 2015). Some of the lightweight materials emerging in Bangladesh today are Cellular Lightweight Concrete block, Poly Concrete Brick, EVG 3D Panel, Sandwich panel, Hollow concrete block and some HBRI products using Ferrocement. Ferrocement channel is found to be 20-30% lighter than RCC floors. Sandwich panel weighs 60-65 lb per cft; whereas, weight of traditional bricks is 120 lb. per cft. Such lightweight materials can add advantage to high-rise structures which ultimately will result in higher percentage of free land and reduced encroachment of natural drainage.

3.2 Lessening impact of fire hazard through technology

Risk of fire hazard is immense in dense urban environment. A total of 1,040 fire accidents occurred within Dhaka City only in 2007, of which 4, 129, 302 and 252 occurrences were respectively in slum, industrial, residential and commercial areas (BFSCDA, 2008).
Considering the fire hazard, ferrocement jacket in structures can be a satisfactory solution due to its post fire flexural strength and toughness as compared to those of plain mortar or concrete cover. The post fire mechanical properties of ferrocement subjected to heating for both long and short period were found to be more or less similar under the same maximum temperature.

3.3 Reducing vulnerability of housing to water logging and flood

Flooding and water logging is another major concern in context of Dhaka. The traditional materials such as brick under standing water are liable to degrade. As an alternative to such susceptible conventional materials, endurable technologies like ferrocement, sandwich panel and EVG 3d panel can prove to be effective under prolonged flood.

4. EMERGENCE OF ENVIRONMENT FRIENDLY MATERIALS

4.1 Alternative to burnt bricks

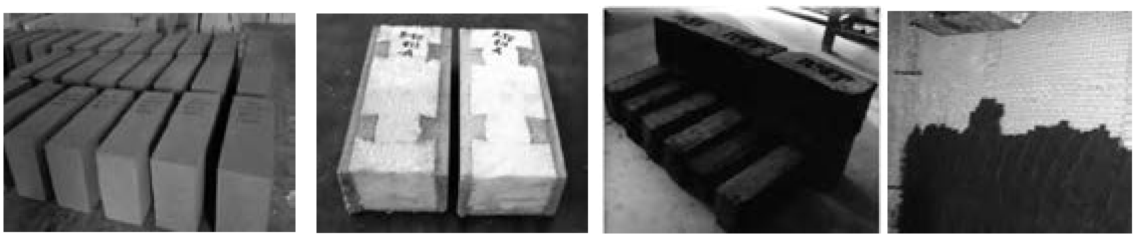
Using burnt brick as the main component of construction has severe damaging properties on the environment. Production of brick involves agricultural top soils posing serious threat to our agricultural land as well as food security. Secondly it involves cutting of trees for burning fuel. Moreover, emission of huge quantity of toxic elements from brick kilns is causing serious health hazards. There are about 45000 of brick kilns in Bangladesh which were found to be producing 79% of CO2 in the last 10 years (Imran, 2007).In the city, brick kilns are a major source of pollution. A majority of the brick kiln clusters are to the North of the city and the measured peak values represent the worst scenario of the maximum wind blowing towards the city. The clusters account for ~700 brick kilns (UrbanEmission.info, 2013). Today alternatives to burnt brick are much looked for in our environmental context. Development of cost effective and environment friendly non-burnt compressed earth block can be a better example of alternative to conventional brick. It involves low energy input in processing and handling soil. Moreover use of river dredged soil as substitute to top soil into brick production can ensure environmental safety in the long run.

4.2 Alternative to Cement Concrete

In the case of cement manufacturing, it is an energy intensive process which is also a major source of greenhouse gas emissions: and close to 5.8 GJ of energy is consumed in the production of a ton of cement (Nassar, 2012).In the last decade, significant progress has been made in understanding the performance of Steel Mesh Reinforced Cementitious Composites (SMRCC) (traditionally known as Ferrocement or thin reinforced cementitious composites as it uses minimum natural resources (Sakthivel et al, 2014). The absence of course aggregates further add to its benefits (Sadeque, 2015). Ferrocement can be an alternative to cement concrete. Its versatility and advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material.

4.3 Utilization of industrial waste (ETP sludge) in building material

The textile industry is one of the oldest and largest sectors in Bangladesh. 70% of the Garment industries are located in Dhaka city (BGMEA, 2011). Treatment of the effluent as per parameter of ECR-1997(Environment Conservation Rule) produces large quantity of sludge each year from various industries. So disposal of sludge has become a major issue. Usage of Textile ETP sludge as substitution for cement can be considered. The use of Textile ETP sludge in these applications could serve as an alternative solution to disposal leading to safer urban environment.



(a) (b) (c) (d)

Fig 2: Alternative building Materials by HBRI. (a) Compressed earth block of dredged soil (b) Thermal block (c) brick from ETP sludge (d) Ferrocement Sandwich panel

5. SECURE HOUSING IN RURAL AREAS TO CONTROL RURAL-URBAN MIGRATION

5.1 Disaster resilient housing

Bangladesh is geographically a disaster prone country and almost every year there are occurrences of flood, cyclone, Norwester’s, river bank erosion severely affecting people’s life and properties. Along with all the other factors acting as causes of migration of rural people to urban centers, insecure living and livelihood is an important one. Poverty driven temporary houses are vulnerable to any type of disaster.
Housing is highly threatened in areas that are erosion prone. A study showed that one family have to migrate 5.5 times in average in a life time due to river bank erosion

(Walsham, 2010). Considering cyclone hazard, housing is the major sector faced by destruction. Cyclone Sidr destroyed 12.4 million houses in affected areas. Following Aila 2009, 40% inhabitants migrated from affected area. In a lower intensity cyclone Mohasen in 2013, one lac houses were damaged.

Among the people moving out to save themselves from such disastrous situation, a major percentage ultimately end up in Dhaka city in search of ensured living and livelihood. By ensuring secure living in the rural areas, it can be assumed that reduction in the migration rate can be achieved to an extent; which in the long term can result in a controlled path of urbanization.

The discussed technologies can contribute to this matter. The ferrocement technology, being versatile, easy technique, cost effective and durable can ensure resilient living in the rural areas and reduced vulnerability towards disaster. Promoting these technologies to rural areas can also create employment opportunities. In this regard studies are undergoing in HBRI towards disaster resilient housing. For flood prone area a floating house made of ferrocement has been designed as community housing and another individual house has been designed with treated materials that will not degrade under prolonged flood. Ferrocement is lightweight and durable under water; so it can be a better material option. It is also used for housing in erosion prone area to produce dismantlable components.

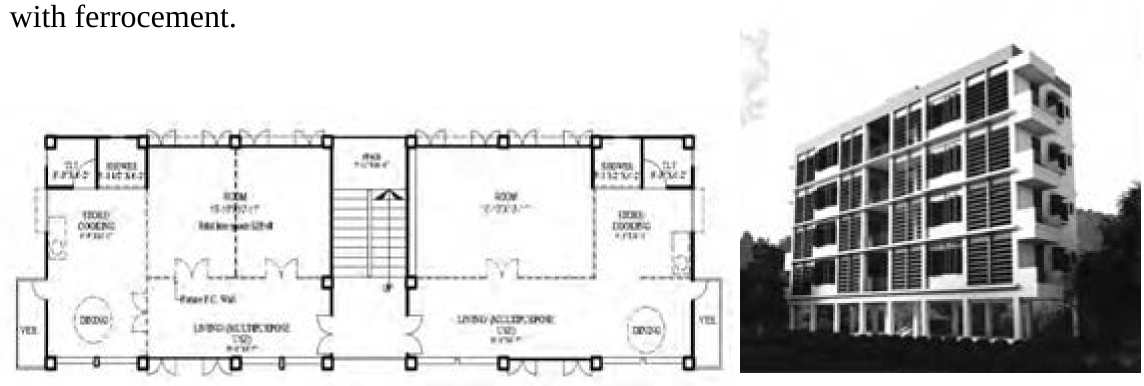
(a) (b) (c)

Fig 3: Housing by HBRI. (a) Dismantlable house (b) Treated bamboo house(b) Floating school cumflood shelter

5.2 Concepts of multistoried rural housing

It is claimed that every year about 1% of farm land in the country is being converted to non-agricultural uses. The converted land is predominantly used for unplanned construction of houses, followed by roads, establishment of business enterprises as well as brick fields (Quasem, 2011).There is a loss of 694 acre of agricultural land of which 97% responsibility goes to housing sector of which 80% is due to the unplanned growth of informal housing. The major cause behind the unplanned growth is lack of institutional control, mostly in rural areas, and awareness regarding environment issues. This percentage of loss of cultivable land is leading to reduction in livelihood opportunities as well as in long term may lead to food insecurity. Consequence of these phenomena is ultimately migration to cities and mega city. So again, ensuring a controlled growth of housing in rural areas can ensure a reduced rate of migration to cities in the long term, leading towards safer cities in terms of controlled population.

In this regard, multistoried housing for rural areas is an emerging concept today and HBRI has proposed a Multistoried Ferrocement Rural House prototype. A Questionnaire survey was conducted prior to the finalization of design and it revealed that major percentage are eager to go with the concept as it involves very little expense compared to its life span. A project is also undertaken by the government to house all the villagers in a compact land with multistoried housing which is to be constructed with ferrocement.



(a) (b)

Fig 4: Multistoried rural model house (a) Typical floor Plan (b) perspective view

6. CONCLUSION

To ensure sustainable living for the inhabitants of megacity, fostering application and improvement of alternative techniques should be emphasized. Lesser environmental impact and promotion of a disaster risk reduction culture towards housing can offer a safer Dhaka city. Moreover, if cost effective technologies, as a whole, can emerge, public will be encouraged to build safer structures following minimum technical requirements within minimum budget. In parallel with the comprehended parameters of urban safety such as urban planning, responsive built environment, urban mobility, economic stability and environmental safety, “alchemy of construction technology” or experimentation of possible technologies needs to be equally emphasized.

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Status of Building Code Compliance: A case study in Karyavinayak Municipality

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ABSTRACT

This paper is outcome of building code compliance observations on the building designs that were filed in for approval at Karyavinayak municipality. On the request from municipality, National Society for Earthquake Technology (NSET) – Nepal has been providing technical support and suggestions for the correction to be made. In a period of six months (November 2014 – April 2015), 200 building drawings and reports have been checked. Out of the designs, 78% of the buildings are C class that can be designed as per Nepal Building Code (NBC):205 while the rest are B class that require detail analysis and design accordingly. Most of the building designs of both class have ductility related problems like stirrups spacing, anchorage of bars, number of bars in column, detailing in staircase and bar diameter. Also, the configuration related problems like short columns, columns not in grid lines, and discontinuous beam were commonly observed deficiencies in both type of building drawings. However, most of the buildings were compliant to strength related checks like size of column, beam, slab thickness and concrete grade. The study concludes that designers should focus more on configuration and ductility criteria of building and their implications. Efforts as this not only help in timely correction of faulty building designs, but also raises awareness and highlights the importance of compliance with building code especially in urban areas lacking technical support.

Keywords: building code, municipality, ductility, configuration, strength

1. INTRODUCTION

In Nepal, earlier the building permit system generally required only the architectural drawings of building in most of the village development committees (VDCs) and municipalities. It has been more than a decade now that government has enforced the building code in Nepal. However due to lack of technical team and proper policy, municipalities and VDCs are struggling to effectively implement the building code. Karyavinayak is one of such municipality which is in its struggling phase to incorporate building code in its building permit system. Since, the Karyavinayak has recently been municipality from VDC, there lacks the technical capacity to effectively implement the building code. Therefore, under the program BCIPN (Building Code Implementation Program in Nepal) implemented by National Society for Earthquake Technology (NSET) with funding support from USAID/OFDA, provided technical support to check building drawings that come in municipality. BCIPN is the program which focuses on

assisting the municipal governments in Nepal in enhancing their capacities to develop and administer the building permits and control system for ensuring improved seismic performance of all new building constructions.
Objectives of this study are
- To understand the major problems in building designs and preparation of construction drawing.
- To get the idea of scenario of building code implementation in newly established municipality.
- To identify the solutions for code compliant building drawings documents.

2. METHODOLOGY AND DATA

2.1 Study area

Since, November 2014 NSET has been providing technical assistance on the building drawings check in the Karyavinayak Municipality under the program BCIPN of NSET. Karyavinayak is located at southeast part of Kathmandu valley, very close to the capital city Kathmandu of Nepal. Its administrative status had been recently moved up the ranks from VDC to municipality in April 7, 2015. Owing to its influencing proximity to the metropolis, the place bears high scope for new settlements. In recent years, the rate of building construction has been quite alarming and so is the inflow of building drawings for construction permit at the municipality with around 24 building drawing per month.

2.2 Research gap

Every building construction require permission from the local government authorities. Building permit system demands construction documents and building drawing is an important part of it. Building drawing such submitted should be guided by the principle of building code (A Guide to Creating Building Code Compliant Documents n.d.) Though the government has enforced the building code, the code compliant status of building drawing that comes in municipality have not been studied/addressed till now. This paper presents the non-compliancy issues observed in building drawings. In order to understand the major problems in building drawings, regular observations and review of the drawings that come in municipality were done and the kind of errors and negligence were recorded.

The present owner-designer situation in Karyavinayak is such that the house owner consults engineer for building drawing. Engineer prepares the drawing and house owner/designer submit it in the municipality for building permit. Most of the drawings even designed by the engineers are observed non-compliant to building code. The building drawings often lack lintel and sill band details, lacks the detailing of beam column joint, foundation tie beam. Irregular building plan and buildings with discontinuous beam which require structural analysis are being designed using thumb rule of simple buildings. This indicates engineers and designers should update themselves on seismic design requirements of buildings. However, it’s hard expecting a compliant building drawing because:

- The designers/engineers are not up-to-date with the current building code

- Implementation of building code in building permit system without prior awareness, training programs and guidelines creates frustration and confusions among the regular designers as well as house owners.
- House owners are not aware about the importance of assessment of their building drawing plan that it is usually cheaper and easier to correct a non-code compliant condition in the design phase than construction phase.
- There is no technical person in municipality and VDCs to check the building compliance check of drawings.

Many works are being done to implement the building drawing, however the analysis of current situation of municipality regarding the building code implementation and common problems not yet addressed. This study aims to conclude the common mistakes/ mal practice trends in building drawings and brew suggestions for the stakeholders of building code implementation.

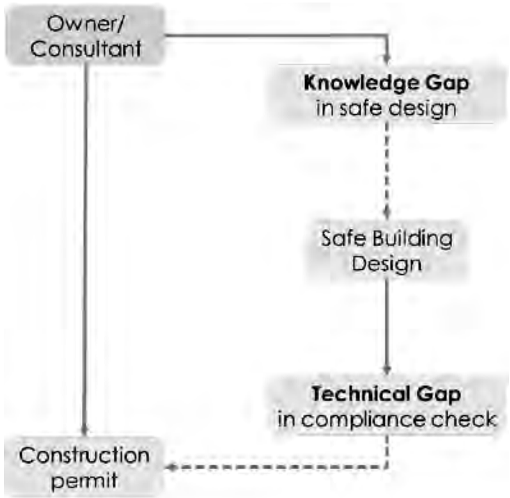

Figure 1: Analysis of research gap for building code compliance in Karyavinayak municipality

In order to effectively implement building code there require technical person in municipality to check the building code compliancy of the building drawing that inflow in municipality. Since there was lack of technical personnel in Karyavinayak municipality for building code compliancy check, this technical gap was fulfilled by technical assistance from NSET.

2.3 Methodological framework

NSET technical assistance in co-ordination with municipality is within the building permit system and allows the NSET technical personnel to approve or disapprove building drawing as per building code. However this study is a just a part of this process.

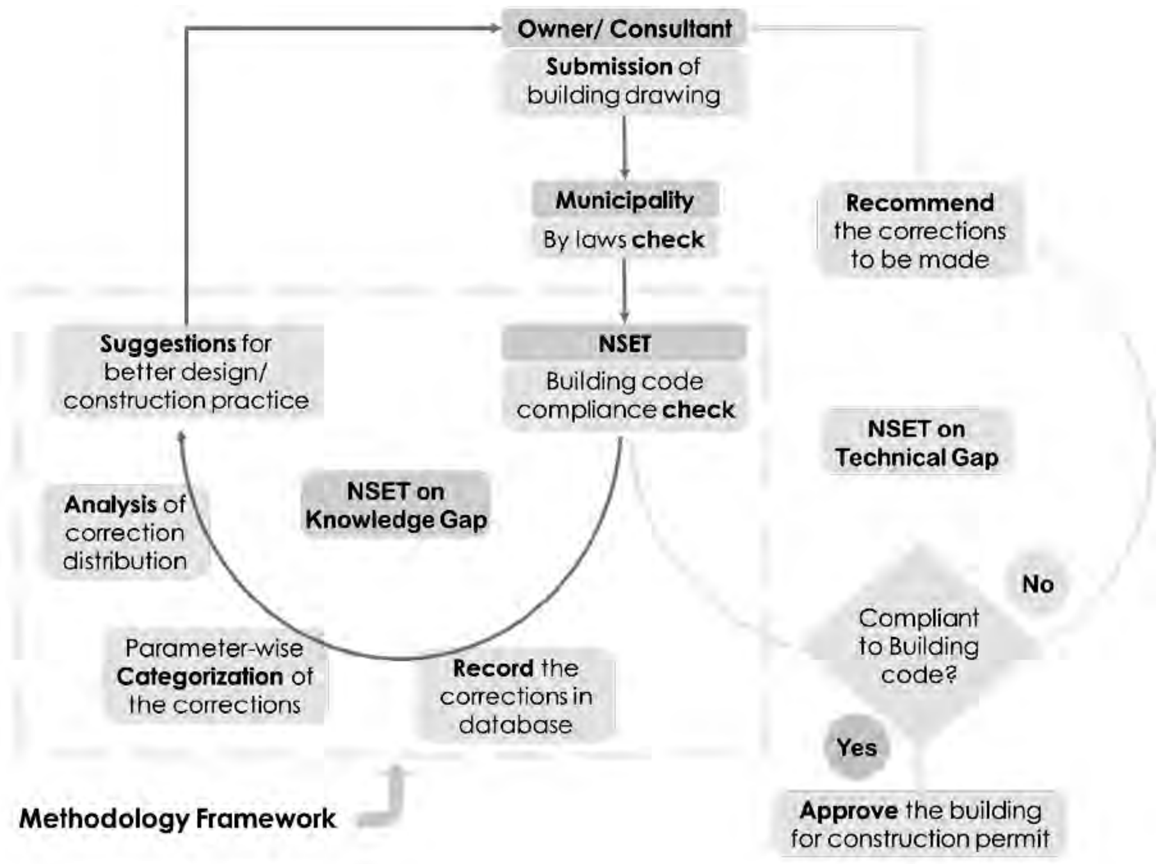

Figure 2: NSET's contribution in building compliance in Karyavinayak municipality; Framework of methodology (dashed box)

Step wise brief description of methodology of the study

1. NSET technical person scrutinize the building drawing according to codal provisions and conceptual requirements of earthquake engineering.
2. If the drawing neglects or violates any of the building code compliancy check and doesn't meet the seismic requirements then those issues were recorded in a database. Along with that corrections to be made are suggested to the designer of the drawing.
3. Categorization of the mistakes/errors/negligence were done from the database into different parameters of building code checks.
4. Analysis of those categorization were done to identify the major and common issues observed in building drawings regarding the building code compliancy.
5. From the analysis the degree and frequency of shortcomings in building drawings were known which helps to visualize the situation of building code implementation in one of the municipality of Kathmandu valley. This brew the suggestions for effective implementation of building code and issues to be focused on.

2.4 Compliance parameters

For systematic checking of building drawings a checklist has been prepared. This includes different provisions of building code and other attributes affecting the seismic performance of the building. The four major conceptual parameters of seismic resistant building were considered in the compliance check. (Scawthorn, et al. 1988), (Hom and

Poland 2004). The Table 1 summarizes the compliance check parameters considered for building drawing check in the municipalities.

Table 1: Compliance check parameters

A. Configuration checks		
Length/Breadth ratio of building	Redundancy	Beam discontinuity
Length of wings of building	Setback	Vertical discontinuity
Length of cantilever	Torsion	Short column
B. Strength check		
Size of beam	Thickness of slab	Strong column weak beam
Size of column	Grade of concrete	Size of shear RC wall(if any)
C. Ductility Check		
Minimum number of bars in column	Shape of stirrups	Detailing of staircase
Spacing of stirrups in column and beam	Beam column joint detailing	Detailing of slab
Bar splice detailing in column and beam	Anchorage length	Bars in beam
D. Connection Check		
Wall connection - Lintel/sill band - Parapet wall band	Foundation connection - Tie beam - Strap/combined footing in eccentric footing	

Apart from this building drawing is also checked if there is any missing documents or incomplete drawing. For building Class B, software analysis and structural report are also checked.

2.5 Compliance check

Buildings are checked on the basis of the building class type. Nepal Building code NBC 000-1994 addresses the four level of design and construction. (Nepal Building Code 000, 1994)

1 International state-of-art (A class building): Such buildings which are designed using sophisticated design philosophies analytical techniques reflected in the codes of wealthy counties are taken into consideration of International State-of-the-Art.

2 Professionally engineered structures (B class building): Building whose plinth area is greater than 1000 square feet / storey greater than 3 / the building having no redundancy in any one direction / the building with structural irregularity / cantilever greater than 1 meter is classified as B class building. This type of building need to be analyzed and designed by professional engineers.

3 Buildings of restricted size designed to simple rules-of-thumb (C class building): Building with regular configuration, cantilever not greater than 1 m, plinth area less than 1000 square feet and number of storey up to 3 as well as beam not spanning greater than 4.5m are classified as C class building. Mandatory Rule of Thumb has been provided in NBC 205 for design of such buildings.

4 Remote rural buildings where control is impractical (D class building): Low strength masonry and Earthen buildings designed as per the guidelines

All the buildings in Karyavinayak were found to be either of B or C class. C class building design drawings were checked on the basis of NBC 205. Whereas B class building drawings were checked on the basis of analysis and structural report submitted with drawings.

3. RESULTS AND DISCUSSIONS

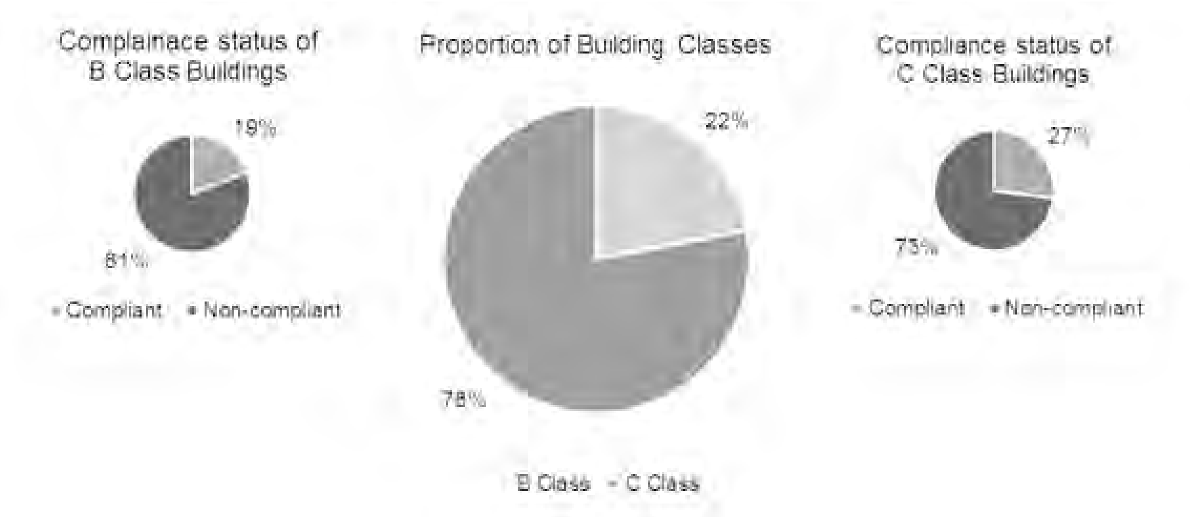

Figure 3: Pie charts showing proportion of the building classes (middle) and the proportion of the compliant and non-complaint of B class (left) and C class (right) buildings design drawings.

Out of the building design applications assessed, the proportion of B class building is significantly less than C class buildings in Karyavinayak municipality (refer **Figure 3**). As per the building compliance rules, B class building application requires analysis and the supporting reports making it a rigorous task for the designers. C class building application on the contrary can be designed as per mandatory rule of thumb provided in NBC 201 & 205 wherein the configurations and design are simpler. This serves as the major reason for the existing trend in the designer community for bypassing the extra effort and time requirement. Designers recommend C class building design application to the owners who in turn get lured by simple and quick building compliance check procedure. Lack of technical support at the municipality had been adding furthermore to this decision among the applicants.

The status of building code compliance of B and C class buildings permit applications as checked by NSET has been illustrated in **Figure 3**. More than $4/5^{th}$ of the B class building permit applications and almost $3/4^{th}$ of the C class building application have been assessed to be non-compliant during NSET's current tenure at the Municipality. Thus it is evident that significanlty large numbers of non-compliant designs applications get collected at Karyavinayak Municipality. The following paragraphs and the rest of the paper analyze the details of the non-compliance and provide suggestions. However, it is up to the stakeholder entities to devise mechanisms based on these suggestions and timely improvement of this situation.

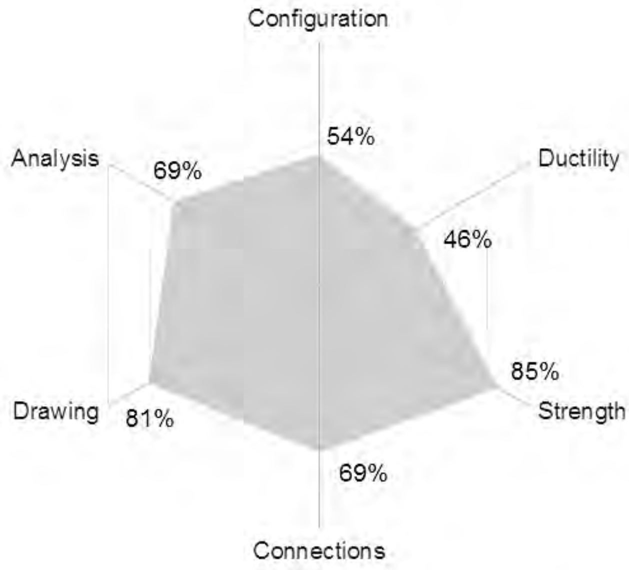

Figure 4: Radar Plot of Performance of B Class Building for various Compliance Parameters

From the radar plot below (**Figure 4**) it is seen that more than half of the non-compliant B class building applications were ill designed in ductility department. Common shortcomings include insufficient number of bars, improper lap detailing, and insufficient development and anchorage length. The compliance negligence in ductility (and other criteria) is attributed to the fact that even after many years of professional practice, most of the designers are still not updated on what the building code demands for compliance. In contrast to the ductility parameter, building drawings fulfill strength criteria in most of the cases.

Strength criteria such as size of the column and beam, thickness of slab, etc. are better understood and practiced by designers as its compliancy was observed in most of the drawings. From these two contrasting practice it can be said that during the design, the designers prioritize the size of the structural elements rather than the detailing within.
The proportion of B class building seems quite fewer than C class buildings. The major reason is that the B class building require analysis and the supporting reports whereas C class building can be designed as per mandatory rule of thumb provided in NBC 201 &205. It’s been observed that most of the designers or consultants don't want to analyze and design the building since it require extra effort and consumes more time than that for C class building. Also, there are not enough technical persons available for analysis of buildings. C class building is quite simpler in configurations and its design too is quite simpler there fore most of the designers prefer going for C class buildings.

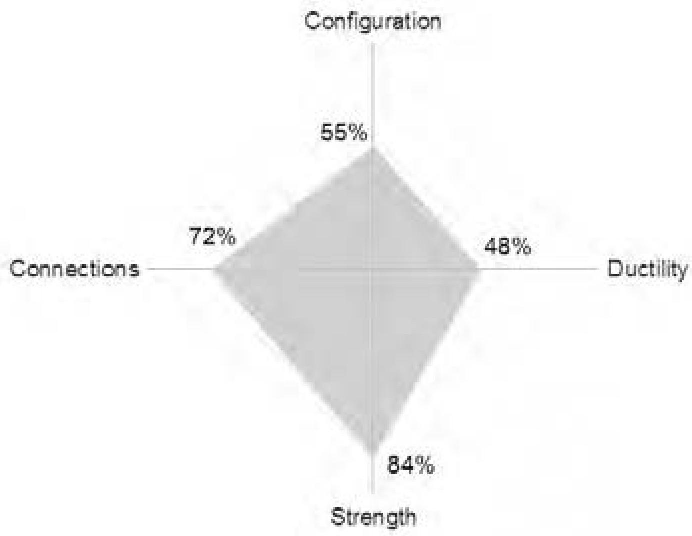

Figure 5: Radar Plot of Satus of C Class Building Drawings for various Compliance Parameters

The radar chart below (**Figure 5**) deals with the compliancy status of C class buildings. Like the B class buildings the major shortcomings in C class building drawings were mostly of ductility parameters like number of bars, spacing of stirrups, anchorage of bars, lap detailing etc. It’s been observed that majority of the designers involved in C class building types are mostly sub-engineers (Diploma level engineer). The ductility criteria are mostly neglected and only concerned in strength parameters like size of the column and beams. Such drawings mostly lacks the lap detail of bars in column and beams, insufficient number of bars in columns and beams, improper detailing in staircase etc. Another shortcomings were observed in configuration criteria. Though the code restrict improper configuration in C class buildings, the drawing often seems violating the configuration criteria. This has been observed mostly due to irregular shape and size of proposed building land. Therefore, designers end up designing the building with irregular configurations to match up the land plot.

4. SUMMARY AND CONCLUSIONS

This paper is based on the experience of building drawing check in Karyavinayak. Out of 200 building drawings checked, 22% were B class buildings and the rest were C class buildings. In both category, building drawings were mostly non-compliant to ductility related checks. However, strength related check was found compliant except in 15% building drawings. Configuration problems were also another parameter neglected in most of the drawings. Configuration problems were observed mainly due to irregular shape of land plot.

Extent of non-compliant building drawings coming in municipality indicates an urgent need for capacity building of engineers and sub engineers as well the implementation authorities. In this context, training for different level of engineers for different class of buildings seems necessary. Training for B class building design should focus on structural analysis of the building whereas, for C class building designers training should focus on how to use the mandatory rule of thumb from the updated NBC 205. Since in most of the buildings the very common negligence were seen in ductility and configurations related check, training should focus on parameters that influence ductility of the buildings. Fancy buildings which often lacks the proper configurations must be guided by the principles addressed in the applicable building code volumes. This study also suggests to develop a guide to creating building code compliant document which help the designers understand the information that needs to be included in a code compliant set of construction documents.

ACKNOWLEDGEMENTS

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Education for Sustainable Development (ESD) for the Sustainable community

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ABSTRACT

Climate change and Disaster are the challenges to the sustainable society. The concept of Education for Sustainable Development (ESD) was declared at the WSSD (World Summit for Sustainable Development) that was held in Johannesburg, South Africa in 2002. United Nations proclaimed the 10year period (2005-2015) as the United Nations Decade of ESD (UNDESD) to promote ESD worldwide. In the UN decade of the disaster (2005-2015), Community disaster preparedness program in the aspect of ESD was done at public schools of Miyagi prefecture before the Great Eastern Great Earthquakes and saved the lives of the school children from the Tsunami disaster. The roles of the non-formal education and life-long learning are as important as the formal education system. Community Learning Centers (CLCs) that were introduced into the Asian Countries by the initiatives of the UNESCO Asia-Pacific Office. This program is based on the social learning system of "Kominkan" (public- citizen-hall) in Japan. In the Kominkan summit 2007, Kominkan-CLC was acknowledged as the platform of the community to link the CBOs (Community Based Organizations) for the learning activity promote ESD as "Okayama Declaration".

In the final year of the decade of ESD (2005-2014), the World Congress on Education for sustainable Development was held in Nagoya and Okayama. One of the stakeholders meetings of the congress, International Community Learning Center and ESD was held in Okayama. The roles of Community Learning Centers (CLCs) were discussed among the 650 international participants. Disaster Risk Reduction was one of the specific topics of the agenda. In the conference document of "Okayama Commitment2014", Disaster Risk Reduction (DRR) and the ESD in the community were mentioned in the document. In the charter of Hyogo Framework for Action (HFA), the role of the community was emphasized to create the resilient community to mitigate the damages of the disaster and prepare for the future disaster. ESD should be integrated with HFA and Sustainable Development Goals (SDGs) as a community based strategy against the disaster to create the resilient community and society.

Keywords: ESD (Education for Sustainable Development), CLC (Community Learning Center), UNESCO (United Nations Educational, Scientific and Cultural Organization), Okayama Commitment 2014, HFA (Hyogo Framework for Action), (MDG) Millennium Development Goals, SDG (Sustainable Development Goal)

1. INTRODUCTION

1.1 Challenge of Sustainable Development (SD)

Climate change and Disaster are the challenges to the sustainable society. Sustainable development (SD) is needed for the adaptation of the climate change and reduction of the damage of the disasters. The concept of the sustainable development is understood as environmental, economic and economical well being for today and tomorrow. The World Commission on Environment and Development (WCED), known as Brundtland Commission, initially proposed the idea of “sustainable development” in 1987. In the “Common Future “ of the commission’s reports, it was defined as “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. To discuss the economic development and find ways to halt the destruction of the natural resources and population of the world, The United Nations Conference on Environment and Development (UNCED), known as Earth summit in Rio De Janeiro was organized by the UN in 1992. In the conference documents, “Agenda 21 “, gave worldwide impacts to the international community to achieve environmentally sustainable development. In the chapter 36 of Agenda 21 is devoted to ‘Promoting Education, Public Awareness and Training’.

1.2 Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs)

Millennium Development Goals (MDGs) was introduced in the global development agenda in the UN general assembly in 2000. MDGs are based on the public management systems. The target period was set as 2000 to 2015. The objectives and targets have become clear and the progresses have been visible – 8 goals and 21 targets with 60 measurable indicators. After the MDGs target period, the new development agenda (post MDGs) was proposed. The concept of the “sustainable development” was emphasized. The new global agenda, “Sustainable Development Goals”, was proposed in the Rio+20 summit in 2012 as the Post-Millennium Development Goals (MDGs) that starts in 2015.

In this article, the role of “Education for Sustainable Development (ESD)” shall be discussed to reduce the disaster risk, minimize the vulnerability and create the resilient society.

2. Education for Sustainable Development (ESD)

2.1 ESD as the international agenda

In 2002, 10 years after the Rio summit in 1992, the WSSD (World Summit for Sustainable Development) was held in Johannesburg, South Africa. That affirmed UN commitment to "full implementation" of Agenda 21 and achievement of the Millennium Development Goals (MDGs) that started in 2000. The role of Education was reaffirmed and emphasized as the foundation of the sustainable development. Education for Sustainable Development (ESD) was main idea of the congress that was declared in the Ubuntu declaration. To promote the Education for Sustainable Development in the global society, Japan and Sweden government proposed the agenda of UN Decade of ESD in the general assembly of UN in 2002. The United Nations launched the Decade of ESD (2005-2014). UNESCO was designated as the lead agency of the UN systems for the decade of Education for Sustainable Development (DESD). In the final year of DESD, Japanese Government hosted the "UNESCO World Conference of Education for Sustainable Development" to evaluate the progress of DESD and prepare the strategy after the UNDESD. The main congress was organized in Aichi, Nagoya and series of stakeholders meetings were organized in Okayama, Japan in October - November 2014.

2.2 ESD and community

High quality of education should be provided at primary level to higher level, formal and non-formal, school children to life-long learning. Education for Sustainable Development (ESD) is beyond the environmental education, broader and inter-disciplinary learning process. ESD contains the 3 pillars plus one; 1) environment, 2) economy, 3) society and culture. The contents of education and teaching should be re-oriented and re-designed for the sustainable development. This teaching model should seek critical thinking, problem solving and understanding the complexities. The linkage of the stakeholders in the community and educational institutions are encouraged by the scheme of the UNU-RCE (Regional Canters of Expertise's). (Fig 1)

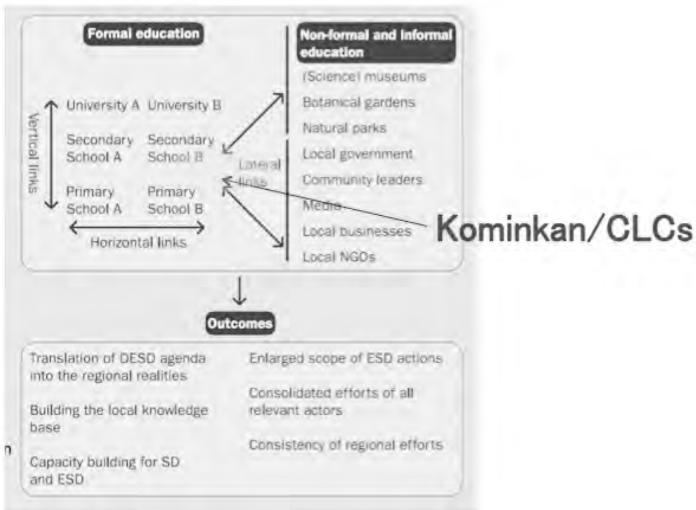

Fig 1: Model of ESD - Linkage of the stakeholders of formal and non-formal education

2.3 Community Learning Centers (CLCs) and Kominkan

In Asia-pacific region, Community Learning Centers (CLCs) were introduced by UNESCO Bangkok office for the Education for All (EFA) initiatives in the 1990s. The original model of CLC is Japanese Kominkan (public-citizen'-hall) that was institutionalized as social education Act in 1949. After the 2nd world war, Japanese government introduced this Kominkan system to promote the education for the adults to learn democracy and social development in their close community. In Japan, most of the Kominkan were usually built and maintained by the expense of municipal governments. The local governments have the responsibility for the proper managements of the

Kominkan – maintaining of the buildings, staff and boarding committee of the Kominkan. Kominkan has given marvelous effects on the hosting Community Based Organizations (CBOs) and linkage of the community citizens that empower the people to solve the problems of the community and improve the lives of the community- such as public health or income generation. The number of the Kominkan has reached about 18,000.

The experience of Kominkans has been shared with CLCs in ASEAN countries and CLCs have been well recognized and utilized in the communities of those countries. Although CLCs were initially introduced for the adult literacy program, the learning contents has been modified and upgraded based on the needs of the community. They have been interested in the environment issues (waste, energy, forest, agriculture), public health, income generation, computer skill etc. Disaster is an important topic to them as well. Since the Asia-Pacific areas are disaster prone area, they pay strong attention for the natural disaster.

2.4 Linkage of CLC-Kominkan for the model of ESD in the community

When the Decade of ESD began in 2005, UNESCO has assigned the lead agency of UN organization. United Nations University (UNU) also has a role to promote ESD through the research, train, exchange and advocacy activities. UNU acknowledged the model area of ESD as the Regional Centers of Expertise (RCEs). Two areas, Greater Sendai and Okayama, were chosen as the initial 7 RCEs. These 2 RCEs are unique in their models of the promotion of ESD. In the Greater Sendai area, it is based on the public educational system and school plays the center of the ESD promotion in the community. On the other hand, Okayama city promoted the community based ESD promotion program that were based on Kominkan. Kominkan plays the central role to facilitate the linkage of the people and promotion of ESD in the community.

In 2007, UNESCO Bangkok office and Okayama University UNESCO chair program of "Research and Education for Sustainable Development" organized the *Kominkan summit Okayama 2007- Community Development and Promoting Education for Sustainable Development"* in collaboration with Okayama city, United Nations University (UNU), Asia/Pacific UNESCO Cultural Center for UNESCO (ACCU), Conference of Okayama International NGO Networks (COINN). International experts, government officials of life-long learning or CLC in 8 Asia and Pacific regions, were invited. They visited the Kominkans in Okayama and discussed with the participants on the role of Kominkan/CLC for the promotion of ESD. All the participants of the conference agreed and committed to promote ESD in the Kominkan or CLCs. It is documented as "Okayama Declaration" on Nov 1, 2007. The contents of the declaration were implemented in their countries. Follow up meeting on ESD-CLCs were hosted in Okayama by COINN and Okayama University UNESCO chair program in 2008-2013 as RCEs Okayama activities.

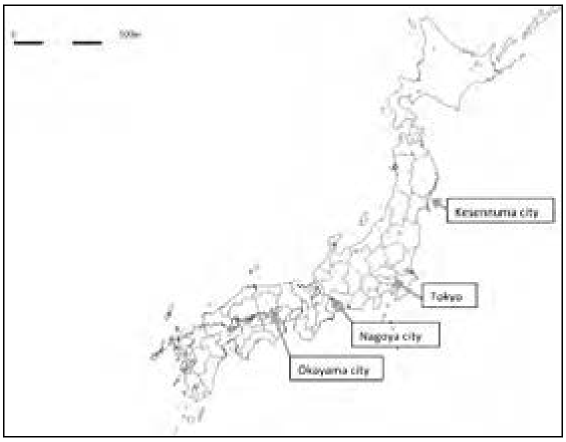

Fig2: Location of RCE of ESD and UNESCO congress

2.5 Final year Congress of the Decade of ESD (2005-2014)- Okayama commitment 2014

Upon those initiatives, Okayama city was selected as the host city of the stakeholder meetings of *” UNESCO World Conference on Education for Sustainable Development”* in Oct – Nov 2014 as the final year event of the UNDESD (2005-2014). One of the stakeholders meeting on “Kominkan-CLC and ESD “ was organized on Oct 9-12, 2014. 650 delegates participated in this conference. (Fig 2: Group of Disaster Risk Reduction session at Mitsu Kominkan). The products of the conference was documented as *“Okayama Commitment 2014- Promoting ESD beyond DESD through Community-Based Learning –“.*

Fig 3: Participants at Mitsu Kominkan, Okayama, Japan

3. Hyogo Framework for Action (HFA) and role of the community for the DRR

In the congress of the “*World Conference for Disaster Reduction*” that was held in 2005 at Kobe, Hyogo, Japan. Hyogo Framework for Action (HFA) was adopted to build the resilience of Nations and communities (HFA: 2005-2015). In the charter 3 of the HFA, disaster preparedness should be linked with sustainable development. International

Strategy of Disaster Reduction (ISDR) recommended that disaster risk reduction would be incorporated in the framework of the “sustainable development”. The strategy emphasized the role of the community to be prepared. Education on Disaster risk reduction should be organized in all the community. UNESCO described that ESD is the most appropriate framework for disaster preparedness in the following reasons: 1) Interdisciplinary and holistic, 2) critical thinking and problem solving, 3) locally relevant and acknowledging local language and culture.

Although the linkage of CLC and educational activities for disaster risk reduction (DDR) was not mentioned in the HFA, the DDR incorporated with ESD could be implemented at the CLCs.

4. Great East Earthquake- community and ESD

4.1 Disaster Risk Reduction (DRR) and ESD

Ichinose, T, (2014) mentioned that community and school based education for disaster risk reduction has been successfully saved the lives of the school children at the Kesennuma-city. Tsunami attacked the Kesennuma-city as high as 9 meter and 1,479 people out of 73,494 citizens were killed or missing. Kesennuma is the part of the Great Sendai Regional Center of Expertise (RCE) of ESD that was acknowledged by United Nation University in 2005. Various kinds of ESD promotion activities were practiced at public school. Before the Great East Earthquake in 2011, school based education for the disaster risk reduction that included the disaster drill that was designed in the aspect of the ESD – oriented in the local culture and history of the community. Several Tsunamis attacked this area and they were recorded in the historical documents or fork tales as historical wisdom.

4.2 Reconstruction of the community with the ESD

Citizens’ earthquakes reconstruction committee of Kesennuma City (2011) reported, Great East Earthquake and Tsunami caused complete destruction of the towns. Although the public buildings, School, Kominkan and Gymnasium, were supposed to host the evacuees who lost the houses during the early phase of the disaster, the magnitude of the damage were much terrible than local government planned for the preparation of the Tsunami disaster. In case of Kesennuma city, School and Kominkans and community houses were completely damaged or washed away by Tsunami. Where those facilities do not exist, those communities lost the center of the platform of the local residents and community based organizations (CBOs). Since ESD was widely practiced in the Kesennuma city, Education of Sustainable Development (ESD) was recommended as the key concept of the reconstruction of the community. As Yamamoto, H., and Chiba, H., reported in 2014, the linkage among the local stakeholders that were based in the Community Learning Center resulted in the close communication and collaboration with different sectors and creation of the resilient community against the disaster. In case of the Maehama-District of the Kesennuma city, Kominkan of “Maehama Marine Center “ was washed way by Tsunami. This is the one of the 54 Kominkan that was washed away out of 194 Kominkan/community houses in Kesennuma-city. The community people in Maehama district organized the great efforts to relocate to the safer place and rebuilt the new building in the safer place in this community area.

Fig 3: Reconstruction of the Kominkan (Maehama Marine Center) after washed away

5. Recommendations/Conclusion

The community is crucial for the disaster risk reduction and building resilient community. Strengthen the community is the challenge. Community based learning is one of the solutions. As the "Okayama Declaration" and "Okayama Commitment 2014" show, the Community Learning Centers (CLCs) are appropriate place to host the local stakeholders and promote the autonomous learning activities. They can learn the peculiar contents of the local community. In the *Okayama Commitment 2014*, it mentioned that "*We have developed and maintained communities' resilience against natural and human-induced disasters through relevant learning and cultivating human relationships anchored on selflessness, empathy and mutual-help. The role of CLC (community learning center) will be the keys to strengthen the community to stimulate bridging function of the social capitals that are necessary for the resilient community*".

Through this learning process, the capacity of the local community will be developed. This capacity will be the enriched resources for the resilience against the disaster in community. This mechanism should be ubiquities for the global community.
Those attempts should be integrated with HFA and SDGs. As UNIDSR (2015) mentioned, Promotion of ESD was "*use knowledge, innovation and education to build a culture of safety and resilience at all levels*" as articulated in the Hyogo Framework for Action 2005-2015. Although the specific name was not mentioned in the 17 goals of the SDGs (2015-2030), 10 out of 17 goals are related to the disaster risk reduction. In the 4th goals of SDGs, it is mentioned as; Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. This is reflected the core concept of ESD.

As IDSR recommended, the ESD should be understood properly and integrated with other international development agenda such as HFA and SDGs to create resilient community, region and country.

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Life recovery models: Cross overs between Kobe and Great East Japan Earthquake recovery stories

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ABSTRACT

Recovery of individual lives has never been a major post-recovery agenda until the 1995 Kobe Earthquake. The author has been involved in social research projects that aimed to identify life recovery facilitating factors and its mechanism, and in the advocacy of individual life recovery policy and programs. Based on these activities, the Seven Critical Element Model (SCEM) of life recovery was formed. The seven facilitating factors consist of housing, social ties, community involvement, physical/mental stress management, preparedness, livelihood, and relations to government. After the 2011 Great East Japan Earthquake, the author has been closely working with the life recovery department of Natori city, Miyagi prefecture. This paper reports the results of the 2015 population survey of Natori survivors (1,533 households, 3,513 individuals) and compares these results with Kobe Earthquake life recovery surveys. It discusses the cross over between the two mega-disaster recovery findings, and examines what can be utilized in order to formulate life recovery policies and programs for future disasters.

Keywords: *life recovery, Kobe Earthquake, Great East Japan Earthquake, Seven Critical Elements model*

1. INTRODUCTION

Life recovery as opposed to livelihood recovery is a relatively new and more holistic construct. Although livelihood has been promoted by income assistance programs of the 1998 Act Concerning Support for Reconstructing Livelihood of Disaster Victims, *life recovery* has been interpreted in more vague terms. It had not been clearly spelled out until Kobe city conducted the fifth year review on 1995 Kobe Earthquake recovery. As a part of the review, a series of grass-roots recovery assessment workshops with impacted citizens were held in order to identify factors that would help each participant to feel that "I am no longer a disaster victim." Out of this review, the Seven Critical Elements Model (SCEM) of life recovery was formed. The seven facilitating elements consist of *housing, social ties, community involvement, physical/mental stress management, preparedness, livelihood,* and *relations to government* (Tatsuki, 2007). After the 2011 Great East Japan Earthquake (GEJE), the author's team has been closely working with the life recovery support department of Natori city, Miyagi prefecture. Our team collaborated with the Natori city administration to conduct the 2013 Natori grass-roots assessment workshops on life recovery, which later confirmed that SCEM was also applicable to Natori people's life recovery (Tatsuki, 2015a). The team and the city then jointly designed the questionnaire and the city administered a population survey on life recovery to all impacted citizens. The first purpose of this paper is to examine if SCEM is empirically capable of predicting a large proportion of life recovery variance as reported by Natori people. Second, it aims to identify the similarities and differences between the 1995 Kobe Earthquake and the 2011 GEJE in terms of which critical elements were relatively more important to determine life recovery in each respective event. Third, it tries to portray the unique aspects of life recovery processes of the 2011 GEJE impacted citizens that were not found or reported before.

2. METHOD

2.1 Subjects

The research subjects of the survey were all 1,533 households and their 3,513 members over the age of 18 that were registered by Natori city as temporary housing residents. The subject households included 1) those who were residing in Natori city prior to the GEJE and 2) those who were residing outside (mostly in Fukushima) and had moved to Natori after the 311 Fukushima disaster. They were residing in two types of temporary housing accommodation: conventional prefabricated temporary housing (PTH) complex units or newly introduced designated temporary housing (DTH) units, which were nothing but private rental units paid for by the prefectural government. Provision of DTH has become mainstream national policy since the GEJE, with 57,825 apartment/housing units rented and 47,839 prefabricated temporary housing units were newly constructed in East Japan prefectures. As of December 2014, 55 % of temporary housing households resided in DTH and 45 % in PTH in Natori city.

2.2 Instrument

The life recovery scale measures the degree to which one feels that he/she is no longer a disaster victim. The scale is a 5 point Likert scale consisting of 6 life readjustment/fulfillment, 7 life satisfaction and 1 future prospect items whose unidimensionality and reliability (i.e., Cronbach's $\alpha > .80$) have been established in Hyogo Life Recovery Surveys in 1999, 2001, 2003 and 2005 (Tatsuki, 2007). Demographic variables included age, gender, family size, disability/vulnerability status, and house damage. With regard to SCEM, *housing* was measured by temporary housing type (PTH or DTH) and concerns/worries about current and future housing issues, *social ties* by the number of people having social conversation/contact pre and post disaster, *community involvement* by a community outlook scale that measures the degree of neighbors' engagement in community affairs, *physical/mental stress management* by a physical and psychological stress scale, *preparedness* by concerns for future disaster risk, *livelihood* by financial impact and leeway scales as well as occupation pre and post disaster, *relations to government* by a communitarian/liberal attitude scale as well as levels of awareness on and attention to local government PR information. In addition, 1 *impact alleviation* and 2 *event evaluation* items were used to measure *life recovery process* variables which were known to intervene between SCEM and life recovery outcomes (Tatsuki, 2007).

2.3 Procedures

The survey questionnaire package consisted of a 2-page household questionnaire and 6 sets of a 4-page household member questionnaire. Both household and its member questionnaires were included in an official Natori city envelope and were sent to all registered temporary housing households during the second week of January in 2015. Each household was asked to answer one household questionnaire and each household member was asked to respond to an individual member questionnaire. A return envelope addressed to Natori city office was included in each package. Postcards reminding the return of questionnaires were sent on January 26th. Furthermore, new sets of questionnaires were mailed again on February 19th to those households that had not returned the questionnaires by February 5th. All those responses that arrived at the city by the first week of March in 2015 were used for the analysis.

In order to compare the current study results with 2001 Hyogo Life Recovery Survey results, a general linear model (GLM) was used to test and estimate the effects of demographic, SCEM and life recovery process variables on life recovery. SPSS version 23 was used for the statistical analyses.

3. RESULTS AND DISCUSSION

3.1 Demographics and house damage

1,107 (702 PTH and 831 DTH) households returned the household questionnaire (72.2 % response rate) and 1,971 (820 PTH and 1,151 DTH) residents returned the household member questionnaire (56.1 % response rate). The average ages of the respondents were 54.4 and 56.1 for males and females, respectively. The average ages by temporary housing type was 59.8 and 52.1 for PTH and DTH, respectively suggesting that nearly half of PTH residents were over the age of 60 while the majority of DTH residents were working age, possibly with school age children.

Table 1: House damage by 2015 Natori and 2001 Hyogo Life Recovery Survey

	2015 Natori Life Recovery Survey		2001 Hyogo Life Recovery Survey	
	N		N	
Full Damage	1503	(76.3%)	195	(16.2%)
Large Scale Half Damage	58	(2.9%)		
Half Damage	80	(4.1%)	231	(19.2%)
Partial Damage			554	(46.1%)
No Damage			223	(18.5%)
Missing	330	(16.7%)		
Total	1971	(100.0%)	1203	(100.0%)

Table 1 compares proportions of house damage categories between the two life recovery surveys. While 2001 Hyogo Life Recovery Survey sampled those who were residing in the most severely earthquake-hit areas and therefore their house damages varied widely from no damage to full damage, 2015 Natori Survey subjects were heavily (almost 5 times higher) concentrated in the full damage category (those who did not answer house damage were mainly those who moved from Fukushima) because Natori survey specifically focused on those who lost their houses due to the 311 tsunami and following Fukushima nuclear power plant disaster and were residing in temporary housing units at the time of the survey. The damage comparison suggests that house damage effects need to be partialed out before comparing SCEM effects on life recovery between the two surveys.

Table 2: Multiple regression (GLM) analysis of house damage and SCEM effects on lifre recovery

Hazard Exposure and Seven Critical Elements for Life Recovery	Parameter	Model 1	Model 2	Model 3
		B	*B*	*B*
	Model Intercept	51.438 ***	51.454 ***	48.161 ***
HOUSE DAMAGE				
	Full House Damage	.544 **	1.384 **	1.305 ***
	Large Scale Half House Damage	-0.166	-0.008	.067
	Half House Damage	2.058 *	2.173 **	2.039 *
	No Answer	0^a	0^a	0^a
HOUSING				
Temporal Housing Type	Prefabricated Temporary Housing (PTH)	-0.870 *	-0.746 (p=.107)	5.014 *
	Designated Temporary Housing (DTH)	0^a	0^a	0^a
Temporary Housing Type by Person with Disability	PTM*No Disability			-.765
	PTM*Disability			0^a
	DTH*No Disability			4.136 **
	DTH*Disability			0^a
Temporary Housing Type by Single Elderly Household	PTH*Any Household Other Than Single Elderly Person Household			-3.492 **
	PTH*Single Elderly Person Household			0^a
	DTH*Any Other Than Single Elderly Person Household			-1.029
	DTH*Single Elderly Person Household			0^a
Temporary Housing Type by Household with/without Physically Vulnerable Person	PTH*Household with Physically Vulnerable Person			1.303
	PTH*Household without Physically Vulnerable Person			1.772 **
	PTH*Household with or without Physically Vulnerable Person Unknown			0^a
	DTH*Household with Physically Vulnerable Person			-1.252 *
	DTH*Household without Physically Vulnerable Person			.084
	DTH*Household with or without Physically Vulnerable Person Unknown			0^a
Concerns about Housing Issues Scale	Concerns/Worries about Public Housing (factor score)		-0.420 *	-.406 **
	Concerns/Worries about Current Temporary Living Arrangements (factor score)		-0.337 *	-.338 *
SOCIAL TIES				
Number of Neighbors/Relatives/Friends having social conversation with before 311	None	1.819 **	1.532 *	1.516 *
	1 to 4	2.728 ***	2.650 ***	2.812 ***
	5 to 9	0.873	0.759	.820
	more than 10	0^a	0^a	0^a
Number of Neghbors/Relatives/Friends having social conversation with after 311	None	-1.759 **	-1.555 **	-1.600 **
	1 to 4	-2.979 ***	-2.834 ***	-3.024 ***
	5 to 9	-1.626 ***	-1.593 ***	-1.522 ***
	more than 10	0^a	0^a	0^a
Number of People meeting in hobby/circle/social gatherings before 311	None	2.832 ***	2.980 ***	2.908 ***
	1 to 4	1.471	1.472	1.310
	5 to 9	0.870	0.936	1.182
	more than 10	0^a	0^a	0^a
Number of People meeting in hobby/circle/social gatherings after 311	None	-3.430 ***	-3.588 ***	-3.309 ***
	1 to 4	-0.737	-0.849	-.840
	5 to 9	-0.433	-0.457	-.742
	more than 10	0^a	0^a	0^a
COMMUNITY INVOLVEMENT	Residents do not socialize with each other and live by themselves	-3.133 ***	-3.212 ***	-3.425 ***
	Residents do not socialize but neghborhood representatives seem to be more or less active	-3.320 ***	-3.403 ***	-3.632 ***
	Residents socialize to a certain degree and some greet each other	-1.968 ***	-1.966 ***	-2.201 ***
	Residents socialize very often and participate well in community events	0^a	0^a	0^a
PHYSICAL/MENTAL STRESS MANAGEMENT				
Subjective Evaluation on one's health condition	Good	4.886 ***	4.739 ***	4.373 ***
	OK	2.463 ***	2.299 ***	2.231 ***
	Bad	0^a	0^a	0^a
Physical and Mental Stress Scale	Physical and Mental Stress (factor score)	-2.656 ***	-2.621 ***	-2.598 ***
PREPAREDNESS				
Concerns for Future Disaster Risks	Low concerns for future disaster risk (optimal scaling score)	0.513 ***	0.496 **	.474 **
LIVELIHOOD				
Financial Impact Score	Household Financial Impact (optimal scaling score)	-0.819 ***	-0.849 ***	-.720 ***
Financial Leeway Score	Household financial Leeway (optimal scaling score)	0.934 *	0.909 (p=.103)	.988 *
Financial Leeway Score by Age	Financial Leeway by Age less than 18	1.775	1.891	1.826
	Financial Leeway by Age between 19 and 64	0.077	0.100	-.025
	Financial Leeway by Age between 65 and 74	-1.945 **	-1.673 **	-1.724 **
	Financial Leeway by Age 75 and over	0^a	0^a	0^a
Occupation	Proprietor (before)	-3.582 ***	-3.547 ***	-1.991 ***
	Proprietor (present)	3.076 ***	3.074 ***	-4.402 ***
	Retired (before)	1.907 **	1.808 **	-1.008 *
	Retired (present)	-2.960 ***	-2.807 ***	-1.100 ***
	Unemployed (before)	2.316 ***	2.168 ***	.098 ***
	Unemployed present	-3.475 ***	-3.306 ***	-5.060 ***
RELATION TO GOVERNMENT				
Relation to Government Scale	Communitarian vs. Liberal Attitude Score (optimal scaling score)	-0.316	-0.327 (p=.103)	-.362 *
Attention to Local Government Public Relation Information Scale	Low Attention to Local Government Public Relation Information (optimal scaling score)	0.541 ***	0.535 ***	.332 ***
RECOVERY PROCESS	Recovery Process Score (factor score)	4.004 ***	3.944 ***	3.885 ***
	R^2 (*df* adjusted R^2)	.547 (.534)	.548 (.534)	.555 (.538)

*** p <.01, ** p <.05, * p <.10

3.2 Effects of seven critical elements on life recovery

3.2.1 Model fit

Table 2 summarizes multiple regression (GLM) analysis results. It compares results of 3 models where varying degree of *housing* parameters were successively added. In Model 1, only temporary housing type (PTH or DTH) was entered. Concerns and worries about current and future housing issues were entered in Model 2, and finally temporary housing type by social vulnerability (e.g., household with person with disability, single elderly, or physically vulnerable person) interactions were added in Model 3. Although the interpretation of the *housing* variable parameters will be discussed in the later section, it should be noted that the final Model 3 predicted highest 55.5 % of the total variance in observed life recovery scores (R^2=.555, adjusted

R^2=.538) compared with Model 1 (R^2=.547, adjusted R^2=.534) and Model 2 (R^2=.548, adjusted R^2=.534). Figure 1 illustrates an observed by Model 3 predicted values plot at

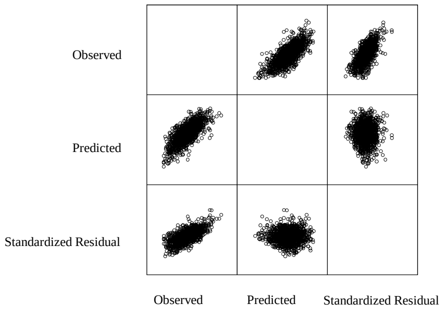

Figure 1: Observed by Model 3 predicted (top center) by standardized residuals (bottom center) plot.

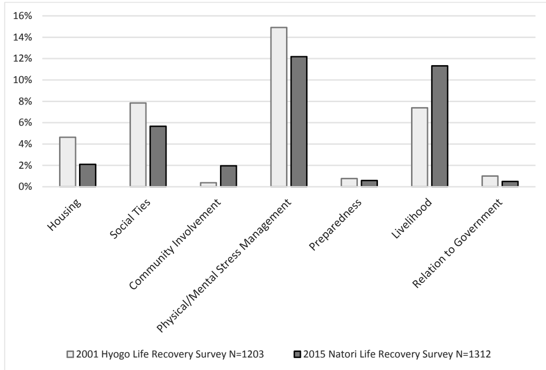

Figure 2: Comparisons of each SCEM parameter effect size (partial η^2) on life recovery between 2015 Natori and 2001 Hyogo Life Recovery Surveys.

the top center which shows a linear fit. At the bottom center of Figure 1, standardized residuals by predicted values were plotted, which showed that residuals were evenly scattered against low to high predicted values without any particular patterns. Those two plots displayed that the final Model 3 showed a good fit (R^2=.555), which is comparable to 2001 Hyogo Life Recovery Survey (R^2=.470 (Tatsuki and Hayashi, 2001) or R^2=.593 (Tatsuki and Hayashi, 2002)), to the observed life recovery scores and therefore affirmed the first research question − whether SCEM is capable of a large proportion of life recovery score variance among Natori impacted people − of the current paper.

3.2.2 Parameter effects on life recovery

Partial regression parameter estimates for house damage and each of SCEM were listed at the last 3 columns of Table 2. Because the effects of other parameters were partialed out when interpreting a given parameter, the effects of other parameters such as house damage categories were controlled. This made it possible to compare SCEM parameters between Natori and Hyogo Life Recovery Survey results despite that Natori study subjects were heavily skewed toward heavy house damages.

With regard to effects of *housing* parameter, Model 1 and 2 demonstrated that PTH on average tended to have negative impacts on life recovery in comparison to DTH. This seems to support the validity of the newly introduced DTH policy for prefecture government's renting privately owned housing units and designating them for disaster survivors' use as temporary housing units. It should be noted that Model 3 PTH parameter became positive suggesting PTH rather than DTH tended to positively promote life recovery. This reversal of effect direction from negative to positive could be interpreted as the result of multicollinearity that were caused by entering 14 additional housing parameters (social vulnerability and temporary housing type interactions) into Model 3.

For such SCEM parameters as *social ties, community involvement, physical/mental stress management, preparedness and livelihood* as well as intervening *life recovery process*, their effect directions were similar to 2001 Hyogo Life Recovery Survey results. With regard to *social ties*, those who used to socialize with more than 5 neighbors/relatives/friends in daily conversations or in social gatherings before the disaster showed better life recovery. However, this threshold value increased to more than 10 in order for socialization or social gathering to have positive impacts on better recovery after the disaster. While *social ties* are an ego-centric and personal social capital indicator, *community involvement* measures levels of communal social capital that are shared by a network of people in a community as a whole. On this ground, better life recovery was predicted only by those who reported that one lived in a community where “residents socialize very often and participate well in community events.” With regard to a subjective evaluation of one’s own health, a measure of *physical/mental stress management*, those who reported “Good” or “OK” showed significant positive impacts on life recovery in comparison with those who answered “Bad.” These findings were further supported by more reliable measures of the 6 item physical and mental stress scale scores. *Preparedness* was measured by how optimistic one was to future disaster losses and the better recovery was predicted by the optimistic attitudes to disaster risks. The similar effect was also observed in 2001 Hyogo Life Recovery Survey. These results seem to support an old saying “danger past and God forgotten.” Disaster’s impacts on household finance and the current financial leeway were very strong *livelihood* predictors of life recovery. Those “younger” elderly between 65 and 74 years old who showed less financial leeway were the least recovered among all ages. With regard to occupation, the proprietors, the retired and the unemployed on average showed significantly lower life recovery scores. Finally, an intervening life recovery process measure, a composite of 1 *impact alleviation* and 2 *event evaluation* items, showed significant positive impacts upon life recovery as has been demonstrated in 2003 and 2005 Hyogo Surveys (Tatsuki, 2007).

The 2015 Natori Life Recovery Survey like the 2001 Hyogo Life Recovery Survey showed the tendency that the respondent’s attitude toward government (*relation to government*) mattered. Unlike the Hyogo Survey, however, the less communitarian and more self-reliance (liberal) oriented Natori temporary housing residents tended to show better recovery. Nature of pre-disaster government-people relationships seems being different between Natori and Hyogo areas and this difference needs to be further examined in future studies.

The second research question of the current paper was to identify the similarities and differences between the 1995 Kobe Earthquake and the 2011 GEJE in terms of which critical elements were relatively more important to determine life recovery in each respective event. Figure 2 directly answers to this question. It compares effect sizes of the seven critical elements upon life recovery as measured by partial η^2 between 2015 Natori and 2001 Hyogo Life Recovery Surveys. The direct comparison of η^2 values in two surveys should be supported because goodness-of-fit estimates were comparable in 2 studies (R^2=.555 for Natori and R^2=.470 (Tatsuki and Hayashi, 2001) or R^2=.593 (Tatsuki and Hayashi, 2002) for Hyogo surveys). Figure 2 illustrates that the top 3 most powerful influences upon life recovery were *physical/mental stress management*, *livelihood*, and *social ties* in both surveys. Between-comparisons of effect sizes for each parameter, however, indicated that *livelihood* as well as *community involvement* mattered more in Natori survey while *physical/mental stress management*, *social ties* and *housing* (*housing* variance was much smaller in Natori Survey because all subjects lived in temporary housing units) were more valued in Hyogo survey. This may suggest relative importance of livelihood assistance programs for Natori impacted citizens.

3.3 Designated versus prefabricated temporary housing

At the onset of the GEJE, National government needed to provide more than hundred thousand temporary housing units urgently nearby the disaster area. Because it was impossible to construct such a large number of prefabricated temporary housings in a limited time, National government allowed prefectural governments to rent out privately owned housings and to use them as temporary housing units to the disaster victims. For the first time in Japanese disaster management history, the impacted citizens had to make decisions whether to dwell in conventional prefabricated temporary housing complex units or in designated private rental housing units that were situated in widely dispersed locations. Japanese disaster research has been mainly focusing on life recovery assistance for prefabricated temporary housing inhabitants who live in a close proximity and not much is known about "diaspora" survivors. The third research question of the present paper was to portray the unique aspects of life recovery processes of DTH residents in comparison with those who were residing in PTH units.

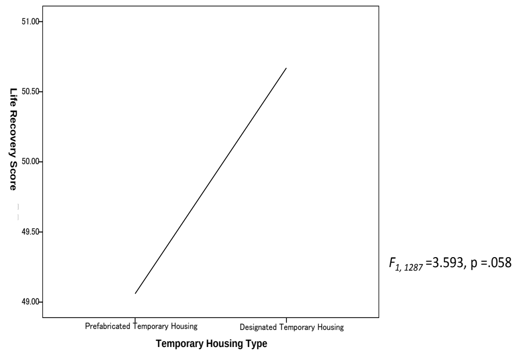

Figure 3: Life recovery score by temporary housing type

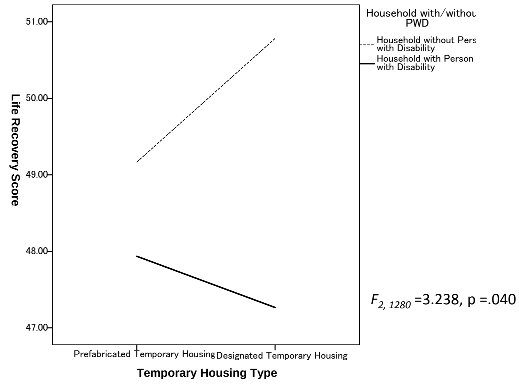

Figure 4: Life recovery score by temporary housing type by household with/without person with disability

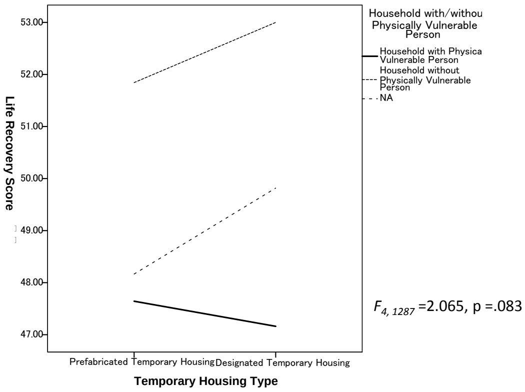

Figure 5: Life recovery score by temporary housing type by household with/without physically vulnerable person

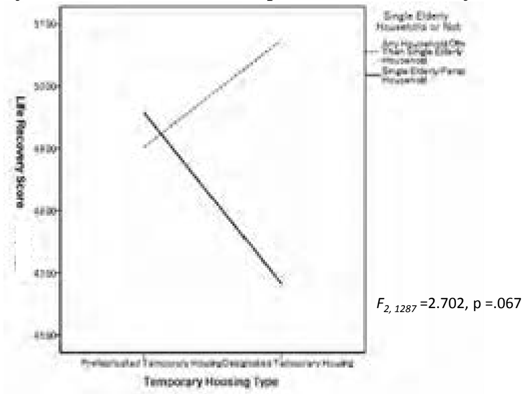

Figure 6: Life recovery score by temporary housing type by single elderly household or not

Our research team decided to work with the life recovery support department of Natori city in early May of 2011 with the concerns that DTH dwellers would have much harder time for them to form mutual support networks, and to obtain necessary public information and assistance, due to the fact that they resided in widely dispersed areas inside and outside of the city/township of their original residence. As was briefly discussed in the previous section and also shown in Figure 3, however, life recovery scores of DTH residents on average tended to be higher than PTH residents ($F_{1, 1287}$ =3.593, p =.058). This seems to support in general the validity of the newly introduced DTH policy. Geographical dispersion seemed not to matter much among the surveyed average Natori impacted citizens. This finding partly supported earlier finings made by ethnographic interviews with impacted Natori DTH residents (Tanaka and Shigekawa, 2014, 2015; Tatsuki, 2015a) which identified 3 groups of DTH households (Tatsuki, 2015a, p. 943):

> 1) Younger, self-reliant and upward mobile families, 2) families with individuals such as PWD and frail elderly that required reasonable accommodations in their everyday functioning, and 3) vulnerable households that would have been benefited from group living conditions in prefabricated housing complexes but failed to submit applications in time.

Figure 3 seems to imply that DTH was a better choice for “1) younger, self-reliant and upward mobile families” according to the classification made by Tanaka and Shigekawa (2014).

In order to examine life recovery situations among the next two categories of “households with persons with disability” and/or “vulnerable households”, Model 3 tested temporary housing type by social vulnerability (PWD, physically vulnerable and single elderly household) interactions. Figure 4 and 5 showed that those households with PWD or physically vulnerable members respectively were better recovered at PTH while any other households’ showed higher life recovery average at DTH. Similarly, Figure 6 demonstrates that such vulnerable households as single elderly households seemed to “have been benefited from group living conditions” in PTH showed better recovery at PTH than at DTH.

In conclusion, the current study affirmed 1) that SCEM was capable of a large proportion of life recovery measure variance among Natori impacted people; 2) that the top 3 most powerful influences upon life recovery were *physical/mental stress management*, *livelihood*, and *social ties* in both 2015 Natori and 2001 Hyogo Life Recovery Surveys while *livelihood* as well as *community involvement* mattered more in Natori survey; and that 3) DTH was better suited to “younger, self-reliant and upward mobile families” while those households with social vulnerabilities were benefitted from PTH group living conditions.

ACKNOWLEDGEMENTS

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Risk Communication in Schools, What Worked and What not: Experience from Nepal

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ABSTRACT

School is a community center in Nepal. Schools are largely established, operated and owned by the local community. So there is close linkage between the community and school system. Disaster awareness is very low in the country at all level. So innovative approach and self-propelling process is the need. For transmitting minimum of knowledge about hazard and risk earn more individual and collective survival in case of disasters such as earthquake.

The school is its design targets the entire community where school is located. Knowledge on disaster risk reduction is transmitted to the teachers in the form of teachers training. Teachers are encouraged to further transmit the knowledge to students through formal and informal teaching and learning process through promotion of environmental and cultural plus social activities such as hazard hunt in the household and family disaster plan in the community. Thus the strategy is transmitting the knowledge for teachers, from teachers to students and from students to parents and community.

The Gorkha earthquake 2015 showed that the approach worked wonderfully well in terms of making the school buildings safe and making the school system safer and by virtue making the community safe against earthquake.
This paper will describe the innovative approaches of risk communication built in to aa majority of those field program activities implemented in the area of earthquake risk reduction. What we learned is that building up of mutual trust and trust to science and technology and fighting the various prevalent myths that hindered the preparedness should be the main thrust for DRR strategy for schools.

Keywords: Disaster, hazard and risk, public relations, risk communication, DRR strategy

Detecting method for liquefaction of ground using strong ground motion

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ABSTRACT

Subsoil liquefaction is disastrous phenomenon affecting houses or infrastructures in a city, especially on underground structures. If liquefaction can be judged at the time of earthquake, this information is useful for estimating damages and planning quick restoration. This study proposes a simple detecting method for non-linear characteristics of surface layer of the ground using accelerometer records at the ground surface. Ground motion's records can be gathered via telecommunication system over the nation. Calculating time variation of dominant period and acceleration amplitude from ground motion record, relative displacement is calculated. The change of acceleration and displacement can be expressed in the characteristic diagram, which represents apparent ground rigidity or deformation characteristics. Then non-linear characteristics is known from the shape of the diagram. In the case of subsoil liquefaction, the shape is widely spread and some values which indicate non- linear characteristics can be known. This information can be used for early warning.

Keywords: *strong ground motion, detecting liquefaction*

1. INTRODUCTION

High quality infrastructure is essential for supporting productivity growth. High quality means safety, durability, low cost, avoiding any risk etc. Infrastructure changes itself due to over time deterioration or natural disasters. Monitoring is effective to find out changes of infrastructure to maintain or restore. Simple method to detect damages is needed for keeping high quality.

Liquefaction is one of newly noticed disasters, so as that many infrastructures are installed at liquefiable land, and in fact, damages due to liquefaction are reported in all over Japan. We know that liquefaction will occur near water side or low land, but have no measures for it.

In Japan, observation network of strong ground motion has been installed all over the nation, if liquefaction can be known after the earthquake, we can act immediately to reduce earthquake disaster.

In this report detection method for liquefaction is proposed, which uses strong ground motion. Liquefaction can be detected by the change pattern of amplitude and period of ground surface motion.

2. Methodology

2.1 SDOF model

A simple SDOF model can be used for wave analysis in order to formulate the relationship between amplitudes of wave and decreased rigidity from earthquake records at liquefied sites. Two assumptions are adopted below.

1) Shear rigidity changes smaller gradually, in the short time of motion, linear equation of motion is feasible, which has constant frequency and damping
2) Vibration of surface layer of the ground is approximated as SDOF which has time-variant frequency

Equation of SDOF motion is below.

$$(\ddot{u}_g + \ddot{u}) + 2hn\dot{u} + \left(\frac{2\pi}{T_g}\right)^2 u = 0$$

Absolute acceleration of the first member is observation data. The peak period of ground motion can be calculate by FFT analysis then to be approximated as natural period. Usually damping is small so as that amplitude of acceleration is in proportion to displacement. Expressing equation is below.

$$u = \left(\frac{T_g}{2\pi}\right)^2 (\ddot{u}_g + \ddot{u})$$

Then we can know amplitude of relative displacement u. Fig.1 shows outline of SDOF motion.

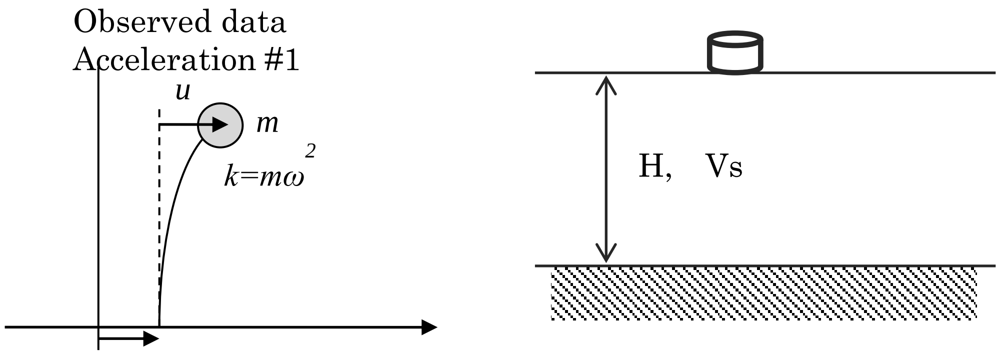

Fig. 1 Outline of SDOF motion

2.2 Non-linear response model

Assuming as bi-linear shear deformation for surface layer, increasing inertia force a (static acceleration), then surface layer is yielded from bottom, displacement of the surface becomes larger according to spreading yielded area. Fig.2 shows outline of push over analysis of surface ground. In the figure, relationship between acceleration and displacement is similar to the shape of stress and strain characteristics. In the case of periodical repeating, motion of large deformation with long period is generated.

We can know some useful information from a-U graph shown as Fig.2. One is natural period before liquefaction from inclination of small value. The other is natural period after liquefaction from inclination of large value. Connection of two lines means yielding point which is affected by depth of layer and yielding stress.

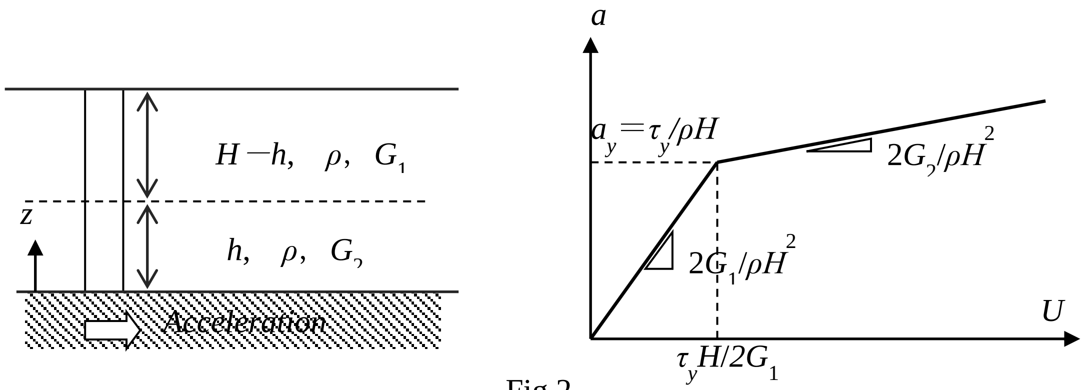

Fig.2

3. Liquefaction detection

Some data of strong ground motion observed at the 2011 Great Tohoku Earthquake are used for verification of this method. Liquefaction has occurred near Inage station which is installed in Chiba Prefecture and located near Tokyo Bay. The wave shapes in horizontal direction are shown Fig.3. Time of ground vibration is longer than 300 seconds, and maximum acceleration is about 2m/s/s.
Calculation steps are below. Data of 16 seconds of total 300 seconds are used and dominant period and acceleration amplitude are defined as representative values of time window. Same calculations are resumed shifting time window.

1) Set 16 seconds time window to calculate dominant period by FFT
2) Average 2 graphs of horizontal directions to determine change of period T
3) Calculate maximum acceleration A in time window as acting force
4) Calculate relative displacement using T and A (U＝（T/2π）^2*A)
5) Shift time window at 1 second, continue same calculation to draw (U,A) plot graph

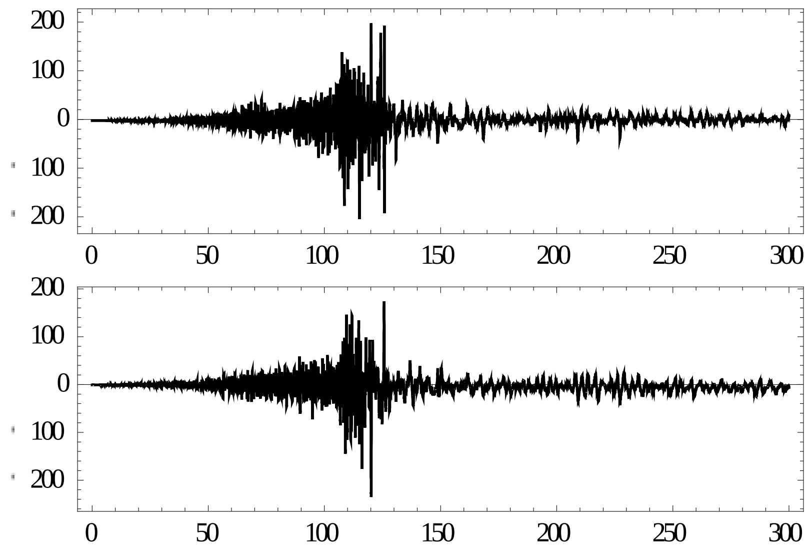

Fig.3 Acceleration forms in horizontal direction

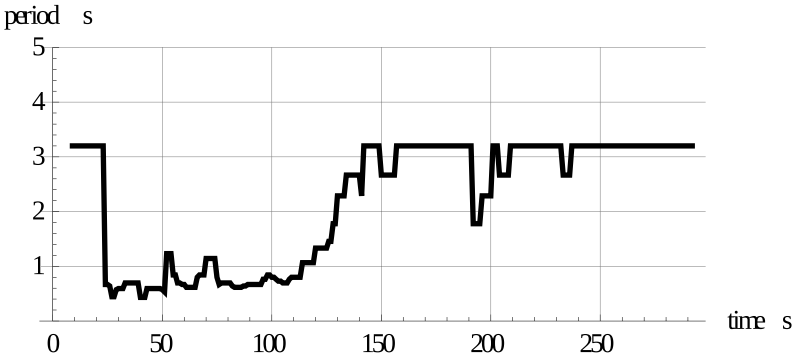

Fig.4(a) Change of dominant period

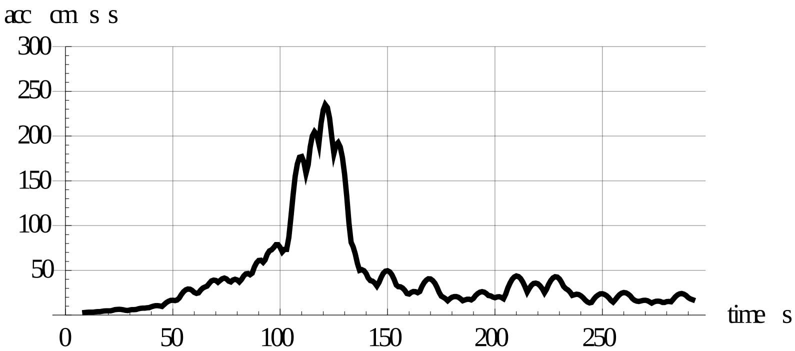

Fig.4(b) Change of amplitude of acceleration

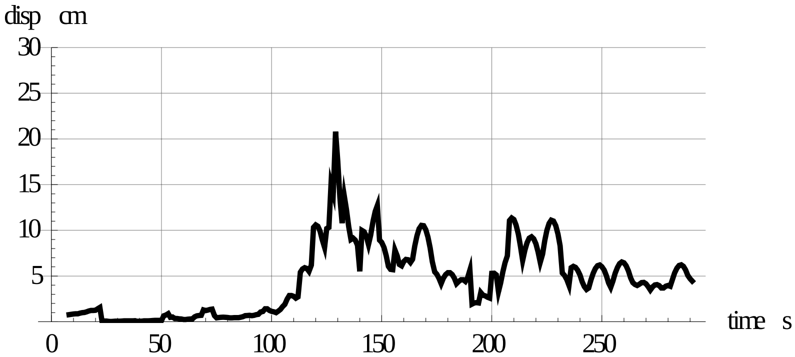

Fig.4(c) Assumed amplitude of displacement

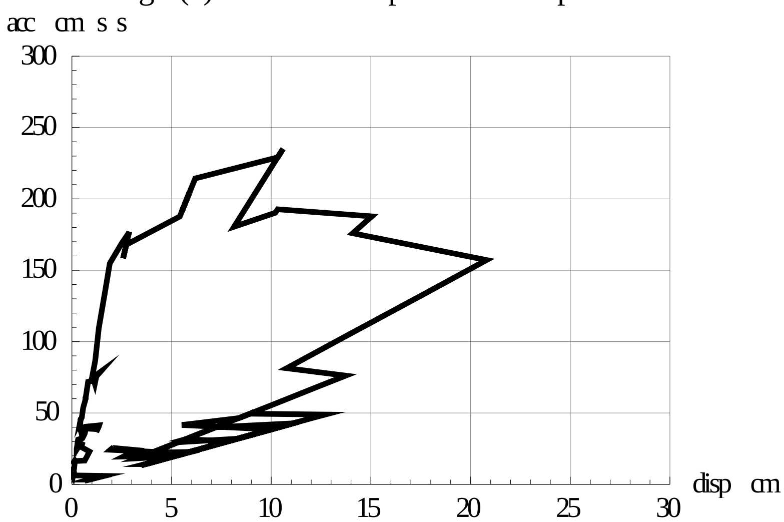

Fig.5 U-A plot graph of Inage station (Liquefied site)

Figures 4 show calculation results. (a) shows change of dominant period, (b) shows maximum amplitude and (c) shows estimated relative displacement. Using Fig.4(b) and Fig.4(c), changing pattern of acceleration and displacement can be drawn, shown in Fig.5. From this, we can know that yielding acceleration is 1.7m/s/s and yielding displacement is 0.02m, maximum acceleration is 2.3m/s/s and maximum displacement is 0.2m. Period before liquefaction is estimated to 0.7 sec, and period after liquefaction is 1.6 sec. It is kwon that non-linear response makes wide shape which means changing period in the time of large acceleration.
For comparing with this, Fig.6 shows calculation result of non-liquefied site which is installed at Urayasu City near Tokyo Bay. Linear response makes narrow shape in U-A graph.

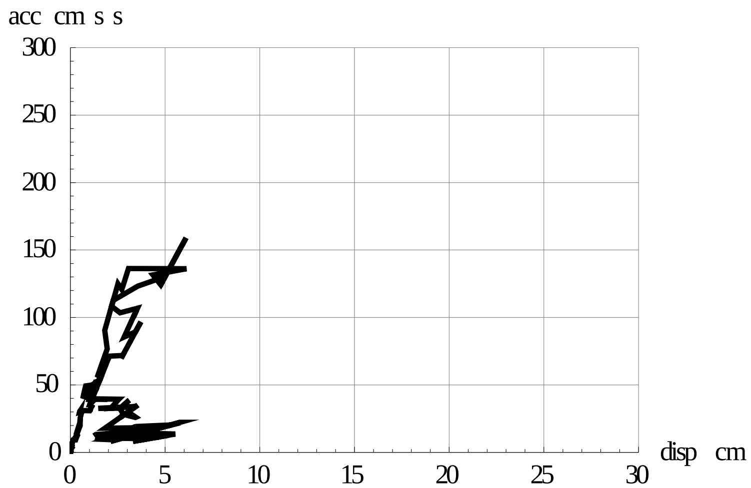

Fig.6 U-A plot graph of Urayasu station (Non-liquefied site)

4. Conclusion

Monitoring is effective to find out changes of infrastructure including surrounding ground to maintain or restore Liquefaction is ground failure by strong shaking. Ground failure generates motion of long period and large displacement same as urban structures. Ground failure can be detected by vibration data at surface of ground calculating frequency and amplitude time by time. Difference of graph shapes which are narrow or wide, informs us ground liquefaction to decrease disaster.

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Simulations of the pull-out performance of mechanical anchorages in concrete with damaged cracks by the discrete analysis

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ABSTRACT

Mechanical anchorages can solve the problem of congestion of rebar arrangement in concrete structures. However, under the condition of complicated earthquake and thin cover concrete, damaged cracks will easily occur and their effect on the pull-out performance of mechanical anchorages is still unknown. In this paper, based on the previous experimental result, the residual pull-out performance was investigated by Rigid Body Spring Model, which is one of the discrete analysis methods. The geometry of knots of rebars is modeled and cracking behavior can be realistically captured.
In both of the experiment and analysis, damaged cracks parallel to the reinforcing bar were firstly induced from cover side by bending. After that, pull-out loading was applied. The analysis revealed the mechanism of damaged cracks which develop from one side of rebar. Also, comparing to the undamaged case, transverse rebars have a different impact during the pull-out stage. The confined effect becomes smaller with damaged cracks increasing because transverse rebars are deformed during bending and cannot easily restore to their original state after unloading. In addition, an eccentric loading occurs and bending stress is induced to the reinforcing bars near the mechanical anchorages due to the damaged cracks in one side of the rebar, indicating that further investigations are necessary including fatigue problems.

Keywords: bond performance, discrete analysis, mechanical anchorage, damaged cracks, transverse bar

1. INTRODUCTION

In structural concrete, conventional anchorages such as straight bars and hooks need the long development lengths and large bend diameters due to the provisions. Especially, the arrangement of rebars at beam-column joints becomes complicated and causes some problems which are difficult to fill concrete and spend times for bending works of steel bars. Mechanical anchorage can be used to shorten the lengths of development and create less congestion, but they require careful attention at thin cover concrete. When earthquake happens, cracks will easily take place from the sides of thin cover concrete. When the damage occurs, the residual bond performance will directly associate with the safety of whole structure, especially at the anchorage parts.

In the previous research, side splitting failure of concrete cover has been examined by Oomori et al., 2009. He reported strain (direction was paralleling to the reinforcing bar) at surface of cover concrete changed from compression to tension near the maximum load. It meant cover concrete began to expand and split closing to the maximum load. However, pullout tests of mechanical anchorage placed in thin cover of concrete with lateral reinforcement were conducted by experiments (Nagai et al., 2010). From experiments, the performances of bond were investigated under damaged cracks. Damaged cracks which were paralleling to the reinforcing bar were created by bending. After that, pull-out loading were applied. But, crack patterns during bend and an eccentric loading occurring near the mechanical anchorage during pull out stage cannot be observed by experimental method. For deeper understanding of bond behaviors and testifying the unsolved problems, numerical simulation at meso-scale is beneficial. In this study, based on the experimental results, numerical simulations with mechanical anchorage are performed by a three dimensional discrete analysis method. Especially, knots of rebar are directly modeled to simulate local fine cracks in the bond region. Through analysis, the residual performance of bond is investigated along with width of damaged cracks changing.

2. ANALYSIS METHOD

2.1 Rigid Body Spring Model (RBSM)

The Rigid Body Spring Model (RBSM), which is a discrete numerical analysis method, is used to simulate the crack propagation of concrete in this study. Hayashi et al. (2013) used RBSM to simulate the crack propagation of RC according to the reinforcement arrangement and the anchorage type. For concept of RBSM, three springs (one normal spring and two shear springs) are placed at the boundary between two adjacent elements shown in Figure 1. Mesh design strongly affects the crack pattern when the cracks occur and propagate through the interface. Therefore, geometry of concrete is randomly generated by a Voronoi diagram (Figure 2a), which reduces mesh bias on the propagation of cracks. Geometry of rebar (Figure 2b) is created by a method which factitiously controls the position of Voronoi point to achieve the regular shape of rebar. For concrete elements, size is set to $10\times10\times10\ mm^3 \sim 20\times20\times20\ mm^3$ in volume, considering the size of coarse aggregate in order to simulate the roughness of the surface of crack. Figure 2 shows random shape of concrete element.

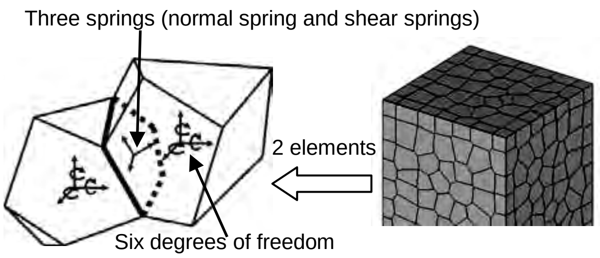
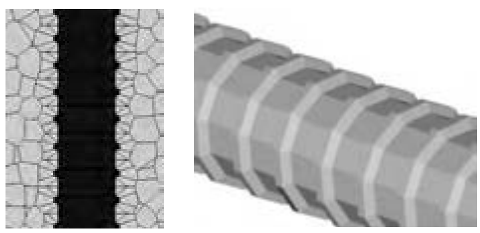
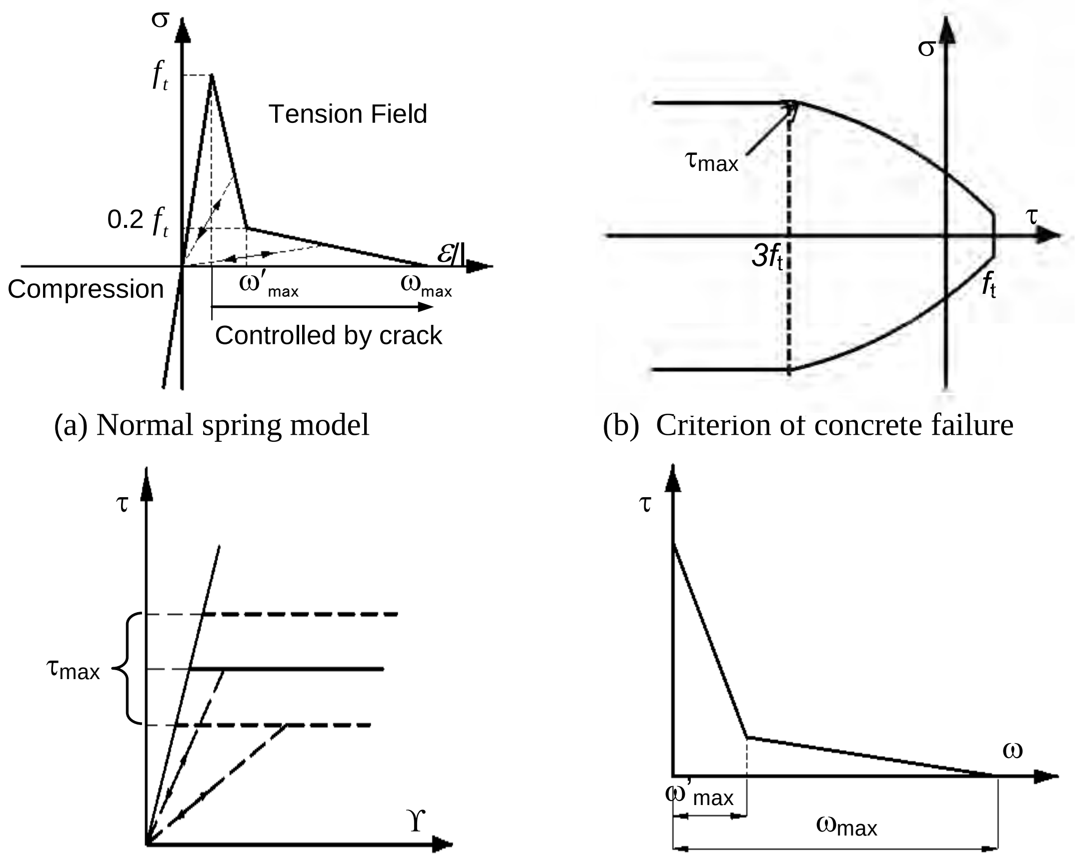


Figure 1: RBSM model



(a) Voronoi Diagram (b) Regular shape of rebar

Figure 2: Shape of element



(a) Normal spring model (b) Criterion of concrete failure

(c) Softening coefficient of shear (d) Model of shear reduction

Figure 3: Constitutive model of spring

2.2 Constitutive model of spring

(1) Concrete constitutive model

For normal spring (Figure 3a), relationship of strain-stress keeps elastic in the compression filed. However, compressive failure behavior can be simulated by shear springs, which follow the criterion of concrete failure (Figure 3b). The tensile behavior of concrete is modeled as linear elastic up to the tensile strength. After cracking, a bilinear softening behavior is assumed. In the model, stress is reduced according to the width of crack. ω'_{max} and ω_{max} are set to 0.03 mm and 0.3 mm, respectively. In shear springs, it shows elasto-plastic behavior shown in Figure 3c. Yield strength of shear spring is calculated by the formulation (1) when stress is less than or equal to f_t and greater than or equal to -3f_t. The maximum shear stress keeps the same value after compressive stress surpassing 3f_t. In addition, calculated shear stress is reduced according to the change of width of crack (Figure 3d) like the normal spring after cracking.

$$\tau_{max}=1.6\times f_t^{2.0}\times(-\sigma+f_t)^{0.4}+0.15\times f_t \qquad (-3f_t \le \sigma \le f_t) \qquad (1)$$

(2) Steel constitutive model

Normal spring of steel behaves elasto-plastic model according to the yield stress of the material properties. Also, strain hardening model is introduced after 1.6% of tensile strain. Shear spring behaves always elastically.

Table 1: Case of analysis

Case	Width of crack during bend (mm)			
	Experiment		Analysis	
	Max	Unload	Max	Unload
T0	-	-	-	-
T5	1.04	0.63	0.97	0.72
T15	2.76	2.34	2.75	2.44

Table 2: Properties of material

Concrete		Rebar			
E_c (kN/mm^2)	33		D25	D13	D6
f'_c (N/mm^2)	52	f_{sy} (N/mm^2)	547	397	374
f_t (N/mm^2)	3.7	E_s (N/mm^2)	190		

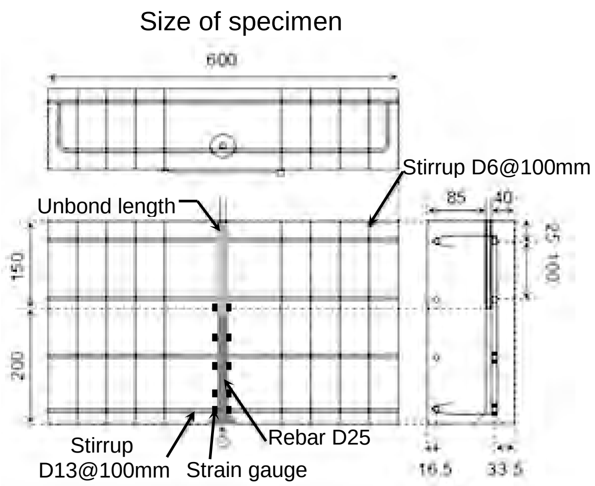
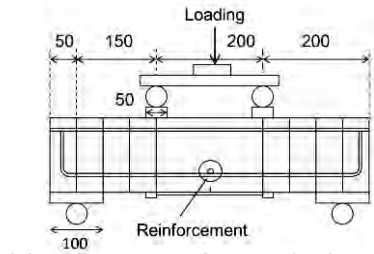
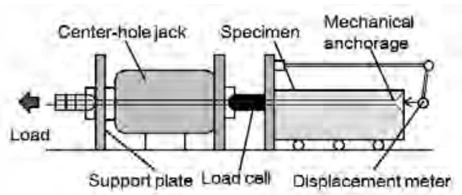


Figure 4: Specimen of mechanical anchorage in experiment (mm)



(a) I-stage: Load setup for bend



(b) II-stage: Load setup for pull out

Figure 5: Load setup in experiment (mm)

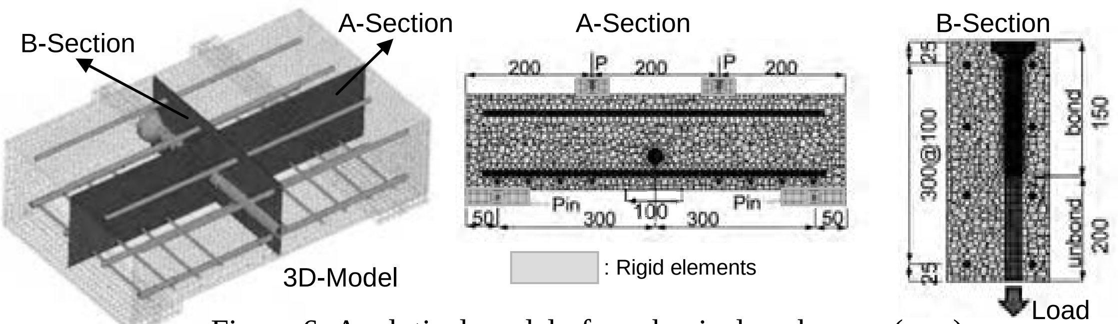


Figure 6: Analytical model of mechanical anchorage (mm)

(3) Interface of constitutive model between concrete and steel

Model of interface is the same with the spring of concrete. But tensile strength of interface is still not clear until recent research. Value of tensile strength is set to a half of the strength of concrete according to the past simulation (Hayashi et al., 2013).

3. ANALYSIS MODEL

3.1 Analysis cases

In this research, bond performance through pullout tests of mechanical anchorage is simulated, which had been done by previous research (Nagai et al., 2010). Table 1 lists the case of analysis and Table 2 shows the properties of material. Figure 4 shows the size of specimens. Figure 5 shows the setup of bending load and pullout load in the experiment. In the first stage (Figure 5a), load is applied to create cracks paralleling to the reinforcing bar at the side of cover concrete. After unloading during bending stage, load of pull out (Figure 5b) is added to the reinforcing bar along with residual cracks. Figure 6 shows the model of analysis. Number of elements is 35,772 in the model of mechanical anchorage. In analysis (Figure 6), loads are firstly applied on the pins of top in vertical direction, but are free in horizontal. The pins of bottom are also fixed in vertical direction and are free in horizontal. Load of pull out is the same condition with the experiment.

3.2 Result of analysis

3.1.1 Relationship of width of crack and load

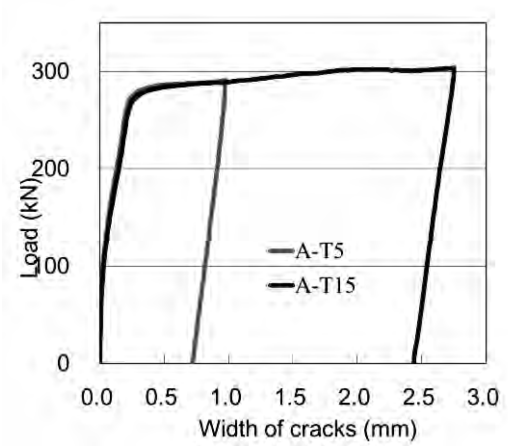


Figure 7: Crack width-load (analysis)

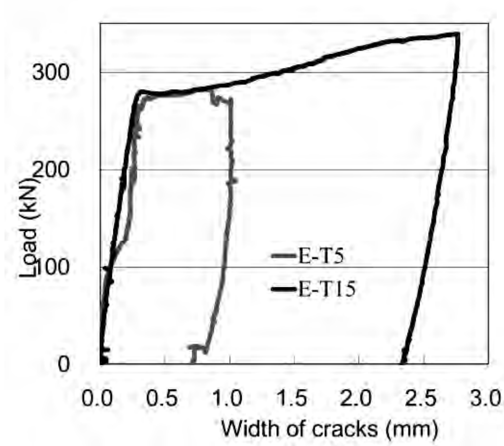


Figure 8: Crack width-load (experiment)

Figure 7 and Figure 8 show the relationships of width of cracks and load, representing the analytical result and experimental result. The width of cracks is calculated by the distance from two elements, whose distance is 100 mm (Figure 6). The residual value of crack in analysis (Table 1) is controlled to the same width in experiment to introduce the same damage level.

The crack pattern at the maximum load is shown in Figure 9 during bending stage. The cracks were induced from the side of cover concrete at the bottom of rebar. With the increase of load, cracks developed along one side of rebar to the top of specimen. As a result, the situation of bond becomes different between left side and right side of rebar due to this damage. Although Figure 9 shows the result of T15 case, case of T5 also has the same crack pattern. From the analysis, crack pattern during bend is confirmed, which cannot be measured by the experiment.

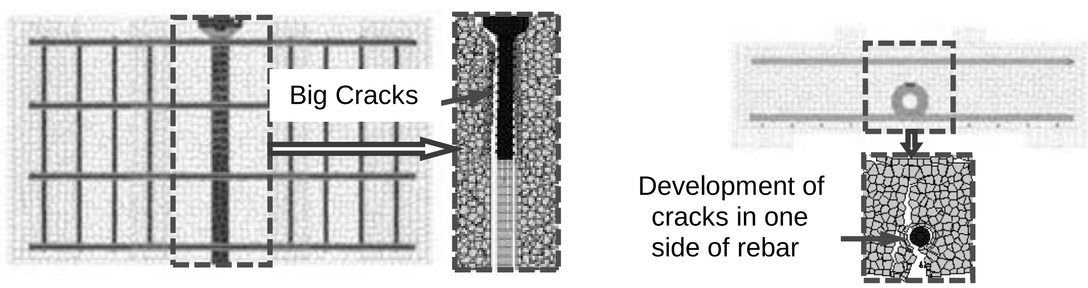


Figure 9: Crack pattern during bend (deformation × 5)

3.1.2 Relationship of slip-load and failure pattern

Figure 10 and 11 show the relationships of displacement of free end and load. In both of the experiment and analysis, initial stiffness and ultimate capacity during pullout (Figure 10, 11 and Table 3) became smaller with the initial crack increasing. In all cases, the capacity of load was roughly the same between the experiment and analysis. For rebar, the yielding load was 269 kN. In the experiment of T0 case, the ultimate load was almost equal to the yielding load of rebar as concrete becoming failure. In contrast, load of pullout in analysis had continued to increase. After yielding load of rebar, failure of concrete occurred. Figure 12 shows the failure pattern in the experiment and analysis. In all cases, the failure pattern is cone failure of concrete, which means the diagonal cracks take place from the plate of mechanical anchorage and make the concrete become blow-out to the cover side.

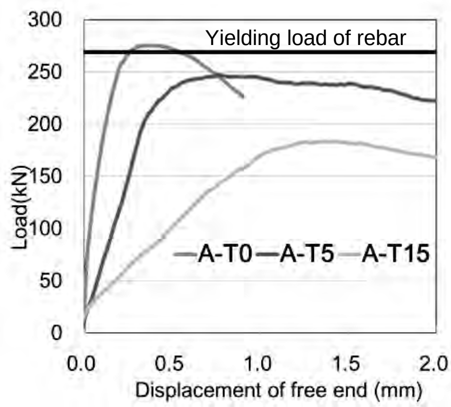


Figure 10: Slip-load (analysis)

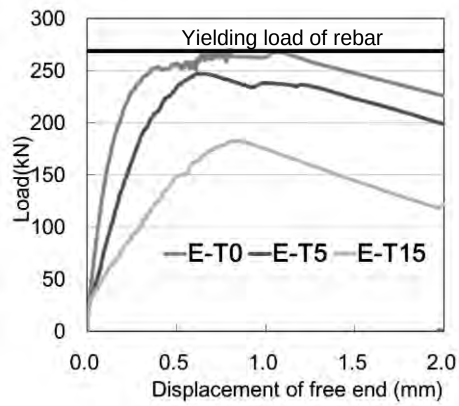
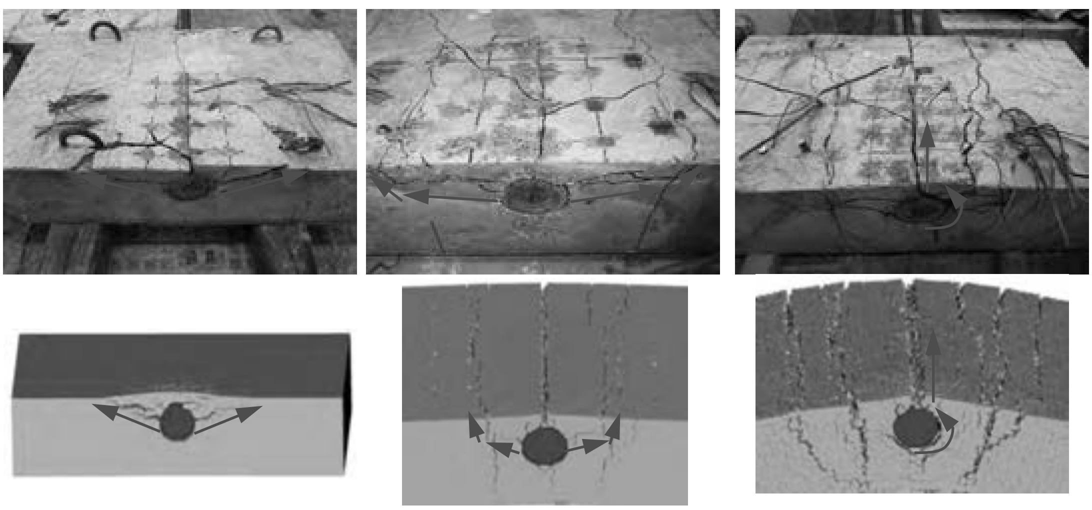


Figure 11: Slip-load (experiment)

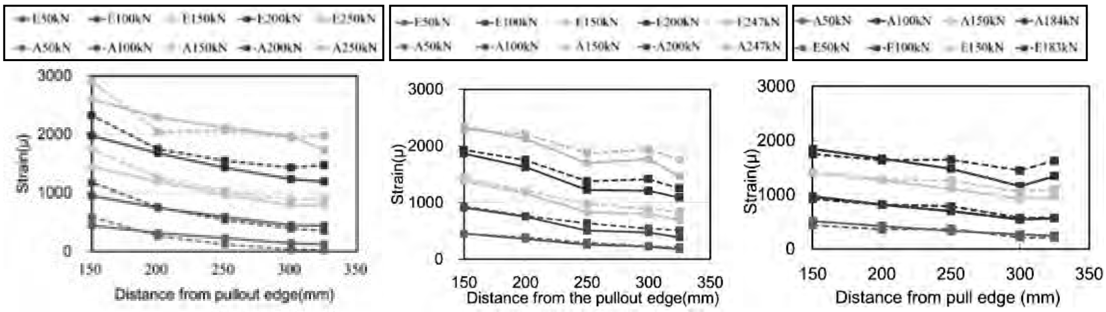
Table 3: Maximum load and failure pattern in pull out test

Case	Maximum load (kN)		Failure pattern	
	Experiment	Analysis	Experiment	Analysis
T0	270	275	Cone failure of concrete	
T5	247	247		
T15	183	184		



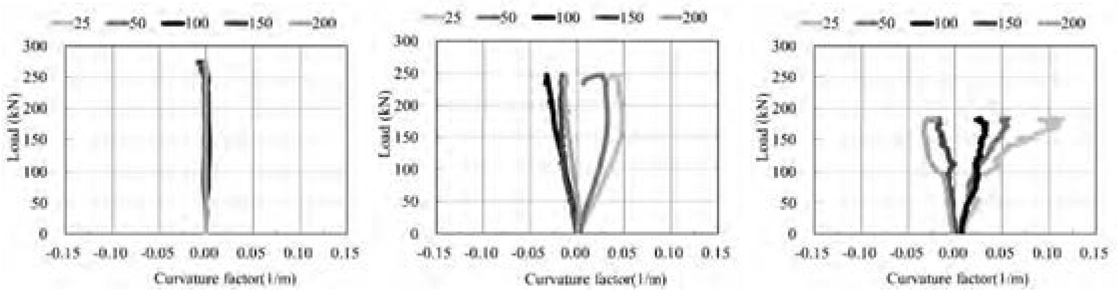
T0 T5 T15

Figure 12: Failure pattern in analysis (lower) and experiment (upper) (deformation × 20)



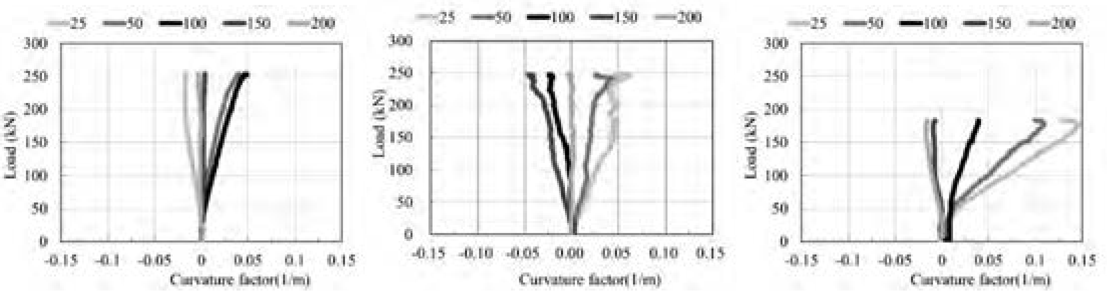
(a) T0 (b) T5 (c) T15

Figure 13: Distribution of strain in analysis and experiment



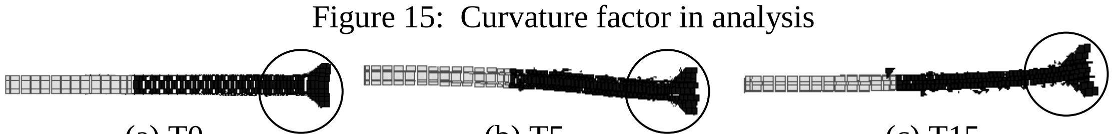
(a) T0 (b) T5 (c) T15

Figure 14: Curvature factor in experiment



(a) T0 (b) T5 (c) T15

Figure 15: Curvature factor in analysis

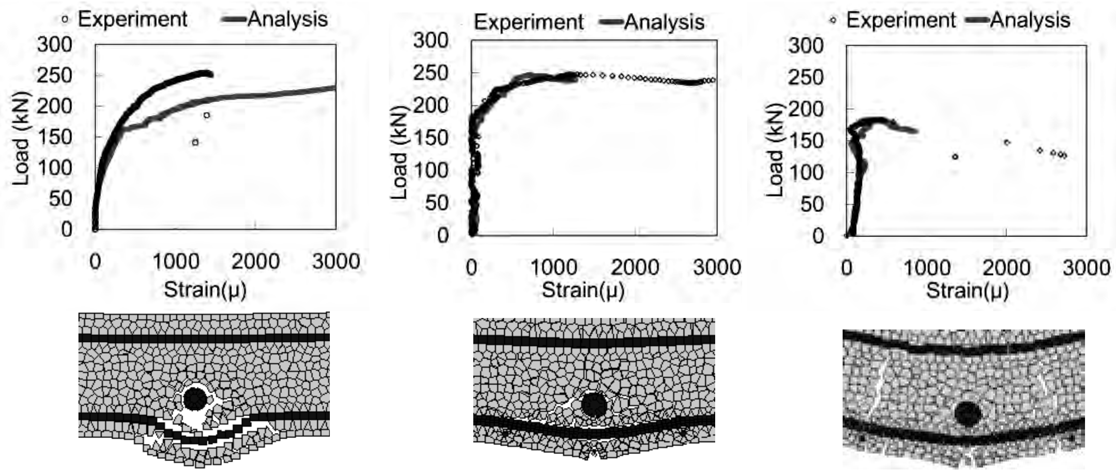


(a) T0 (b) T5 (c) T15

Figure 16: Deformation of rebar at the maximum load (deformation × 100)

3.1.3 Distribution of strain and curvature factor

Figure 13 shows the distribution of average strain which is calculated from left side and right side of rebar under different load. Solid line is the experimental result and dashed line is the analytical result. Bond stresses are proportional to the slope of strain and distances. From Figure 13, slopes of strain and distances become smaller comparing the T0 with T15. It means bond performances decrease with the initial cracks increasing. Figure 14 and Figure 15 show the curvature factor, which was calculated through the difference of strain of left side and right side. The number of 25, 50, 100, 150, 200 means the distance (units: mm) from free end of rebar. Regardless the analysis and experiment, the factor of curvature near to plate of mechanical anchorage shows an eccentricity. Deformation of rebar (Figure 16) is viewed from the top of specimen. The plate of mechanical anchorage shows an eccentricity and force of bending occurs at the position near the plate.



(a) T0 (b) T5 (c) T25

Figure 17: Strain and deformation of transverse bar (deformation × 50)

3.1.4 Strain and deformation of transverse bar

Figure 17 shows the stain of transverse bar near to the plate of mechanical anchorage (25 mm from free end) and deformation at the maximum load of pullout. With the initial cracks increasing, the strain of transverse bar almost kept the same level under 150 kN during pullout stage. Also, the deformation at the maximum load was not obviously changing with the initial cracks. The confining effect is weaker with initial cracks increasing when the transverse bar is near to plate of mechanical anchorage. This tendency is caused by the bending damage. The initial crakcs which are induced from the bending make the transverse bars difficult to close during unloading.

4. CONCLUSION

(1) The damaged cracks paralleling to the reinforcing bars induced by bending develop from one side of rebar to the depth.
(2) An eccentric loading occurs and bending stress is generated from the position near to the mechanical anchorages due to the damaged cracks at one side of the rebar.
(3) For transverse bar near to the free end, the confined effect becomes smaller in damaged case because transverse rebars are deformed during bending and cannot easily restore to their original state after unloading.

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Creating safer Kathmandu Valley: From the perspective of Kathmandu Valley Development Authority

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ABSTRACT

Urban safety is a major issue in context of planning, both for individual residents and for local and national governments. In addition, major concerns related to disaster vulnerability, climate change and socio-political imbalance have further led urban planners to re-think how the urban planning and related professions could play an important role in promoting urban safety. The issue is even more pressing in case of Kathmandu Valley, one of the fastest urbanizing regions in South Asia, which is also considered as one of the most vulnerable regions in context of multi-hazard risks- generating significant loss of life and property. This paper presented the outcome of the 20 years Strategic Development Master Plan (2015 – 2035) on how urban safety and resilience- in physical, socio-economic and environmental milieu - could be emphasized and incorporated in context of Kathmandu Valley. The perspective of Kathmandu Valley Development Authority as the major planning authority was used to discuss how the Master Plan could aid in shaping the valley from a Distant, Dispersed, Disconnected area to a Compact, Coordinated and Connected region. It puts forward new approaches to develop healthy urban planning practices to achieve its vision and mission: "To establish Kathmandu Valley as a Safe, Clean, Organized, Prosperous and Elegant (SCOPE) national capital region by enhancing the interdependence of Nature, Community and Culture".

Keywords: *urban safety, Kathmandu Valley, urban planning, disaster resilience*

Institutionalization of disaster education In state of Uttarakhand, India

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ABSTRACT

Disaster risk reduction (DRR) education is implemented in various forms by different organizations. In state of Uttarakhand, India which lays on the middle part of Himalayan range and the state is thus prone to flood, landslide and earthquake. Educational approach is being carried out in that area in order to enhance the resilience against the disasters. Department of education infused DRR contents into curriculum and other governmental and non-governmental sectors conduct the project on DRR education. Besides, community itself has some means of knowledge transfer on DRR such as launching community radio, sharing of experiences and local knowledge to predict strong rain fall. However, these different practices are not conducted in synergetic way. Therefore, this research categorizes these different forms of education under three modes; formal, non-formal and informal education and aims to suggest the coordinated implementation to enhance the educational effectiveness. The result indicates the effective collaboration beyond the modes of education while further collaboration among different stakeholders will enhance the effectiveness of disaster education. It is important to establish the mechanism for the coordination in conducting DRR education beyond the modes of education.

Keywords: *institutionalization, DRR education, Uttarakhand, India*

1. INTRODUCTION

The disaster risk reduction (DRR) education is being recognized as one of the important strategies to reduce the impact of natural disasters because it contributes to enhance awareness and let people equip with the knowledge and skills to prepare for and protect themselves from the impact of natural disasters. In fact, various governmental and non-governmental organizations carry out the DRR education program and disaster prone communities share the disaster-related knowledge among people through various means such as local custom, storytelling, media and so on. These different forms of knowledge transfer is categorized under the following three modes of education; i) formal, ii) non-formal and iii) informal education. Formal education features to be delivered in an organized and structural means (Dib, 1988; Tissot, 2004), results to award certificate or diploma (Tissot, 2004) and basically adopts the “ladder system” (ISCED, 1997).

Therefore the formal education is defined as the education which is delivered based on the curriculum through the framework of school. Non-formal education as well delivers the knowledge in an organized way however this mode is being carried out apart from the framework of school education (Coombs and Ahmed, 1974; Norland, 2005). The other feature is that non-formal education adopts various forms of modalities and methodologies according to the interests of learners. In short, this mode refers to the education conducted with various learning modalities and methodologies through the governmental and non-governmental organizations except formal education sectors. Third mode of education is informal education. This is unintentional learning process through the daily life experiences such as occupational life and family relationship (Coombs and Ahmed, 1974; Norland, 2005) and the form of knowledge transfer is neither organized nor structured (Dib, 1988; Tissot, 2004). Hence the informal education comes to be defined as the unintentional learning through various means in daily life. As indicated, there are three modes of education and integrated implementation of them enhances educational effectiveness. Tudor (2012) indicated that education is needed in the direction of combining formal one which is specific to class, with non-formal and informal strategy. Most importantly in the context of DRR education, the effectiveness of disaster education has to be enhanced through the coordination of three types of education (Shaw et al, 2011). Therefore, this research aims to study the integrated and synergetic implementation of three modes of education thus institutionalized implementation is suggested. The terminology of “institutionalized” or “institution” refers to a basic norm that society or certain group of people follows so that the action is being taken place as organized system (Hodgson, 2006).

2. METHODOLOGY

The study was conducted in the state of Uttarakhand, India. The state is highly prone to landslide and flood due to the heavy rainfall in monsoon season and earthquake due to the collision of Indian plate into Eurasian plate. The practices of three modes of education were studied through literature reviews and the interviews of 11 governmental agencies, 14 schools, 5 villages, 2 community radio stations.

3. PRACTICES OF THREE MODES OF EDUCATION IN UTTARAKHAND

3.1 Formal education

The formal education in Uttarakhand is provided by state department of education. The constitution of India prescribes the education as a state matter due to the variety of languages and ethnic group through India hence its system and educational contents are different from state to state. Uttarakhand adopts the curriculum of Central Board of Secondary Education (CBSE) which is developed by the autonomous education board of Indian government and its contents are modified into Uttarakhand context. DRR related contents are infused into the subjects of Hindi, English, Environmental education, Mathematics, Science and Social science. Especially, the curriculum of social science of class 9 and 10 are modified into local context with the collaboration of DMMC and local NGO. Furthermore, the textbook was elaborated by the DMMC.

Apart from the curriculum, co-curricular activities are the opportunities to learn the skills to save lives in the situation of natural disasters. First aid training and search and rescue training are observed in some programs such as the scheme of National Social Service (NSS) and Scout and Guide. Besides, role play with DRR topic is also conducted occasionally. The curriculums and co-curricular activities are reviewed and evaluated annually and the evaluation is conducted by the department of education with participation of NGO. There is also institution to provide teacher's training at state level which is called State Council of Educational Research and Training (SCERT). The council is a responsible institute for training of Trainers of Teachers (ToT) and the trainers carry out the training directly for teachers at District Institute of Educational Training (DIET). Due to the severe damages from flood and landslide took place in 2013 in the state, DRR components were newly integrated into the teacher's training although officer stated the unavailability of training material on DRR. Teachers who receive training can give feedback to DIET regarding the contents and its opinion transmit to SCERT. Thus the evaluation of teacher's training is also periodically conducted in order to reflect the opinion of teachers. Ensuring the safety of school building is also one of the important elements of formal education sector. One national scheme called Sarva Shiksha Abhiyan (SSA) which aims to accomplish the universal and quality education is ongoing. The SSA has a component to construct the school building and all safety measures are applied and design is developed by governmental technical institutions. Although some DRR education is conducted in the state, the policy to promote DRR education is not observed and there was no funding mechanism specific for the promotion of DRR education while SCERT has deployed one person in charge of DRR education training.

3.2 Non-formal education

Non-formal education is provided mainly by Disaster Mitigation and Management Centre (DMMC). DMMC is the autonomous institution of the state government with the aim of addressing issues on disaster related awareness, research and capacity building besides policy implementation and other interventions related to disaster management. The DMMC conducts different types of educational programs for school students and community members. Earthquake awareness program, search and rescue training and first aid training are the major programs carried by DMMC. One of the features of non-formal education is the variety in modalities and methodologies in knowledge transfer therefore DMMC also utilizes different kinds of educational materials. In addition to the materials developed by National Disaster Management Authority (NDMA) such as booklets and posters in both English and Hindi language, DMMC prepared movies on landslides in local dialect for children's awareness. In the collaboration with UNDP, DMMC also developed storytelling booklets on various topics such as landslides, flood, traffic accident and so on. To equip teachers with DRR knowledge, DMMC also delivers teacher's training.

DMMC also promotes the establishment of local group for disaster management and the disaster management plans at community level are also elaborated in some districts. Personnel of DMMC are deployed in different districts of Uttarakhand state and search and rescue training is given to local volunteers and equipment for search and rescue are provided. Community is a first responder of natural disasters thus the education and training to provide knowledge and skills for community is necessary. While there are many activities conducted by DMMC, evaluation and documentation processes are observed challenges. In fact, evaluation and documentation are the process of clarifying the effectiveness and points to be improved of each program therefore better programs can be conducted in the following time.

3.3 Informal education

Informal education practice is different from place to place. The study was conducted in Dehradun, Rudraprayag and Bageshwar district. In terms of the common points among study areas, it was found that people tend to obtain the disaster related information through media. Even in the rural area, smart phone and internet are prevailed and people get the information through social networking service such as Whats App and Facebook besides mass media. Obtaining information includes not only the emergency warning, but also do’s and don’ts and sometimes those information are shared to other friends through social medias. In each study area, interviewed community has local knowledge to predict the heavy rainfall and the risk of landslide through the past experience. These local knowledge can be transmitted widely among community members if the strong bond among community members exists. In fact, the various community based activities were organized through the community body such as clean-up project and fair. Random interviews to school students were also conducted and it was identified that students have heard about the past experiences of disasters from their family at home and students usually share the knowledge they learn at school with family. Hence the promotion of DRR education at school can contribute to spread the DRR knowledge even to the community. Apart from these, community radio in Rudraprayag broadcasts community related information. The radio allocated certain amount of time to focus on delivering the knowledge on DRR through the interview of specialist, experience of local people and local knowledge.

4. INSTITUTIONALIZATION OF DRR EDUCATION

Three modes of education were thus studied and some integrated and synergetic implementation beyond the modes of education were observed. Department of education adopted the CBSE curriculum and its contents related to DRR were localized in the context of Uttarakhand disasters. Especially, DMMC which is state authority in disaster management has collaborated to elaborate the textbook for DRR part of social science. This is an example of synergetic implementation of DRR education because DMMC has accumulated data and knowledge on Uttarakhand disasters and these knowledge makes educational contents more practical therefore its effect is enhanced. Other effort to include different stakeholder is as well observed in the mechanism of evaluation at department of education that the periodical review of educational activities are conducted through the participation of NGO. While there is a good example of mechanism for collaboration, there are some aspects which can be improved. Advantage of DMMC is the accumulation of educational materials for students and teachers as mentioned earlier. Since there is a lack of educational materials at DIET, DMMC and formal education sector can increase its collaboration through the joint implementation of teacher’s training on DRR. In terms of informal education, interviews show the tendency that students tell to family what they learn at school. This suggests that improvement of DRR education at school through formal and non-formal education can contribute to increase the informal education at family level. Therefore, it is important to consider the linkage between school and community to enhance the effectiveness of

DRR education. In addition, media such as community radio and local newspaper function to disseminate the DRR knowledge to community. Therefore, formal, non-formal and informal means of knowledge transfer should be conducted to supplement each other thus duplication of activities can be avoided and the accuracy of DRR information delivered become also practical. To realize the further integrated implementation of three modes of DRR education, it is important to establish a mechanism to promote the communication among stakeholders. For example, both education department and DMMC give training on DRR for teachers and further collaboration can maximize the effect of the practices among stakeholders. In addition, means of informal education such as community radio station can include DRR contents if there is more support of education and disaster related organization. Thus, mechanism to promote the communication is required for further effective implementation of DRR education.

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Analysis of degree of regional health considering disaster risks ~Using National Health Insurance data~

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ABSTRACT

In Japan, a lot of natural disasters are expected to occur such as typhoon, heavy snowfall, flood, sediment disaster, earthquake, tsunami and volcanic eruption.
Problems that Japan has includes the super aging society.
The aging of Japan progressed to the world at speed not to watch an example and invited super aging society in 2007. With it, people in need of long-term care increase. Such examples people with special needs to disaster suffered from by natural disaster occur frequently, and it is found by natural disaster that we find security, the relief of these people. At disaster, it is expected that people who are behind with evacuating increase. In considering the disaster prevention measures of our country, we cannot ignore distribution of people with special needs to disaster in the future. In this study, using National Health Insurance database (KDB), we clarify distribution of the patient according to each disease and clarify distribution of people in need of long-term care. I grasp the place where the elderly and people in need of long-term care live in by these analyses and a kind suffering from of illness and consider it from the viewpoint of medical care to future disaster prevention measures.

Keywords: National Health Insurance database (KDB), super aging society, disaster prevention measures, medical care, senior citizen

1. INTRODUCTION

In Japan, a lot of natural disasters are expected to occur such as typhoon, heavy snowfall, flood, sediment disaster, earthquake, tsunami and volcanic eruption. People with special needs to disaster refer to the people in need of assistance in evacuation in disaster. For example, the elderly, people with disabilities, victims, infants, stranded commuters, travelers, artificial dialysis patients, diabetic, patients suffering, psychiatric and neurological disease patients, and people in need of long-term are people with special needs to disaster. Diabetics are people with special needs to disaster because diabetic may lead to metabolic disorders in the event of disaster even if their conditions are stable in peacetime.

In this study, we analyzed about people in need of long-term, patients requiring high medical costs, and artificial dialysis patients using the data of the National Health Insurance database (KDB).

We analyzed data of the National Health Insurance database (KDB) of Nanto City. Nanto City is located in the southwestern part of Toyama Prefecture. The area of Nanto City is 668.64 square kilometers. The population of Nanto City is 53582 people (2015 of March 31). In age three segment population of Nanto City, young population (0-14 years old) and the working-age population (15-64 years) has reduced, and the elderly population (over 65 years) has increased. Nanto City has aging populations. In November 2004, four towns and four villages merged into Nanto City.

Figure 1 shows Toyama Prefecture and each cities.

Figure 2 shows previous four towns and previous four villages in Nanto City.

Figure 1: Toyama pref. and each cities

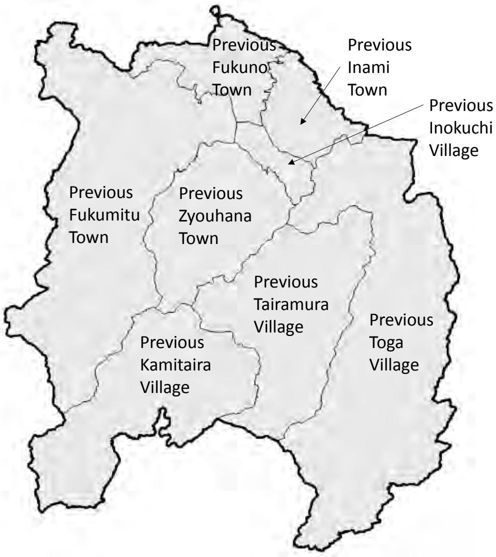

Figure 2: Previous four towns and previous four villages in Nanto City

2. OVERVIEW OF NATIONAL HEALTH INSURANCE DATABASE (KDB)

Previously data preparation for grasping the current area situations and health problems were often done by hand work, and it was inefficient. It was difficult to sufficiently understand the current area situations and health problems because the data was huge. It is possible to do a lot of work automatically, it is possible to implement a more efficient and effective health service with National Health Insurance database (KDB) system. By using this system, people can share not only information but also recognized health problems in the region. As a result of using National Health Insurance database (KDB), a lot of health problems can be examined. Figure 3 shows example of the data of National Health Insurance database (KDB). KDB has gender, age, date of birth, address, expenses, main disease name and so on.

Figure 3: Example of the data of National Health Insurance database (KDB)

3. PREVIOUS RESEARCHES

A research result on disaster contingency planning dealing with the elderly as people with special needs to disaster has been presented by Mr. Namba et al. A research result on evacuation dealing with the elderly and people with disabilities as people with special needs to disaster by Mr. Ariga.
Research results on dealing with the elderly and people with disabilities as people with special needs to disaster has been done, but research results on dealing with diabetic patients, artificial dialysis patients, and psychiatric and neurological disease patients as people with special needs to disaster has not been done.
No studies to understand the distribution of people with special needs to disaster using National Health Insurance database (KDB).

4. EARTHQUAKE RISK OF PEOPLE WITH SPECIAL NEEDS TO DISASTER IN NANTO CITY

4.1 Earthquake risk of people in need of long-term

Certification of Needed Long-Term Care is intended to determine the necessary level of care service. Therefore, there is a case in which seriousness of the disease and the level of the care do not always coincide. Certification of Needed Long-Term Care is divided into seven levels of support required 1-2 and care levels 1-5.
We analyzed people in need of long-term level three or more as people with special needs to disaster care because people in need of long-term level three or more care cannot do by themselves. This study was targeted for people in need of long-term level three or more care from June 2012 to February 2015.

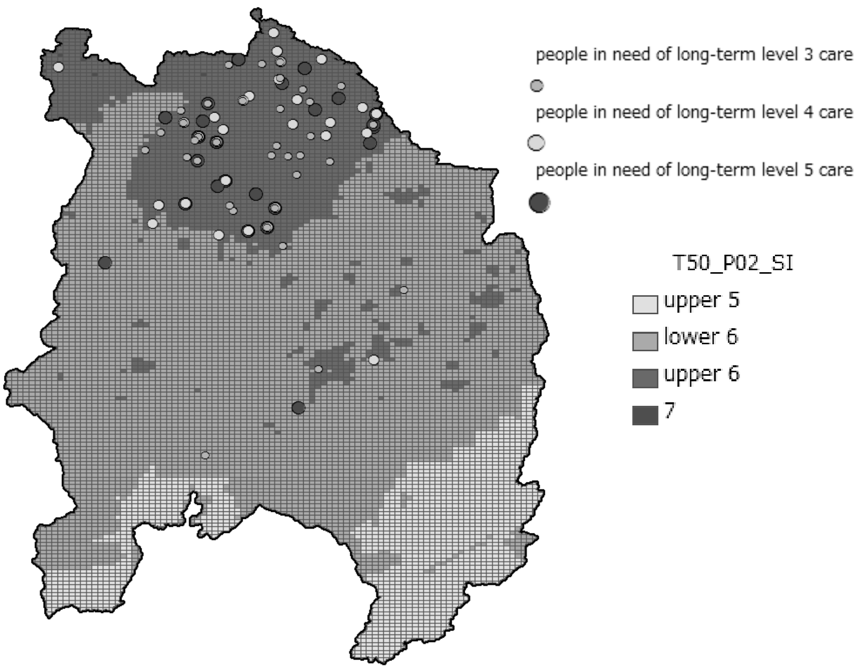

Figure 4: Distribution of need of long-term level 3-5

Figure 4 shows that people in need of long-term level three or more care and of measuring seismic intensity (JMA-scale) which is a 2% under 50-year exceedance probability distribution. Figure 5 shows that relationship between need of long term and seismic intensity (JMA-scale). From figure 4 and 5, it can be seen that most living in places where seismic intensity of upper 6 (JMA-scale) and at any care level despite residence of people in need of long-term level 3-5 care is different.

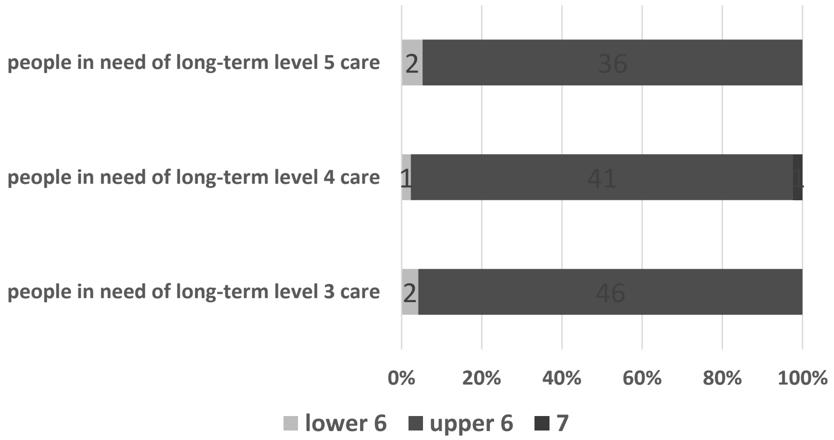

Figure 5: Share of need of long-term level under seismic intensity

Figure 6 shows that the distribution of people in need of long-term level three or more care and the distance (km) from major medical institutions of Nanto City. Figure 7 shows that the distance from major medical institutions of people in need of long-term level three or more care.

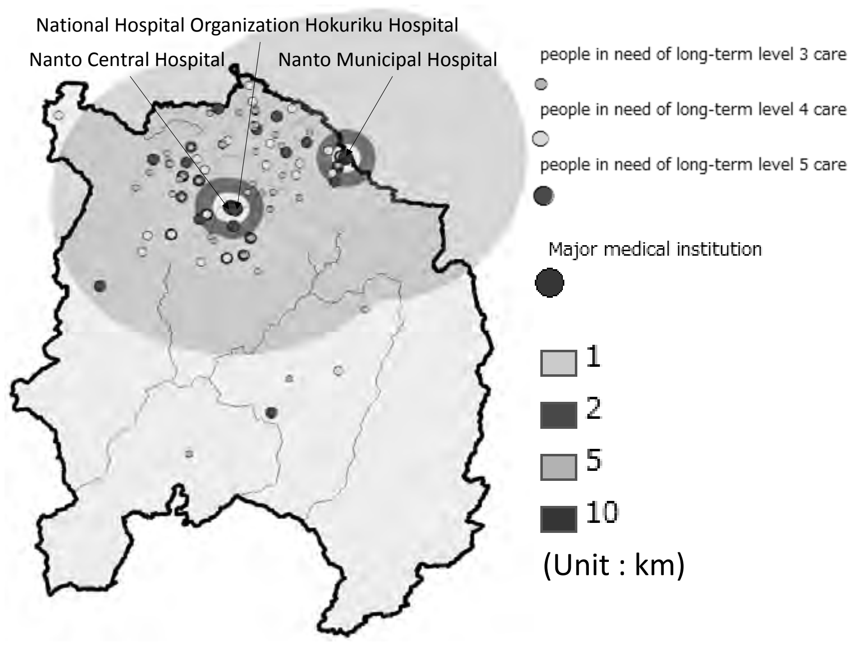

Figure 6: The distribution of people in need of long-term level 3-5 care and the distance (km) from major medical institutions of Nanto City

From figure 6 and 7, the proportion of people in need of long-term level three or more care living in 5km distance from major medical institutions is high. Therefore, there is concern that the evacuation due to traffic congestion is delayed during the disaster.

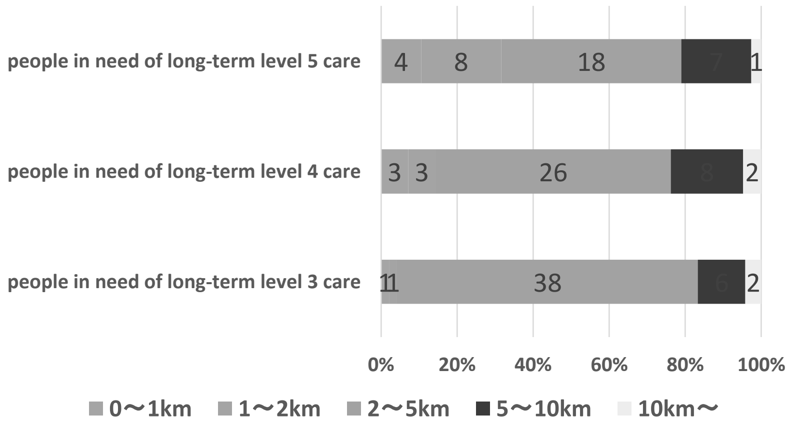

Figure 7: The distance from major medical institutions of people in need of long-term level 3-5 care

4.2 Earthquake risk of patients to be determined as people with special needs to disaster

This study was intended for diabetic patients, psychiatric and neurological disease patients, and artificial dialysis patients from June 2012 to February 2015. It is only a patient in need of medical expenses of more than ¥ 300,000 in one month for diabetic patients and psychiatric and neurological disease patients.

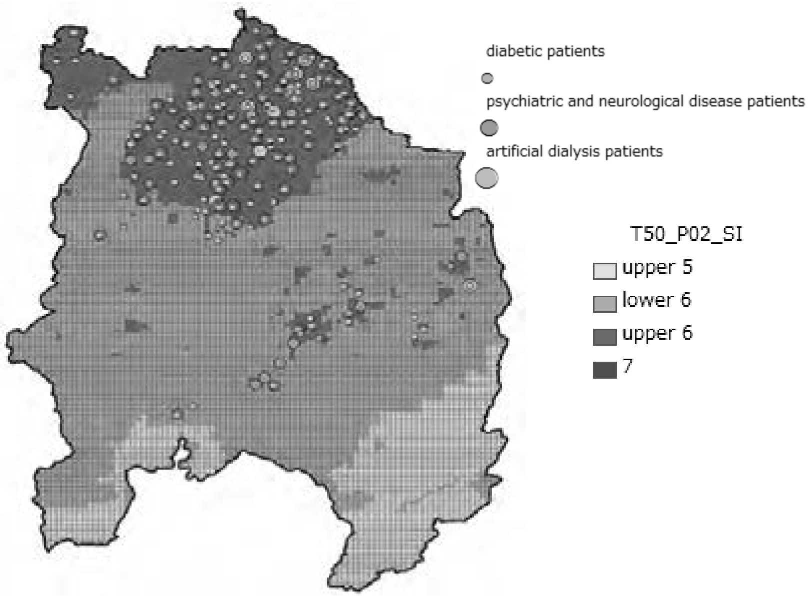

Figure 8: Distributions of patients and distributions under seismic intensity

Figure 8 shows that distributions of these patients and distributions of the seismic intensity (JMA-scale) of a 2% under 50-year exceedance probability. Figure 9 shows that the measurement seismic intensity (JMA-scale) distribution state to be 2% under 50-year exceedance probability of each disease. As a result of figure 8 and 9, more than 90% of these patients are living in places where seismic intensity of upper 6 (JMA-scale).

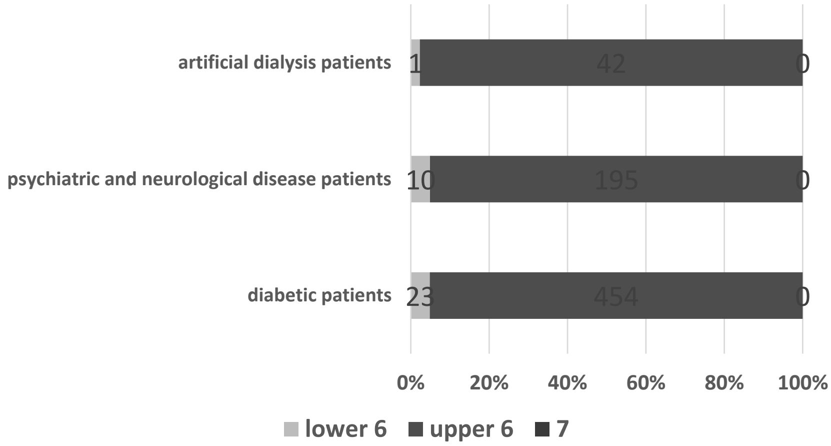

Figure 9: Share of major patients under seismic intensity

Figure 10 shows the distribution of major patients and the distance (km) from major medical institutions of Nanto City. Figure 10 shows the distance from major medical institutions of major patients. As a result of 10 and 11, the proportion of these patients living in 5km distance from major medical institutions is high as in the case of people in need of long-term level three or more care. It is important to determine shelters of people with special needs to disaster for each residence in order to avoid traffic congestion during the disaster.

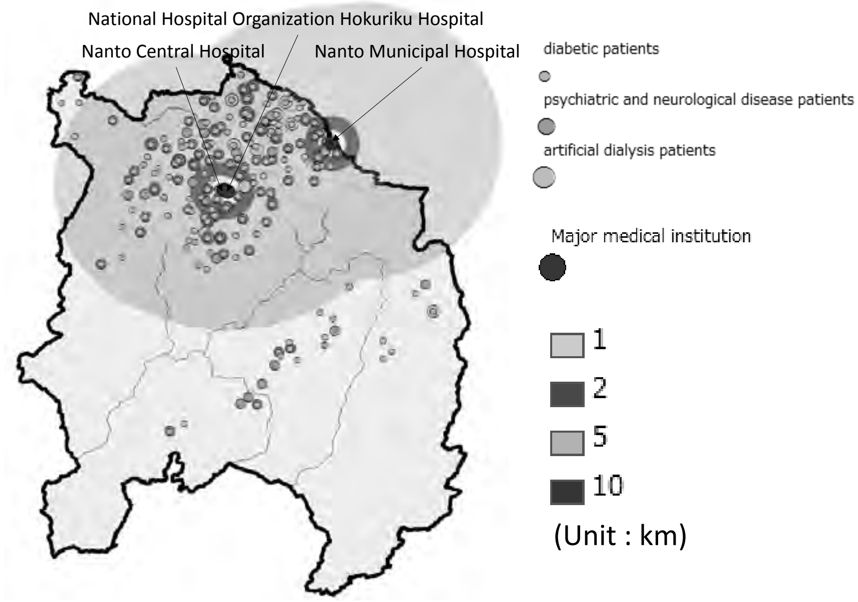

Figure 10: The distribution of these patients and the distance (km) from major medical institutions of Nanto City

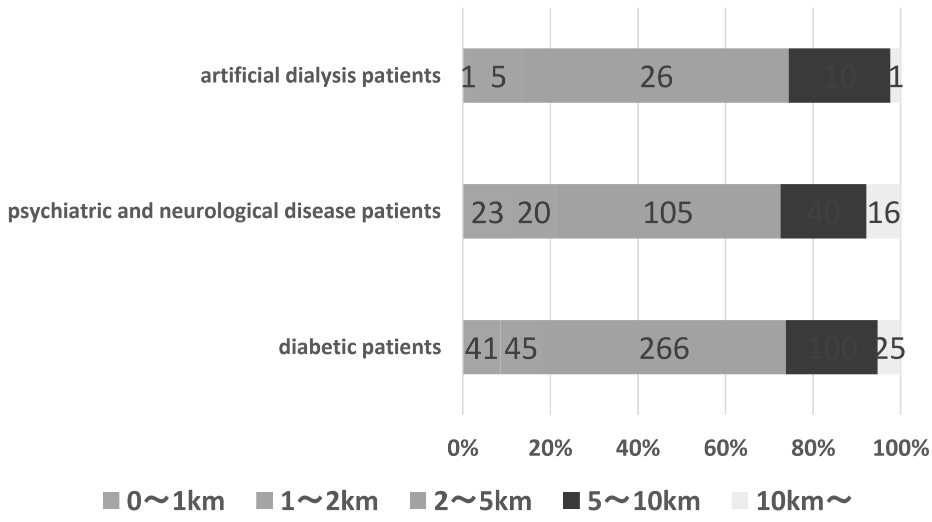

Figure 11: The distance from major medical institutions of major patients

5. CONCLUSION

By using National Health Insurance database (KDB), we visualized addresses of people in need of long-term level three or more care, diabetic patients, psychiatric and neurological disease patients, and artificial dialysis patients in Nanto City on GIS. Furthermore, by using the J-SHIS Map, we visualized the distribution of seismic intensity (JMA-scale), which is 2% in 50 years exceedance probability in Nanto City on GIS. Instrumental seismic intensity, which is 2% in 50 years exceedance probability in Nanto City are distributed from seismic intensity upper 5 to seismic intensity 7 (JMA-scale), seismic intensity is greater in the north of Nanto City. Although there is little place of seismic intensity 7 (JMA-scale) in Nanto City, most of people with special needs to disaster are living in places where seismic intensity upper 6 (JMA-scale). It was found that the proportion of those who are living in close from the main medical institutions in people with special needs to disaster is high. It is important to clarify for each residence shelters for each residence because major medical institutions are built close together in Nanto City. As future problems, we will analyze the data about other cities. Also, we will do evacuation simulation.

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Design of spatial decision support tool for understanding cumulative environmental exposure

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ABSTRACT

To support the experts and decision makers with the information on cumulative environmental exposure, a spatial decision support tool for understanding cumulative environmental exposure ($SDST_{CE}$) is designed. The ROMC design approach and the Use Case approach were used to design the $SDST_{CE}$. The design was operationalized as $SDST_{CE}$EnL in Community Viz by using secondary data from Dortmund, Germany. It is capable of producing index maps, graphs; which is interactive in nature. Multiple environmental deprivation index (MEDIx) was used to understand the geographic extent of cumulative environmental stressors. It is also able to assess the area and population exposed to cumulative environmental stressors. Additionally, it can overlay different layers such as health, immigrant data over the index map for further analysis. The research concluded that the area around transportation network of the case study city is environmentally deprived with the highest combination of environmental stressors. It is a generic tool; therefore, can be also be utilized in understanding the multiple environmental exposure in Kathmandu Valley.

Keywords: multiple environmental stressors, cumulative environmental exposure, spatial decision support tool, index, conceptual design

1. INTRODUCTION

1.1 Background and justification

Various environmental stressors exist in an urban environment. According to Briggs (2003) environmental stressors do not work in isolation nor do they lead to single and specific health outcome, indeed they act in consort and lead to a wide array of health outcome. This leads to the concept of multiple environmental stressors and its cumulative effects. According to Vlachokostas et al. (2012) urban environment is mostly effected by two environmental factors, air and noise pollution. He measured the combined exposure of air and noise pollution further highlighted on the importance of considering several environmental stressors. Similarly, exposure to excessive (Prasher,

2002) and prolonged noise (Jonsson & Hansson, 1977) is associated with annoyance and reduced quality of life due to environmental noise.

According to the EEA (2013) environmental stressors can be tackled with the proper integration of new technology and policies. Plans, policies and innovative ideas are important for the reduction and prevention of environmental burden. Hence, for that planners and decision makers should have the overview of the situation of actual problem. To create a healthy city it is important that planners, health practitioners, environmentalist, policy makers and other stakeholders work in collaboration. It is important to have a good understanding of the health and environmental condition of the city, for that there should be enough data, and outputs should be simple and understandable to all the stakeholders. Quality information helps to identify and prioritize problems which lead to well informed solutions and decisions making.

Spatial decision support system (SDSS) is a flexible problem solving environment, where stakeholders can first understand the condition then generate and evaluate alternative solutions.

1.2 Research problem

At present there is a large volume of spatial decision support systems (SDSSs) developed to address individual environmental stressors such as air pollution in major cities of the world. Liu et al. (2012) presents some facts explaining that only 3% of decision support tools (DST) deals with 36 environmental stressors, 25% of deals, with only one stressor and 50% deals with only one disease; additionally, most of the tools are non-spatial. This leads to the realization that there is a need of a spatial decision support tool (SDST) covering more environmental stressors and more diseases. Therefore, this research attempts to make a contribution to that apparent void by designing and developing a spatial decision support tool for mapping cumulative environmental exposure. According to Couclelis (1991) the challenge lies in finding out the problem rather than solving it. Hence the main objective of the research is to design and develop the Spatial Decision Support Tool (SDST) for mapping cumulative environmental condition of the area. The tool will help the stakeholders to identify and understand the geographical extent of environmental condition of an area rather than solve the problem.

2 PROCESS of BUILDING SDST$_{CE}$

Figure 1 illustrates the methodology adopted for the development of conceptual design of SDST$_{CE}$.

2.1 Problem definition and identification of end users

The first step leading to the development of SDST was

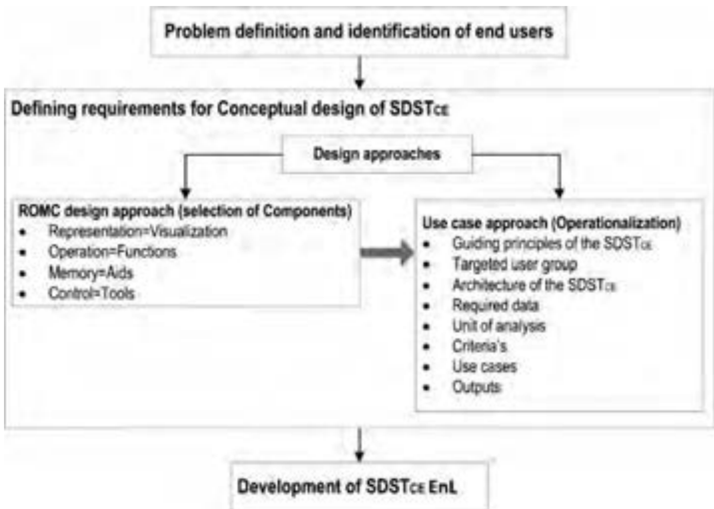

Figure 1: Methodology of developing SDST$_{CE}$ (own source)

recognizing the problem and the benefit of addressing that problem with computerized spatial decision support tool. In addition to the problem recognition, end users of the tool and the contribution that they could make in solving the problem was identified.

2.2 Defining requirements for the conceptual design of $SDST_{CE}$

This is the most important phase in the research. The main objective of conceptual design of $SDST_{CE}$ is to provide all the information required for the development of the prototype. This research uses two approaches for the design of $SDST_{CE}$ namely 1) ROMC design approach and 2) Use case approach. ROMC design approach (Sprague Jr & Carlson, 1982) is the methodology suitable for the design of a specialized decision support system. Use case approach is the methodology used in the system analysis to identify, clarify and organize the systems requirement (Gibilisco, 2013).

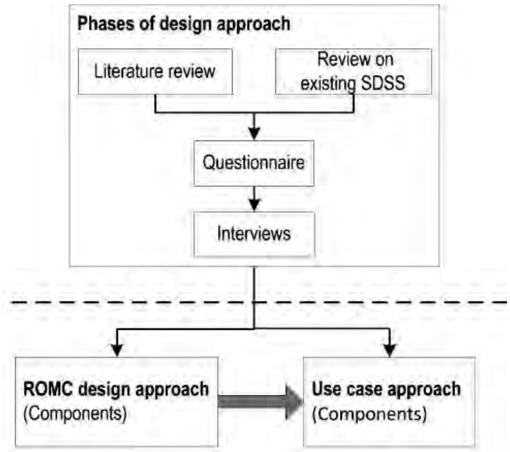

Figure 2: Phases utilized in the design approach (own source)

Both the 'ROMC design approach' and the 'Use case design approach' go through the sequence of phases for defining the requirements. Figure 2 shows the phases adopted by these design approaches.

2.3 Development of the tool

Although this research provides conceptual design of the $SDST_{CE}$; however, it does not develop the overall tool. This research develops a small section of the $SDST_{CE}$ which is termed as '$SDST_{CE}$ EnL'. It addresses the few sub objectives of $SDST_{CE}$.

2.4 Data collection

Basically two types of data are utilized in the research 1) primary data and 2) secondary data. An online questionnaire survey has been used in this research for the primary data collection. Secondary data was collected and provided by JuFo Salus project working for healthy and equal cities. Environment data, administrative data and land use data were provided.

3 CONCEPTUAL DESIGN of $SDST_{CE}$

The main objective of conceptual design of $SDST_{CE}$ is to provide a framework for the development of a prototype which will provide information on cumulative environmental state and exposure. It is used to identify, clarify, and organize systems requirement. It will provide information on the guiding principles of the tool, targeted user group, major components, required inputs and outputs, unit of analysis, assumptions, different functions and its operationalization. It will also provide a possible sequence of interaction between the system and users.

A spatial decision support tool for cumulative environmental exposure ($SDST_{CE}$) aims to understand the geographical extent of multiple environmental stressors in the area.

$SDST_{CE}$ will be used in the first phase of the decision making (intelligent phase) since it is more important to understand the problem rather than find the solution (Couclelis, 1991). $SDST_{CE}$ is a generic tool that will function according to availability of data. It will mostly focus on different functions, methods, visualization techniques and tools in assessing and analyzing the cumulative environmental exposure.

From the literature review, reviews on existing DST and analysis of questionnaire it can be concluded that the Guiding principles for the design of $SDST_{CE}$ should be 1) Easy to use, 2) Easy to understand, 3) Fast, 4) Flexible, 5) Interactive. The probable end users of the $SDST_{CE}$ are urban planners, public health experts, environmentalist, decision makers and non-profit organization.

3.1 Architecture of $SDST_{CE}$

Figure 3 shows the architecture for spatial decision support tool ($SDST_{CE}$) for mapping cumulative environmental health effects. In general $SDST_{CE}$ is a data intensive tool; it requires data on environmental factors, health of the citizens and social, economic and other demographic data of the citizens. Ideally, data required for the mapping of environmental effects of the city depends upon the major environmental problems in the city. This research tries to design a conceptual framework of SDST for a data rich condition which will be addressed as ideal SDST (iSDST). It consists of database management, model management, and dialogue management. ROMC design approach is used for identifying different components of the ideal SDST such as functions, methods, tools, aids and visualization.

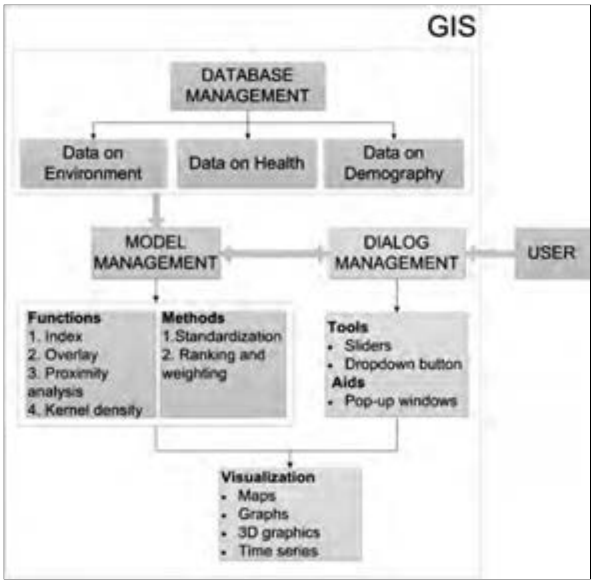

Figure 3: Framework for ideal SDST (iSDST) Adapted from (Sugumaran & Degroote, 2011)

4 DEVELOPMENT of $SDST_{CE}$ ENL

This research develops a small section of the $SDST_{CE}$ as a test wise development to illustrate the operation of an entry level prototype. It is termed as '$SDST_{CE}$ EnL'. It demonstrates the interactive tool that allows easy and fast assessment of functions and produces interactive maps and graphs. Scenario 360 in community Viz is used to create the $SDST_{CE}$ EnL.

4.1 Case study area: The city of Dortmund

The city of Dortmund, Germany is the case study city. It is a one of the largest and most populated German cities with a population of 572,087 (2012). According to Bezirksregierung Arnsberg (2011) many German cities are struggling with air pollution, which is affecting the health of people. Dortmund is also facing the environmental problem specially pollution due to air and noise. According to LANUV (2009) road section exceeding the limit value of NO2 and PM10. The city is also affected by night noise disturbances. Therefore, this research tries to understand the cumulative environmental exposure in the case study city of Dortmund. It also tries to investigate the relation between the environment and socio-economic condition of the area.

4.2Environmental state in Dortmund

Figure 4: Road traffic noise in Dortmund
Source: Jufo Salus, modified by author

Figure 5: Air pollution (NO2) in Dortmund
Source: Jufo Salus, modified by author

This research uses data on noise due to road, rail, industries and air traffic. Figure 4, illustrates the spatial extent of noise due to road. Similarly, Figure 5 shows the spatial extent of NO2. These maps clearly provide information on individual environmental stressors that the city is facing; however, it is important to understand the cumulative environmental state due to the multiple environmental stressors. Therefore, a map was produced to understand the spatial extent of the number of individual environmental stressors in a single map by using the overlay technique in the GIS; however, the process was not successful to show the cumulative environmental state by using the overlap of multiple environmental stressors. It is challenging to find out the hotspots due to multiple environmental stressors. It is even more of a problem if the socio-economic or other data are to be studied in combination to these multiple stressors.

4.3 SDST$_{CE}$EnL interface

Figure 6 shows the screen shot of SDST$_{CE}$ EnL in the Community Viz interface. In the figure, 'A' is the slider bar. It is mainly used to change the weight of the environmental factors used to create the multiple environment deprivation index (MEDIx). 'B' is the map area where the maps can be visualized. 'C' is the table of contain which helps to track different layers available in the tool. The simple overlay technique can be used to visualize and compare different data. In figure 5, map showing the location of migrated population is overlaid on the MEDIx map. This function will provide flexibility to the users in switching on and off the layers as per the requirement. 'D' shows the graphs; it is used to present the result of exposure analysis. The slider bar, the map and the graphs are interconnected and are interactive, meaning that a change in the weightage of the environmental factors in the slider bar will result changes in the map and the graphs.

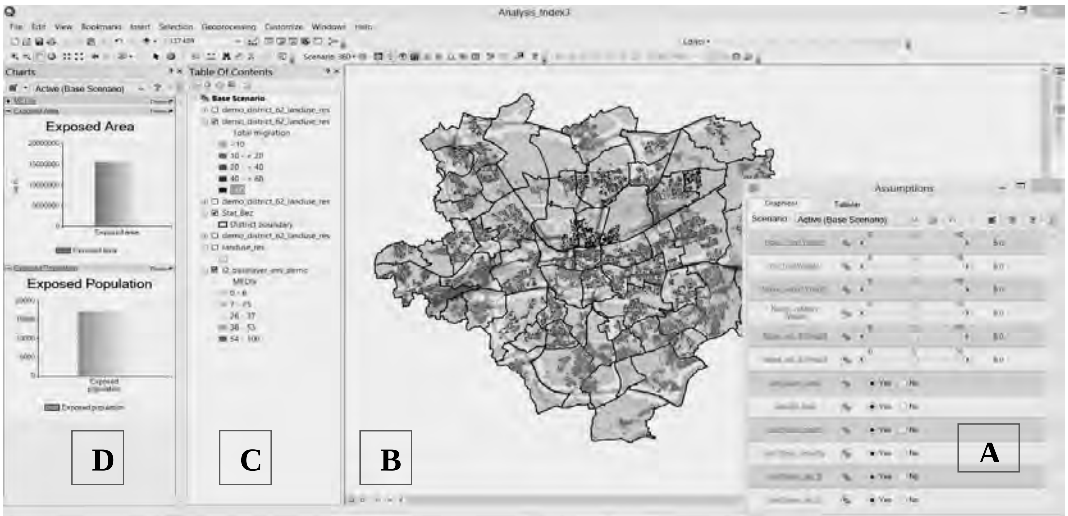

Figure 6: Screen short of $SDST_{CE}$ EnL within community Viz showing the use of overlay technique (overlay of migrated population)

4.4 Results

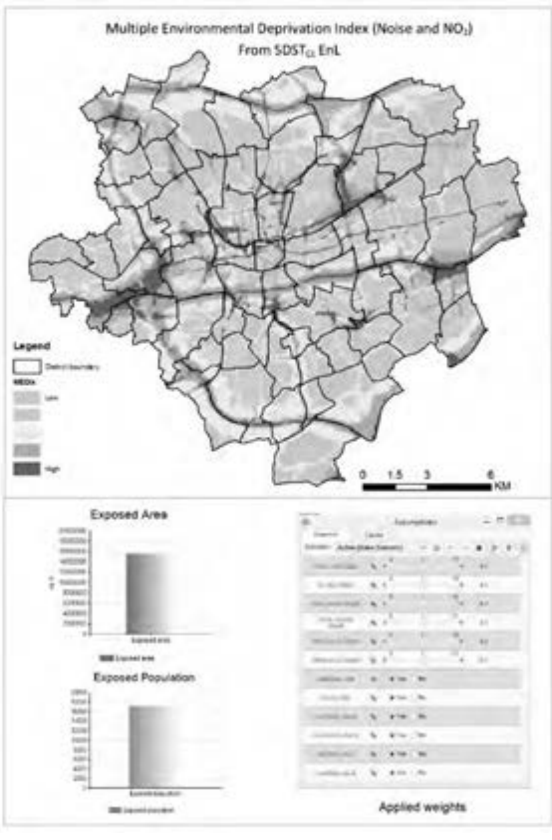

Figure 7: Input and Outputs of $SDST_{CE}$ EnL (equal weight to all the factors)

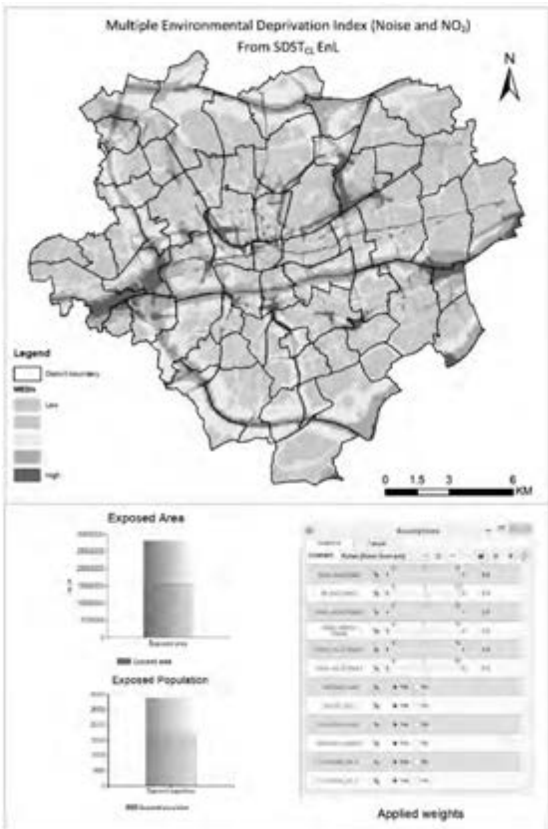

Figure 8: Input and Outputs of $SDST_{CE}$ EnL (high weight to road noise)

Figure 7 shows the map of multiple environmental deprivation. In the figure green color is characterized as an environmentally well off area, whereas red color is characterized as a poor or the environmentally deprived area with high combined environmental stressors. $SDST_{CE}$ EnL creates an index that captures co-exposure of several environmental stressors. Weighting of environmental factors are used in this research; the effect of one environmental stress may be more than the other hence the method of weighing provided in this research is to reflect the experts point of view regarding the significance of pollutants considering risk to human health.

After developing MEDIx, weight was changed several times to recognize the variation in the environmental state and the population exposure in the area. In figure 7 all the factors are provided equal weight (that is 50%); the area exposed in this condition is 15.5 sq.km and 17,170 population is exposed. When weight of one of the factor Noise from road is increased to 80%; the area exposed in this condition is 28.10 sq.km and 28,873 population is exposed. Similarly, when the weight of Air_NO2 was decreased the exposed area and population both was decreased. When salutogenic factors were considered in the index, it was realized that the area and population exposed to the multiple environmental deprivation were increased. From Figure 7 and Figure 8 it can be clearly seen that area along the road and railway together with the area around the airport area are mostly exposed to the multiple environmental stressors. From above results it can be drawn that the decrease in environmental stressors can have a positive impact on the environment of the city.

The population exposed to air and noise pollution was overlaid on the MEDIx map, it was found that that the area along the road and railway together with the area around the airport (central and the western districts of the city)are mostly exposed to the multiple environmental stressors. Similarly, data on migration is overlaid on the MEDIx. Due to the road and railway networks running from the central of the city; central statistical districts are mostly exposed to multiple environmental stressors which is also true in the case of western statistical districts of the city. These districts are struggling with high unemployment, has high number of migrants and the life expectancy is also comparatively low.

5. USE OF $SDST_{CE}$ IN CASE OF KATHMANDU VALLEY

This section of the paper discusses on the probable use of $SDST_{CE}$ in case of Kathmandu Valley.

According to (Ministry of Science, Technology and Environment , 2012) air pollution in Kathmandu Valley exceeds the WHO standard by several times. According to the Ministry of environment in 2005 the ambient air pollution was responsible for the premature death of almost 1600 people per year in Kathmandu valley. A study of world bank 2006-2007 shows that the annual health cost of the country attributed by the urban air pollution is 21 million US dollars.

Kathmandu Valley Development Authority (KVDA) is the planning, developing, monitoring/regulating and coordinating agency. Considering the present situation of population growth and its impact on social, cultural and environmental aspects of the valley; KVDA has developed the 20 year Strategic Development Master Plan (SDMP 2015-2035). The vision of SDMP is “to promote the Kathmandu Valley as a livable city with the interdependence of nature, community and culture." And the mission is to establish the valley as a safe, clean, organized, prosperous and elegant (SCOPE) national capital region.

Therefore, KVDA aims to use $SDST_{CE}$ to understand the environmental exposer due to the development projects such as Kathmandu urban transport master plan, outer ring road development, improvement of strategic road network and analyze the positive impacts of open space and water bodies. It also aims to use the tool to understand the spatial-temporal extent of multiple environmental exposure and investigate the relation between environmental condition and social, economic and health aspects of the valley. Hence, it supports decision makers in selecting environment friendly; safer alternatives.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The main objective of the study was to design the Spatial Decision Support Tools ($SDST_{CE}$) for understanding the cumulative environmental condition of the area. The conceptual design of $SDST_{CE}$ was partly realized through $SDST_{CE}$ EnL. Although $SDST_{CE}$ EnL is an entry level prototype it clearly illustrated how the cumulative environmental exposure due to multiple environmental stressors could be assessed and visualized. Furthermore, it clearly demonstrated the interactive tool. The functions such as overlay technique demonstrated the comparison of different data which could be of great importance to different professionals and decision makers in planning better and healthier cites. This tool can also be used to understand the relation between environmental and the social economical condition of people.

It is a generic tool; therefore, can be utilized in understanding the multiple environmental exposure of any city or spatial region; however, it's output highly depends upon the availability of data. Additionally, it can also be utilized to understand the multiple environmental exposure due to the future development projects and help the decision makers to selection an environmentally friendly projects.

6.2 Recommendations

Due to the lack of temporal data, only spatial dimension of cumulative environmental exposure was considered in $SDST_{CE}$ EnL. Furthermore, due to the lack of health data, health effects were not considered in $SDST_{CE}$ EnL. With these limitations in the research some recommendations are presented for further research directions.

This research focuses on the intelligent phase; the future research could be done on design and choice phase. Along with air, noise, green spaces and water bodies, facilities such as industries and heat island effects could be considered in studying multiple environmental deprivation to provide a larger picture on the environmental condition of the area. Although the relation between cumulative environmental exposure and socio-economic condition was checked in the case of Dortmund through overlay and visual analysis, correlation cannot be proved by using this tool. Although the tool helps the experts to draw the hypothesis, the causality between environment and health cannot be explained. Introducing the statistical analysis in the tool could be the future direction for more concrete results.

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Distribution characteristics of vacant houses usable in future Nankai earthquake disaster in Wakayama Prefecture

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ABSTRACT

The Great East-Japan Earthquake in 2011 brought an opportunity to make the extensive use of houses for rent in the context of public temporary housing due to the lack of site and manpower for the construction of new temporary houses. Active use of existing housing stocks can provide the people with much better living environment more rapidly than the conventional way. Moreover, it can be anticipated that the probability of using vacant houses may be increased in accordance with the decrease in population and the increase in vacant houses, which are nationally taken place. Therefore, it is worth assessing distribution characteristics of vacant houses which can be used as temporary shelters during the expected earthquake disaster. This paper aims to estimate the number of vacant houses which can be used after the expected Nankai earthquake happens in Wakayama Prefecture. In this study, the number of vacant houses usable in future Nankai earthquake disaster, including both on the market and not for rent, and that of victims who may lose their houses are estimated. Then, areas will be identified where it is worth establishing the system by which houses can be used for victims at emergency case.

Keywords: temporary housing, recovery, depopulation, Nankai earthquake, vacant house

1. INTRODUCTION

When massive-scale disaster happens, Japanese Government is to furnish prefabricated houses as temporary shelters for the victims who lost their houses. The Great East-Japan Earthquake in 2011, however, brought an opportunity to make the extensive use of existing houses for rent in the context of public temporary housing due to the lack of site and manpower for the construction of new temporary houses. More than 130 thousands houses were provided as temporary shelters, and 68 thousands, more than half of them, were provided by using rented houses available for victims.

Active use of existing housing stocks by public can provide the people with much better living environment more rapidly than the conventional way, but there are less number of privately rented houses in the rural area than in the city area. It can be anticipated, however, that the probability of using vacant houses may be increased in accordance with the decrease in population and the increase in vacant houses, which are taken place especially in the countryside. Making use of such vacant houses may enable to provide temporary shelters by existing housing stocks not only in the city area but also in the rural area. Therefore, it is worth assessing distribution characteristics of vacant houses usable in future mega disaster such as expected Nankai earthquake, which may cause more than 320 thousands of fatalities and 2.3 millions of totally collapsed buildings in some worst case, much more serious than the Great East-Japan earthquake.

This paper aims to estimate the number of vacant houses which can be used after the expected Nankai earthquake happens in Wakayama Prefecture, whose location is shown in Figure 1, which faces the problem of rapid and significant depopulation and has high risk of Nankai earthquake and its induced tsunami. Wakayama Prefecture has relatively less number of vacant houses in the market but more number of those not for rent among the prefectures where Nankai earthquake will cause damage as shown in Figure 2. Therefore Wakayama Prefecture can be thought appropriate as target area to take consideration into using vacant houses even not for rent.

This study evaluates the demand and supply of private vacant houses as temporary shelters in Wakayama Prefecture, whether or not they are in the market, by using the statistical data of vacant houses and the expected data of ground motion caused by future Nankai earthquake. Then, this study considers conditions of area where it may be effective to establish the system by which vacant houses even not in the market can be used for victims at emergency case.

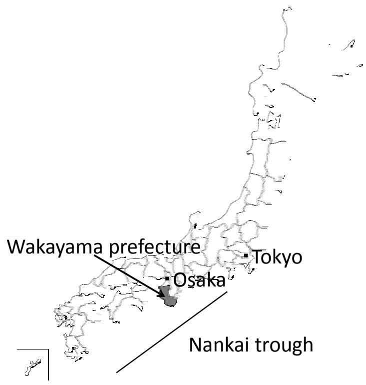

Figure 1: Location of Wakayama prefecture and Nankai trough

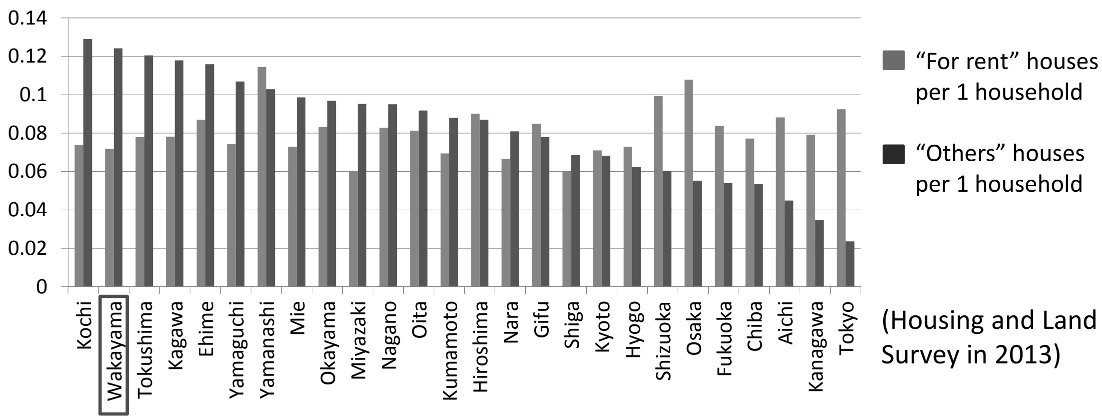

Figure 2: Ratios of vacant houses to households in the expected disaster regions by the future Nankai earthquake

2. ESTIMATION METHODOLOGY

2.1 Definition of demand and supply of vacant houses

Vacant houses are classified into four categories according to Housing and Land Survey done by Statistics Bureau of Japan: second dwellings, for rent, for sale, and others. “Others” dwellings are described as follows: those not inhabited for a long time due to transference or hospitalization, or those to be destroyed for the purpose of rebuilding. In this paper, all of “for rent” and “others” are assumed available as temporary shelters for victims although some “others” dwellings may be impossible to use because of deterioration or lack of maintenance.
The number of usable vacant houses, the supply of private vacant houses, is defined as the houses not totally collapsed; partially collapsed houses are regarded usable by repairing them. The demand is defined as the number of households whose houses are totally collapsed following past researches.

2.2 Vacant houses classified by building characteristics

In order to estimate the damage to vacant houses in Wakayama Prefecture caused by earthquake, it is necessary to classify the number of vacant houses by structure type and age. Total number of vacant houses and households in Wakayama Prefecture can be obtained from Housing and Land Survey result in 2013. The survey result, however, does not contain the data of vacant houses in the municipalities whose population is less than 15 thousands. Moreover, there is no statistics of vacant houses classified by building characteristics while there is that of resident households. Therefore, the number of vacant houses classified by building characteristics for each municipality has to be assessed in some way.
Firstly, the total number of vacant houses in the municipalities with population less than 15 thousands was calculated by subtracting the total number of these in the municipalities with more than 15 thousands of population from the total vacant houses in the whole Wakayama Prefecture. Then, the number of vacant houses in each municipality was assessed in accordance with the population.
Secondly, the total number of vacant houses was classified into four groups by structure type (wood or non-wood) and age (old (built before 1981) or new) based on two cases of assumption, the best case and worst case, since it was impossible to make precise classification of vacant houses. In the worst case, the number of collapsed houses would be the biggest, all vacant houses were regarded as old and timber, which has the highest vulnerability against earthquake. In the best case, the same proportion of building characteristics of resident dwellings was applied to vacant houses, based on the assumption that the probability of total collapse of vacant houses would not exceed those of resident dwellings. With respect to the municipalities with the population of less than 15 thousands, however, because the data of vacant houses classified by building characteristic was not available, all vacant houses were regarded as new and non-wood made, which has the lowest vulnerability against earthquake.

2.3 Damage estimation of vacant houses and households

Combining the estimation result with the hazard data of expected Nankai earthquake, it can be evaluated how many households will lose their houses and how many vacant houses will be usable for victims in Wakayama Prefecture. First, PGV (peak ground velocity) in each location was referred from the massive earthquake model which would cause the biggest damage in Wakayama Prefecture among the ones made by Japanese Cabinet Office. Then, the ratios of total collapse of four each building type were derived from PGV by applying fragility function made by Midorikawa (2011). By multiplying the ratio of total collapse with the number of houses for each building type and summing them up, it was calculated in both the best case and the worst case that how many households and vacant houses would be totally collapsed by earthquake. Total collapse ratios due to tsunami and fire were referred from the result of damage estimation conducted by Wakayama Prefectural government. Then, total numbers of collapsed vacant houses and households were calculated and thus the demand and supply of vacant house could be assessed.

3. RESULTS OF ESTIMATION

Figure 3 shows the number of total households according to the national census in 2010. Wakayama City, located on northwest side of the prefecture and adjoined to Osaka, is the biggest city in Wakayama Prefecture and has 183,754 households as of 2010. Figure 4 shows how many percentages of households would lose their houses in both the best case and the worst case due to future Nankai earthquake disaster. It can be said that south and southwest areas would suffer relatively serious damage although there is some difference between two ways of estimation in the municipalities with less than 15 thousands of population. It was estimated that 117 to 125 thousand households would lose their houses totally in the prefecture.

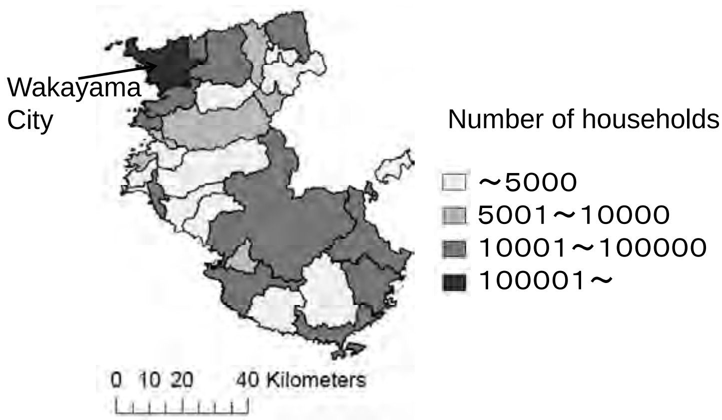

Figure 3: The number of total households in 2010

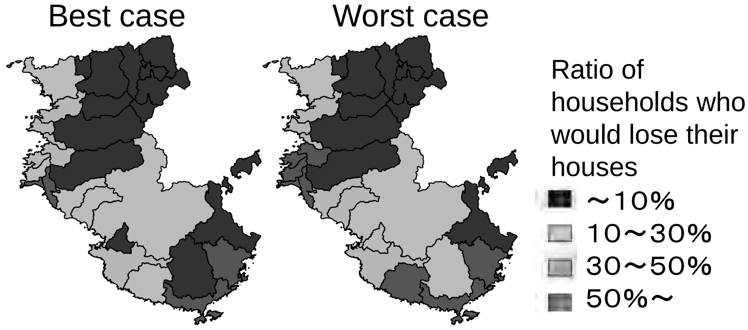

Figure 4: Ratios of households who would lose their houses to total households

Figure 5 and 6 show distribution characteristics of vacant houses usable for victims whether or not the house is in the market for rent. While at the north part, more than one thousand vacant houses for rent would be usable, less than one hundred ones would be available in some rural municipalities at the south or southwest part and facing the Pacific Ocean. With respect to the “others” vacant houses not in the market for rent, however, hundreds of houses might be remaining even in the area which would have few vacant houses for rent. It was estimated that 18 to 21 thousand of “for rent” vacant dwellings and 32 to 36 thousand of “others” dwellings would be remaining through the future Nankai earthquake disaster and have potential to use them for victims. It can be said based on the estimation that it would be difficult in the municipalities with relatively small population to rapidly provide victims with comfortable living place unless existing vacant houses would be actively used. Making use of them might have the function to mitigate the effect of population decreasing in such municipalities.

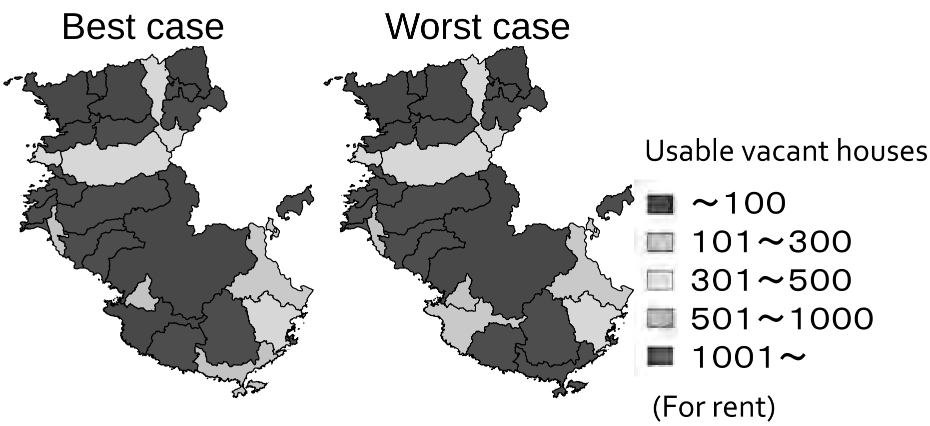

Figure 5: Number of vacant houses usable in future Nankai earthquake (for rent)

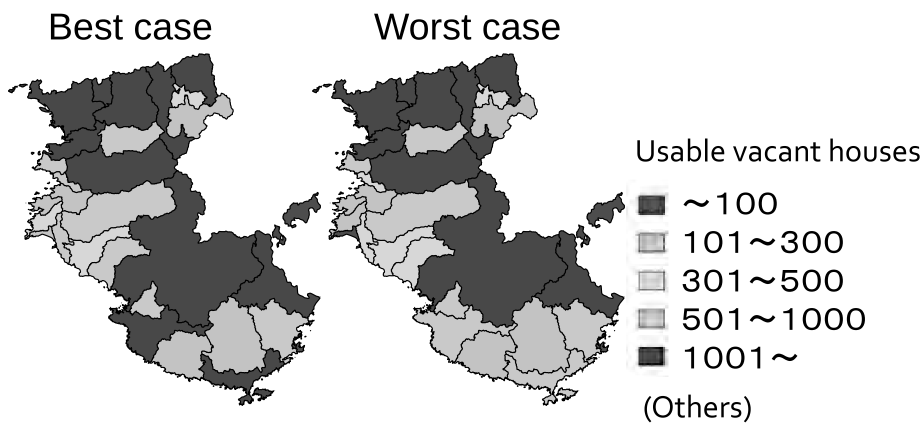

Figure 6: Number of vacant houses usable in future Nankai earthquake (others)

Figure 7 and 8 compare demand with supply of vacant houses in the case of taking consideration into only the houses for rent and also not for rent. It was found from the estimation that in the municipalities at the north part not facing the Pacific Ocean the demand would exceed the supply and thus have the potential to accept the victims from other adjacent municipalities. It would be effective for such cities to establish the system by which existing vacant houses can be used for victims at emergency case, which would make it possible to keep more victims in Wakayama Prefecture than conventional way of temporary housing. In many cities facing the sea, on the other hand, the number of usable vacant houses would be less than that of households who would lose their houses by more than one thousand. It would be important to make active use of existing housing stocks especially at the south or southwest part, which is far from inland cities or other prefectures, although it would be impossible to meet the demand even if vacant houses not in the market could be used.

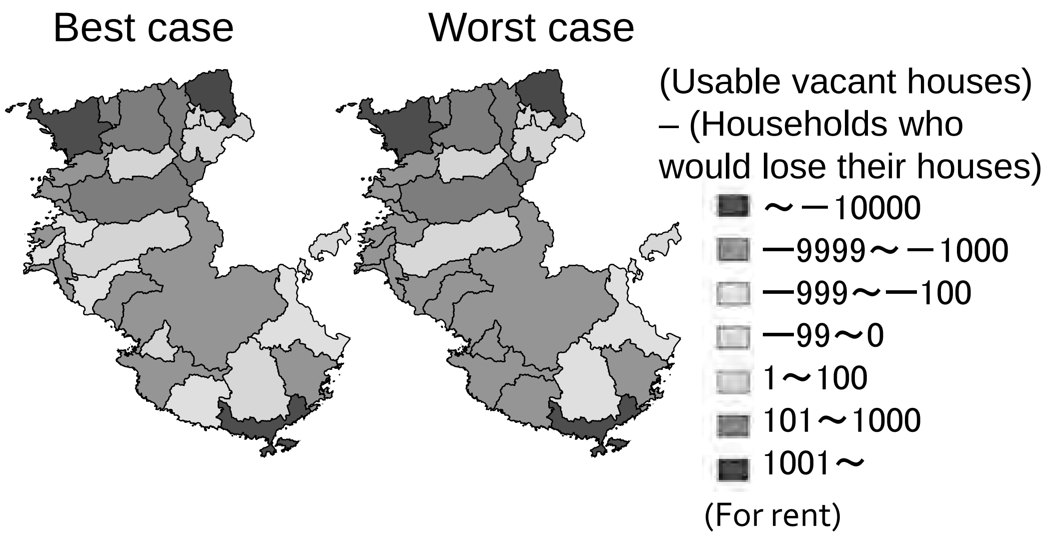

Figure 7: Demand and supply of vacant houses (for rent)

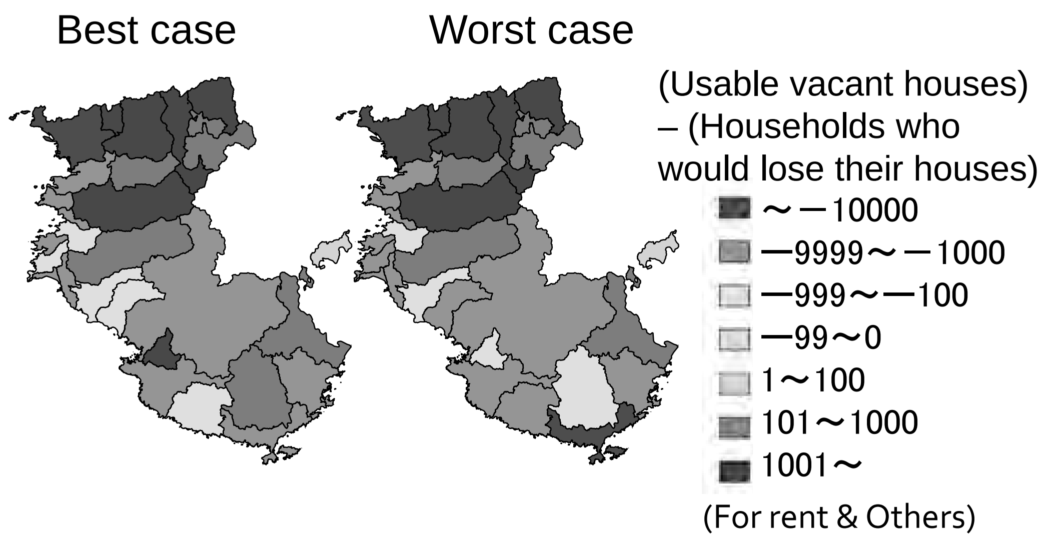

Figure 8: Demand and supply of vacant houses (for rent and others)

4. CONCLUSIONS

This paper analyzed distribution characteristics of vacant houses usable in future Nankai earthquake disaster in Wakayama Prefecture as a basic study for the consideration of establishing the system by which existing vacant houses can be used for victims at emergency case. It was found that on the south or southwest sides many households would lose their houses and there would be small number of vacant houses for rent but large number of vacant houses out of the rental market, while on the north side, the supply of vacant houses would exceed the demand. Especially in such area, it would be effective to make active use of existing vacant houses for victims. In order to realize it, it will be necessary to design the administrative procedure which would enable to use even the houses not for rent. Moreover, it will be important to think in detail whether such houses will be really usable in terms of building strength, living environment, or consensus making with the owners of vacant houses.

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Land use planning as an Effective Tool for Disaster Management in Nepal

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ABSTRACT

The effective land use management relies on two major aspects of planning i.e. Compliance with the citizens and control by the implementing authority, the balance between the two components signify the effectiveness of the planning process. The land use management is the critical component of disaster preparedness as well as response and recovery, especially in a dense and unplanned urban regions of Nepal. The study analyses the prospects of risk sensitive land use planning for disaster risk management in Nepal and compares the case studies of best practices in South East Asian context along with experiences of risk sensitive land use planning of Kathmandu Valley with respect to governance, existing policy and capacity. Also the study highlights the key interventions required for effective implementation of risk sensitive land use planning. The study incorporates the policy review, perspectives of key actors in disaster management in Nepal, paradigm shift caused by the earthquake of 2015 April, awareness at the community level and the condition of prerequisites for the land use planning based disaster risk management in Nepal.

Keywords: disaster management, governance, risk sensitive land use planning, policy, Kathmandu Valley

Development of evacuation facility management system "COCOA" for effective evacuation facility operations by sharing information among stakeholders

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ABSTRACT

Key point to operate evacuation facilities effectively is to manage the information sharing among disaster headquarters and sites of evacuation facilities or among families who need to know the life safety or location of evacuees. But, it was difficult to obtain and share the information in the 2011 Great East Japan Earthquake disaster. For examples, to create a refugee roster was difficult under the condition of a concentration of a lot of evacuees. And, a lot of inefficient operations to share the information such as the total number of evacuees in each facilities and those personal information, the needs and demands of refugees, etc. were seen in damaged areas.
It is necessary to achieve effective and smooth operations of the evacuation facilities by sharing the information environments among stakeholders.
In this study, we have developed the IT evacuation facility system "COCOA" that can manage and support in accordance with conditions of each evacuation facilities by sharing the information such as the needs and demands, the number of evacuees and those personal information. "COCOA" can serve and collect the various personal conditions and manage the information of all evacuation facilities.
The personal identity number service (PIN service) will start in Japan. "COCOA" can be used in many cases (during staying the evacuation facility, moving to the temporary house, condition of received administrative services, etc.) by applying PIN service. For the next huge disaster, "COCOA" can provide the environments for sharing the information among the evacuation facilities and support appropriate decision-making for stakeholders.

Keywords: information sharing, evacuation facility, refugee, development of IT system, personal identity number

1. INTRODUCTION

Local government in Japan is in charge of managing evacuation facilities during the disaster. It is necessary to share information of conditions of evacuation facilities and of refugees between the headquarters and the sites for effective disaster managements. Actually, unbalance of foods or living wares supplies and the staff assignments in evacuation facilities appear due to without information sharing among stakeholders during the 2011 Great East Japan Earthquake disaster.

The reasons are those of no preparation for information sharing strategy by the disaster drill in pre disaster phase and of no information sharing tools between the headquarters and the evacuation sites.
Normally, staffs to be assigned to manage an evacuation facility use a notebook to share the information including an evacuee roster. Therefore, it is difficult to share the information among stakeholders such as the headquarters and the sites during emergency phase. After a disaster, the review is also important to improve the management of evacuation facilities. However, it is not easy to analyze the lessons learnt from current disaster due to the huge documents of disaster response records. And also, the staffs who worked for a disaster response returns to normal tasks. Therefore, the updating a disaster manual following to the past lessons is difficult.
In the points of information sharing, COCOA is developed to share the information among stakeholders such as a disaster headquarter office and the sites of evacuation facilities in this research. COCOA can manage and support in accordance with conditions of each evacuation facilities by sharing the information such as the needs and demands, the number of evacuees and those personal information. COCOA can serve and collect the various personal conditions and manage the information of all evacuation facilities.

2. IT SYSTEM TO MANAGE AN EVACUATION FACILITY

2.1 Current IT system

Some evacuation facility management tools have been already developed (Table 1). Information Technology can play an important role to manage the information related to the evacuation facility operations.
The requirements for the IT system of disaster management is to be used and prepared before the disaster, and be used in the daily activities. It means to be used in the management of evacuation facility to check the instruments, capacity and tools settings.
Table 1 shows some existing systems as for the evacuation facility system. ORANGE is developed after the 2011 Tohoku disaster by Ishinomaki city in Miyagi prefecture. Victim support system is developed after the 1995 Great Hanshin Earthquake disaster by Nishinomiya city.

Table 1: Existing IT systems

Name	Content
ORANGE (Ishinomaki City) [1]	Safety confirmation system at the time of the disaster.
Victim support system (Nishinomiya City) [2]	System for local governments developed after the 1995 Great Hanshin Earthquake disaster.
IT support system (ISE Ltd.) [3]	System that manage the doctor assignment of the evacuation facility and the doctor who are in the distant place take the communication using video call application.
Amazon (Amazon)	The site which investigates and delivers refuge's requisite material at the time of

	the disaster.
Disaster needing people refuge support system (MJC Inc.) [4]	Support system that needs of people evacuate smoothly and safely at the time of disaster.
Refuge guides of the whole country (first media Inc.) [5]	Navigation application for disaster that we search the refuge around the present location, and a route guides the route

2.2 Necessary function for IT system to manage evacuation facilities

The important point is that most problems regarding to information sharing in evacuation facility operation are improved by using IT system. The problems can be categorized in three points of big elements. Namely, three problems are (1) People, (2) Supply and (3) Document.

(1) People

The problem about people is that grasping the locations of various people (manager or evacuees) is difficult at the time of the disaster. Using IT system like ORANGE can grasp the information about people, but it is not easy. Because, information can be exchanged through a data base, not paper. Information sharing about people can become smooth.

(2) Supply

The problem about supplies is managing an evacuation facility in the state. There are no any information on supplies and equipment. Using system like Amazon was available to deliver supplies to each evacuation facility.

(3) Documents

The problem about documents is that it is difficult to extract only necessary information, to share and to keep information as long as be managed by paper. Using IT system for the information on the enormous amount about the evacuation facility can manage by lumping.

IT system can contribute to perform evacuation facility management with decreasing the workload of assigned staffs in an evacuation facility. The necessary elements for IT system are three elements (1) People, (2) Supply and (3) Document in evacuation facility management stated above.

And, it can be made by effective and average supply by performing the management of people and the management of supplies with a system. Furthermore, the knowledge of past disaster is used for responding disaster or disaster drill. Therefore, the system can reduce the workload of staffs and provide the past knowledge for managing the evacuation facility. As the results, the environment for the life of refugee can be improved.
Those three elements are needed to develop the IT system for managing the evacuation places. But, there are a few IT systems installed with the three elements. And, the systems have not ever been used for a real disaster. Therefore, COCOA is developed to consider all of these elements (people, supply and document).

3. Evacuation facility management system "COCOA"

COCOA is named from a cocoa of a drink. Drinking cocoa give the effect of the relaxation, prevention of cavity and cold prevention, poor circulation. COCOA want to become the system which can provide better space of an evacuation facility with comfort environment. COCOA has been developed by authors from the beginning on the PHP (Hypertext Preprocessor) basis. It can make the evacuation facility administration manual to which past lessons learnt is applied.

3.1 Function of “COCOA”

Function of COCOA consider to three elements for evacuation facility management. Three requirements are following people, supply and documents.

(1) People

- COCOA can manage evacuees’ personal information by Individual Number. Therefore, it's possible to know the location of evacuees in where evacuee is staying
- It can be added the person who doesn't get on a resident ledger (foreigners, a new-born infant and so on.).
- It can indicate the number of evacuation facility and the number of evacuees by a chart and indicate the number of evacuees on the map.
- The number of evacuation facility and the number of evacuees are recorded by time series, and it can be indicated.
- It can share evacuees’ requests and questions to a manager of an evacuation facility.
- It can do the family's safety confirmation.
- It's possible to record a request of duties of each staff and make a shift using that.

(2) Supply

- COCOA can manage a use of storage supplies.
- It can manage the kind and the number of storage supplies.
- It can grasp more and less of supplies according to the situation.
- It can manage equipment.
- It can indicate the location of the equipment in an evacuation facility on the map.
- It can make a layout in an evacuation facility

(3) Document

- COCOA can be recorded and shared a daily report.
- It can see the case in the past in evacuation facility operation. And, it can make a manual based on that case and manage it.
- It can see questions and answers to psychology of evacuees.
- It can issue and management of all kinds' certificate about a disaster.

3.2 System structure of "COCOA"

Figure1 shows an illustration of information flow of "COCOA. Refugee and Evacuation facility are connected by Database. Table 2 shows the users of "COCOA".
Figure2 shows the system constitution of COCOA. The language for coding COCOA is used by PHP (Hypertext Preprocessor) for this development. Data tables of MySQL are structured.
The main parts of the government and the nation are defined as users. The ID number of evacuee is used to manage the location of each evacuee. Tables are prepared for People, Things (Supply) and Documents to store information.

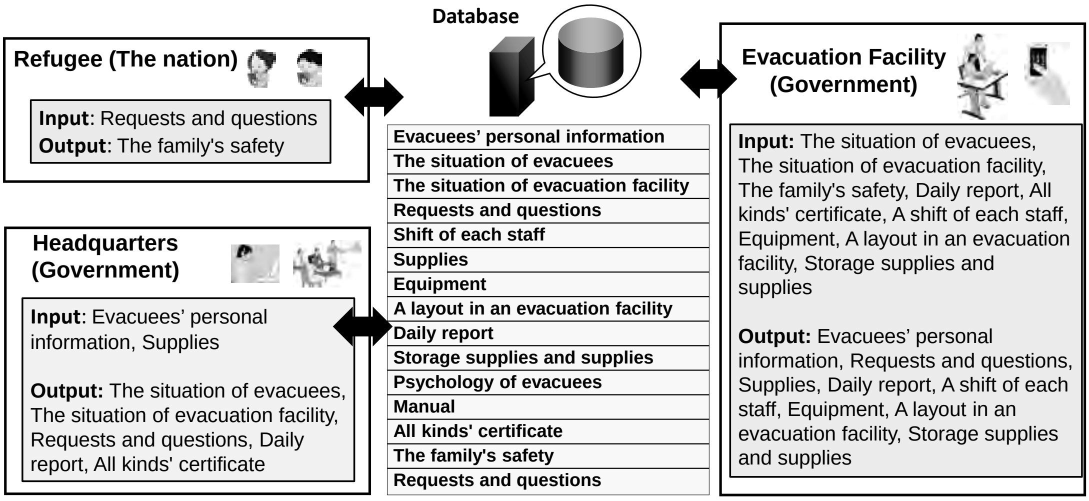

Figure 1: Information flow of "COCOA"

Table 2: Users of "COCOA"

User	Information	Phase of use
The headquarter (Official servants)	Evacuees' personal information	Search of the evacuees
	The situation of evacuees	Manage to evacuees
	The situation of evacuation facility	Manage to facility
	Evacuees' requests and questions	Reflection of the opinion
	A shift of each staff	placement of the staff
	Supplies	Manage to supplies
	Equipment	Grasp of facilities
	A layout in an evacuation facility	Placement of the evacuees
	Daily report	Succession of duties
Manager of an evacuation facility	Evacuees' personal information	Search of the evacuees
	The situation of evacuees	Manage to evacuees
	Evacuees' requests and questions	Reflection of the opinion
	A shift of each staff	Placement of the staff
	Storage supplies and supplies	Manage to supplies
	Equipment	Grasp of facilities
	A layout in an evacuation facility	Placement of the evacuees
	Daily report	Succession of duties
	Psychology of evacuees	Mind care of the evacuees
	Manual	Grasp of doing anything

	All kinds' certificate	Administrative procedure
Evacuees (The nation)	The family's safety	Safety confirmation
	Requests and questions	Reflection of the opinion

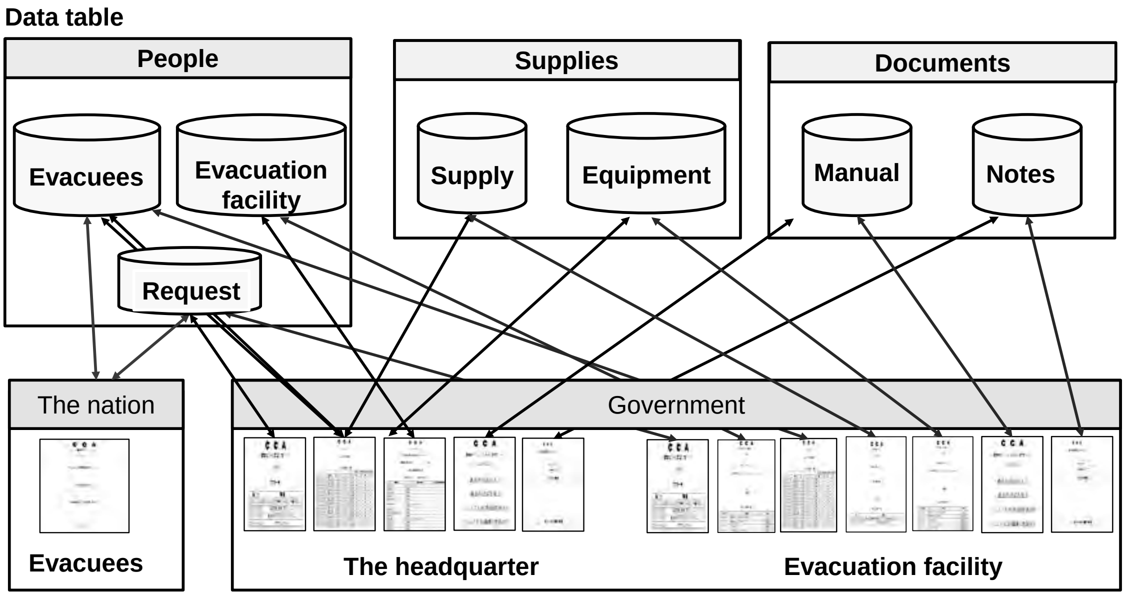

Figure 2: System constitution of "COCOA"

3.3 Verification of "COCOA"

Figure 3 shows the number of the refugees and input time simulation. This simulation shows the comparing the required time to make the evacuee list. This is to be compared that to input the information by PC or smartphone ("COCOA") and writing the information by hand for same number of refugee. The result shows the half of time for using PC or smartphone against to by hand writing. Therefore, COCOA can reduce the workload of assinged staffs in evacuation sites to make the refugee roster.

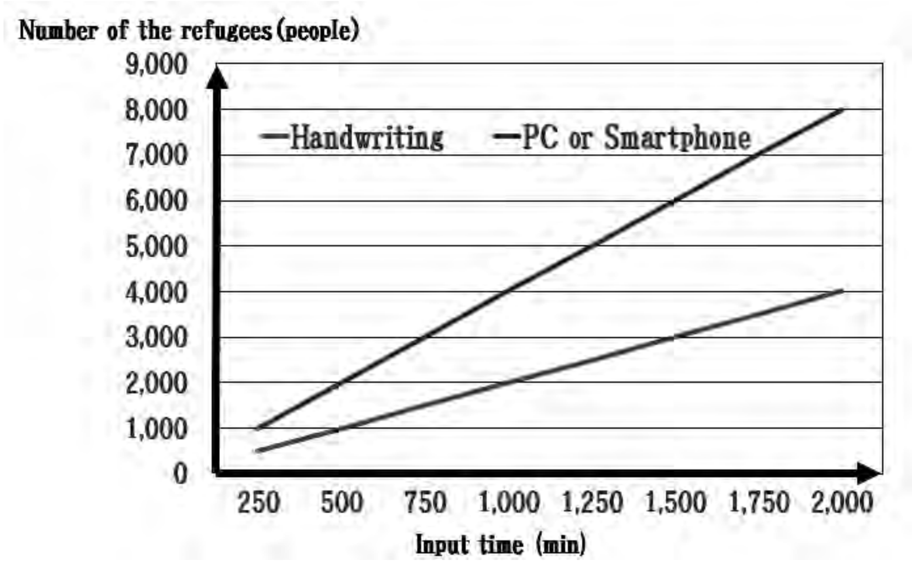

Figure 3: The number of the refugees and input time

Followings describe the advantage of COCOA in the points of the government and the evacuee.

Government

- It is available to reduce the workload to make a evacuee list.
- It can share the conditions at the time of the disaster and can verify the responses after a disaster.
- It can make the manual including the lessons lerant by past disasters and update it.
- It can share the information of the responses at the time of the disaster smoothly.

Evacuee

- Waiting time of the refugee registration can be shortened.
- Comments such as request or assisstance of physical problems can be shared with governments.
- Latest information for the evacuee to apply the public services can be accessed.

4. CONCLUSION

It is necessary to achieve smooth information sharing at the time of the disaster. But information obtaining and sharing was difficult during the past disasters. And the lessons learnt from the past disasters are also difficult to update or apply to next disaster by a system. Even Japan have experienced for many kinds of disasters, the experiences cannot be applied to other places.

This research focuses on the information sharing among evacuation facilities and the headquarters. Developed system “COCOA” in this research includes the information sharing and knowledge from past disasters. Then the assigned staffs for evacuation facilities can work for effective responses according the past knowledge and real-time information sharing.

COCOA can manage the schedule of assigned staffs and calculate optimum assignment schedule. To manage the evacuation facilities for large scale disaster, only the number of local government staffs is not enough to work in all evacuation facilities. The volunteer is necessary by optimum assignment and manage the schedule. COCOA can also manage the volunteer staffs not only government staffs.

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Urban Safety:
Role of law enforcement for better urban management in Kathmandu Valley

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ABSTRACT

Urbanization in developing countries is a defining feature of the 21st century. Between 2000 and 2030, the entire built-up urban area in developing countries is projected to triple. Urbanization has enabled economic growth and innovation but it has also contributed to environmental and socioeconomic challenges. Kathmandu Valley has been experiencing a fast but haphazard urbanization. As urban populations grow, the risk rises for the most vulnerable ones on city streets. A safe city not only saves lives, it can boost the quality of lives, demonstrating a close connection between safety and prosperity.

After establishment of KVDA, execution of plan with enforcement of law has been geared up. This study has focused on mapping the existing laws related to urban development, analysis of implications, overlaps and gaps in between and among them and recommends appropriate policy (re)formulation especially for the Valley. The study has revealed that promulgating laws and its enforcement are different but equally important to shift planning into practice. Smart cities that are connected and compact are generally safer than cities that are spread out over a large area.

So often, inadequate laws or legal environment are blamed as constraint for not being able to achieve a safe, secure and livable urban settlement. In case of Nepal, particularly Kathmandu Valley, inadequacy or over abundance of law is not the key problem. Instead it is unwillingness and/ or inability of concerned city planners, managers, development controllers to understand and use them properly. Furthermore, the study has identified that the lack of coordinated action in line with existing laws and contemporary orders from Supreme Court in-favor of implementation of city planning with safety, liberty and property are the common issues to be dealt with as it is indicated in the long term plan of the KVDA.

Keywords: urban planning, challenges, sustainable development, safety, law enforcement, Kathmandu Valley

1. INTRODUCTION

As the world is undergoing the largest wave of urban growth in history, urbanization in developing countries is a defining feature of the 21st century. More than half of the world's population now lives in towns and cities, and by 2030 this number will swell to about 5 billion. Much of this urbanization will unfold in Asia, bringing huge social, economic and environmental transformations. Nowhere is the rise of inequality clearer than in urban areas, where wealthy communities coexist alongside, and separate from, slums and informal settlements (UNFPA, 2015). Urban population refers to people living in urban areas as defined by national statistical offices. Urban population in Nepal was last measured at 4,913,312 in 2013, with an annual growth at 3.11 percent (World Bank, 2015). In the same year, the urban population in Nepal was at 17.68 percent of total population. Kathmandu's urban cosmopolitan character has made it the most populous city in Nepal with an annual growth rate of 6.12% with respect to the population figure of 2001 (CBS 2011).

In Kathmandu Valley, population growth has reached six percent, with nine to twelve percent new construction in the urban area yearly. Rapid urban growth can be easily seen in farmland, land plots, river banks and cultural heritage sites. As a result of poor law enforcement, the number of houses is increasing and the infrastructural facilities in the valley are in a pathetic state (Kharel, 2006). On the other hand, a huge number of people are migrating to the Kathmandu valley resulting in more than 30,000 slum dwellers living on the banks of the Bagmati, Bishnumati River and other tributaries. The open area in the Kathmandu valley has fallen from 63 percent to 41 percent within the last 20 years. Thus, this growing population and increasing traffic congestion are forcing the government to think seriously about urbanization (KVDA, 2015). Nepal is also notoriously prone to earthquakes. In the latest April 25th earthquake, after the one of 1934, Nepal lost thousands of lives and millions of property. Thus, Kathmandu Valley needs a smart look in the past efforts of planning, implantations and state of law enforcement, so that new plans can be formulated in accordance to the need of urban future of the valley.

1.1. Research Problem

The general impression of the public and outside agencies over the performance of planning and executing bodies is not good. Several laws, acts, policies, plans and programs were developed but never resulted in affirmative results. Even today, despite the large scale deteriorated conditons of urban living in the valley, the plans have not been implemented properly and evidence based research on the causes are also lacking. Therefore, Nepal’s urban governance system has been blamed for poor management with weak law enforcement. Thus, there is a need to analyze the existing legal and policy documents, state of enforcement of laws, overlaps and gaps in between and among them, so that, further steps can be taken to develop and execute urban plan effectively to make the valley livable. In response to this statement, this article is a result of a study conducted recently that intended to analyze the existing laws and their enforcement in relation to the execution of plan made in the past and recommend the solutions for improvements.

1.2. Objectives

The objectives of the study were to:

- Map out the existing urban planning and management related laws, acts, policies and guidelines and their level of enforcement,
- Analyse the implications, gaps in between and among them and recommend solutions to ensure enforcement of existing laws or appropriate policy (re)formulation especially for the Kathmandu Valley.

2. DISCUSSIONS AND FINDINGS

This chapter explores and analyzes the urban development trend, legal and administrative mechanism, role of existing laws in urban development, problems occurred due to delay in implementation of KVDA Act. The institutions for coordinated development, planning efforts, role of Ministry of Urban Development and KVDA in the changed urban context and existing laws that attract to KVDA's functions were also reviewed.

2.1. Historical Urban Development in the Valley

Kathmandu valley is the largest urban agglomeration and a capital city with highest population density that homes about a twelfth of Nepal's population (KMC, 2015). The valley is a part of the middle mountain physiographic region that lies in the Bagmati river watershed and covers area of about 677.58 sqkm and comprises of 3 historic cities, Kathmandu, Lalitpur and Bhaktapur along with other small municipalities and settlements. The valley is rich with many cultural and religious heritages, including the 7 World Heritage Sites (UNESCO, 2009). The historical evidence shows that the structural urban development began during the Lichhavi rule by establishing small towns in the Valley but the great change was marked after the unification of Nepal made by the King Prithvi N Shah in 1825 BS. The valley was the main Indo-Tibet trade route, hence it contributed in developing the infrastructures to serve the traders but the perpetual political ups and downs slowed down the smooth development of towns in the valley (KVDA, 2015). Later, when Junga Bahadur Rana started his regime, the first modern urban infrastructures - buildings, road, pond, park, open space, sport ground, market and electricity, water and sewerage system were initiated.

Being a primary gateway for administrative, industrial, socio-cultural and economic activities, it is one of the most densely populated and fastest growing urban areas in Asia (KVDA, 2015). The population of the valley is 2.5 million (excluding floating population); growing at the rate of 4.3 percent per year has brought a drastic change in land use. With this growth rate, the population is estimated to reach 3.99m in 2020 and 6.70m in 2030 (CBS, 2011). Hence, sustainable urban development should be a strategy to balance socio-economic and environmental needs of today and the future. Looking at the history of urban planning, the organized physical development of city centers had begun with 1st 5-year plan (2013-2018).

The momentum of urban expansion was further upheld after the restoration of democracy in 2047 BS promulgating new laws for local governance bodies with specific roles. Based on the Local Self-Governance Act 'a settlement that has basic urban service and facilities[1] with minimum population of 10,000 in mountain and hilly region and 20,000 in Terai region can be officially designated as municipality[2]' and considered as urban area in Nepal. Similarly, the 12th 5-year plan (2nd 3-year interim plan) has clearly spelled out the policy arrangement, objectives and strategies accepting the urban development as responsibility of the state. As a result, MOUD and KVDA were established. With this arrangement, the number of urban centers increased - from 10 in 1952 to 217 (1 metropolis, 12 sub-metropolises and 204 municipalities) in 2015 making Kathmandu valley a single urban agglomeration (with 22municipal bodies) that has no

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[1] infrastructure represent: transportation, communication, health & education service (LSGA 2055)

[2] lower level urban governance structure are metropolis, sub-metropolis & municipality (LSGA 2055)

more VDCs. In this way the valley has been experiencing the new policies and institutional changes but urban development is moving haphazardly due to poor enforcement of laws.

2.2. Legal and Administrative Mechanism

Taking experience from well managed cities from around the world, Nepal has developed certain legal and administrative mechanism promulgating different laws and policies and established institution accordingly to facilitate the urban planning and management (Table 1). Adopting the changes in legal and administrative mechanism, law and policy, the efforts on urban planning also began simultaneously (Table 2).

Table 1: Key Existing Laws Directly Attract to the KVDA's Functions

Year (BS)	Legal Documents
Predemocracy era (2019-2046)	1. Land Measurement Act 2019; 2. Land Act 2021; 3. Guthi Corporation Act 2033; 4. Land Acquisition Act 2034; 5. Land Revenue Act 2034; 6. Natural Disaster (Rescue) Act 2039; 7. Pashupati Development Fund Act 2044; 8. KVDA Act 2045; and 9. Nepal Drinking Water Corporation Act 2046
Democracy era (2047-2060)	1. Property Tax Act 2047; 2. VDC Act 2048; 3. Municipal Act 2048; 4. DDC Act 2048; 5. Vehicle & transportation management Act 2049; 6. Monument conservation Act 2049; 7. Directive on the formation of UN Park Development Committee 2052; 8. Nepal civil Aviation Authority Act 2053; 9. Telecommunication Act 2053; 10. Consumer Protection Act 2054; 11. Joint Housing Ownership Act 2054; 12. Local Self Governance Act 2055; 13. Building act 2055; 14. Electricity Act 2055; 15. Environment conservation act 2055; 16. Directive on Formation of Melamchi Drinking Water Development Committee 2055; 17. Road Board Act 2058; and 18. Joint Housing Ownership Bylaw 2060
Federal Republic (2063-2072)	1. Drinking Water Management Board Act 2063; 2. Private Investment in Infrastructure Development And Operation Act 2063; 3. Nepal Trust Act 2064; 4. Building code for the municipalities and urbanizing VDCs in the valley 2064; 5. Private Investment in infrastructure development and operation bylaw 2064; 6. Building Bylaws 2066; 7. Directive on high level Bagmati Civilization Integrated Development Committee 2066; 8. KVDA Bylaws; 9. Waste Management Act 2068; 10. Constitution of Nepal 2072

Source: Compiled by the Author

2.3. Function of Law in Governing Urban Planning and Development

Law is defined as "rules of conduct of any organized society that are enforced by threat of punishment if they are violated (Ref.com, 2007). Essentially Laws play a vital role in society to guarantee the rights of those who are weaker either physically or socially in any given social structure. According to Mallor, et al (2007), the most important functions of law include law and order to maintain peace, promote and protect freedom, facilitate planning execution for benefit of society, promote economic growth, promote social justice and protect environment. These functions of law protect the interests of individuals and businesses through a system of rules, enforced by governing bodies. Without laws, society would be at the mercy of anarchists whose main mission is to disrupt the orderly progress of a society. Laws are written to be followed and applied equally to all people in a society to ensure that no one feels abused and protect members of society from each other (Bushman, 2007). The law protects against anarchy, therefore the law is the backbone of organized society so as for the management of urbanization.

2.4. Institutions established to coordinate the development of the Valley

Even having a lot of such changes in the legal and institutional mechanism in the past, coordinated urban planning and execution could not happen because of the poor law enforcement. One of the examples is a more than two decades delay in the implementation of the KVDA Act 2045 that resulted in a number of problems, which hampered the effective implementation of urban development activities in the valley (Box 1).

Therefore, the government has decided to establish a separate Ministry of Urban Development while also reviving the KVDA Act 2045 and forming the KVDA to have a new authority with mandate for effective urban plan, coordination and implementation to turn the valley from a haphazard and unmanaged city to a safe, smart and livable city – in other words, a compact, coordinated, connected national capital region of Nepal. In this context, KVDA is responsible to review, enforce and reformulate if needed, the existing laws related to urban development and planning to minimize the duplication, gaps and make effective intervention of the integrated development of Kathmandu Valley.

2.5. Role of MOUD in the changed urban development context

Urban development may be understood as an attempt or a process to enhance the socio-economic, physical infrastructural, cultural, environmental, urban facilities and services and resolve the problems associated to them through the necessary policy arrangement and planning. Therefore, the government of Nepal has established a new Ministry of Urban Development in 2012 with special mandate to ensure the basic urban facilities and service – urban development, housing, construction, drinking water, sanitation and sewerage system etc. After the ministry was established, it revived the KVDA act and established the KVDA in 2012 to look overall urban development in the valley.

Table 2: Efforts in urban management of Kathmandu Valley

Year and Efforts	Year and Efforts
1969:Physical development plan of KV	1994:Bagmati basin water management strategy and investment program
1976:Land use plan of Kathmandu Valley	
1977: Bhaktapur town development plan	1995: Regularization of urbanization - study
1979:Beginning of Site & Services Scheme	1996:Formation of high-level council
1984:Physical development concept of KV	1999:Environmental plan & management
1986: urban land policy study of KV	2002:Longterm development concept of KV
1988:Housing & physical planning ministry	2007:National urban policy
1988:Urban development & conservation	2009:Bagmati action plan 2009-2014

Box 1: Problems occurred due to delay in implementation of KVDA Act

- No authorized institution to implement urban plan with effective enforcement of law
- Many committees were formed under the different ministries but in absence of coordinating institutions like MOUD and KVDA, unnecessary competition took place among the ministries, committees and complexities in technical and legal field.
- Duplication in roles among the institutions like committee, sub-metro, municipality, VDCs, guthi, corporation, squatter problem resolve commission, Dept of Road, NEA, Telecom anddrinking water.

1991: Urban development plan & program	2012:National land use policy
1992:KTM urban development project	2012:Ministry of Urban Development
1994: National building code for Nepal	2012:KTM Valley Development Authority

Source: KVDA, 2015

2.6. Role of KVDA in the changed urban context of Kathmandu Valley

In light of fast growing haphazard urbanization, KVDA was formally established on 13th April 2012, with mandate to prepare and implement an integrated physical development plan for Kathmandu Valley that encompasses the entire valley with estimated regular population of 3 million and floating population of another 2.5 million under the KVDA Act 2045. To address the fast growing population growth and its impact on social, cultural and environmental aspects of the valley; KVDA has developed the 20 year Strategic Development Master Plan (SDMP, 2015-2035) to promote the Kathmandu valley as a “livable city” with the interdependence of nature, community and culture and establish the valley as a safe, clean, organized, prosperous and elegant [SCOPE] national capital (KVDA, 2015).

In order to achieve this, KVDA has envisaged several strategic plans that need legal back up and honest enforcement of existing laws. There are numbers of legal documents that attract attention of KVDA in planning and execution in the valley (Table 2). In addition to this list, there are many evidences that the Supreme Court has played decisive role by giving legal verdict in-favor of mass population on the complaint filed against urban infrastructure development or expansion drive. As the Supreme Court verdict has the legal status equivalent to other existing laws, it is also necessary to review and list out the relevant verdict ordered by the court in the past, so that if any confusion arises in future, reference can be taken from the latest decision from the Court.

2.7. Orders of Supreme Court in Public Urban Concerns

As discussed above, in a rare public concern, the supreme court has said, “Public Interest Litigation (PIL) is a strategic novelty of the judiciary that addresses the activism of the court and responsibility of the court towards the society because the Judges sometimes go forward than the traditional judicial process, analyze whether the government policies are against to the constitution, acts and law, if found so, the Judges can interfere over such policy matters and provide fare treatment” (NLP, 2061:p794).

Following this, the Supreme Court has made final verdicts against the public complaints made to hurdle urban infrastructure development or expansion drives in the valley. There are many cases of Supreme Court verdicts that are milestone to establish the right of the people as well as institutionalization of urban development efforts in the valley (Table 3).

Table 3: Supreme Court verdicts in enhancing institutionalized urban development

Writ in public affairs	Court order/final verdict
Conserve environment of Godawari	Close the industry & do needful for environment conservation - 2052-7-14
Drinking water corporation should supply potable water	Drinking Water Corporation and the concern ministry should ensure supply of potable water - 2057-03-26
Stop misuse constituent development fund	Establish legal mechanism to expend such fund - 2058-06-11

Stop pollution produced by Bhrikuti Pulp & Paper Mills	Water used in Bhrikuti Pulp & Paper Mills should purified & dust collector should be installed & used effectively on 2058-8-19
Public land in dispute	Order to cabinet: Disputed land be use for public purpose
No religio-cultural, property of historic importance policy	Develop and implement the policy on religious, cultural and property of historical importance, on 2054-2-27
Put imported vehicle under the set standard	Establish the testing mechanism for imported vehicle, on 2058-6-11
Methane gas in Gokarna Land Field Site	Do needful to have legal arrangement for balancing environment around Gokarna, on b 2059-2-7
Protect public from pollution caused by smoke/ vehicles	Adopt effective measures within two years, on 2059-11-27
Infrastructure to implement slaughter & meat test act 2055	Prepare infrastructure, inform to public then implement the act, on 2062-2-23
Protect public health from the negative effect of polluted environment	To protect the health of general public from polluted environment is constitutional duty of government, hence government should initiate necessary action on 2062-8-24
Stop economic and sexual exploitation in unregister restaurant, cabins, dance bar and massage parlors	Unregister got minimum infrastructure no code of conduct, hence, women are suffering from sexual and financial exploitation. So before law enforced govt should direct an urgent directive on 2065-8-11

Another important area is that the security and utility service providers in the valley are functioning in such an independent way that everywhere one can observe duplication and delay and thus, this leadsto the misuse of resources in the infrastructure construction and maintenance work. To respond this, KVDA is to ensure an effective coordination throughout the planning and implementation process with as the main coordinating agency – the Metropolitan Police; the emergency response agency – Fire Control Service, known as the Barun Yantra; and the utility service providers – Nepal Electricity Authority and the Kathmandu Upatyaka Khanepani Limited (KUKL) in the valley.

To sum up, it is only the condition that if the plans are facilitated and backed up strongly by laws and urban authorities give an honest try, it is possible to manage the ever increasing urbanization and make the Kathmandu Valley more organized, safer and liveable.

3. CONCLUSIONS

Kathmandu Valley has been experiencing a continuous growth in terms of urban population and built up area. Therefore, there is a need to have an effective plan and execution by enforcing the existing laws to make the valley smart, safe, connected, coordinated and livable. This study revealed that promulgating laws and enforcement are two different but equally important factors to turn planning into practice.

Existence of too many laws, bylaws and policies are not the problem but consolidation of those existing laws and policies, bringing all the stakeholders on board, sharing responsibilities under the nodal umbrella are the challenges. To make it happen, mapping of existing laws related to urban development, finding overlaps and gaps in between and among them and recommending appropriate policy (re)formulation especially for the Valley are important. Often, inadequate laws are blamed as constraint for not being able to achieve a safe, secure and livable urban living, on the other hand existence of too many laws are also to blame for an inability to perform effective urban management. In Kathmandu, inadequacy or over abundance of law is not the key problem instead unwillingness and inability of commitment from city planners, managers, development practitioners to understand (interpret) and use them properly are. Funding is prioritized for implementation phases only whereas the prime need of funding is felt in planning stages.

In the context, if the existing laws and policies related to urban planning and development are consolidated, coordination mechanism will be established under the nodal umbrella of the KVDA – it is possible to achieve the vision of 20 years SDMP 2015-2035 that reads *"promote Kathmandu valley as a livable city by enhancing the interdependence of nature, community and culture by establishing valley as a safe, clean, organized, prosperous and elegant national capital region"*.

4. RECOMMENDATIONS

Despite of several efforts, the poor implementation of plan and programs together with weak enforcement of law is always a problem in making the valley safe, smart, connected, coordinated and livable. To overcome such problem, proper enforcement of existing laws, policies and plans is required. Keeping all this in mind, the following recommendations need to be considered for effective planning and implementation in Kathmandu valley in the future:

- Laws, bylaws, standards, codes and the verdicts of Supreme Court that are related to urban development should be integrated and publish in a compilation form. This may be helpful to everyone associated to urban development and planning to minimize the confusion and find base for the coordination. Then, KVDA can act as nodal agency to oversee the coordinated program activities.
- Promulgating laws and its enforcement are different but equally important actions to turn the planned actions into the practice. Therefore, KVDA should update the existing legal and policy documents and orders from the Supreme Court, identify the contradiction if any and advocate for redefinition or reformulation if necessary.
- In case of Kathmandu Valley, inadequacy or over abundance of law is not the key problem instead it is the lack of commitment of concern city planners, managers, development practitioners to understand (interpret) and use them properly. Therefore, there should be a reward and punishment mechanism to the key officials responsible to plan and execute the plans and programs.
- There is a lack of coordinated action in-favour of the implementation of city plan where safety, liberty and property are the common issues to be dealt with. Therefore, a bottom-up approach should be established among the stakeholders and led by KVDA to incorporate:
    - Information, Education & Communication (IEC) for behavioral/ attitudinal changes
    - Creation of abundant technical manpower readily available for land buyers, owners and builders
    - Built in financial incentive and dis-incentives mechanisms for DRR
- Honoring and pursuing the commitments expressed in political parties manifestos, policies and programs and even budget speeches.
- Drafting and implementing simplified and easily understandable bye-laws which could have facilitated the community policing system

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Walking speed based on pedestrians' behavior at mid-block cross in Kathmandu

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ABSTRACT

Ensuring safety to pedestrian on road is a function of road infrastructure and traffic control devices. The later depends on the walking speed of the pedestrian. In a city like Kathmandu where speed of a pedestrian depends on various factors related to behavior is under researched. Therefore, this study was felt deemed important. Data were collected through observational and interview method for 400 randomly selected pedestrians at mid block uncontrolled crossings from eight locations in Kathmandu. Individual's crossing time was recorded followed with an interview with predetermined questionnaire. The walking speed was determined by dividing the road width covered by individual within the crossing time. The simple means were determined to compare the speed for different variants. The results are validated statistically adopting ANOVA test. The road geometry, societal and location parameters greatly affect the walking speed. However the speed at peak time and off time is nearly the same. Refuge Islands is recommended in two-way multilane roads. The recommended crossing speed is 1.22 m/s, however at business area the speed 1.27 m/s shall be taken as safe speed however out-side the ring road speed more than 1.10 m/s seems unsafe.

Keywords: *traffic safety; pedestrian; crossing speed; ANOVA; policy implications*

1. INTRODUCTION

1.1 Background

Journey itself is not a primary need of society. In order to fulfill the need of society, travel demand is generated and people start journey to get their destination. They can use public vehicles, private vehicles or both combine to make their journeys successful. Walking is such a simple and essential mode, which either involved for journeys with transport media or comes separately. In Kathmandu valley, about 40% journeys are made on foot (JICA, 2012). However, the trend of planning and designing the road system are based on automobile oriented one, resulting the large number of accidents. Many of the road accident in Kathmandu were found occurring at pedestrian crossings MTPD (Metropolitan Traffic Police Division, Kathmandu). So there is a need of road infrastructures and traffic control devices oriented to pedestrians' safety. In order to install these control mechanism, there is a need of pedestrian road crossing speed. So there is a need of research to carry out in order to determine the walking speed of pedestrian at road crossings.

WHO predicts that the road traffic injuries will rise to become the fifth leading cause of death by 2030, while it was under 9th position in 2004. Over 1.2 million people die each year in the world's roads and between 20 and 50 million people suffer non-fatal injuries (WHO, 2009). In 2010/2011 among 5096 road accidents in Kathmandu Valley, 148 were fatalities, 396 serious injuries and 3317 were minor injuries (MTPD, Kathmandu). The data shows that over 90% of the world's fatalities on the roads occur in low income and middle income countries, which have only 48% of the world's vehicle. Almost half of those who die in road traffic crashes are "vulnerable road users" and this proportion is higher in low economic countries of the world. Tanaboriboon and Jing (1994) found that pedestrian in Beijing, preferred signalized crossings to other types, such as under or over pass crossing. So the behavior of road users is important parameter that affects safety. This research is thus focused on the study of behavioral perspective of pedestrian during crossing the road.

1.2 Research Objectives

The main objective of this research is to determine the walking speeds of pedestrians' based on a variety of behaviors and thus recommend appropriate crossing speed at mid-block cross in Kathmandu.

Specifically this research has the following objectives:

- To quantify the significance level of pedestrians' individual behavior that would influence the pedestrian speed at mid-block road crossing
- To assess the education level and social parameters of pedestrian as a significant variable
- To assess the role of following parameters for determining walking speed
    - Road surface condition
    - Road geometrical parameters
    - Time of day
- To recommend walking speed for pedestrians at various locations

2. LITERATURE REVIEW

First of all, pedestrians' personal features play an important role in pedestrian safety crossing (McMahon et al., 1999 as cited by Guo, 2012). Some studies point to a link between age-related declines in driving and road-crossing skill and increased crash risk (Carthy et al., 1995; Helmers et al., 2004; Mathey, 1983; Oxley et al., 1997; Oxley 2000 as cited by Oxley, 2000). Male pedestrians tend to violate traffic rules more frequently than females and are more likely to cross in risk situation (Rosenbloom et al., 2004; Diaz, 2002 as cited by Tom, ND). Besides the personal features, the external environmental factors also affect the street-crossing behavior. Sisiopiku and Alking, (2003) presented findings from an observational study of pedestrian behavior at various types of urban crosswalks and questionnaire survey which sought pedestrian perceptions towards various crossing facilities near university campus. For example, pedestrian waiting countdown timer can influence pedestrian behavior at signalized pedestrian crossing (Keegan and Mahony, 2003). Tanaboriboon and Jing (1994 as Cited by Tiwari et, al., 1998) found that pedestrian in Beijing, preferred signalized crossings to other types, such as under or over pass crossing. However, crashes involving pedestrians often occur in signalized intersections (Tiwari et al., 1998). The road crossing behavior of pedestrians is also influenced by the social factor. The road waiting time at pedestrian crossings decreases as pedestrian flow increases, (Hamed, M. M., 2001), suggesting that pedestrians are more inclined to cross the road along with others. Goh B. H. et al. (2012) recommended separate speed at signalized and un-signalized crosswalk in Malasiya. The paper concludes with current design on traffic signal using 1.22 m/s does not provide sufficient time for pedestrian to cross safely. Tim J. G. et al. (2006) were analyzed to determine the effect of age, disability, intersection traffic control condition, group size and gender on walking speed. They found that the groups of two or more pedestrians crossed 0.122 to 0.183 m/s slower than individual crossers. The report identifies that the current speed of 1.22 m/s is insufficient for elder pedestrians have age 60 or more, children assisted by adults, physically disabled persons, and large group of pedestrians.

Hence, it is evident to consider societal and environmental parameters along with individual behavior parameters during studying crossing speed. The road geometrical is a new indicatory that is included in this research as researchers own interest.

3. METHODOLOGY

3.1 Data Collection

For the determination speed, total 400 pedestrians attempting to cross the street were observed on August, 2012 at eight midblock crossings. These locations have similar road geometry and traffic characteristics. The one set of locations with undivided streets are five and the other set with divided street are three locations. The information was gathered at different time of the day including both am and pm with peak hour and off hour. The data collection part includes two phases: firstly the pedestrians were observed for waiting time and secondly they were interviewed for some questions. The time lapsed for crossing the road by pedestrians was also noted. Once the pedestrians have successfully crossed from opposite location of observers, they were asked a set of questions related with this research.

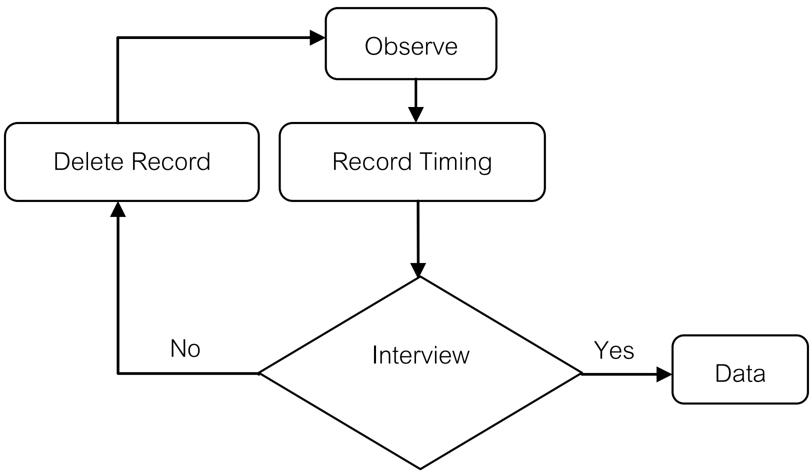


Figure 1, Framework for data collection

Data includes the following parameters and are collected manually.

- Survey location based on higher frequency of occurring accidents
- Sample size (Krejcie and Morgan, 1970) and random sampling techniques

- Time of the day (AM, PM and Day, Night)
- Behavioral and Societal parameters
- Road geometrical parameters

3.2 Data Analysis

Randomly selected data thus collected were checked for multi-colinearity. The data were tabulated, organized and coded into a single data file for detailed analysis of walking speed as a function of various factors. The walking speed of pedestrians was then determined dividing the section of road width by the time taken to cross the road. The walking speed data were analyzed using *Univariate General Linear Model in* SPSS-16.

3.3 Validation of Results

We can use the One-Way ANOVA procedure to test the hypothesis that the means of two or more groups are not significantly different or not (Montgomery and Runger, 2004). For the comparison of various means, ANOVA test was conducted with the null hypothesis that the various categories do not have the statistically different mean. From the test it is seen that the some results accept null hypothesis and some reject it.

4. RESULTS AND DISCUSSIONS

4.1 Distribution of pedestrian speed based on categorical variables

Table-1 shows that the speed of road at mid-block crossings for male is 1.186 m/s, while for female is 1.115 m/s. Male pedestrians walk 0.0536 m/s faster as compared with Female pedestrians. Similarly unmarried pedestrians walk 0.0502 m/s faster as compared with married pedestrians. Those pedestrians who do not have the children at their home are crossing the 0.0676 m/s faster as compared with the pedestrians who have children at their home. Hence it is concluded that the behavior of pedestrians affect the speed during crossing the road. Again the crossing speed doesn’t seem different for pedestrians who have own private vehicle with who do not have and those who are involved in road accidents with those who are not. Pedestrians who are going to their office for the work seem quite hurry as they walk 0.0627 m/s faster with respect to those who are not going for the office work. Pedestrians carrying hand bag or something other than hand bag are walking nearly same speed as those who are not carrying anything.

The results show that the pedestrian feel comfort to cross roads along with others rather than single, as they walk 0.0700 m/s slower as compared with pedestrians crossing road individually. This result is at the range of significance level. Hence we conclude that the societal parameters also affect the speed of pedestrians at mid-block road crossings. Again, the speed between divided and undivided road is significantly different and at un-divided roads, pedestrians are crossing 0.0771 m/s faster than divided. Hence we can say that road geometrical parameters also affect the speed during crossing the road.

Table 1, Distribution of pedestrian speed based on categorical variables

Indicator	Category of Indicator	Mean	N	Std. Deviation	Sig.
Gender	Female	1.17678	145	0.299682	0.131
	Male	1.23504	253	0.40365	
	Total	1.21381	398	0.369848	
Marital Status?	Unmarried	1.24707	154	0.406806	0.189
	Married	1.19685	245	0.347087	
	Total	1.21624	399	0.371582	
Have Children?	No	1.2546	176	0.396899	0.072
	Yes	1.18702	222	0.348665	
	Total	1.21691	398	0.37181	
Have own Vehicle?	No	1.22041	300	0.379576	0.762
	Yes	1.20724	97	0.350261	
	Total	1.21719	397	0.372236	
Have involved/ witness of road accident?	No	1.21258	230	0.384938	0.822
	Yes	1.22116	164	0.353649	
	Total	1.21615	394	0.371797	
Destination toWork?	other than work or office	1.20706	329	0.320998	0.213
	to the work or office	1.26976	64	0.552068	
	Total	1.21727	393	0.368424	
Carrying something during Crossing	nothing	1.21619	216	0.335527	0.934
	something	1.21305	173	0.414799	
	Total	1.21479	389	0.372368	
Crossing in Group?	not in group	1.24117	226	0.320666	0.067
	in group	1.17118	163	0.432243	
	Total	1.21184	389	0.372603	
Location	Gaushala	1.12506	55	0.51891	0.000
	Bauddha	1.08473	50	0.314578	
	Jaulakhel	1.28633	50	0.35692	
	Thapathali	1.08259	45	0.352446	
	Durbarmarga	1.28738	51	0.293961	
	Koteshor	1.27413	49	0.275391	
	Soltimod	1.12902	50	0.267071	
	Kalanki	1.45541	50	0.360476	
	Total	1.21615	400	0.371121	
Does Lane Divided?	Undivided	1.24507	250	0.340832	0.044
	Divided	1.16794	150	0.41346	
	Total	1.21615	400	0.371121	
Time of Observation?	Off time	1.22225	237	0.330195	0.692
	Peak Time	1.20727	163	0.424571	
	Total	1.21615	400	0.371121	

Table-1 shows that the pedestrian at business area are walking much faster as compared with hospital areas and other intermediate crossings. At Durbarmarga and Koteshor (in front of Bhatbhateni Super Market) the walking speed is 1.28 m/s. However the speed at Bauddha (in front of hospital) is only 1.08 m/s. The result is Kalanki seems quite different because of jaw-crossings. Soltimode shows the the speed of pedestrian is 1.13

m/s. Hence it can be concluded that the nature of surrounding area or location is one parameter that affect the speed during crossing the road.

4.2 Distribution of pedestrian speed based continues variables

Figure-2 shows that the crossing speed distribution based on the pedestrians' age. It is clear that the speed declines with older pedestrians than younger pedestrians. However this result is not statistically significant. So the result may be due to the chance. Again the speed doesn't seem much changing based on average number of road cross per day.

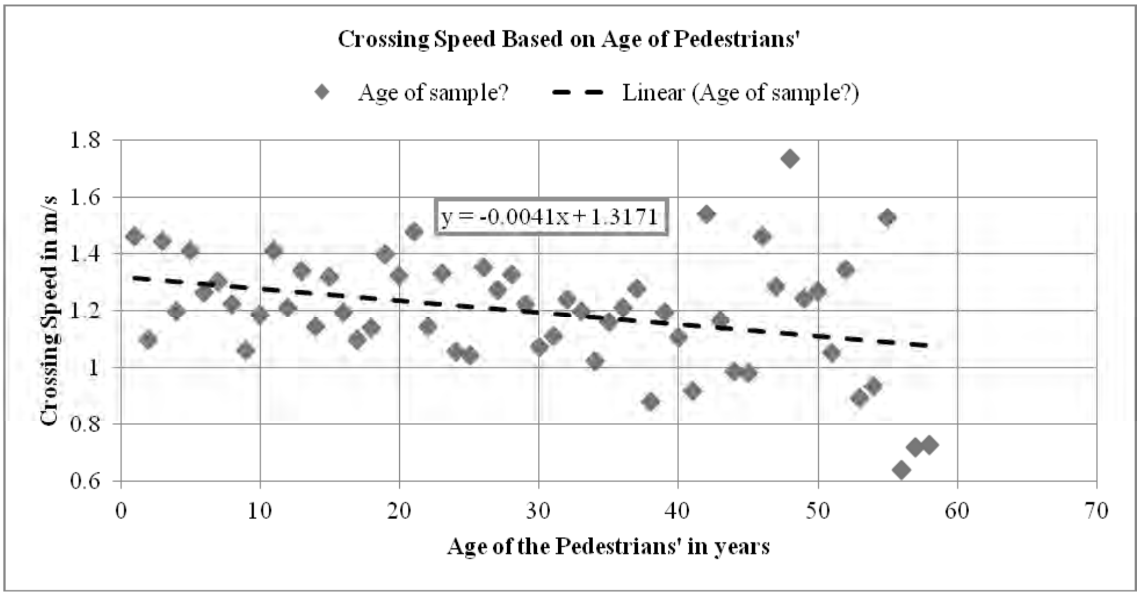


Figure 2, Distribution of pedestrian speed based on age

Figure 6, shows that the as number of unsuccessful attempts increases, the crossing speed of pedestrian also increases. This shows that pedestrian feel force to cross the road after some unsuccessful attempts which ultimately increases the risk of crossing.

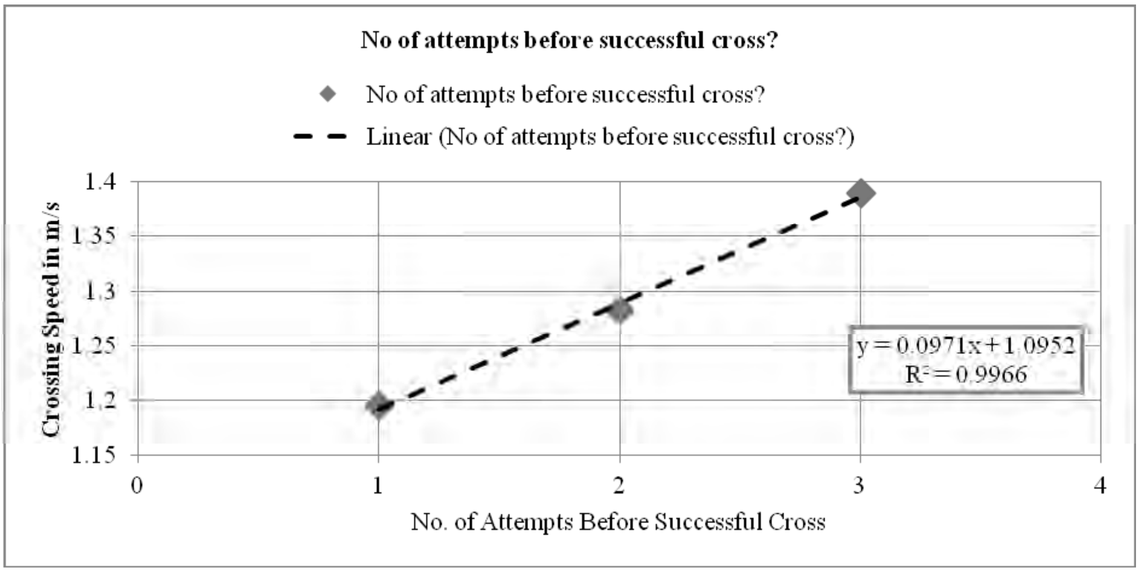
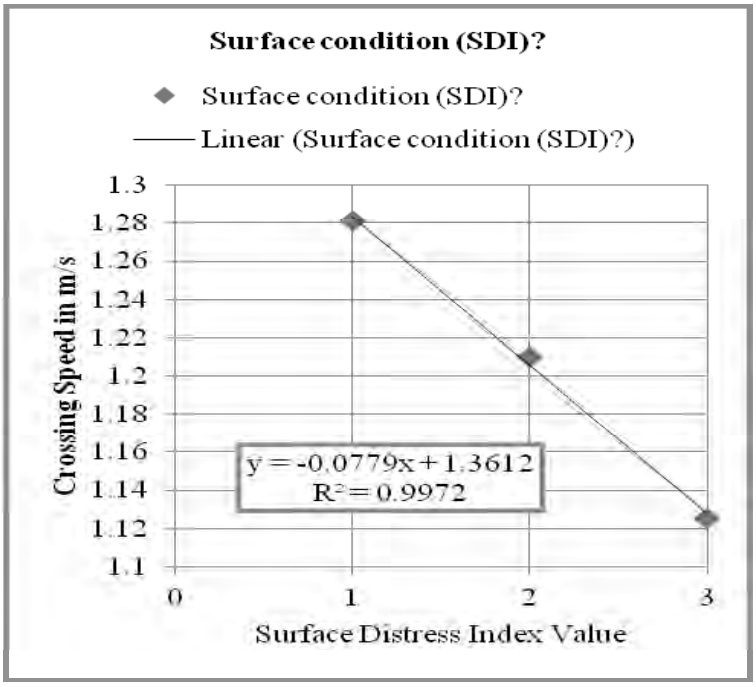


Figure 3, Distribution of pedestrian speed based on Average Number of Attempts before Successful Cross

The result of crossing speed based on pavement condition is presented in Figure-4. As the result is statistically significant, we can strongly say that the road surface condition goes on poorer, the speed of crossing road by the pedestrian decreases. Again the linear model is formulated for the crossing speed based on Surface Condition Index of the road pavement. The result is validated based on statistically using R-square value.



4.3 Distribution of pedestrian speed based on ordinal variables

Figure-5 shows that the higher educated persons walk faster. The composition of higher educated person is more around market area or business area.

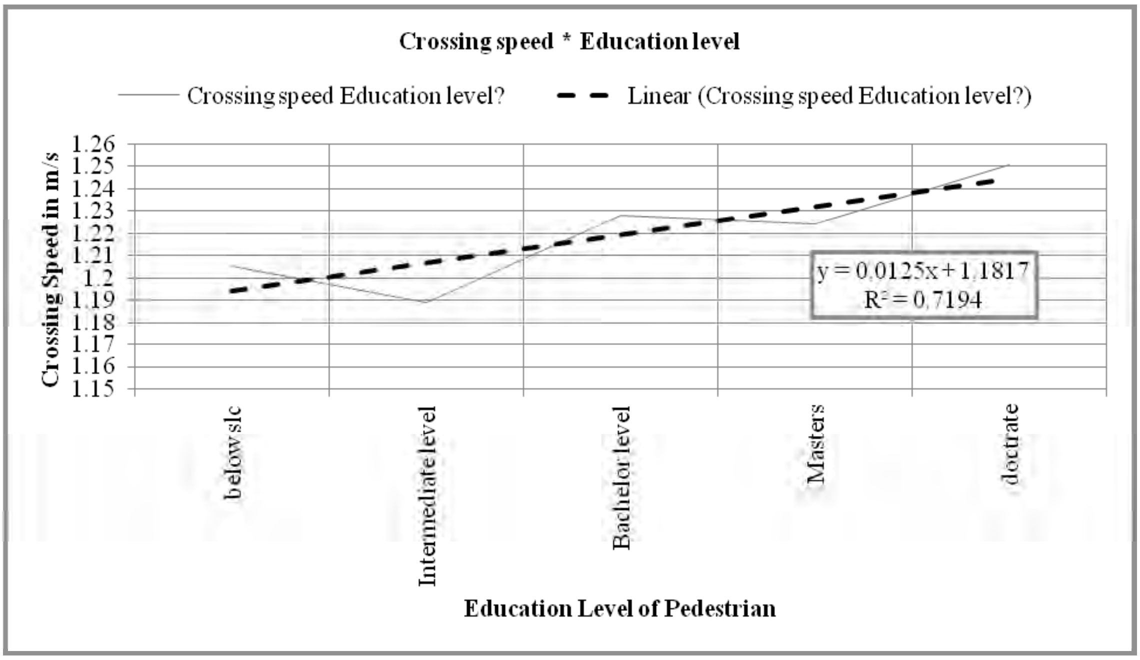


Figure 5, Distribution of pedestrian speed based on Education Level

5. CONCLUSIONS AND RECOMMENDATIONS

The walking speed of pedestrians at mid-block road cross in Kathmandu is determined based on the road geometrical parameters, environmental parameters, pedestrians' individual behavior and societal parameters. Categorical variables are presented in tables wheatear ordinal and continuous variables are presented graphically. Based on findings, it is concluded that the individual behaviors of pedestrians along with the societal parameters significantly affect the speed of pedestrians. Road geometrical parameters greatly affect the speed of walking at mid block crossings. However the speed at peak and off time is nearly same. The nature of surrounding area or location is one parameter that affects the speed during crossing the road

As road geometrical parameters affect the walking speed, refugee inland or divider is recommended to construct in two-way roads for comfort and safety of pedestrian during crossings. Road surface is recommended to maintain in good condition, which increases crossing speed of pedestrians thus enhance road capacity. The speed in mid block cross in Kathmandu significantly depends up on the nature of location and the recommended speed is 1.22 m/s. However at business area the speed may be taken as 1.27 m/s and for the locations out-side the ring road the speed more than 1.10 m/s seems to be unsafe. A detail comprehensive study considering disabled people is recommended for further study including both signalized and un-signalized intersections.

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Mathematical analysis of road blocking to improve evacuation time from tsunami

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ABSTRACT

On March 11th, 2011, the big earthquake occurred in the waters off Miyagi, Japan and huge tsunami came to Sanriku seacoast. After this disaster, research of the way to escape from tsunami is focused again. In Japan, government asks people to escape from tsunami not using car, but walking. However, many people used car to escape to hill in the cause of big earthquake in December 2012 and many traffic jam were to be found. However, there aren't many earlier studies taking consideration of traffic jam in the case of tsunami evacuation. From this background and earlier studies, we suggest to block several road links and making people using car in the case of emergency inconvenience. People can walk through blocked road, but car is not allowed. In the result of this suggestion, we can expect that people will tend not to use the car in the case of emergency and the number of links which cause traffic jam will be decreased. In this research, we will call into account of the choice of how to escape, and we set a goal of minimization of total time of evacuation thinking all evacuees. In this research, we consider Shizuoka city in Japan for example and take in network of this city. Then, we also set the area of water exposure consulting the city's hazard map. To calculate optimal combination of road blocking, we used Genetic Algorithms because there are huge combinations in Shizuoka city's network.

Keywords: Tsunami, evacuation time, road block, genetic algorithms

1. INTRODUCTION

In the Great East Japan Earthquake Disaster of March 11, 2011, a tsunami of unimaginable proportions assailed the region, costing many lives. In its aftermath, tsunami evacuation procedures came under review. The Japanese government had set evacuation on foot as the rule for tsunami evacuation, but when a tsunami warning was issued in Ishimaki City, Miyagi, following the strong earthquake at the end of 2012, many people attempted to evacuate to a higher ground by car, causing major traffic congestion. Such situations may occur in the event of similar future events, so alternative measures should be instituted expediently.

While there have been many studies of evacuation from tsunamis, including the study by Sasa et al. 1) on the allocation of evacuation sites, few studies have applied mathematical analysis and few have analyzed traffic congestion during an evacuation. Although there are road regulations aimed at securing passage for emergency vehicles or prohibiting entry to areas forecast for inundation, few regulations have been put in place concerning evacuation times.

This study attempts to reduce preferential car use in major earthquake disasters by setting road restrictions. Initially, restrictions are defined as road closures. The goal is to reduce the number of car users and detours during emergency periods, leading to a reduction in traffic congestion and evacuation time. The study is aimed at minimizing the total time taken for evacuation by proposing appropriate road closure strategies for a range of evacuation options.

2. EXISTING RESEARCH

Oe et al.[2)] identified the effective positioning of tsunami evacuation facilities in coastal cities as an important factor in disaster prevention planning against tsunamis that reach the area in a short period of time after the earthquake strikes. They treated the positional planning of tsunami evacuation facilities as a mathematical planning problem and introduced an optimization formula. Their mathematical model selected the locations for new tsunami evacuation facilities and allocated residents to existing and new tsunami evacuation facilities. To achieve this, the model calculated the distance to the nearest prospective tsunami evacuation facility by solving the shortest route problem.

Takada et al.[3)] identified the impossibility of smooth evacuation using automobiles as one cause of increased human casualties during a tsunami. They discussed the necessity of post-analysis of evacuations by car when planning future tsunami evacuations strategies. Using the urban areas of Kesennuma City as the subject area, they reconstructed the situation of the tsunami evacuation by car during the Great East Japan Earthquake Disaster. They also used the hearings on the congestion of roads leading to the Kesennuma City Hall to individually identify road networks, origins of vehicles, and evacuation destinations.

This study analyzes the possible reduction of the total time required to evacuate by closing key links (roads) in the network. We take Shizuoka City as our example, where tsunami damage from a Nankai megathrust earthquake is anticipated.

3. DESCRIPTION OF THE STUDY

We used the basic road data available in the 2005 edition of the National Digital Road Map Database created by Sumitomo Electric as the network in this study. The projected inundation area in Figure 1 is based on the Tsunami Hazard Map of Shizuoka City published by the City of Shizuoka.

Figure 1: Details of the road network in the subject area

When a major earthquake strikes, evacuees will start to evacuate from a point in the gray-lined area (start of evacuation node) using roads (links) to evacuate to a point in the black-lined area (high ground node). At the same time, some of the roads will be closed to automobile traffic and evacuees are expected to recognize road closures in advance.

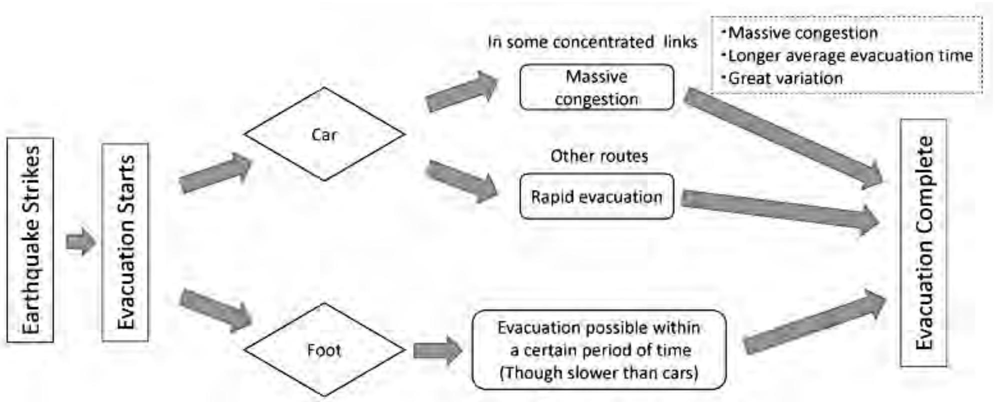
People are expected to choose the shortest evacuation route and evacuation time by car and by foot. This was modeled using a logit model, which is a method to predict the selection behavior of a means of transportation. Using the logit model, the probability of selecting a car as the means of transportation is given by Equation (1) below:

$$C = \frac{e^{-\alpha car}}{e^{-\alpha car} + e^{-\beta walk}} \qquad (1)$$

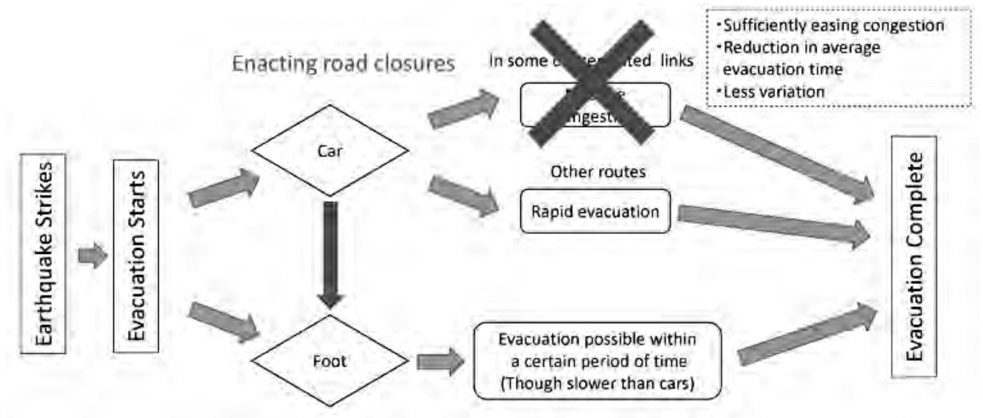
Here, *C* is the probability of selecting a car and *car* represents the required time to the evacuation site reachable in the shortest amount of time by car. The time required to travel by foot to the evacuation site reachable in the shortest amount of time is represented by *walk*. The parameters ± and ^{2} were both set at 1.

If there are no road closures, a large percentage of people will choose *car*, as that will allow them to evacuate more quickly while fewer people will choose *foot*. Although evacuation speed on foot is slower than by car, the absence of congestion means that evacuation can be completed in a predictable amount of time. In contrast, evacuation by car can be completed quickly on roads where congestion does not occur, but major roads, such as highways and roads in densely populated areas, will become extremely congested, leading to wide variation in the amount of time taken for evacuation. The *average* time required for evacuation by car will actually become greater.

For this reason, road closures were introduced. These change the routes available for car evacuation, producing a (perceived) increase in the time required. Under the road closure scenario, some evacuees who would have previously used a car will evacuate on foot or will take a detour, avoiding the concentration of traffic on certain roads. This avoids major congestion, reducing the average time required to evacuate. (Figure 2)



(a) Where road closures are not enacted



(b) Where road closures are enacted

Figure 2: Easing congestion by enacting road closures

In this study, we assumed a walking speed of 2.75 km/h, based on the recommendations in the Tsunami Affected Urban Area Restoration Method Survey issued by the Ministry of Land, Infrastructure, Transport and Tourism. Cars were modeled with route selections that did not take congestion into account and assigned movement speeds for each link using the Bureau of Public Roads (BPR) function described below in Equation (2), following Takada et al.[3)]

$$t_a(x_a) = t_{a0} \cdot \left\{1 + \alpha \cdot \left(\frac{x_a}{c_a}\right)^{\beta}\right\} \qquad (2)$$

Here, t_a is the travel time on link ±, t_{a0} is the free travel time on link *a* (travel time when there is zero traffic), x_a is the traffic volume per hour in link *a*, and c_a is the traffic capacity per hour in link *a*. Following Takada et al. [3)], the parameter values were set at ± = 0.48 and ² = 2.82.

Ultimately, a road closure combination that yielded the shortest average evacuation time was found, and this was compared to the situation with no road closures.

In this study, the combination of roads for closure exists as 2 to the power of the number of links, so searching through all of them is not realistic. Therefore, the study expressed the decision whether to close a road or not as 0 or 1, where 0 is no road closure, and used a meta-heuristic genetic algorithm to derive the solution.

Values were set for each constant. For evacuees, 142 people were allocated to each node. This was calculated based on the population data for Shizuoka prefecture. The traffic volume per link was set as 70 vehicles per min, the number of individual units in the genetic algorithm was set to 50, and the number of generations at 100. Also, the genetic algorithm employed *elitism*, wherein the highest values found in the top tier are carried forward. No particular termination conditions were set. The specification of the algorithm is described below:

1. Generate 49 individual units expressed as 0 or 1 for the number of links, with 0 or 1 values assigned randomly. One unit is generated as a unit with no road closures where all values are 0.
2. Calculate the average time required for evacuation of each unit. The average time required for calculation is listed separately below.
3. Use bubble sort for the average time required for evacuation in each unit.
4. Take the top 15 units with the best average times required for evacuation and newly generate the remaining 35 units. The generation method uses two-point cross-over in roulette selection.
5. Treat this as the first generation and repeat steps 2 through 4 is for up to 100 generations.

The average time required for evacuation was calculated as follows.

2-1. After taking into account road closures, calculate the evacuation time by car and by foot from each node to each evacuation site. Assume that evacuation uses the shortest route, and that traffic congestion is not taken into account. Add three min as time for preparing the car.
2-2. Based on the calculations in 2-1, determine the percentage evacuating on foot and by car from each node using the logit model (Equation (1)).
2-3. Based on the calculated number of cars and people and the route data for each evacuee, calculate the cumulative total of vehicles passing through each link.
2-4. Based on the cumulative vehicle count, use the BPR function (Equation (2)) to calculate the time taken to reach each link by car.
2-5. Based on route data and the time required for each link, calculate the time taken to reach the evacuation site from each node both by car and on foot.
2.6 Calculate the total amount of time and divide it by the number of people to derive the average evacuation time.

The existing literature gives recommendations for each region by solving the shortest route problem, where *single* evacuation methods are discussed, but few studies have simultaneously considered multiple modes of evacuation, such as driving or walking.

In general, solutions of optimization problems tend to deteriorate when restrictions are applied. The significance of this study is that we have added restrictions in the form of road closures, yet have derived improved solutions. This is possible because the excessive traffic generated by the BPR function was resolved by implementing road closures.

4. CALCULATION RESULTS

In this study, the average time required for evacuation in Shizuoka City improved from 9.41 min prior to applying road closures to 6.62 min after application. The road closure sites used in this scenario are shown in Figure 3. In this figure, the gray-lined areas in the network are nodes requiring evacuation, the areas in black are the destination nodes, and the bold lines are the links that are subject to road closure.

The distribution graphs of evacuation times from each node to their evacuation sites are shown in Figures 4 and 5, while comparisons of car traffic before and after road closures are shown in Figures 6 and 7. It can be seen that there are roads with reduced traffic volumes and that vehicles have taken detours.

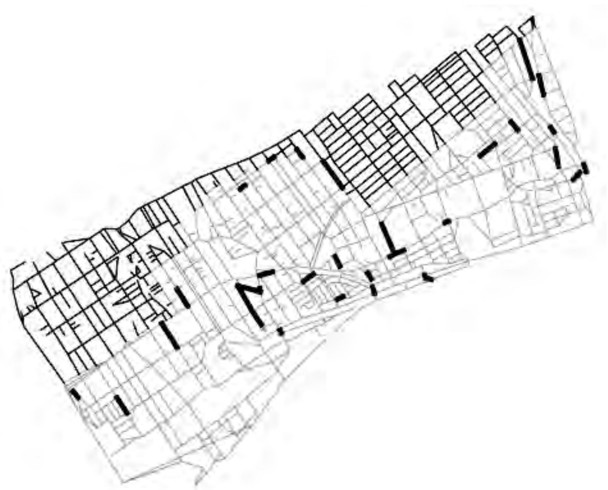


Figure 3: Network showing road closure locations

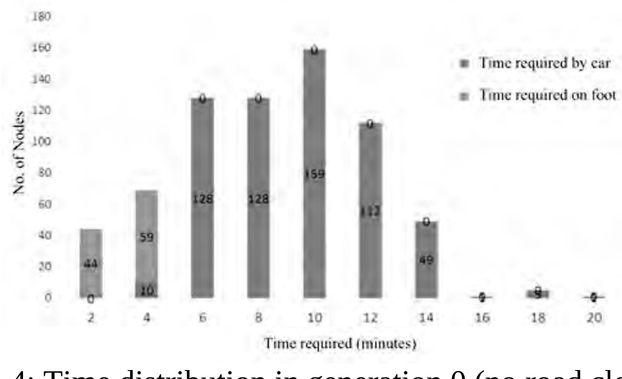


Figure 4: Time distribution in generation 0 (no road closures)

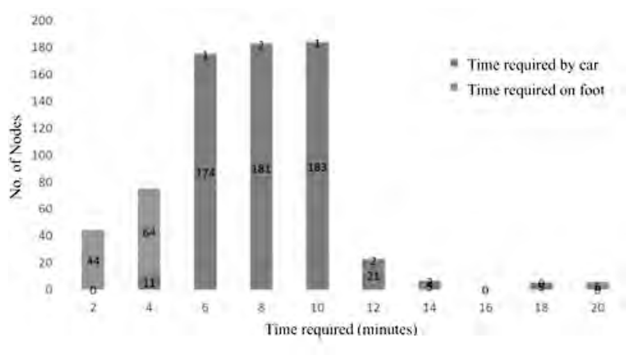


Figure 5: Time distribution in generation 100 (optimal solution)

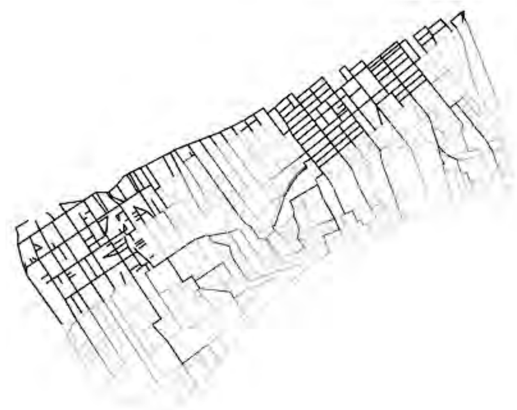


Figure 6:Traffic volume in generation 0

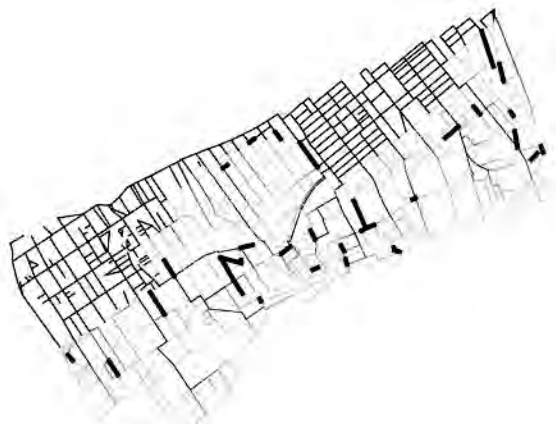


Figure 7:Traffic volume in generation 100

5. FUTURE PLANS AND ANTICIPATED CONCLUSIONS

These trial calculation results still leave some issues unresolved. One is that the results are largely determined by the parameters chosen. In particular, the number of people and traffic capacity settings have a significant impact and have not been appropriately allocated. By setting the number of people in the model, the application of population distribution data would attribute more appropriate populations to each node. Traffic capacity is typically set as a number of vehicles per day or per hour, on the assumption of an even number of cars flowing through. In this study, the number of vehicles in each link was calculated as the cumulative total when deriving the number of cars passing through a link and calculating the average time required for evacuation. In reality, the flow of car traffic is not even; hence, using a cumulative total will exaggerate traffic congestion. A more accurate per minute calculation will yield more accurate timings. To do this, it is necessary to build an understanding of traffic volumes at each link on a per minute basis.

The study assumed that evacuees will select the shortest route. In fact, not all evacuees will know the shortest route, so this is an unrealistic assumption. Adding the possibility of selecting second and third routes should improve the accuracy of the model.

The traffic capacity of all roads was assumed to be similar, but in reality, there are larger and smaller roads, and the number of vehicles that they can handle varies greatly. This must also be built into the model.

Finally, we are considering the introduction of emergency vehicles and applying Pareto optimization. Road closures are normally used to prioritize the passage of emergency vehicles. Operators of emergency vehicles would prefer closures on all roads but that would prevent any evacuees from using vehicles. Our approach considers road closures that are beneficial both for evacuees and for emergency vehicles.

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Flexural strengthening effect of pretensioned UFC panel on RC beams with low reinforcement ratios

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ABSTRACT

The new strengthening method by using pre-tensioned ultra high strength fiber reinforced concrete (UFC) panels was proposed in this study with the concept of safety and durability. The amount of PC strands and prestressing level in UFC panel were varied in order to investigate the flexural enhancement and corresponding mechanical behavior of reinforced concrete beam strengthened by pre-tensioned UFC panels. Moreover, the amount of tensile bar in RC beams was changed to study the effect of new strengthening method on different damaged level of RC beams. Finally, the experimental results revealed that the strengthening by using pre-tensioned UFC panel can highly enhance the flexural performance of RC beam and durability of structure.

Keywords: structural concrete, flexural strengthening, crack resistance, UFC, prestress

1. INTRODUCTION

Japan has frequently confronted to disaster and earthquake. The vastly unpredictable earthquake is the Great Hanshin Earthquake in 1995 which devastated over 150,000 reinforced concrete structures. After that, many specifications related to structural design and construction were seriously revised to support the higher resistance from seismic and structural loading in the future. Consequently, many former reinforced concrete structures have been diagnosed and modified to satisfy the load resistance according to the new specification.

Recently, the strengthening of RC structures is one of the widely interesting methods. It has been applied to various kinds of structure because the high performance and sustainability can be provided with economical investment. Nowadays, there are various well-known strengthening methods for example steel-plate attaching, bonding with Fiber Reinforced Polymer (FRP), external post-tensioning and so on. However, each method still has some drawbacks such as corrosion problem, brittle behavior of FRP, lack of fire prevention and less durability in severe environment. Therefore, the new strengthening method by using pre-tensioned ultra high strength fiber reinforced concrete (UFC) panel will be proposed in this research in the concept of safety and durability.

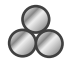
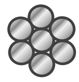
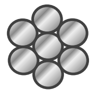
UFC is the advanced cementitious material which consists of short steel fiber and fine grain binders: silica fume, silica sand, cement. UFC has the outstanding properties in

Table 1: Experimental series

Name	Pre-tensioned UFC panel		Series
	A_{PS} (mm^2)	f_{ci} (N/mm^2)	
0.3RB-40PS-5	40	5	I
0.3RB-103PS-5	103		
0.3RB-139PS-5	139		
0.5RB-40PS-5	40	5	I
0.5RB-103PS-5	103		I, II
0.5RB-139PS-5	139		I
0.5RB-103PS-3	103	3	II
0.5RB-103PS-7	103	7	

A_{PS}: Total cross sectional area of PC strands
f_{ci}: prestressing level in UFC

Table 2: Details of PC strands in series I

Name	Detail	$\varnothing_{PC}$ (mm)	Area (mm^2)	f_{py} (N/mm^2)	f_{pu} (N/mm^2)
3 wires		6	40	1705	1910
7 wires		9.3	103	1463	1720
7 wires		10.8	139	1463	1720

$\varnothing_{PC}$: The diameter of PC strand
f_{py} :Yielding strength of prestressing strands
f_{ci} :Ultimate strength of prestressing strands

Table 3: Mix proportion of concrete

G_{max} (mm)	W/C (%)	s/a (%)	Unit weight (kg/m^3)				
			W	C	S	G	SP
20	60	45	178	296	859	956	0.444

W: Water, C: Cement, S: Fine aggregate,
G: Coarse aggregate, SP: Superplasticizer,
s/a: Volume ratio of sand to aggregate

Table 4: Material properties of reinforcing bars

Rebar	Type	Diameter (mm)	Grade	f_{sy} (N/mm^2)
Tension bar	D16 D13	15.9 12.7	SD345	412 408
Comp. bar	D10	9.53	SD345	411
Stirrup	D10	9.53	SD295A	>295

f_{sy}: Yielding strength of reinforcing bar

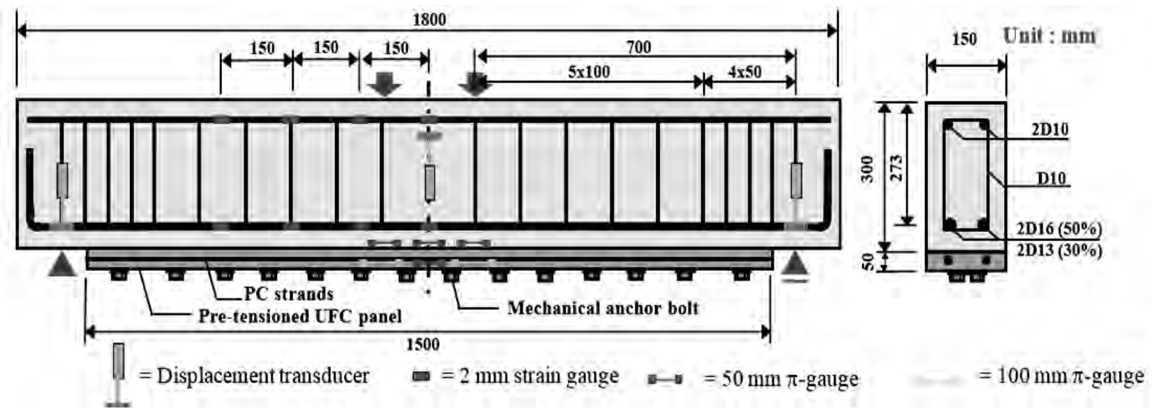


Fig. 1: Details of specimens

high strength that exceeds 150 N/mm^2 in compressive strength and 5 N/mm^2 in tensile strength (JSCE 2006), high durability and high ductility. Moreover, it has very high flowability which eases in rheology of complex structure.

Accordingly, with the outstanding concepts of UFC, it has been applied to the new flexural strengthening method for RC beams. In order to enhance the tensile behavior of UFC to satisfy the flexural strengthening scheme, PC strands were used to prestress UFC panel under pre-tensioning method. In addition, the expanding end anchor bolts were used as the connection between a RC beam and the pre-tensioned UFC panel for providing sufficient bonding. Therefore, there are three objectives in this study; to investigate the flexural capacity of RC beams strengthened with pre-tensioned UFC

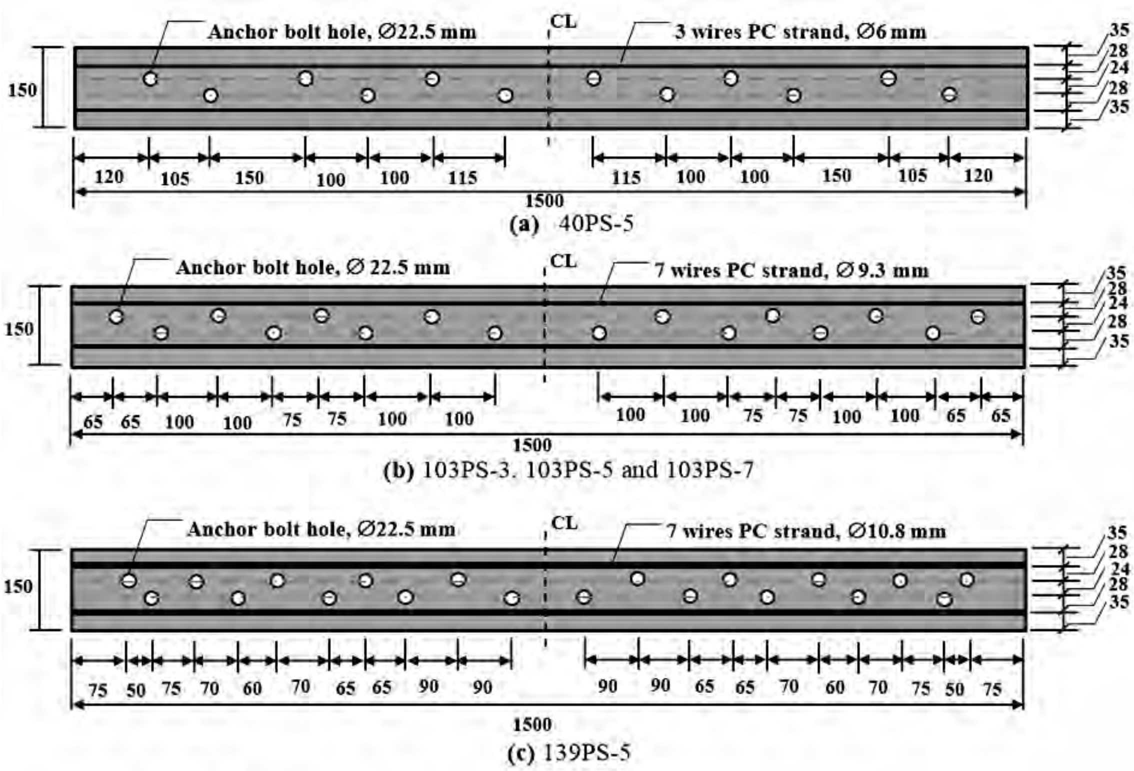


Fig. 2: Detail of PC strand and bolt arrangement in pretensioned UFC panel (Unit: mm)

panels and to examine the corresponding mechanism of flexural strengthening by using pre-tensioned UFC panels. To accomplish these research objectives, two parameters were varied in this research, which were the amount of PC strands and prestressing level in UFC panels. The eight RC beams were strengthened with different pre-tensioned UFC panels and were subjected to the four-point bending test. The experimental results were collected for discussion. The comparison of loading capacity between strengthened and non-strengthened beams, loading resistance mechanism and the effect of each parameter are presented.

2. OUTLINE OF THE EXPERIMENT

2.1 Experimental series

In this study, two parameters were varied in pre-tensioned UFC panel which were the amount of PC strands and the prestressing level in UFC panel. Moreover, to investigate the flexural performance of new strengthening method in different damage level of RC beams, the cross section area of tensile bar was also changed. The 0.5RB and 0.3RB represented the 50% and 30% of tensile bar in RC beams which equaled to 379 mm^2 (2 × D16) and 253 mm^2 (2 × D13), respectively. The details of eight strengthened specimens are shown in Table 1.

2.2 Details of the specimens

In this study, one specimen consisted of one RC beam strengthened with pre-tensioned UFC panel as shown in Fig. 1. Eight RC beams were prepared before fabricated with pre-tensioned UFC panel. All RC beams had 1.8 m in length and 150 × 300 mm of cross

Table 5: Mix proportion of UFC

Flow (mm)	Unit quantity (kg/m³)			SP (kg/m³)
	Water	Premix binder	Steel fiber	
260±20	180	2254	157	24

Fig. 3: Expanding end anchor (left) and finished specimen (right)

section. The shear reinforcement ratio in RC beams was 0.95% for preventing shear failure. Each pre-tensioned UFC panel had 1.5 m in length and 50 × 150 mm of cross section. Each panel was prestressed by two PC strands with different prestressing level in a UFC panel. The types of PC strand and prestressing level of each specimen are described based on the experimental series as follows.

2.2.1 Series I

The amounts of PC strand were varied in this series while prestressing level in UFC panel was constant as 5 N/mm^2. Three kinds of PC strands with different diameter as shown in Table 2 were prestressed inside UFC panel. Consequently, six RC beams of 0.3RB and 0.5RB were strengthened with pre-tensioned UFC panels with different amounts of PC strand as illustrated in Fig. 2.

2.2.2 Series II

In this series, the prestressing levels were varied from 3 N/mm^2, 5 N/mm^2 and 7 N/mm^2 in UFC panels while the amount of PC strands was fixed to 103 mm^2. The detail of pre-tensioned UFC panel is also shown in the Fig. 2. Therefore, there were three specimens of 0.5RB-103PS-3, 0.5RB-103PS-5 and 0.5RB-103PS-7 subjected to the four-point bending test for investigating the effect of prestressing level.

2.2.3 Materials

The same mix proportion of concrete was used for casting eight RC beams as shown in Table 3. The compressive strength of concrete was designed to 30 N/mm^2 at 7 days. The steel reinforcement of compression, tension and stirrup in RC beams was different in type and properties as tabulated in Table 4. And Table 5 shows the mix proportion of UFC that was mixed with 0.2 mm diameter and 15 mm length of short steel fibers.

2.2.4 Fabrication procedure

The specimens were consisted of two parts as mentioned. Due to the heat curing process of UFC material to reduce shrinkage and provide high quality, the pre-tensioned UFC panels were fabricated in the factory. All reinforced concrete beams were cast by using 100-liter capacity of mixing machine. After preparing the RC beams, the pre-tensioned UFC panel was attached to them by anchoring with expanding anchor bolt as shown in Fig. 3(a). The complete specimens are shown in Fig. 3(b).

2.2.5 Loading method

All prepared specimens were subjected to four-point bending test. Teflon sheets and grease were put under the specimens at supporting points in order to satisfy the simple support condition by preventing the horizontal friction. On the top surface of specimens, leveling was adjusted before putting loading plates by using gypsum. Then the 100 mm width of loading plates were set up at the location of loading points to reduce the stress concentration. The load was applied by a 2000 kN loading machine.

2.2.6 Measuring items

The measuring items in this study are illustrated in Fig. 1. Four displacement transducers were installed at the supporting point and mid-span of a specimen in order to measure the relative mid-span displacement. Six π-gauges were attached on two sides of a RC beam at the bottom edge of concrete and other sixπ-gauges were also attached in two sides of a UFC panel. At the tensile bars, 2 mm of strain gauges were attached on many locations of compression bars and tension bars as displayed in the figure.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Loading capacities

The mechanical properties and experimental results of all specimens are shown in Table 6. In this table, the loading capacity of 1RB, 0.5RB and 0.3RB can be calculated under the flexure-tension failure assumption. The load enhancement ratio that can be calculated from the loading capacity of strengthened to non-strengthened beams can show the performance of this strengthening method. Figures 8-11 show load-displacement relationships. The effect of each parameter is discussed as follows;

3.1.1 Series I: Effect of amount of PC strands

According to Table 6, the loading capacity can be increased with higher amount of PC strand in both series (0.3RB and 0.5RB). However, the effect of amount of PC strand does not show the proportional strengthening performance as shown in Fig. 4. In comparison of the flexural enhancement of 0.5RB as shown in Fig. 6, the pre-tensioned UFC panel can enhance high loading capacity over 0.5RB equal to 1.99, 2.79 and 3.06 in 0.5RB-40PS-5, 0.5RB-103PS-5 and 0.5RB-139PS-5. In the case of 0.3RB, the strengthened specimens can increase the loading capacity equal to 2.78, 3.50 and 3.56 in 0.3RB-40PS-5, 0.3RB-103PS-5 and 0.3RB-139PS-5 as indicated in Fig. 5. Moreover, in comparison to non-

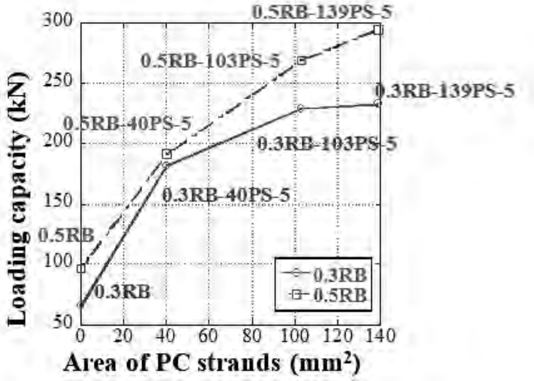


Fig. 4: Comparison of loading capacity of specimens in series I

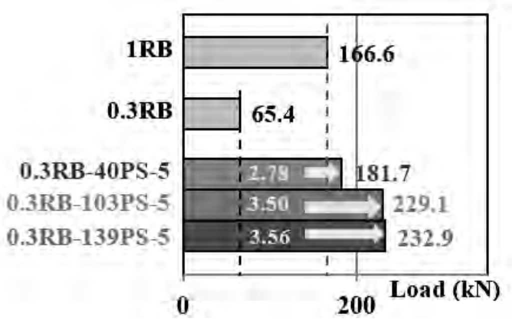


Fig. 5: Comparison of flexural enhancement in 0.3RB of series I

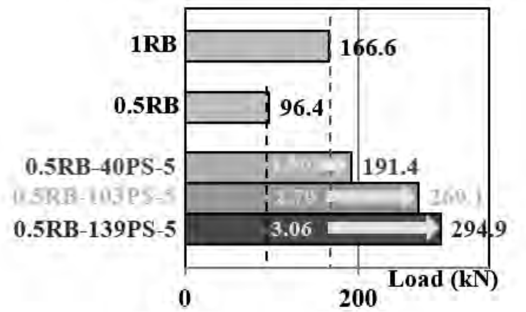


Fig. 6: Comparison of flexural enhancement in 0.5RB of series I

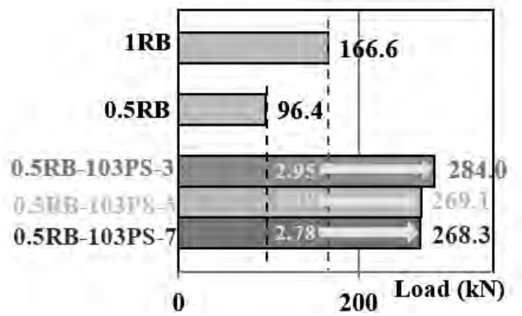


Fig. 7: Comparison of flexural enhancement in series II

Table 6: Mix proportion of UFC

Name	Compressive strength, (N/mm^2)		Loading capacity, P_U (kN)	Failure mode	Enhancement ratio of capacity		
	Concrete, f'_c	UFC, f'_{c_UFC}			n_1	$n_{0.5}$	$n_{0.3}$
1RB	43.0		166.6	FT			
0.5RB	43.0	-	96.4	FT		-	
0.3RB	43.0		65.4	FT			
0.3RB-40PS-5	47.5	194.8	181.7	FS	1.09		2.78
0.3RB-103PS-5	47.6	194.8	229.1	FS	1.38	-	3.50
0.3RB-139PS-5	47.0	210.7	232.9	FS	1.40		3.56
0.5RB-40PS-5	44.5	194.8	191.4	FT	1.15	1.99	
0.5RB-103PS-5	40.3	194.8	269.1	FS	1.62	2.79	-
0.5RB-139PS-5	43.6	210.7	294.9	FS	1.77	3.06	
0.5RB-103PS-3	30.1	210.7	284.0	FT	1.71	2.95	-
0.5RB-103PS-7	45.4	211.4	268.3	FS	1.61	2.78	

FT: Flexure-tension failure, FS: Flexure-shear failure, n_1: Enhancement ratio of capacity to 1RB, $n_{0.5}$: Enhancement ratio of capacity to 0.5RB, $n_{0.3}$: Enhancement ratio of capacity to 0.3RB

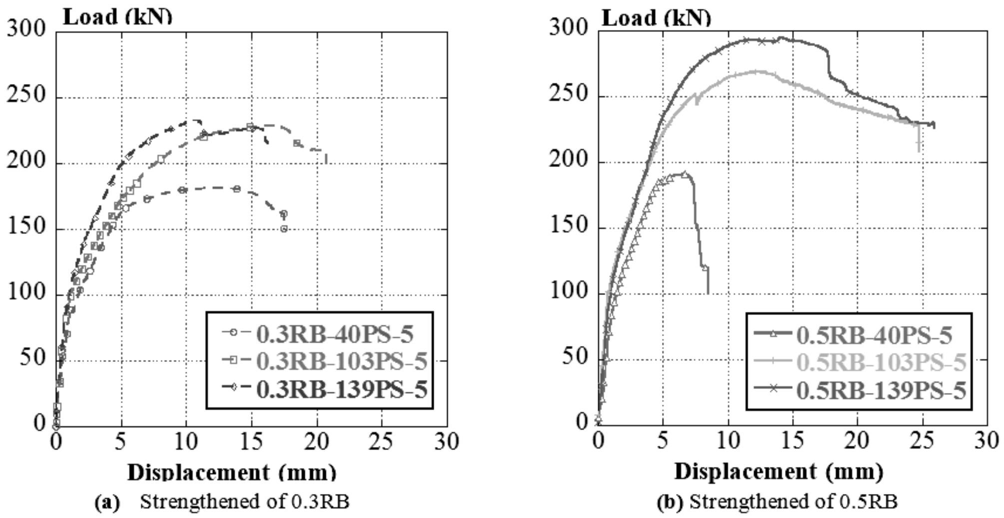


Fig. 8: Load-displacement relationship of specimen in series I

damaged beam or 1RB, all strengthened specimens can recover the capacity higher than 1RB as shown in Fig. 5 and 6.

3.1.2 Series II: Effect of prestressing level in UFC

In this series, the prestressing levels were increased from 3, 5 and 7 N/mm^2. According to the results of series II, it is indicated that the higher prestressing level in UFC insignificantly affects the increase in the loading capacity. However, it can enhance very high resistance to 0.5RB which equal to 2.95, 2.79 and 2.78 in 0.5RB-103PS-3, 0.5RB-103PS-5 and 0.5RB-103PS-7 as shown in Fig. 7. Moreover, these strengthened specimens can recover the capacity over than that of 1RB.

3.2 Effect of prestressing in UFC on durability of strengthened structures

According to the results of loading capacity in series II, the increase in prestressing level in UFC insignificantly influenced to increase in loading capacity. However, the

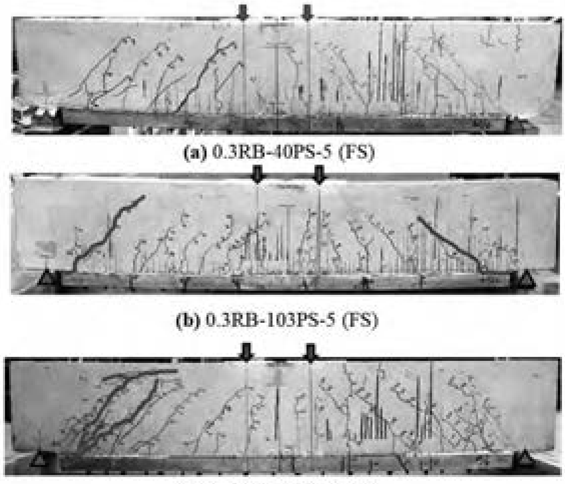


Fig. 9: Crack pattern of strengthened 0.3RB specimens in series I

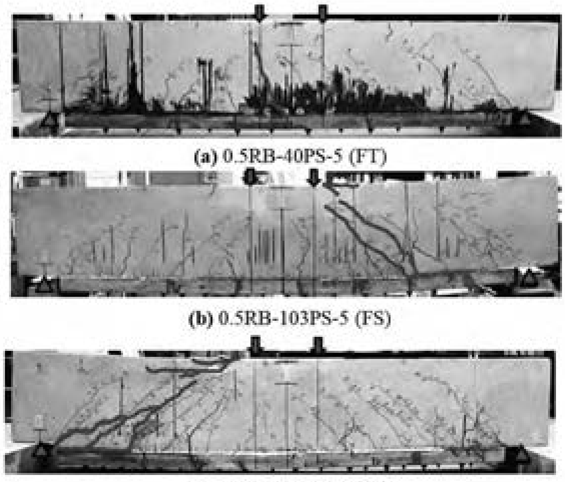


Fig. 10: Crack pattern of strengthened 0.3RB specimens in series I

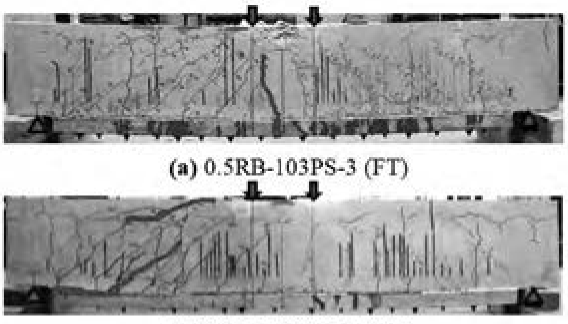


Fig. 11: Crack pattern of specimens in series II

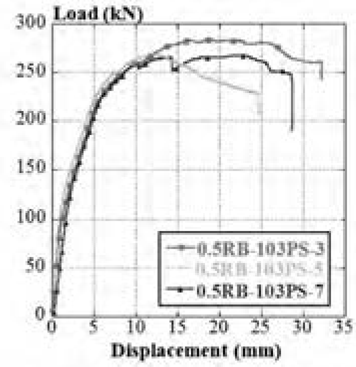


Fig. 12: Load-displacement relationships of specimens in series II

crack patterns on UFC panel of specimens 0.5RB-103PS-3, 0.5RB-103PS-5 and 0.5RB-103PS-7 were observed. Large number of cracks on UFC panel in the specimen 0.5RB-103PS-3 could be observed while the crack on panel was reducing in the specimen 0.5RB-103PS-5 as shown in Figs. 10(b) and 11(a). Only a few cracks could be seen in the specimen 0.5RB-103PS-7 as shown in Fig. 11(b). Therefore, the higher prestressing level in UFC can affect the number of crack in UFC panel which related to higher durability of structure at high prestressing level.

By setting the π-gauges at constant moment region, the initial cracking load on UFC panel of each specimen could be summarized in Table 7. The loads at 0.1 mm of crack widths were observed to indicate the initial cracking load because the crack could be clearly seen and abruptly increased after this point as shown in Fig. 13.

According to series I, the load at the crack on panel was in the range of 103.4-114.7 kN in 0.3RB and 123.5-130 kN in 0.5RB. Range of cracking load in this series does not seem to vary with the amount of PC strand. On the other hand, the initial cracking loads were changed significantly from 105.8 to 143.9 kN in series II and the numbers of crack on UFC panel were remarkably reduced with higher prestressing level because the applied prestressing force in this research can rescue too many cracks in UFC panel which relates to reduce the number of crack on pre-tensioned UFC panel with higher prestressing level in UFC. Therefore, it can indicate that the prestressing level in UFC significantly affects crack propagation of strengthening system and subsequently influences on the durability of strengthened structures.

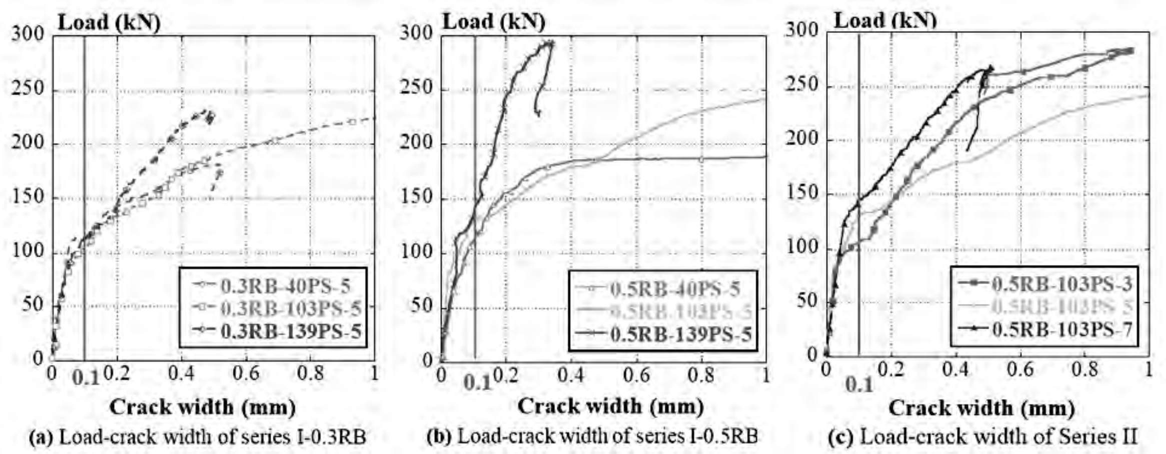


Fig. 13: Load-crack width relationships on UFC panel of all specimens

Table 7: The initial cracking load on pretensioned UFC panel

Name of specimens	Initial cracking load (kN)
0.3RB-40PS-5	113.0
0.3RB-103PS-5	103.4
0.3RB-139PS-5	114.7
0.5RB-40PS-5	123.5
0.5RB-103PS-5	130.0
0.5RB-139PS-5	130.0
0.5RB-103PS-3	105.8
0.5RB-103PS-7	143.9

4. CONCLUSIONS

(1) By using the pre-tensioned UFC panel as strengthening method, the increasing amount of PC strand can drastically increase the loading capacity.

(2) With different prestessing levels in UFC in the range of 3 to 7 N/mm^2, the loading capacity did not significantly increase with higher prestressing levels. But this variable parameter can be significantly related to durability of structures. In the case of providing higher prestressing level, it can increase the initial cracking load and reduce the number of crack on panel because the prestressing increases the tension resistance at the bottom edge of concrete and UFC panel.

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Effective analysis of soundness of bridges affected by environmental factors ~Using bridge inspection data in Hokuriku region~

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ABSTRACT

Recently, extending the service life of the bridges has come to be studied. Many bridges are built in the period of high economic growth, and they reached their service life. Consideration of rebuilding and extending the service life must be carried out. Under such circumstances, the bridges in the Hokuriku region has been placed under the harsh environment. For example, flying salt due to the weather characteristics of winter, the influence of the water from pipe buried under a road with nozzles that spray liquid to melt snow, sprinkling salt for antifreeze, the damage of alkali silica reaction that peculiar to Hokuriku region, seismic risk occurred by active fault . I got the inspection data about of the bridge in three prefectures in Hokuriku. The soundness of bridge and the degree of degradation recorded in the inspection data.
In this study, we propose a repair priority determination method taken into account the seismic risk by using a principal component analysis.

Keywords: soundness of bridge, bridge inspection data, seismic risk, environmental factor.

1. INTRODUCTION

Recently, the lifelong duration of bridges are discussed in Japan. There are about 70000 bridges (bridge length 2 meter or more) in Japan at present. About 18 percent of the bridges were built more than 50 years ago. It is expected that older bridges passed 50 years will account for 43 percent. Many of the bridges were built in the period of high economic growth, and they will reach bridge service life all at once. In Ishikawa prefecture, about 24 percent of the bridges were built more than 50 years ago. It is expected that older bridges passed 50 years will account for about 69 percent as shown Figure 1. Rack of human resources and public works spending makes repair of bridges difficult in the future. Stopping traffic during the bridgework has a harmful effects on transportation services.

Under such circumstances, National and local governments attaches importance to maintenance, and carries out regular inspections of bridges to make frameworks of asset management. It is difficult to use inspection results in determining the proper priority of bridges because inspection results has many inspection items. Present priority of bridges is determined on the basis of degradation situation and importance. But present priority of bridges are not considered seismic risk to determine the repair priority of bridges.
Bridges in the Ishikawa prefecture has been placed under the harsh environment. For example, flying salt due to the weather characteristics of winter, the influence of the water from pipe buried under a road with nozzles that spray liquid to melt snow, sprinkling salt for antifreeze, the damage of alkali silica reaction (ASR) that peculiar to Ishikawa prefecture. The Morimoto Togashi fault is active faults that develop in the southeast edge of the Kanazawa plains. It is estimated to cause the earthquake of about magnitude 7.2 in 2-8% of probability in the next 30 years. As a result of this risk evaluation, a lot of bridges will be affected by earthquake.
The purpose of this study is to make the decision of repair priority including the seismic risk by using the regular inspection data.

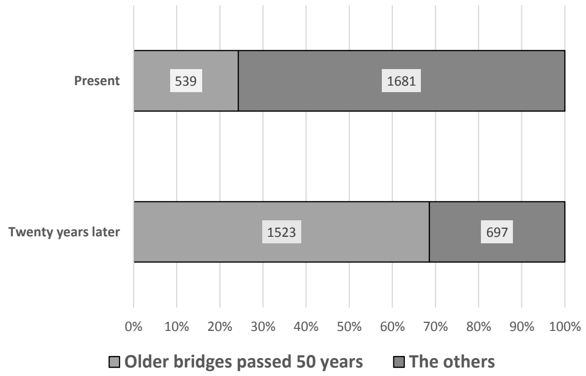

Figure 1: The number of older bridges passed 50 years

2. PREVIOUS STUDY

Up to now, a lot of maintenance priority decision of bridges using regular inspection data is researched.
Dr.Oshima selected items related to the earthquake resistance based on the physical health assessment that has been conducted, and carried out a questionnaire to the expert, the results were analyzed by quantification theory, proposed the earthquake resistance soundness evaluation considered the weighting factor.
Dr.Kaito proposed a degradation prediction based on Markov process which is focused on the degradation rate by using the inspection results for 829 bridges in NY city. Also has established the assumed top event as a control limit state on the visual inspection of long-span bridges, configured the lower event that causes the top event in the fault tree, and calculated change with time of the occurrence probability of the top event by giving the probability of the backward events in Markov deterioration hazard model.
Dc.Chikata solved combinatorial optimization problem of repair bridges and sites to maximize the total health of the managed bridge group after the repair based on the soundness of the bridge using the results of analysis by quantification theory of

inspection data of Ishikawa Prefecture, by applying the knapsack problem with the aid of gene algorithms.
No study have attempted to suggest the repair priority decision that takes into account the earthquake risk by using the regular inspection data.

3. ANALYTICAL DATA

Ishikawa prefecture conduct regular inspection of the bridges every 5 years. Damage of the bridge can be assessed by regular inspection. Soundness of bridge is determined by damage degree of the bridge, and is recorded as inspection results. We got bridge inspection data in Ishikawa prefecture. The 2314 bridges are managed by Ishikawa prefecture. The 2086 bridges has information of latitude and longitude, address. In this study, the 2086 bridges are adopted for analysis.

3.1 Bridge inspection data

Figure 2 shows example of bridge inspection data. It has various elements and inspection results of the bridge.
Various elements of the bridge : construction year, the number of span, length of bridge, width of bridge, daily traffic volume, much large-sized car traffic volume, address, latitude and longitude, priority levels.
Inspection items: main girder, floor slab, substructure, bearing apparatus, expansion device. Soundness of them has been evaluated in five levels. Soundness has been evaluated in five stages in health order 5, 4, 3, 2 and 1.

Identification number	Years	Length	ASR	Emergency transportation route	Soundness					Priority
橋梁基本番	架設年次	橋長	塩害･ASR	緊急輸送道	主桁健全度	床版健全度	下部工健全	支承健全度	伸縮装置健	優先度指標
23049	1964	34.5	1	指定なし	5	3	3	5	4	70.5
23050	2001	19	0	指定なし	5	4	5	5	4	94
23051	1983	7.2	0	指定なし	5	5	4	5	5	89.5
23052	1963	3.2	0	指定なし	5	5	4	5	5	90.5
23053	1962	5.7	0	指定なし	5	5	4	5	5	90.5
23055	1964	5.6	0	指定なし	5	4	4	5	5	86
23056	1962	2.5	0	指定なし	5	3	3	5	5	73
23057	1962	4.5	0	指定なし	5	4	3	5	5	76.5
93801	1994	14.5	0	指定なし	5	5	3	5	5	78
23109	1991	20	0	指定なし	4	4	4	5	4	75
23059	1991	30	0	指定なし	5	4	4	5	4	84.5
23032	1973	3.8	0	第2次緊急輸送道路	5	3	3	5	5	73
23031	1974	148.4	0	第2次緊急輸送道路	4	4	4	5	4	73
23029	1975	99.9	0	第2次緊急輸送道路	3	5	3	3	3	57
23026	1977	10.5	0	第2次緊急輸送道路	3	4	3	5	5	57.5
23027	1975	37.8	0	第2次緊急輸送道路	4	4	3	3	3	64
23028	1973	27.5	1	第2次緊急輸送道路	5	2	4	5	5	77
21009	1997	52	0	第2次緊急輸送道路	4	4	3	5	4	64.5
22029	1964	6.8	0	指定なし	5	5	4	5	5	87.5
21101	1996	96.8	0	指定なし	4	5	4	5	3	77
21010	2003	19	0	第2次緊急輸送道路	5	5	4	5	5	90.5
21099	1996	38	0	指定なし	5	5	5	5	3	96
21097	1963	5	0	指定なし	5	3	3	5	3	71
22030	1973	36	0	指定なし	4	3	4	3	5	70
22031	1970	10	0	指定なし	4	4	3	3	4	64
22293	1938	7.9	0	指定なし	3	3	2	5	5	45.5
21011	1964	2	0	第2次緊急輸送道路	5	4	3	5	5	77.5
21012	1961	31	0	第2次緊急輸送道路	4	4	4	4	4	75
21145	2003	5	0	第2次緊急輸送道路	5	5	4	5	5	89.5
21146	1999	3.5	0	第2次緊急輸送道路	5	5	4	5	5	89.5
21147	1999	4.2	0	第2次緊急輸送道路	5	4	3	5	5	77.5

Figure 2: Example Bridge inspection data

3.2 Earthquake risk data

We used a probabilistic seismic hazard map of the J-SHIS seismic hazard station. The probabilistic seismic hazard map shows how much each point shake and what probability each point shake on the basis of probability, position and scale of all earthquake in Japan and surroundings. In this study, assuming the maximum case, we used prediction on seismic intensity distribution map that occurred 2% in 50 years. Figure 3 shows that many bridges in Ishikawa will be affected by earthquake.

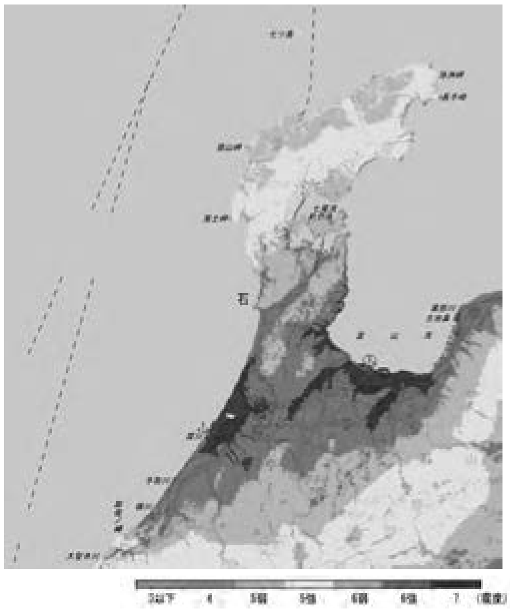

Figure 3: Distribution of seismic intensity (occurred 2% in 50 years)

4. THE BASIC ANALYSIS OF BRIDGES IN ISIKAWA

Figure 4 shows the number of bridge by the year of construction. 513 bridges has passed more than 50 years, 1443 bridges has passed more than 30 years in Ishikawa.
Figure 5 shows the number of bridge by superstructure material. 624 bridges are made of prestressed concrete, 997 bridges are made of reinforced concrete, 277 bridges are made of steel.
Figure 6 shows the number of bridge by length of bridge. The length of the about 65 percent of the bridges is from 2 meter to 15 meter.
Figure 7 shows the number of bridge by emergency transportation route. Primary emergency transportation route and Second emergency transportation route are almost equal, with the former accounting for about 23 percent and the latter about 20 percent. .
Figure 8 shows the number of bridge by prediction on seismic intensity. Bridges in Ishikawa may suffer from damage caused by earthquakes

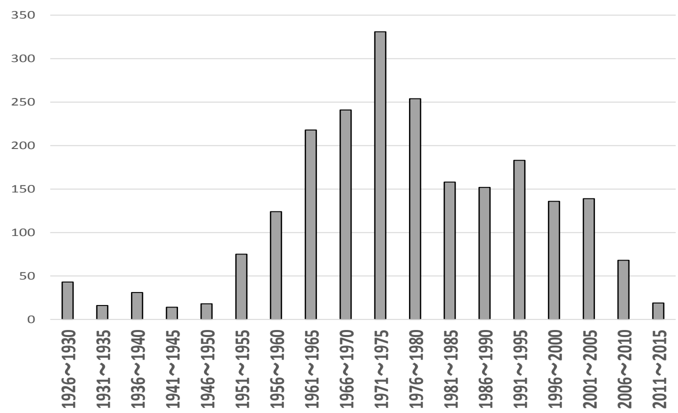

Figure 4: The number of bridges by the year of construction

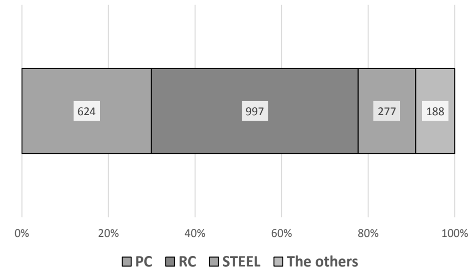

Figure 5: The number of bridges by superstructure material

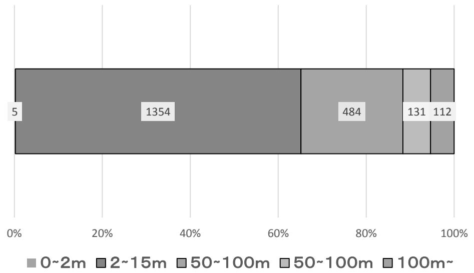

Figure 6: The number of bridges by length of bridge

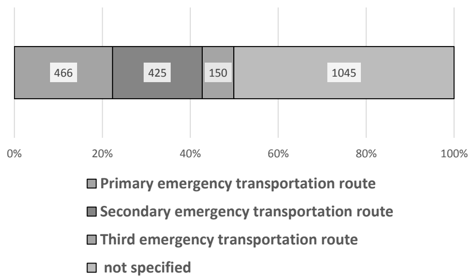

Figure 7: The number of bridges by emergency transportation route

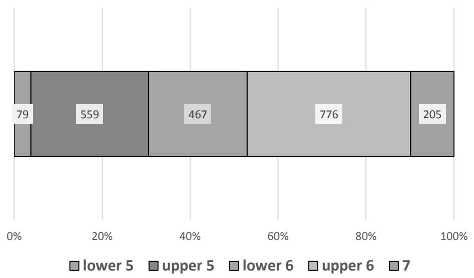

Figure 8: The number of bridges by prediction on seismic intensity

5. ANALYSIS CONDITION FOR PRINCIPAL COMPONENT ANALYSIS

Total score of each bridges was calculated by principal component analysis to decide repair priority taken into account the seismic risk. Importance score of bridge and destruction risk score were used as the variable. Importance score of bridge were taken into account how large impact on traffic at breakdown time, for example “Emergency route”, “Crossing”, ”Daily traffic volume”, “Length of bridge”. Destruction risk score were taken account how high probability of destruction at the time of earthquake, for example “Soundness (Main girder, Bearing apparatus, Expansion device)”, “Seismic intensity”, “Salt damage”, “ASR”.
Soundness has been evaluated in five stages in health order 5, 4, 3, 2 and 1. Figure 9, 10, 11 shows the number of bridge by soundness. Figure 9 shows that the percentage of soundness 5 about main girder was 59 percent. Figure 10 shows that the percentage of soundness 5 about bearing apparatus was 73 percent. Figure 11 shows that the percentage of soundness 5 about expansion device was 64 percent. In comparison with bearing apparatus and expansion device, soundness about main girder was worse.
Table 1, 2 shows the categorization for each variable. Principal component analysis was performed using this categorization.

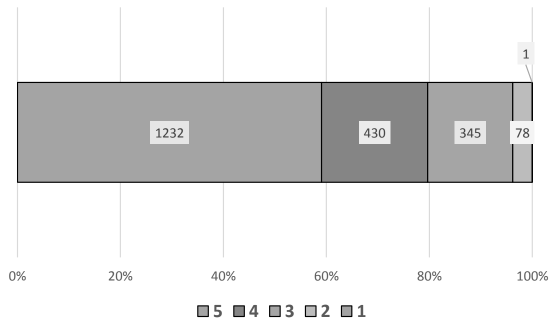

Figure 9: The number of bridges by main girder soundness

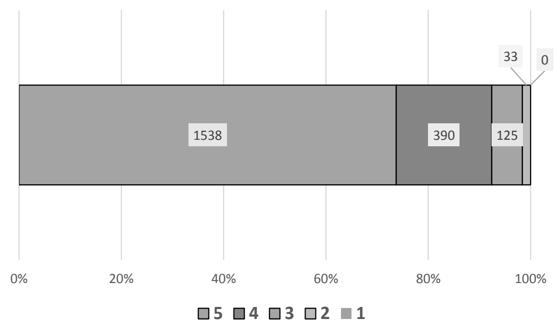

Figure 10: The number of bridges by bearing apparatus soundness

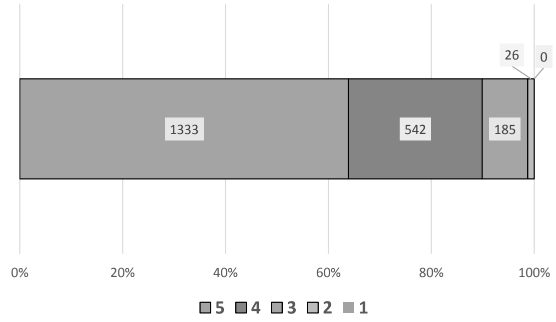

Figure 11: The number of bridges by expansion device soundness

Table 1: Importance of bridge

Item	Subdivision	Importance score
Emergency route	Primary	3
	Second	2
	Third	1
	Not specified	0
Crossing	Railroad,River	3
	Road	2
	The others	1
Daily traffic volume	20000 and over	5
	From10000 to 20000	4
	From 5000 to 10000	3
	From 1000 to 5000	2
	1000 and less	1
Length of bridge	100m and over	5
	From 50 to 100m	4
	From 15 to 50m	3
	From 2 to 15m	2
	2m and less	1

Table 2: Destruction risk

Item	Subdivision	Destruction risk score
Soundness (Main girder, Bearing apparatus, Expansion device)	1	5
	2	4
	3	3
	4	2
	5	1
Seismic intensity	7	5
	Upper 6	4
	lower 6	3
	Upper 5	2
	lower 5	1
Salt damage, Alkali aggregate reaction	Yes	1
	No	0

6. PROPOSAL OF REPAIR PRIORITY

Eigenvalues of the first principal component was 2.029, the contribution rate was 22.55 percent. The first principal component can be total score because all of the first principal component became positive value. Weighting of the variables by the first principal component load quantity got total score of the priority. Figure 12 shows First main component load quantity. Total score was defined as shown equation 1. We compered priority obtained based on a total score with existing priority. Existing priority was classified into five stages based on the priority index obtained by the soundness of the each elements. Priority obtained by principal component analysis was classified into five stages in the order of descending total score. Table 3 shows priority classification.

Figure 13, 14 shows the proportion of priority by prediction on seismic intensity

Figure 13 shows that percentage of bridges of priority 5 in the high prediction seismic intensity was small. Therefore, it clearly shows that how to determine existing priority didn't consider seismic risk.

On the other hands, Figure 14 shows that percentage of bridges of priority 5 in the high prediction seismic intensity was high and percentage of bridges of priority 1 in the low prediction seismic intensity was low. Therefore, it is obvious from Figure 14 that priority obtained by the principal component analysis considered the seismic risk.

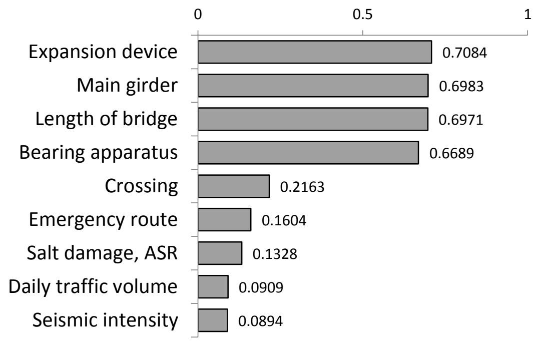

Figure 12: First main component load quantity

$$\text{Total Score} = \sum_{i=1}^{9} \alpha_i x_i \qquad (1)$$

α : The first principal component load quantity

x : The variable

Table 3: Priority levels

Priority	Priority levels
1～417 place	5
418～834 place	4
835～1251 place	3
1252～1668 place	2
1669～2086 place	1

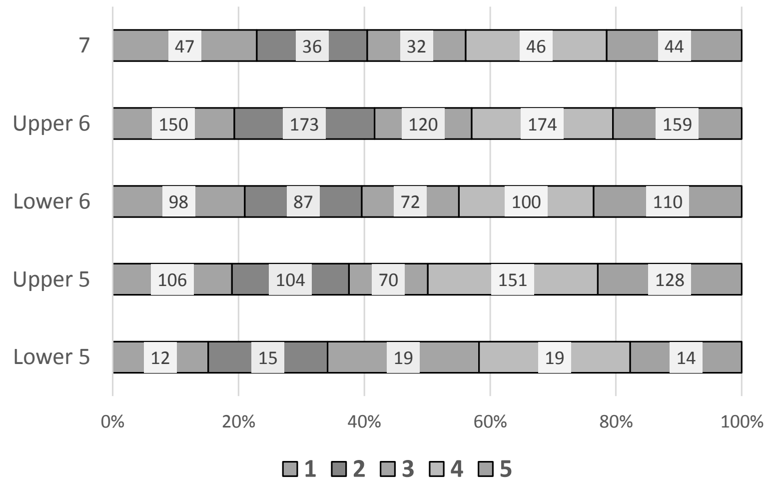

Figure 13: Existing priority levels by seismic intensity

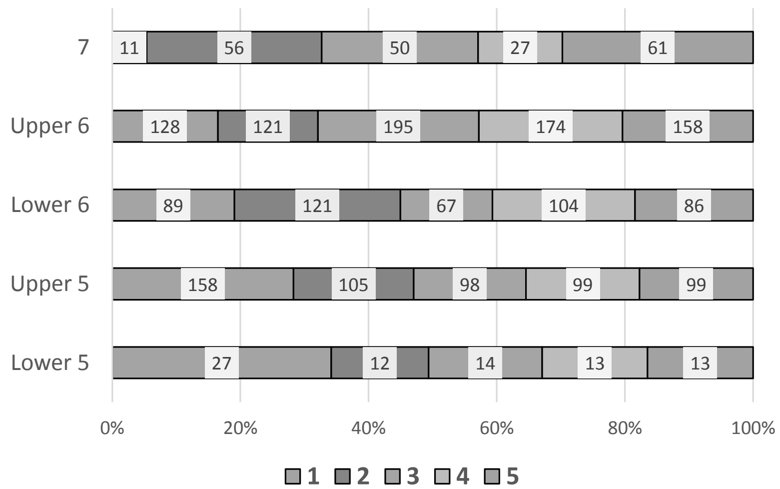

Figure 14: Priority levels in consideration of seismic risk by seismic intensity

7. CONCLUSION

The basic analysis of bridges in Ishikawa was examined using the inspection data of Ishikawa Prefecture

The proposal of repair priority determination method considering the seismic risk was carried out using a principal component analysis. When considering the seismic risk, it was confirmed that the priority of the bridge changed in comparison with the existing method.

A further study of generalization of the inspection order determination method that takes into account the seismic risk using the inspection data of the whole country should be conducted. Also, not only earthquake risk, we are going to do a study of consideration of other disaster risk.

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J-SHIS Japan Seismic Hazard Information Station. http://www.j-shis.bosai.go.jp/

Ministry of Land, Infrastructure, Transport and Tourism. http://www.mlit.go.jp/road/sisaku/yobohozen/torikumi.pdf

Architectural and Structural Characteristics of Indigenous Newari Chhen: Study of Seismic Risk and Resilience in the Historic Urban Nucleus of Bhaktapur City, Nepal

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ABSTRACT

This paper highlights the structural and architectural properties of indigenously constructed Newari houses. This article aims to disseminate the main properties of traditionally houses in the urban center of Bhaktapur in comparison to modern earthquake resistant unreinforced masonry construction. The growing trend of modern reinforced concrete construction has overshadowed the importance of masonry construction in urban areas of Nepal, though a large fraction of buildings are unreinforced masonry structures so that their behavior during earthquakes may be important. This study highlights the features like symmetrical construction, vertical load transfer system, cantilevered load distribution, openings, structural integrity, timber bands, non-structural members, and introduction of special building components, among others. The geometrical properties of building components and their significance have been discussed in this paper so as to correlate with prevalent standards and codes. Through a detailed structural and architectural survey of 42 owner built houses, it observed several features with interest for reconstruction after the 2015 Gorkha earthquake. Culture is inseparable dimension of the society in the study area and the importance is emphasized more by the world heritage site, thus earthquake resistant construction of unreinforced masonry buildings with cultural components is must for Bhaktapur. In this regard, this paper has attempted to identify those features and associated structural sufficiency through detailed survey, phenomenological and archival study and non-structured interviews.

Keywords: *Bhaktapur city, culture, earthquake resistant construction, Newari Chhen, seismic risk, unreinforced masonry construction*

1. INTRODUCTION

Indigenous knowledge and practices in building construction have very long influence and guidance through adoption and subsequent formulation of cultural settlement localized to any geographical boundary. Afterward, such knowledge is propagated to

generations as customs. Indigenous knowledge and practices are dynamic and time variant with frequent combination of contemporary cultures, beliefs and skills.
The growing trend of reinforced concrete (RC) construction has overwhelmed the traditional construction practices globally, though unreinforced masonry structures are dominant over modern RC constructions in indigenous communities of Bhaktapur city till date. In many past earthquakes, masonry structures have shown significant resilience against the ground shaking and amplification so assessing features of masonry buildings is nowadays more pronounced. During many past earthquakes, traditional masonry buildings constructed with timber components survived significantly (e.g. Boen, 2001; Decanini et al., 2004; Gulkan and Langenbach, 2004; Bothara et al., 2007; Audefroy, 2011; Langenbach, 2010; Siswanto et al., 2013; Gautam, 2014a). In this context, the genius aspects of traditional construction practices need to be analyzed with regard to seismic response. Previous studies have figured out some earthquake resistant features in monumental buildings in Kathmandu valley (Bajracharya, 1982; Dixit et al., 2004; Shrestha et al., 2004; Sinha et al., 2004; Dixit et al., 2008; SDMC, 2008; Jigyashu, 2013; Gautam, 2014b). However, detailed assessment of residential buildings and detailing earthquake resistant features and geometrical properties have been felt more in recent dates only.

While identifying the earthquake resistant features of unreinforced masonry (URM) buildings (Newari Chhen) of Bhaktapur city, this study attempts to figure out the construction technology, technology transfer, geometric and architectural specifics, earthquake resistant features and recent trend of incorporation of indigenous knowledge in construction scenario. The features have been justified by reconnaissance immediately after the 2015 Gorkha earthquake as well.

2. SEISMIC HAZARD IN THE STUDY AREA AND NEPAL

Nepal is situated amongst the world's seismically most active region, so frequent earthquake events and associated damages are common. As Nepal lies in the convergence zone of Indian plate beneath the Eurasian plate leading the entire region one of the most seismically active region of the world. Also, Nepal is placed in the 11th place by The Bureau of Crises Prevention and Recovery of the United Nations Development Program (UNDP). Events like the earthquake of 1255, 1833 M_L 7.7, 1934 M_W 8.1, 1988 M_L 6.5 (Dixit et al., 2013) and 2015 M_W 7.8 Gorkha earthquake show the severity of impact clearly. In these events, the preponderance of the observed damage is concentrated in Kathmandu valley. Global seismic hazard map designates Nepal in Zone IV with the possible shaking of MMI-IX or above with 10% probability of exceedance in 50 years (JICA, 2002). In addition to this, the local soil condition dominates the peak spectral acceleration and amplification factor even in a small spatial variation (Chamlagain and Gautam, 2015).
The start of modern reinforced concrete construction began in the major urban centres of Nepal some thirty years back, and concentrated in the Kathmandu valley and other urban centres. However, it nevertheless supplanted the traditional URM construction practices in some of the urban nuclei, like Bhaktapur; where unreinforced masonry construction is dominant comprising of more than 90% buildings (Gautam, 2014b).

3. METHODOLOGY

In order to identify the genius features of traditional Newari houses of Bhaktapur city, 42 owner built URM houses from 14 different wards (three houses from each ward) of the municipality were selected. While selecting the sample houses, at least throughout timber band(s) was assured. Due to difficulty in identifying the housing components in row houses, isolated houses were chosen. The number of isolated houses is very less throughout the city; so three houses constructed at least 40 years before were selected for study. Structural integrity, ductile connections, load concentration and distribution, roofs, overhangs and other commonly noticed defects of masonry buildings were checked on field with a checklist. Some geometrical features were also measured in field as well. The findings are presented in terms of weight distribution, plan and elevation symmetry/asymmetry, provisions of bands, roofing materials, binding materials, projections, load path continuity, building proximity, openings, foundation site condition and plinth, wall dimensions and number of stories, non-structural members, geometrical and architectural specifics, among others. Phenomenological studies across the city were also conducted for identifying and validating the buildings features incorporated during field survey. Non-structured interviews, library and archive consultations were also performed for identifying and formulating the seismic risk, resilience and structural as well as non-structural preparedness technologies adopted locally.

4. RESULTS AND DISCUSSION VIS-À-VIS SEISMIC RISK AND RESILIENCE

Most of the studied *Newari chhens* were found to be composed of three storied houses consisting of *chheli* (ground floor), *matan* (first floor), *chota* (second floor) and sometimes *buigal* (terrace). Exterior walls were usually found to be constructed as thick layers up to the third storey and subsequently reduced in upper storey. The upper storey is constructed of similar type of material. As per the utility; *chheli* is commonly used for storage and occupational purposes/activities and *matan* is used for living, sitting and bed room purposes. *Chota* is used for kitchen, dining and worshipping purpose (as *pooja* room). Geometrical properties of studied buildings in terms of wall thickness, storey height, building dimensions, opening dimensions have been presented in table 1. At the meantime, other findings have been disseminated in detail under following heads.

Table 1: Geometrical properties of various components of *Newari chhen*

Building components	Mean (m)	Standard deviation
Wall thickness	0.42	0.08
Storey height	1.84	0.05
Length of building	10.28	0.12
Width of building	6.85	0.09
Height of khapa	1.35	0.10
Length of khapa	0.65	0.06
Height of jhya	0.71	0.05
Length of jhya	0.36	0.06
Average building height	8.05	0.08
No. of storeys	3.5	0.03

4.1 Bands at various levels

Plinth band was found placed immediately above the plinth using a wooden flake throughout the wall. Such bands usually contribute in bearing the differential settlements. The foundation soil below plinth is soft due to prevalence of loose fluvio-lacustrine soil. Though purpose of such band was not justified while incorporating as a construction component, it has positive influence upon seismic performance of buildings. During reconnaissance immediately after the 2015 earthquake, houses with plinth/sill/lintel bands were found to be more resilient than those without plinth and wooden plinth bands. Wooden bands are found to be extensively used in every *chhen* and are contributing in integrity of structure and resistance to out of plane wall bending. The level of openings is usually found incorporated with lintel bands. Moreover, lintel band and the gable band, performing similar function like that of the lintel band, also effectively incorporate prevention of roof collapse.

4.2 Building configuration and dimensions

A rectangular configuration walls restricting any re-entrant corners usually compose URM houses. At the meantime, buildings are typically constructed as row houses joining walls and other components throughout the city. Due to this procedure, storey heights were found constant. This practice usually prevents the pounding effect in the aggregate. The average length of wall is about 10.3m with the standard deviation of 0.12; whereas the average width is 6.85m at the standard deviation of 0.09 (Table 1). This suggests length to width ratio to be less than 2, which is well within the limit of 3 as per Nepal Building Code (NBC 205) (NBC, 1994). Lower value of this ratio justifies most of the modern URM construction practices and codes as well; however there was no any prevalent code of practice during construction of studied houses.
All the studied buildings were found to be simple rectangular in configuration (Fig. 1); with a proper configuration in accordance with modern construction practices.

Fig. 1 Symmetrical matchbox construction practice at Bhaktapur

Most of the houses were constructed at least four decades earlier than introduction of earthquake resistant building construction practice in Nepal in 1994. A matchbox type-building configuration was found to be prevalent in studied buildings and throughout the city in the field survey.
Openings in *Newari Chhen* were found in the form of windows and doors; at the meantime their construction mainly dominates typical cultural forms of windows.

These forms are *tiki:jhya* (lattice window), *sa: jhya* (relatively larger opening in *chota*), *ga: jhya* (depressed window) and *khapa* (door with smaller dimensions). In case of openings, all of these were heartwood timber elements tied properly with the structural wall systems. Moreover, in case of openings, smaller openings are preferred instead of larger ones and avoiding the arches above openings.

4.3 Elevation and stories of buildings

Average height of houses is found to be 8.05m at the standard deviation of 0.08 and average stories of houses are depicted to be 3.5 (Table 1). Figure 2 represents the frequency of buildings in terms of their storey heights separately. Each of the *chheli*, *matan*, *chota* and *baiga* has different heights as per the purpose of utility and mobility. However, such difference is height is not large and primarily low storied houses are found throughout the city.

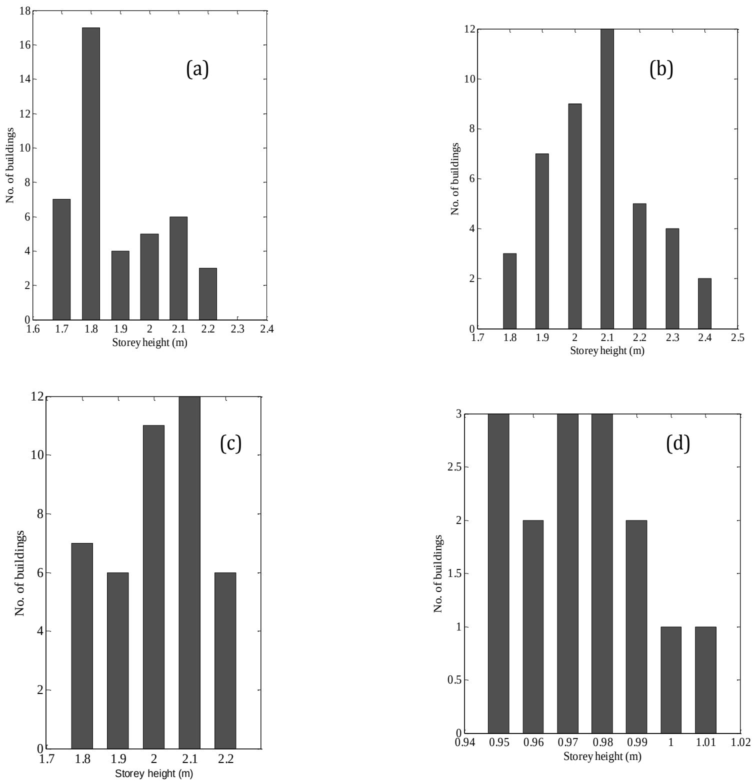

Fig. 2 Height distribution of (a) *Chheli* (b) *Matan* (c) *Chota* and (d) *Buigal*

Usually *matan*, which is used for living purpose is found to be having the greatest height upto 2.07m in average; however all other stories are found to be having smaller height than that of the *matan*. *Baiga*, which accommodates roof, either thatched with *jhingati* (roof tile) or even the corrugated sheets, is found to be having its height less than 1m. Immediately after the 2015 Gorkha earthquake, field reconnaissance was performed and hence the majority of damage is found to be concentrated in upper stories.

4.4 Wall system

Building materials were identified as *appa* (sun dried clay bricks) or *si appa* (non-burnt clay brick), though compressive strength of such bricks was nevertheless verified. However, Japanese specialists during the study on earthquake disaster mitigation in Kathmandu valley experimentally verified that the traditional bricks were stronger than expected and prohibit the pancake destruction unlike the RC construction (JICA, 2002) leading a strong evidence of resilience of such structures during many past earthquakes like 1934 Bihar-Nepal earthquake, 1988 Udyapur earthquake, 2011 Sikkim-Nepal border earthquake and 2015 Gorkha earthquake. While at the level of *chota*, the wall thickness decreased and above this storey, usually smaller wall thickness is provided. Projections were not observed frequently on walls though some projections in terms of wooden *ga:jhya* were observed with struts supported beneath it.

4.5 Other building features

Struts are observed to be connecting the roof to the lower stories usually the *chota*, and sometimes used for aesthetic purpose in the form of *tudals* (struts with carved appearance within the timber element) as well. Struts are significant in transferring the cantilevered load to the continuous and regular load path, thus during vibration, detachment of cantilevered portion is usually prevented. Beside the architectural purpose, struts help to reduce the problem of vertical deformation in case of cantilevered load leading to improvement building behaviour during earthquakes. Without struts, even minor vertical earthquake may cause damage in the houses.

In traditional buildings, vertical transportation system is provided by *sona* (moveable timber ladder) of low weight within a staircase opening found in corners of buildings. Use of such timber ladder has reduced the load of non-structural members in greater extent as most of modern constructions are experiencing wider damage in non-structural members. Ladders are assembled with small pieces of wooden flakes having low weight.

Newars are gregarious culturally and they establish settlements as row housing. Beside construction of row housing, height of every storey is found to be almost similar as most of such houses were built by the similar technology and craftsmanship.

During this study, some of additional features of houses are identified, which have significant contribution during earthquakes like; vertical corner post, wooden pegs at various levels, and double boxing of openings.

5. CONCLUSION

Indigenous housing technology has been significantly playing an important role in the survivability and sustainability of unreinforced and traditionally built houses in seismic zones. During past events, many of such buildings survived significantly. People usually develop unique coping mechanism through unrelenting trials and errors and experiences. Such knowledge system is reflected in prevalent construction technology and institutionalized as a custom for the built environment. While analysing the indigenous knowledge of housing construction in the world heritage site and vicinity in historic urban nucleus of Bhaktapur city, it has been concluded that some excellent features regarding earthquake resistant constructions were introduced into the *Newari chhens*. Based on detailed survey of 42 houses and other phenomenological studies and non-structured interviews, the features like structural integrity, wall system, smaller openings, subsequent load reduction in upper stories, provision of bands at various levels, horizontal diaphragm, struts, proper rectangular configuration with low length to width ratio, opening dimensions, among others have been identified in residential buildings of Bhaktapur city. These features are widely accepted in terms of structural performance and reduction of damage level worldwide.

In the National Building Code of India, indigenous knowledge of building construction has been provisioned for encouragement and blending with the modern technologies. Moreover this code has kept indigenous knowledge as an approach to sustainability (BIS, 2012). Till date Indian code is widely followed in Nepal. In this regard, assuring cultural reconstruction may be pivotal in city sustainability. Likewise, in Dhajji construction guideline has been prepared and practiced in Pakistan with special reference and promotion of indigenous constructions (UN Habitat and National Disaster Management Authority, Pakistan, 2009). Regional paradigm from these two evidences could be replicated in Nepal National Building Codes through sustainability approach.

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Shake table tests on one-quarter scaled models of masonry houses retrofitted with fiber reinforced paint

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ABSTRACT

Over the last century, the greatest proportion of fatalities caused by earthquakes have been attributed to the collapse of masonry buildings most of which were constructed by local people with no engineering background using locally available materials without following structural code. These masonry houses and buildings, which are called non-engineered structures and distributed in seismic areas around the world (Coburn and Spence, 2002), collapse very rapidly even in low intensities of ground shaking. Therefore, seismic strengthening of existing and new masonry buildings is vital regarding earthquake disaster mitigation in the world and many methods have been developed to improve their seismic capacities. However, most of methods are time-consuming and labor-intensive, but not attractive as they don't directly increase amenity of the life of residents, which slowed down the spread of these methods. In our research group, a much easier new method has been developed using SG-2000, a kind of newly developed paint. Paint is commonly used for buildings (Yamamoto, 2014). Based on the results obtained from previous tests, wallettes coated with SG-2000 have approximately 14 and 16 times larger deformation capacities in cases of in-plane and out-of-plane tests, respectively, than those of the unreinforced masonry wallette. In this research, we have conducted shake table tests using one-quarter scaled models of a masonry house retrofitted with SG-2000 to investigate its dynamic failure behavior, crack patterns, and total seismic capacities.

Keywords: *masonry, seismic retrofitting, fiber-reinforced paint, shake table test*

1. INTRODUCTION

In the last century, there were many earthquakes and they have caused a total loss of life exceeding 1.53 million people. Masonry buildings are highly vulnerable and common in seismic areas around the world. Therefore, the collapse of masonry buildings is the major cause of the deaths in the past earthquakes in the world. Besides, much of the increased populations in developing countries continue constructing these structures and using them (Coburn and Spence, 2002). Therefore, retrofitting masonry structures is one of the most important issues for reducing casualties by earthquakes in the world. Also, seismic retrofitting ultimately reduces the costs for recovery from earthquake disaster (reduces the cost of rescue and first aid activities, rubble removal, temporary residence building, and permanent residence reconstruction to re-establish normal daily life) (Yoshimura and Meguro, 2004).

To retrofit these structures, many seismic retrofitting techniques (Shotcrete, FRP and so on) have been developed (Amiraslanzadeh et al., 2012). However, these techniques need much time and labor, but they are not attractive for local people because these methods don't improve the quality of lives. These facts have delayed these techniques' spreading in developing countries. Considering these problems, a new retrofitting technique using glass fiber reinforced paint (SG-2000) has been suggested. The material needed for this technique is only SG-2000, which significantly reduces the amount of time and labor for retrofitting. Also, paint is usually used to make houses look fine, and many masonry structures are coated with paint. Therefore, SG-2000 can be easily used by local people as the form of paint. The experiments in-plane diagonal shear tests and out-of-plane bending tests showed that wallettes coated with SG-2000 whose ratio of fiber was 1.5 % achieved larger deformation capacities than unretrofitted wallettes did (Yamamoto, 2014).

In this study, a shake table test using one-quarter scaled model of a masonry structure retrofitted with SG-2000 was conducted to investigate its dynamic responses.

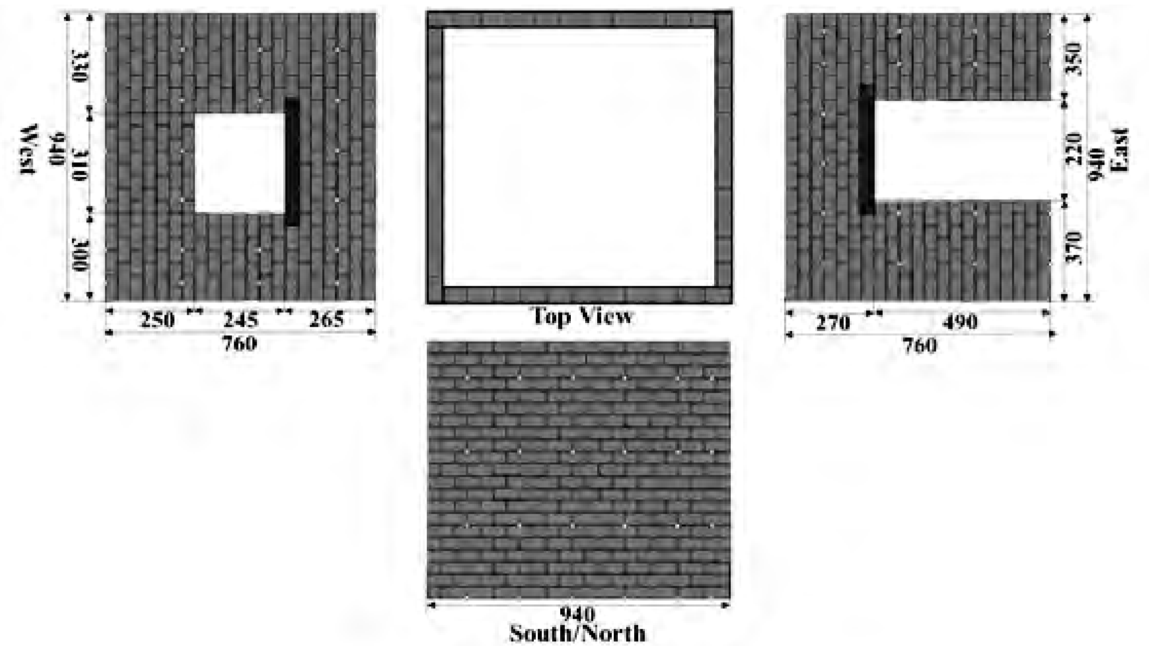


Figure 1: the dimension of the model house

2. EXPERIMENTAL SET UP

2.1 Specimen

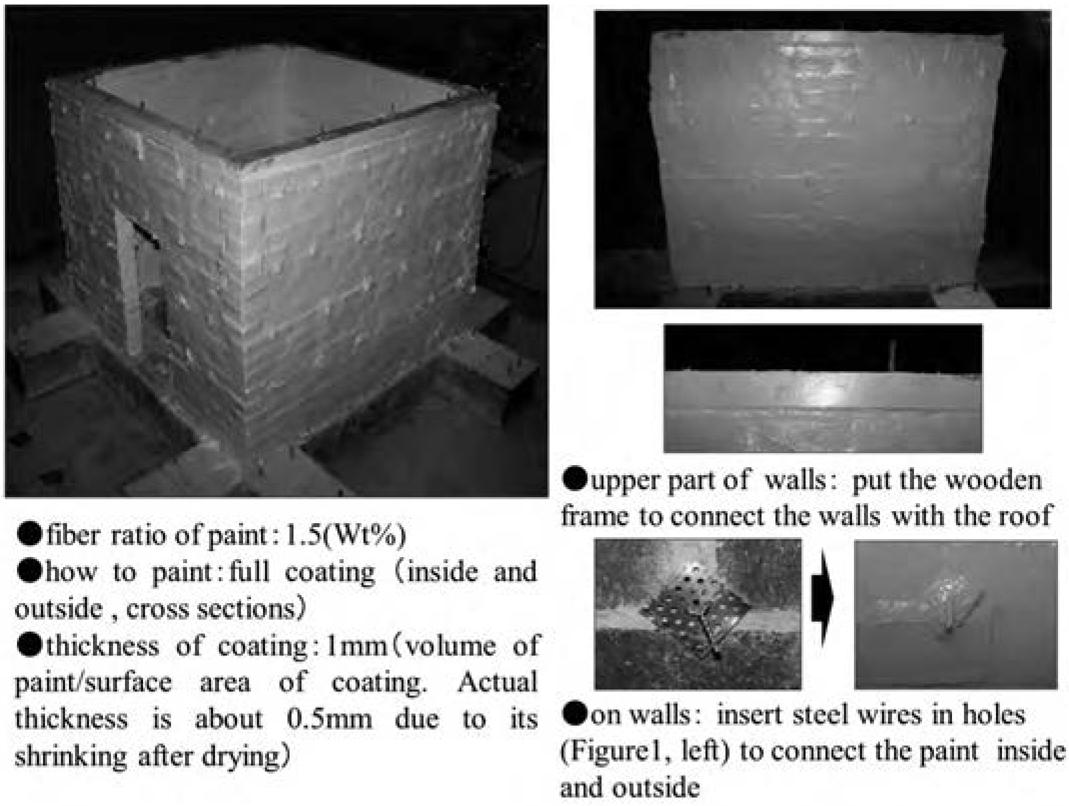


Figure2: Retrofitting procedure

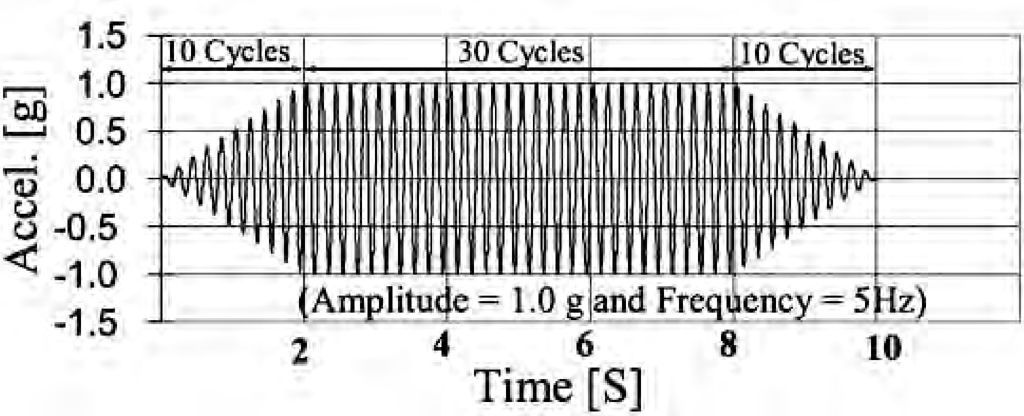


Figure 3: Typical shape of input sinusoidal wave motion (Meguro et al., 2005)

The specimens were built with burnt bricks in reduced scale (1:4). Joints between bricks were filled by mortar with c/w ratio of 0.14 (cement:lime:sand=1:7.9:20). These materials were made in Japan, but the specimens were made with great attention that it could be a suitable replica of masonry buildings in developing countries, following previous experiments conducted by our research group (for example: Meguro et al., 2005). The model was one-story building with roof, with the dimensions of 940mm940mm×760mm with 50mm thick walls and the sizes of door and window on the east/west walls were 220mm×490mm and 310mm×245mm, respectively as shown in Figure1. The dimension of the bricks used was 75mm×50mm×35mm and the same bricks had been used for the previous experiments conducted by our research group.

2.2 Retrofitting Procedure

Straws were put to make the holes placed approximately 200mm pitch as shown in Figure2 while constructing the house model. Before coating SG-2000 on the wall, steel wires were inserted to connect inside and outside of the wall. After inserting wires, we coated SG-2000 fully on the wall with 1mm thickness.

2.3 Experimental Equipment

The test was conducted using the shake table facility available in IIS, the University of Tokyo. The size of the shaking table is 1.5m×1.5m. It has six degrees of freedom and it can produce waves whose frequencies ranging from 0.1 to 50 Hz. Its maximum displacement capacities are ±100mm and its maximum capacity of weight is 2 tons.

2.4 Acceleration and Input Motions

Totally 54 runs were conducted applying sinusoidal wave motions whose frequency and amplitude range from 35Hz to 2Hz and 0.05g to 1.4g respectively to investigate the dynamic response of the house model retrofitted with SG-2000 (Figure 3, Table 1). The number of cycles was constant for all runs and therefore the lower the frequency of the run's wave is, the longer the run endures. The experiment was started with a sweep motion whose amplitude is 0.05g and frequency changes from 60 to 2 Hz to identify the dynamic property of the model. The sequence of these runs was determined by the values of the Japan Meteorological Agency (JMA) seismic intensity of JMA scale from smaller to larger one.

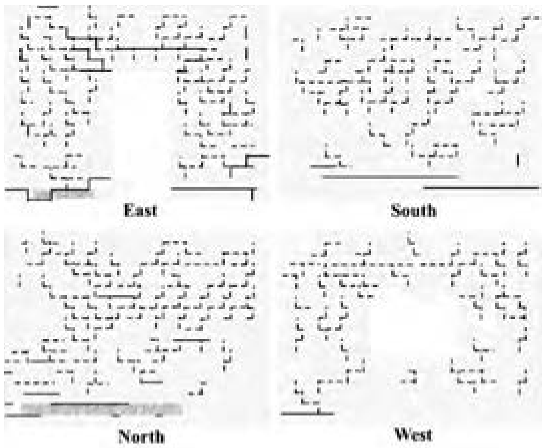
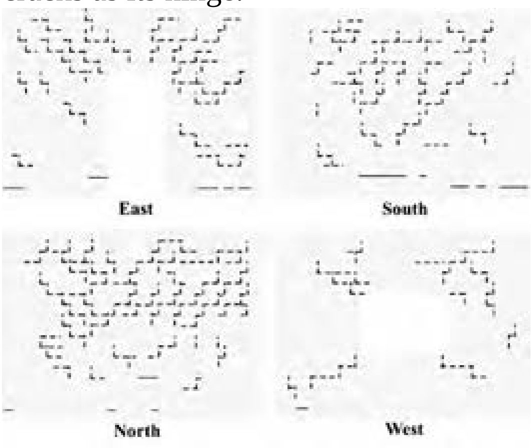
Table 1: Loading sequence

Amplitude	Frequency(Hz)							
	2	5	10	15	20	25	30	35
1.4g		50						
1.2g	54	49						
1.0g		48						
0.8g	53	47	43	40	37	34	31	28
0.6g	52	45	42	39	36	33	30	27
0.4g	51	44	41	38	35	32	29	26
0.2g	46	25	24	23	22	21	20	19
0.1g	18	17	16	15	14	13	12	11
0.05g	10	09	08	07	06	05	04	03
Sweep	01,02							

3. CRACK PROPAGATIONS AND FAILURE BEHAVIOUR

The crack patterns were investigated and marked after each run. Broken lines were drawn on the part where cracks are only inside the coating, and Solid lines were drawn on the part where the coating was also damaged. The highlight of the crack patterns were in the Table 2.

Table 2: Highlight of crack pattern and failure behavior (~Run50)

<table>
<tr><th>~ Run 39</th><th>Run 50</th></tr>
<tr><td>There was no crack observed on the surface of coating and the cracks inside the coating could not be recognized well because of the small motions.</td><td rowspan="3">There were heavy damages to mortar joints inside the coating. Also, the coating was heavily damaged on the bottom part of the east wall and therefore there was a separation between the first and the second layer of bricks. There were not so much damages to the coating on the west wall, which had larger stiffness than on the east wall. Therefore, the east wall rotated when shaking with the west wall as the center of rotation.
The gray area indicates where the coating had been totally separated from bricks due to the lack of adhesion.
</td></tr>
<tr><td>Run 42</td></tr>
<tr><td>A small damage to coating was observed at around the bottom of the east wall, which has the smallest stiffness of all walls.
According to the motion of the wall when shaking, some parts inside the coating were thought to be damaged. On the out-of-plane direction, most of the part from the middle to the top is damaged inside and these damaged parts have been shaked by making those cracks as its hinge.
</td></tr>
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4. ANALYSIS BASED ON JMA SCALE

4.1 Damage Evaluation

The damage levels of house models during shake table test have been evaluated based on the same damage categories used in previous experiments carried out by our research group as shown in Table 3 (for example: Meguro et al., 2012). Also, all the runs have been conducted in a certain order based on the JMA seismic intensity scale. This JMA scale is an indicator of the strength of earthquake ground motions used in Japan. The comparison between the performances of two model houses (non-retrofitted and retrofitted with SG-2000) is shown in the Table 4.

Table 3: Highlight of crack pattern and failure behavior (Run50~54)

Run 52	**Run 54**
Some part of the wall on the east wall was separated from the house, but did not fall down as the coating connected the part and the south wall.	Totally collapsed. However, the coating connected bricks after the structure had been broken, which produced some rooms inside the rubble. 
Run 53	
All part of the east wall was separated with the diagonal cracks on the coating that had been produced in the previous runs. So far there was no dust and no bricks falling down inside the house. 	

Table 4: Damage categories (Meguro et al., 2012)

Category	Damage extension
D0: no damage	No damage to structure
D1: light structural damage	Hair line cracks were observed in very few walls. The structural resistance capacity did not decrease noticeably.
D2: moderate structural damage	Small cracks were observed on masonry walls. The structure resistance capacity decreased partially.
D3: heavy structural damage	Large and deep cracks were observed on masonry walls. Some bricks are fallen down. Failure in connection between two walls was observed.
D4: partially collapse	Serious failure and partial structural failure were observed on walls and roofs, respectively. The building was in dangerous condition.
D5: collapse	Structure was totally or partially collapsed.

From these results, it is concluded that the house retrofitted with SG-2000 could save the lives of the residents, but could not be used after a large earthquake because of its heavy structural damage.

4.2 Energy Dissipation Capacity

The energy dissipation capacity is one of the key parameters for discussing three seismic capacities of structure that a house has to have in order to resist an earthquake.

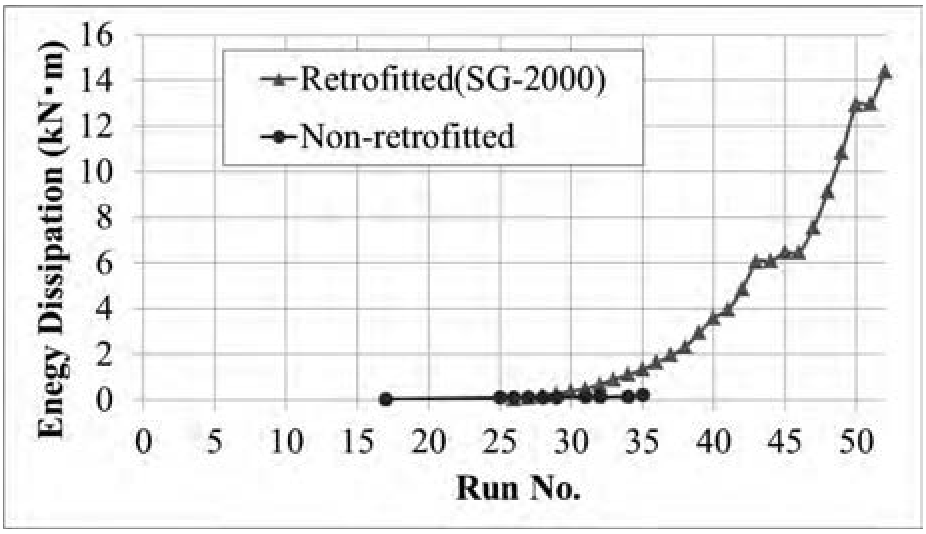
It is calculated by cumulating the area of each cycle in the hysteresis loop of the graph of total force and horizontal displacement at the top of the house model.
The energy dissipation capacity of the retrofitted house was much larger than that of non-retrofitted house as shown in Figure 4.

Table 5: Performance evaluation based on input motion intensity by JMA scale

Non-retrofitted																																					
Retrofitted with SG-2000																																					
Amplitude (g)			0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.4	0.8	1.0	1.2	1.4	0.4	0.6	0.8	1.2
Frequency (Hz)			30	25	20	15	10	5	35	35	35	30	30	30	25	25	25	20	20	20	15	15	15	10	10	10	5	5	2	5	5	5	5	2	2	2	2
JMA scale			4																								5-			5+		6-				6+	7
Run No.	01	•••	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

D0: No damage	D1: Light structural damage	D2: Moderate structural damage
D3: Heavy structural damage	D4: Partially collapse	D5: Collapse

Figure 4: Comparison of energy dissipation capacity between non-retrofitted and retrofitted structures



5. CONCLUSION

We compared the results of shake table tests using 1/4 scaled masonry of unretrofitted and retrofitted with SG-2000 as the retrofitting material. As the SG-2000 did not improve the structure's stiffness, the damage inside the coating was observed in the same way as the unretrofitted house. On the other hand, SG-2000 connected bricks after the mortar joints of them had been broken. It is concluded that SG-2000 improves both the structure's deformation capacity and energy dissipation capacity, and make the structure resistant against much larger ground motions. Also, SG-2000 covers the mortar joints and bricks, and therefore it prevents the dust from spreading and bricks from falling down inside the house. From the failure pattern of the retrofitted house,

SG-2000 could save the lives of residents in earthquake, but could not enable them to use the house again because of its heavy structural damage.
Future researches should improve SG-2000 as it prevents heavy structural damage so that the residents can use the retrofitted house even after a large earthquake.

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Earthquake Response Analysis of Five-Storied Pagoda Considering Rocking Motion

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ABSTRACT

We have many traditional timber structures such as temples and shrines in Japan. Recently the preservation and utilization of such buildings has been increasing. Therefore even traditional buildings need sufficient aseismic performance in order to use them safely. However many traditional timber buildings have been built by the knowledge and experiences of carpenters. In order to understand their seismic capacity, we need to increase quantitative data to evaluate the earthquake-resistant performance of traditional timber structures. In this paper, we focused on the seismic evaluation method of five-storied pagodas. A previous research pointed the effect of the bending deformation of a whole building on the vibration characteristics of a pagoda. In addition, it said a bending deformation was caused by the rocking behavior of each floor. In this research, we developed the three dimensional model of five-storied pagoda considering rocking motion and conducted non-linear dynamic analysis. We focused on the vertical stiffness of a roof truss and Kumimono on cloumns as the structural elements causing rocking motion. In a previous study, shaking table tests were performed with our simulating five-storied pagoda model. Analysis results were compared with the test results.

Keywords: traditional timber structure, five-storied pagoda, earthquake response analysis, non-linear dynamic behavior, Kumimono

1. INTRODUCTION

It is said that five-storied pagodas have a good seismic performance because no five-storied pagoda have collapsed against earthquakes in Japan. There are some various theories about the seismic capacity. However it is not clarified why five-storied pagodas have aseismic performances. A previous research (Kawai, 2007) pointed the effect of the bending deformation of a whole building on the vibration characteristics of a pagoda. It said a bending deformation was caused by the rocking behavior of each floor, and compressive strain inclined to the grain will happen at the parts of *Kumimono* etc., when each floor moved rocking motion. The previous research (Kawai 2007) developed the model considering the vertical stiffness of *Kumimono*, which means bracket complexes and is between columns and roof in traditional temples and shrines, and roof truss. But the stiffness was evaluated by adjusting the period of analysis model to the result from a micro tremor measurement. In this research, we focused on the vertical stiffness of a roof truss and *Kumimono* as the structural elements causing rocking motion. We conducted the compression tests of *Kumimono* and developed the evaluation method of vertical stiffness of *Kumimono*. The model method of roof truss was applied from the evaluation method. The three dimensional model of a five-storied pagoda considering rocking motion was developed and earthquake response analysis was conducted.

2. ANALYSIS MODEL

2.1 Object model

The simulated five-storied pagoda was the one-fifth scaled model of *Asuka* Style Five-Storied Pagoda used in a previous research (Chiba, et.al, 2005). (Figure 1) shows the picture of the object building. Shaking table tests were conducted with it in the research. Therefore we chose the model because we could compare analysis results with experimental ones. The height of the top of the model was 6.607m. The size of the first floor was 1.296 x 1.296m.

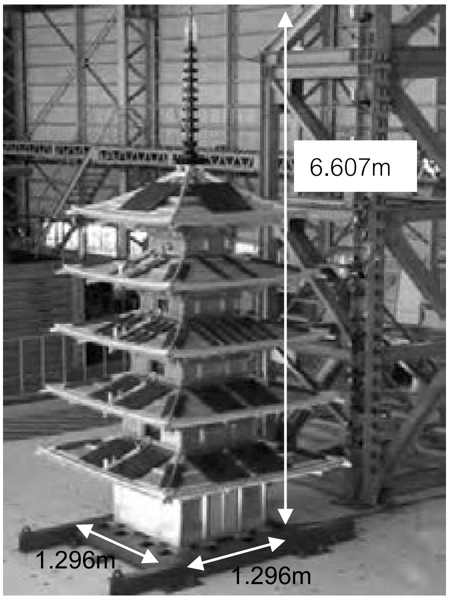


Figure 1: Object model (Chiba, et.al, 2005)

2.2 Modelling method

A three dimension analytical model like (Figure 2) was developed. All columns and horizontal members considered as a structural element were replaced with member elements in the model. In addition, all earthquake resisting elements considered in the pagoda model were replaced with spring elements. The aseismic elements were the following six things and were shown in (Figure 3).

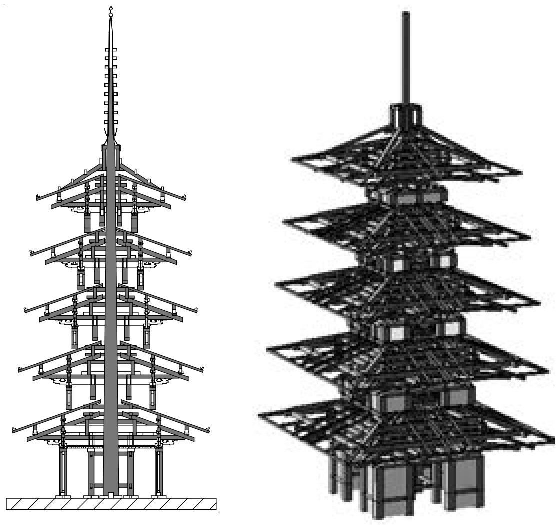


Figure 2: Analysis model

1: Rotational stiffness of restoring force of columns
2: Rotational stiffness of column-*Nuki* joints
3: Shear stiffness of wall
4: Shear stiffness of *Kumimono*
5: Vertical stiffness of truss roof
6: Vertical stiffness of *Kumimono*

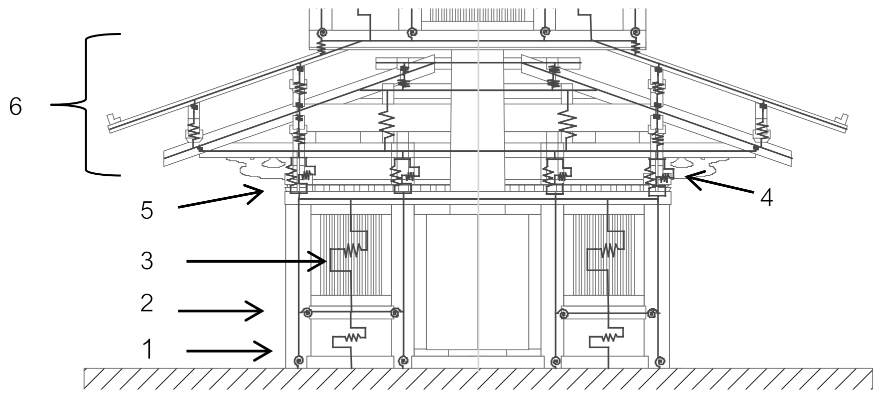
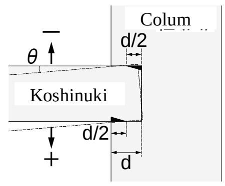
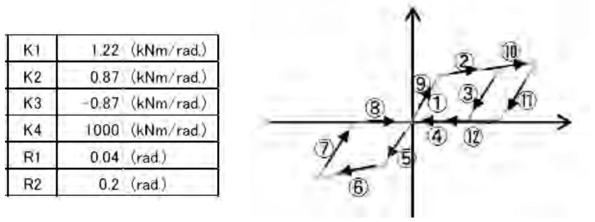
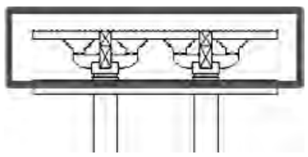
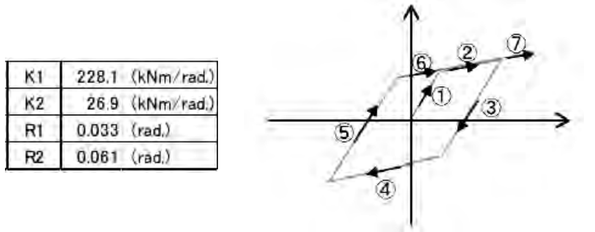


Figure 3: Earthquake resistant elements

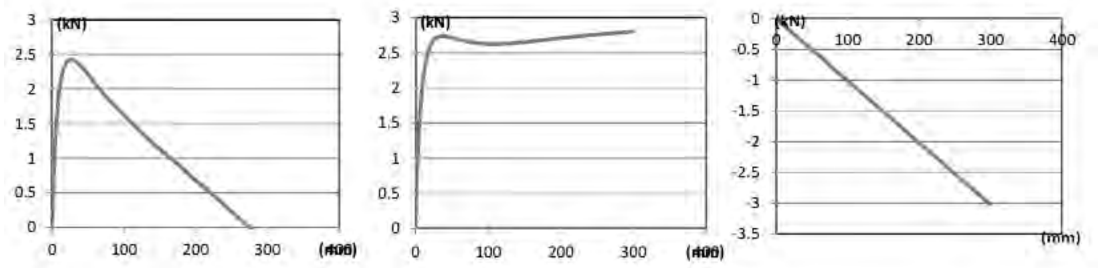
Stiffness was evaluated based on previous researches and theories. The restoring characteristic for No.2 and No.4 of a spring was like (Table 1). No.2 was set based on a shaking table test results from our previous research (Tsuwa, 2006). The test was conducted with one frame modeled *Asuka* Style pagoda, and composed by two columns, *Nuki* and *Kumimono.* The building style of specimen was same as this analysis model. The specimen was 2/3 scale model. This analysis model was 1/5 scale model. It is supposed that rotational stiffness at a column-*Koshinuki* joint occurred by compressive strain inclined to the grain at the joint. Therefore it was assumed that the rotational

stiffness was proportional to the ration of a size and was calculated with the results of the shaking table tests of frames.
The shear stiffness of *Kumimono* was calculated based on previous research (Fujita, 2001).

Table 1: Some comments on tables

<table>
<tr><th>Structural element</th><th>Hysteresis Curve</th></tr>
<tr><td>Koshi-nuki (No2. in Figure 1)

</td><td>
</td></tr>
<tr><td>Kumimono (Shear Spring No.4 in Figure 3)
</td><td>
</td></tr>
</table>

The restoring characteristic of rotational stiffness of columns was set like (Figure 4 (b)) based on a previous experiment (Ban, 1942) and research (Kawai, 1992). The analysis soft includes the effect of P-delta. On the other hand, the restoring characteristics of columns are usually defined like (Figure 4 (a)). It also includes the effect of P-delta. To be called, the effect is counted for twice. Therefore the effect was subtracted from the characteristic of the previous research.



(a) Characteristic from a previous research (b) Characteristic in analysis (c) The effect of P-delta

Figure 4: Characteristic of rotational stiffness at a column

The compression stiffness of materials in a truss roof and *Kumimono* which means bracket complexes was modeled as vertical stiffness of those elements. (Figure 5) shows the evaluation method of the compression stiffness for a part of *Kumimono* as an example. The vertical stiffness was calculated by the following (equation 1).

$$K_n = \frac{E_{\perp} A}{L_n} \qquad (1)$$

where Kn = vertical stiffness, E = Young's modulus for compression perpendicular to grain of the wood, A = area being subjected to pressure, Ln= the length of an element and n =1, 2, 3.

A was defined as 20% of the contact area with components of *Kumimono*. This equation was derived by compression tests of *Kumimono* (Figures 6) (Ryno et. Al., 2012).

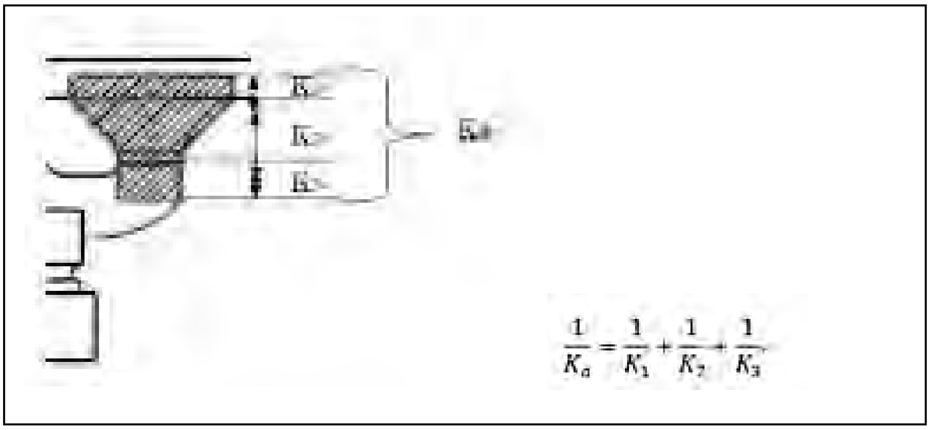


Figure 5: The evaluation of compression stiffness for roof and *Kumimono*

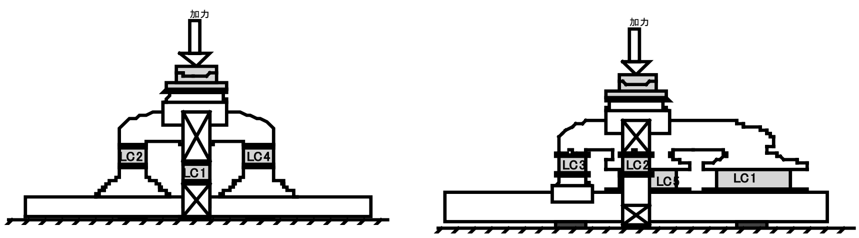


Figure 6: Compression tests of *Kumimono*

2.3 Analysis method

We utilized the analytical program improved "wallstat" developed by Building Research Institute. Distinct Element Method (DEM) was used in the program. Viscous damping was in proportion to momentary stiffness. The value was 2.0%. For the input wave, we used results from the shaking table tests of a previous research (Chiba, et.al, 2005). One input wave was a random wave for checking the natural period of the analysis model (Figure 7). The other one is the one of the maximum input waves, No.58 wave, changed JMA Kobe recorded during the South Hyogo prefecture Earthquake in 1995. In experiments, the time axis of the wave was one- third of the original axis. (Figure 8) shows the input wave No.58.

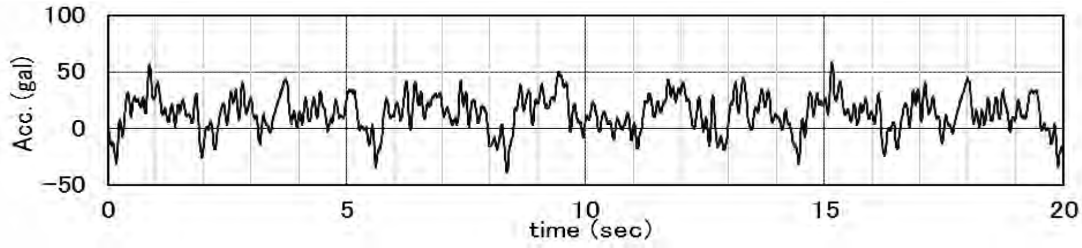


Figure 7: The input acceleration wave of random

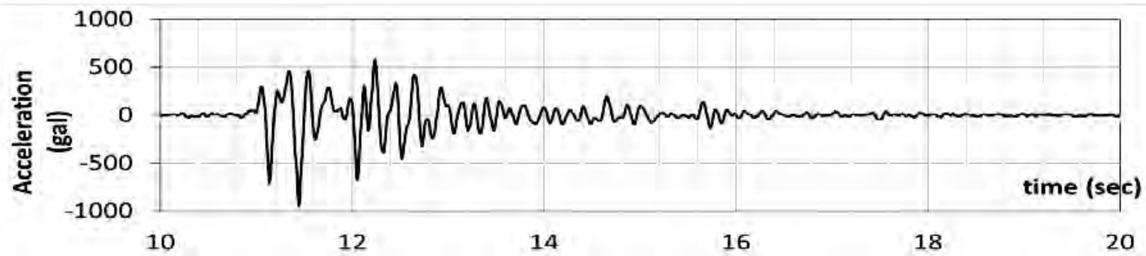


Figure 8: The input acceleration wave of JMA Kobe (No.58)

3. RESULTS AND DISCUSSIONS

3.1 Natural frequency

(Figure 9) shows the time history of horizontal displacement at Daiwa in each floor from the analysis result of random wave. Daiwa is an element on a column. The natural frequency of the analysis model was 1.95 Hz. The value almost agreed with an experimental result. In this experiment, the maximum input acceleration was 50 gal, and the response deformation angle at the top of specimen was 1/450 rad. It confirmed that the frequency of the analysis model was same as one of experimental specimen in the range of an elastic deformation.

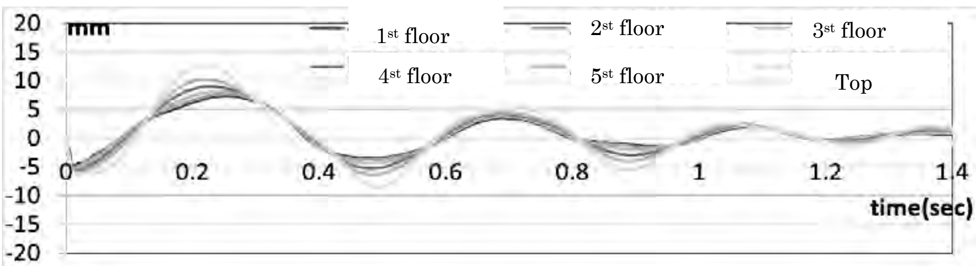


Figure 9: The time history of horizontal displacement from the analysis of Random wave

3.2 Analysis with an earthquake wave

(Figure 10) shows the time history of horizontal displacement at *Daiwa*, the element on a column, in each floor of pagoda. The phase of the wave from analysis results corresponded to experimental ones. Analysis results almost agreed with the experimental ones in the first maximum displacement. However the difference between an analytical wave and an experimental one at the top and the fifth floor increased at the large amplitude around 1.2 second. When the pagoda deformed largely, shear deformation was seen at the first wave in the experimental result. The uplift of a plate under columns occurred around 1.2 second. The uplift value of analysis model was smaller than one of the experimental specimen. Therefore it can be seen that the horizontal displacement of analytical model was smaller than an experimental result.

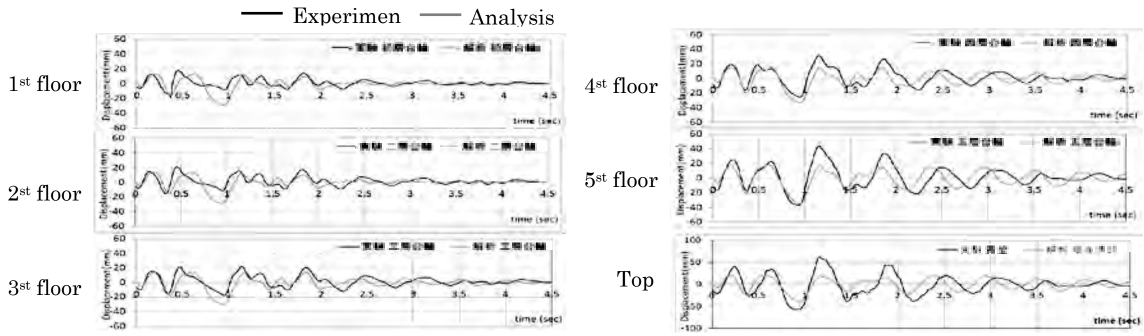


Figure 10: The time history of horizontal displacement in each floor

4. CONCLUSIONS

We developed a three dimensional analytical model of five-storied pagoda including the vertical stiffness of *Kumimono* and truss roof as a factor of rocking motion. In addition, we conducted earthquake response analysis with the analysis model. The analysis results almost agreed with experimental ones on the time history of horizontal displacement in each floor. But the largest deformation upper the 4th floor of this analysis model was smaller than experimental results. It is supposed to be caused by the difference of the uplift of a plate under columns. It can be seen that the uplift of a plate under columns had a great effect on the rocking motion of each floor. Therefore we need to reconsider the setting method of the spring under the plate furthermore and to make a lot of parametric studies.

ACKNOWLEDGEMENT

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Influence of frequency characteristics of dynamic seepage flow in a porous medium containing a cavity

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ABSTRACT

Dynamic seepage flows, which fluctuate with the passage of time, have mainly been estimated by static parameters at the maximum amplitude. However, such estimations do not consider either the underground cavities in practical grounds or the various components of the seepage frequency. This study has revealed the influence of the seepage frequency in a porous medium, containing an area of regular flows, by a numerical analysis which takes into account the Beavers-Joseph conditions at the boundary of the different flow phases. We applied the Darcy-Brinkman equations to calculate both the regular flow and the Darcy flow as the governing equations. The calculated results suggest that the fluctuations in seepage force and velocity disappeared with an increase in the frequency of the subjected hydraulic gradient at the surface. On the other hand, high water pressure remained in a wider area of the ground and the cavity when the imposed pressure had a higher frequency. This was due to the limitation of the reduction in pressure in the porous medium. These trends were also proved by theoretical solutions for one-dimensional seepage flows. Consequently, in this study, a new index was proposed for evaluating the effect of frequency, which was affected by the permeability of the porous medium and the existence of zones filled with pure fluid. In addition, it was found that the high frequency component of the seepage should be especially related to the effective stress in practical grounds.

Keywords: seepage flow analysis, finite volume method, Darcy-Brinkman equations, pipe flow, erosion

1. INTRODUCTION

Unsteady seepage through a porous medium, such as the ground, has not been revealed, especially in terms of the influence of the seepage frequency. Previous studies evaluated the periodical seepage by means of static values such as maximum/minimum velocity[1)]. In addition, practical grounds include cavities and soil pipes, as mentioned by Kuwano et al. (2010)[2)]. The fluid domain in cavities is directly influenced by unsteady seepage; and therefore, it is necessary to simulate the unsteady seepage through grounds containing cavities. Recently, various single-domain approaches have been proposed that adopt one set of governing equations for the seepage analysis of both porous and fluid domains (e.g., Mu et al., 2007[3]; Fujisawa and Murakami, 2013[4]). The aim of this study is to improve the simultaneous method proposed by Fujisawa and Murakami in order to solve the unsteady seepage flows through porous and fluid domains.

2. NUMERICAL METHOD

2.1 Governing equations

The Darcy-Brinkman equations are adopted as the governing equations, as they can be used for calculating both fluid and porous media.

$$\frac{\partial u_i}{\partial x_i} = 0 \tag{1a}$$

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_i}\left(\frac{u_i u_j}{\lambda}\right) = -\frac{\lambda}{\rho}\frac{\partial p}{\partial x_i} + \nu\frac{\partial^2 u_i}{\partial x_j x_j} - \frac{\lambda g}{k}u_i \tag{1b}$$

where u, p, ρ and ν denote the flow velocity, the piezometric pressure, the density and the kinematic viscosity of fluids, respectively. t and x_i are time and the Cartesian coordinates. u_i denotes the flow velocity in the fluid medium and the Darcy velocity in the porous medium. k and λ are hydraulic conductivity and porosity, respectively. The Navier-Stokes equation for the fluid medium is expressed by making $1/k = \infty$ and $\lambda = 0$ in Equation (1b).

2.2 Calculation method

Details of the calculation method and the interpolation were given by Fujisawa and Murakami (2013)[4]. The Darcy-Brinkman equations are discretized by the fractional step method over the finite volume grids, proposed by Kim & Choi (2000)[5]. Figure 1 shows the parameters calculated in each finite volume cell; the velocity and the pressure are stored at the centoroids of the cell and flux U is stored at the center of each cell face. The definition for flux U is shown by the following equation:

$$U = (u_i)_{face} n_i \tag{2}$$

where $(u_i)_{face}$ and n_i denote the velocity and the outward normal unit vector on the cell face, respectively. The equations for temporal and spatial discretization are

$$\frac{\Delta u_{i,r}^D}{\Delta t} = -\frac{\lambda_r g}{k_r}\left(\theta\,\Delta u_{i,r}^D + u_{i,r}^m\right) \tag{3}$$

$$\begin{aligned}\frac{\Delta u_{i,r}^F}{\Delta t} = &-\frac{1}{2A_r}\oint_{l_r}\frac{U^m\Delta\tilde{u}_i^F + \tilde{u}_i^m n_j \Delta\tilde{u}_j^F + 2\tilde{u}_i^m U^m}{\lambda_r}dl \\ &-\frac{\lambda_r}{\rho A_r}\oint_{l_r}\tilde{p}^m n_i\,dl + \frac{\nu}{2A_r}\oint_{l_r}\left.\frac{\partial \Delta u_i^F}{\partial n}\right|_r + 2\left.\frac{\partial u_i^m}{\partial n}\right|_r dl\end{aligned} \tag{4}$$

$$u_{i,r}^P = u_{i,r}^m + \Delta u_{i,r}^D + \Delta u_{i,r}^F \tag{5}$$

$$u_{i,r}^M = u_{i,r}^P + \frac{\lambda_r \Delta t}{A_r \rho}\oint_{l_r}\tilde{p}^m n_i\,dl \tag{6}$$

$$\oint_{l_r}\frac{\tilde{\lambda}}{\rho}\left.\frac{\partial p^{m+1}}{\partial n}\right|_r dl = \frac{1}{\Delta t}\oint_{l_r}U^M dl\ ,\ U^M = \tilde{u}_i^M n_i \tag{7}$$

$$u_{i,r}^{m+1} = u_{i,r}^{M} - \frac{\lambda_r \Delta t}{A_r \rho} \oint_{l_r} \tilde{p}^{m+1} n_i \, dl \tag{8}$$

$$U^{m+1} = U^{M} - \frac{\tilde{\lambda} \Delta t}{\rho} \frac{\partial p^{m+1}}{\partial n} \bigg|_r \tag{9}$$

where $\theta\,(0 \leq \theta \leq 1)$ is the coefficient, $\theta = 1$ and the explicit method is adopted for the Darcy-term. u_i^P and u_i^M stand for the velocity at the prediction step and the intermediate velocity for the computation of the pressure, respectively. Superscript *m* represents the m^{th} time steps. $\partial / \partial n$ is the outward-normal derivative. A_r and l_r denote the area and the side of the r^{th} cell, respectively. Superscript ~ represents the interpolation of the parameters computed from the stored parameters at the centroids of the cell onto the cell faces. The next section describes the interpolation method.

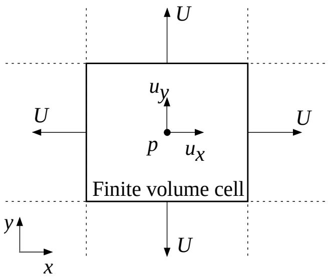

Figure 1: Computational cells and stored variables

2.3 Interpolation and derivatives at the cell face

The following equation was adopted for the stable and accurate computation particularly at the boundary between the fluid and porous media. First, the interpolation of the pressure is performed as follows:

$$\tilde{p} = \frac{\dfrac{\delta_b}{k_b} p_a + \dfrac{\delta_a}{k_a} p_b}{\dfrac{\delta_a}{k_a} + \dfrac{\delta_b}{k_b}} \tag{10}$$

Subscripts a and *b* are the values of cells *a* and *b*, respectively. They are adjacent cells. δ is the distance from the cell center to the interface (See Figures 2 and 3). The different formulae are applied for normal and tangential velocities because the Beavers and Joseph conditions (1967)[6)] should be satisfied along the tangential direction. The normal velocity is interpolated by the following equation:

$$\tilde{u}_n = \frac{\dfrac{\delta_b}{k_a} u_{n,a} + \dfrac{\delta_a}{k_b} u_{n,b}}{\dfrac{\delta_b}{k_a} + \dfrac{\delta_a}{k_b}} \tag{11}$$

On the other hand, the tangential velocity is computed as follows:

$$\tilde{u}_t = \frac{\delta'_b u_{t,a} + \delta'_a u_{t,b}}{\delta'_a + \delta'_b} \tag{12a}$$

$$\delta' = \begin{cases} \delta & \text{Fluid domain} \\ \sqrt{\dfrac{K}{\lambda}} & \text{Porous domain} \end{cases} \tag{12b}$$

K means the permeability calculated from $K = k\nu / g$. α is a coefficient related to the characteristics of the porous medium and $\alpha = \sqrt{\lambda}$ in this paper.

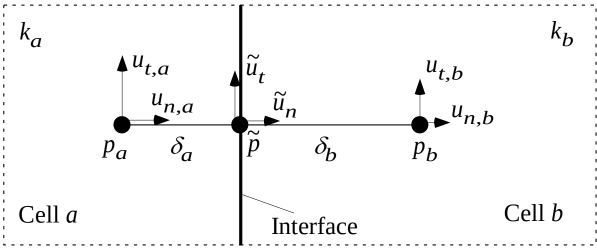

Figure 2: Variables of cells a and b

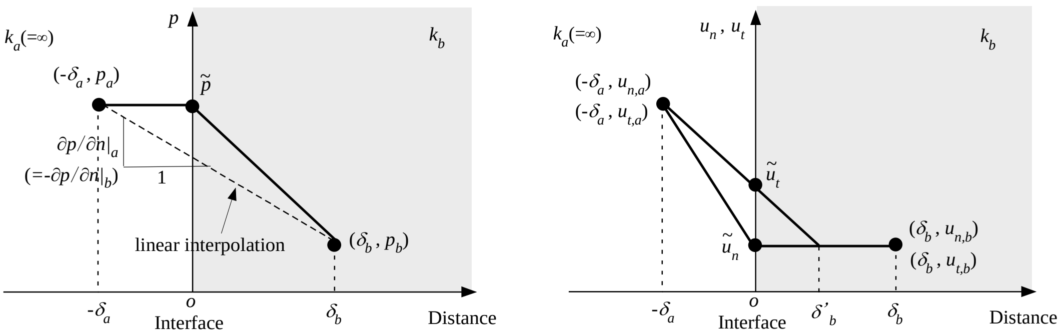

Figure 3: Interpolation of the variables (Left: Pressure, Right: Velocity)

3. THEORETICAL SOLUTIONS OF ONE-DIMENSIONAL SEEPAGE FLOW

The Darcy-Brinkman equations are theoretically solved for the one-dimensional seepage flow as follows. Theoretical solutions are accorded with a numerical analysis; and therefore, the former is described in this chapter. Firstly, we postulated that $\partial u_x / \partial x = 0$ in the one-dimensional case and then Equation (1) was modified as follows:

$$\frac{du_x}{dt} + \frac{\lambda g}{k} u_x = -\frac{\lambda}{\rho} \frac{\partial p}{\partial x_i} \tag{13}$$

$p(x,t)$ denotes the pressure for coordinate x at time t. $p(0,t) = q \times \sin \omega t$ (q = 0.98 kPa) and $p(L,t) = 0$ at the boundaries. The integration of Equation (13) over $0<x<L$ gives the following equations:

$$\begin{aligned} &\int_0^l \frac{du_x}{dt} dx = -\int_0^L \frac{\lambda}{\rho} \frac{\partial p}{\partial x} dx - \int_0^L \frac{\lambda g}{k} u_x dx \\ &\Rightarrow \frac{du_x}{dt} \times L = \frac{\lambda}{\rho} (p(L,t) - p(0,t)) - \frac{\lambda g}{k} u_x \times L \\ &\Rightarrow \frac{du_x}{dt} = -\frac{\lambda}{\rho L} q \sin \omega t - \frac{\lambda g}{k} u_x \end{aligned} \tag{14}$$

The theoretical solution is calculated as

$$u_x = \left(\frac{\dfrac{\lambda q}{\rho L}}{\dfrac{1}{\omega K'} + \omega K'} \right) \left\{ \left(\frac{1}{\omega} \sin \omega t - K' \cos \omega t \right) + K' e^{-\frac{t}{K'}} \right\} \tag{15a}$$

$$K' = \frac{k}{\lambda g} \tag{15b}$$

The trigonometric function of Equation (15) is shown below and the amplitude of the equation is governed by $K'/\sqrt{1+\omega^2 K'^2}$. $K'/\sqrt{1+\omega^2 K'^2}$ converged as Equation (17).

$$u_x = \frac{\lambda q}{\rho L} \left(\frac{K'}{\sqrt{1+\omega^2 K'^2}} \right) \sin(\omega t + \theta), \ \sin\theta = -\frac{\omega K'}{\sqrt{1+\omega^2 K'^2}} \tag{16}$$

$$\frac{K'}{\sqrt{1+\omega^2 K'^2}} \to K' \left(\omega \to 0 \right) \tag{17a}$$

$$\frac{K'}{\sqrt{1+\omega^2 K'^2}} \to 0 \left(\omega \to \infty \right) \tag{17b}$$

Therefore, the amplitude of the velocity was the same as the seismic value, calculated by the Darcy-law when the frequency was close to zero, and it converged to zero when the frequency was high. The attenuation of the amplitude is proportional to hydraulic conductivity *k*. The phase difference in velocity, from pressure θ, increases to $\pi/2$ with a rise in frequency. Theoretical u_x, calculated by the different frequencies, is shown in Figure 4, for the rectangular porous medium that is 0.015 m in width and 0.2 m in length, when permeability coefficient *k* is 1.0×10-2 m/s.

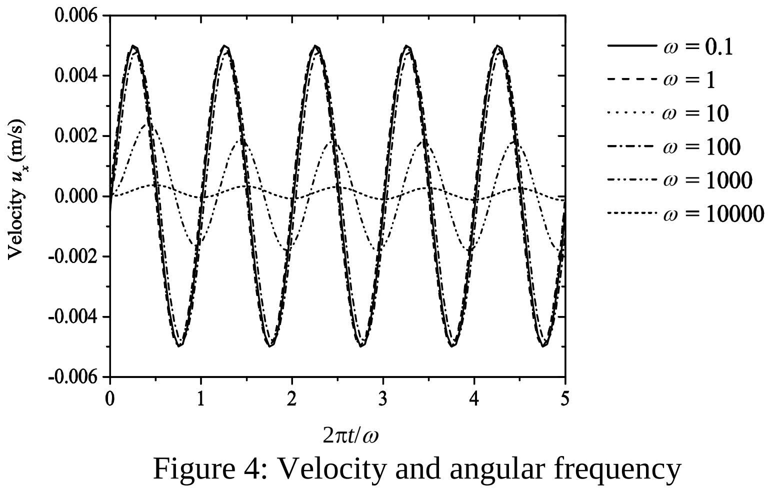

Figure 4: Velocity and angular frequency

4. TWO-DIMENSIONAL SEEPAGE ANALYSIS OF PIPING HOLES IN THE GROUND

4.1 Geometry, coordinates and boundary conditions

Figure 5 shows the geometry, the coordinates and the boundary which simulate the ground including the pipe vicinity of the impermeable wall. The computational domain is 700 mm long and 300 mm high, having a pipe-shaped cavity (fluid domain) of 215 mm in length and 15 mm in width beneath the impermeable structure. Water pressure of 0.98 kPa was applied on the left side of the upper face. The non-slip condition was applied beneath the impermeable wall and to the left and bottom sides of the porous domain, as seen in this figure. The hydraulic conductivity is assumed to be 1.0E-3 m/s or 1.0E-2 m/s and the porosity of the porous domain is 0.45.

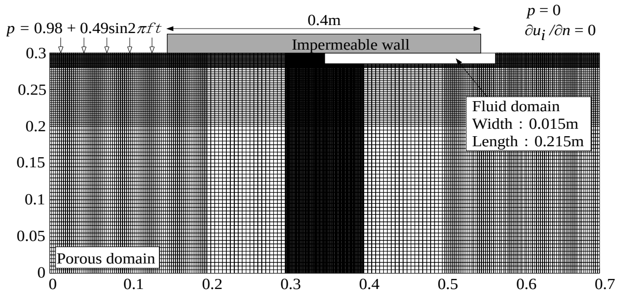

Figure 5: Geometry and boundary conditions

4.2 Amplitude of the pressure and the velocity

The amplitude of the velocity in the *x*-direction, u_x, and the pressure are depicted in Figure 6. Positive and negative amplitude from the average value is equivalent for the entire portion. The velocity is especially large at both ends of the impermeable wall. It changes due to the frequency, particularly in the cavity. It initially increases with the rise in frequency and subsequently decreases. The boundaries of the frequencies ascend and descend and are influenced by the hydraulic conductivity of the ground (see the next section). The pressure gradient also decreases with an increase in frequency; this suggests that high pressure remains in the cavity. The average velocity and pressure are not affected much by the frequency, being similar to the value at f = 0(Hz).

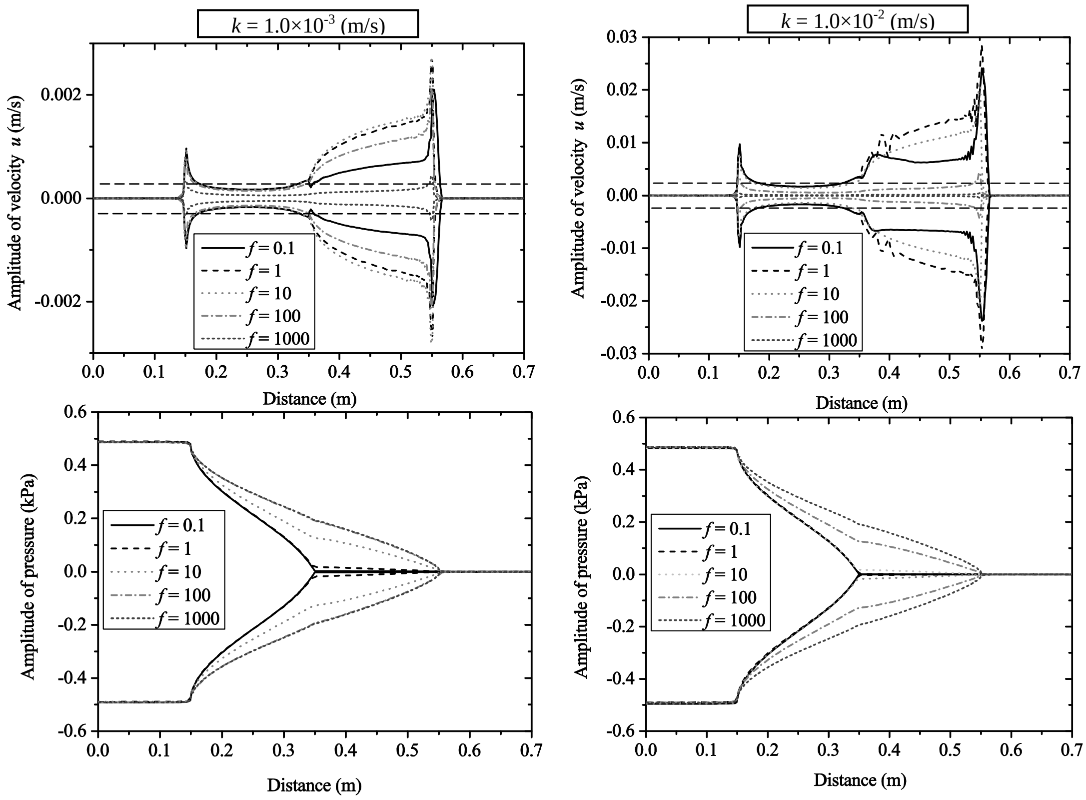

Figure 6: Upper: velocity u_x distributions, Lower: pressure distributions

4.3 Seepage force

The dynamic seepage force is computed, as shown in Equation (18), by solving the pressure and surface friction of the soil particles. Details of the derivation are given in Fujisawa et al. (2010)[7]. We focused on seepage force f_x along x which is the principal direction of seepage. It is separated into the pressure term and the velocity term for the discussion. Figure 7 represents the average and the amplitude of f_x on the cell located at the end of the porous medium and contacting the fluid medium ($0.349 < x < 0.35$, $0.285 < y < 0.3$), where the seepage force is most significant. The dotted line of the average f_x is the value of $f = 0$ (Hz). The average f_x increases slightly with the rise in frequency, but the influence of the frequency is very subtle. On the other hand, the amplitude of f_x is attenuated with the rise in frequency and the attenuation is similar between the pressure term and the velocity term. The attenuation of the two-dimensional simulation is relatively proportional to $K'/\sqrt{1+\omega^2 K'^2}$. u_{1D} in the figure is a theoretical amplitude of the velocity for the one-dimensional seepage, as shown in Equation (16).

$$f_i = -(1-\lambda)\frac{\partial p}{\partial x_i} + \frac{\rho \lambda g}{k} u_i \tag{18}$$

$$\text{Pressure term: } -\left(1-\lambda\right)\frac{\partial p}{\partial x_i} \tag{19a}$$

$$\text{Velocity term: } \frac{\rho \lambda g u_i}{k} \tag{19b}$$

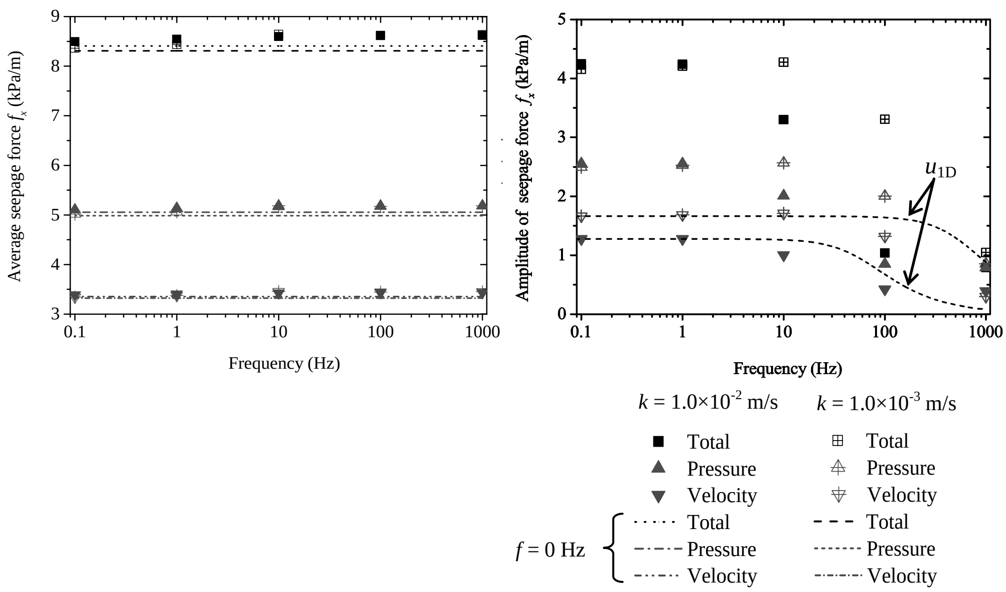

Figure 7: Seepage force (Left: average, Right: amplitude)

5. CONCLUSIONS

1. We proposed a dynamic seepage analysis applying the Darcy-Brinkman equations as the governing equations. In addition, the Beavers-Joseph conditions were satisfied at the interface of the porous and the fluid media.
2. The phase difference became larger and the amplitude of the velocity became smaller due to the increase in frequency of the seepage pressure. This was also indicated by the theoretical solutions for the one-dimensional seepage. The attenuation of

velocity was found to be proportional to $K'/\sqrt{1+\omega^2 K'^2}$, which is capable of being applied to a two-dimensional analysis including both porous and fluid domains. The amplitude of the velocity and the seepage force was negligible for the high frequency range of the seepage. On the other hand, the amplitude of the pressure decreased with the rise in frequency, and high pressure remained in the pipes, which threatened to cause a decrease in the effective stress in the porous medium.

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Community response to water stress in the megacity of kolkataand impiications to urban resilience

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ABSTRACT

One fifth of the world's population currently live in regions affected by physical water scarcity, economic water scarcity affects another one fourth. Increasing population, enhanced per capita water use, climate change and allocations for water conservation are potential threats to adequate water availability. With climate change producing variations in rainfall, these challenges would intensify. Like most Indian cities, Kolkata also faces severe water stress under impacts of rapid urbanisation and expanding city size. With one of the oldest water supply systems in India, the city suffers from inadequate zonal mains, old worn out supply mains, low pressure of water supply and high leakage loss. The urban community is already coping with inadequate and intermittent supply, low per capita availability, inadequate coverage and dependence on ground water. No part of the city has 24 hours of supply, exposing the water supply lines to sewage and other contaminants when pressure is low and during hours of no supply. With widespread realisation of the significance of global warming and climate change, urban communities are seeking resilience to existing and future uncertainties in urban water supplies brought about by a combination of climate variability, and population growth. The challenge is to make cities resilient to future urban growth.

Keywords: *urbanisation, water stress, community, sustainability, resilience*

. INTRODUCTION

Around one fifth of the world's population currently live in regions affected by physical water scarcity, with inadequate water resources to meet total demand, including the water needed to fulfil the demand of ecosystems to function effectively (Watkins,.et.al. 2006). Economic scarcity because of inadequate infrastructural facilities affects another one-fourth. With climate change producing variations in rainfall, the challenges would intensify. Changes in global and regional climates are projected to influence both the total amount and variation of water throughout the globe (Easterling et.al. 2000). Future climate scenarios suggest spatial variation in precipitation responses (Giorgi and Bi, 2005), with altered water availability in many regions. Changing climate would modify all elements of the water cycle. It may change the timing and intensity of precipitation, snowmelt, and runoff (Vörösmarty et al., 2005).

With an increase in global temperatures and climatic variability, there is a higher risk of migration inducing events, such as droughts, desertification, flooding, soil erosion, and the transmission of airborne diseases. The Intergovernmental Panel on Climate Change (IPCC) has documented that the global climate is becoming warmer and wetter, and that precipitation extremes as well as the severity of extreme events themselves are expected to increase globally (IPCC, 1996; Matthews & Quesne, 2009). Megacities, defined as metropolitan areas with a total population in excess of 10 million, are becoming focal points for climate change impacts and mass urbanization, resulting in their growing vulnerability. According to conservative estimates, the annual migration to urban centres because of environmental change currently totals 50 million people (Warner, 2010). Reasonable estimates by the International Organization for Migration suggest that the annual migration total could reach 200 million by 2050 (Warner 2010). Urban growth is most rapid in developing countries, where cities gain an average of 5 million residents each month (United Nations Environment Programme, 2011). Megacities and metacities – defined by UN Habitat as cities with more than 10 million and 20 million inhabitants respectively – are increasing in Asia, Latin America and Africa, spurred by economic development and increased population. Associated with rapid increases in urbanization is the growth of urban water uses, combined industrial and domestic sectors (Falkenmark, 1998, Gleick, 2003 and Jury and Vaux, 2005).

Large cities are experiencing mass urbanization and increasing vulnerability to climate change impacts, dual stresses that are unique to the 21st century. These stresses are putting pressure on the ability of cities, primarily megacities in developing countries, to provide basic services and support for their population. City infrastructure failed to keep pace with the massive urban growth, leaving many without adequate access to drinking water and sanitation. Having to rely on private vendors for their daily water supply, the urban poor pay up to 50 times more for a litre of water than their richer neighbours (United Nations Environment Programme, 2011).

With climate induced water shortage and rapid urbanization, ensuring sustainable supply of water for cities is of increasing concern (Lundqvist et al., 2005). A central component to the adopted international development goals, including the Millennium Development Goal, is to reduce the share of population without adequate water and sanitation services (McGranahan et al., 2005). Sustainable urban-industrial growth across regions need to minimise the demand-supply gap of the carrying capacity differentials (Bishop. 1974) in urban infrastructure, through supply management with capacity building and demand management with rational pricing of infrastructure and activity allocation strategies (Joardar, 1998).

Like most Indian cities, the megacity of Kolkata also faces severe water stress under impacts of rapid urbanisation and expanding city size. According to Census of India 2011, the city of Kolkata had 4.5 million residents while the population of the urban agglomeration was 14.1 million making it the third most populous megacity in our country. Kolkata Municipal Corporation is responsible for water supply to Kolkata, though 30MGD is also supplied to Maheshtala and Pujali municipalities within the urban agglomeration.

The key objectives of this study are as follow:

- To study the evolution and current status of water supply in the city of Kolkata
- To understand community response to stresses in the water supply system
- To explore possibilities of building resilience in the urban water supply system of Kolkata

Following methodology was adopted for the study:

- Literature Survey: to understand the reasons for water stress under growing challenges of rapid urban growth and climatic variability.

- Secondary Data Collection: to review the historical background and current status of water supply in Kolkata
- Structured Interview of governmental officials and local community: to review the current status of water supply in Kolkata and its spatial variation
- Questionnaire Survey at household level: to appreciate community response to water stress in different parts of the city
- Focussed Group Discussions: to explore challenges to building resilience in the urban water supply system of the city

2. EVOLUTION OF THEEXISTING WATER SUPPLY SYSTEM OF KOLKATA

The city of Kolkata, known as Calcutta till 2001, has one of the oldest water supply systems in India. In its earliest days, Kolkata was dependent on River Hooghly for its drinking water supply. Having an aversion to polluted river water, the city's European residents, in this trading port of the East India Company since 1690, preferred rainwater stored in large jars. But more substantial means of storage were needed as the city grew in size and importance. Many public and private tanks were excavated to conserve monsoon rain. Lal Dighi, in the city's heritage hub at Dalhousie Square, was deepened and extended in 1709 to ensure a good supply of water for the garrison at Fort William, around which colonial Kolkata later developed. Between 1805 and 1836, the excavation of large water tanks in College Square, Wellington Square and Wellesley Square, ensured water supply in colonial Kolkata.

It was only in 1820 that a small pumping station and a system of open masonry aqueducts was constructed (Dasgupta, 1991). In 1822, for a population of 2lakh, a pumping station was constructed at Chandpal Ghat. It lifted water from River Hugli into open masonry aqueduct to distribute the water by gravitation to parts of central Kolkata, including water for washing streets and for fire fighting. Pumping stations operated for seven hours in a day, between 6a.m. to 10.00 a.m. and between 4p.m. to 7p.m. By1870, most principal streets had access to piped water through 500 stand posts (Kolkata Water and Sanitation Authority).

In 1870, 6MGD plant was constructed at Palta with a 1MG reservoir & pumping station at Tallah and another pumping station at Wellington Square. The residents obtained access to filtered water supply with the per capita availability at 60litres per day. The site of the water works 30km upstream at Palta, reduced the risk of contamination and diminished the presence of tidal sea water. In 1888, three underground reservoirs were constructed for improved distribution. The supply was, however, intermittent. From 1909 to 1914, capacity was increased at Palta and an elevated reservoir constructed at Tallah to ensure uninterrupted supply. Continuous supply could not, however, be maintained due to wastage by consumers. Although supply was being supplemented by groundwater sources, the latter hardly compensated for the wastage up to 30% in the Palta network as estimated by Calcutta Environmental Management Strategy and Action Plan in 1995**.** As worn distribution pipes began to leak, they delivered a much lower volume of water to consumers in south Kolkata, towards the limits of the supply system from Palta.After independence, production capacity of Palta was increased to 120MGD and further to 160MGD in the year 1952. For a population of 2.70 million, per capita availability was more than 130litres per day.

3. CURRENT STATUS OF WATER SUPPLY IN THE MEGACITY OF KOLKATA

River Hugli remains the main source of water supply for Kolkata. The water is treated at three main water treatment plants. The oldest is the Indira Gandhi Water Treatment Plant of capacity 260MGD at Palta. Water from Palta is sent to Tallah pumping station for onward distribution to the city through four zonal mains which feed a distribution network of 3,800 kilometres. The other water treatment plants include a 135MGD capacity plant at Garden Reach and another one of 120MGD capacity at Dhapa, for the arsenic contaminated eastern fringe area. Dhapa Water Treatment Plant now functions at 30MGD. Jorabagan and Wattgunge have smaller plants of capacities with respective capacities of 8MGD and 5MGD (Table 1). The total capacity of the water treatment plants in 2015 is 438MGD and supply to the city is 315MGD. Power driven tube wells supply another 30MGD in areas not covered by surface water supply. The average per capita availability of water is 130litres per day.

Table 1: Water Supply in the City of Kolkata

<table>
<tr><th>Location of Water Treatment Plant</th><th>Capacity (MGD)</th><th>Supply (MGD)</th><th>Remarks</th></tr>
<tr><td>Indira Gandhi Water Treatment Plant</td><td>260</td><td>200</td><td rowspan="6">Treated surface water</td></tr>
<tr><td>Garden Reach Water Treatment Plant</td><td>120+ 15</td><td>82+15</td></tr>
<tr><td>Jorebagan</td><td>8</td><td>5</td></tr>
<tr><td>Wattgange</td><td>5</td><td>3</td></tr>
<tr><td>Dhapa</td><td>30</td><td>10</td></tr>
<tr><td>Total</td><td>438</td><td>315</td></tr>
<tr><td>Groundwater</td><td>30</td><td>30</td><td></td></tr>
<tr><td>Total</td><td>468</td><td>345</td><td></td></tr>
</table>

Source: Kolkata Municipal Corporation, 2015

35 per cent of the total urban population, however, are not covered by municipal water supply. Another 20-25 per cent is served by single tap connections in their houses. 8000 stand posts provide water to40-50 per cent of the population living in slums or squatter colonies without access to piped water.

Daily hours of supply vary between 6.5 hours in the city proper to 4.5 hours in the peripheral areas (Table 2). Residents in most parts of the city, except the main city, have their own ground water sources to supplement municipal water supply. Ground water is also the main source of drinking water in areas proposed to be covered by Dhapa Water Works.

Table 2 Water Supply in the City of Kolkata

<table>
<tr><th>Area</th><th>Water Treatment Plant</th><th>Supply Hours</th></tr>
<tr><td>Main city</td><td>Palta, Jorabagan, Wattgange</td><td>3.5 hours in morning
3.0 hours in the afternoon and evening</td></tr>
<tr><td>Southern fringe</td><td>Garden Reach</td><td rowspan="2">3.0 hours in morning
1.5 hours in the afternoon</td></tr>
<tr><td>Eastern periphery</td><td>Dhapa</td></tr>
<tr><td>Uncovered by piped water supply</td><td>Ground water</td><td></td></tr>
</table>

Source: Kolkata Municipal Corporation, 2015

Questionnaire survey was conducted by the author at household level in 100 households from each of the three peripheral areas and from the central city to assess water stress and response of the community. The survey revealed that the hours of supply are low. The supply is also highly erratic. In the south and east peripheral wards served respectively by Garden Reach and Dhapa Water Works, the duration of supply is not more than 4 hours in a day. (Figure1).

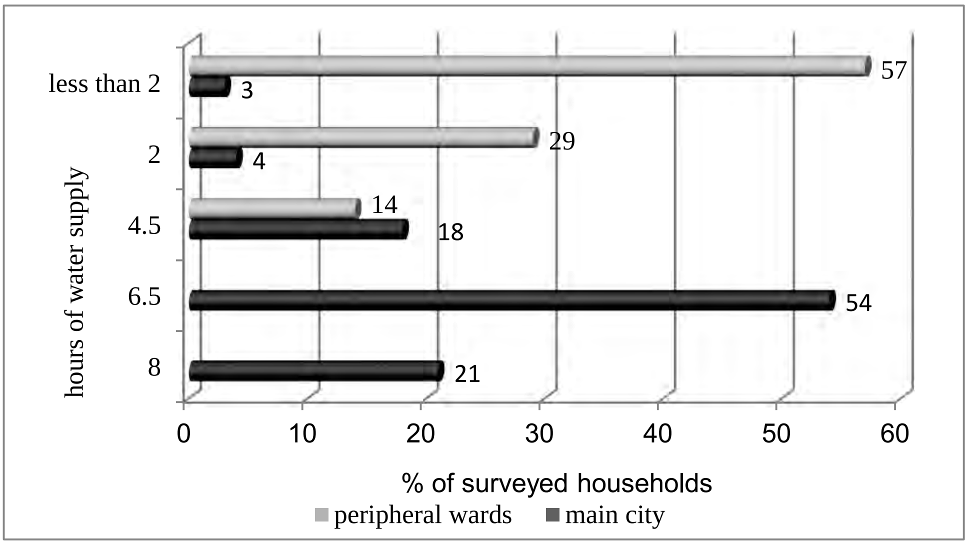

Figure 1: Hours of Municipal Water Supply

The intermittent supply and the low pressure in supply mains to reduce leakage expose the water supply system to contaminants.A survey, conducted by the Federation of Consumers Association West Bengal and Better Business Bureau, found that 80 per cent of the 1,000 water samples collected from allmunicipal wards of the city contain *E.coli* (bacteria in faecal matter), S*almonella* (responsible for typhoid), *Shigella* (causes dysentery) and *Vibrio* (causes cholera). Though chlorinating the water kills these microbes, not the slightest trace of Chlorine was found in even a single sample (The Telegraph, April 14, 2003). Ground water, on the other hand, exposes the population to arsenic contamination and salinity

Kolkata Municipal Corporation’s recovery of operational costs, at only 15 %, is one of the lowest among Indian cities (McKenzie & Ray, 2009). With under pricing of supply, overstaffing in the corporation and the high levels of unaccounted for water, the corporation can hardly cover maintenance costs or provide capital for network improvement. The policy of not pricing water for domestic use, has earned the authorities criticism for promoting wastage (ADB, 2007, McKenzie & Ray, 2009).

4. COMMUNITY RESPONSE TO WATER STRESS

In spite of its favourable hydrological setting with the River Hugli on one side and extensive ground water reserves, large parts of Kolkata suffer from inadequate municipal supply. Major deficiencies in respect of water service delivery include intermittent supply, inadequate pressure, high leakage loss and dependence on groundwater (Majumdar & Gupta, 2007).Though the average performance of the water supply subsector in terms of coverage, supply amount and hours supply is above the national average, variations exist within the city(Table 3). No part of the city receives 24 hours of supply, exposing the water supply lines to sewage and contaminants when pressure is low and during hours of no supply. In the absence of metered domestic connections, cost recovery is only 15 %, one of the lowest among Indian cities.

Table 3: Urban Service Delivery Status in Different Areas of KMC

Area	Population %	Coverage %	Litres/capita/day	Hour	metered connections %
National average		81	123	4	25
All KMC area		92	134	8	0.1
Central	69	100	146	9	N.A.
East peripheral	6	76	109	6	N.A.
West peripheral	7	45	120	6	N.A.
South peripheral	18	83	120	6	N.A.

Source: Kolkata Municipal Corporation. 2011

To cope with theerratic and short duration supply, the residents have opted for a dual water system where municipal water supply is supplemented by alternate sources including ground water (Figure 2). The central city is better served and most households depend on municipal water supply. Earlier, the high pressure of supply allowed individuals to lift enough water to individual overhead tanks to ensure 24 hours of supply. In an attempt to minimise leakage from the supply mains, the pressure is now reduced making it difficult to lift water for storage. Only 18 percent of the surveyed households in central city reported water availability to be sufficient for 24 hours when stored in overhead tanks during hours of supply. Many households, without individual connection, buy the municipal supply water from the water man, an indication of their willingness to pay for potable water and hence for water metering. The eastern peripheral wards, without piped water supply, depend primarily on ground water with arsenic above permissible limit. Infact over greater part of Kolkata, ground water sources supplement the inadequate municipal supply resulting in sinking reserves with excessive withdrawal.

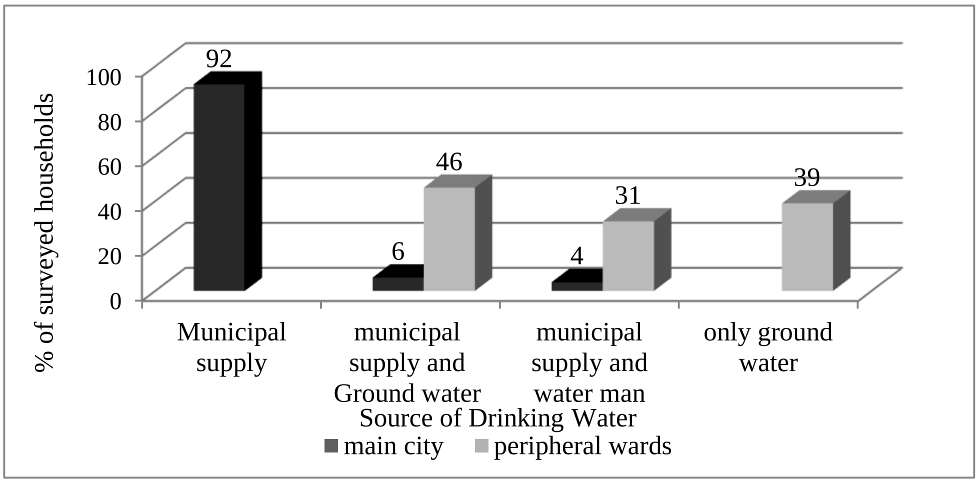

Figure 2: Source of Drinking Water in Kolkata

The city also suffers from inadequate zonal mains and old dilapidated networks, leading to high transmission and distribution losses to the tune of 30 per cent. The existing stand posts add to the wastage as 60 per cent of the water from stand posts is never utilised and there is back flow of water during hours of no supply in the service main. But the stand posts are an integral part of the city, being the main and often the only source of water for the poor. Habitations and economies have emerged around these water sources. Families have installed shelters (which often double as vending spaces). Tea stalls and street kitchens cluster around these points as washing utensils are easier, increasing the risk of contamination.

5. IMPLICATIONS TO URBAN RESILIENCE

The challenge facing mankind is to make cities resilient to future urban growth and ecological degradation. With origin in ecological sciences, resilience is considered as the capacity to absorb external shocks without significant deformation (Cutter et.al. 2008). It refers to urban systems bouncing back to equilibrium in the aftermath of shocks such as natural disasters as well as the adaptive capacities of systems to long-term stressors or shifts such as climate change (Leichenko, 2011; Lankao and Qin, 2011:). The broader socio-ecological notion focuses on learning, innovation, adaptive capacity and transformation (Folke, 2006). With the widespread realisation of the significance of global warming and climate change, urban communities are seeking resilience to existing and future uncertainties in urban water supplies brought about by a combination of climate variability, population growth and climate change (Wong and Brown, 2009).The Water Provision Resilience was thus developed for urban water system. Built on the ‘percent of the population with access to safe water’ the indicators evaluate the ability of an urban water system to maintain or improve the current level and quality of access over the next 50 years (Milman and Short, 2008).Critical aspects of urban water supply systems that impact water system resilience include supply, finances, infrastructure, service provision, water quality and governance (Milman and Short, 2008).

A resilient water supply system in the city of Kolkata should address governance issues and climatic variability. Aiming to increase coverage and per capita supply, immediate measures would be to increase the number and efficiency of booster pumping stations, revamping the zonal mains, controlling the backflow from stand posts, providing piped water supply to the urban poor and managing demand. The long term measures would be to discontinue the use of stand posts, shift to surface water, increase capacity of treatment plants, recharge ground water and undertake rainwater harvesting at institutions and residential complexes, aim at cost recovery through domestic water meters and resource mobilisation.

6. CONCLUSION

The Kolkata Municipal Corporation is already into implementing many of the suggested interventions that would determine the resilience of the water supply system. It includes increasing the supply and coverage through the seven upcoming and two proposed booster pumping stations. In its Vision 2025 the Kolkata Municipal Corporation aims to replace ground water by surface water supply for the entire city. Charging for domestic water supply and demand management options would increase urban resilience through awareness building. Ground water recharge is recommended, to increase the adaptive capacity, for a more resilient water supply system.

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Building Damage due to 2013 Typhoon Yolanda in Basey, the Philippines

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ABSTRACT

Typhoon Yolanda (Haiyan) widely affected urban areas in Philippines. It damaged 3,42 households (161 million people) with 6,300 casualties and 1,061 missing in the Philippines as of April 17. The total number of damaged buildings became 1,084,762: heavily 489,613 and moderately 595,149 (NDRRMC, 2014).
This paper analyzes building damage due to the typhoon and tidal wave based on the field surveys conducted by the authors in Basey, the Province of Samar Island, referring to building damage dataset provided by JICA.
Based on a data-set of building damage investigated by JICA, the relationship between building damage mainly caused by tidal wave and the distance from the coastline was clarified, and a building vulnerability function was obtained.

Keywords: super typhoon, storm surge, land use regulation, logistic regression, Typhoon Haiyan

1. INTRODUCTION

The 2013 Typhoon Yolanda (Haiyan) widely affected approximately 3.42 million households (161 million people) with 6,300 casualties and 1,061 missing in the Philippines. It damaged 1,084,762 buildings in the country including heavily 489,613 and moderately 595,149 (NDRRMC, 2014). The authors investigated building damage in Basey, a province of Samar Island, twice in February and December 2015. This paper analyzes building damage due to the typhoon and tidal wave based on the field surveys and a building damage dataset provided by Japan International Cooperation Agency (JICA).
The purpose of this research is to clarify the relationship between the building damage and building characteristics (structural type, stories, outer walls, and location) in Basey. The following procedure was conducted to this end.

(1) At first, the authors carried out two field surveys to collect building damage data, which contains structural types, stories, and material of outer walls, in Basey in February and in December 2014. This building damage data (hereinafter the field survey data) was used for an analysis later.
(2) Apart from the field survey data, the authors were provided another set of building damage data by Japan International Cooperation Agency (JICA) (herein after the JICA data), which includes location of the buildings, namely the distance from the coastline. Based on the JICA data, a relationship between building damage due to the tidal wave and the distance from the coastline is analyzed.
(3) Thirdly, the field survey data is arranged to understand the tendency of building damage and building characteristics.
(4) Finally, a relationship between building damage conditions and building characteristics is evaluated, and impact of parameters on the building damage is assessed with logistic regression analysis.

2. BUILDING DAMAGE OVERVIEW AND FIELD SURVEYS IN BASEY

2.1 Damage conditions in Basey

Basey is a municipality of 50,423 population (as of 2012) located in Samar Island, the opposite shore of Tacloban City, which was the mostly devastated by Typhoon Yolanda in the country, as shown in Figure 1. It is one of the oldest cities in the country, and its name "basey" originates from "beauty." According to information provided by the municipality in the field survey, The 2013 Typhoon Yolanda killed 235 people including missing person and damaged 12,223 buildings; heavily 489,613, and moderately 595,149. Especially many barracks were damaged by the tidal wave.

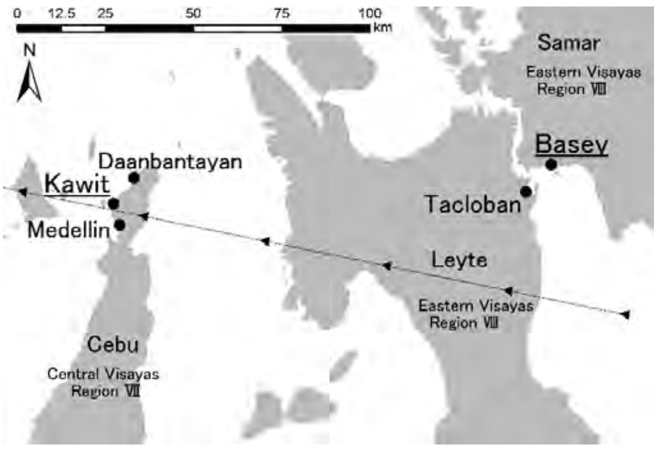

Figure 1: Location of Basey and the course of Typhoon Yolanda

2.2 Field surveys in Basey

The authors carried out two field surveys in Basey on 19 and 20 in February and on 18 and 19 in December. The purpose was to understand the damage condition of Basey and to collect building inventory data. Not getting available official digital base map, we used Open Street Map for the first survey. In order to record on-site information of buildings along the street, we basically used a driving recorder equipping GPS and camera.

3. BUILDING DAMAGE ANALYSIS BASED ON JICA DATA

3.1 Building damage data surveyed by JICA

This chapter analyzes building damage due to tidal waves with a building damage dataset provided by JICA. The building damage data has building damage level and locations, on which the analysis of relationship between building damage and the distance from coastline was based. Table 1 shows criterion for damage interpretation for the JICA survey and the number of buildings. Building damage level itself is classified into four levels, but actual damage was assessed into only two levels: moderately affected and totally affected.

Table 1: Criterion for damage interpretation for the JICA survey and the number of buildings

Level	**Definition**	**Number**
1	Not affected	0
2	Moderately affected	944
3	Highly affected	0
4	Totally affected	338
	Total	1,282

3.2 Building damage analysis based on JICA data

The Buildings judged as level 4 (totally affected) were located in front of the ocean and were mainly collapsed by the tidal wave caused by Typhoon Yolanda. The other buildings judged as level 2 (moderately affected) were mostly located in the blocks inland. The two-level classification is useful to assess the building damage condition caused by tidal wave. The relationship between building damage and the distance from coastline is analyzed.

Figure 2 shows the building damage and distance from the coastline in Basey with equidistance lines, and Figure 3 indicates the number of damaged buildings according to the distance from the coastline/river in Basey. As abovementioned, these figures demonstrate that there were many buildings washed away or collapsed by the tidal wave near by coastline.

Here, the building damage ratio is defined as the ratio of the buildings judged as level 4 per the total number of buildings in each buffer shown in Figure 2. Figure 4 shows the relationship between the damage ratio of buildings and the distance from the coastline/river in Basey.

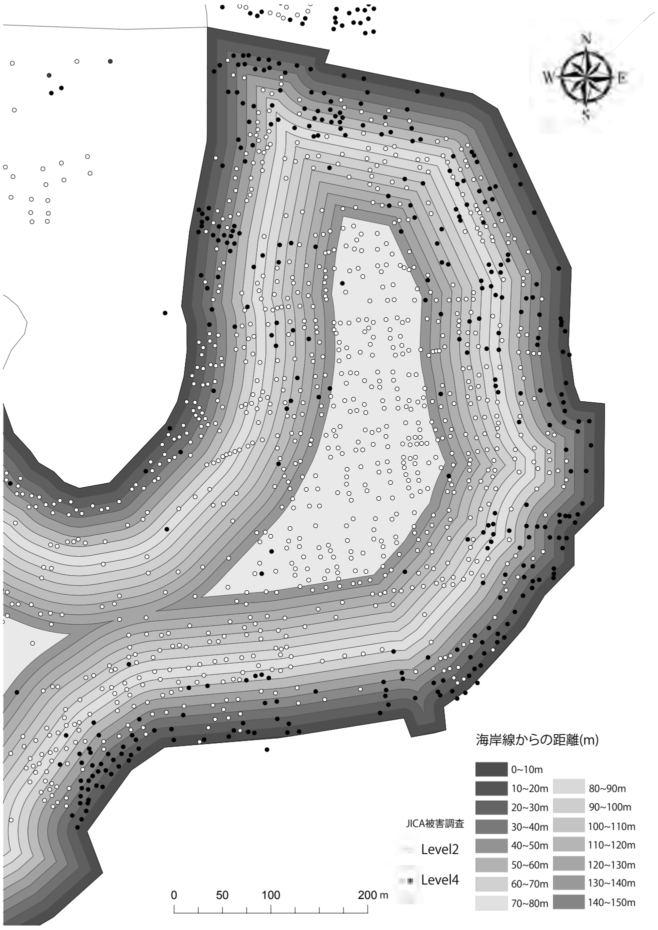

Figure 2: Building damage and distance from the coastline in Basey

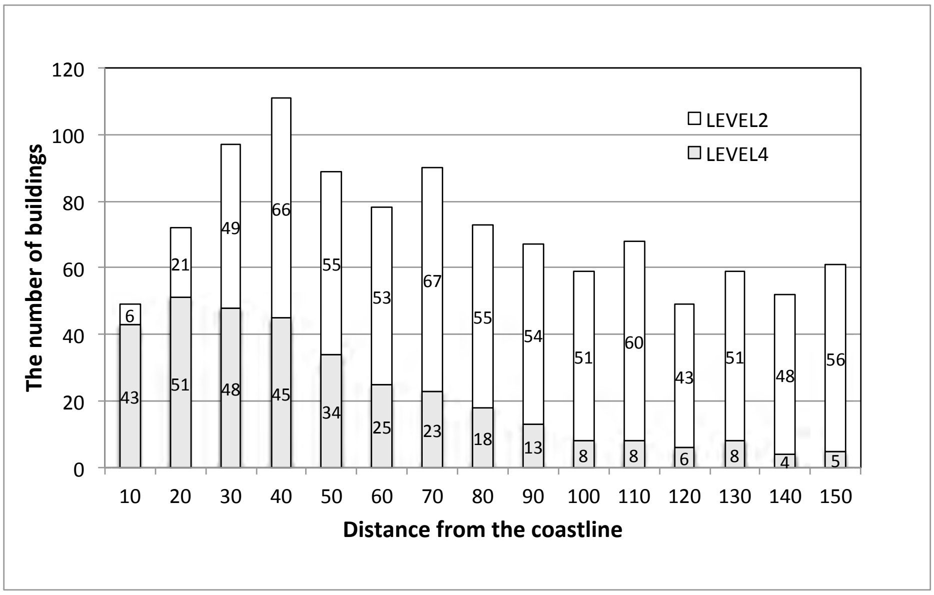

Figure 3: The number of damaged buildings according to the distance from the coastline/river in Basey

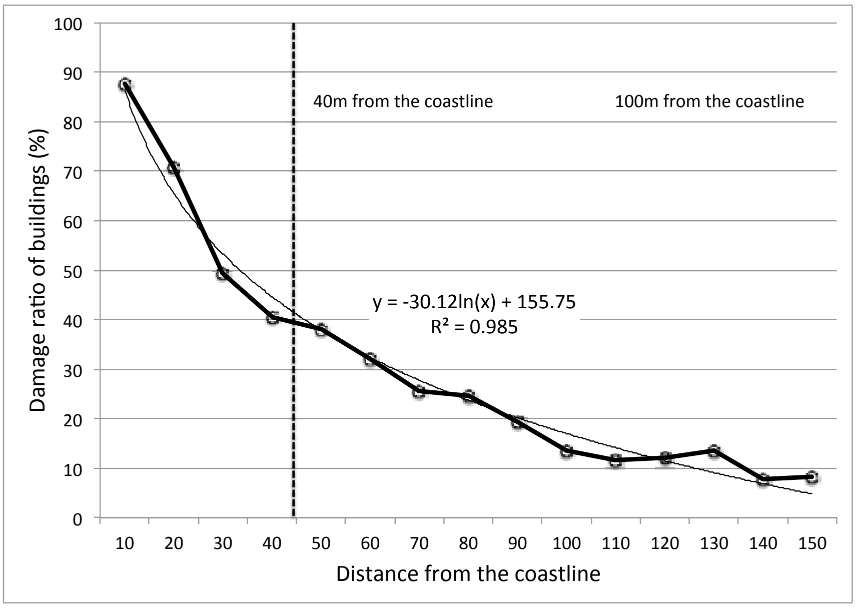

Figure 4: Relationship between damage ratio of buildings and the distance from the coastline/river in Basey

It shows a tendency that the building damage ratio is gradually decreasing from coast areas to inland. The national government establishes “no build zone,” namely 40m buffer zone from the coastline in which building construction is limited (Photo 1), based on PD1067 (NEDA, 2013). Figure 4 implies an adequacy of the 40m buffer zone, in which the building ratio is more than 40%.

Photo 1: “No build zone” in coastal area

The approximate curve was obtained from Figure 4 by logarithmic approximation as Equation (1). This equation quantitatively indicate the relationship between the building damage due to tidal wave and the distance from the coastline in Basey.

$$D_R(x) = -0.30 \ln(x) + 1.56 \quad (1)$$

in which $D_R(x)$ is the building damage ratio in a buffer zone of distance x.

4. CONCLUSION

2013 Typhoon Yolanda (Haiyan) widely affected urban areas in the Philippines. Buildings damage caused by the typhoon in Basey Municipality was analyzed in this paper. Based on a data-set of building damage investigated by JICA, the relationship between building damage mainly caused by tidal wave and the distance from the coastline was clarified, and a building vulnerability function was obtained.

ACKNOWLEDGEMENTS

This work was supported by the Japan Society for the Promotion of Science (JSPS) through the Grants-in-Aid for Scientific Research No. 23404019 "Examination of Urban Recovery Plans after the 2004 Indian Ocean Tsunami and Urban Risk Evaluation of Tsunami in Asia Influenced by Global Warming." I would like to give special thanks to the Municipality of Basey, residents in Basey, JICA who provided the important dataset of building damage to IRIDeS, and Prof. Minai at Japan Women's University who supported the first field survey.

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Analysis of vehicle running on elevated expressways during earthquake

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ABSTRACT

Expressways, main city links of road transport is dominant in Japan as like other developed countries where we need to deploy safety measures for users during earthquake. Mega cities should have to cater traffic with elevated city expressways. Viaducts, bridges structures are prone to earthquake, along with structure, driving through elevated roads are also subjected to certain level of risk during shaking. As local site effect of soil leads to different response of ground motion in surface; we should consider local effect of earthquake motion in structures. Bridge model is taken as 1320m long cable stayed bridge, nodal response are recorded after analysis with input of Japanese Road Associations design ground motion of level two. Vehicles are modeled, considering six degree of freedom with considering translational and rotational motion; in one way road of two lanes with speed of average 80 and 100 kmph. Each vehicle is subjected to an individual ground motion that depends on speed and location. In this study, the ground motions for individual vehicle from bridge response were obtained using the Lagrange three-point interpolation of nodal responses. Seismic response analysis of vehicles was performed and presented the result for a vehicle with speed of 101 kmph.

Keywords: seismic response analysis, vehicle model, city expressways, ground motion interpolation

1. INTRODUCTION

Driving through highways during earthquake shaking tends to high risk of accidents with loss of control to steering by drivers even though they may not recognize the ground motion in moderate level of earthquake. Risk of structural collapse with high intensity of earthquake is another factor. As discussed by (Kawashima, Sugita, & Kanoh, 1989), about effect of earthquake on drivers from questionnaire survey found that, about fifty percent of drivers felt earthquake vibration due to unusual behavior of vehicle and movements of surroundings. Seismic response of running vehicles (Maruyama & Yamazaki, 2002) were analyzed for road considering constant speed and same input ground motion for all vehicles even with different speed. This analysis only concentrated for road surface that goes through ground.

Hanshin expressway in Japan is of total about 200 km in length (Kitada, Maekawa, Nakamura, & Horie, 2000) comprises of total 93.1% of steel and concrete bridges, another 5.6% of road surface and 1.3% of tunnel structures standing to complete the network. Earthquake ground motion that propagates through the surface of earth will be different in the road surface where it passes via bridges or viaducts depending on properties of structures which have directly or indirectly influence on response of bridge. The response of the bridge structures will be the earthquake motion that vehicles feel actually during earthquake when they move through elevated structures. Seismic response analysis of vehicle considering earthquake ground motion is not enough explaining the real scenario in case of bridges.

We are considering a cable stayed, symmetrical bridge having total length of1320 m. Dynamic analysis of bridge with input ground motion in base of piers had given nodal acceleration response in bridge deck. Interpolation of nodal acceleration for each vehicle in each time step of calculation gives input ground motion for each vehicle which depends on the location of vehicle (Parajuli, Kiyono, & Yatsumoto, 2015). Seismic response analysis of vehicle had performed with modelling of vehicle in six degree of freedom. Equation of motion was used as basic equation for analysis. We also considered longitudinal, transverse and vertical displacements along with pitching, rolling and yawing motions as rotations in three directions. Forces acting on tyres were calculated using Magic Formula Model (MFM) (Pacejka, 2006). MFM coefficient were taken from literature (Alagappan, Rao, & Kumar, 2014) using trust region reflective method algorithm. Flow chart of the analysis is shown in figure 1.

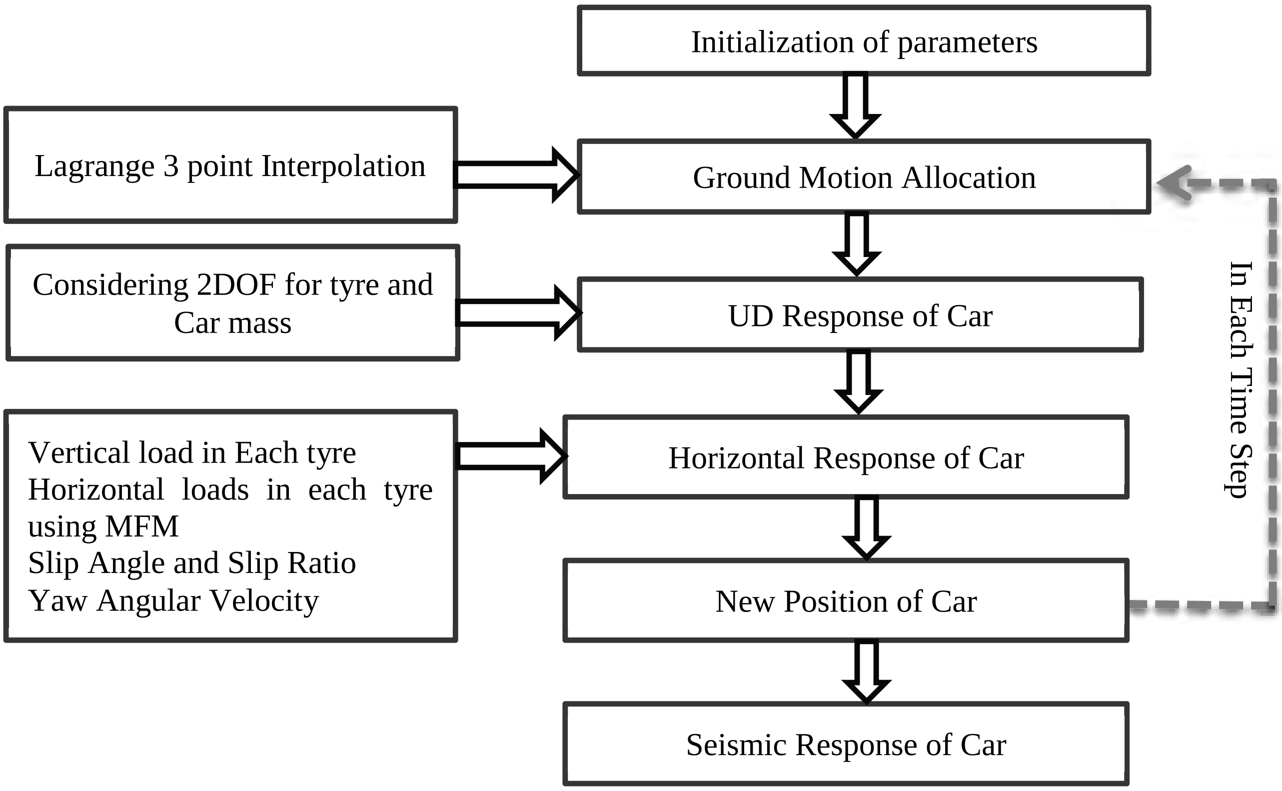

Figure 1 Flow chart of analysis

2. BRIDGE MODELLING

A cable stayed symmetrical bridge of total length 1320 m was modeled with nodal distance of 5 m between central three nodes and mostly 15 m in rest of part except two nodal distances of 7.5m in both side near short piers in between long and edge piers. Central span of bridge is 580m long with three columns in each side as shown in figure one. Total numbers of nodes in bridge deck level are ninety-one. Analysis was performed using commercial software Forum 8, Engineering Studio. Dynamic analysis of bridge with input ground motion as shown in figure 2, in base of piers give nodal acceleration response. Nodal response accelerations of bridge model were later used in determination of earthquake motion for analysis of vehicle behavior.

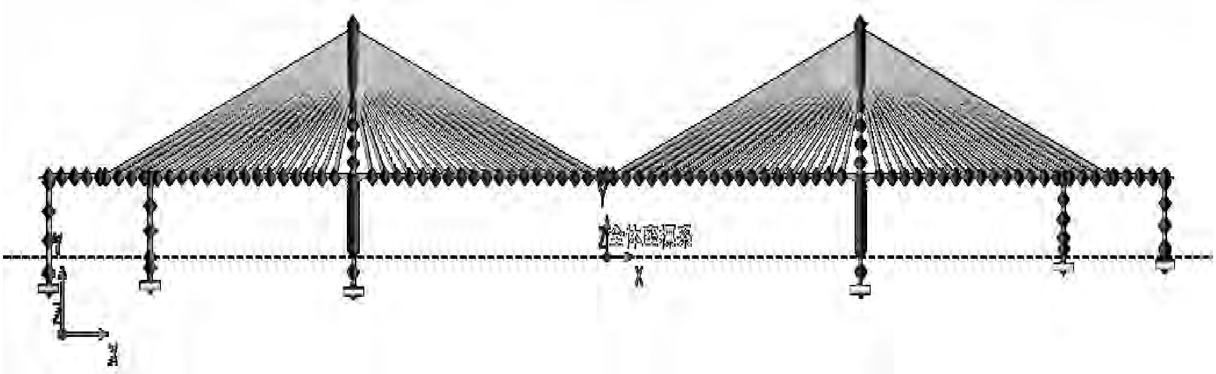

Figure 2 Bridge model

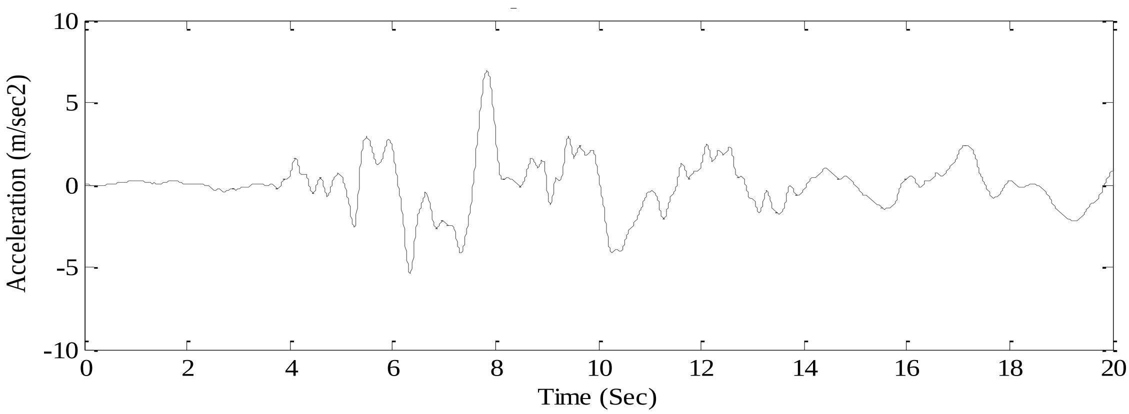

Figure 3 Input ground motion

3. INTERPOLATION OF EARTHQUAKE MOTION

Speed and starting location of vehicle varies in each case for multiple vehicle analysis, which lead to variation of real exciting earthquake motion depends on the response of bridge where the vehicle stands in that particular time. Hence to find out the real earthquake motion for running vehicle, we use interpolation of bridge response by considering three points around the location of vehicle. We use Lagranges' interpolation, considering the known three points (nodes), could find new value for new location with in this range. This form of interpolation is suitable in case of cubic or square parabolic functions. Lagrange's form of polynomial interpolation is combination of linear functions. In our case as nodal distances are maximum of 15 meters and the relation of data within three points (45 m) are seemed square parabolic functions, three point interpolation had chosen. We had checked the plot of relation of acceleration with location in some time steps, that shows there is no any sharp or uneven changes, it has square parabolic functions. Three points interpolation using Lagranges interpolation of (x0, y0), (x1, y1) and (x2, y2) for $x0 \le x \le x2$ is given by equation 1 and 2.

$$L(x) = \sum_{k=0}^{n} y_k l_k(x) \qquad For\, n + 1\, data \tag{1}$$

$$\mathrm{l_k(x)} = \frac{(\mathrm{x} - \mathrm{x0})}{(\mathrm{x_k} - \mathrm{x0})} \dots \dots \frac{(\mathrm{x} - \mathrm{x_{k-1}})}{(\mathrm{x_k} - \mathrm{x_{k-1}})} \frac{(\mathrm{x} - \mathrm{x_{k+1}})}{(\mathrm{x_k} - \mathrm{x_{k+1}})} \dots \dots \frac{(\mathrm{x} - \mathrm{x_n})}{(\mathrm{x_k} - \mathrm{x_n})} \tag{2}$$

Analysis of vehicle running on elevated expressways during earthquake

4. VEHICAL MODELLING

We defined three translational motions ad longitudinal, transverse and vertical with three rotational rolling, pitching and yawing motions as shown in Figure 4. Vehicle model parameters were chosen from data provided for Honda civic. Mass of each tyre taken as 100 kg, mass of body is 1100 kg. Distance of front drive axel and rare drive axel from CG is taken as 1000 and 1635 mm respectively. Height of CG from ground level is 350 mm where distance between right and left tyre is 1505 mm. Spring and damping coefficients between tyre and surface are 800 kn/m and 0.098 kn-s/m, whereas same for suspension of vehicle are 70 kn/m and 4.9 kn-s/m respectively.

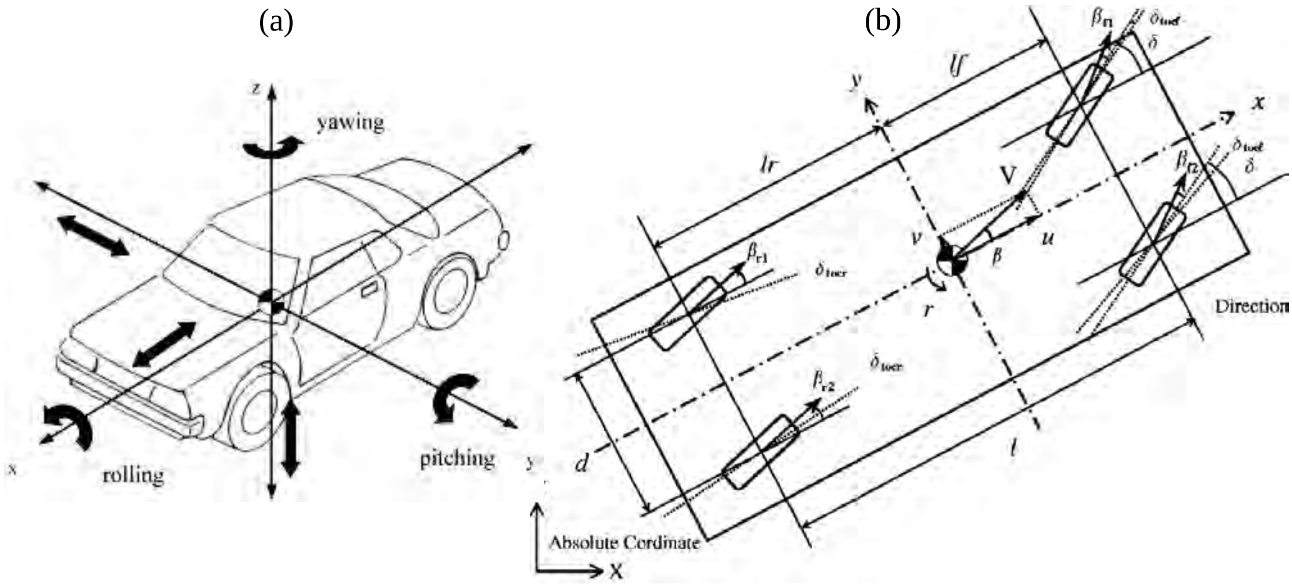

Figure 4 Vehicle model (a) Fundamental motions of vehicle (b) Geometric parameters of vehicle in X-Y plane

5. ANALYSIS

Seismic response of vehicle model calculated in each time step. Newmark method was used for integration of ground motion with beta and gamma value of 1/6 and 1/2, as linear acceleration method. Equation (3) and (4) are equations of motion used in analysis, corresponding to x and y direction respectively. Here "i" represent front or rear and "j" represents right or left tyre, $\mu$is frictional coefficient between car tyre and road surface considering dry and clean surfaces taken as 0.72. Vertical motion of vehicle was calculated by using quarter vehicle model, four tyre models with spring and dashpots connection with ground and one car mass modeled with spring and dashpot over tyre. Input earthquake acceleration was calculated by interpolation of nodal responses around the location of vehicle in each time step, which depends on speed and location of vehicle. Force acting on each tyre of vehicle, longitudinal and transverse along with self-aligning moment was calculated by using Magic Formula Model (MFM) as equation (5) - (7) considering pure slip condition, the situation when either longitudinal or lateral slip occurs in isolation defined as pure slip condition. MFM coefficients were used from TRR algorithm, that found best in compare with several algorithms (Alagappan et al., 2014). Ten sets of vehicles are used in analysis, five in each lane with different speeds. Two vehicles with speed of 77 and 101 kmph are considering to show the result for interpolated ground motion. Seismic response of vehicle are calculated without considering the driver's behavior, hence the condition of analysis is free flow of a vehicle without driver. Human behavior of driving will consider in near future.

$$m_2(\dot{u} - vr + \ddot{x}\cos\phi + \ddot{y}\sin\phi) = \sum_i \sum_j (F_{xij}\cos\delta_{tij} - F_{yij}\sin\delta_{tij} = \sum_{i,j} F'_{xij} - \mu\, mg \quad (3)$$

$$m_2(\dot{v} + ur - \ddot{x}\sin\phi + \ddot{y}\cos\phi) = \sum_i \sum_j (F_{xij}\sin\delta_{tij} - F_{yij}\cos\delta_{tij} = \sum_{i,j} F'_{yij} - \mu\, mg \quad (4)$$

$$y(x) = D\sin[C\arctan\{Bx - E(Bx - \arctan(bx))\}] \quad (5)$$

$$Y(x) = y(x) + S_v \quad (6)$$

$$x = X + S_h \quad (7)$$

6. RESULT AND DISCUSSION

Figure 5 (a) and (b) show the earthquake acceleration that that two vehicles running in speed of 77 and 101 kmph get excitation respectively. Figure in left shows acceleration and corresponding Fourier spectrum in right. Both of the accelerogram seems different from input ground motion for bridge which will be same when vehicle running in the surface road. Most importantly, accelerations for running vehicles depends on speed as in these figures we clearly see that high frequency is dominant for low speed of 77 kmph and higher for 101 kmph. Hence seismic response analysis of running vehicle over the bridge must consider the real exciting earthquake motion which can get from interpolation of response of bridge structures.

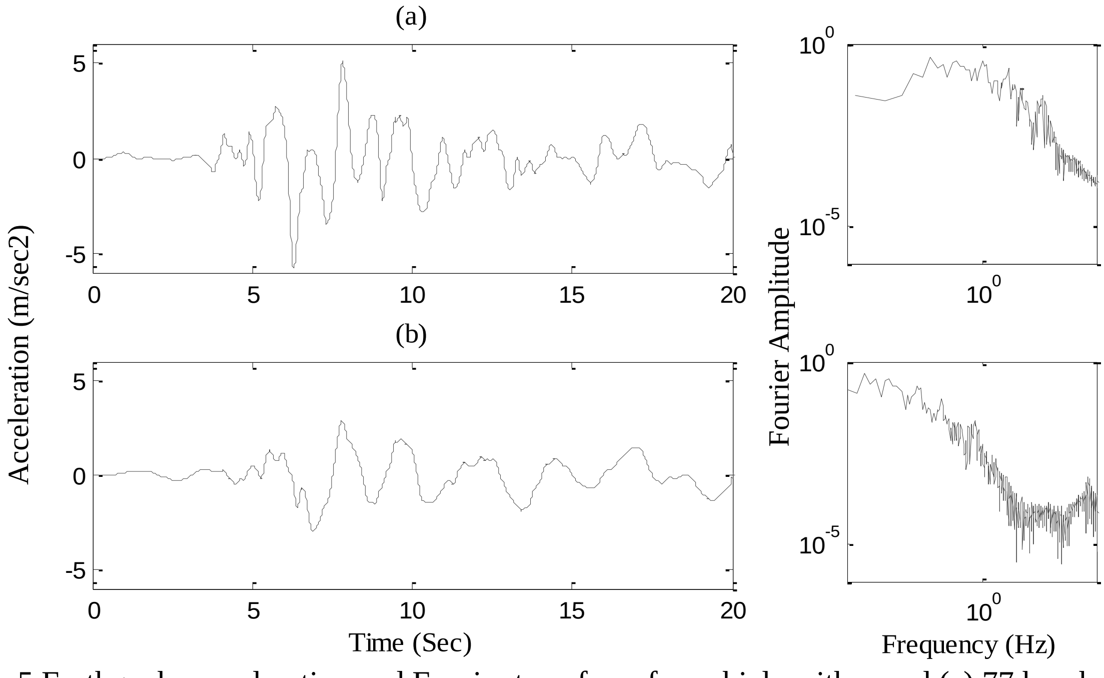

Figure 5 Earthquake acceleration and Fourier transform for vehicle with speed (a) 77 kmph and (b) 101 kmph

Seismic response of vehicle in lateral direction is more critical that cause instability of steering. Longitudinal response of bridge itself is not that sufficient to excite the vehicle, the speed of vehicle itself has much higher values so we are focusing on lateral lateral response. Lateral acceleration, velocity, displacement and yaw angular velocities for the vehicle with speed of 101 kmph is shown in figure 6 (a), (b), (c) and (d) respectively.

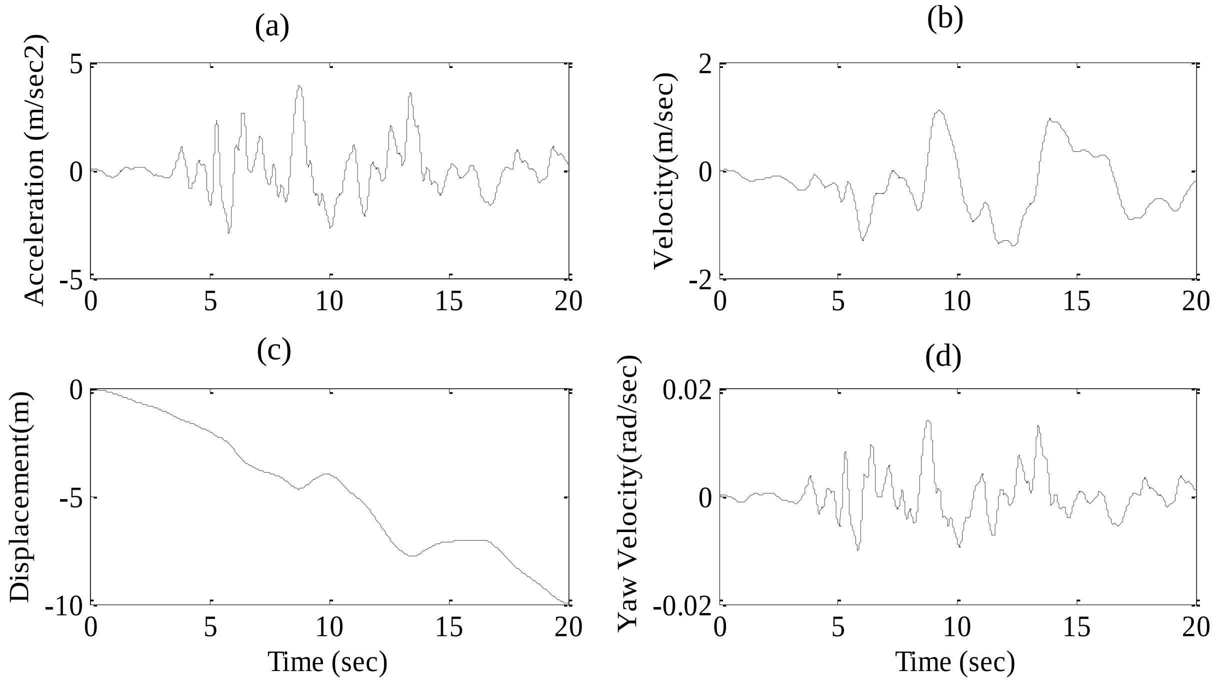

Figure 6 Response of vehicle (a) Lateral acceleration (b) Lateral Velocity (c) Lateral displacement (d) Yaw angular velocity

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Non-Structural Vulnerability Mitigation in Hospital and Experience in Recent Medium Intensity Earthquake

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ABSTRACT

Hospitals is one of the most critical facility that needs to be functional during and after the large earthquake. Non-structural elements like equipment and contains covers 80% of construction cost in Hospitals. Generally, non-structural damage occurs even in medium intensity earthquake. The damage in non-structural element not only cause huge monitory loss but also affects in the functionality of the hospital. The hospital cannot provide its services even after medium intensity earthquake if non-structural element are not functional. Therefore, authors think the non-structural vulnerability reduction is necessary to make hospitals functional aftermath of earthquake and is not costly. Each non-structural element first has to be identified as a potential threat in terms of loss of life, property and /or function and the appropriate measures must be identified to reduce or eliminate the risk. The risk reduction option might be different for each individual components. Authors present here the appropriate technology in local context for non-structural vulnerability reduction through this paper. The following reduction measures are identified: removal, relocation, and anchorage, hooking/chaining, strapping, provision of flexible connections in rigid joints, support and modification (plastic lamination in glass panel). Locally available gadgets can be used for different types of reduction measures. Most items can be fabricated in local market using locally available expertise. Authors also present some of the major lessons learn during the implementation of the non-structural mitigation options in different hospitals in Nepal and documented the experience in recent earthquake of M7.8 Gorkha Earthquake on th April 2015 at 11:56AM local time. Most part of the Kathmandu Valley was shaken at medium intensity due to this earthquake.

Keywords: non-structural element, non-structural vulnerability, risk reduction measures, appropriate technology, medium intensity

Evaluation of evacuation method through the pedestrian crowd evacuation simulation -Case study for Adachi-ku Senju district in Tokyo-

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ABSTRACT

In this study, Adachi-ku Senju district in Tokyo was selected as an investigated district because this district has been designated by the Tokyo Metropolitan Government as an area having high fire and flood risks. Questionnaire survey was conducted for the residents in this district to collect data on level of recognitions about disaster damage estimates and recommended evacuation method. Moreover, stated-preference for disaster evacuation was also investigated. The obtained stated-preference data was utilized to estimate model describing citizen's disaster evacuation behavior that was formulated by nested-logit mode with three hierarchies. First hierarchy is evacuation/no evacuation choice behavior, second hierarchy is vertical/horizontal evacuation choice behavior and third hierarchy is evacuation place choice behavior. The evacuation behavior model was estimated by maximum likelihood estimation method and it was utilized to forecast the number of evacuee under certain disaster situation such as outbreak of the earthquake disaster and imminence of flood. Level of safety of evacuation method was evaluated using the pedestrian crowd evacuation simulation built in this study. The safety of each evacuation method was verified in terms of evacuation completion time, the risk of encountering danger during evacuation such as approaching to fire spot, walking in excessively crowded space, collision of falling object caused by aftershock, walking in inundated area, and etc.. It is expected that the results of this study is utilized as basic information to examine the safer evacuation method of the investigated district.

Keywords: evacuation behavior model, stated preference, nested-logit model, pedestrian crowd simulation

1. INTRODUCTION

Four years have passed since the Great East Japan Earthquake of March 11, 2011 which brought serious damage in the Tohoku district. Previous disaster prevention measures were reviewed and the actions to reduce disaster damage is progressed. In addition, the correspondence to the complex disaster also is to be considered. Senju district in Adachi-ku is focused on in this study since this district is evaluated by the national and local organizations to be high-risk of the different disaster such as earthquake and flood. According to the Seventh Community Earthquake Risk Assessment Study by the Tokyo Metropolitan Government, this districts is appointed to the area with high combined risk of building-collapse and fire due to earthquakes. In addition, the Ministry of Land, Infrastructure and Transport shows that there is an area flooded more than 5m in this district when Arakawa overflowed.

As described above, there are many problems for disaster reduction in this district. Therefore, this study research on the disaster evacuation of the residents in this district. Evacuation behavior model was built and the number of evacuee was estimated under the different disaster situations. Moreover, the evacuation safety is evaluated by using a pedestrian crowd simulator.

2. STATED PREFERENCE SURVEY

Questionnaire survey was conducted to investigate evacuation behavior of the residents. Stated preference experiment was adopted for the survey since there was no data about revealed preference for evacuation.

Figure 1 shows an example of the stated preference experiment. Each respondent is required to answer the evacuation behavior under the presented disaster situation.

The disaster situation is different by setting status of disasters. Possibility of fire spread to the residence, possibility of flood, status of road congestion, suffered state of urban lifeline were considered as the variables of the disaster situation. Respondents answered their expected evacuation behavior under five different situations.

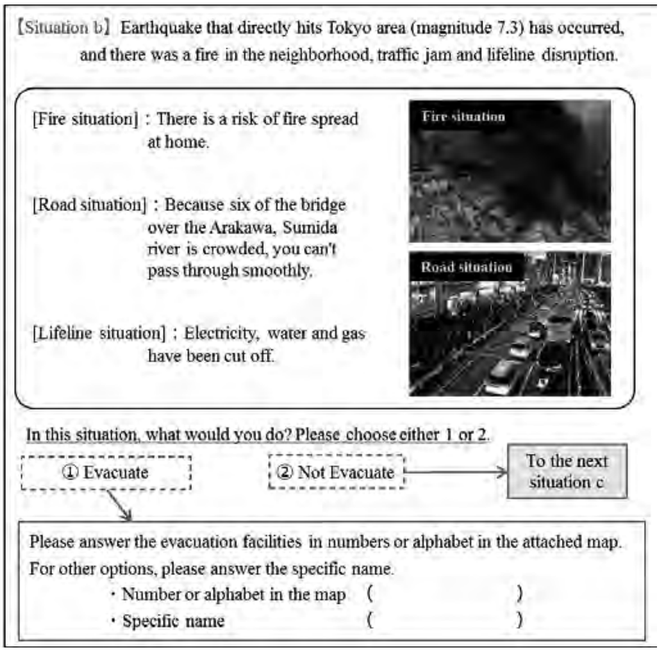

Figure 1: Example of the question about stated preference

3. ESTIMATION OF EVACUATION BEHAVIOR MODEL

3.1 Hierarchy of evacuation behavior

Evacuation is conducted by corresponding to the status of disaster. Figure 2 shows hierarchical structure of disaster evacuation. Decision making for evacuation is conducted from the top to the bottom.

At first an evacuee decides whether to go out from the residence or not. Secondly, the evacuee decides whether to conduct horizontal evacuation or to conduct vertical evacuation. Finally, the evacuee decides the evacuation facility to go. However, in the case of an earthquake disaster, the second stage regarding the decision regarding horizontal/vertical evacuation is not considered.

For estimating mathematical models of evacuation behavior, the discrete choice model was utilized in this study. To consider the hierarchical structure of the behavior, nested logit model was applied. Parameter estimation was executed from the bottom to the top according to the estimation method of nested logit model.

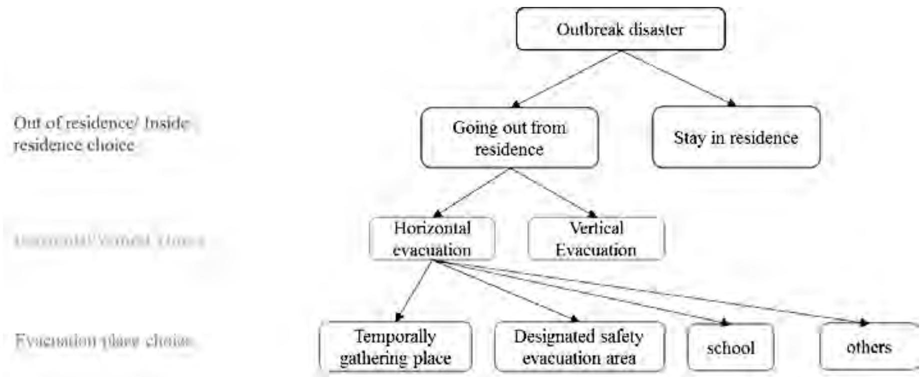

Figure 2: Hierarchical structure of disaster evacuation

3.2 Evacuation place choice model

3.2.1 Choice set and explanatory variables

Alternatives of evacuation place choice were set as temporally gathering place, designated safety evacuation area, school not designated for temporally gathering place and others.

Choice possibility of these four facilities was set by the following methods. After measuring the distance from the residence (center of gravity of the residential zone) to the facilities to be chosen, more than 80 % of the facilities were in less than 500m. Therefore, the evacuation facilities located within less than 500m were from the center of the zone were considered as alternatives.

The explanatory variables of this model are described in the Table 1. Moreover, the dummy variables of each facilities are considered. If there are plural temporally gathering places in the residential zone, the means of distance and the number of floors are used for the variables.

Table 1: Explanatory variables of evacuation place choice model

Explanatory variables	Measurement
Distance to evacuation place	Minimum distance from the zone to the place(m)
Number of floors of evacuation place (floors)	Number of floors of the facilities (floors)
Decrease of building collapse risk	Difference between the building collapse risk at the residence and that of the evacuation place (building/ha)
Decrease of fire risk	Difference between the fire risk at the residence and that of the evacuation place (building / ha)
Decrease in the inundation depth	Difference between inundation depth at residence and that of the evacuation place (m)

3.2.2 Estimation result

On the occasion of parameter estimation, the respondent whose individual attributes such as place of residence, age and gender were unknown were removed from the dataset for the estimation.

Table 2 shows the estimation result of the evacuation place choice model. There are three models presenting evacuation behavior under different situation such as possibility of fire spread, possibility of flood and possibility of complex disaster. These model can explain the reason why certain place was chosen for the evacuation place. T-statistics indicates statistical significance of each coefficient.

Table 2: Estimation result of Evacuation place choice model

Disaster situation	Fire spread		Flood		Complex disaster	
Explanatory variables	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics
Distance to evacuation place(m)	-0.0022	-5.17	-0.0030	-3.35	-0.0020	-4.19
Number of stories of evacuation place			0.0053	0.023	0.013	0.079
Decrease of building collapse risk (building / ha)	0.23	6.28			0.14	2.39
Decrease of fire risk (building / ha)	-0.01	-0.31			0.024	0.95
Decrease of inundation depth (m)			4.41	0.097	0.79	3.13
Constant term for designated safety evacuation area	0.45	0.77	-3.04	-0.44	-0.61	-0.70
Constant term for school	1.58	3.68	1.90	1.32	0.94	0.93
Constant term for others	2.48	3.85	1.22	1.25	0.44	0.69
Initial likelihood	-195.01		-95.15		-111.49	
Last likelihood	-97.98		-28.79		-59.94	
Likelihood ratio	0.50		0.70		0.46	
Adjusted likelihood ratio	0.47		0.63		0.39	
Hitting ratio (%)	75.8		72.9		83.9	
Number of samples	179		96		112	

3.3 Evacuation direction choice model

3.3.1 Definition of direction

In the questionnaire survey, respondents were required to answer the floor level for the evacuation. If this answer is same level of respondent's residence, this respondent evacuates to the higher floor of the residence. In this study, such a vertical evacuation in the residence is not include vertical evacuation. In other words, evacuation by moving out from residence and going to upper floor of neighboring building is defined as vertical evacuation in this study.

3.3.2 Explanatory variables and estimation result

The explanatory variables of this model are described in the Table 3. Beside these variables, constant term for vertical evacuation is considered.
Binary logit model is applied to estimate evacuation direction model which can explain the reason why evacuee choose vertical evacuation and horizontal evacuation.
The estimation result shown in Table 4. There are two models presenting evacuation behavior under different situation such as possibility of flood and possibility of complex disaster.

Table 3: Explanatory variables

Explanatory variables	Measurement
Logsum utility	Expected value of the maximum utility for evacuation place choice.
Dummy variable of multistory building	If the building is with more than four floor, set to 1 Otherwise, set to 0

Table 4: Estimation result of vertical/horizontal choice model

Disaster situation	Flood		Complex disaster	
Explanatory variables	**coefficient**	**t-statistics**	**coefficients**	**t-statistics**
Logsum utility	0.05	0.47	0.15	0.75
Dummy variables of multistory building	3.00	6.58	0.18	4.42
Constant term (vertical evacuation)	-1.94	-6.26	-2.89	-7.21
Initial likelihood	-90.15		-68.65	
Last likelihood	-62.63		-55.95	
Likelihood Ratio	0.31		0.19	
Adjusted likelihood ratio	0.27		0.14	
Hitting ratio (%)	83.1		84.0	
Number of samples	142		156	

3.4 Move/Stay choice model

At first, evacuee must decide whether to going out from the residence or to stay in the residence. In this study, the binary logit model was utilized to estimate this move/stay choice model.
The explanatory variables of this model are described in the Table 5. Beside these ten variables, constant term for evacuation by going out from the residence is considered.
The reason why two kind of logsum variables are considered is the difference of evacuation behavior under the disaster with and without the possibility of flood.
The result of parameter estimation is shown in Table 6.

Table 5: Explanatory variables

Explanatory variables	Measurement
Dummy variables of elder person	Dummy variables (64 years old or older)
Number of stories in the residence	Number of floors of the residence
Cognition situation of earthquake damage	When earthquakes directly under North Tokyo Bay has occurred, whether you are aware of the expected seismic intensity of the district (If you are aware, set to 1)
Cognition situation of flood damage	In the case of dike break of Arakawa river, whether you are aware of the expected inundation height of the residence (If you are aware, set to 1)
Logsum utility of evacuation place choice	Expected value of the maximum utility of evacuation place choice
Logsum utility of evacuation direction choice under flood risk	Expected value of the maximum utility of evacuation direction choice
Dummy variables of disaster situation (Fire spread)	Setting condition of SP survey
Dummy variables of disaster situation (Flood)	Setting condition of SP survey
Dummy variables of disaster situation (Traffic jam)	Setting condition of SP survey
Dummy variables of disaster situation (Lifeline disruption)	Setting condition of SP survey

Table 6: Explanatory variables

Explanatory variables	coefficients	t-statistics
Dummy variables of elder person	-0.53	-3.42
Number of stories in the residence	-0.16	-5.77
Cognition situation of earthquake damage	0.32	2.11
Cognition situation of flood damage	-0.46	-2.24
Logsum utility of evacuation place choice	0.91	7.26
Logsum utility of evacuation direction choice under flood risk	0.79	5.60
Dummy variables of disaster situation (Fire spread)	4.03	5.91
Dummy variables of disaster situation (Flood)	-0.52	-1.44
Dummy variables of disaster situation (Traffic jam)	-2.14	-5.42
Dummy variables of disaster situation (Lifeline disruption)	-1.93	-4.87
Constant term (Evacuation by going out the residence)	0.10	0.72
Initial likelihood	-879.48	
Last likelihood	-780.15	
Ratio of likelihood	0.113	
Corrected ratio of likelihood	0.100	
Hit ratio (%)	65.5	
Number of samples	1305	

4. ESTIMATION OF THE NUMBER OF EVACUEE

Three kinds of model estimated previous chapter were utilized to estimate the number of evacuees under assumed disaster situation.

Estimation was executed by zone and age group (less than 70/ more than 70).
The population in residential zone is based on the national census in 2010 and the mean of the number of floors of residence in a zone is used. Cognition situations of the earthquake and flood damage are both set 0.5.
Table 7 shows the number of evacuees under different disaster situation.
Moreover it shows the number of evacuees by evacuation place and evacuation. These estimates are to be input data of pedestrian crowd evacuation simulation.

Table 7: Estimation of the number of evacuees

		Case1	Case2	Case3	Case4	Case5	Case6
Disaster situation (○:Considered)	**Fire spread**	○	○			○	○
	Flood risk			○	○	○	○
	Traffic jam		○		○		○
Horizontal evacuation	Temporary gathering place	21,876	21,139	30,349	25,570	11,770	10,283
	Designated safety evacuation area	1,222	1,186	12,066	10,550	33,444	28,191
	School	45,007	43,674	242	194	15,212	13,466
	Others	4,819	4,706	5	4	6,474	5,466
Evacuees (horizontal evacuation)		72,923	70,704	42,662	36,318	66,900	57,406
Evacuees(vertical evacuation)		0	0	28,425	23,333	4,308	3,687
Staying at home		320	2,539	2,156	13,592	2,035	12,150
Total number of people in Senju district		73,243	73,243	73,243	73,243	73,243	73,243

5. EVALUATION OF THE EVACUATION METHOD

In this chapter, evacuation method is evaluated by using CrowdWalk that is a multi-agent simulator developed by the National Institute of Advanced Industrial Science and Technology (AIST) of Japan.
In this study, effectiveness of the temporary gathering place for safer evacuation was examined. The evaluation indices are mean of travel time to the designated evacuation area and mean time when evacuee cannot move by pedestrian congestion.
Three scenarios were prepared for the examination as follows.
First scenario is the situation that all the residents evacuate directly to the designated safety evacuation area at once. Second scenario is the situation that all the residents evacuate to the temporary gathering place for the first stage and move to the designated safety evacuation area after certain time has passed. The third scenario is the situation that scenario 1 and scenario 2 is mixed in half-and-half. Figure 3 shows the screen shot of the pedestrian simulation.
Meanwhile, Figure 4 shows the evaluation results of evacuation safety. As seen in the figure, the scenario 2 has better performance compared to the scenario 1. It demonstrate that the evacuation to temporary gathering place might be a good evacuation method.

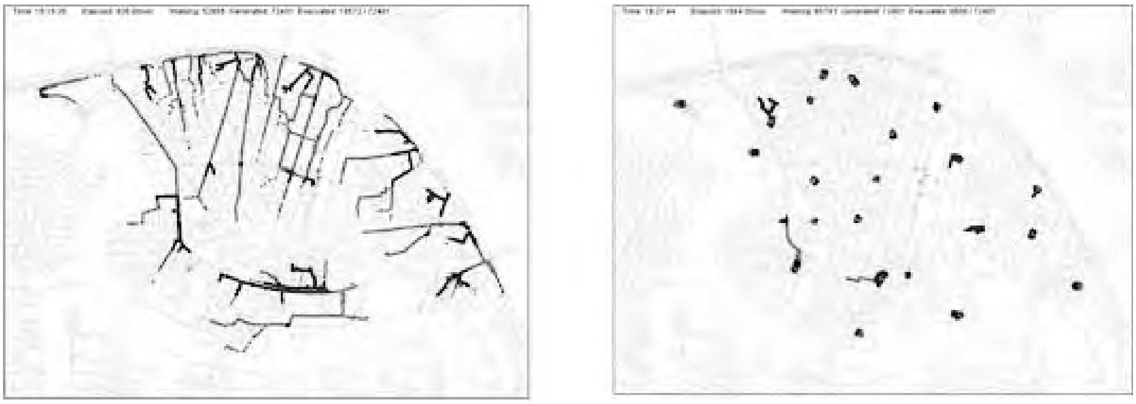

Figure 3: Screen shot of the CrowdWalk (left: Scenario 1, right: scenario 2)

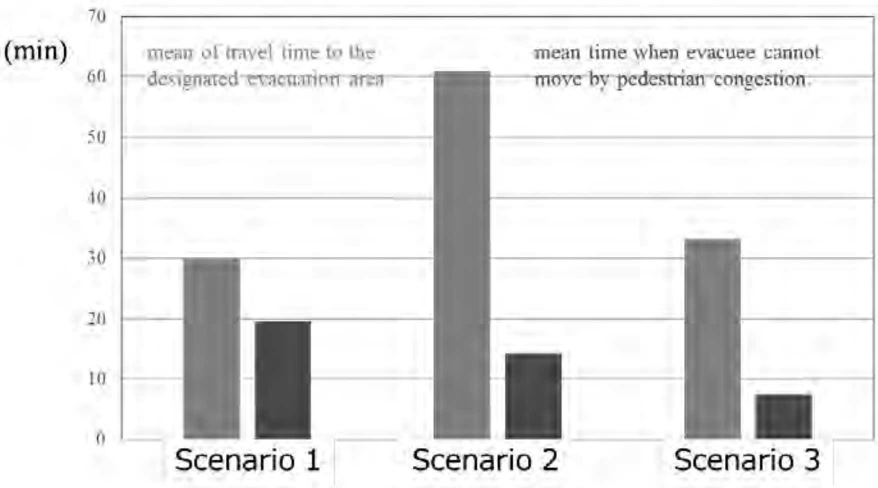

Figure 4: Evaluation of the safety of evacuation method

6. CONCLUSION

In this study, Adachi-ku Senju district in Tokyo was selected as investigated district. Questionnaire survey was conducted for the residents in this district. The stated-preference data for disaster evacuation was utilized to estimate models describing citizen's disaster evacuation behavior. The evacuation behavior models were estimated and it was utilized to estimate the number of evacuee under certain disaster situation. Level of safety of evacuation method was evaluated using the pedestrian evacuation simulation. The safety of each evacuation method was verified in terms of evacuation completion time and time length in pedestrian congestion. It is expected that the results of this study is utilized as basic information to examine the safer evacuation method of the investigated district.

Strategy for Developing Professional Emergency Responders in Nepal

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ABSTRACT

Preventing hazard at source is difficult in many cases, and for earthquake- it is impossible! However, timely initiatives for awareness and preparedness for proper response can make a huge difference for facing devastating hazard events. The possibility of rescuing live victims in disasters decreases with the passage of time. Community responders are the first at the scene and operate spontaneously but due to lack of proper skills and equipment many victims remain either unreached or don't get proper professional response. Here the term 'professional response' means the services by responders having formal trainings on Search and Rescue and able to operate powered tools and equipment. It has been widely realized that more lives could have been saved, if there were more professional responders sooner at the scene during the April 25, 2015 Gorkha Earthquake. Due to the location (landlocked), poor infrastructure, physical diversity resulting difficult accessibility; Nepal cannot expect to get immediate international support for response. Therefore, developing national capacity in professional response is an urgent need in Nepal.

This paper, based on the experiences from recent earthquake and international practices, recommends a strategy for developing competent professional emergency responders at different levels from community to formal emergency response organizations.

Keywords: *strategy, emergency, professional responders*

1 INTRODUCTION

Physical diversity, climatic variation, fragile geology and location astride the plate boundary are the natural characteristics of Nepal. As a consequence, the country is one of the multi-hazard prone countries of the world. Further, the hazards usually tend to be converted to devastating disasters due lack of awareness, preparedness, capacity, proper response system and resources to cope with. Everyday two people are losing their lives in the country due to hazard events (MOHA, 2011 a). Earthquakes have devastated the country many times in the past. While we can stop or modify the earthquake, it is impossible! However reducing its impact through timely initiatives for awareness and preparedness for proper response; it can make a huge difference during a real disaster.

It has been learned from the past disasters around the world that immediate and proper response to disasters can save significant lives and property. Nepal realized this during the recent April 25, 2015 Gorkha earthquake. The responders of different levels will have different capacity and limitations in terms of skills and equipment. It is obvious that community responders are the first to reach at the scene and will operate spontaneously. However, due to lack of proper skills and equipment many victims remain unreached and waiting for professional responders. Here the term 'professional responders' means the responders having formal skill-based trainings on Search and Rescue (SAR) and able to operate SAR powered tools and equipment. The Gorkha Earthquake has shown the need of developing more such 'professional responders' in the country. It is widely accepted that the possibility of rescuing live victims in disasters decreases with the passage of time. In this connection, every country should give the highest priority for being capable to cope with disasters for saving lives. Moreover, in the context of Nepal, due to location (landlocked), poor infrastructures, physical diversity resulting difficult accessibility; immediate support from international community cannot be expected. Therefore, developing national capacity regarding professional responders is an urgent need of Nepal.

It was unfortunate for the people who lost their loved ones and property due to the recent earthquake. However, by the energy itself, 7.8 magnitude, the earthquake was not very big, it was of moderate level. Moreover, the earthquake was in favor of people occurring on Saturday and at the time of day. Had the earthquake occurred at night or on a working day, the scenario could have been more tragic in terms of number of deaths. Similarly, the only one international airport, Tribhuvan International Airport was functional allowing coming-in the international humanitarian assistance and SAR teams in Nepal. It was also a luck the major road network and the 51 domestic airports remained functional. The international SAR teams started to arrive from day one and could be deployed to different affected areas.

2 CURRENT INITIATIVES FOR DEVELOPING EMERGENCY RESPONDERS IN NEPAL

2.1 Traditional Emergency Response

Regardless of the scale, people are facing one or other kind of disasters since their existence. They have made efforts to cope with such disasters, they are living with disasters, say- disaster emergencies are part of their life. People cannot wait for the skills and technologies; they tend to response spontaneously with available resources and skills while they encounter with disasters. However, the effectiveness of response is always directly related with the skills and resources; and it has inversely related with success in saving lives and property. Rural communities usually learn from their parents and neighbourhood, they have been responding the disasters in ad-hoc to save lives and property and struggling long to be recovered, but tend to forget while it is over. The same thing is reflected at the national level especially in developing countries like Nepal. The phases of disaster management, preparedness, response, recovery, and mitigation, are not given importance equally. They are activated while there is disaster putting all efforts, once disaster is over, mitigation and preparedness activities are not in priority. The response centered disaster management system demands huge investment for response during disasters even for saving minimum lives and property.

The response mechanism of Nepal is still guided by the Natural Calamities (Relief) Act of 1982 (NCRA 1982), which is more focused on response and relief activities after disaster not in preparedness before disaster. Therefore, while disaster strikes, without any plan and preparedness people spontaneously tend to respond with whatever skills and knowledge and equipment they have, putting themselves at risk. Effective response always demands good preparedness including strategy for capacity enhancement of responders, arrangement of equipment, adaptation of modern technologies, and tested operation system through simulation exercises.

2.2 Program for Enhancement of Emergency Response (PEER)

Enhancing capacity of responders with proper knowledge and skills and developing a system owned by government is one of the crucial activities for developing emergency response capacity for any countries. In this direction Program for Enhancement of Emergency Response (PEER) is an effort implemented by National Society for Earthquake Technology-Nepal (NSET) in South Asia with support from the United

States Agency for International Development, Office of U.S. Foreign Disaster Assistance (USAID/OFDA). PEER is an experienced program in the field of emergency response capacity enhancement from in Latin American and Caribbean countries to Asia and now being implemented in South Asian countries. Since 1998 PEER has implemented emergency response capacity enhancement programs through three different stages mainly in the field of Collapsed Structure Search and Rescue (CSSR), Medical First Response (MFR), Hospital Preparedness for Emergencies (HOPE) and Community Action for Disaster Response (CADRE). Stage 1 (1998-2003) was implemented by the Asian Disaster Preparedness Center (ADPC) in four earthquake-prone countries of Asia, namely, India, Indonesia, Nepal and the Philippines to bring the experience from LAC countries to Asia at a regional level. PEER Stage 2 (2003-2009) was implemented by NSET in six Asian countries including two new beneficiary countries, namely, Bangladesh and Pakistan. This stage focused on nationalization and institutionalization of MFR and CSSR courses and instructor development courses as a training system and finalization of HOPE course materials. PEER Stage 3 (2009-2014) was jointly implemented by NSET and ADPC. NSET was focused for MFR and CSSR and ADPC for CADRE and HOPE. PEER Stage 4 (2014-2019) is being implemented by NSET in four South Asian countries, namely, Bangladesh, India, Nepal and Pakistan with possible extension in other four countries namely Afghanistan, Bhutan, Maldives and Sri Lanka. PEER stage 4 objectives are to enhance emergency response capacity of South Asian countries by providing training on MFR, CSSR, CADRE, HOPE and Swift Water Rescue (SWR) courses and by providing networking and collaboration among relevant individuals and institutions in the region.

Since 1998, PEER has developed a pool of 287 MFR graduates, 113 MFR instructors, 250 CSSR graduates and 87 CSSR instructors, 340 HOPE graduates, 67 HOPE instructors, 233 CADRE graduates and 71 CADRE instructors in Nepal. The PEER program has helped the countries for translating and customizing regional courses in their local context which has made more effective delivery and integration in regular training programs for responders. It has established a link between the responders for sharing skills and informations. The PEER curricula, PEER-trained graduates and instructors are instrumental for implementing related emergency response trainings for formal response groups and disaster volunteers, towards strengthening national emergency response capacities. The partner organizations adhere to and adapt PEER program guidelines in terms of course facilities, either improvising or upgrading of training equipment and materials for effective and efficient delivery of their non-PEER training programs.

The response during the recent April 25, 2015 Gorkha Earthquake was great contribution of PEER in Nepal. The PEER graduates could significantly make difference for saving lives during this earthquake. The PEER trained responders mainly from Nepalese Army, Nepal Police, Armed Police Force, Nepal Red Cross Society (NRCS) and NSET were immediately mobilized for search and rescue operation. The impact of earthquake was huge, many professional as well as community responders got involved for search and rescue, however, most of the national search and rescue operations were led by PEER trained responders. The national responders, mainly from security forces, had the skills of CSSR and MFR and community responders were led by the CADRE. The skills and equipment handling learned during the course was very useful and that could make difference during response. It was very helpful for hospitals to deal with mass casualties due to HOPE program. The PEER graduates were involved even in international teams such as the teams from India and Bangladesh. Since PEER is the standard regional course and follows the INSARAG guidelines, it was easy for national responders to work jointly with other international teams.

2.3 Initiatives of the Government

The disaster management policy of Nepal is guided by the Natural Calamities (Relief) Act (NCRA) 1982. Prior to 1982, rescue, relief as well as resettlement of disaster victims were carried out in Nepal on an ad-hoc basis, primarily as a social work. The act has been amended thrice in 1986, 1989 and 1992 enunciating the significance of the pre-disaster and post disaster activities. It helped to develop an organizational structure from central to local level, to deal with response and relief works, and has provided the basis for coordination among various agencies, government and non-government in emergency response activities (MOHA, 2011a).

The National Strategy for Disaster Risk Management (NSDRM) developed in 2009 has provided the strategic direction to Nepal addressing all phases of disaster management. This document has worked as one of the milestones in the disaster management activities in the country. As guided by NSDRM, the National Disaster Response Framework (NDRF) has been developed and approved in 2013. The NDRF has clarified the roles and responsibility of different government and nongovernment stakeholders and developed a coordination mechanism among the national and international actors in case of emergency.

One of the important activities of Government of Nepal is establishment of National Emergency Operation Centre (NEOC). The NEOC, led by undersecretary of MOHA, is responsible to coordinate and mobilize emergency operation activities from the national level. However, the executive body, comprised of CDRC members, provides overall direction and control of disaster operations in Nepal. The executive body makes decisions about strategy and policies, which are beyond the authority of the Chief of NEOC that may include beginning of discussion with the regional and international response bodies depending on the scale of disaster. It provides policy decision, guidelines, procedures and direction for emergency operation. NEOC has established four activation levels for responding appropriately to the various degrees of emergencies that can affect the country. The NEOC's Standard Operating Procedures (SOP) has made provision to handle activation level 1 by NEOC chief, undersecretary, activation level 2 by joint secretary of MOHA, activation level 3 by CDRC, and activation level 4 by CDRC with instruction and guidance by cabinet. The MOHA has plan to establish the district level emergency operation centres as DEOCs in all 75 districts of the country. So far 42 DEOCs have been established. (MOHA, 2011 b)

District Disaster Preparedness and Response Plans (DPRP) have been prepared by all 75 districts. The District Lead Support Agency (DLSA) assisted to District Disaster Relief Committees (DDRC) for preparing DPRPs. The DPRPs have developed scenario based action plans of respective districts analysing associated hazards, vulnerabilities and resources. DPRP has made difference in the districts regarding the preparedness activities for response developing the coordination mechanism and identifying role and responsibilities of district level stakeholders (MOHA, 2010). The Government of Nepal has endorsed the different groups as "clusters" of disaster risk management actors representing from different national and international humanitarian agencies led by national government line ministries and/or departments. This is similar with the "Cluster Approach" promulgated by the UN Inter-Agency Standing Committee (IASC) in 2005. This has helped to systematic and effective coordination and mobilization of resources among different actors during disasters.

Very importantly all security forces of Nepal, namely, Nepalese Army, Nepal Police and Armed Police Force have established separate disaster management sections with stand-by responders within their organizations. All security forces have adopted MFR and CSSR courses from PEER along with other emergency response courses for their standby responders. APF has established well facilitated Disaster Management Training Centre. Similarly Nepalese Army has established 2 battalions with stand by responders providing emergency response trainings and equipment. Nepal police has one disaster management squadron with standby responders.

2.4 Initiatives by other Humanitarian Agencies

Several national and international organizations have accelerated their efforts for raising awareness and building capacity for emergency response in recent years. Nepal Red Cross Society (NRCS) has been working for relief management since its establishment in 1963. It has a good network of volunteers throughout the country through its 75 district chapters and 1,339 sub-chapters covering the entire country. NRCS has trained human resources at different levels such as Field Assessment and Coordination Team (FACT), Emergency Relief Unit (ERU), Regional Disaster Response Team (RDRT), National Disaster Response Team (NDRT), District Disaster Response Team (DDRT), First Aid, First Aid trainers, Light Search and Rescue (LSAR), Community Action for Disaster Response (CADRE), Dead Body Management, WASH and Shelter. The National Disaster Response Framework has given specific mandate to NRCS for responding to emergencies.

The National Society for Earthquake Technology- Nepal (NSET) is one of the pioneer non-governmental organizations working in Nepal in aspects of disaster risk management since its establishment in 1993. Though, its focus was in earthquake risk reduction and preparedness in initial days, now it focus is multi-hazard risk management. NSET has its activities almost throughout the country for supporting government bodies at different levels, communities and other DRM stakeholders for awareness-raising, capacity building and other DRM activities. It has been implementing the PEER since 2003 in Nepal including other Asian countries for building capacity of professional responders in the region and developing cooperation and network among the countries for sharing experiences, common understanding and mutual help during disasters. Beside PEER, NSET has been supporting individuals, communities, government/nongovernmental organizations, academic and health institutions, and other international agencies through emergency response trainings namely, Basic Emergency Response (BEMR), Community Search and Rescue (CSAR), Damage Assessment Trainings (DAT), Vulnerability and Capacity Assessment (VCA), Community Fire Response Trainings (CFRT), developing and testing emergency response plans and prepositioning emergency supplies at different levels (Jimee, et al., 2012). So far NSET has provided earthquake preparedness orientation programs for more than 37,000 people, has produced more than 1,400 CSAR responders, more than 300 BEMR responders and more than 100 DAT graduates.

The Disaster Preparedness Network-Nepal (DPNet-Nepal) was established in 1998 as a network of the organizations working in the field of disaster preparedness and management. It aims to assist the Government of Nepal for disaster preparedness and management through its member organizations. DPNet assists the member organizations for their effort to make communities, individuals and the organizations prepared against disasters. DPNet has been working for establishment of linkages among the DRM stakeholders through networking approaches.

The National Disaster Management Network Nepal (DiMaNN) is a network of the organizations working in disaster management sector from different areas of Nepal. DiMaNN aims to mobilize local, natural and human resources working as an agent of social change (MOHA, 2011a).

There has been many other initiatives by different organizations in Nepal in the past decade to improve disaster preparedness and response mechanism of the country. This effort has paid off as experienced during April 25, 2015 Gorkha Earthquake. Mainly there has been significant improvement in awareness, response capacity of communities and organizations and the coordination among the stakeholders. In addition to above mentioned organizations, there are many national and international non-governmental organizations contributing to this. Despite such successes, Nepal has to move ahead to cope with different hazards with better preparedness and improved response mechanism. Most of the plan and policies made and amended at different levels, are quite new, which has to be tested and reviewed through simulation exercises resembling realistic scenarios to build the confidence and developing common understanding among the actors while applying in real disasters. Due to geographical location of the country and physical diversity within it, the country has difficulties in accessibility from other countries resulting very less possibility to receive immediate international assistance in case of big disasters. The bitter fact is the delayed response reduces the chance of saving lives in disasters. This justifies that Nepal urgently has to develop its response capacity in terms responders, equipment, infrastructures and system to respond independently.

3 INTERNATIONAL PRACTICE IN DISASTER RESPONSE

Disaster impacts are generally high in urban areas due to high exposure as they are highly populated with concentration of structures, infrastructures and other facilities. Due to complex built up environment, infrastructures and potential risk due to hazardous materials, involvement of responders having advance skills, equipment and technology are required for urban search and rescue (USAR) operations.

The United Nations Disaster Assessment and Coordination (UNDAC) “Disaster Response Preparedness Mission” and INSARAG “USAR Capacity Building Assessment Mission” are UN OCHA tools that are available to assist countries to analyse and assess the capability of their disaster management frameworks. UNDAC is a stand-by team of disaster management professionals for assisting the disaster affected countries and in-country UN for meeting international requirements for early and qualified information during the first phase of emergency. INSARAG is a global network of more than 80 countries and organizations under the UN umbrella. It deals with USAR related issues, aiming to establish minimum international standards for USAR teams and methodology for international coordination in earthquake response. USAR, as defined by the INSARAG guidelines, refers to the processes used to safely remove entrapped victims from collapsed structures. The INSARAG network is strongly encouraged to assist disaster prone countries in developing the capacity of their national USAR teams. In this context, the term “national USAR team” refers to a USAR team, which is employed at the national level but not encouraged to deploy internationally. This can be a governmental or non-governmental team.

NerdWallet studied 239 cities with populations of 100,000 or more that provide police and fire services (NerdWallet, 2014). The study has shown that the cities which invest heavily in their fire department personnel generally provide services beyond fire suppression and emergency medical response. These services often include high-angle rescue, vehicle extrication, confined-space rescue and collapsed-structure rescue. The Baltimore City Fire Department has 27 fire staff for every 10,000 residents and offers an extensive infrastructure of fire, Emergency Medical Service (EMS) and special operations teams. Memphis has nearly 30 fire personnel for every 10,000 residents, one of the highest ratios among cities the study analysed. The Memphis Fire Department provides a range of services, including rope, structural collapse, confined space, trench and water rescue, as well as hazardous-material response. The largest city in New Jersey has the fire resources to match its population, with more than 25 fire personnel for every 10,000 residents.

The Latin America and the Caribbean countries have been practicing that in every 50,000 of the population, there is a need for about 20 responders and 10% of them as the instructors (personal communication by Rene Carillo, Regional Advisor for Disaster Training, USAID/OFDA – Latin America and Caribbean Regional Office), which should be the target for Asian countries also (M. R.. Tandingan, 2012).

In India, the Ministry of Home Affairs (MHA) is the nodal ministry of central government of India for natural disaster management. National Disaster Management Authority (NDMA), chaired by the prime minister, is the apex body for disaster management. The National Disaster Response Force (NDRF) has been constituted under Section 44 of the DM Act, 2005 by up-gradation/conversion of eight standard battalions of Central Para Military Forces to build them up as a specialist force to respond to disaster or disaster like situations. The eight battalions of NDRF consist of 144 specialised teams trained in various types of natural, manmade and non-natural disasters. Each NDRF battalion consists of 1,149 personnel organised in 18 teams comprising of 45 personnel, who are being equipped and trained for rendering effective response to any threatening disaster situation or disaster, both natural and manmade. Based on vulnerability profile of different regions of the country, these specialist battalions have been presently stationed at eight places of India (MHA, 2011).

China does not have national level emergency management departments; many departments share their responsibility for emergency management with a different scope or approach. The Ministry of Civil Affairs (MCA) generally leads natural disaster relief, with support from other related departments (Victor Bai, 2008). The National Disaster Reduction Centre (NDRC) of MCA is a specialized agency under the Chinese Government engaged in information services in order to support decisions on various natural disasters. The Emergency Management Office (EMO) is the main body to coordinate other agencies for disaster management. It has been set up at both national and local level. The military and police forces are key actors for disaster response and relief. Similarly social groups, volunteers and NGOs are also actively been involved for disaster response. The Chinese International Search and Rescue (CISAR) Team was founded in 2001. CISAR is comprised of 480 people including administrators and technical experts from China Seismological Bureau, the 38th Division of Military search and rescue crops and medical team from China Armed Police General Hospital. CISAR was recognized as high level international rescue team in 2009, becoming as 12th high-level team in the world and second in Asia (CISAR, 2015).

4 USAR LESSONS FROM THE APRIL 25 APRIL, 2015 GORKHA EARTHQUAKE

The April 25, 2015 Gorkha Earthquake (M 7.8) caused 9,256 deaths, 22,326 injuries (Nepal Police, July 2, 2015) and more than 900,000 buildings are severely damaged or destroyed (Bizan et.al. 2015). Thirty-one of the country's 75 districts have been affected, out of which 14 were declared 'crisis-hit' for the purpose of prioritizing rescue and relief operations; another 17 neighbouring districts are partially affected. The effects of the disasters illustrate that the estimated value of total damages and losses (changes in flows) is equivalent to about one third of the Gross Domestic Product (GDP) in FY 2013-2014. In addition, the estimated value of damage is equivalent to more than 100 percent of the Gross Fixed Capital Formation (GFCF) for FY 2013-2014 (NPC, 2015).

Immediately after the event, the NEOC was activated at its activation level 4, the highest level of activation as per the SOP. The concerned authorities including the then acting Prime Minister met at NEOC for the emergency meeting. The central command post was established and all the security forces were instructed to be mobilized for search and rescue operation. The meeting of CNDRC was called and the cabinet decided to declare emergency in all earthquake districts and appeal for international assistance. All chief district officers were instructed to call emergency meetings and to be mobilized for emergency response in their respective districts.

Prior to the earthquake, in Kathmandu valley and some other urban areas, there has been some initiatives for emergency response capacity development by different organizations such as NRCS and NSET etc. however such activities were infrequent in the villages and smaller towns; virtually there are no trained responders and prepositioned equipment in the villages. As always, immediately after earthquake the community people were the first responders everywhere. They worked spontaneously for rescuing the victims and saved many lives using traditional knowledge and locally available tools and equipment during this earthquake. Further they played crucial role while the professional responders arrived at the scene, providing information, assisting in search and rescue and logistic arrangements in local context.

All security forces, namely, Nepalese Army, Nepal Police and Armed Police Force Nepal were mobilized for search and rescue. They deployed the responders within 2 hours of earthquake. The SAR operations were mainly led by disaster management sections of the security forces who are trained in MFR, CSSR, Water Rescue, Fire Fighting etc. However, immediate reach was only in nearby places, mainly in urban areas. As of May 26, the Nepalese Army mobilized 66,000 responders, Nepal Police 41,776 and Armed

Police Force 24,775 responders (MOHA, May 26, 2015). Fortunately, the only one international airport, Tribhuvan International Airport (TIA), of Nepal was functional and the major roads didn't have significant damage. Thus allowed the international SAR teams to arrive and operate smoothly. There were 76 international SAR teams with 4,316 responders arriving from day 1 to 6 (Figure 1) (Nepalese Army Report, June 16, 2015).

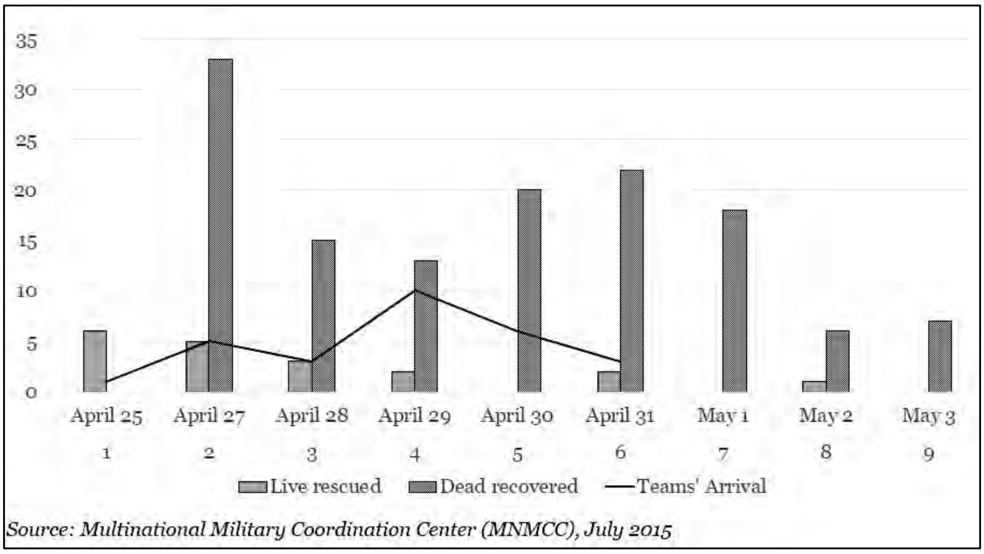

Figure 1: Arrival time in Nepal and Operation Success of International SAR Teams

However, due to different reasons such as remote location, damaged roads, difficult terrain and adverse weather etc. the arrival time of different level responders varied in the affected areas, which was reflected also in the success rate of saving lives. Out of 22,326 injuries, only 19 were rescued by international SAR teams, 4,420 rescued by national teams and rest 17,887 live victims were rescued by community responders and/or by the victim themselves. Similarly out of 9,256 deaths, 135 were recovered by international teams, 2,133 by national teams and 6,988 by communities responders developed spontaneously (Figure 2).

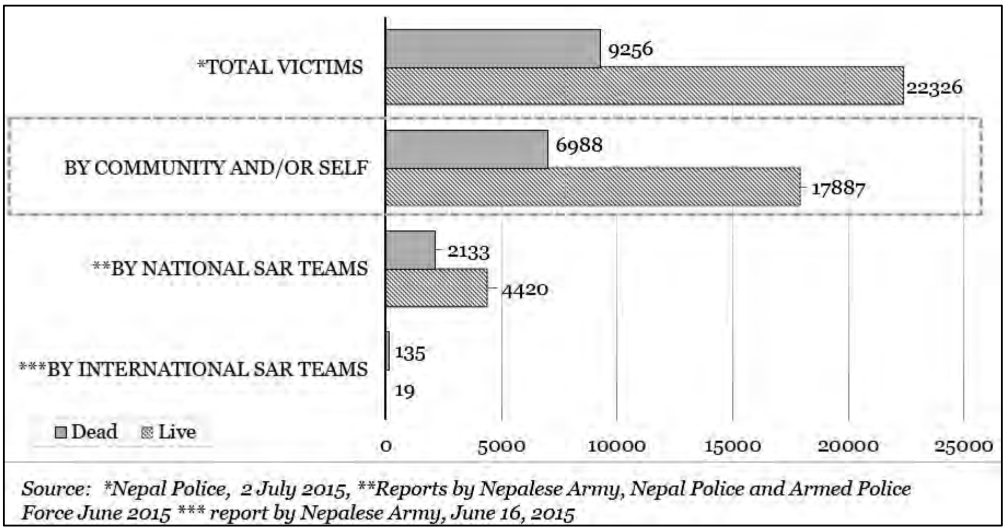

Figure 2: Extricated Victims and Recovered Dead Bodies by Different SAR Teams

The Gorkha Earthquake experience has made all resolved in USAR to recognize the importance of community SAR volunteer responders. There is an urgency to adopt a strategic approach and strategy to develop a system of volunteers with minimal skills and SAR equipment in every village. During this earthquake more lives could have been saved, if there were sufficient trained national responders with equipment. Had the initiatives made by different government and nongovernmental organizations for disaster preparedness and developing capacity of emergency responders and planning been encouraged, could make huge difference during this earthquake. The achievements regarding the SAR by national responders is highly appreciated. If same level of earthquake had happened a decade before, the performance of SAR could have been much less effective.

5 WAY FORWARD FOR DEVELOPING PROFESSIONAL RESPONDERS IN NEPAL

No doubt effective disaster response demands better preparedness with skills, advanced technology and functional management system. Fast and efficient searching is best performed with the latest proven technologies that confirm the likely presence of voids and potential entrapped survivors. These allow focusing rescue efforts where the person is likely to be entrapped and recovering the survivor as quickly and safely as possible (M. Statheropoulos, et.al, 2015). Enhancing capacity of responders is crucial for Nepal. The country has to come up with strategic plan of comprehensive efforts including designing standard courses, developing qualified instructors, arranging equipment and facilities, conducting trainings and developing mechanism for sustainability, maintaining the standards. Considering this fact, this study has put forward a draft strategy for developing qualified responders mainly in Collapsed Structure Search and Rescue (CSSR) and Medical First Responder (MFR) areas for efficiently enhancing the country's capability to respond the disasters with minimized mortality and property losses.

5.1 Strategic Planning for Developing Responders

This strategy builds upon the experiences and achievements accomplished under the Program for Enhancement of Emergency Response (PEER) and other initiatives made so far as the basis for developing professional responders. To start with, the responders having MFR and CSSR skills are considered as professional responders. MFR capability is to provide lifesaving skills mainly caring for victims in pre-hospital stage, and CSSR is for conducting searching, locating and extricating victims from collapsed structures. Both MFR and CSSR are for providing lifesaving skills to the responders to take care of the disaster victims before they are taken to the hospital of health centres. The MFR and CSSR courses are managed by NSET since 2003 under its PEER program in 6 Asian countries with support from USAID/OFDA. The strategy envisions to provide package of CSSR and MFR courses to the responders. However, as per a need realization, the responders should also be provided with other additional emergency response training skills in future for making them more competent. So far, the PEER program has developed 87 instructors in Nepal who can teach both courses, MFR and CSSR. As the instructor development process in PEER is quite long and expensive, the strategy has proposed to use the existing instructors to the extent available and some new instructors which are yet to be developed. Further, most of the existing instructors are government service holders therefore all may not be available to serve as instructor. Assuming 43 (50%) of total are available to serve as instructors, practically three teams of instructors (one team comprises 13 instructors) can be involved for conducting training courses. Hence, involving existing 43 instructors, the year-one year is proposed for conducting 3 series of instructor development courses to produce 72 instructors. The instructor development trainings are proposed to be conducted at central level inviting participants from different potential emergency response organizations, namely, Nepalese Army, Nepal Police, and Armed Police Force.

The lessons from Gorkha Earthquake, existing national plan and policies and international practices are widely reviewed for identifying the need of responders in Nepal. Considering the country's risk profile, geographical condition and population, it is proposed to start with developing at least 1professional responder for 10,000 population requiring 2,628 responders for total 26,494,504 population of Nepal (CBS, 2011). So far PEER has developed 287 MFR and 250 CSSR responders including some other responders in different fields. However, 250 PEER responders can be considered as professional responders having skills of both MFR and CSSR. Considering existing 250 responders and assuming 30 percent attrition of total responders, based on total population of 2011 at least 3,505 responders are required in Nepal. However, the population has been increased significantly during the past 5 five years, therefore the country has to develop at least 4,000 responders. Considering the existing capabilities in terms of physical facilities, human resources and equipment, the Nepalese Army, Nepal Police and Armed Police Force (APF) are the main organizations, who can conduct the training such training courses. However, NSET and NRCS, depending on their capacities, can provide the technical support for this effort. As stated above year-one is planned to develop the instructors. Hence, for developing 4,000 responders, each organizations namely, Nepalese Army, Nepal Police and APF has to develop 1,333 responders. This means each organization has to develop 333 responders per year to meet the target within 4 years, which means 14 trainings by each organizations per year considering the standard number of 24 participants per training. However, the responsibility division among the security forces for conducting trainings should be assigned by the government considering their mandates, availability of resources and other capabilities.

5.2 Deployment of Responders and Prepositioning Response Equipment

Nepal has diverse physical features such as plains, plateaus, deep gorges, steep slopes and high mountains resulting climatic variations within a very small area. This has direct effect in the emergency management planning and also in the effectiveness of the response activities during real disaster emergencies. The remote hilly and mountainous villages are difficult to access due to no and/or poor road networks, and usually due to adverse weather condition. Population distribution is not uniform throughout the country; some major cities, urban areas, district headquarters and market centres are the ones with high population density, but the villages in hills and mountains have very low population density with scattered settlements resulting difficult in providing services. Therefore, it is very crucial to preposition the standby responders and response equipment considering the spatial and temporal proximity in relation with the exposure of population. Table 1 gives an overview of population distribution and deployment of standby responders considering the total population in five development regions of Nepal. At least one set of response equipment is proposed for every 4 squads (24 responders). However, the responders and the equipment should be further deployed and prepositioned in different places considering the population and geography.

Table 1: Population (2011) and Proposed Responders and Equipment by Development Regions in Nepal

Development regions	Total population (CBS, 2011)	Number of squad (6 responders/squad)	Number of responders	Set of response equipment	population/ responder
Eastern Development Region	5,811,555	148	888	37	6,545
Central Development Region	9,656,985	246	1,476	62	6,543
Western Development Region	4,926,765	120	720	30	6,843
Mid Western Development Region	3,546,682	90	540	23	6,568
Far-Western Development Region	2,552,517	62	372	16	6,862
Total	26,494,504	666	3,996	167	6,630

5.3 Arrangement of Training Facilities

An appropriate learning environment for running indoor classes and outdoor exercises is required for developing professional responders. Conducting indoor classes for both (MFR and CSSR) courses a standard room of 9 m x 15 m with acoustic facility for conducting class room lectures, 1 secretariat room, 1 instructors' room and 1 store room for arranging and storing training materials, are required. Similarly for conducting demonstration practice skills, 4 breakout rooms for MFR and one 30m x 30m open field and appropriate simulation areas and structures are required for CSSR. The courses should be residential, for both instructors and participants. Hence appropriate accommodation facility is required.

5.4 Implementing Partners

For the success of this strategy all concerned stakeholders should work jointly and the Government of Nepal should take the lead. Recent National Strategy Action Plan for Search and Rescue (MOHA, 2014) has mandated all security forces, Nepal Army, Nepal Police and APF, for SAR activities in the country, and has developed a plan for developing their capacities. However, it is proposed to work also with local bodies of government (municipalities) and other relevant stakeholders such as fire departments, private security groups, NSET and NRCS etc.

5.5 Institutional Mechanism

An institutional mechanism for sustainability and continuity of responders development and management is very essential. In this regard this strategy has recommended to develop a mechanism for the program's sustainability. The sustainability and continuity of the program depends on the ownership by the government authority. Developing responders and upgrading skills and capacity is a continuous process; this has to be given priority by the government and should allocate the budget. It is proposed that the developed responders should be under the District Disaster Relief Committee (DDRC) of respective districts led by Chief District Officer (CDO). The DDRC and/or assigned authority will be responsible for timely maintenance and replacement of equipment. Further the CDO should have the authority for making arrangement of deploying the responders in need. However, it is also recommended the involvement of local authorities under Ministry on Federal Affairs and Local Development (MOFALD) i.e. District Development Committee (DDC), municipalities/VDCs and different local level Disaster Management Communities (DMCs). Likewise, a mechanism for continuation of training programs, reviewing, maintaining/updating courses, database of responders, effective mobilization of responders in case of disasters, timely maintenance/replacement and record keeping of equipment and an effective coordination with the local community responders also need to be developed.

5.6 Budget Estimation

The strategy has proposed to develop 4,000 professional responders in 5 years. The year-one is focused for developing instructors with the involvement of existing instructors developed under PEER. The cost for conducting three series (each series includes: MFR, CSSR, training for instructor, MFR instructor development workshop and CSSR instructor development workshop) of instructor development trainings for producing 72 instructors is estimated to be USD 0.741 million. The rest 4 years are proposed for developing responders. The cost for conducting 167 trainings to produce 4,000 responders is estimated to be USD 10.14 million. The responders are planned to be deployed in different regions with prepositioned response equipment in strategic locations. At least one set of equipment is proposed for 4 squads (6 responders in one squad). Hence, 167 sets of equipment are proposed to be prepositioned in different locations for 667 squads, for which total cost is estimated to be USD 8.33 million.

6 CONCLUSIONS

Nepal has physical diversity the mountains, hills, gorges and cliffs and adverse weather usually creates problems for effective response. The population is highly concentrated in urban centres including capital city Kathmandu, some other municipalities and district headquarters. However, significant number of population is scattered in many remote villages, who are not connected with transportation, electricity, and telecommunication and lacking of awareness and response skills. The communities are the first responders, they have been responding disasters with limited knowledge, skills and equipment, which have put themselves at risk many times and the success is significantly very low. The capacity and existing status regarding emergency response in the country has been experienced during April 25, 2015 Gorkha Earthquake. It is widely realized the need of capacity building of community and national responders with prepositioned equipment. In recent years there have been several initiatives by government and I/NGOs, however, most of those are city centred and not enough to address the need. This paper has put forward a strategy for developing professional responders considering the geographical condition and population of the country. However, it has been recommended to develop community responders as well, who can work at local level and assist the professional responders.

Reviewing the practices from the region and world, the strategy is developed based on local context. It has proposed for developing at least 1 professional responder for 10,000 population requiring about 4,000 responders for the total 26,494,504 population of Nepal. The strategy has assumed at least 3,500 can be practically available during disasters. The strategy aims to achieve this target in 5 years, the first year is planned for developing instructors and rest 4 years are focused for developing the responders. All responders are proposed to be deployed, with prepositioned response equipment, in different regions of the country considering the population and geography. Further it has proposed for developing an institutional mechanism in respective districts under Ministry of Home Affairs for sustainability and continuation of the process.

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A study of vulnerability of emergency transportation road network to various hazard

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ABSTRACT

In Japan, a natural disaster occurs frequently in recent years. An emergency transportation road network is designated for a large-scale seismic hazard, and a network is maintained so that it may become possible to do smooth transportation of goods when a large-scale disaster happen in Japan. However, while frequency and the kind of accidents are diverse, emergency transportation roads are not quantitatively grasped how degree have a disaster risk. In this study, the risk of emergency transportation road network were quantitatively evaluated considering the various hazards such as earthquakes, floods, landslides, tsunami, volcanic and storm surges. As a result, currently disaster risk of the road that is designated the emergency transportation road network is high, and the emergency transportation road network does some disaster, and it became clear to be impassable in the case of floods, landslides, and volcanic disaster. In addition, emergency transportation road network at the time of Tokai, Tonankai and Nankai earthquakes it became clear the risk is high to be impassable. The further study, the possibility of emergency transportation road network can be connected disaster prevention shelter base.

Keywords: emergency transportation roads, disaster risk, earthquake, landslides, floods

1. INTRODUCTION

In recent years, natural disasters occur frequently in Japan. Not only the large-scale low-frequency disaster like earthquakes or eruption, but also the small-scale high-frequency disaster like landslides or flood occur frequently accompanied by the guerrilla heavy rain or torrential rain. For such a situation, the designation of the emergency transportation road is accomplished for a large-scale earthquake disaster in our country.
The network of designated road is maintained to become able to transport smooth supplies at the time of a large-scale disaster, but there are few studies that evaluate how the degree of disaster risk can be controlled by the emergency transportation road while the type and frequency of the disaster diversify quantitatively. And again, it is the present conditions that it is not performed the evaluation that assumed a complex disaster.

In this study, it is intended to evaluate quantitatively the risk of emergency transportation roads that is hit by various hazards such as earthquakes, floods, landslides, tsunami, volcanic and high tide, and we also conducted an analysis of the disaster risk of emergency transportation roads. In this article, we will describe the risk of emergency transport roads to various hazards such as earthquakes, landslides and flooding.

2. DISASTER RISK IN JAPAN

As a disaster in Japan, it can be mentioned the name of the earthquake, flood, and volcano. For the earthquake hazard assessment, the probability is equal to or greater than 5 of the seismic intensity in 30 years, has been assessed by the measured seismic intensity that becomes each exceedance probability of 30-50 years.
For the flood hazard assessment, we used the data relating to flood provided by the county, prefectures or metropolitan that is evaluated as a boundary at 3.0m, 0.5m with 3 phases. In addition, 5.0m is added to the border when flood levels exceeding 5.0m, then it is widely distributed with the boundary at 5.0m. The relationship between the boundary height and the happening phenomenon is for 0.5m, flooded above 1st floor level of the building; for 3.0m flooded 2nd floor surface of the building; for 5.0m, 2nd floor is submerged with water and there is possibility of 3rd floor surface is flooded.
About the volcano, the risk is evaluated by the total number of Japan's active volcano with the proportion of the existing volcanic hazard map. The total number of Japan's active volcano is 110, of which, the number of hazard map that has been published is 82.The total number of the active volcano of our country is 110, and the number of hazard map which is officially published is 82. Therefore, the risk of the volcano it is estimated to be 74.5%.

3. ABOUT EMERGENCY TRANSPORTATION ROAD

Based on the lessons learned from the Great Hanshin-Awaji Earthquake, the emergency transport road is set for smooth emergency transport immediately after the earthquake for a high-speed automobile national highway, the general national highway and the trunk road which is designated by the governor to contact mutually between the disaster prevention bases. The emergency transport road is categorized of primary to road for each prefecture. It is seen a little difference in the name and selection criteria, but basically the primary road covers the wide area range of the national highway, highway, and the trunk road. Then it shapes such a way that secondary and tertiary can connect with primary road and also can communicate mutually between the disaster prevention bases as well as with the government offices.
Table 1 shows the total length of each specified rank of emergency transportation road and Figure 1 shows the road network diagram of emergency transportation road. The emergency transportation roads have occupied high ratio with the High-speed automobile national highway and the general national highway and as well as the total extension accounts for a high ratio. Therefore, it is thought that enough wide range area are secured by the emergency transportation roads.

Table 1: The total length of each specified rank

(Unit:km)	National highway & Highway	Prefectural road	Municipal roads	Total length
Primary	45928.63	8077.59	1063.4	55069.62
Secondary	13368.92	22380.69	2428.48	38178.09
Tertiary	799.69	3152.69	714.29	4666.67
Unspecified	93.58	23.11	—	116.69
Total	60190.82	33634.08	4206.17	98031.07

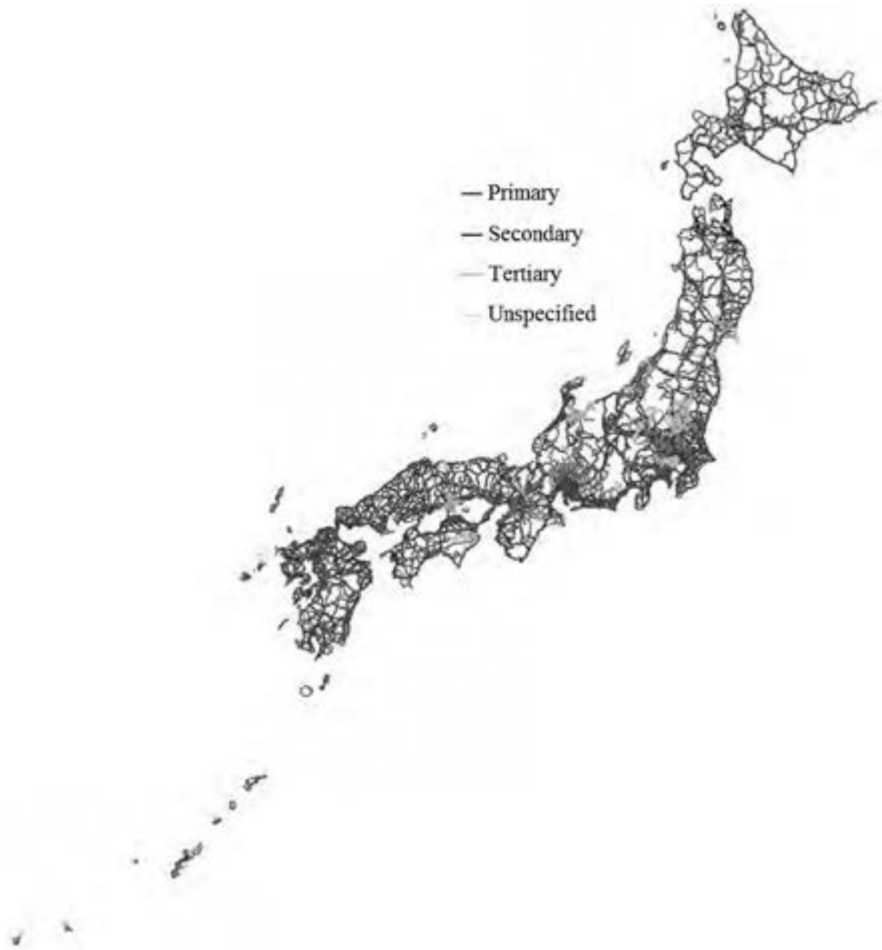

Figure 1: The road network diagram of emergency transportation road

4. ANALYSIS OF DISASTER RISK OF THE EMERGENCY TRANSPORTATION ROAD

4.1 The disaster risk due to earthquake

It has analyzed the disaster potential of the emergency transportation roads about the earthquakes, floods and landslides. For the earthquake, it is described the results of the analysis for the emergency transport roads are duplicated with the predicted seismic intensity distribution.

Emergency transport roads are duplicated in each evaluation criteria listed in Chapter 2, ①~④is every probability from 0 to 1, ⑤ ~ ⑩ are color-coded disaster risk in each measurement seismic intensity of from 4.5 to 6.5 or more. In any case, the Pacific side showed dangerous numerical value of risk, and, at every measurement seismic intensity, it is added it to the Pacific side again, and even Itoigawa - Shizuoka tectonic line was found to be a large disaster risk in ③. In the case of probability of being hit by an earthquake of seismic intensity a little less than 6, it is observed that the risk of Kanto region is large, Tokai, and there was also seen the risk of the capital earthquake directly above the focus in addition to Tokai and Tonankai region.

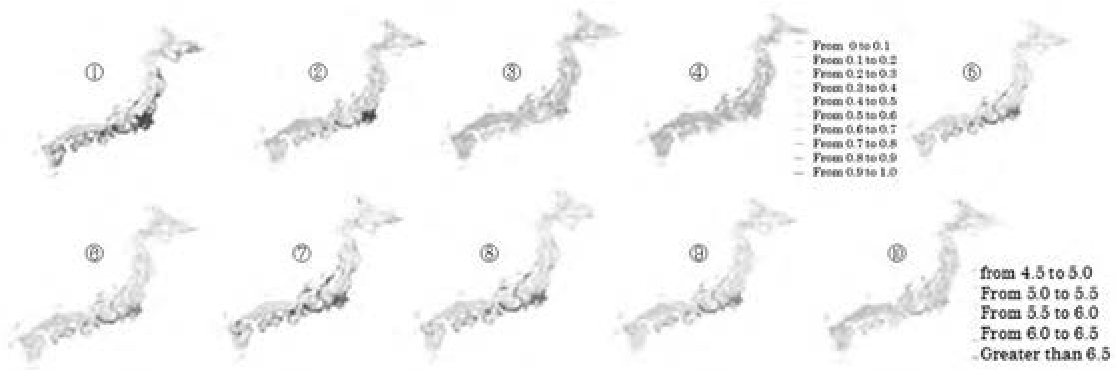

Figure 2: Disaster risk of emergency transportation road viewed in difference prediction seismic intensity

4.2 The disaster risk due to landslides

For landslides, it was analyzed the overlap ratio of the emergency transportation roads and landslides danger zone as a disaster risk in every metropolis and districts. In addition, overlap ratio assumed it to the (extension of the emergency transport roads are duplicated in each hazard area) ÷ (total extension of emergency transportation road). We analyzed the disaster risk for each item of avalanche e.g. debris flow, steep slope place collapse and landslide. Furthermore, we describe the aggregate result of only the primary road in this paper. Figure 3 shows a graph that aggregates the duplicates ratio for each item about the primary road.

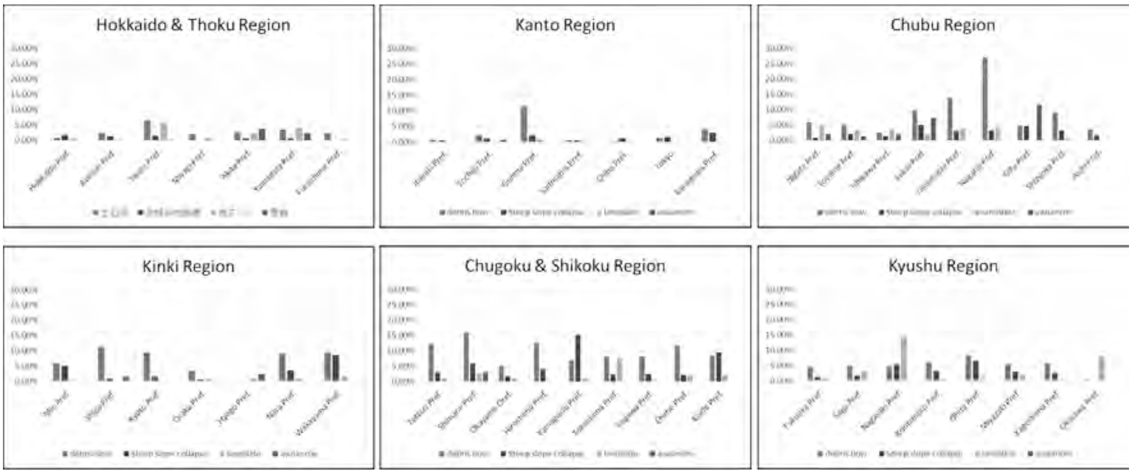

Figure 3: Overlap ratio of landslide disaster and emergency transportation road (primary road)

From Fig. 2, it is observed that the overlap ratio in the Chubu District, the Chugoku and Shikoku district was big by the local distinction. In addition, it is revealed that Nagano is paying attention to be the prefecture with the highest ratio compared to other prefectures. If you look at the percentage of large scale for each item in comparing with prefectures, then it is revealed that the debris flow is in Nagano prefecture, steep slope collapse is in Yamaguchi prefecture, landslides is in Tokushima prefecture, avalanche is in Gifu Prefecture has resulted in most overlap.

4.2 Disaster risk due to flood

Like landslide disaster risk, we analyzed the overlap ratio with the flood assumption area and emergency transportation road in every prefecture. It can be noted that, we analyzed the disaster risk by defining flooded with 0.5 m for flood estimated areas, use data have boundaries of 0.5 m, 1 m, 2 m and 5 m. And this study was designed to be transported by car, and the exhaust port completely flooded and non-driving motors, to specify the rank. Figure 4 shows the graph which added up the duplicates ratio with every designated rank.

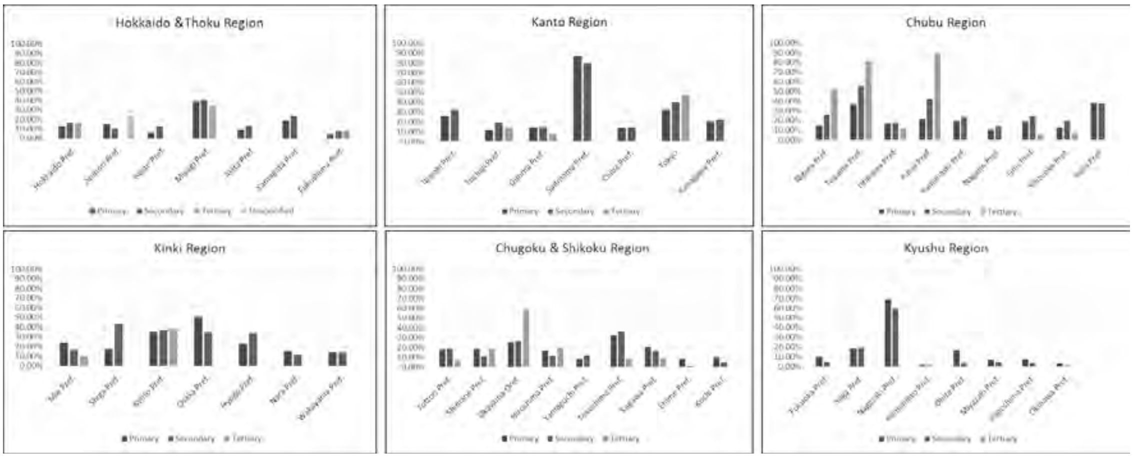

Figure 4: Overlap ratio of flood estimated areas and emergency transport roads

Both primary and secondary roads show a higher overlap ratio in Saitama Prefecture, the third-order road became the results of showing a higher overlap ratio in the Nigata prefecture and Hokuriku region such as Toyama Prefecture. It can be considered for Saitama prefecture that its roads are concentrated around the river, so there is a high risk of flooding due to overflowing. For the Hokuriku region, rainfall throughout the year is often considered as a factor. For Toyama and Niigata prefectures, as selection criteria for the 3rd order road, the primary and secondary roads here to contact the disaster prevention bases, so the overlap ratio of tertiary roads is high, along emergency transport roads, large disaster risks and was found with the disaster prevention center.

5. THE SUMMARY OF THIS STUDY AND FUTURE PLAN

In this study, we estimated the disaster risk of the emergency transportation road due to three factors such as earthquake, landslides and floods. It is clarified that the emergency transportation road is likely to be impassible of traffic at the time of the disaster. About the earthquake, it was revealed that not only the Pacific side, but also the dislocation had a big suffering risk. It can be considered that the situation of broad-based transportation becomes difficult as the Itoigawa - Shizuoka Tectonic Line fault spread to north-south road network is split into east and west by the earthquake. Overlap was frequently happening due to landslide disasters in hilly and mountainous areas. When we consist a road in the mountain areas become impassable of traffic due to landslide,

then it is not only be considered merely road, but also it brings into question that substitute characteristics of the road are low. A difference was seen in the metropolis and districts about the flood risk. Due to the flood disaster, the wide range area can be restricted with impassible of traffic regionally, and the risk to become by a certain inundation above a certain level in comparison to the landslide disaster. In this way, it is revealed that the disaster risk of the emergency transportation road was big even if we focused on individual hazards, such as earthquakes, landslides and flooding.
As a future work, we will take an evaluation of the importance of the emergency transport roads, focusing on alternative ways like severity of transportation road affected by avalanches and typhoon, combined various types of seasonal hazards. We want to push forward this study with a focus of occurrence of hazard probability in real life situation.

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Significance of developing Community Responders in the context of Nepal

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ABSTRACT

The tremor of 25th April, 2015 with magnitude of 7.6 in Gorkha district, Nepal resulted massive loss of human lives and property. The loss would have increased more if immediate response operation was not carried out by the local people. Due to the geography and poor infrastructure, immediate access to the affected areas for saving lives was obstructed for professionals. Just after the earthquake the very first responders at the scene were the community people spontaneously gathered for mutual help with tools and equipment whatever they had. Among those, most of the responders were not trained with rescue skills. However, being first at the scene and if provided with minimum skills could save more lives. Community people can assist the professional responders by providing necessary information of the locality and communicating with the local people. This shows the significance for the need of trained community responders.

This paper can work as a convincing effort for the government and local authorities as well as other stakeholders to prioritize emergency response capacity building activities in the communities. During this process research was conducted based on the experience of the community responders, reports of rescue operations.

Keywords: *casualties, community, responders, community responders, professional rescuers, ease of access*

1. INTRODUCTION

Nepal is one of the 20 most disaster-prone countries in the world. It is ranked 11th in terms of risk from earthquake, 30th in terms of flood risk, and 5th in terms of risk from the impacts of climate change. Nepal is classified as one of the global “hot-spots” for natural disasters (World Bank-2005).

Nepal witnessed a devastating earthquake on April 25, leaving hundreds of thousands of people homeless and destroying property worth hundreds of billions of rupees. The earthquake has not only been the cause of the death of more than eight thousand people but has also exposed the weaknesses, inefficiency, inability in different sectors. However, life cannot stand still. It has to go ahead with a progressive frame of mind, leaving the past behind, learning from the mistakes and weaknesses, and making the life

of future generations safer. In recent Gorkha earthquake most of the community were unable to get response from the professional rescuer also after a week which increased the number of casualties even more. This experience taught the need of responders in the community level with rescue equipment prepositioned in the community or the infrastructure that can mobilize the professional rescuers throughout the nation in a short period.
It is realized that the community responders are required to cope up the needs of affected people during the disaster. Also the strategy of achieving the sufficient number of community responders should be made in order to incorporate the lesson learnt from the recent Gorkha earthquake.

2. ROLE OF COMMUNITY RESPONDERS IN DISASTER

Community first responders are trained to provide assistance to those with search and rescue technique, medical emergency, and most importantly to start and maintain the chain of survival in mass casualties until the professionals arrive. Also after the professional rescuers are in the scene, the community responders can assist them by providing the information on probable location of victims and also the information about the infrastructures within the locality. The schemes were originally visualized for rural areas where emergency medical services response is expected to be delayed during which a number of deaths are likely to become irreversible.
Following major earthquakes and other disasters, community members play a critical role as first responders, particularly as gaining access to affected locations can often be difficult for emergency responders from other locations. This is especially true in Nepal, where geography and poor infrastructure can obstruct access to more remote areas. If community members are prepared as first responders, they can play a vital role in reducing the impact of disasters by providing community search and rescue as well as first aid services immediately after and during the relief phase of the disaster.
The framework of the Search and Rescue (SAR) response in Nepal will be as shown in the figure 1.

Figure 1: Framework of the Search and Rescue (SAR) response in Nepal

Coordination approach between national and international responders during major disaster shall be as determined by the national response framework. The first responders shall be local emergency service and community responders and there shall be light, medium and heavy SAR taskforces in the national SAR squad. There shall be medium and heavy taskforces in the international squad (National Strategic Action Plan for Search and Rescue, 2014). This action plan also emphasis the need of community responders and enhancing overall capacity of the community people for every new emergency response. The first responders are the community responders and the local emergency service who have the quick access to the affected area.

Thus the need is even more in case of Nepal, due to geographically rugged country and physical diversity. Also the nation can be isolated from immediate international response if the only international airport is not functional. During this only the option remains is the national search and rescue and the local community people within their community. National search and rescue team also may not reach the affected area in time due to the poor infrastructure and the fragile geology which may block the land transport. Even the air transport may lack to reach the affected community due to adverse weather condition. In this recent earthquake also it was seen that the land and the air transport was unable to function properly due to landslide and adverse weather condition.

Local people are the means of information of their community and can help a lot in the response operation. Even if the professional responders reach the affected area they will not be aware of infrastructure and the facilities present in that area. The professional responders can waste their golden time searching the victim where there is no any casualties inside. By providing the detail about the damaged building such as, the size of building, use of that particular building and the probable number of people trapped inside that damaged building, helps to make the response operation more effective.

Community responders can also make use of local resources and make the response operation more effective. They can improvise the equipment from locally available resources.

Community responders being directly involved in response operation, can also assist the professional rescuers by providing them the information about the hazardous area within the community which needs to be avoided during rescue operation. They can also interact with the community people in their won local language and facilitate as translator for the professional rescuers if they are already in the scene.

3. EXISTING CAPACITY OF COMMUNITY RESPONDERS IN NEPAL

As a part of strengthening overall disaster preparedness and the disaster response system in Nepal, the government has formulated a National Strategic Action Plan on Search and Rescue Capacity; but much work remains to be done to make this plan a reality (MoHA, 2013). Capitalizing on the motivation and training the different security forces are developing dedicated search and rescue units. Ultimately, these dedicated units will train and work together as a cohesive search and rescue response across the country. It was agreed that community first responders and the security forces will have to work together, as the foundation is established, building a unified system that will be able to search and rescue Nepali people in the future. The real implement of this was seen in this Gorkha earthquake in which all the security forces foreign rescuers and also the community responders were working together in a scene, along with different NGOs and INGOs.

A lot of organization have been assisting in the development of community responders and orienting people about the disaster activities, their impact and the skill to cope them. Government organizations and different national and international NGOs are noticeably working in the field of developing the responders in the community level. There is the need of bringing these responders under a single umbrella, maintaining their database and providing the required equipment in the community level.
Despite this encouraging information, capacity is currently scattered across the country with limited coordination, inadequate equipment and no national standards. Based on these findings, a consensus emerged that this effort seems insufficient to cope the real need in the mega disaster. Since most of the place were not easily assessable and also there was lack of community responders in that particular area. Due to this reason prompt response and rescue operation was not effectively achieved during Gorkha earthquake. The community person from each and every community of Nepal should be trained with basic lifesaving skills so that the lives can be saved more and minimize the casualties.

3.1 NSET activities for enhancing the emergency response capacity of community

Awareness-raising and capacity building of community/organization becomes an effective approach for earthquake risk reduction. In making the community aware of earthquake safety and also developing the community responders, National Society for Earthquake Technology (NSET) -Nepal has continuously contributed from its bud stage. NSET has come up with some figures of community responders who can perform search and rescue, provide pre hospital treatment and also rapid damage assessment of damaged building in the community level during disaster. General awareness level of community people, professionals, school students, and teachers as well as of the authorities has increased significantly due to the continuous efforts. However, there is a need of continuous awareness-raising and capacity building activities throughout the country in different levels.

3.1.1 Conducting earthquake preparedness orientation

The earthquake orientation program intends to aware the community people in terms of earthquake risk, preparedness and risk mitigation measures. This orientation is interactive presentations for groups all around Nepal to increase earthquake awareness. Audiences vary widely from village and community groups, organizations, schools, businesses, media personnel and many more. These presentations cover the science of why earthquakes occur, what are the risk reduction strategies and what you can do to prepare yourself. More than 37,000 people have taken part in this program. It means, virtually, the earthquake awareness massage is conveyed to more than 37,000 families.

Figure 2: Community people participating in earthquake orientation

3.1.2 Community Search and Rescue (CSAR) Training

The CSAR training is intended to develop capacity of community, school and organizations for performing search and rescue operation. This training mainly focus on techniques and methods necessary for searching, locating and extricating victims on the surface using the safest and most appropriate procedure. It also incorporates the fire extinguishing technique by the process of bucket brigade which is most effective in the community level.

Figure 3: Participants performing hands on practice in CSAR training

3.1.3 Basic Emergency Medical Response (BEMR)

BEMR training course is developed with a focus to prepare more number of individuals at community, institution and household levels, to respond to basic health emergencies such as bleeding, burn and fractures and also to act as an agent to bridge the gap between health emergency and medical treatment. Beside this NSET also conducts basic First Aid training focusing on school earthquake safety.

Figure 4: Community people participating in BEMR training

3.1.4 Conduction of Damage Assessment Training (DAT)

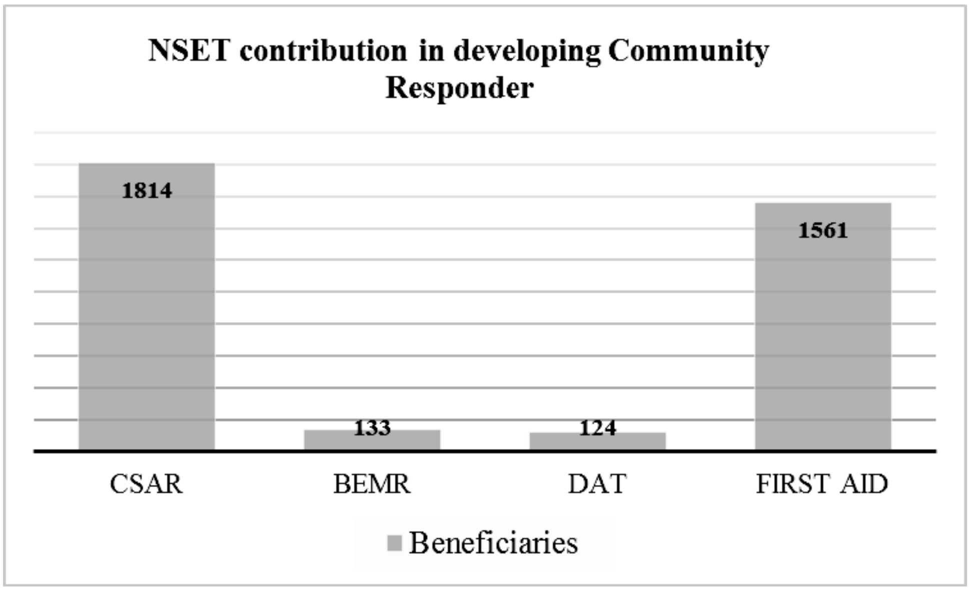
The building needs to be assessed before entering for the search and rescue operation. This training helps to provide the general idea of the extent of damage in the building. It mainly deals with the building system and typology, structural and non-structural component of the building, damage pattern of the buildings and procedure of the damage assessment. Beside this there are different level of damage assessment training mainly focused for the professional engineers.

Figure 5: Participating in DAT

3.1.5 Conduction of First Aid Training

Realizing the extensive need of disaster preparedness in schools which is directly linked with the community, Nepal Red Cross Society (NRCS) and NSET have been conducting first aid training program for student, teachers and community members. This helps to develop the basic first aid trained people in different community who can contribute in disaster. More than 1500 first aid graduates are prepared in different community along with the trainers for basic first aid training (NSET,2015).

Chart 1: Total beneficiaries from NSET emergency response training



3.2 Nepal Red Cross Society (NRCS)

The purpose of NRCS is to reduce human suffering, through mobilization of volunteers and building capacity at different levels with special focus on vulnerable communities. NRCS mission is to relieve human suffering and to reduce vulnerability through community participation and mobilization of an increased number of volunteers.

The Community Action for Disaster Response (CADRE) programme is a local response tool which includes basic life support (first aid) and light search and rescue skills in order to develop local responders to save life during disaster. This course is introduced in both urban and rural parts of Nepal. In the process of enhancing the capacity of the community Nepal Red Cross Society (NRCS) has developed 661 CADRE graduates among them 134 are the instructors who can conduct the training programs. NRCS has also developed significant number of First-Aiders who actively participated in this Gorkha earthquake (NRCS, 2015).

The Emergency Preparedness and Response (EPR) programme of NRCS aims to enhance the resilience of vulnerable population facing disaster and health risks. The target group of the programme is potential disaster affected population. The programme supports staff members and volunteers at regional, district and community level to carry out assessment, response and health care activities.

Nepal Red Cross Society, in coordination with American Red Cross and National Society for Earthquake Technology (NSET), jointly implemented Disaster Preparedness for Safer School in Nepal- 2 (DPSS-2) programme. The programme is based in the School Based Disaster Risk Reduction (SBDRR) process and focused on the involvement of students, teachers, community members and local authorities in all activities. The programme aimed to reduce harmful effect of disasters in targeted schools and communities through awareness and proper knowledge on disaster preparedness measures, to ensure disaster management and response coordination systems.

The Earthquake Preparedness for Safer Communities (EPS) programme is being launched by NRCS and the aim of the programme is to reduce vernalibility, and impact of disaster , including an improved capacity to respond, as envisaged in the national risk reduction consortium plan. Toal direct and indirect beneficiaries from the programme are 650,000 in kathmandu valley. The programme has worked out to make the Valley safe from the earthquake hazard and its adverse effects. In total, the programme has produced 10,000 NFRI kits and preparing to pre-position in different four strategic locations in Kathmandu valley (NRCS,2014).

4. LESSONS LEARNT FROM RECENT EARTHQUAKE 2015

Looking back to Gorkha earthquake, the total casualties was found to be 24,053 (MoHA, 2015). Among them only about 12451 people were rescued by the rescuers from Nepal and other 34 countries. This shows that almost 50% of the lives were saved by community based first responders and their spontaneous acts or the affected people managed to come out of debris by themselves. If these community first responders were trained and well equipped the loss would have decreased significantly. There were a lot of case where community people were involved in rescuing the victim with bare hand which made them so difficult and time consuming. In some areas community people attempt to extricate the victim but they were not successful and the situation of the victim was worsen when the professional rescuers reached there.

In most of the area people were afraid of entering the building due to the damage seen in it although the cracks were minor. This shows the need of training to identify the damage level of the building so that the building can be identified as safe or unsafe before entering. This also helps a lot in minimizing the loss and also plays significant role in health related issue since most of them were in temporary shelter although their house was safe. This knowledge about rapid damage assessment also helps in rescue operation, in some community people died in aftershock when they were inside the unsafe structure.

During Gorkha earthquake, in some remote areas the access for professional rescuers were not possible due to damage of road and infrastructures, physical diversity and adverse weather. Due to this the local people were unable to perform search and rescue operation alone in their community level. This resulted in more loss of life and property.

Table 1: Search and rescue deployed and the achievement

Title	Numbers
Nepalese Army deployed	66069
Nepal Police deployed	41776
Armed Police Force deployed	24775
Civil servants deployed	22500
Total Foreign Rescuers from 34 countries	4521
Total people rescued by national and international professional rescuers	12451
Total injured	16033
Total dead	8020
Total population rescued by community or by themselves	11602

Source: MoHA June 25, 2015

Analyzing as per the investment perspective a lot of resource was invested for the preparation of professional search and rescue (SAR) personals who have less access to remote areas due to geography and poor infrastructure. But there is negligible investment for the development of community responders who have easy and prompt access to the affected area during disaster. During the Gorkha earthquake the

professionals were unable to reach the affected area even after a week, but the community people were heavily involved in rescuing buried and wounded people from rubble without any trained skill and equipment. The foreign SAR team from 34 countries were in Nepal during the response period. These foreign rescuers could have covered many districts but the land transport was blocked due to landslide caused by earthquake and the air transport was not effective due to adverse weather. Also the poor infrastructure made more difficult to reach the affected area within the short period.
In this case if there were community responders in every community, village or districts the rescue operation would have been more effective. The need of rescue tools and equipment was also highly felt. However if the community people were well equipped they could have performed more effectively.

5. CONCLUSION

For the better tomorrow we have to be prepared from now. The investment before disaster is more efficient than after the event. It is seen that the number of casualties and death can be minimized if we could plan and develop responders in each and every community. Due to physical diversity in the country it will be more difficult to have access by the people of different place to the affected area. For this the responders should be developed in every community. The community people does not require any professional skills but every people should be trained for lifesaving skills. This will help to response immediately in disaster and we can minimize the loss significantly. The need of trained community people is very high to minimize the loss due to disaster.
The community responders should sufficiently equipped with hand operated tools. This can be made efficient by prepositioning the required amount of tools and equipment for every community within their community or village. This is also the finding of recent earthquake. The need of improvising the equipment with locally available resources can minimize the loss of life and also makes the optimum use of resources.

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Development of support system for large area evacuation plan around of nuclear power plant

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ABSTRACT

In Japan, with the happen of the accident at the Fukushima Daiichi Nuclear Power Plant that occurred in 2011, there is a growing awareness about disaster prevention of nuclear disaster. In addition, a major revision of local disaster prevention plans and large area evacuation plans from nuclear disaster is also underway. However, it is in the stage that still need to be reviewed in the development of realistic and safe plan. In this study, performs the evacuation simulation of the vehicle, in order to help found problems and create alternative of evacuation plan. The target of this study is the area around of Shika Nuclear Power Plant in Ishikawa Prefecture. In this study, simulated until arriving at the shelter, not only to leaving the evacuation zone. As a result, vehicle are concentrated in only a part of road, it resulted that cannot be safely evacuated, when it is evacuated to a shelter that is defined in the state of the evacuation plan. Therefore, it found that it is necessary to disperse the shelter and evacuation routes.

Keywords: evacuation simulation, nuclear disaster, large area evacuation plan

1. INTRODUCTION

In Japan, Fukushima Daiichi nuclear power plant accident occurred in 2011. After that, there has been a growing interest of public in the nuclear disaster. The Fukushima nuclear accident is the first large-scale nuclear accident in Japan, and overturned the safety myth of up to it, had a major impact on the world. In the evacuation from the Fukushima nuclear power plant accident, there were many problems. For example, big traffic jam caused by evacuation in private cars has been occurred frequently, and health condition of inpatients (people requiring assistance during a disaster) deteriorated due to long-term evacuation. As such the background causes, nuclear disaster has been revised significantly. Specifically, in recent years in Japan, international standards such as PAZ (Precautionary Action Zone) and UPZ (Urgent Protective action Planning Zone) suggested by International Atomic Energy Agency (IAEA) have been introduced. The PAZ is the area preparing a preventive protective measures (in region of 5km from the nuclear plant), an area people should start prophylactically evacuation before radioactive material release. The UPZ is the area preparing emergency protective measures (in region of 30km from the nuclear plant), an area people should evacuate to indoor or shelter if it exceeds the reference dose after the radioactive material release.

With the introduction of those criteria, the range where should take nuclear disaster prevention is greatly expanded to the region of 30km zone from the region of 10km, and it was promoted revision of disaster management plans and evacuation plans in the region.
While four years have elapsed from the Fukushima nuclear power plant accident, even now, the topic of nuclear emergency preparedness has been frequently featured in the news, and still there is room for improvement evacuation plan. So, prefectures which have nuclear plant was carried out traffic simulation called "evacuation time estimate" for the purpose of confirmation of the execution of the evacuation plan. However, many prefectures regard that evacuation is complete when all vehicles have escaped out of the UPZ. And not considered about screening in simulation. So it is difficult to say that has been sufficient verification of the evacuation plan. In this study, evacuation simulation from nuclear plant was carried out to extract the problems of the current evacuation plan. The target of this study is an area around of the Shika Nuclear Power Plant in Ishikawa Prefecture. Furthermore, extract the problems of evacuation plans, perform the verification of the alternatives, and aims to make the support of the evacuation plan.

2. PREVIOUS RESEARCH

In Japan, a lot of evacuation research from natural disaster are studied, but almost studies are not considered the evacuation simulation. Evacuation simulation regarding the surrounding area of the Kashiwazaki-Kariwa nuclear power plant in Niigata Prefecture has been carried out by Fujita et al. According to the results of the simulation by the scenario which is considered wind direction. Furthermore, by Todo et al., Summarized the transition of nuclear disaster prevention system created before the Great East Japan Earthquake. Problems of nuclear disaster prevention system that became apparent from the Fukushima Daiichi nuclear power plant accident, and changes about that system from then until now, were discussed mainly about disaster prevention measures of Niigata Prefecture. By Nishino et al., questionnaire about evacuation behavior after the Fukushima nuclear accident was carried out, and basic data available to estimate evacuation time was organized. After performing the formulation that focus on the travel preparation time of residents in evacuation zone and the voluntary evacuation rate of residents, and data reduction was subjected being careful to the variations in the value. Also, questionnaire survey regarding evacuation to target the residents of the 30 km distance of the Kashiwazaki-Kariwa nuclear power plant in Niigata Prefecture has been carried out by a Nagai et al.
In the research about car use when disaster occurs, return home behavior has been analyzed by using traffic simulation by Ishikawa et al., when a large-scale disaster such as Tokai, Tonankai and Nankai earthquakes occurs. It was examined that how much impact has been given to traffic state by car use. As a result, it was shown that car use significantly reduce people giving up return home, but might inhibit rescue efforts by large traffic jam.
A study on the evacuation simulation, by Katada et al., scenario simulator that precisely express the state of flood inundation, evacuation of residents,and flood damage has been constructed, intended to a large-scale flood in large cities. From the simulation that reflects the evacuation intention of residents in Arakawa river outburst, it has been grasped the specific issues of urban areas, such as the damage expansion by occurrence of large-scale evacuees.

From the above, about the nuclear disaster, evacuation simulation on the basis of the evacuation plan has been carried out, and problems of the evacuation plan have been pointed. But, mostly of them were carried out along the Fukushima nuclear accident earlier nuclear disaster prevention system, so it has become different content from the current disaster prevention plans and evacuation plans. For example, in the above study, major evacuation means are buses provided from local governments, and the scope of the evacuation is within a 10km radius from the nuclear power plant. But in the current evacuation plan, major evacuation means have been changed to private cars, and preparing evacuation area has been changed to 30km within from nuclear plant. Therefore, it is considered when a traffic jam occurs, the range and impact of that is greater than the simulation, and it is necessary to carry out evacuation simulation along current evacuation plan. In addition, about studies that was done after the Fukushima nuclear power plant accident, there are many studies that have been investigated current situation or problems of nuclear disaster prevention systems and evacuation systems. But there are no studies that have been discussed specifically about the traffic jam extent and improvement plans by the use of simulation. Also, after the Great East Japan Earthquake, became forgiving to private car evacuation, but there is likely to occur new problems such as the fear of traffic jam. In addition to evacuation simulations by walk that have been carried out many until now, recently, evacuation simulations by private cars have been carried out, but most of the target disaster of them are floods or tsunami. Moreover, most of them assuming a single disaster.
Even in the same private car evacuation, nuclear disaster evacuation and water disaster evacuation are significantly different. For example, the damage of nuclear disaster spread invisible to the eyes, and accident occurrence point is determined. Also, there is a possibility that the damage range spread to very wide area, and the damage spread over relatively long time from the accident occurs. In addition, nuclear disaster is very likely to occur as a complex disaster with the earthquake and some disaster. Since the spread of nuclear disaster damage invisible, residents evacuate rely only information obtained from administrative etc., and it is necessary to establish a disaster prevention system. On the other hand, since the accident occurrence point is determined, it is possible to be considered beforehand the evacuation routes or shelter or the like in detail. Therefore, using evacuation simulation results is considered very effective in considering the nuclear disaster, to understand the problems such as traffic jam location, and consider the evacuation routes or procedures that residents can evacuate safely.

3. EVACUATION SIMULATION FROM NUCLEAR POWER PLANT

3.1 Target area

Target area of evacuation simulation to be performed in this study is a Shika Nuclear Power Plant area of Ishikawa Prefecture. Figure 1 shows the evacuation destination location and the starting point that was decided in this study. The circle-shaped points represent start points, and star-shaped points represent shelters. Peripheral population is about 170,000, in region of 30km. There are not large population compared to other nuclear region in Japan, but the direction is limited since located in the peninsula, there is a possibility that traffic jam occurs. In addition, there is no big city in region of 30km distance from the nuclear power plant, but the refuge has been decided to the area that has larger population and traffic volume such as Kanazawa. Therefore, there is a possibility that a large traffic jam occurs from outside region of 30km.

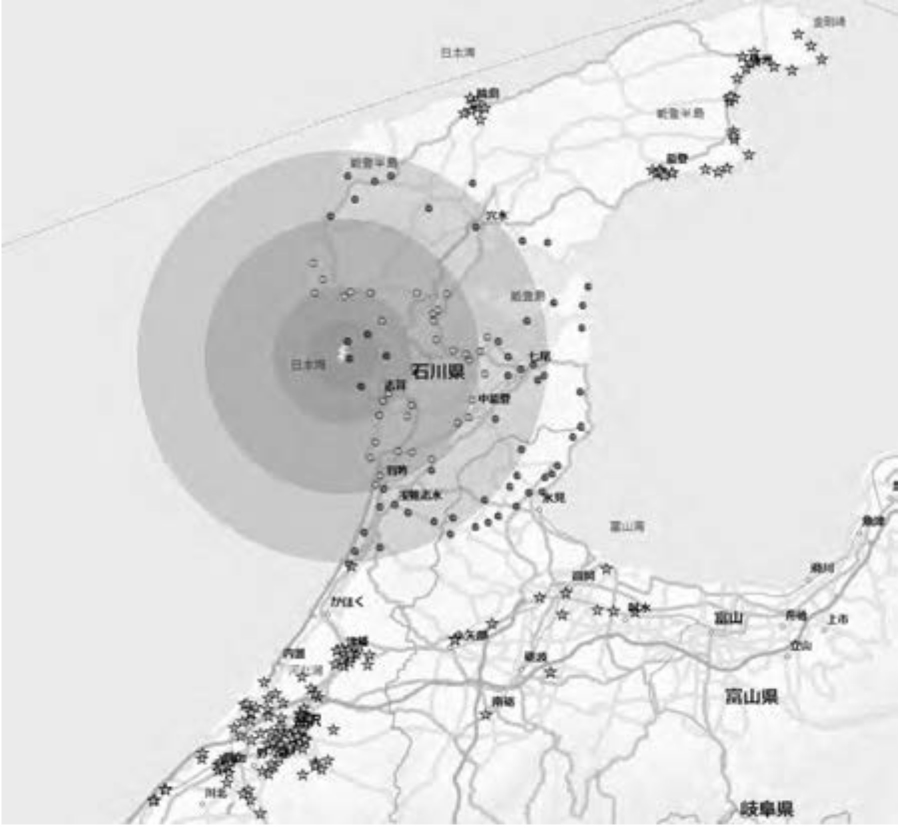
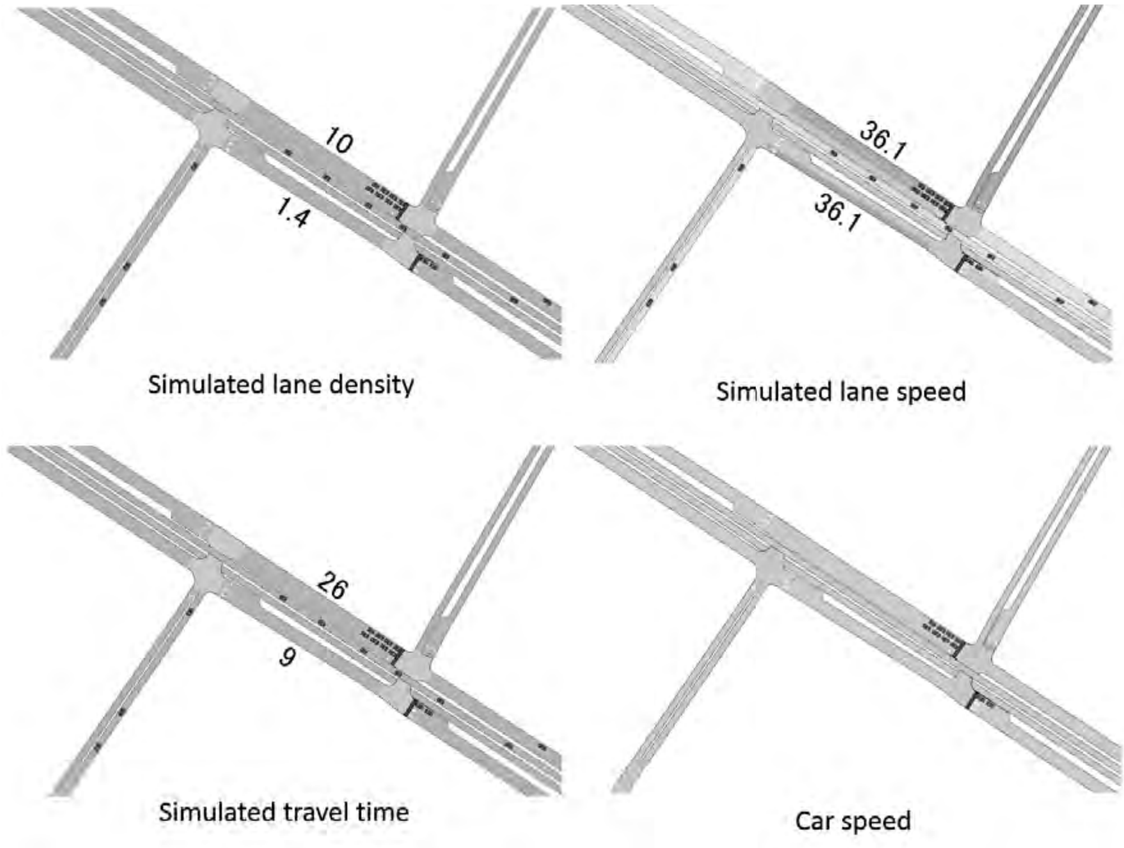


Figure 1 Start points (circle-shaped) and shelter (star-shaped) in target area

Also, the UPZ includes part of the Himi city in Toyama Prefecture. Shelters are defined by the evacuation plan of Ishikawa Prefecture, Toyama Prefecture. Ishikawa Prefecture has 157 shelters, and Toyama Prefecture has 12 shelters. In this study, the starting point of evacuation vehicle was placed about 90 places to suit Ishikawa prefecture and Toyama Prefecture, It is assumed that evacuation to the shelter that has been defined in the evacuation plan from each starting point.

3.2 Simulation system

Evacuation simulation was examined using Aimsun8.1.0 in this study. Aimsun8.1.0 is an integrated traffic simulator of macro-meso-micro, and is widely used at home and abroad. This system can import the data such as road network from GIS and google map easily. In this study we have imported the main road network such as national highway, high-speed roads and prefectural road from the GIS of detailed map data. The OD model and branch rate model can be used for route selection. In this study we used the OD model that specifies the evacuation destination occurrence point of the vehicle.
Figure 2 shows an example of a simulation screen. Aimsun8.1.0 can show some information such as average speed and average density of each node, and so on. Also, Aimsun8.1.0 can show the information of each car, such as speed. Furthermore, not only regional analysis, Aimsun8.1.0 also can wide area analysis. In this study, targeted very wide area. So we can use some methods of analysis.



Figule 2 Examples of simulation screen

3.3 Simulation condition

In the evacuation it was assumed that all residents use private cars. It assumes that each household use one vehicle. Number of vehicles is about 65000. In signalized intersection, be set up a signal that is 120 seconds one cycle. Speed limit was set 80km/h in Noto-Satoyama-Kaido and the highway, and set 50km/h in the other road. Evacuation simulation was carried out on the assumption that, immediately after the accident, evacuation instruction is issued to residents in the region of 5km from the nuclear power plant, and 1 hour later, issued it to all residents in the region of 30km. Evacuation instruction is well known to residents at the issued time, and all the residents was assumed to act in accordance with evacuation instructions. Evacuation is started at the same time with evacuation instruction is issued. Residents in the region of 5km from the nuclear plant are assumed to start evacuation within one hour from the evacuation instructions, and residents in the region of 30km are assumed to start evacuation within three hours. However, if a part of cars could not start in time for reasons such as traffic jam, the cars continues to occur until a specified number. Generation traffic is only evacuation cars, so background traffic is not taken into consideration.

4. RESULTS OF SIMULATION

Figure 3 shows that a representation of the one by one cars speed in color during simulation. Red represents that car speed is most slow (0~15km/h), so the place where

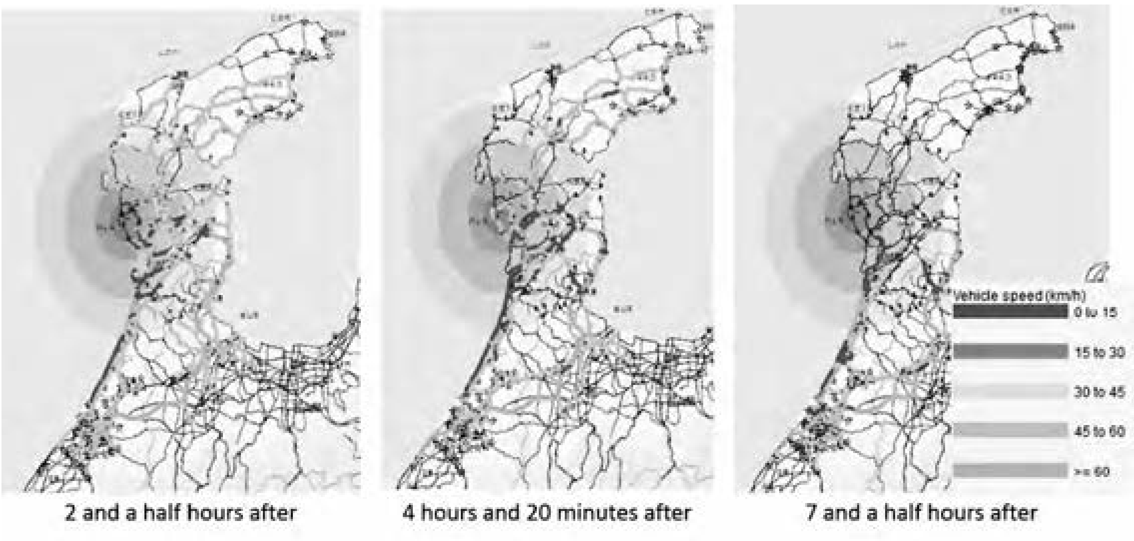


Figure 3 Evacuation speed (car) during simulatio

red is continuous has occurred traffic jam. Since residents in the region of 5km start the evacuation earlier, so after two and a half hours there are no cars in the area. But when traffic jam out of the region of 30km becomes violently, the cars were seen to bypass in the direction of the nuclear power plant and Toyama Prefecture. After seven and a half hours, cars that were evacuated to the northern Noto Peninsula have completed evacuation, but the tail end of the vehicle to evacuate to the south remain in the region of 10km. While the many cars directed toward Kanazawa direction from Ishikawa direction became violently for above reasons. Finally, the time all of the cars took to arrive at the shelter was about 14 hours. So the evacuation to the Kanazawa direction took time of about twice of the evacuation to the Noto Peninsula north. From these results, the vehicle was found to be likely to concentrate on the road going from inside of the region of 30km to Kanazawa direction.
Therefore, it is considered necessary to determine evacuation routes previously to pass through a safe detour and to disperse the shelter, and the like.

5. Conclusion

In this study, basic simulation about evacuation using private cars in nuclear disasters was carried out, to extract the problem of evacuation plans and to propose an improvement plan. As a result, particularly heavy traffic jams were occurred at Kanazawa direction, because cars from the peripheral area of nuclear plant to Kanazawa direction is large and the route to be selected is limited, as compared to the other regions. Since evacuation completion time is slow, it is necessary to flow a part of cars to unused path and to disperse the vehicle.
From now on, carried out simulation using a plurality patterns scenario and compare simulation results, we will consider the best evacuation procedures.

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Efforts of nepal towards bulding a disaster resilient country

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ABSTRACT

With its unique geo-physical settings and socio-economic conditions, Nepal is highly vulnerable to natural disasters and climate risks. A combination of poverty, climate change, rapid urbanization and mountainous terrain makes Nepal highly prone to disasters. The 2014 flood and landslide in the Mid West and Sindhupalchowk followed by 25TH April and 12th May 2015 devastating earthquake clearly indicate that flood, landslide and the earthquake are deadly threat because of the likelihood of massive loss of lives and infrastructures, particularly in densely populated area. History of systematic disaster risk reduction practices in Nepal goes back to 2009 when Government launched Nepal Risk Reduction Consortium and also launched the National Strategy for Disaster Risk Management in the same year. Nepal's efforts towards building resilient communities are grounded on five Flagship priorities in coordination and collaboration of humanitarian agencies, financial institutions and development partners. Flagship 4 under NRRC has identified nine minimum characteristics of resilient community targeting to reach 1000 VDCs in five years starting from 2009. The Natural Calamity (Relief) Act 1982, the Local Self Governance Act 1999, National Strategy for Disaster Risk Management 2009, Central Disaster Relief Committee, Local Disaster Risk Management Planning Guideline 2011, District Disaster Risk Management Planning Guideline, Disaster Preparedness and Response Plan in the District, National Disaster Response Framework, National Adaptation Program of Action, Local Adaptation Plan for Action and National Building Code 1993 are some of the key policy documents that Nepal has prepared so far towards its attempt in building resilient communities.

Key words: Geo-physical, Vulnerable, Natural Disasters, Climate Risks, Climate Change, Rapid Urbanization and Mountainous Terrain, Nepal Risk Reduction Consortium (NRRC), Flagship Priorities

Comparison of housing reconstruction process after Typhoon Haiyan: "community-driven" vs. "production-based" approach

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ABSTRACT

This paper describes the post-disaster housing provision activities in the region VI by twenty humanitarian agencies during the recovery phase after Typhoon Haiyan, which hit the central Philippines on 8th November 2013. The author investigated the process of beneficiary selection, shelter design, implementation as well as policy on land ownership by interviewing various national and international agencies and compared its characteristics. The findings indicate similarity in the process of shelter implementation by most agencies which seemed effective and sensitive to the local culture. Two distinct types of approach, "community-driven" and "production-based" were identified and pros & cons of both approaches are analyzed and the role of local government and international agencies and an ideal way of working in the future is examined based on official reviews conducted by international organizations.

Keywords: humanitarian assistance, post-disaster housing, Typhoon Haiyan

1. INTRODUCTION

Typhoon Haiyan (locally known as Yolanda) made landfall in the central Philippines on 8 November 2013, and the strong wind up to 300 km/h and storm surge as high as 4m devastated both coastal and inland areas and destroyed nearly 1.1 million houses and displaced 4.1 million people. Despite the fact that the damage level was equal for coastal and inland areas, a study showed that 82% of shelter assistance was concentrated in coastal areas (Shelter Cluster Philippines 2013). There was a massive emergency operation in response to the Presidential Proclamation issued on 11 November 2013 declaring a state of national calamity and announcing that international assistance would be accepted. Although the national government should be responsible for disaster response and reconstruction, it is inevitable that many disaster-prone, developing countries still rely on external support, therefore it is important to examine these activities carefully and verify their effectiveness.

Discussion in this paper is based on the study conducted by the author during her stay in Roxas city, Capiz province of the Philippines for seven and a half months from May 2014 through March 2015 during the 1) implementation of 610 core shelter construction project with UN-Habitat, 2) assisting the "interim Shelter Cluster" for coordinating shelter activities in the region VI and 3) conducting individual interviews with representatives from national and international agencies implementing shelter programs in region VI (Western Visayas) (**Figure 1**), which was the second hardest hit area by the typhoon, more than a year after the typhoon.

Figure 1. Map of typhoon path and damaged houses by municipality
(UNOCHA, 18 Nov 2013)

Source :http://reliefweb.int/map/philippines/philippines-damaged-houses-18-nov-2013-1800-utc8

2. SHELTER OPERATION OVERVIEW

Time, cost and quality are the three critical factors to verify housing reconstruction operation and its effectiveness after disaster. In order to investigate how various actors from different backgrounds are working in the region to reach the same goal of providing shelter to those who lost their homes, the author conducted interviews of thirteen representatives from national and international organizations that were working in the shelter cluster in the region VI, and also consolidated shelter activity information by active agencies to create a simple database to help all involved parties including local government comprehend the on-going activities. As a result of the study, the author identified two distinct approaches and verified their characteristics in an attempt to understand their effectiveness and make useful suggestions for the future of shelter construction operation. This chapter will give background information to help understand the comparison of two approaches: findings from data consolidation of shelter activities by different agencies are described to grasp a common feature or general tendency of shelter operation, followed by explanations of various processes of shelter implementation.

2.1 Findings from data consolidation of shelter activities

There were approximately twenty national and international organizations providing shelters in region VI and they can be classified into four types; National or local organization (22%), International organization (44%), International organization with nationally based office existing prior to typhoon (28%) and International organization in partnership with local NGO (6%). Most of the international organizations had one or two international personnel assigned in the field office but the rest of the teams were locally hired. According to the Yolanda Recovery Shelter Guidelines drafted in May 2014, the Shelter Cluster Philippines describes nine options for shelter assistance from 1) Emergency Shelter Upgrade (ESU) as Emergency Shelter Assistance for 6 months to

1 year, 2) Temporary Shelter (TS), 3) Host Family Programs (HF), 4) Rental Support (RS), 5) Bunkhouse Program (BH) as Temporary Shelter Assistance for 2 years, 6) Repair and Retrofit (R&R), 7) Core House (CH), 8) Permanent House (PH) and 9) Settlement Plan (SP) as Permanent Shelter Assistance for up to 9 years. The definition for each type of assistance does not specify construction method or materials and the naming of shelters was left up to the interpretation of each agency (Shelter Cluster 2014). In region VI, based on the categorization of shelter type by each agency, 50% of all provided shelters were "permanent" (Core Houses (39%) and Permanent Houses (11%)) and 50% were "non-permanent" (Temporary Shelter (6%), Transitional Shelter (22%) and Semi-permanent houses (22%)).

2.1.1 Size

An average unit size of a shelter was 21m^2 and 79% of them ranged between 18 to 20 m^2. The size is likely to be decided based on a minimum standard set by The Sphere Project of a covered area of 3.5 m^2 per person for a temporary shelter, multiplied by 5, the average family size in the Philippines, to become 17.5 m^2 (The Sphere Project). It should be noted that this standard is minimum for temporary shelters and not for permanent shelters and 20 m^2 does not seem sufficient for a family of five to live, but it is also observed that the typical indigenous homes in the affected area before the typhoon are more or less the same size.

2.1.2 Cost & Materials

The cost of a shelter ranged greatly from 25,000 to 200,000 PHP – Philippines Pesos (550 to 4,428 USD), with the average cost for "non-permanent" shelter at 68,000 PHP (1,505 USD) per unit while that of "permanent" shelter was 110,600 PHP (2,450 USD), 1.63 times that of non-permanent one. Needless to say, the cost is directly related to the materials used for construction and most of the shelters were built with mixed materials of concrete as main structural members and light materials such as wood or bamboo as wall frame & panelling. For those categorized as "permanent", 70% of them used concrete solely or in combination with other light materials while 30% used light materials only. For "non-permanent" type, 40% of them used concrete and 60% used light materials only. This implies that concrete was used more with "permanent" shelters while light materials were used more for "non-permanent" shelters. However it also indicates that the categorization of shelters does not necessarily denote specific construction types.

A slight correlation was acknowledged between the cost of a unit and the total number of shelters provided by an organization. It indicated that the less expensive a unit costs, the greater number of units could be provided. However it may be misleading to assume the correlation since the decision to build in large quantity depends not only on the unit cost but on the size of the agency, scale of its operation and its policies, etc.

2.1.3 Time

Construction time required to build a unit varied greatly and this proved to be a challenging comparison because it depends on many factors such as the number and type of workers assigned, the type of construction approach – whether on-site or prefabrication off-site, by hiring a general contractor or by separate order, and complexity of design which differed from agency to agency and so on.

Table.1 Shelter implementation by various agencies in region VI (2014-2015)

		
INT-1c: **Temporary**/18m^2/36K/400	**INT-4:** **Transitional**/20m^2/NA/520	**INT-9c:** **Transitional**/19m^2/118K/141
		
FOR-1: **Transitional** /20m^2/95K / 150	**FOR-4:** **Semi-perm**/18m^2 / 50K/1,750	**INT-6c:** **Semi-perm**/18m^2/135K/540
		
NAT-5: **Core**/40m^2/60-80K/1,028	**NAT-5:** **Core**/24m^2/80-100K/1,322	**NAT-1c:** **Core**/20m^2/130-150K/280
		
FOR-3: **Core** / 20m^2 / 65.5K/400	**INT-7:** **Core** / 20m^2 / 165K/123	**INT-8c:** **Permanent**/20m^2/115K/141

(Agency code: shelter type/floor area/cost (Philippines Peso)/total # planned)
(Agency code: **INT**: International NGOs/IOs/UN, **FOR**: Foreign NGOs, **NAT**: National NGOs, **c**: Christian)

Comparing the shelter designs from various agencies as shown in **Table 1** indicates that designs are not radically different from one another and they can be classified into two general types: light-construction with raised floor, and half or full-concrete construction on-grade. The similarity of the designs is perhaps due to material availability, cost and structural constraints, acceptability by both cultural and environmental climate, in addition to the design guidelines provided by the Shelter Cluster. Roof structural design is the most critical part of the typhoon resilient shelter and this has to be examined carefully to ensure that adequate countermeasures were taken. In the following section, the process of shelter implementation is discussed.

2.2 Findings from interviews

2.2.1 Process: Beneficiary Selection

Ideally, the affected population who lost homes due to disasters should all be eligible to receive shelter assistance equally however there is almost never enough assistance available to accommodate all the needs thus agencies must choose the beneficiary based on a careful selection process. Beneficiary selection process is considered to be one of the most critical aspects of shelter construction because it determines to whom the limited resources will be allocated and the organizations are almost always required to be impartial and accountable to the affected population.

The Shelter Cluster recommends a certain procedure and criteria for beneficiary selection in its guidelines and the majority of organizations followed some system to involve community leaders in the early stage of selection, to consult the community people, make site assessment and verify applicants by interviewing each household if necessary. An example of a beneficiary selection process applied by one of the international organizations indicated eight steps for selecting beneficiaries which takes a minimum of 15 days per community, starting with step-1: courtesy call to the leaders of local government and community (1 day), step-2: conducting an orientation to the community about the shelter provision project including the selection process (1d), step-3: submission of application by the people (1d), step-4: assessment of individual sites and the community (1d), step-5: beneficiary selection based on the submitted application and the eligibility (2d), step-6: second assessment if necessary (1d), step-7: public posting (3d) and step-8: accepting objections to the final list (1d). By making a courtesy call, it informs the local officials about the potential shelter assistance activity so that they are well-informed about the on-going activities while critical information such as vulnerable members of the community can be obtained from them.

Engineering is not the only expertise required in shelter construction but community mobilization is another essential skill that is required for verifying the applicants. Although it is important to establish a good relationship with the community and its leaders, sometimes the community leaders could be biased about their own people, providing information that favour certain groups. Therefore the challenge on the ground was to understand the community dynamics well enough by frequent communication with the community by the community organizers so that the right approach is taken and consequently a fair selection is made.

One of the most critical questions during the beneficiary selection is whether the potential beneficiary owns the land or not. Typically the most vulnerable people are those without land ownership yet it is often a pre-condition for receiving permanent shelter assistance. Although all agencies that were interviewed said that they require land ownership as beneficiary criteria, most agencies accepted an alternative solution which is to have a written agreement made between the owner and the beneficiary to assure the use of land for a certain period of time.

2.2.2 Process: Shelter Design

Shelter design influences the project budget and is one of the most visible outputs of the project thus it is a critical decision who designs and how it is done. Based on the interviews conducted in the region VI, twelve out of thirteen (92%) organizations design their shelter using in-house staff –locally or internationally hired for the project and only one out of thirteen (8%) contracted out to architects. The latter was a unique case where the donor has found a group of national architects in the Philippines and requested the operation team to work with them. And from those which used in-house staff, 33% used a design developed by the people in Headquarter office and 66% used a design that was developed by the locally stationed staff. Some agencies hired a local architect to come up with a design in less than one week while others spent as long as three months developing a design, trying to strike a balance between cost and effect, and not outdo the work of the government.

Many of the organizations expressed that the guideline by the Shelter Cluster was useful and they often made reference to it. Though some organizations mentioned about actively exchanging information with other organizations during the design process, many of them seemed to have developed the design by themselves, not collaborating with others.

2.2.3 Process: Shelter Construction

There is a number of ways post-disaster shelter construction is carried out, but it can be generalized into two types: one managed by a general contractor like in a regular practice and the other one participated by the beneficiaries which is a unique approach after disaster and it is used mainly to create jobs for the affected population, increase a sense of ownership and build strength among the people. It does not necessarily lower the cost of construction since it often takes more time when constructed by non-trained labours. There are several ways to involve the beneficiaries in the process of construction and the most common and simple way is to hire them as labourers for simple tasks that do not require training such as carrying construction materials and doing simple carpentry work. Less common and more systematic but effective ways to involve the beneficiaries were observed and they were both well-planned but distinctly different in their approach which will be discussed in the next section.

3. COMPARISON AND ANALYSIS

After examining various aspects of shelter implementation programs in region VI, the author identified two approaches that were uniquely systematic in their operation and based on specific ideas toward shelter reconstruction.

3.1 Community-driven Approach

3.1.1 Community as beneficiary

A unique method called “community-driven approach” was taken to implement shelters by the UN-Habitat Philippines, with its country office located in Manila prior to the typhoon. Its objective was clearly set and focused on the capacity building of the people by promoting the participation of the affected population. A similar method is also known as “People’s Process” (UN-HABITAT 2008) implemented by the UN-

Habitat in other countries such as Afghanistan, Bangladesh and Pakistan. It can be said that shelter construction is a good catalyst for bringing peoples' power together because everyone needs better shelter after disaster. UN-Habitat used a strategy of providing not only shelters but also infrastructure assistance to the community and this has promoted active involvement of the community as a whole, not just partial participation by those who receive shelters. If building shelters was the only outcome of the project, it would have been difficult to involve the whole community to help those who need more support. By involving the community as a counterpart of the project, it creates a sense of collective responsibility and mutual participation which reinforces the activity.

3.1.2 Community Empowerment

In the program run by the UN-Habitat, those who receive shelter assistance are not called beneficiaries but *household partner(s) (HPs)* to make clear that they are not passive recipients of goods but are active members of the program, given important roles and responsibility to realize the project. As an example, the community is required to form four kinds of committees on voluntary basis: finance committee, construction committee, procurement committee and monitoring committee in order to handle all aspects of shelter implementation from the start to finish. It includes payment to the workers and ordering of materials by themselves, with the support of UN-Habitat field office staffs. It is a unique practice since the money which is funded mainly by the Japanese government is directly transferred from UN-Habitat Headquarters to the account of the community without involvement of the UN-Habitat country office. This arrangement puts a great pressure on those who handle the finance and creates difficulty at times. Procurement of the materials is also handled by the community which allows them to make direct negotiation with the local suppliers and creates contact for them.

3.1.3 Amateurism

Despite the difficulties that they face due to the lack of expertise, the experience ultimately gives them the confidence that they can do complicated tasks, a sense of pride for taking over difficult roles though one may not be compensated for it, and a strong attachment to the final product that is the shelter itself. It is a time and energy consuming approach and depends on available resources in the given community which makes it difficult to control and less efficient, however seeing how people gained confidence and became empowered through the process, it can be said that this is one way of implementing shelter successfully.

3.2 Production-based Approach

3.2.1 Individual as beneficiary

The other approach which the author calls "production-based approach" is a highly systematic approach taken by two international NGOs independently who established its method based on previously successful experiences of post-disaster shelter construction projects in other countries. Unlike the "community-driven approach", their program focused on providing shelters to selected individuals with no involvement of the community required. An advantage of working with a community was felt when visiting to these projects. If the entire community was involved, there was always someone from the community to meet staff and respond to inquiries, but if only an individual was involved, it wasn't guaranteed that someone would be available to answer if the workers were absent or the provided house was unoccupied.

3.2.2 Off-site operation

The main objective seemed to be the efficiency of operations by an effective use of off-site operation, and the setting up of workshops and warehouses. Setting up off-site workshops allowed for the prefabrication of shelter components such as windows and wall panels as much as possible, which reduced on-site construction work and enabled better quality control. Setting up warehouses allowed for making bulk orders, reducing the effort and possibly the cost, and it also allowed for stocking of materials in an organized manner so that the right amount of supplies are readily available to be delivered to the construction site without delay. Such off-site operations assured the creation of stable jobs for the affected population and local people employed at these workshops and warehouses could be part of the reconstruction process giving them a sense of participation and pride.

3.2.3 Professionalism

Workers salaries were paid when the assigned task was achieved by the locally hired staff and the entire operation was managed by one or two international staff with expertise in shelter construction in other countries. These two international NGOs had in common that their shelter designs were developed by an international staff with a high degree of expertise in shelter construction and they both spent a good amount of time consulting with the local people including local government, engineers and community members. Their construction drawings were thorough, well prepared and presented compared to other organizations. Studying the ways they operated their shelter implementation, a sense of professionalism and confidence was observed backed by past experiences of successful operation.

3.3 Analysis

The differences in approach taken by two types of organizations may be explained by the fact that the former approach was taken by an organization that has a presence in the country prior to the typhoon with close relationships with the national actors including the government while the latter approach was taken by international organizations without a country office or pre-existing relationship. Naturally the former has more knowledge and understanding about how the country operates and the issues they have, therefore their way of developing the method of implementation and involving themselves in the project may be based on the idea that they will continue to be involved on a long term basis, while the latter may have entirely different approaches to have a good exit strategy since the organization will leave after completing the implementation. Thus it can be said that each organization with different strength employed an approach that is suitable to them in each way and they both succeeded in achieving their set goals.

In order to verify which type of approach was more effective, one needs to consider not only the total number of shelters provided and the amount of time spent to implement them but many other factors must be taken into consideration and it is not possible to simply compare and evaluate. Although cost and time are both undoubtedly important factors in the disaster recovery process, there are other unquantifiable qualities such as the strengthening of community ties that contributes to building resiliency against future disasters. **Table 2** shows pros and cons of two types of approach. The optimal solution may be midway between the two.

Table 2 Pros & Cons for two types of approach for shelter implementation

	Community-driven approach ➢ community as beneficiary ➢ on-site construction, managed by the committee formed by the community ➢ from insider's view	**Production-based approach** ➢ individual as a beneficiary ➢ systematic operation using off-site prefabrication as much as possible ➢ from outsider's view
Pros	▪ Building capacity ▪ Strong sense of ownership ▪ Collective responsibility	▪ Systematic, fast and efficient ▪ Easier to control quality ▪ Creating constant jobs
Cons	▪ Time consuming ▪ Dependent on personal ability ▪ Difficult to control	▪ Limited capacity building ▪ Less sense of ownership ▪ Little community involvement

4. OBSERVATIONS

4.1 Temporary Housing as Humanitarian Assistance vs. Permanent Housing as Development

An inherent and complex issue with regards to post-disaster housing is the gap between humanitarian and development assistance. Both temporary and permanent houses were provided after the typhoon and the line between the two is not clear as to when the provision of temporary shelter ends and permanent shelter begins. It is inevitable that some organizations will provide temporary housing while others provide permanent housing during the same period of time. But the consequence is that the quality, cost and the delivery time (QCD) of the shelters vary depending on which agency provided the service and this has caused some issues among the beneficiaries.

It seems that the government is concerned about permanent housing but not temporary housing because it is supposed to be used only temporarily while waiting to be replaced by permanent housing. However, one issue is that many of these temporary houses end up becoming permanent due to lack of financial capability to build a new house. It is important to advocate "Building Back Better", to promote permanent housing solutions rather than temporary ones and in order to do so, a strategy for a smooth transition from emergency phase led by a humanitarian actor such as Shelter Cluster (IFRC) to the reconstruction phase succeeded by a development actor such as UN-Habitat is needed, while involving governmental actors at each step.

4.2 Shelter in Urban context

Of the various housing designs, the core shelter form has various advantages, but the successful implementation depends on the site. After visiting projects by other agencies and comparing them with that of UN-Habitat, it was confirmed that the core shelter works better in rural settings where there is enough land around the house to allow for building extensions, which is the original idea of building a core shelter. However unfortunately there were many core shelters built on tight property lots in urban areas where there is no more room to grow. Follow up visits are needed to verify the consequence of the core shelters built in urban contexts.

5. CONCLUSION

The study of shelter operations in region VI revealed that outputs and methods used by various organizations proved to be fairly similar though despite the similarity, it seemed that each agency conducted its operations independently without much collaboration.

A comparative study of two types of shelter implementation approaches – “community-driven” and “production-based” – indicated that each approach was effective and successful in achieving its own set goals. Both types of approaches demonstrated strengths and weaknesses and it is important to carefully study both methods to come up with an optimal solution.

5.1 Ideal roles for government and international organizations

As mentioned in the introduction, the government should be responsible for disaster response and reconstruction process but in reality, many disaster-prone developing countries still rely on external support due to the lack of resources and management expertise. However it is important to recognize the downside of not taking the initiative in the operation. If the government has difficulty grasping overall situation due to lack of sufficient information sharing with organizations, it could cause imbalance, unfairness or inefficiency due to lack of coordination in the assistance. In order to avoid such situation, the government should be the focal point in the operation, taking charge of damage assessment, verification and listing of affected populations which should be thoroughly done by the local government and then it should concentrate on the overall management while the actual implementation work can be outsourced to NGOs and international organizations with high level of expertise and sufficient resources. International organization could play an important role as a third party to assure transparency by checking the quality and fairness of implementation.

In order to take further steps for a more effective post-disaster shelter implementation, government involvement is required to be better prepared, two basic actions are recommended based on the study of this paper to: 1) study the shelter implementation processes of various agencies and survey actual shelters provided to check the quality and structural integrity; and 2) select and prepare a few optimal solutions (shelter designs) endorsed by Shelter Cluster and UN to be used by agencies that join their operations in order to achieve faster implementation with quality control. A holistic approach is needed to reach a common goal of providing enough shelters to those in need, rather than focusing on the individual goals set by each actor.

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New technology for urban safety or more concentration on the fundamentals?

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ABSTRACT

More than two decades ago the authors were part of an international team entrusted with drafting a national building code for Nepal, investigating alternative construction materials and methodologies, and providing an implementation plan and law. This was the result of a government initiative led by Madhab Mathema (urban planner) in response to the 1988 Udayapur earthquake (M 6.9)[1] in which nearly 1000 people died in Nepal and India. The seismic design provisions were underpinned by a probabilistic hazard analysis of a comprehensive seismicity model compiled from all available fault and historical information within and beyond the country's border. The building code, largely owing to the guidance of Dr.Anand Arya of India, was innovative in that it included sections for engineered structures, mandatory rules-of-thumb for less formal buildings, and guidelines for traditional buildings. Few buildings in Kathmandu exceeded five storeys, reinforced concrete construction practices and material qualities were not well controlled, and only a few engineers followed international best practice. After the 25th April earthquake this year, there have been national and international calls for a more stringent enforcement of the building code and its review. This paper examines what changes have occurred in Kathmandu since the building code was passed into law (1993), and concludes that there are very few substantial improvements in common practice. It is suggested that not necessarily new technology is needed in Kathmandu, but an improvement in the implementation of existing, well-tried, well-proven technologies are required so that at the very least there is a much better compliance with the existing building code. Reinforced concrete was once considered a new technology. There is plenty of evidence from the observation of reinforced concrete buildings that were destroyed in this earthquake that this technology is still poorly-understood.

Keywords: New technology, code compliance, Nepal Building Code, alternative materials, reinforced concrete

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[1] As per a web article "The Udayapur earthquake of August 20, 1988 (M b 6.4, Ms 6.6, Origin time: 23:09:10, epicenter at 26.8 o N 86.6 o E and Focal depth 57 km) occurred in the Himalayan front arc which caused severe damage in the region will loss of 1100 lives."http://www.researchgate.net/publication/260105223_Anomalous_seismic_activity_associated_with_1988_Udayapur_earthquake

Building Resilient Urban System: Approach of National Urban Development Strategy[a]

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ABSTRACT

The urban areas are often termed as 'engines of growth' that drives development of the nation. However, it is equally true that urban development is investment intensive hence security of the investment is vital in attracting further resources to push development forward. Therefore, National Urban Development Strategy, 2015 (NUDS), prepared by Ministry of Urban Development, Nepal, has envisaged a safer and resilient urban space which expands from existing responsive approach of disaster management to an integrated approach for achieving desirable condition of physically, socially, economically, environmentally and culturally safe and resilient urban areas. Furthermore, NUDS has established resiliency as one of the five guiding principles to achieve its vision of a 'Balanced and prosperous national urban system'. The paper mainly summarizes the concept of resiliency drawn by NUDS, major impediments or issues in achieving the desirable condition and the strategies together with pertinent activities that need to be taken to address the identified issues.

Keywords: urban development, resiliency, safer settlements, existing status, national strategies

1. INTRODUCTION

Natural disaster in Nepal can be characterized into events such as earthquake, flood, land slide, drought and epidemics. According to GFDRR, more than 90 percent of Nepal's population lives in relatively high risk area from two or more hazards, of which the unpredictable and highly probable one is earthquake. This region has one of the most active fault lines and subduction of Indian plate under Tibetan plate by 2.5 cm per year gives up thrust to these Himalayas, which releases the stored energy in the form of seismic waves. Hence, this region is under high seismic vulnerability and incurs more than thousand earthquakes ranging from 2-5 on Richter scale every year. However, it has also succumbed to some major earthquakes with the average return period

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[a] *National Urban Development Strategy, 2015 has been prepared by Ministry of Urban Development and it is in the process of approval from the cabinet. Dr. Pitamber Sharma was the team leader and the NUDS secretariat at the Ministry was led by. Dr. Mahendra Subba, then Joint Secretary, for preparing the document. Both writers were the members of the NUDS secretariat.*

of 70-80 years. The historical great earthquake of 1934 was measured as 8.4 rector scale, which was followed by the recent earthquake in April 2015 of 7.9 rector scale that resulted in widespread destruction and casualty of 8856 people. Also, the period of seismic gap in the Far western region of the country has been indicating possibility of a major seismic activity in the region. On the other hand, landslides and flooding are yearly events that claim most lives and have displaced large number of families. According to Nepal Disaster Report 2013, with an exception of 2009, flood and landslides have resulted in most number of human causalities since 2000. In 2009, the highest numbers of death was caused by epidemics.

However, the concept of resiliency in Nepal is limited to disaster management framework and policy, which is evident in analysis of the cost such that major government expenditure for disaster management is concentrated in post disaster response and recovery. It was also evident in the nation's response to April 2015 earthquake, which was reactive in nature and and lacked preparedness in dealing with an evident catastrophe. Therefore, National Urban Development Strategy, 2015 (NUDS) has attempted to establish the concept of 'resilience' in building safer urban space, that entails integration of multiple sectors and stakeholders in a proactive approach of building resilient urban system. Therefore, based on the existing identified issues with regards to building resiliency and lessons learnt from April 2015 earthquake, NUDS has formulated strategies to guide Ministry of Urban Development in integrating resiliency as a vital element of the urban planning process in developing resilient urban system.

2. NATIONAL APPROACH TOWARDS DISASTER MANAGEMENT

Ministry of Home Affairs is the national agency for disaster management, which under Department of Narcotics, Drug Control and Disaster Management formulates and implements the national policy for disaster mitigation and preparedness. "All activities in disaster management are guided and directed by the Central Disaster Relief Committee chaired by the Home Minister in accordance with the Disaster (Relief) Act 1982", which coordinates emergency and preparedness activities. The responsibility of onsite action is passed down from the Ministry to Local Natural Disaster Management Relief Committee (Municipality) through the Regional and District Level Relief Committees. However, this system is focused on post disaster scenario of emergency rescue and relief. According to World Bank analysis in 2010, in Nepal the pre-disaster spending for disaster management has doubled in the past decade; but it is still less than post disaster spending and the Natural Calamity Relief Act 1980 focuses on response only. This leaves a large scope to divert funds towards preparation and mitigation plan to build resiliency towards natural disasters, which will have significant role in reducing the post disaster spending.

3. SECTORAL APPROACH TOWARDS DISASTER MANAGEMENT

Urban development sector is resource intensive, therefore security of the investment is vital and that can only be ensured through promulgating resiliency as the principle for development. Other way round, resiliency is a critical factor that attracts investment towards urban development sector so that it can function as engines of growth. Therefore, underscoring the significance of 'resilience' NUDS has established resiliency as one of the five guiding principles for development of "Balanced and Prosperous National Urban System", which demands integrating resilience as a key component of the planning process in building resilient cities that are adaptive, and capable to anticipate and plan for future vulnerabilities.

NUDS has defined resiliency on the basis of four basic elements that are:

i) **Physical Status:** It is based on physical planning such as building codes, bye-laws, land use zoning, etc. and requires preparation of hazard maps and geological feature of the area to develop safer settlements.
ii) **Social Status:** It is reflected by the social capital of the community, which is based on their preparedness to and capacity to respond during disasters.
iii) **Economic Status:** Vulnerability is directly proportional to level of poverty or economic condition as it has direct implication of capacity of the people to mitigate, adapt and recover from a disaster.
iv) **Institutional Status:** The strength of local and national governments, and institutions both in the government and non-government sectors to plan, prepare, respond and recover from the disaster is vital in reducing vulnerability of the people.

However, the concept of resiliency is still to be integrated in the urban planning process, which ensures its establishment as a vital factor to guide development activities. At present, there are urban sector related policies, acts, regulations, standards that are stand-alone documents, but with impact on building urban resilience. They are, Town Development Act, 1988 and Regulations, 2004; National Shelter Policy, 1997 (revised on 2011); Building Act, 1998 and Regulation, 2009, which is the legal basis for enforcing National Building Code; National Urban Policy, 2007, which seeks DRM Plan for all local bodies and inter-alia community mobilization for its implementation; Local Self Governance Act, 1998, which mandates local bodies to implement DRM activities; Apartment Act, 1997 and Regulation, 2003; Urban Drinking Water Supply and Sanitation, 2009, etc. These documents together with national framework for disaster management have to be integrated to develop a comprehensive urban resiliency plan and strategy.

4. EXISTING STATUS OF URBAN RESILIENCE

NUDS has attempted to analyze the existing condition of the identified four basic elements of resilience in the urban context of the country, which is as follows:

i) **Physical Status:** As of 2014, out of 58 municipalities, only 12 have enforced building code for construction work within the municipality jurisdiction. With total of 217 municipalities in 2015, and predominant rural setting of most of the new municipalities, enforcement of existing building code seems even more challenging.
   Therefore, the issue is to strictly implement bye-laws and National Building Code in all municipalities, including VDCs that are rapidly urbanizing. Also, enforcement of land use zoning is almost nonexistent in municipalities, which has been a major hurdle in development of safer settlement.
ii) **Social Status:** At present, out of 806 wards in 58 municipalities, 403 have Ward Citizen Forum, which is a group with legal status, whose members are the local people residing in the particular ward. Though most of the forums are inactive, there is scope for preparing targeted community based disaster management plans for both pre and post disaster situations that mobilizes these forums.

iii) Economic Status: Based on the data of CBS (2012), the percent of people below the poverty line in the urban areas of Nepal increased from 9.55 in 2004/05 to 15.46 in 2010/11. With rise of poverty in urban area, it is also an indicator of decreased resiliency of urban population to disasters. A survey in Ratnanagar Municipality in Chitwan shows that 27% are below poverty level; nearly 41 % of the population are vulnerable and can easily be pushed into poverty. This shows low level of resiliency in majority of population with weak economic status in many urban areas in Nepal. In the national context, according to the records of 2014, Nepal is ranked 184^{th} country (out of 213 countries) in the World Banks list of Gross National Income per Capita category, which explains lowest degree resilience in straight interpretations.

iv) Institutional Status: Disaster management component was included in the periodic plan of municipalities only since 2009. The Earthquake Vulnerability Maps have been prepared for only 5 municipalities by Earthquake Risk Reduction and Recovery Preparedness Program for Nepal. Further, Risk Hazard Maps have been prepared for 4 municipalities as of 2012. This shows lack of preparation to deal with disasters and even in cases where the maps have been prepared it has not been utilized for reducing vulnerability. Most of the municipalities even do not have a disaster management section within their institutional framework.

Other issues identified in NUDS are:

- Even though DRM has been incorporated in Periodic Plans of the municipalities, the support system is inadequate and the internalization of Disaster Risk management activities in municipal planning is quite slow.
- DRM framework lags linkage with other sectors and relationship between mapping, planning, land use and building code is not established prominently. There is no national seismic standard for lifeline facilities such as bridges, water supply, etc.
- Rapid depletion of open spaces in urban area with urban expansion towards marginal lands such as steep slopes and flood plains has increased vulnerability of the people.
- The local governing bodies lack post disaster preparedness plans, such as reconstruction and debris management, which is critical for speedy recovery to the society from a disaster.
- Lack of multi-hazard approach that deals with different types of disasters.
- Lack of information on historical events such as flood inundation areas based on return period, climate change and its impact, etc.

5. STRATEGIES FOR BUILDING SAFER AND RESILIENT URBAN AREAS

The following section enlists the strategies, as formulated in NUDS, for building safer and resilient urban areas. Each strategy is followed by proposed activities that are vital in achieving the goal set by the strategy.

S1. Promote multi-hazard approach in dealing with disasters including climate change

- Identify high risk areas in all urban areas based on available information
- Develop rapid hazard appraisal technique to identify hazards and prepare multi-hazard map of all urban areas
- Incorporate disaster risk management component in urban development plans
- Generate information on climate change in urban areas of different ecological regions

S2: Plan and develop Integrated Safe Settlement.
- Prepare norms and standards for safe settlement.
- Prepare resource map, soil capability map and risk sensitive land use plan for all urban areas

S3: Establish system of periodic review to strengthen building code, building regulations and guidelines and planning by-laws on the basis of lessons learnt with mechanisms to enforce and monitor them in all urban areas
- Conduct periodic review of building code/regulations/guidelines and planning by-laws
- Increase technical capacity of the local bodies to enforce building code/regulations/guidelines and planning by-laws
- Prepare simplified building guideline s and planning bylaws that can be understood at grass root level
- Facilitate mandatory enforcement and periodic monitoring of land use regulation, building code/regulations/guidelines and planning by-laws in all urban areas

S4: Build back better after any disaster.
- Prepare guidelines for retrofitting private & public building s and enhance technical capacity of municipalities to provide retrofitting services
- Provide technical support for safer building practices at household level
- Monitor structural and functional changes in the buildings

S5: Establish institutional framework for DRM
- Establish institutional framework and Standing Operating Procedures identifying key actors and their roles and responsibilities for and during any disaster
- Develop adequate capacity, legislative base and financing mechanisms for the institutional framework to function immediately after any disaster

S6: Enhance preparedness and adaptive capacity of the government and local bodies
- Develop capacity building tools and training programs
- Enhance human resource and institutional capacity of the government and local bodies

S7: Build awareness and capability of the community and civic bodies based on volunteerism to reduce vulnerability
- Prepare awareness material, educative tools and infrastructure and capacity building tools for communities and civic bodies
- Plan and implement appropriate periodic drills through community organizations and civic bodies

6. CONCLUSION

Urbanization is inevitable in the context of Nepal, however quantitative growth of urban centres should also be couples with quality so that a livable space is created with enhanced quality of urban life. Reduction of vulnerability and capacity to cope with natural disaster is a vital component of the urban areas that provides safer spaces and in other words attracts resources, both monitory and human, to grow as centre for innovation and opportunities. Therefore, National Urban Development Strategy, 2015 underscores the concept of building safer and resilient urban system, which is incorporated as a guiding principle for urban development. The strategies proposed in NUDS attempts to build resilience towards multiple hazards through development of integrated safer settlements. It focuses on strengthening institutional capacity of the local bodies and government, but with equal emphasis of capacity building of the community and civic bodies to reduce vulnerability. Operationalization of the strategies is key, which will demand an integrated approach that entails engagement of various stakeholders. Therefore, Ministry of Urban Development is in the process of formulating National Urban Development Plan with focuses on implementation of NUDS to achieve the desirable conditions.

Steel fiber-reinforced pervious concrete for urban roads

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ABSTRACT

In urban cities, heavy rain due to global climate changes frequently results in flash flooding. Pervious concrete pavement prevents flash flooding by draining away rainwater quickly and serving as a water bank because of its porous nature. However, to apply it in urban traffic pavement, the pervious concrete must have adequate strength besides resistance to clogging and good sound absorption characteristics. This study investigated the use of discrete hooked-end steel fibers in enhancing the flexural strength of pervious concrete without compromising its permeability and porosity. The target strength was 3.6 MPa and the permeability and porosity were 10 mm/s and 20 percent, respectively. The incorporation of 1.5% of steel fibers by volume of concrete was found adequate in achieving the desired characteristics. Also, clogging tests carried out using residual soils and construction sand ranging from 600 μm to 1.18 mm, indicated that pervious concrete was less susceptible to clogging compared to porous asphalt with the same porosity, and that the incorporation of steel fibers did not affect the results. In addition, acoustic absorption measurements on samples indicated that steel fiber reinforced pervious concrete possessed superior sound absorption characteristics compared to porous asphalt.

Keywords: flexural strength, permeability, pervious concrete, steel fibers, urban roads

1. INTRODUCTION

Due to global climate changes, heavy downpour of rain are increasingly seen in many parts of the world. In urban cities, such downpours frequently result in flash flooding as a result of the heavily built-up areas. Pervious concrete pavement provides a solution to flash flooding by draining away rainwater quickly and serving as a water bank because of its porous nature.

Pervious concrete is a near zero-slump, open graded material consisting of Portland cement, coarse aggregates with little or no fine aggregates, admixtures and water (ACI, 2010), with typical compressive strength between 2.8 to 28 MPa. To apply it in urban traffic pavement, the pervious concrete must have higher strength besides functional properties such as resistance to clogging and good sound absorption characteristics.

This study investigated the use of discrete hooked-end steel fibers in enhancing the flexural strength of pervious concrete without compromising its permeability and porosity. The target strength was 3.6 MPa and the permeability and porosity were 10 mm/s and 20 percent, respectively. Also, clogging tests were carried out using residual soils and construction sand ranging from 600 μm to 1.18 mm in size, and results were compared to porous asphalt with the same porosity. In addition, acoustic absorption measurements were conducted on samples using the impedance test tube procedure to compare the sound absorption characteristics of steel fiber reinforced pervious concrete with porous asphalt.

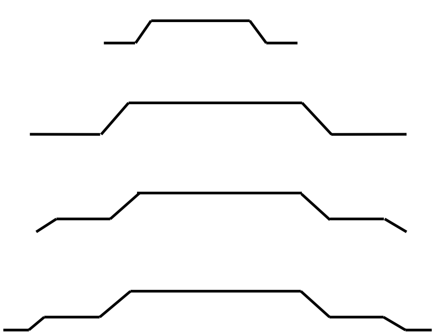
2. TEST PROGRAM

2.1 Tests on physical and mechanical properties

Pervious concrete specimens reinforced with hook-end steel fibers were fabricated and tested. The reference mixture proportion of the pervious concrete, determined from a previous study (Lim et al., 2013), consisted of cement at 367 kg/m^3, coarse aggregates at 1560 kg/m^3 and water at 110 kg/m^3. The water-to-cement ratio was thus 0.3, and the ratio of coarse aggregate to cement content was 4.25.

ASTM Type I ordinary Portland cement was used. The coarse aggregates were natural crushed granite complying with size 89 (9.5 to 1.18 mm) and size 67 (19.0 to 4.75 mm) of ASTM C 33-11a and having a specific gravity of 2.65, were separately used in different mixes. To improve workability and enhance the bond between the paste and aggregates, a comb polymer superplasticizer meeting the requirements of ASTM C494 was added at a dosage of 800 ml/ 100 kg of cement.

Steel fibers with properties shown in Figure 1 and Table 1, were added to the reference mix in dosages of 1% to 2.5% by volume in steps of 0.5%. There were a total of 39 different mixes covering the different coarse aggregates and type and dosage of steel fibers.



3D-S Fiber (1 hooked-end)

3D-L Fiber (1 hooked-end)

4D Fiber (1.5 hooked-ends)

5D Fiber (2 hooked-ends)

Figure 1: Types of hooked-end steel fibers

Table 1: Properties of steel fibers

Steel Fiber Type	Length (mm)	Diameter (mm)	Aspect Ratio	Tensile Strength (N/mm^2)
3D-S	30	0.50	60	1130
3D-L	60	0.75	80	1100
4D	60	0.92	65	1500
5D	65	0.92	65	2250

2.1.1 Test specimens

The samples for permeability and porosity tests had a diameter of 150 mm and a height of 50 mm. Concrete cubes of 100 mm side dimensions were used to study the compressive strengths of the mixes; whilst prisms 100 mm by 100 mm in cross-section and 400 mm in length, were used for the flexural tests. After casting, the samples were covered with a non-absorptive, non-reactive sheet of tough, durable impervious plastic for 24 hours, after which they were removed from the molds and cured in a fog room for 28 days. Three samples were used in each test to obtain the average values.

2.1.2 Test methods

The NUS constant head permeameter (Singapore Patent number 67286, 2001) was used to determine the permeability coefficient of the specimens. Porosity test was based on Archimedes principle and determined from the difference in weight between the oven-dry and water saturated submerged samples.

The Avery Denison compression and flexural machine was used to test the compressive and flexural strengths. The compressive strength test was done according to BS EN 12390-3: 2009 while the flexural strength test was done according to ASTM C78-10.

2.2 Clogging test

The clogging characteristics of steel fiber reinforced pervious concrete was studied by introducing clogging materials in stages and measuring the reduction in permeability coefficient. Residual soil and construction sand between 600 μm and 1.18 mm, which were most detrimental to clogging, were introduced into the samples by the flowing water in the NUS constant head permeameter. The amount of clogging material introduced was equivalent to 2000 g/m^2 for each stage, up to 10 cycles. Three samples were prepared and tested using the mixture proportion with small coarse aggregates, described in Section 2.1, and 5D steel fibers varying in volume fraction from 0 to 2.5%.

2.3 Sound absorption test

The acoustic absorption coefficient of pervious concrete (PC), steel fiber reinforced pervious concrete (PF) with 2% 5D fibers, and porous asphalt (PA) was measured using a Bruel&Kjaer (B&K) impedance tube for a frequency range from 100 to 2000 Hz following the ISO 10534-2: 2001 specification, using an extended plastic impedance tube. Measurements were carried out according to the standing wave method in which a pure tone signal is supplied to a loudspeaker to set up a sound wave in the tube. The wave is partially reflected from the sample at the end of the tube, and the interference between the incident and reflected waves gives rise to a standing wave pattern. By measuring the ratio between the maximum and minimum sound pressure, the absorption coefficient of the sample for zero degree incident sound can be calculated. Since the only absorbing material is the sample, the numerical figures obtained are very closely related to its sound absorbing properties. Amplifiers enable the absorption coefficient to be read off directly.

3. TEST RESULTS AND DISCUSSION

3.1 Physical and Mechanical Properties

Regardless of the use of small or large coarse aggregates in the mixes, inclusion of steel fibers resulted in increasing compressive and flexural strengths without compromising the permeability and porosity. No significant difference in permeability, porosity, and compressive and flexural strengths were observed between mixes reinforced with short or long 3D steel fibers. The use of 3D, 4D and 5D hooked end steel fibers however did not show significant differences in permeability and porosity. With increasing number of hooks at the ends of the steel fibers, the flexural and compressive strengths were found to increase due to further interlocking between the fibers and cement paste, up to fiber dosage up of 2.25%. Higher fiber content did not provide improvement in strengths, permeability and porosity, due to the balling effect and the uneven spread of the fibers.

Figure 2 shows the results of the mixes in terms of flexural strength and permeability. Regardless of the size of coarse aggregates and fiber type, the permeability in general decreased with increasing flexural strength. It is however noted that mixes with smaller coarse aggregates and steel fibers of multiple hook ends performed better than the others.

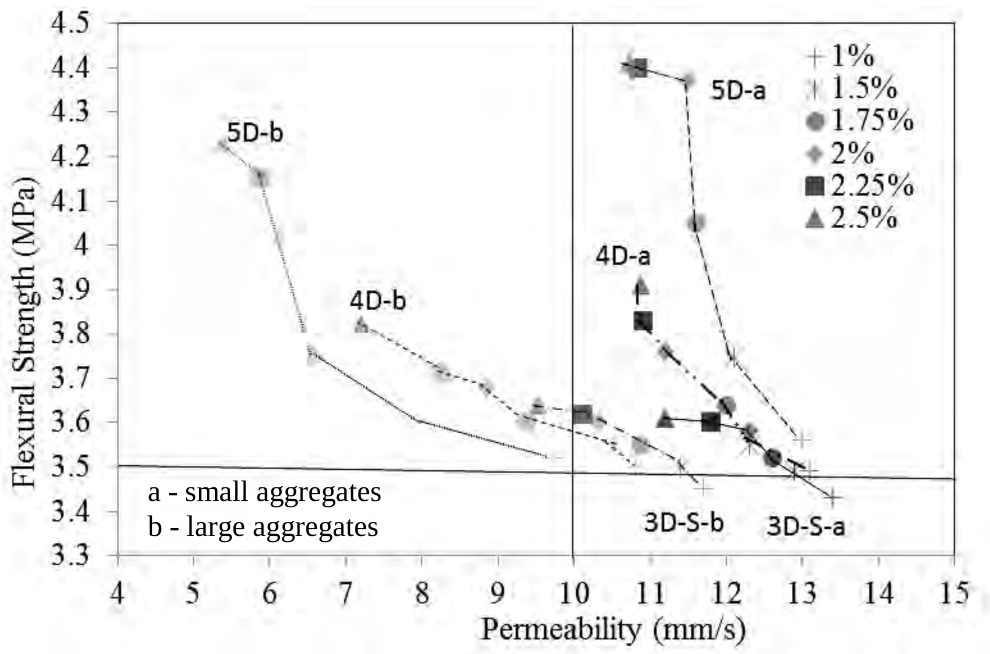


Figure 2: Flexural strength and permeability

The target permeability of 10 mm/s and flexural strength of 3.5 MPa, as recommended by AASHTO (2009) for road pavements, are also indicated in the figure. It is seen that mixes satisfying the target performance were those using small coarse aggregates with a dosage of at least 1.5% for 3D fibers and 1% for 4D and 5D fibers. For mixes using large coarse aggregates, the mixes meeting the targets had between 1.5 and 2.25% of 3D fibers, or between 1 and 1.5% of 4D fibers.

Figure 3 shows the results for the compressive strength and porosity. In general, the compressive strength decreased with increasing porosity of the mix. The target porosity is 20% and compressive strength is 12 MPa. These were achieved in mixes with small coarse aggregates having 3D or 4D fibers up to 2.25% or 5D fibers up to 2%. For mixes using large coarse aggregates, the target compressive strength and porosity were achieved if the fibre dosage is not more than 1.75%, 1.5% and 1%, respectively, for 3D, 4D and 5D fibers.

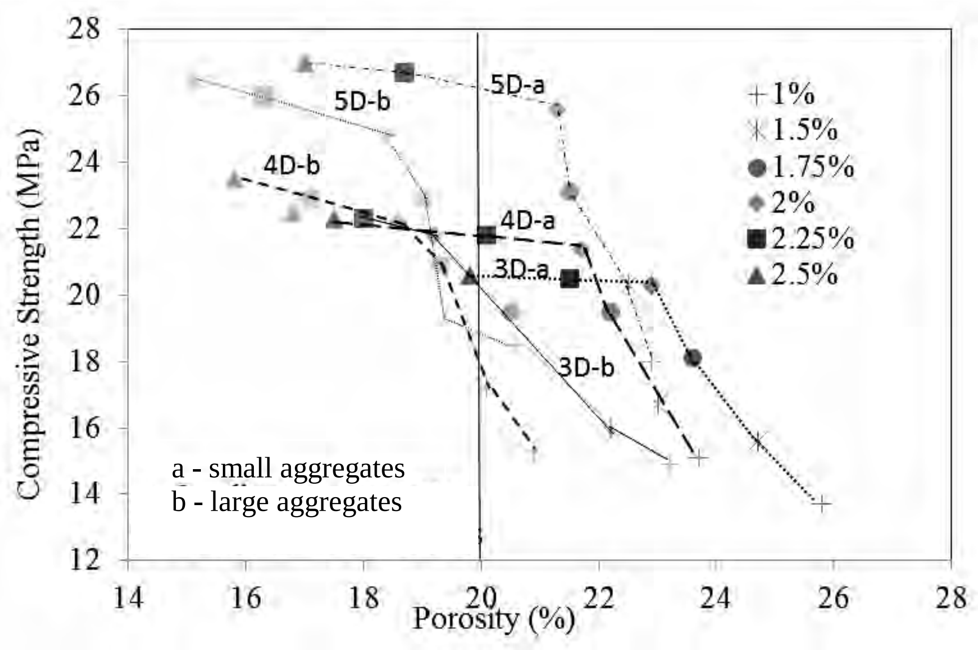


Figure 3: Compressive strength and porosity

From the above observations, the recommended fiber dosages to ensure adequate flexural strength and reasonable permeability and porosity for pavement use are summarized in Table 2. In general, a dosage of 1.5% appears to be the optimal.

Table 2: Recommended steel fiber dosages

Maximum size of coarse aggregates (mm)	3D Fibers	4D Fibers	5D Fibers
9.5	1.5 – 2.25%	1 – 2.25%	1 – 2 %
19.0	1.5 – 1.75%	1 – 2 %	Nil

3.2 Clogging characteristics

The reduction in permeability coefficient of steel fiber reinforced pervious concrete due to the introduction of clogging materials is shown in Figure 4. All mixes have porosity of around 20% (see Figure 3), that is, 23% with 1% fiber, and 17% with 2.5% fiber. The initial permeability coefficient was around 13 mm/s for Mix F1 (with 1% fiber) decreasing to 11 mm/s for Mix F2.5 (with 2.5% fiber), compared to about 15 mm/s for the pervious concrete mix PC20/F0 without steel fibers. For comparison, the results for a porous asphalt mix PA20 (Fwa et al., 2015) with a porosity of 20% and initial permeability of about 9 mm/s is also shown in Figure 4.

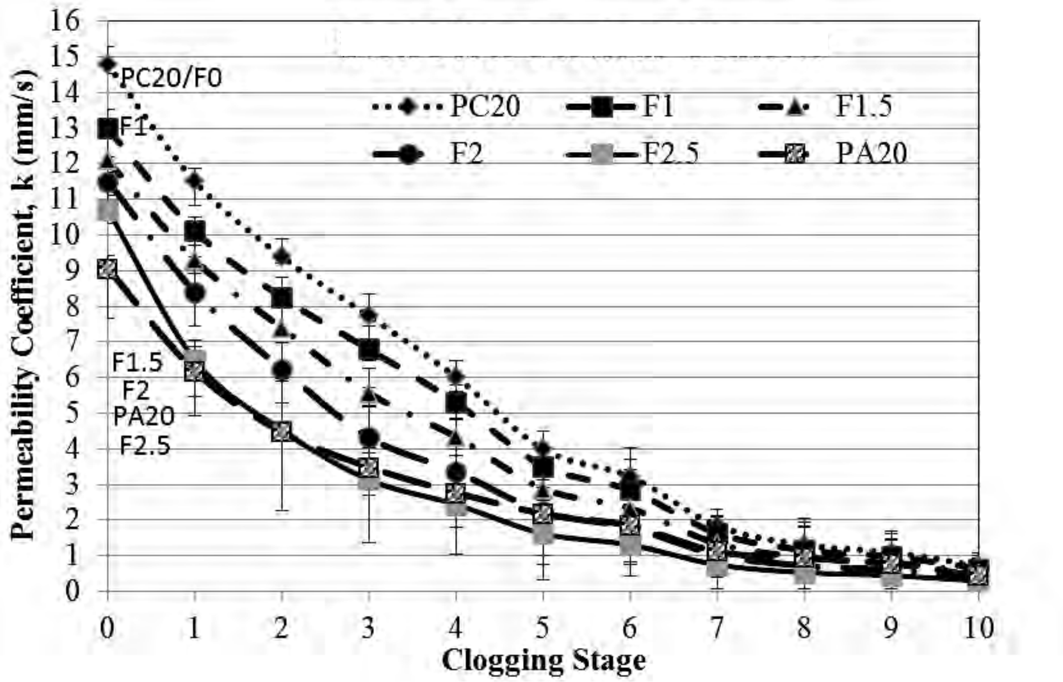


Figure 4: Clogging characteristics

The reduction in permeability coefficient was similar for mixes containing fibers up to about 2%. With higher steel fiber dosage, the reduction was higher especially in the initial few cycles. The permeability coefficient of previous concrete was higher than that of porous asphalt at all stages, especially where the steel fiber content was less than 2%, indicating that it is less susceptible to clogging. After 10 cycles of clogging, however, the permeability coefficient of all samples reduced to below 1 mm/s.

3.3 Sound absorption characteristics

Figure 5 shows the results of the sound absorption tests. The PC, PF and PA samples all had a porosity of about 20%. It is seen that the sound absorption of pervious concrete with or without fibers (that is, comparing Samples PC and PF) do not differ much, and are greater than that of porous asphalt (Sample PA). The peak sound absorption coefficient of pervious concrete occurring at a frequency of 800 Hz is of significance since most highway noise falls within the frequency range of 800 to 1200 Hz (Neithalath et al., 2005).

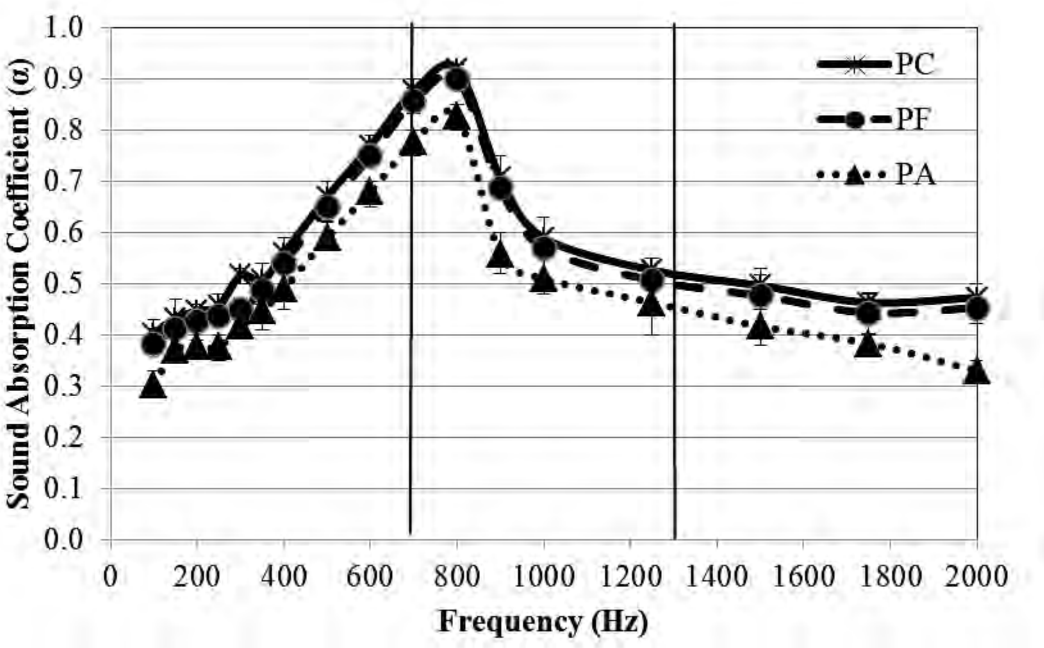


Figure 5: Sound absorption characteristics

4. CONCLUSION

The use of pervious concrete in urban road pavement would alleviate the problem of flash flooding due to heavy rain. This study investigated the use of discrete hooked-end steel fibers in enhancing the flexural strength of pervious concrete without compromising its permeability and porosity. The incorporation of 1.5% of steel fibers by volume of concrete was found adequate in achieving the target strength of 3.6 MPa and permeability and porosity of 10 mm/s and 20 percent, respectively.

Also, pervious concrete was less susceptible to clogging compared to porous asphalt with the same porosity, and that the incorporation of steel fibers up to about 2% did not affect the results. In addition, acoustic absorption measurements on samples indicated that steel fiber reinforced pervious concrete possessed superior sound absorption characteristics compared to porous asphalt.

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The Evaluation for the Structural Performance of Traditional Townhouses with Timber Through Columns in Japan

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ABSTRACT

This paper presents a study of the structural performance of traditional timber townhouses in a historic town in Japan. The aim of this study was to clarify the structural performance of traditional townhouse with timber through columns in Japan. The target area "Sawara" has many traditional timber townhouses built in from the late of 18th century to the early 20th century and these townhouses have few structural walls in the frontage direction at the first floor. In the previous study, the structural evaluation of the frame with through columns to verify the relationship of wall quantity at the 2nd floor. Moreover the earthquake response analysis of the townhouses were performed to clarify the seismic behavior. In this study, the earthquake response analysis were performed on the five townhouses in Sawara with through column or jointed column as parameter. As results, it was clarified that the structural performance of the through columns was greatly influenced by the wall quantity at each floor.

Keywords: traditional timber construction, seismic diagnosis, seismic analysis, parametric study

1. INTRODUCTION

1.1 Background of research

Japan has a long history of earthquakes and timber structures in Japan have suffered great damage caused by strong earthquakes. Old traditional timber structures suffered especially heavy damage. Besides, many of historical towns in japan have many traditional timber buildings that construction system and structural elements are same in each area. If the structural performance of their system and elements is clarified, the technique of earthquake-proofing suitable for those buildings can be examined. Therefor it is important to clarify structural performance of their elements in each historical area.

1.2 Characteristics of through column

In the previous study, the static tests and the seismic analysis of the frame with through columns were performed. The static tests were performed on the three type specimens that have the overall wall at the second floor. As the result of the test, the structural performance of the frame with through columns were verified (Sato, 2010 and 2012). The seismic analysis was performed on the mass system model with parameter study. In the case the townhouse has not the wall at the first floor, it was verified the relationship of the wall quantity at the 2nd floor (Sato, 2012).

2. OBJECT TOWNHOUSES

2.1 Sawara district and the target townhouses

The research area of the present study is the Sawara district of Chiba Prefecture, which is located near Tokyo. The Sawara district is a historical town arranged on the riverside and contains traditional timber townhouse and storehouse with thick walls. They are built in from the late of 18th century to the early 20th century (The Sawara City, 2004). In townhouses in this area, the frontage direction of the first floor has few walls and the frames which consist of through columns. In this study, five townhouses faced on the main street were targeted (Figure 1 and 2).

Figure 1: Facade of the target townhouses

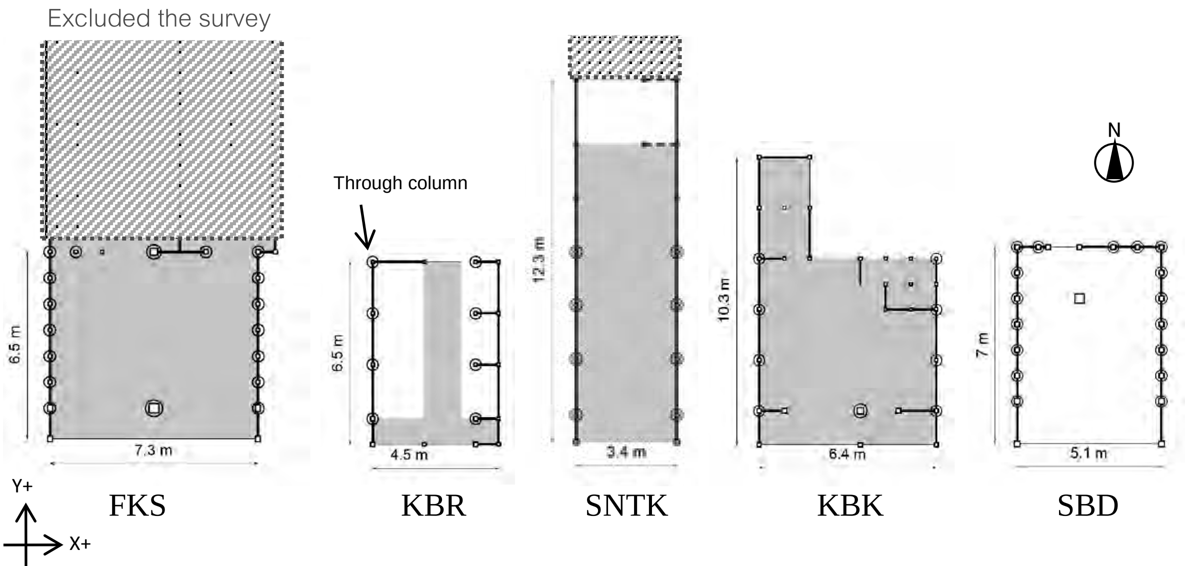


Figure 2: Plan on the first floor of objects

2.2 Seismic diagnosis

Seismic diagnosis was performed on the target townhouses based on the investigation (The Japan Building Disaster Prevention Association, 2004). The marks of the seismic diagnoses at the first floor varied from 0.03 to 0.20 in the X direction (Table 1). The mark calculated horizontal load-carrying capacity by necessary horizontal load-carrying capacity and if it was less than 1.0, the building have possibility of collapse by large earthquake in Japan Cord. The seismic diagnosis on five townhouses indicated 'high possibility of collapse' because these townhouses on the X direction of the first floor have few bearing walls.

Table 1: Characteristics of the object townhouses

name		**FKS**	**KBR**	**SNTK**	**KBK**	**SBD**
Construction year		1895	1892	unknown	unknown	1880
Building area (m^2) [Total floor area (m^2)]		47.5 [87.1]	28.7 [51.8]	41.4 [79.7]	49.1 [91.7]	35.5 [63.3]
Number of through columns		18	8	8	9	17
Size of through columns (cm)		12	11.5	12	14.5	16.5
Mark of seismic diagnosis*1,2	X	**0.06**	**0.07**	**0.03**	**0.20**	**0.10**
	Y	**0.36**	**0.16**	0.71	**0.40**	**0.51**

*1: at the first floor
*2: based on reference [5]; -1.5: Safe, 1.0-1.5: Temporarily Safe,
0.7-1.0: Possibility of Collapse, -0.7: Dangerous (High Possibility of Collapse)

3. EARTHQUAKE RESPONSE ANALYSIS

3.1 Model of analysis

To evaluate the structural performance, the five townhouses were modelled two type as three-dimensional frame model, as shown in figure 3. To clarify the influence of the through column on whole performance, the models of TC have through columns with the actual situation and the models of NTC consist without through columns as replacing through column with jointed column.

The horizontal load-resisting elements are mud walls and frames which consist of the through column and beam. The skeleton curves of the structural elements were shown in figure 4. The models of hysteresis characteristics were referenced (Architectural Institute of Japan, 2010). The roof truss was not modeled but just considered to the weight.

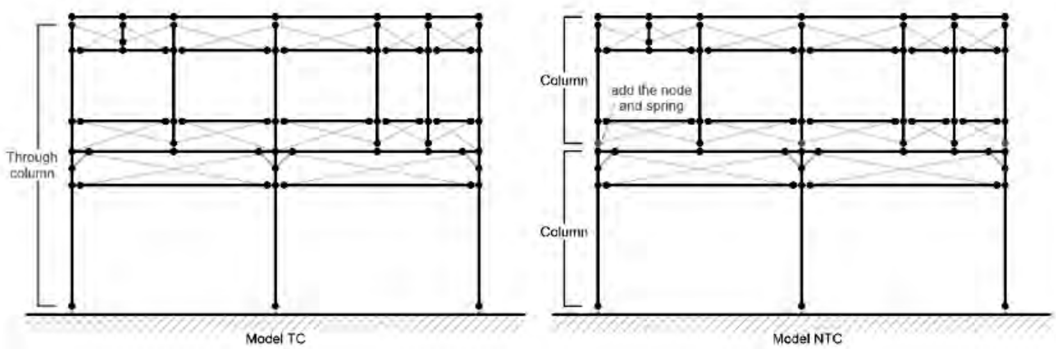
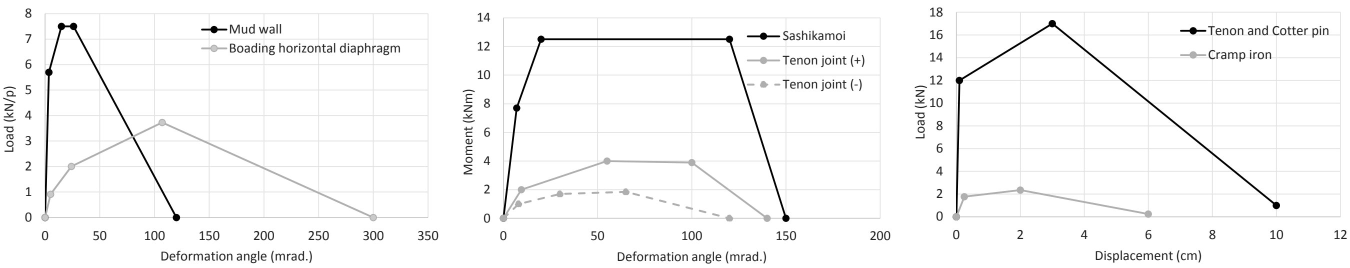


Figure 3: Analysis models (FKS)

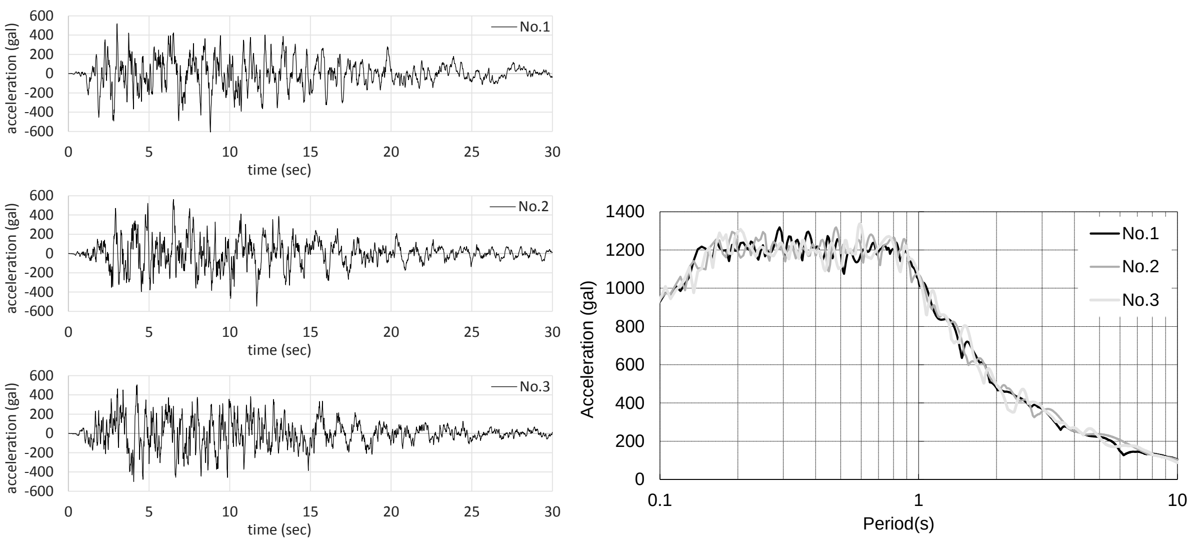


(1) mud wall and floor (2) beam-column joint (3) joint

Figure 4: Skelton curves of structural elements

3.2 Input wave

The input waves of the analysis were three simulated earthquake motions equivalent to design earthquake ground motion based on the Japanese Code, as shown in figure 5. The simulated waves were modulate to the standard level using coefficient 0.85 and the input scale was changed to determine the seismic clearance of them.
Moreover, to determine the limit of collapse, the input scale of the simulated waves were controlled.



(1) Time history waveform (2) acceleration response spectrum

Figure 5: Characteristics of the input waves

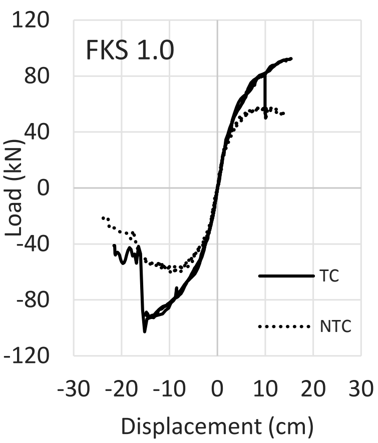
3.3 Results of analysis

The earthquake response analysis was performed on the five townhouses (Table 2 and Figure 6). In the results of the TC model, KBR and SNTK were collapsed by the large earthquake scale on equal with the Japanese Code, therefore they were not satisfied the structural requirement of the Japanese Code. The seismic shear coefficient (C_0) varied from 0.06 to 0.42. In the results of the NTC model, it was found that in the case of almost half, they were collapsed by the same earthquake scale of TC model. The seismic shear coefficient varied from 0.04 to 0.41. The structural performance of FKS and SBD became lower, however that of KBK was indicated almost the same.

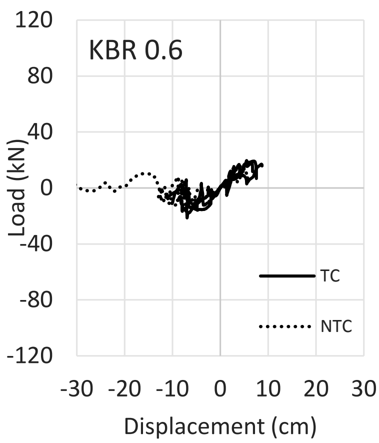
Table 2: Results of the analyses (X)

Type	Wave	Value of	FKS	KBR	SNTK	KBK	SBD
TC	Input scale		1.0	0.6	0.5	1.7	1.5
	No.1	Maximum load*1 (kN)	102.7	19.1	16.2	112.9	106.2
	No.2		92.5	21.5	15.8	111.3	111.0
	No.3		92.8	19.4	16.8	108.1	110.1
	Ave.		96	20	16.2	110.8	109.1
	C_0*2		0.30	0.18	0.06	0.42	0.35
NTC	Input scale		1.0	0.4	0.2	1.6	0.7
	No.1	Maximum load*3 (kN)	60.4	17.5	10.4	109.3	54.4
	No.2		57.2	14.8	9.8	108.0	54.1
	No.3		60.8	19.6	9.8	107.3	55.6
	Ave.		59.5	17.3	10	108.2	54.7
	C_0*2		0.19	0.15	0.04	0.41	0.18

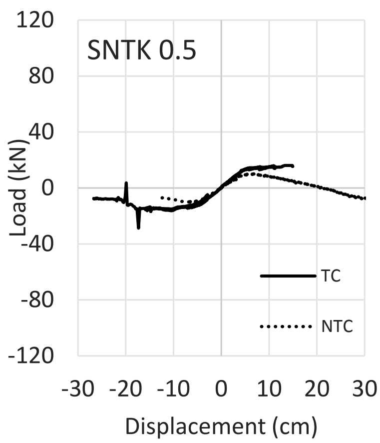
*1: at the first floor, the scale of the input wave is on the safety clearance
*2: the seismic shear coefficient, the maximum load divide by the weight of the building
*3: in the shaded parts, the maximum load were adopted before collapse



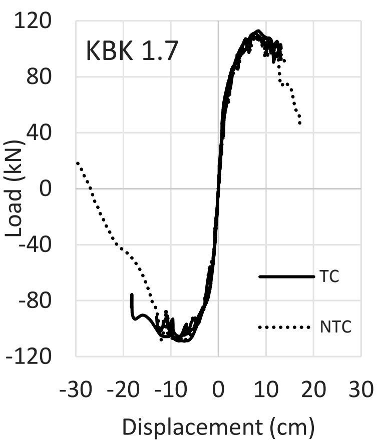
(1) FKS (input scale: 1.0)



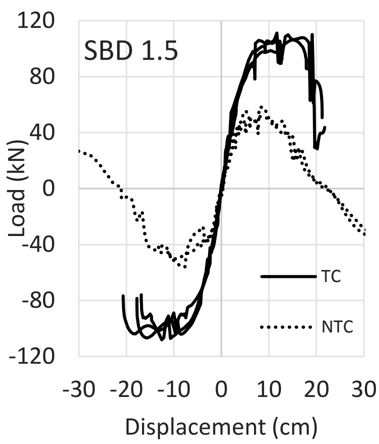
(2) KBR (input scale: 0.6)



(3) SNTK (input scale: 0.5)



(4) KBK (input scale: 1.7)



(5) SBD (input scale: 1.5)

Figure 6: Load - displacement relationship (1F-X)

3.4 Comparison with through column and jointed column

The results of the model with through column (TC model) are compared with that of the model without through column (NTC model), as shown in table 3. As the result of the TC model, FKS, KBK and SBD have enough structural performance. On the other hands, as the result of the NTC model, Only KBK have high structural performance. Moreover, the bearing load per one through column and the bearing load ratio were calculated from difference of the two models. In the case of FKS and SBD, they have high seismic coefficient in the TC model and the bearing load, because they have many or large size of through column. In the case of KBR and SNTK, they have few structural performance for lack of through column and other structural elements. However, in the case of KBK, though there were through columns of the fairly large size the bearing load of the through column was very small. It was indicated there are also other factors that determines the structural performance of through column in addition to the number and the size of column and the wall quantity at the second floor.

Table 3: Seismic Performances on the frontage direction (X)

			FKS	**KBR**	**SNTK**	**KBK**	**SBD**
Through column	Number		18	8	8	9	17
	Size (cm)		12	11.5	12	14.5	16.5
Total weight (kN)			319	114	259	265	309
Structural Performance	Seismic diagnosis*1		0.06	0.07	0.03	0.20	0.10
		Px-1F (kN)	4.4	3.4	2.2	13.8	6
		Px-2F (kN)	14.4	5.4	6.1	11.3	18.3
		Px-2F/1F	3.3	1.6	2.8	0.8	3.1
	C_0*2	TC	**0.30**	0.18	0.06	**0.42**	**0.35**
		NTC	0.19	0.15	0.04	**0.41**	0.18
	Bearing load*3 (kN)		**2.0**	0.3	0.8	0.3	**3.2**
	Load ratio*4 (%)		**38**	13.5	**38.3**	2.3	**49.9**

*1: Px is bearing capacity, *2: the seismic shear coefficient, refer to the Table 2
*3: the bearing load is the value per one through column. it was calculated from difference of two models
*4:bearing load ratio of the through column, (TC - NTC) / TC×100, refer to the Table 2

4. VERIFICATION OF THROGH COLUMN

Furthermore, to verify the other factor that determines the structural performance of through column, the structural analyses were performed on the new models changing the wall quantity. It was focused on the wall quantity at each floor and the relationship between them.

4.1 Model of analysis

In the results cited above, it was focused on the difference between KBK and FKS or SBD. The difference between KBK and other two townhouses were few number of through column and high performance at the first floor. Therefor the new model were made as changing the wall quantities at the first floor or the second floor, as shown in table 4.

Table 4: Parameter of the new models

name	FKS	KBK	
	+1F	+2F	-1F
Seismic diagnosis*	0.17	0.17	0.06
Px-1F (kN)	13.2	13.8	4.2
Px-2F (kN)	14.4	27.6	11.3
Px-2F/1F	1.1	2.3	2.7

*: Px is bearing capacity

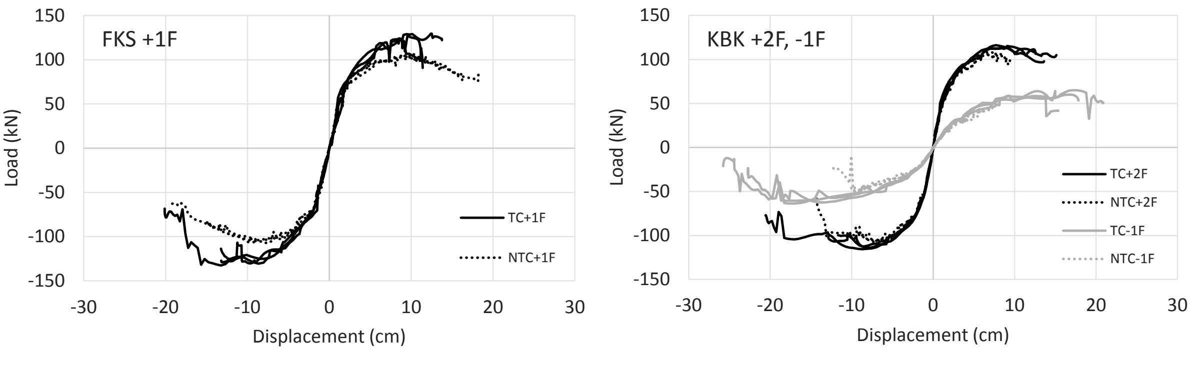
4.2 Results of factor analysis

As the results of new models, the bearing load per one through column were indicated from 0.8 to 1.5 (Table 5 and Figure 7). In the result of FKS, the structural performance of the whole townhouse, as the maximum load and the seismic coefficient, became larger but the performance of the through column, as bearing load, became decrease. In the result of KBK, when the wall quantities at the second floor was increased, the structural performance of the whole townhouse was the almost same and that of the through column improved slightly. Moreover, in the case of KBK decreasing the walls at the first floor, though the structural performance of the whole townhouse decreased too that of the through column improved.

Table 5: Result of the new models

name	FKS		KBK			
	+1F		+2F		-1F	
	TC	NTC	TC	NTC	TC	NTC
Maximum load (kN)	131.1	107.1	114.9	107.4	63.2	49.4
C_0*1	0.41	0.36	0.43	0.41	0.24	0.19
Bearing load*2 (kN)	1.3		0.8		1.5	
Load ratio*3 (%)	18.3		6.5		**21.7**	

*1: the seismic shear coefficient
*2: the bearing load is the value per one through column. it was calculated from difference of two models
*3:bearing load ratio of the through column, (TC - NTC) / TC×100



(1) FKS (2) KBK

Figure 7: Load - displacement relationship of new models (1F-X)

4.3 Factor on the structural performance of through column

The new models of FKS, KBK increasing the walls at the second floor and the original model of KBK have the enough wall quantity about the first floor. However their through columns were bearing small load. Meanwhile, in the new model of KBK decreasing the walls at the first floor, there were few structural performance, however the through columns were bearing much load. Thereby, it was indicated that the factors that determines the structural performance of through column are the excess of the walls at the first floor and the relationship the wall quantity between the each floor.

5. CONCLUSIONS

In this study, the earthquake response analyses were performed on the five traditional townhouses. It was presented the following conclusions:

1. As a result of the earthquake response analysis with actual situation (TC model), the seismic shear coefficient (C_0) varied from 0.06 to 0.42.
2. The bearing load ratio of the through column varied from 2.3 to 49.9 %. The bearing load per one through column varied from 0.3 to 3.2 kN.
3. In the seismic diagnosis based on the current building code, all of the five townhouses have high possibility of collapse. However, in the earthquake response analysis, three townhouses (FKS, KBK and SBD) have the structural performance which are needed in Japanese Code.
4. The factors that determines the structural performance of through column are the excess of the walls at the first floor and the relationship the wall quantity between the each floor.

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Detection of deteriorated region in soil structures using particle filter and elastic wave survey simulation based on FIT

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ABSTRACT

The detection of deteriorated areas in soil structures is carried out by applying a Particle Filter (PF) along with an elastic wave survey simulation based on Finite Integral Technology (FIT). Particle filtering is one of the sequential data assimilation methods employing a technique of ensemble approximation. It can repair and update certain parameters in numerical simulations by integrating observations in order to improve prediction accuracy. FIT, one of the discretization methods for wave propagation equations, is advantageous in that it provides simple definitions for the material parameters and boundary conditions, and it allows for parallel computing when explicit time integration is used. The target problem in this study is elastic wave propagation in a ground that includes a single circular cavity. A seismic source, placed at the center of the ground surface, generates an exciting force, and several receivers, corresponding to the observation points and set to the right and left of the seismic source, receive the velocities of the waves scattered by the cavity. Some receivers are placed only on the surface of the ground, while others are placed both on the surface of the ground and at the bottom. The velocities observed at all the receivers are assimilated into the computed velocities of the propagating waves by implementing the PF. This process identifies the position and the size of the cavity so as to minimize the difference between the observed and the computed velocities. The results show that the position and the radius of the cavity are not obtained simultaneously when the receivers are placed only on the surface; and thus, the receivers should be placed both on the surface and at the bottom in order to determine the position and the radius of the cavity.

Keywords: *cavity in soil structures, particle filter, elastic wave propagation, FIT*

1. INTRODUCTION

Infrastructures constructed from the 1950s to the 1970s have exceeded their lifespan in recent years; and thus, it is urgent that the continuous management of these structures be considered. In particular, soil structures consisting of materials with high levels of uncertainty that, over the years, have developed structurally weak areas, such as piping holes or cavities, must be examined. These weak areas may induce the collapse of rock-fill dams and sinkholes in the embankments. In past cases of collapsed rock-fill dams, reports have indicated that 46% of the collapses were caused by piping (Foster et al., 2000). Therefore, it is necessary to diagnose the deteriorated areas of soil structures and to maintain and manage them as safe structures against disasters such as heavy rain and earthquakes. Various methods, like sounding or geophysical exploration, are applied to structures as diagnosis methods, but it is still difficult to determine deteriorated areas correctly using just a single method. Thus, it becomes necessary to appropriately couple several methods in order to comprehensively assess the consequences and to improve the ability to both diagnose and detect deteriorated regions. We focus here on the Particle Filter (PF), which is one type of data assimilation, and perform a numerical computation to detect the deteriorated areas of soil structures.

Particle filtering is one of the sequential data assimilation methods. It employs an ensemble approximation technique, which can repair and update certain parameters in numerical simulations by integrating observations in order to improve predictions. Shuku et al. proposed a method for the detection of deteriorated areas in geotechnical structures by using PF and the simulation of ground settlements by a load-roller (Shuku et al., 2012). However, performing a survey with elastic waves is a more general method in practical testing. Therefore, the deteriorated areas of soil structures are detected by combining PF with an elastic wave survey simulation based on the Finite Integral Technique (FIT). FIT is one of the discretization methods for wave propagation equations. It can be computed with the same precision as BEM. The target problem here is elastic wave propagation in a ground that includes a single circular cavity. A deteriorated area in the ground is assumed to be a cavity and its spatial position and radius are to be identified by PF. Numerical experiments are carried out in this paper to verify the effectiveness of the detection of deteriorated areas in soil structures by combining PF with the elastic wave survey simulation based on FIT.

This paper is organized as follows: Section 2 provides the computational procedure for PF. Section 3 presents the formulation of FIT in a two-dimensional PSV wave field. Section 4 introduces the conditions for the simulation of the elastic wave propagation and the application of PF. Section 5 presents the results of the identification of the cavity, and a conclusion is given in the last section.

2. Particle Filter

In this section, we give an outline of the Particle Filter (PF) (Murakami, 2013). The following set of system equations is assumed:

$$x_t = F_t\left(x_{t-1}\right) + v_t \tag{2.1}$$

$$y_t = H_t\left(x_t\right) + w_t \tag{2.2}$$

Equation (2.1) is the state equation or the system model, while Equation (2.2) is the observation equation. x_t is the state vector, that includes the state of the system, and vector y_t is observation data. v_t is a system noise vector, while w_t is an observation noise vector. F_t denotes the state transition function. H_t is a matrix consisting of 0 or 1 when the observation and the state of a system have a linear relationship. PF employs an ensemble approximation technique in which the Probability Density Function (PDF) of the stochastic variables is approximated with its realization, called 'particles'. 'Particles' denote the parameters and the results of an analysis using these parameters. The filtered distribution at time $t = t-1$, $p(x_{t-1} \mid y_{1:t-1})$, for which $y_{1:t-1}$ denotes $\{y_1, y_2, \cdots, y_{t-1}\}$, is approximated with ensemble $\{x_{t-1|t-1}^{(1)}, x_{t-1|t-1}^{(2)}, \cdots, x_{t-1|t-1}^{(N)},\}$ by the following equation:

$$p(x_{t-1} \mid y_{1:t-1}) \approx \frac{1}{N}\sum_{i=1}^{N} \delta\left(x_{t-1} - x_{t-1|t-1}^{(i)}\right) \tag{2.3}$$

where the superscript (i) of $x_{t-1:t-1}^{(i)}$ is the number of particles and N is the total number of particles in the ensemble. To the left of the subscript, $t-1|t-1$ of $x_{t-1:t-1}^{(i)}$ denotes the current time, while to the right, it denotes the last time of the used observation. δ is Dirac's delta function. Predicted distribution $p(x_t \mid y_{1:t-1})$, at time $t = t$, can be obtained from the filtered ensemble seen in Equation (2.3):

$$p(x_t \mid y_{1:t-1}) \approx \frac{1}{N}\sum_{i=1}^{N} \delta\left(x_t - x_{t|t-1}^{(i)}\right) \tag{2.4}$$

Filtered distribution $p(x_t \mid y_{1:t})$, at time $t = t$, can be obtained with Equation (2.4) and Bayes' theorem, namely,

$$\begin{aligned} p(x_t \mid y_{1:t}) &= \frac{p(x_t \mid y_{1:t-1}) p(y_t \mid x_t)}{\int p(x_t \mid y_{1:t-1}) p(y_t \mid x_t) dx_t} \\ &\approx \frac{1}{\sum_j p\left(x_t \mid x_{t|t-1}^{(j)}\right)} \sum_{i=1}^{N} p\left(y_t \mid x_{t|t-1}^{(i)}\right) \delta\left(x_t - x_{t|t-1}^{(i)}\right) \\ &= \sum_{i=1}^{N} w_i \delta\left(x_t - x_{t|t-1}^{(i)}\right) \end{aligned} \tag{2.5}$$

$$w_i = \frac{p\left(y_t \mid x_{t|t-1}^{(i)}\right)}{\sum_j p\left(y_t \mid x_{t|t-1}^{(j)}\right)} \tag{2.6}$$

where $p\left(y_t \mid x_{t|t-1}^{(i)}\right)$ denotes the likelihood of $x_{t|t-1}^{(i)}$ obtained from observation y_t and weight w_i. Equation (2.5) shows that $p(x_t \mid y_{1:t})$ is approximated with the ensemble weighted by w_i. As the observation model, when the observation noise follows the Gaussian distribution, the likelihood of $x_{t|t-1}^{(i)}$ is computed by the following equation:

$$p\left(y_t \mid x_{t|t-1}^{(i)}\right) = \frac{1}{\sqrt{(2m)^m}|R_t|} \exp\left[-\frac{\left(y_t - H\left(x_{t|t-1}^{(i)}\right)\right)^T R_t^{-1}\left(y_t - H\left(x_{t|t-1}^{(i)}\right)\right)}{2}\right] \tag{2.7}$$

where R_t is the co-variance matrix. In the process of PF, the time step of $x_t^{(i)}$ is advanced by Equation (2.1), and predicted distribution $p(x_t \mid y_{1:t-1})$ and filtered distribution $p(x_t \mid y_{1:t})$ can be obtained by updating the weight from Equation (2.7) and the observation. Figure 1 shows the computational procedure for PF.

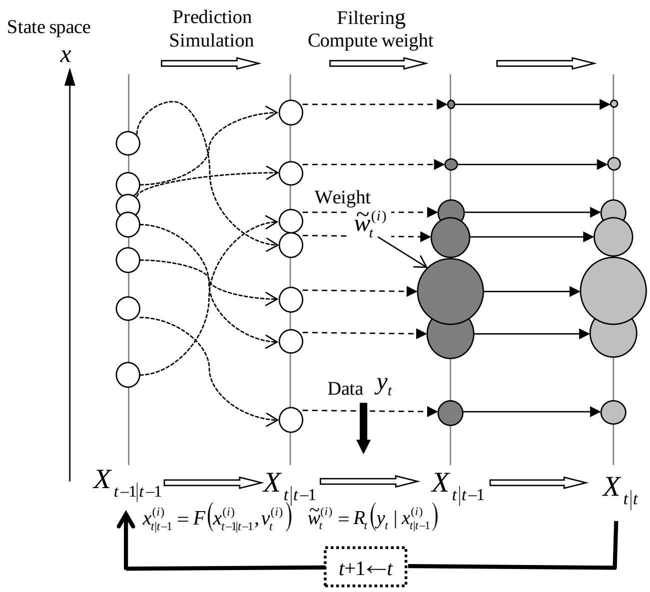

Figure 1: Computational procedure for particle filter

3. Finite Integral Technique

In this section, we give an outline of the two-dimensional PSV elastic wave survey simulation based on the Finite Integral Technique (FIT) (Nakahata, 2014). The target areas are assumed to be linear elastic fields that satisfy small-deformation. The Cartesian coordinates (x_1, x_2) are considered. The governing equations of the elastic wave are the constitutive law and the Cauchy equation of motion. These equations are given in integral form for a finite volume V with surface S by

$$\int_V \frac{\partial \tau_{ij}(\mathbf{x},t)}{\partial t} dV = \int_S c_{ijkl}(\mathbf{x}) v_i(\mathbf{x},t) n_j(\mathbf{x}) dS \tag{3.1}$$

$$\int_V \rho(\mathbf{x}) \frac{\partial v_i(\mathbf{x},t)}{\partial t} dV = \int_S \tau_{ij}(\mathbf{x},t) n_j(\mathbf{x}) dS + \int_V f_i(\mathbf{x},t) dV \tag{3.2}$$

where v_i is the particle velocity vector, τ_{ij} is the stress tensor of the second rank, ρ is the mass density, n_j is the outward normal vector on surface S, and f_i is the body force vector. In Equation (3.2), c_{ijkl} is the stiffness tensor of rank four. In the case of isotropic materials, c_{ijkl} can be written as

$$c_{ijkl} = \lambda \delta_{ij} \delta_{kl} + \mu(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) \tag{3.3}$$

in terms of the two Lamé constants, λ and μ. In Equation (3.3), δ is Kronecker’s delta tensor, and the summation convention is used. The pressure (P) and shear vertical wave velocities (S) are given as follows:

$$c_p = \sqrt{\frac{\lambda + 2\mu}{\rho}}, \quad c_s = \sqrt{\frac{\mu}{\rho}}. \tag{3.4}$$

The staggered spatial grid shown in Figure 2, having square cells, is used for the discretization of Equations (3.1) and (3.2). The material constants, the mass density and the two Lamé constants are defined in the τ_{ii}-integration volume (Figure 3(a)).

Assuming that τ_{11} is constant in V, the discretization of pressure stress τ_{11} is given as follows:

$$\dot{\tau}_{11} = \frac{1}{\Delta x}\left\{(\lambda + 2\mu)\left[v_1^{(R)} - v_1^{(L)}\right] + \lambda\left[v_2^{(U)} - v_2^{(D)}\right]\right\} \tag{3.5}$$

where $\dot{\tau}_{11} = \partial\tau_{11}/\partial t$ and Δx is the length of a side in V. In Equation (3.5), the superscripts denote the positions of the physical quantities of the integral volume, as shown in Figure 3(a). The discretization of shear stress τ_{12} in Equation (3.1) is given as follows:

$$\dot{\tau}_{12} = \frac{\bar{\mu}}{\Delta x}\left[v_2^{(R)} - v_2^{(L)} + v_1^{(U)} - v_1^{(D)}\right] \tag{3.6}$$

where $\bar{\mu}$ is given by

$$\bar{\mu} = \frac{4}{\left[\frac{1}{\mu^{(U,R)}} + \frac{1}{\mu^{(D,R)}} + \frac{1}{\mu^{(U,L)}} + \frac{1}{\mu^{(D,L)}}\right]} \tag{3.7}$$

since μ is given in the τ_{ii}-integration volume, as shown in Figure 3(b).
Similarly, the discretization of Equation (3.2) yields

$$\dot{v}_1 = \frac{1}{\bar{\rho}_1 \cdot \Delta x}\left[\tau_{11}^{(R)} - \tau_{11}^{(L)} + \tau_{12}^{(U)} - \tau_{12}^{(D)}\right] \tag{3.8}$$

where we let $f_i = 0$. Since density ρ is given in the τ_{11}-integration volume, as shown in Figure 3(c), the average value $\bar{\rho} = \left(\rho^{(R)} + \rho^{(L)}\right)/2$ is used in the integration of v_1 in Equation (3.8). A similar formulation is adopted for the other quantities, τ_{22} and v_2.
For the time discretization, stress components $\boldsymbol{\tau}$ are allocated at half-time steps, while velocities $\boldsymbol{v}$ are allocated at full-time steps. The following time discretization yields an explicit leap-flog scheme:

$$\{\tau_{ij}\}^{z+\frac{1}{2}} = \{\tau_{ij}\}^{z-\frac{1}{2}} + \Delta t\{\dot{\tau}_{ij}\}^{z}, \quad \{v_i\}^{z} = \{v_i\}^{z-1} + \Delta t\{\dot{v}_i\}^{z-\frac{1}{2}} \tag{3.9}$$

where Δt is the time interval and superscript z denotes the integer number of the time step. FIT repeats the operations in Equation (3.9) from $z = 1$ to N under suitable initial and boundary conditions. A specific stability condition (the Courant-Friedrichs-Lewy (CFL) condition) and adequate spatial resolutions are required to calculate the FIT accurately.

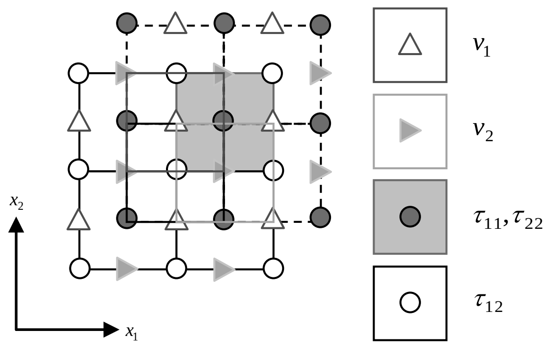

Figure 2: Staggered grid for FIT.

On the free reflecting boundary, the surface traction is defined as $T_i = \tau_{ij} n_j = 0$. On the boundary between the solid and the liquid, the particle velocity and the pressure stress should be continuous and the shear stress should be zero.

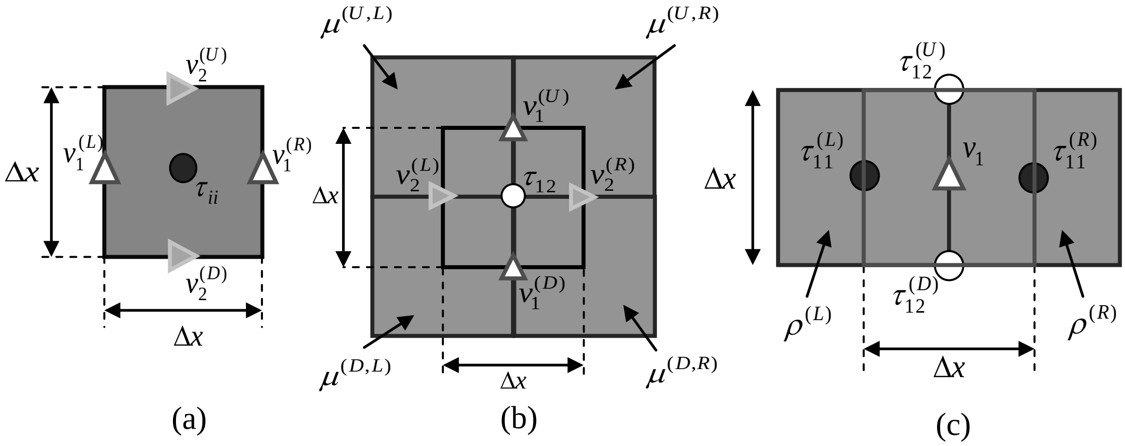

Figure 3: τ_{ii}-integration volume (a), v_1-integration volume (b) and τ_{12}-integration volume(c).
All material parameters are defined in the τ_{ii}-integration volume.

4. Setting of numerical analysis

The target area of the ground, shown in Figure 4, is assumed to be linearly elastic and to include a single circular cavity. The material constants of the ground are the mass density, ρ = 2.6×10^3 kg/m^3, the P wave velocity, c_P = 2.50 km/s, and the S wave velocity, c_S = 1.44 km/s. A seismic source placed at the center of the ground surface generates an exciting force, and this has the function of a receiver. In addition, two receivers are placed at 18-mm intervals to the right of the seismic source and two more are placed to the left of the source. Finally, five receivers are placed on the bottom of the target area at 18-mm intervals. These ten receivers correspond to the observation points and receive horizontal velocities. A Perfectly Meshed Layer (PML) (Francis, 1998) is installed on both sides of the target area in order to express the transmission of the elastic wave to the outside of the target area. The bottom of the target area is the free reflecting boundary.
The special position (*x*: horizontal direction and *y*: vertical direction) and the radius *r* of the circular cavity in the ground are parameters to be identified. Particles $X^{(i)} = \left(x^{(i)}, y^{(i)}, r^{(i)}\right)$ are generated according to the uniform random numbers in the ranges shown in Table 1. The deteriorated areas are detected by computing the filtered distribution from the sequential observation. The identified parameter, $\overline{X}_t$, is obtained as follows:

$$\overline{X}_t = \sum_{i=1}^{N} w_t^{(i)} X_t^{(i)} \tag{4.1}$$

where $w_t^{(i)}$ is the weight of each particle, which has been defined in Equation (2.6).
Three cases are conducted, as shown in Table 1. In Case 1, the radius of the cavity is

constant at $r = 5.0$ mm, and the five receivers at the ground surface are used. In Cases 2 and 3, the position and the radius of the cavity are to be identified. In Case 2, the five receivers at the ground surface are used, while in Case 3, all ten receivers are used. The number of generated particles is 128 in Case 1 and 200 in Cases 2 and 3.

For the numerical experiment, a cavity is prepared in the target area for each case (Case 1: x = 47.52 mm, y = 16.60 mm, and r = 5.00 mm; Cases 2 and 3: x = 54.34 mm, y = 21.46 mm, and r = 7.87 mm). The wave velocity obtained in each case is regarded as the observation data.

Table 1: Range in each parameter for particle generation

Parameters	Range in particle generation
x [mm]	45.0~55.0
y [mm]	55.0~65.0
r [mm]	6.0~8.0

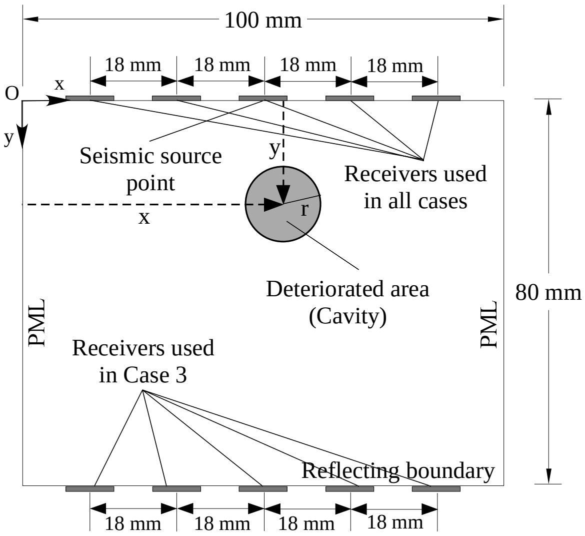

Figure 4: Target area and receiver arrangement

Table 2: Cases of numerical computation

Case	Parameters to be identified	Number and position of observation points	Number of particles
1	Center of identification circle	5 at ground surface	128
2	Center of identification circle and radius	5 at ground surface	200
3	Center of identification circle and radius	5 at ground surface and 5 at bottom	200

5. RESULTS

The identified circular cavity in Case 1 is shown in Figure 5(a). The gray circle is the true cavity (x=47.52 mm and y=16.60 mm) and the circle formed by the solid line is the identified cavity ($x = 47.33$ mm and $y = 16.56$ mm). The assumed deteriorated area is accurately detected. Figure 5(b) shows the results of Cases 2 and 3. The gray circle is the true cavity (x = 54.34 mm, y = 21.46 mm, and r = 7.87 mm), the full-line circle is the identified cavity of Case 2 (x = 54.53 mm, y = 19.94 mm, and r = 6.67 mm) and the dotted-line circle is the identified cavity of Case 3 (x = 54.18 mm, y = 21.32 mm, and r = 7.88 mm). The position and the radius of the cavity are not indicated simultaneously when receivers are placed only on the surface of the ground, but they are indicated accurately when receivers are placed both on the surface and at the bottom. Since the receivers collect only the scattered waves from the upper surface of the cavity, the parameters are not identified accurately in Case 2. Accordingly, another numerical analysis, assuming that the cavity is filled with water, is carried out in Case 4. Since the elastic waves are divided into transmit waves and scattered waves at the boundary between the different kinds of materials, the probes can also receive scattered waves from the lower surface of the deteriorated area. In Case 4, the five receivers on the surface of the ground are used, and the position and the radius of the cavity are identified using 200 particles. The circle of the identified cavity for Case 4, shown in Figure 5(c) and indicated by the broken-line circle (x = 54.70 mm, y = 22.06 mm, and r = 7.23 mm), is a better result than that for Case 2, shown in Figure 5(b), and can identify the lower surface of the cavity.

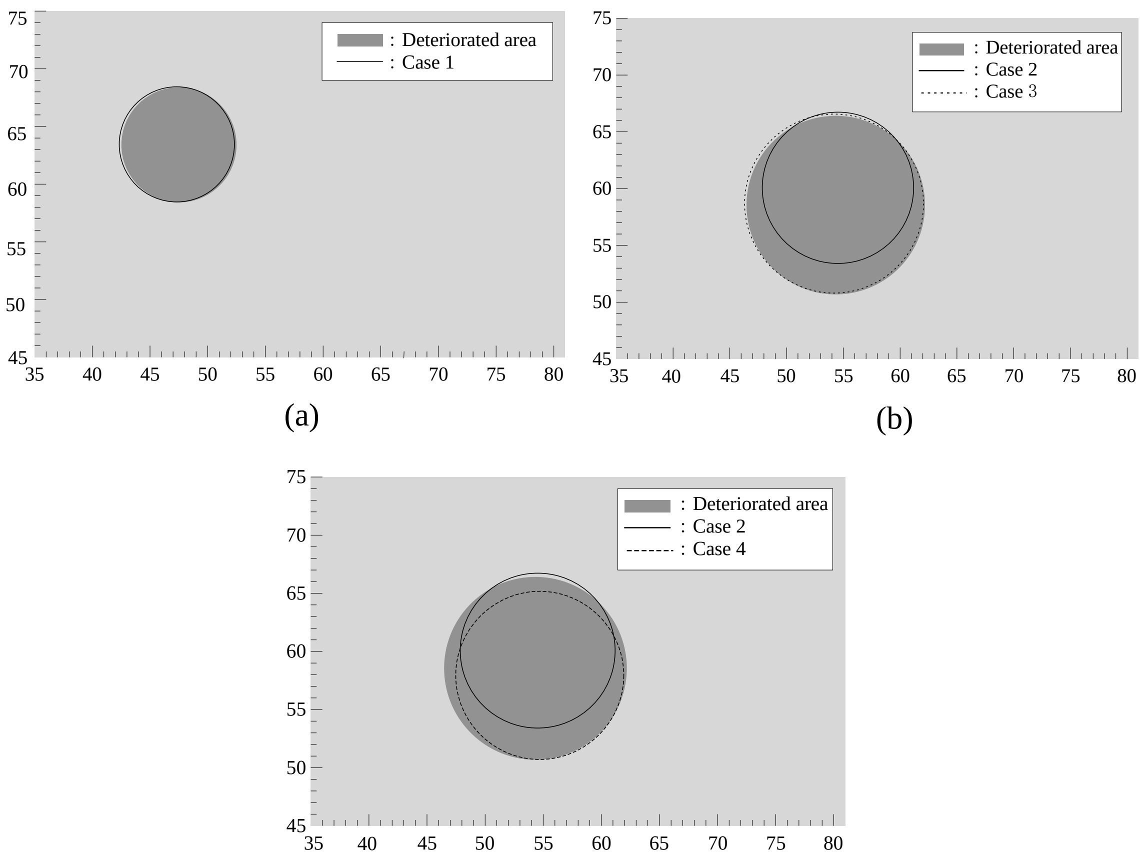

Figure 5: Deteriorated area and identified circular cavity of Case 1 (a), Case 2 and Case 3 (b) and Case 4(c)

6. CONCLUSION

The position and the radius of the cavity are not identified simultaneously when the receivers are placed only on the surface of the ground, and thus, the receivers should be placed both on the surface and at the bottom in order to determine the radius as well as the position. However, in this approach, only a single circular cavity can be detected. The actual cavity in soil structures has a more complicated shape and several cavities may exist in the same vicinity. The next goal is to propose a novel method to detect several complicated cavities using PF.

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A proposal on the simplified structural evaluation method for existing reinforced concrete buildings in Bangladesh

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ABSTRACT

In the 1995 Hyogoken Nanbu (Kobe) Earthquake of Japan, a large number of buildings, which were designed by the old Japanese seismic code, suffered severe damage. Based on this lesson, the Japanese government has encouraged promoting of the seismic evaluation and retrofitting work for existing buildings, especially constructed before the latest code of 1981. After 1995, several big earthquakes occurred in Japan but these retrofitted buildings survived safely. Now buildings all over Japan are becoming better seismic resistant and remarkably decreasing damage even to higher level hazard by earthquakes. On the other hand, the developing countries in the earthquake prone regions in the world are still suffering a lot of casualties as well as building damage. These damages might be caused by inadequate structural design by engineers and/or poor quality control of construction works. In order to contribute to disaster mitigation for existing reinforced concrete buildings in developing countries, the simplified structural evaluation method based on the philosophy of Japanese evaluation standard vis-a-vis the international seismic code was developed by Seki (2015). In this paper, the developed simplified evaluation method is introduced and structural evaluation of existing reinforced concrete buildings of readymade garment factories in Bangladesh is performed using it.

Keywords: structural evaluation, reinforced concrete, existing building, seismic capacity, service load capacity

1. INTRODUCTION

Many of countries in the world, especially the developing countries which usually suffer severe damage by reason of poor quality buildings, are yet on the way to the goal of achievement for disaster mitigation for the strong earthquakes. Generally these countries tend not to have the seismic evaluation provision and retrofitting technology in their national seismic code and/or other related regulations.

The developed simplified structural evaluation method can be utilized as the first stage screening of the structural capacity, especially, for the lots of vulnerable buildings in the developing countries which induced the international seismic code for their own

building national code. In this paper, a case study applying to Bangladesh using the data from readymade garment factories project by JICA is discussed.
Table 1 shows the three kinds of structural evaluation such as simplified structural evaluation (SE), advanced simplified structural evaluation (ASE) and detail seismic evaluation (DE). This paper's evaluation method (SE) can be useful for the first stage screening for lots of buildings as above mentioned.

Table 1 Structural evaluation procedure for existing reinforced concrete buildings

Title	SE	ASE	DE
Evaluation Method	Simplified structural evaluation	Advanced simplified structural evaluation	Detail seismic evaluation
Objective	Average ultimate capacity for lots of buildings (Screening)	Between SE and DE (Screening)	Accurate ultimate capacity for individual building
Resource data	Structural drawing	Structural drawing & brief site investigation (Non-destructive tests)	Structural drawing & detail site investigation (destructive tests)

2. BASIC PRINCIPLE FOR EVALUATION

The flow diagram of the proposed simplified structural evaluation is shown Figure 1. In this figure, various index for Bangladesh such as seismic index (I_{BS}), Judgement seismic index (I_{BS0}), service load index (I_{BD}) and judgement service load index (I_{BD0}) are used in this figure.
The proposed simplified structural evaluation method is based on the following basic principles and the detail content of evaluation method can be referred in Seki(2015).

(i) Seismic evaluation is basically based on the philosophy of the Japanese Seismic Evaluation Standard for existing reinforced concrete buildings issued by JBDPA2001 and IBC2000.

(ii) The target building is the reinforced concrete moment resisting (beam-column) frame building.

(iii) Evaluation is done by only original structural drawings and architectural drawing. This evaluation is performed on the condition that the building was constructed faithfully due to the approved original drawings.

(iv) Evaluation is basically performed at the ground floor (level-1) which may be usually the weakest floor of the whole building floors.

(v) If the necessary information such as material strength, profile of rebar is lack in the structural drawings, these may be assumed with construction year and/or the experience of engineer, etc.

(vi) As for the final judgment after simplified structural evaluation, the vulnerability evaluation on two items; (1) seismic capacity by horizontal seismic load, (2) service load capacity by vertical service load is carried out. Final structural rank based on combination of seismic capacity and service load capacity can be obtained. If the evaluation result doesn't satisfy the target capacity values, the detail evaluation method will be recommended.

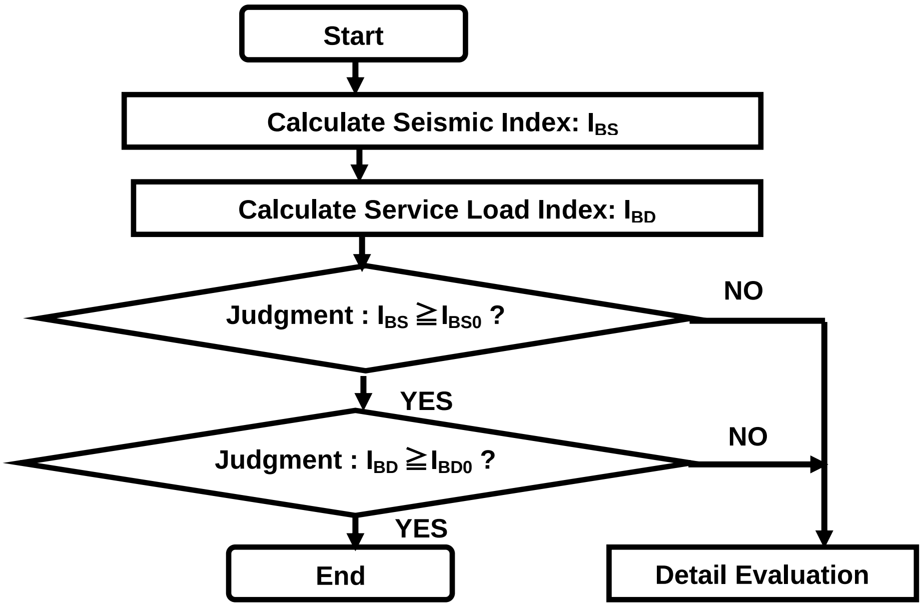

Figure 1 Flow diagram of simplified structural evaluation for the existing reinforced concrete buildings in Bangladesh

3. EVALUATION METHOD

3.1 Seismic Index (I_{BS})

$$I_{BS}=E_{BS} * S_D * T \quad (1)$$

Where,

E_{BS} : Basic Structural Index

$$E_{BS}=C_{BS} * F_B \quad (2)$$

C_{BS} : Strength Capacity of Building

$$C_{BS} = \tau * \Sigma Ac/W \quad (3)$$

τ : Average shear strength of Column (N/mm^2, JBDPA 2001)

$h_0/D > 6$: τ=0.7 N/mm^2 (4)

$h_0/D \leqq 6$: τ=1.0 N/mm^2

h_0: Clear height of column (mm)

D: Depth of column section (mm)

ΣAc : Total area of columns (mm^2)

W: Total weight of building (N)

F_B : Ductility Index

$$F_B = R/\Omega_0 \quad (5)$$

R: Response modification factor based on structure type in BNBC2015 Final Draft

Ω_0: Over strength factor (FEMA450-2.2003 &IBC2000)

S_D : Irregularity Index (here, S_D=1.0)

T : Time deterioration Index (here, T=1.0)

3.2 Service Load Index (I_{BD})

$$I_{BD} = W/\Sigma Ac \tag{6}$$

Where,
W: Total weight of building (N)
ΣA : Total area of columns (mm^2)

4. JUDGMENT

4.1 Definition of Judgment Index

4.1.1 I_{BSO}: Seismic Index

$$I_{BSO} = V \tag{7}$$

V: Total design base shear coefficient (BNBC2015 Final Draft)

$$V=2/3 * Z * I * C_S \tag{8}$$

Where,
Z: Seismic zone coefficient (Table 2, Figure 2)
I : Structural importance coefficient (here, I=1.0)
C_S: Normalized acceleration response spectrum, which is a function of structure (building) period and soil type (site class) (Figure 3)

Figure 2 Seismic zoning map of Bangladesh (BNBC 2015 Final Draft)

Table 2 Seismic zone coefficients, Z (BNBC2015 Final Draft)

Zone	Zone Coefficient (unit: g)
1	0.12
2	0.20
3	0.28
4	0.36

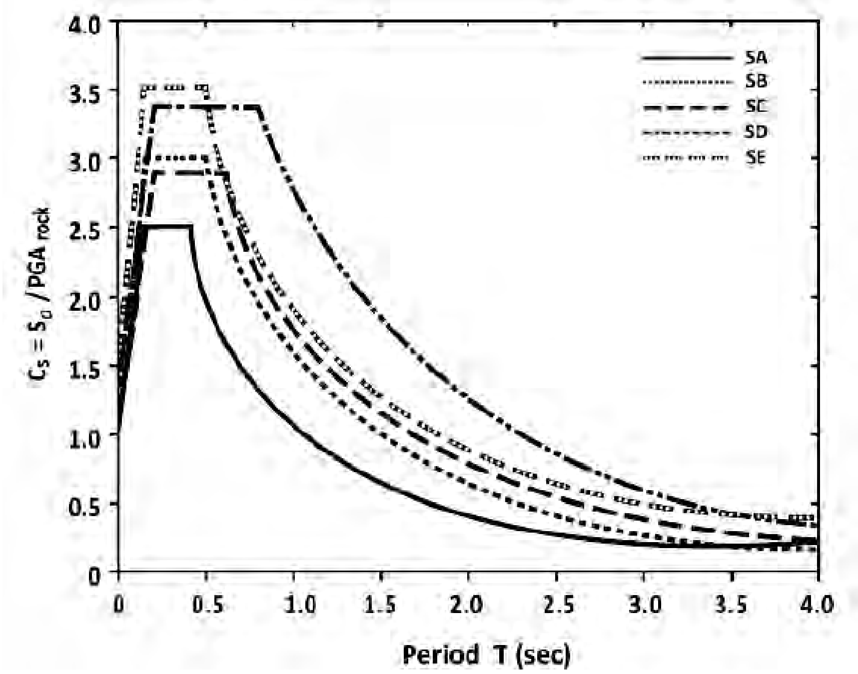

Figure 3 Normalized design acceleration response spectrum for different site classes (BNBC2015 Final Draft)

4.1.2 I_{BD0}: Service Load Index

$I_{BD01} = 0.4 * Fc$ (9)

$I_{BD02} = 0.7 * Fc$

Where,

Fc: Designed concrete strength (N/mm^2)

4.2 Judgment

4.2.1 Seismic Capacity

$I_{BS} \geqq I_{BSO}$: Higher than seismic demand (Rank SA) (10)

$0.5I_{BSO} \leqq I_{BS} < I_{BSO}$: Lower than seismic demand (Rank SB)

$I_{BS} < 0.5I_{BSO}$: Remarkably lower than seismic demand (Rank SC)

4.2.2 Service Load Capacity

$I_{BD} < I_{BD01}$: Higher than service load demand (Rank DA) (11)

$I_{BD01} \leqq I_{BD} \leqq I_{BD0}$: Lower than service load demand (Rank DB)

$I_{BD02} < I_{BD}$: Remarkably lower than service load demand (Rank DC)

4.2.3 Final Rank based on Combination of Seismic Capacity and Service Load Capacity

Final structural rank based on combination of seismic capacity and service load capacity can be defined as following Table 3.

Table 3 Final capacity rank of simplified structural evaluation

Final Capacity Rank	Combination		Recommendation
	Seismic Capacity	Service Load Capacity	
A	SA	DA	Safe
B	SB	DA, DB	Detail Evaluation Recommended
C	SC	DA, DB, DC	Immediately Detail Evaluation Recommended

5. EXAMPLE OF STRUCTURAL EVALUATION IN BANGLADESH

5.1 Target buildings and method of structural evaluation

Target buildings for structural evaluation are reinforced concrete moment resisting buildings of readymade garment factories in Dhaka city, Bangladesh by JICA project. Total number of buildings is fifty one. For decision of ductility index; F_B, response modification factor; R is 5 defined as ordinary moment resisting frame in BNBC1993 and over strength factor; Ω_0 is 2.0 in FEMA450-2.2003 because this value is not defined in BNBC1993. If the information from structural and architectural drawings is deficient in evaluation, the following assumption was done; if there is no description on aggregate, concrete strength; Fc= 17 Mpa, and if there is, for stone chip Fc=21 Mpa, for masonry chip Fc=17 Mpa. Story height is 3600 mm for ground floor and 3000 mm for other floor. Story average unit weight is 7 KN/m^2 for top floor and 10 KN/m^2 for other floor, etc.

5.2 Results of structural evaluation

(1) I_{BS}-I_{BSO} Relationship (Figure 4); Two dashed lines, I_{BS}=I_{BSO} and I_{BS}=0.5*I_{BSO}, are shown. The buildings with I_{BS} above the I_{BSO}, which satisfy the target earthquake resistance, represent approximately 25% of all the buildings.
(2)I_{BD}-I_{BD01} Relationship (Figure 5); One dashed line, I_{BD}=I_{BD01} is shown. The buildings with I_{BD} above the I_{BD01}, which don’t satisfy the target service load resistance, represent approximately 35% of all the buildings.
(3)I_{BS}/I_{BS0}-I_{BD}/I_{BD01}, I_{BD}/I_{BD02} relationship (Figure 6); This figure shows the earthquake resistance index and the service load index. Approximately 20% of the buildings are higher in both indices; I_{BS0} and I_{BD01}. Namely 75% of buildings are recommended to perform the detail seismic evaluation. Approximately 35% of buildings are above I_{BD01} and two buildings above I_{BD02}. These buildings show the remarkably low vulnerability in vertical resistant capacity.

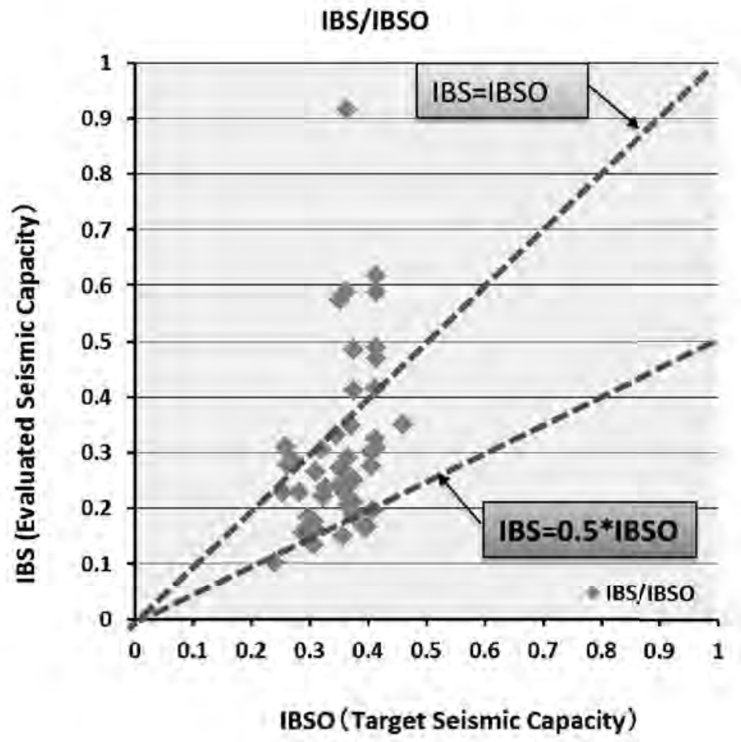

Figure 4 IBS-IBSO relationship

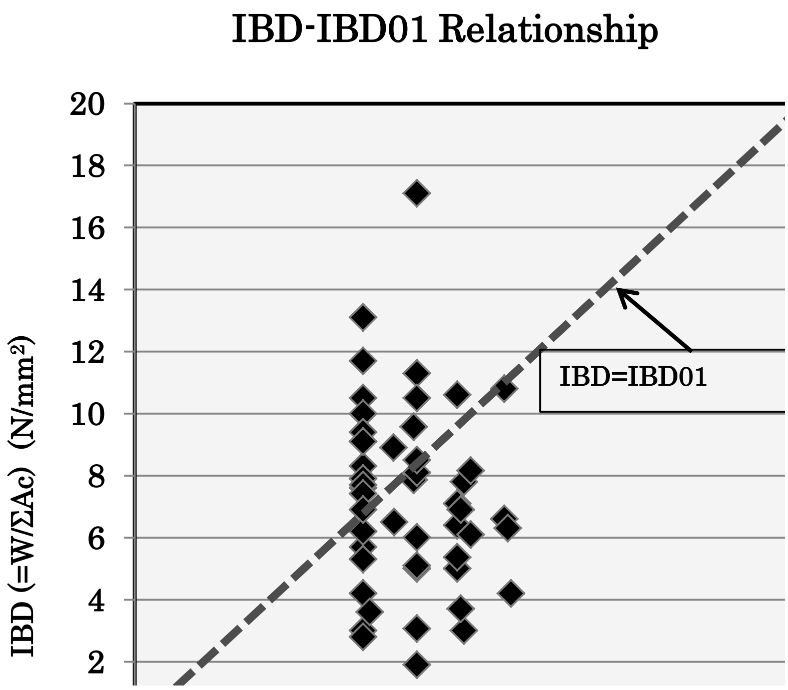

Figure 5 I_{BD}-I_{BD01} relationship

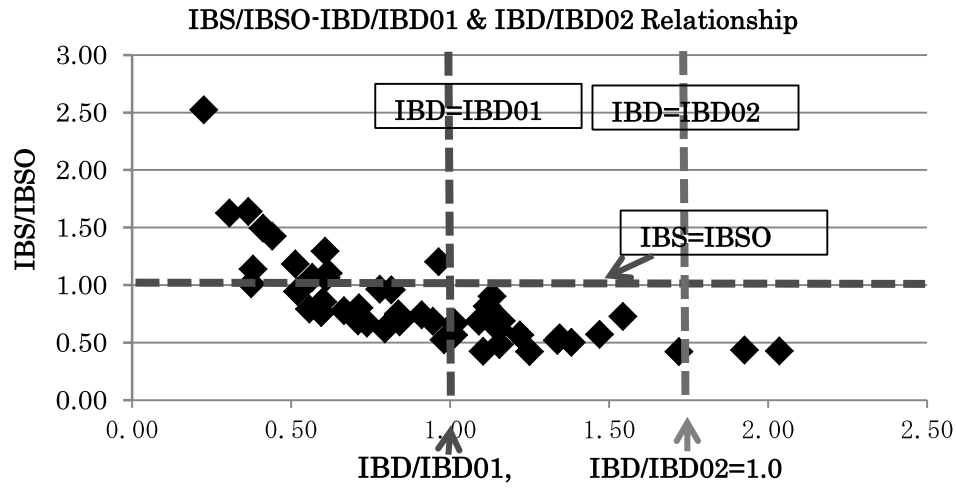

Figure 6 $I_{BS}/ I_{BS0} – I_{BD}/I_{BD01}$& I_{BD}/I_{BD02} relationship

6. CONCLUSIONS

A simplified structural evaluation method developed by Seki(2015) was able to be applied to the vulnerable buildings in Bangladesh and was verified to be suitable for the preliminary structural screening evaluation for the developing countries. This will also help to fix the priority among lots of vulnerable structures.

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Distributional and Cascaded Reusability Aspects of Indigenous Water Management System of Bhaktapur City, Nepal

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ABSTRACT

Present paper highlights the practices of traditional cascading and blending water reuse frameworks of Bhaktapur city, Nepal. Non-structured interviews, expert consultation, phenomenological as well as archival studies were performed in terms of efficacy and distributional features of traditionally used Rajkulo and other pre-existing systems. The indigenous water management technology has been found to be incorporating cascading water reuse and blending features as well. The Rajkulo fed Hiti, Tunche and Pukhu have been placed in such a way so as to ensure relative water quality and reuse. Rajkulo has been found to be established as a gravity supply network for around 6 kilometers long and supplying water for household, occupational as well as agricultural purpose. The homogenous Newari settlement of Bhaktapur city is situated in relatively higher relief than adjoining areas, however the supply management and subsequent discharging mechanism has been found to be arranged in such a way that surplus water from Hitis and Tunches was ideally supplied and stored in Pukhus for irrigation, occupational and cattle feeding purposes. Gravity supply and distribution, cascaded reusability and network management have been identified as ideal features of the indigenous water management system.

Keywords: *indigenous water management system; water distribution; water reuse; sustainability; Bhaktapur city*

1. INTRODUCTION

Water is identified and proclaimed as the greatest problem for human beings in the 21st century, similarly many of the scholars have identified water as most urgent and extreme case of resource depletion. It has been highlighted that the world is running out of water and described as most serious ecological and human right threat of present time (Barlow, 2013). Present day water and energy crises have imposed additional pressure on natural resources. It is predicted that two thirds of the world population would be living in water stressed condition by 2025 (Arnell, 2004). According to FAO (2012), agricultural water demand would be sharing 70% of the total global water withdrawal and for agricultural based economies; such withdrawal would challenge sustainability and agricultural production. The global paradigm of water scarcity has nowadays attracted many of the researchers from across the globe to search and replicate sustainable water solutions.

It has been around four decades that international conventions and protocols have paid attention towards indigenous resource rights like in the case of United Nations Declaration on the Rights of Indigenous Peoples. Indigenous knowledge is defined as a unique traditional framework of operation and management developed by unrelenting trial and error and subsequently propagated to generations as cultural practices. Indigenous people have developed unique self-reliant and self-sustained frameworks for managing natural resources and good practices are identified in terms of water resource management as well. Deviations in resource governance systems would mar the customary forms of management practiced by indigenous people worldwide. Development is imposing severe pressure on natural systems, the prime concern is focused towards whether the indigenous communities could sustain customary use of water for livelihoods or not (Finn and Jackson, 2011). Indigenous communities worldwide have harvested and managed water in (sometimes more) sustainable ways (e.g. Warren, 1991; Critchely et al., 1994; Dijk and Reji, 1994; Dijk, 1997; Yu, 2000; Strang, 2001; Rose, 2004; Jackson, 2005; Toussant et al., 2005; Singh, 2006; Jackson et al., 2012; Ayre and Mackenzie, 2013; Gautam, 2014; David and Ploeger, 2014) and these are often visualized as efficient and economic practices. The propagation of water resource management technology has legacy regarding efficacious, proportional and productive water use and reuse aspects. Such water management systems are regarded as 'Indigenous Water Management System (IWMS)' and practiced by indigenous people in various parts of the world. IWMS is almost forgotten in Nepal, as people seldom rely on traditional water resources, though there are some settlements within Kathmandu valley where water is used in many aspects differently.

This paper reviews the IWMS in Nepal's most preserved and homogenously indigenous Newari community in Bhaktapur city identifying the distributional features, their rationality and cascaded reusability of fresh as well as marginal water. The water fetching mechanism and scientific premise is accounted in this study and attempts have been furnished in terms of efficacy and sustainability of IWMS. Various findings have been disseminated as per the relevance and significance with regard to distributional proportionality and cascaded reusability.

2. CASE STUDY AREA AND METHODS

2.1 Case Study Area

Bhaktapur city lies in central Nepal and is an ancient settlement of 13th century established by the then Malla dynasty (a medieval dynasty in Kathmandu valley). This city occupies 6.88km^2 area with densely populated Newari (an ethnic group with peculiar cultural practices in Nepal) communities. About 99% of the people in this city are Newars (CBS, 2012) and also significant part of the occupied area is enlisted in the UNESCO World Heritage Site. Bhaktapur is located at 27^{0}36' to 27^{0}44' north and 85^{0}21' to 85^{0}31' east, a homogenous Newari settlement 12km east of the capital city.

Occupational peculiarity, artistic reflection and preserved cultural milieu have created a different flashback to the rest of the world. Indigenous Newars have developed unique tradition in terms of their livelihoods and customary practices. The homogenous settlement is usually favorable for assuring the customary practices hence such practices are well established and propagated in Bhaktapur city.

2.2 Methods

The pre-existing as well as present day IWMS of Bhaktapur city is assessed through expert interviews, phenomenological studies, non-structured interviews and archive study. People with strong cultural background and knowledge were selected while interviewing. For non-structured interviews, older people were selected randomly primarily focusing on their knowledge regarding pre-existing IWMS. Many of the older people were unable to understand English or Nepali languages so translations were made possible through native speakers. The findings were identified under various heads as distinct database was not observed during field work. Water reuse, cascaded use of fresh/marginal water, water consumption related cultural practices, water storage and occupational distribution, route and distributional features of *Rajkulo* (the royal canal) among others were accounted as key variants for this study. The information obtained after study were analyzed in terms of distributional features, cascaded reusability aspects and subsequent scientific bases and also analysis has been done in terms of revitalization of the traditional system through field visit.

3. RESULTS AND DISCUSSION

3.1 Water use perception

Newari livelihood is largely dependent on water use. They use water for household, occupational activities and irrigation. There are primarily three types of water bodies *Hiti* (stone spout), *Tunche* (drag well) and *Pukhu* (pond). *Hitis* and *Tunches* are the freshwater discharging bodies which usually supply potable water. Previously potable water was also supplied largely by the *Rajkulo* (the royal canal). Virtually all population used to depend on these bodies before the great 1934 Bihar-Nepal earthquake which devastated Bhaktapur city and obstructed the *Rajkulo* canal. Before 1934 earthquake, the 6km long canal was found to be supplying for the city in chronological way. The first discharge was found to be provided on the royal golden *Hiti* and subsequently distributed to other parts of the city as per the caste hierarchy in semi-concentric town setup. The general water conveyance system within Bhaktapur city has been delineated as in figure 1. Water was found to be distributed as gravity supply thereby assuring proper alignment to the canal and also *Hitis* were fed by *Rajkulo* in some cases. *Tunches* were found to be major groundwater bodies constructed across the city in every square so as to supply water to the residents. *Tunches* are the oldest water supply units for this city. The surplus water from *Hitis* and *Tunches* was subsequently stored to the *Pukhus* for marginal water use. Beside this, *Pukhus* are also rainwater harvesting hubs. Surplus water and runoff water was found to be supplied to *Pukhus* through open canals or even through the burnt clay sewerage canals.

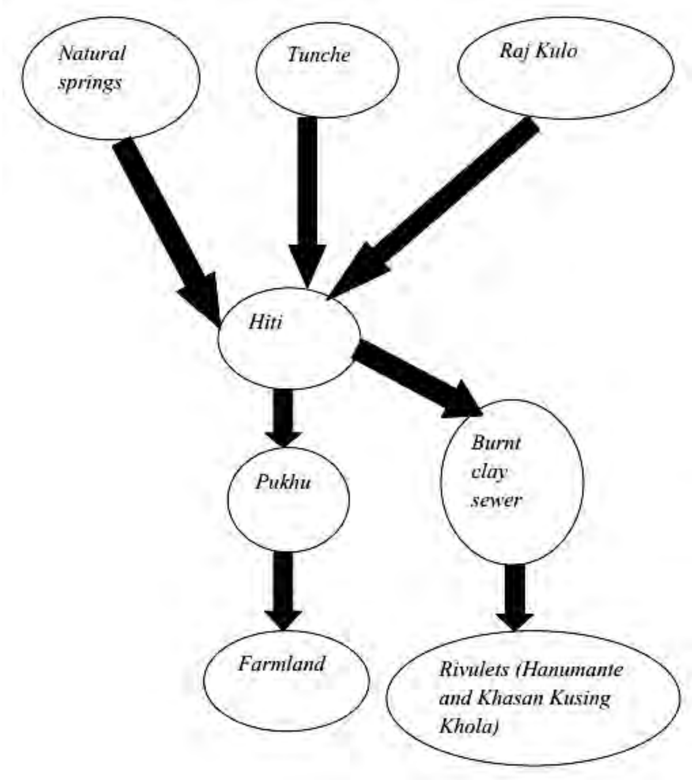

Fig. 1 General water conveyance system of Bhaktapur city

The marginal water is used for cattle, occupational activities like pottery and also for irrigation purpose. There is yet a popular trend of fetching water through *Kharpan* (a balanced water carrying system on both shoulders using a bamboo beam and rope arrangement). Rajkulo was the backbone of potable as well as water for irrigation purpose. Primarily the peasants (*Jyapu*) cluster within the semi-concentric settlement was engaged in agricultural activities. Moreover, the potters (*Kumha* or *Prajapati*) were amongst the water users in greater extent. The peasants were just above the potters in concentric setup due to the fact that the agricultural lands are relatively nearer. Most of the arable land was beside the settlement so that peasants were settled in such a way that they would get better access to farmlands. Moreover, most of the *Pukhus* were found to be established in the periphery so that the stored water could be used for farming in low scale by fetching through *Kharpan*. The *Kumhas* were also found to be benefitted through *Pukhus* in terms of water used for pottery.

3.2 Cascaded reusability of water

As Newars are concerned more about the religious and cultural beliefs, it has been found that they try to assure water quality as much as possible. After assuring potable water, the *Hitis* and *Tunches* are found to be connected with *Pukhus* through surface drainage or even underground drainage system. Figure 2 delineates the cascaded reusability of water existing within Bhaktapur city.

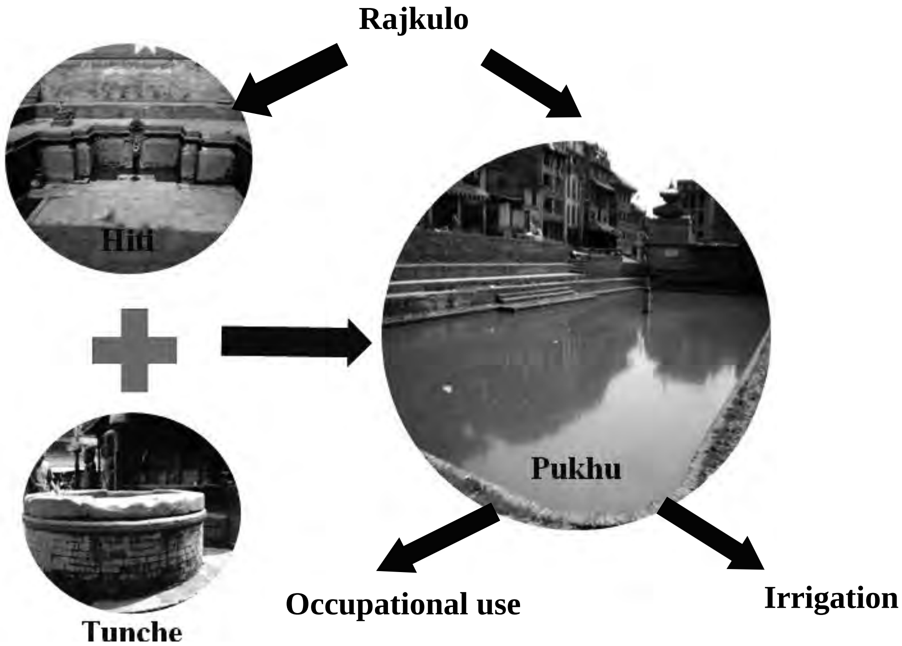

Fig. 2 Cascaded reusability framework of IWMS of Bhaktapur city

Freshwater is primarily found to be used for drinking purposes and other household activties, the surplus water from freshwater resources is found to be stored in Pukhus or directly discharged to farmland or rivers. The urban nucleus of Bhaktapur city is found to be settled in relatively higher relief in comparison to other adjoining areas. This terrain setup has well facilitated the water flow condition and subsequent water discharge into *Pukhus*. *Pukhus* are found to be ideally located in relatively low level in comparison to adjoining land so as to facilitate higher water accumulation.

3.3 Distributional features

Starting from the *Mahadev Pokhari* rivulet some around 6km east of the city, the gravity water supply was found to be existed. Beside this, even in the city center, gravity supply was assured through the open channel constructed. The *Rajkulo* was the water conveyance channel from the rivulet to the city center and managed by *Guthi* (trust) system. Rajkulo is amongst the ancient farmer managed irrigation as well as water supply in Nepal, and in some cases this is yet functional. Local wisdom and participation have performed effectively in order to assure water quantity as well as quality, as the supply was pivotal to the core city area. Even in the higher reliefs, water conveyance was assured and subsequently water was found to be distributed to *Hitis*. Beside this, *Rajkulo* was subjected for supplying to the farmlands covered by it. Farmer managed irrigation system (FMIS) has been found to be generated after this, at the meantime the *Guthi* system was strict towards managing and assuring water quality as well as quantity. Marginal water as well as storm water was found to be blended and supplied for storage into *Pukhus* so as to harvest a remarkable quantity of water. Stored water was found to be used for cattle, occupational use and also for small scale farming. The water fetching mechanism was associated with water carrying by *Kharpan* for occupational as well as small scale farming. The energy efficient gravity distribution system existed in Bhaktapur city was pragmatic solution of water scarcity and could be replicated nowadays for city supplies as well.

3.4 Water culture and city sustainability

Bhaktapur city has unique water culture; annual water body cleaning campaigns are organized as celebration called *Sithi Nakha*. Livelihoods in Bhaktapur go along with the water culture and assurance of water supply was the governing factor for sustainability in terms of agricultural productivity, continuation of domestic industries. Marginal water use was the efficacious water culture so as to minimize the overexploitation of ground as well as surface water. Moreover, the pavements in core city area are still found to be facilitating the groundwater recharge through clearly distinct voids preventing intact concretization.

3.5 Future insight

After 1934 earthquake, the IWMS has been almost forgotten. Bhaktapur is facing severe water scarcity these days as well. There are as many as 87 *Hitis*, 32 *Pukhus* and around 220 *Tunches* in Bhaktapur city, though most of these water bodies are dry nowadays. Through phenomenological studies of the reminiscent of *Rajkulo*, it is found that, it would be functional this time as well. If revitalized with minor repair, the economic gravity water supply could be assured in Bhaktapur city. As *Rajkulo* was the backbone of city sustainability and agricultural practices in the past, the cultural dimensions and practices are not transited vastly so indigenous knowledge could be instrumental in assuring effective water management. Arable and fertile lands are still there beside the historic settlement of Bhaktapur city, so assurance of irrigation facility through *Rajkulo* system and governing the water conveyance through *Guthi* would be ideal solution to present day water scarcity of drinking as well as agricultural water. The drawdown of groundwater is alarming in Kathmandu valley (e.g. Pathak et al., 2009; Pandey et al., 2012; Gautam and Prajapati, 2014) so future scenario would be cataclysmic in terms of availability of drinking as well as agricultural water. The optimal usability, blending use and cascaded reusability from IWMS are particularly instrumental for city sustainability in terms of drinking water, water for household use and water for irrigation in the homogenous communities like Bhaktapur where livelihoods are largely dependent on customary practices and agriculture is associated with culture.

4. CONCLUSION

Indigenous water management system evolves from the continuous trial and error knowledge, practices and traditions. Such practices are later metamorphosed as customs in indigenous communities. The unrelenting experimentation and subsequent adaptation lead to develop unique and sustainable dimensions in indigenous setups. This study reveals that the traditional practices were cost-effective, sustainable and often incorporated as cultural practices from across the boundary. Water management and distribution, cascaded reusability, marginal water use in terms of occupational and agricultural water, water blending, harvesting and storage and gravity water supply through a long open channel have been identified as dimensions of IWMS practiced in Bhaktapur city. The *Rajkulo*, *Hiti* and *Tunche* are the major freshwater supplying bodies existed in Bhaktapur city, though after the devastating 1934 Bihar-Nepal earthquake;

the network was obstructed. Still there is potential of revitalization of *Rajkulo* and subsequent feeding to *Hitis* could be assured. *Rajkulo* was the backbone for irrigation of arable land beside Bhaktapur city remarkably contributing in the sustainability of Bhaktapur city. Livelihoods of people in Bhaktapur city is dependent on water culture, customary practices and agriculture so use and reuse of water particularly in terms of blending and cascading are instrumental. Those practices were efficient in the past and found to be well practiced through social institutions like *Guthi* hence were efficaciously implemented; replication of the customary practices would be effective in present context. As the genesis of FMIS, *Rajkulo* was among the most vital framework of water management and distribution, so revitalization of *Rajkulo* and feeding *Hitis* along with harvesting and storage of blended water would a landmark effort for sustainable water management of indigenous Newari settlement of Bhaktapur city.

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Combination of different means for effective warning in a rural mountainous area

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ABSTRACT

In terms of disaster information dissemination including warning, it is important to combine multiple means in a mutually complementary manner. The more means are applied the more resilient warning system is built; the system works even if some of them become unavailable due to unexpected failures at the time of disasters. However, available means are very limited in rural areas especially in developing countries where communication infrastructures are poorly developed. Here we show an effective warning method useful in those areas which combines two means: a loudspeaker, sound-based mean, and Short Message Service (SMS), text-based one. It was demonstrated that the loudspeaker is able to warm mass simultaneously within the reachable area of its sound. Meanwhile SMS reaches unreachable area of the sound from loudspeaker which is affected by terrain and decreased drastically by noise created by heavy rain. For further understanding to develop a warning method in the areas, not only the two means but also other ones used conventionally including community radio, and face-to-face direct communication should be considered.

Keywords: warning, rural mountainous area, Short Message Service, loudspeaker

1. INTRODUCTION

1.1 Background of the research

In terms of waring at the time of disasters, decent media are differed for various factors such as social attribution of public to be warned, type of disasters and so forth. Besides, media themselves would become unavailable due to unexpected accidents happen during disasters such as failures of communication infrastructures. It is too difficult to cover all necessary functions for warning by use of single medium. Therefore, the idea of media mix, multiplexing media for warning, becomes important. At the event of the 2011 Great East Japan Earthquake, not only conventional means: newspaper, television, radio, but also internet and social media including Twitter exerted in warning and contributed to emergency response aftermath of the quake. Meanwhile, there were cases that disaster prevention radio communication systems could not function adequately due to failure and collapse of the systems. The importance of media mix has become more important since the event.

However, there is a problem that available media to be used for waning is significantly limited in developing countries especially in rural areas. According to International Telecommunication Union calculations, individuals using the internet per 100 inhabitants in 2015 would reach at 82.2 in developed countries while at 35.3 in developing countries. Besides, there would be over 2 times gap between developed and developing countries in number of mobile-cellular telephone subscriptions in 2015; 86.7 and 39.1, respectively. It can be said that number of those users shall be less in rural areas compared to urban areas even in same countries under developing.

1.2 Literature review

Kondo (2012) mentioned importance of multiplexing communication networks taking lessons learnt from the Typhoon Talas. Suzuki (2015) indicated to combine different tools is more than extremely effective in warning with three transmission characteristics: fastness, rightness, and sureness. On the other hand, there are many researches have been done which show a high potential of Short Message Service (SMS) to be used as warning mean in the area where information communication infrastructures have not been developed. SMS, mobile phone’s mail service, is standardized by Global System for Mobile Communications (GSM) and being popular and widely used in all over the world even at developing countries. Samarajiva (2008) said SMS combined with informative and robust website contribute smooth coordination within government officers who take important roles in warning. Cioca (2008) proposed reliable and effective flood warning system using SMS which can be a complementary to existing traditional warning system. Saysoth (2012) proposed an appropriate flood warning system in developing countries to reduce the loss of lives and property during flood occurrences.

1.3 Research purpose

Although SMS combined with existing means can be adopted for warning in developing countries and rural areas, there is little research has been done which examine actual effect of the SMS. Basically, SMS is said to be useful because of its high penetration rate in the world. We also have to consider not only the high penetration rate but also characteristics of recipients, technological issues to dispatch SMS at the areas and so forth so that SMS can be reached and opened by recipients. This research therefore aims to clarify actual effect of SMS especially when it is combined with an existing mean. Firstly, we examined an effect of each mean by issuing warnings by SMS and an existing media. Secondly, both effects were combined to clarify a multiplex effect when the media are used together.

2. EXPERIMETN AND SURVEY

2.1 SMS dispatch

2.1.1 Research area and an existing warning mean

The authors’ research team (2013, 2014) has been conducting research to understand social characteristics and attribution of local residents in rural mountainous area in Loei province, northeastern Thailand, and to analyze possibility of SMS to be utilized as warning method in the area. Two flood prone villages in the area were chosen as study areas for this research namely Loei Wang Sai village (hereinafter called LW) and Loei Taw Tad village (hereinafter called LTT) that locate along the Loei River (see Figure 1). Since the areas are surrounded by 600 to 1,500 meters high mountains, major disasters in the areas are flooding, level of inundated water changes rapidly, and landslide. Therefore, a warning that reaches residents promptly is highly required. A major existing warning mean in the areas is a loudspeaker although a handy siren is used when the speaker is not available due to blackout (see Fig. 2). In addition to blackout, there is another problem that warning from the loudspeaker is disturbed by noise which will occur when heavy rain pelts roofs of the residents' houses; majority of houses use corrugated-roofed made out of a thin metal sheet (see Figure 3) which creates severe noise when it rains. Therefore, the loudspeaker, sound-based system, has a limitation to warm residents in the villages.

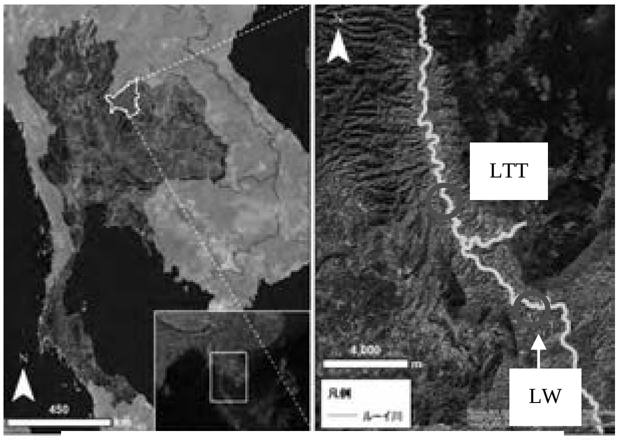

Figure 1 Research area, Loei province, Thailand

Figure 2 (left) Loudspeaker / (right) handy siren

Figure 3 Common house style in the study area

2.1.2 Warnings by both media

In Thailand, the service which sends SMS simultaneously to mass is provided by many companies and available even in rural areas if a user is accessible to an internet and mobile numbers of recipient are known. In this study, the service called Smart Messaging provided by Advanced Info Service PLC, the biggest carrier in Thailand, is adopted. A total of 216 and 168 mobile numbers were collected from LW and LTT prior to dispatch SMS, respectively. SMS was sent at 17:00 on 25 September 2014 when a rain was observed. Message of SMS is designed as following: "*Water level of Loei River has reached dangerous level to be flooding. For those people who are near the area, please evacuate properly. Please inform following message to other people as many as possible*". The same message was announced from the loudspeakers by each village leader of both villages at 6:00 on 22 September 2014.

2.2 Questionnaire survey

To investigate how the warnings transmitted by SMS and loudspeaker reached and accepted by residents, a questionnaire survey was conducted for four days from 26 to 29

September 2014 with a cooperation of students from Loei Rajabhat University. A face-to-face method was adopted for the survey by considering the situation of the research area where fixed-line phone, fax, and internet are unfamiliar, and misunderstanding of questions by respondents whose literacy rate are low. Total of 167 and 95 samples were collected from LW and LTT, respectively.

3. RESULT

3.1 Penetration of SMS

Smart messaging, the service, keeps sending SMS for 24 hours until it is received by a recipient. In this experiment, 149 out of 216 (69.0%) and 130 out of 168 (77.4%) messages were received by respondents at LW and LTT, respectively. Time taken from dispatch of SMS to receive by respondents is shown in Figure 4. Majority of SMS were received by recipients within a minute after dispatch. Besides, causes of SMS dispatch failure are summarized in Table 1. "The destination mobile number has suspended all SMS" marked major cause followed by "System Error" for both villages.

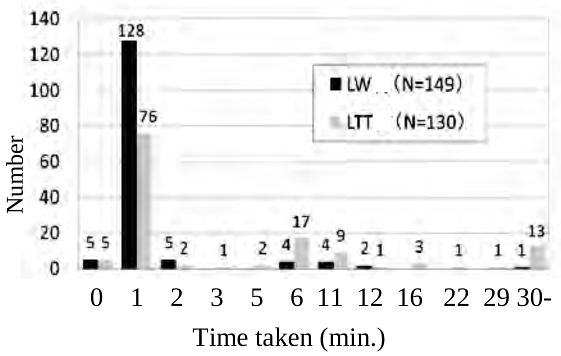

Figure 4 Time taken from dispatch to receive of SMS

Table 1 Causes of failure of SMS delivery

Causes	LW (N=67)	LTT (N=38)
The destination mobile number has suspended all SMS	61.2%	31.6%
System Error	22.4%	44.7%
Error caused by other mobile operators	9.0%	13.2%
Mobile phone switch off	7.5%	7.9%
Mobile Phone memory is full	0.0%	2.6%

3.2 Comparison of warning effect of loudspeaker and SMS

Following two questions were asked to examine how waring from both means, SMS and lou speaker, reached to the respondents: 1) Listening level of the loudspeaker in 5-

Table 2 Comparison of warning effect between the loudspeaker and SMS at both sunny and rainy days

		Listening level of the loudspeaker- sunny day*					Listening level of the loudspeaker- rainy day*				
Receive condition of SMS	LW	1 N=89	2 N=24	3 N=40	4 N=11	5 N=3	1 N=35	2 N=47	3 N=56	4 N=14	5 N=8
	Received/Opened	7.9%	20.8%	17.5%	18.2%	0.0%	5.7%	10.6%	19.6%	21.4%	0.0%
	Received/Unopened	15.7%	29.2%	27.5%	27.3%	0.0%	17.1%	19.1%	26.8%	14.3%	12.5%
	Not received	76.4%	50.0%	55.0%	54.5%	100%	77.1%	70.2%	53.6%	64.3%	87.5%
	LTT	1 N=50	2 N=19	3 N=19	4 N=6	5 N=1	1 N=25	2 N=26	3 N=29	4 N=10	5 N=2
	Received/Opened	20.0%	26.3%	21.1%	0.0%	0.0%	16.0%	34.6%	17.2%	10.0%	0.0%
	Received/Unopened	8.0%	42.1%	15.8%	16.7%	0.0%	8.0%	26.9%	17.2%	20.0%	0.0%
	Not received	72.0%	31.6%	63.2%	83.3%	100%	76.0%	38.5%	65.5%	70.0%	100%

* 1. Very clear, 2.Clear, 3.Neutral, 4.Not clear, 5. Not clear at all

scale from “Very clear” to “Not clear at all” at rainy day - the time of experiment- and ordinal sunny day. 2) Receive of SMS in 3 conditions 1) “Received/Opened”, 2) “Received/Unopened”, and 3) “Not received”. A result of cross tabulation with listening level of the loudspeaker and receive of SMS is shown in Table 2. 76.4% and 72.0% of respondents at LW and LTT, respectively, who could listen the warning from the loudspeaker “Very clear” answered “Not received” SMS. On the other hand, it was clarified that a number of respondents who could listen the warning from loudspeaker as “Very clear” decreases drastically at rainy day; from 89 to 35, and 50 to 25 respondents at LW and LTT, respectively.

A result of cross tabulation with past flood disaster damage experience and listening level of the loudspeaker at both days and villages are shown in Figure 5. A percentage of respondents who could listen the warning from loudspeaker as “Very clear” decreased from 21.8% to 3.8% and from 35.2% to 7.4% at LW and LTT, respectively. The decrease in listening level of the loudspeaker becomes obvious when the result is visualized. Figure 6 shows the visualized result of the listening level of the loudspeaker and receive condition of SMS in LTT at both sunny and rainy days. A method of kriging, function of ArcGIS, was used to create the figure. It could be seen that the two

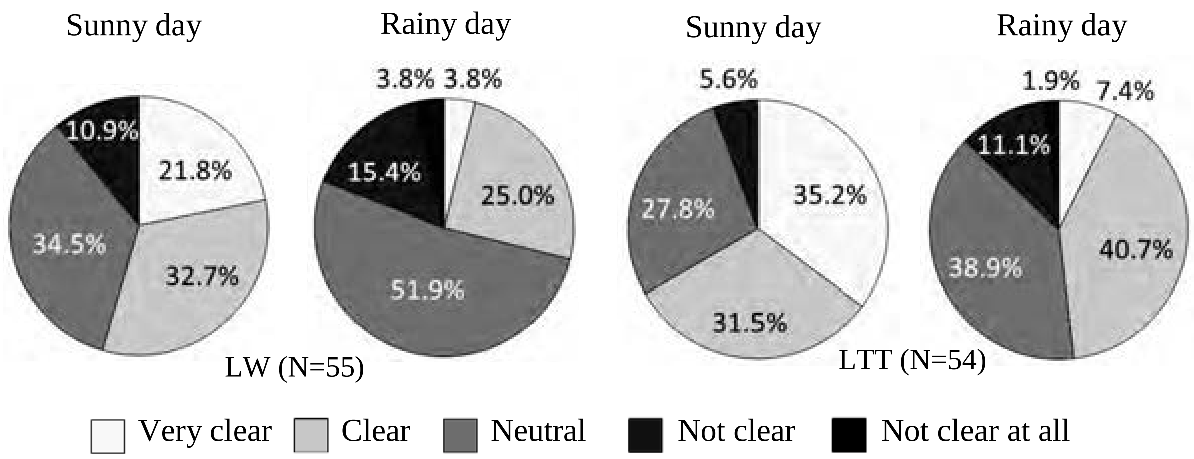

Figure 5: Listening level of the loudspeaker
of the respondents who have experienced flood damage

Figure 6-a Map of LTT with houses

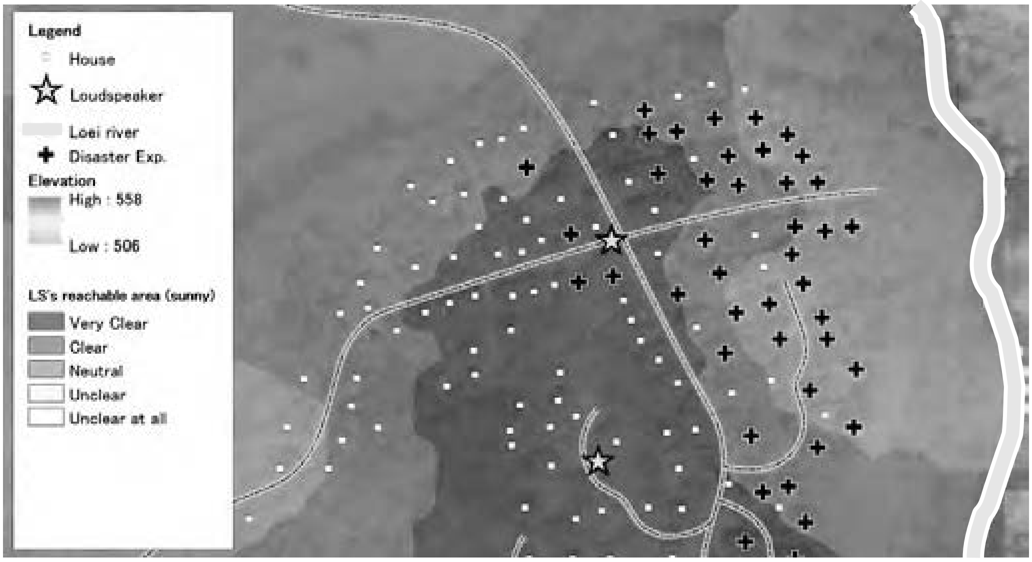

Figure 6-b Listening level of the loudspeaker- sunny day of LTT

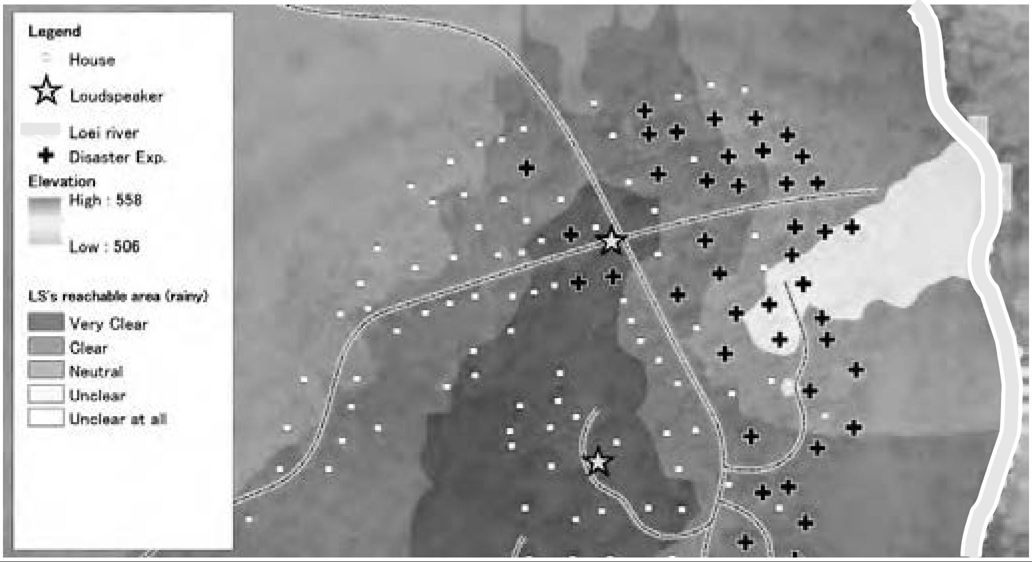

Figure 6-c Listening level of the loudspeaker- rainy day of LTT

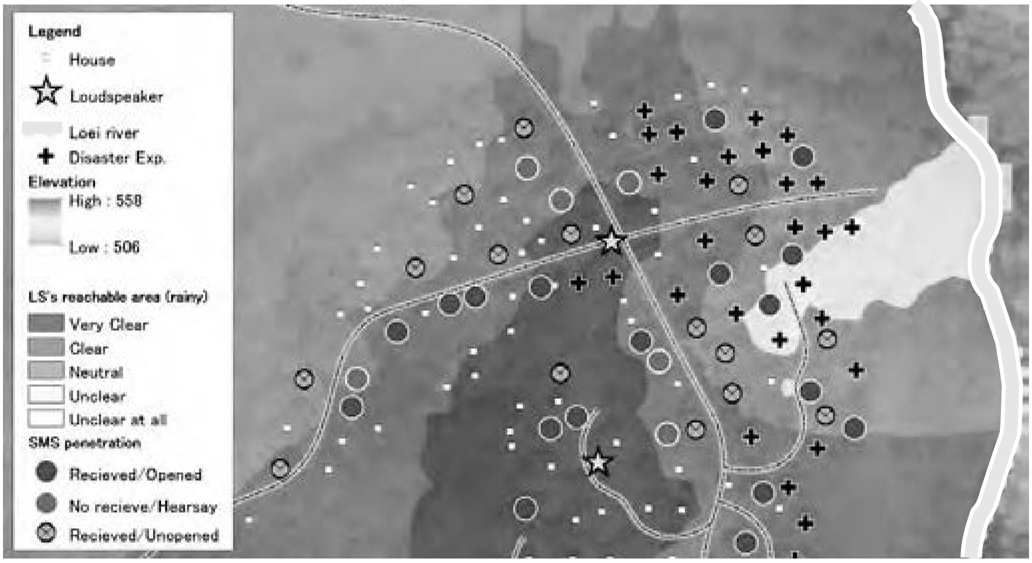

Figure 6-d Comparison between loudspeaker and SMS in warning- rainy day of LTT

means work complementary to each other; the loudspeaker can cover large number of people but decreases its reachable area when it rains, meanwhile SMS reaches less number of people but covers people who would not be able to get clear information from the loudspeaker at rainy days.

4. DISSCUSSION

People who have experienced flood disaster damages live in an areas far from the center of a village; loudspeakers are mostly installed at the village center so that reachable area of its sound can cover more people than when they are installed in the outskirts of the village. Therefore, it can be said that people who live in flood prone areas tend to be threaten by a flood risk without being warned enough by the loudspeaker. The more rain falls in the area the more risk of flooding and non-availability of warning people get. In the worst case, the loudspeaker will be unavailable when electricity supply is cut by blackout. Therefore, SMS, text-based warning, can be used to complement the loudspeaker, sound-based one.

However, SMS is needed to be opened by recipients otherwise it cannot function as warning. In this study, people were observed who did not open SMS even they received it. Besides it would be difficult to register and manage all residents' mobile numbers and dispatch at the event of flooding. Therefore, SMS shall be sent arbitrary recipient who are appropriate to disseminate warning to other people based on the information obtained from SMS. The recipients can be a village leader or someone who have high reputation in a community so that the information delivered by them would be believed by others. In addition, SMS shall be sent to the areas where warning from loudspeaker is hard to be reached especially at the situation that there is a heavy rain and high possibility that flooding occurs. The areas can be found easily by visualizing Listening level of the loudspeaker.

5. CONCLUSION

The importance of the idea to combine multiple means for warn public has been increasing. In developing countries especially in rural areas where available information communication technology is very limited, SMS of a mobile phone is featured to be used for warning because of the high penetration of the mobile phone. Although a combination of SMS and existing warning mean, the loudspeaker in this study, would be useful for the warning, there is a little research have been done which prove SMS is actually applicable and useful by a reason other than its high penetration rate. Therefore, this research demonstrated warning by both SMS and loud speaker to clarify the effect when they are combined. As a result, it was cleared that both means worked in a mutually complementary manner. The loudspeaker was able to warm mass simultaneously but easily affected by rain that causes decrease of its reachable area of sound. On the other hand, SMS could warn limited number of people but reached unreachable area of the sound of loudspeaker. The complementary effect would become more obvious at the time of heavy rain when severe noise disturbs the sound of the speaker. For further understanding in the effect of the combination of means for warning, other means used in the area, community radio, and face-to-face direct communication should be also considered.

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Trend and geographical distribution of landslides in Nepal based on Nepal DesInventar data

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ABSTRACT

Nepal is known as one of the most disaster-prone countries in the world. Fragile geological condition, diverse topographical feature, high precipitation and deeply weathered rock material as well as socio-economic conditions have made the country vulnerable to various types of natural disasters. Floods, landslides, earthquakes, epidemics, fires, thunderstorm and windstorm are quite common and frequent in the country. Every year it is suffering from number of large to small-scale natural disasters, causing a significant loss of life and property throughout the country.
This study is mainly based on DesInventar database, being maintained by NSET. Nepal DesInventar database shows that more than 3,220 landslide events have been reported in different printed media during the last 42 years. While looking these analysis and data for this period, one can specify the following losses: Besides the high number of human deaths 4,691, about 18,902 houses were destroyed and nearly 34,126 damaged. Moreover, almost 225,76 ha. of arable land and more than 10,798 livestock were lost. Concerning public property, more than 130 educational facilities, 8 medical centers and 334 km roads were damaged. The total loss by disasters during this period is about 12 billion NRs at present value. In early years, reports on disasters were not frequent. There is a gradual increase in the number of reports in recent years. Mountain and hill regions are more prone to landslides. However, landslides are also affecting Churia and Mahabharat range of the Terai region..

Keywords: landslide, historical data, trend, geographical distribution

1. HAZARD PROFILE OF NEPAL

Nepal lies in the most active and fragile mountain range. Mountain is still rising and its rocks are under constant stress, Thus pressure forces the Himalayas to rise continuously, which is released from time to time in the form of earthquakes. Active nature of the range and the process is also manifested by frequent earthquakes in this region. This stress is responsible for the complexities in folding, faulting and fracturing of subsurface rock strata making the entire country very fragile and susceptible to other natural hazards such as landslide and erosion (UNDP/BCP 2004). Intense monsoon rainfalls also trigger slope failure, landslide, debris flow, and other secondary hazards.
Hence that a combination of rough topography, steep slopes, active tectonic and seismic process and intense impact of monsoon rain has made this fragile environment vulnerable to a variety of natural hazards. Nepal is one of the most disaster-prone countries in the world and has experienced several natural catastrophes causing high economic and human losses. Heavy

rain and storms cause severe flooding, or trigger landslides that have an enormous effect on property, structures and lives.

The geological reasoning of Nepal being susceptible to a variety of natural hazards is confirmed by the real occurrence of disastrous events. Most frequent hazards are landslides, floods, epidemics, fires, earthquake and other hydro-meteorological disasters (heavy rain, thunderstorm, hailstorm, windstorm etc.), causing heavy loss of human lives as well as economic loss including housing and infrastructures. For example, the 1934 Bihar-Nepal Earthquake (M8.3), the 1988 Udaypur Earthquake (M6.6) and the 2015 Gorkha Earthquake (M7.6) were the most devastating earthquakes in Nepal during last 80 years. Jure landslide of 2014 and the 1993 floods in south-central Nepal resulted in huge loss of lives and properties including housing and other infrastructures (roads, hydropower, and electricity). The economic cost associated with natural disasters has increased tremendously.

The Terai experiences sheet flooding that becomes serious when the flow along braided rivers overflows the banks because of heavy deposition of sand and gravel in the river bed. Fire, drought and epidemics are also prevalent in this geographic region. The Hill region, including the Siwaliks (or the Churia Range) experiences landslide, debris flow along creeks along steep slopes, floods in the lower stages of river terraces and erosion along the river banks during monsoon period. The higher Mountain region is exposed to rock and snow avalanches, rock slides, and debris flows. There are numerous lakes of glacial origin in the higher Himalayan regions of Nepal. These lakes are rapidly expanding in area and volume due to melting of the glacier tongue, believed to be due to rise in global temperature. "20 lakes in Nepal are potentially dangerous. The lives of tens of thousands of people who live high in the mountains and in downstream communities could be at severe risk"(ICIMOD, 2007; Mool, 2001). The following table provides an overview of the hazard exposure of Nepal.

Table 1 : Types of Natural and Man-induced Hazards in Nepal

Types of Hazard	Prevalence
Natural Hazards	
Earthquake	All of Nepal is a high-hazard earthquake zone
Flood	Terai (sheet flood), Middle Hills
Landslide and landslide dam breaks	Hills, Mountains
Debris Flow	Hills and Mountain, severe in areas of elevations greater than 1700 m that are covered by glacial deposits of previous ice-age
Glacier Lakes Outburst Floods (GLOF)	Origin at the tongue of glaciers in Higher Himalayas, Higher Mountains, flow reach up to middle Hill regions
Avalanche	Higher Himalayas
Fire (forest)	Hills and Terai (forest belt at foot of southern-most Hills
Drought	All over the country
Storms/ Hailstorm	Hills
Man-Induced Hazards	
Epidemics	Terai and Hills, also in lower parts of Mountain region
Fire (settlements)	Mostly in Terai, also in mid-Hill region
Accidents	Urban areas, along road network
Industrial/Technological Hazards	Urban / industrial areas
Soil erosion	Hill region
Social Disruptions	Follows disaster-affected areas and politically disturbed areas

Source: NSET 2009 (adopted from Dixit, 1996)

The seismic record of the country suggests that a major earthquake of the 1934-magnitude (up to MMI Scale X) occurs approximately every 75 years (UNDP/BCP 2004). Even though this is only a statistical estimate, no one questions that major earthquakes are an unavoidable part of Nepal's future.

A large part of the country is affected by severe meteorological events (floods and landslides) during rainy season (particularly in monsoon season during late June to September). Also, there are events of cloudburst in the part of the hills causing debris flow and landslides. Precipitation records show that 80 percent of rainfall occurs during monsoon; whereas rest of rainfall occurs during pre-monsoon (5 percent during April – May) and post-monsoon (15 percent during October to March). Precipitation varies from place to place and ranges from 250 mm to over 5,200 mm per annum (Pokhrel, 2003).

As global environmental changes have affected the world throughout the age of time; which generate a complex of risks and vulnerabilities for areas and societies especially for those not well prepared to face them. The impact of global change is more readily visible in the form of melting of glacier ice and increasing potential of glacier lakes outburst floods (GLOFs) that have been recorded as causing great loss of life and damage to physical infrastructures and property. In Nepal, glacier lakes are common in mountainous region and out of them many are potentially dangers in terms of GLOFs. These lakes containing huge volume of water and remain in unstable condition (ICIMOD, 2007).

Epidemics and fire cases are other most significant disaster types in Nepal; they are frequent during the months of hot and rainy seasons. The poor access to health facilities are the most important thing to epidemics particularly in remote areas of the country as well as among the people living in poverty. Fires are frequent in thatch-roofed houses in the Terai and also in slum areas. In recent times, cases of fire are increasingly happening in small industries using or producing synthetic materials.

Thus Nepal faces a variety of natural hazards of geologic and climatologic origins. The entire country is exposed to one or multiple forms of natural hazards. Compared to the area of the country and the population, the extent and intensity of natural hazards are way too high if looked at from global perspective. Further, most of the hazard events easily get translated into disasters because of prevalent vulnerability.

2. METHODOLOGY

Although living in the "information age" and in a culture that is very data incentive, the organized and uniform data pertaining to natural disaster losses is quite less. No exact statistics are available on the loss of lives and property caused by historical disaster events. Few available records are only on the events with big impacts but thousands of small and medium size events are missing from the records, which sum to significant loss of lives and property.

In this context, the effort was carried out by the National Society for Earthquake Technology – Nepal (NSET) to establish a systematic data inventory of natural disaster events in Nepal. The effort has been focused on collection and computer-entry of natural disaster data. So far NSET has maintained the data for 42 years (1971-2013) and has been continued for subsequent years. The information is collected from different printed media and entered into the DesInventar System, a methodological tool developed by Latin American Network of Social Studies on Disaster Prevention (LARED).

Daily newspapers and periodicals have been considered as major sources of information. Beside these, relevant reports, journals and researches are also taken into account. The data thus collected is verified for consistency and accuracy, largely by going to the source when in doubt. After the verification, trained personnel entered the data into the DesInventar System.

The inventoried landslides data have been analyzed from different angles to draw an overview of landslides. Furthermore, distribution and other analysis also made based on geographical

and political regions while finding spatial distribution as well as making analysis on seasonality, trend, pattern, and the extent of human and property losses. The findings are presented in the form of tables, graphs, and maps.
This study draw a brief overveiw of the landslides in Nepal and how each impact variable has distributed spatialy, seasonally and chronologically. All these findings are based on the information collected through secondary source of information and findings are depends on how accurately the information was reported in the printed media.

3. LANDSLIDES – OVERALL SCENARIO

Landslide is a kind of moderate to rapid soil movement including lahar, mudslide and debris flow (CRED 2009). It is the movement of soil or rock controlled by gravity and the speed of the movement usually ranges between slow and rapid. It can be superficial or deep, but the materials have to make up a mass that is portion of the slope or the slope itself. The movement has to be downward and outward with a free face. But this study has focused only on the ground movement, such as rock falls, deep failure of slopes and shallow debris flows.
Although gravity is the primary reason for a landslides, there are other contributing factors affecting the original slope stability: The natural causes are: erosion by rivers, glacier melting, saturation by snowmelt or heavy rains, seismic activity, volcanic eruptions, excess weight from accumulation of rain or snow, and groundwater pressure acting to destabilize the slope. Human impacts such as vibrations from machinery, traffic and road construction, explosions or mining as well as the removal of deep-rooted vegetation that binds the soil to bedrock or overgrazing can also trigger landslides.
For the period of 1971 to 2013 the number of landslide events is summed to a total of 3,220 – a yearly average of 76 disaster events. The overall death toll is about 4,691 people which mean that on average every year in Nepal causes 111 fatalities. A striking number is seen on affected population, totaling of more than 600,736 (average of about 14,303 people per year). Besides the high number of human losses (fatalities, missing, injured, affected : 607, 806), about 18,902 houses were destroyed and nearly 34,126 houses damaged. Moreover almost 22,576 ha land and more than 10,798 livestock were lost. Concerning public property, more than 130 educational facilities, 8 medical centers and 334 km roads were damaged. The total loss by disasters during this period is about 12 billion NRs at present value. However, landslide impacts on human and property is differ as year and geographic location.

4. SEASONAL VARIATION OF LANDSLIDES

As stated above, the factors contributing to high vulnerability of landslides are of geographic, geological, ecological and demographic nature. This factor mainly open the fragility of the land masses, high elevation and steep gradient of the mountain slopes. Specific weather events related to the geography of the country, high degree of environmental degradation and the rapid growth of population as well slow economic development are also forces to the vulnerability of landslides.
Regarding the geography of Nepal, the Hill region seems to be the most affected area by landslides. As the peak of landslide events is in July during monsoon season, we can say heavy rain, floods and landslides are interrelated. Some landslides are triggered by riverbank erosion, undercutting of slopes by fast flowing rivers or human impact on slopes such as the construction of roads. On the other hand landslides can block riverbanks and consequently aggravate the risk of (flash) floods.

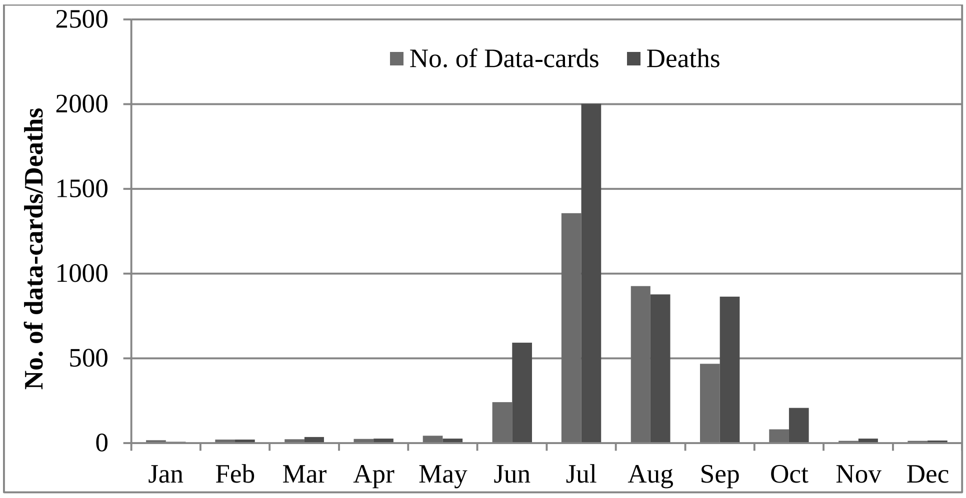


Figure 1: Seasonality of Landslides, 1971-2013

(Data source: Nepal DesInventar Database, NSET 2015)

Figure 1shows that death from landslide was recorded high in the rainy season from June to October.

5. TREND OF LANDSLIDES

Besides the above stated natural causes of landslides, in Nepal the major anthropogenic factors for landslides are: intensive deforestation, improper agriculture and irrigation practices, overgrazing on slopes, quarrying for construction materials, and construction of infrastructure beyond the bearing capacities of the hill slopes(Petley et.al 2007). Moreover the haphazard urbanisation with so called modern development without proper studies in hills has forced people to move at risk of landslide, which has been increasing everey year.

The analysis of effects of landslide during the 42 years period shows that each year, on average 111 people are killed and 14,303 affected with high number of buildings destroyed and damaged (about 1262 each year). Makwanpur, Sindhupalchok, Dhading and Kaski districts are highly affected.

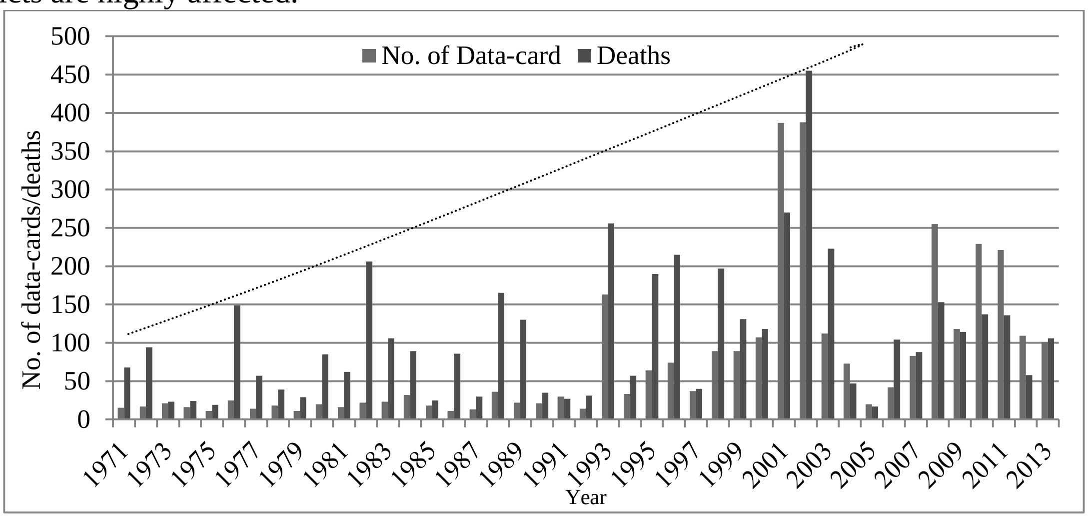


Figure 2: Trendline of landslides, 1971-2013

(Data source: Nepal DesInventar Database, NSET 2015)

The analysis of landslides trendline shows that in the beginning of 1990s, it can be observe a high number of landslide events. Moreover, the number of fatalities increased as well. However, in recent years, the number of events and fatalities went down again. An explanation for this curve cannot be found solely from the DesInventar database. However one could question whether this trend is interlinked with the construction of roads and increase of population.

6. ANALYSIS BY GEOGRAPHIC REGIONS

Nepal comprises high altitudinal variation from about 60 to over 8,000 meter above sea level within 90-120 km distance. Because of the east-west orientation of the mountains the climate changes from tropical to alpine according to elevation and latitude – temperature decreases from south to north with increasing altitude. Ecologically, Nepal is typically divided in three regions with regard to elevations and climate from North to South; The Mountain, Hill and Terai Region.

6.1 The Mountain Region

The northern part of Nepal – typically higher than 5,000 meter above mean sea level includes northern 16 districts of Nepal. This region covers approximately 15% of the country's land surface, contains nine of the fifteen highest peaks of the world. In the region, the winters are rather strong – long and severe – with only short and cool summers. Due to this fact, the most severe disasters besides epidemics – which cause almost ¾ of all fatalities – are landslides. During the time (1971-2013), no glacier lake outburst flood (GLOF) happened; however due to the topography of this area the region is prone to Landslides and GLOFs as well.

Jure Landslide

On August 2, 2014, due to heavy rainfall, a landslide was occurred at the Sunkoshi River, killing 156 people and blocking the river to form and artificial lake in Sindhupalchok district, Nepal. Araniko highway, the main (and only) artery of goods and people flow to China, was blocked by the landslide ripping out of 5 km of highway, and causing huge traffic jam, 2 dozens houses had been swept by the landslide. The landslide had a volume of 5.5 million cubic meters.

The landslide had a massive effects far beyond. The dammed river was threatening to unleash a torrent of water to hundreds of downstream villages that would ravage as far as Northern India. Despite the use of dynamite, it took the Nepal Army 45 days to dig a canal through the blockage to allow water in the lake to drain. The Lake created was 47 meters deep and over 400 meters long. The hasty emergency draining through the lake canal itself had caused damage to houses downstream and threatens to take out Lamosanghu Hydropower dam.

6.2 The Hill Region

The Hill Region contains some of the most populated districts of Nepal, naming especially the Kathmandu and Pokhara Valley. The topography contains hills, valleys, plateaus and gorges between approximately 1,500m and 5,000m above mean sea level – about 70% of the total land in Nepal. In this area, different influences cumulate: Because of the steep gradients of the mountains, this area is exposed to avalanches in the winter, but also prone to landslides and mud flows during monsoon, when the slopes are soaked and weakened from the rain. Therefore, settlements in the valleys and on mountain terraces are in danger of landslides. Furthermore, as mentioned before, the monsoon has multiple effects in this region: Many rivers overflow their bed and cause severe flooding and the cloud bursts cause harsh erosion that affects agriculture.

Landslides triggered by rainfall

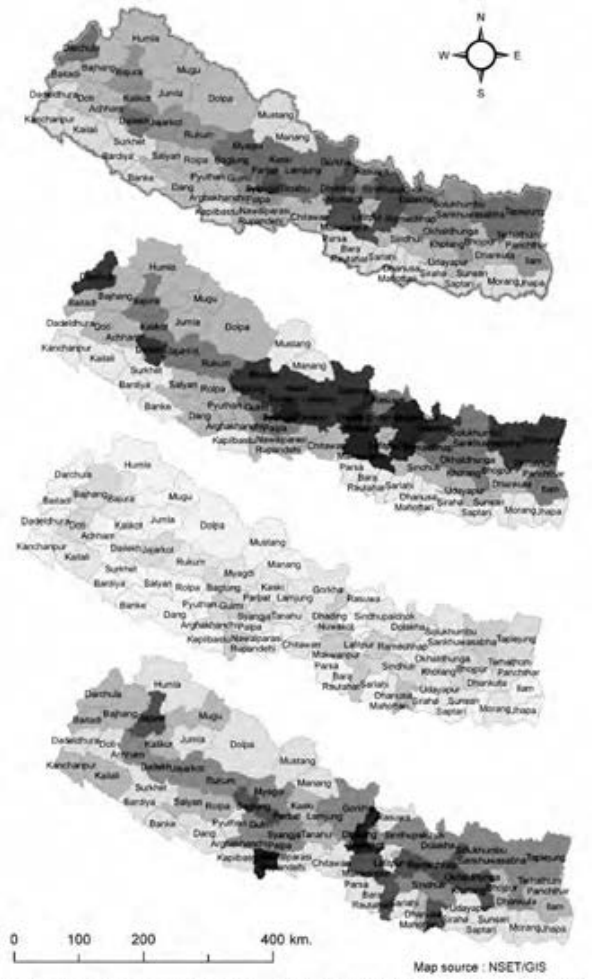
In July 2002, many landslides occurred in the southern hills of the Kathmandu, because of torrential rainfall. A single flow-like landslide occurred at Matatirtha, a small village situated at the south marginal hill of Kathmandu, killing 16 people who lived at the foot of the hill. Much damage was caused to roads and houses because of landslides and debris flows in small streams. Although some more flow-like landslides occurred in southern marginal hills, the Matatirtha was most devastating one. Some of flow-like landslides also damaged road of hills but casualty was not reported

6.3 The Terai Region

Altitudes between 60m and 1,500 m above mean sea level are encountered to build the Terai region. The lowlands – 17% of the Nepalese land area – include very fertile plains formed by the chain of historical floods. However churia and mahabharat range from the east to the west can be found on this region.

Similarly to the afore-analyzed regions the Terai also face the severity of landslides. Landslide of Mukundapur, Nawalparasi (2003), Rukuwa, Nawalparasi (1981), Kabilaspur, Chitwan (2003 & 2006) are an example of huge landslides occurred in Terai region, that are highly interlinked with the rainy season.

As Nepal is affected by the south-west monsoon, the Terai Region will have the first hit. Therefore all consequences of heavy rain, storm and thundershowers (flooding, erosion, lightning etc.) can be observed in this area. As the Terai is heavily used in terms of agriculture, small slides as well topples mainly due to rive bank erosion, have a severe effect not only causing high numbers of fatalities but also resulting high financial and agricultural (irrigation canal) losses.



Top to bottom - Map1 : Occurence of Landslides in Nepal; Map2 : Human deaths due to landslides in Nepa
Map3 : Affected Population due to landslides in Nepal; Map4: Building Destroyed due to landslides in Nepa

7. ANALYSIS BY DEVELOPMENT REGIONS

7.1 Eastern Development Region (EDR)

In comparison to the overview – that the eastern region comprises 19% fatalities due to landslides. The districts with high occurrence of landslides are Taplejung, Panchthar,Ilam,Sankhuwasabha,Solukhumbu, Okhaldhunga and Khotang. Taking the number of deaths into consideration the districts remain most hit by landslides. The significantly high reports on human deaths and other losses (building destroyed & damaged) in Eastern Region are because of landslides with high impact in Okhaldhunga (1976), Jhapa (1980), Dhankuta (1987) and Khotang (2002) etc .

The high number of affected people in Bhojpur (1996), Sankhuwasabha (2008), Sankhuwasabha (2011) and Terhathum (2011) can be traced back to the fact of a severe landslides (see above Map). However in the other districts have also high number of affected people. The districts with extremely high economic losses are Khotang, Taplejung, Okhaldhunga and Sankhuwasabha.

All thematic maps shows that the northern parts of this development region are more affected than the southern areas. This can be ascribed first to the differences of the population density and second to the severe weather conditions during the monsoon period.

Region	No. of occurrence	Deaths	Missing	Injuries	Affected Population
EDR	599 (18.6%)	900 (19%)	166 (26.4%)	355 (10.2%)	10, 4700 (17.4%)
CDR	920 (28.5%)	1,543 (32%)	212 (33.8%)	417 (23.8%)	300,720 (50%)
WDR	917 (28.4%)	1,313 (27.9%)	166 (26.4%)	577 (32.9%)	116,509 (19.3%)
MDWR	478 (14.8%)	492 (10.4%)	43 (6.8%)	224 (12.7%)	33,799 (5.6%)
FWDR	306 (9.5%)	443 (9.4%)	40 (6.3%)	179 (10.2%)	45,008 (7.4%)
Total	3,220 (100%)	4,691 (100%)	627 (100%)	1,752 (100%)	600,736 (100%)

Source : Nepal DesInventar Database, NSET 2015

7.2 Central Development Region (CDR)

Concerning the Central Development Region landslide prone districts are Dhading, Sindhupalchoke, Kavre and Makwanpur. Especially the Makwanpur district is outstanding not only because of the number of deaths but also because of the number of affected people (see above Map). In this district fatalities are mainly caused by the landslide events during the rainy seasons.

The number of affected people in Makwanpur, Dhading, Kavre and Dolakha districts is remarkable. In-depth analysis as shown that topography is responsible for this high impact. Whereas in the Terai district Dhanusa, the disaster of landslides affected a high number of people and caused high financial losses.

It can be concluded from the database that landslides lies on third places (16% of all disasters) in terms of most destructive and deadlist events in the central region.

7.3 Western Development Region (WDR)

In the Western Region, the districts with the highest numbers of landslides are Syangja, Baglung, Kaski, Parbat and Lamjung. Otherwise, Kaski, Syangja, Myagdi, Baglung, Gulmi and Tanahun encounter the highest number of deaths (see above Map). The events occurring most in this region are landslides (21% of all disasters).

In Myagdi district, there is a high losses in terms of finance and the number of affected pople are mainly due to destructive landslides. This supports the argument that the Hill region is most affected by disastrous landslides. Moreover, the study shows that the Terai is somehow affected by landslides is supported by the fact that the high number of affected people in the Terai districts, especially in Rupandehi, can be ascribed to landslide events.

7.4 Mid-Western Development Region (MWDR)

The districts most at risk of landslides are Dailekh, Rukum, Jajarkot and Kalikot. Moreover Pyuthan, Kalikot, Jajarkot, Rolpa and Dailekh comprise the highest number of fatalities in the Mid-Western Region. The number of affected people in the Terai, as proven by the Dang and Banke district, come off the effects of the landslides during monsoon season.

Comparing the ratio of number of events to number of deaths of the different development regions one can conclude, that the landslides in the Mid-West are less destructive than in the previous three regions. This can also be interpreted in the way that the mid-western districts are more vulnerable to other type of disasters ; flood, epidemic etc.

7.5 Far Western Development Region (FWDR)

Considering the above maps the finding is that the districts most hit by landslides and also the highest numbers of deaths. These districts are Darchula, Bajura, Doti and Baitadi. The landslides are more severe which cause more than 9 % fatalities. Additionally the number of affected people in the whole development regions comes off the side effects of the monsoon.

Moreover one can say likewise other regions, the districts in the Far Western Region are also vulnerable to landslides as the numbers of events and deaths are fairly high. This means, that the events of landslides are affecting on the population of Far-western development Regions.

8. CONCLUSION

Nepal lies in a multi-hazard zone exposed to various types of disaster. However, due to the various geography, topographic features, climatic variation and different levels of socio-economic development within the country, the type, frequency and degree of the impact of disasters differs from place to place.

Landslide impacts on human life, property and economy seems vary. Landslide is the most destructive natural disaster in Nepal. It does not only cause a high number of casualties and grave agricultural losses but also effects structures and infrastructure causing huge economic loss. Landslides, moreover, occur on a regular basis during monsoon.

The trendline of landslide shows that in the beginning of 1990s, there was a high number of landslide events. Moreover, the number of fatalities increased as well. In recent years, the number of events and fatalities went down again.

Districts of hill region as well mountain region are mostly affected by disastrous landslide events. However, the effects in the latter are more severe because landslides can cause other disasters like flash flood. Among the development regions, central development region recorded the highest number of human deaths 1,543 (32%) closely followed by western development regions with 1,313 (27.9%) deaths (above table). Similarly eastern and mid-western regions each have accounted for 19% and 10.4% respectively. Furthermore, in terms of the affected population, Central development region has recorded the highest population 300,720 (50%) with the lowest in far western development region 45,008 (7.4%).

Querying disaster impact by political regions, mostly landslide disasters can be seen on the central and eastern part of Nepal. Nearly 50 percent of landslides are recorded in these regions. Moreover as the aforementioned regions have high population these landslide events have also a high effect on people and property.

Furthermore, the high number of events does not imply a high number of deaths and vice versa. For example in the mountainous part of the eastern development region, the number of disaster events is high but due to the fact of a small density of population, the death toll is rather low. However, in the far western region, where only a small number of events occur, the death toll is lesser high. the analysis also shows that the landslides are highly interlinked to the geographic conditions – whereas the northern mountains are highly affected by

landslides. The Hill districts mostly experiences the side effects of the landslides. And the Terai suffers all monsoon effects – especially floods and landslides together.
One concluding remark for further research and mitigation approach is necessary in Nepal.

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Performance Based Engineering by using Seismic Dampers for Improved Performance and Reduction in Repair Cost

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ABSTRACT

Performance based design with seismic protection devices such as seismic dampers have fundamentally altered the landscape of earthquake engineering and design worldwide including Nepal. Structures designed and built without such devices typically use a code-prescribed design that implies extensive structural and nonstructural damage, loss of operation, and likely replacement at design-level earthquake. In contrast, performance based design incorporating earthquake protection devices leads to a combination of best engineering practice and reducing life-cycle costs. These devices are robust, cost-effective, and have a proven exceptional performance record in past earthquakes. The long-term performance is the key parameter used for evaluation. Structures properly designed with these devices will likely provide immediate occupancy performance with minimum post-earthquake repair.

Keywords: *seismic dampers, risk reduction, earthquake resiliency, enhanced performance*

1. INTRODUCTION

Fluid viscous dampers (FVDs) were originally developed as shock absorbers for the defense and aerospace industries. In recent years, they have been used extensively for seismic application for both new and retrofit construction; see Figure 1. During seismic events, the devices become active and the seismic input energy is used to heat the fluid and is thusly dissipated. Subsequent to installation, the dampers require minimal maintenance. They have been shown to possess stable and dependable properties for design earthquakes.

FVDs consist of a cylinder and a stainless steel piston. The cylinder is filled with incompressible silicone fluid. The damper is activated by the flow of silicone fluid between chambers at opposite ends of the unit, through small orifices. Figure 2 shows the damper cross section.

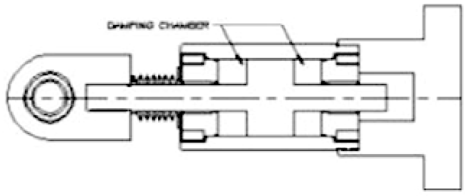


Figure 1. Steel SMF with dampers

Figure 2. Damper cross section

2. STEEL MOMENT FRAME APPLICATION

Provisions of ASCE/SEI 7-10 (ASCE 2010) were used to design a new steel framed multi-story building in the Los Angeles area. The steel members were sized using conventional code design procedures. Dampers were sized to control the story drifts. A parallel design was carried out using the conventional design methodology. This model was designed following the conventional code procedure for both strength and drift. The four-story commercial building is 18.5 m tall and has a total floor space of 8,000 m^2. The seismic mass of the building was approximately 9 MN. Architectural rendering of the building is presented in Figure 3. For the damped model, the bases of all columns were modeled as pinned. For conventional design model, the fixity, provided by the grade beams, was assumed at the base of all columns. Figure 4 depicts the mathematical model of the building. Sixteen nonlinear FVDs were used.

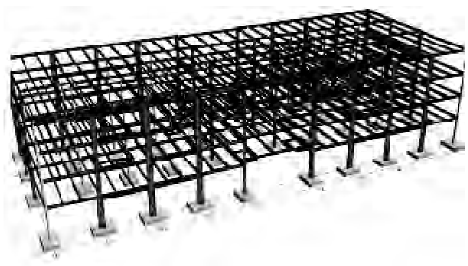


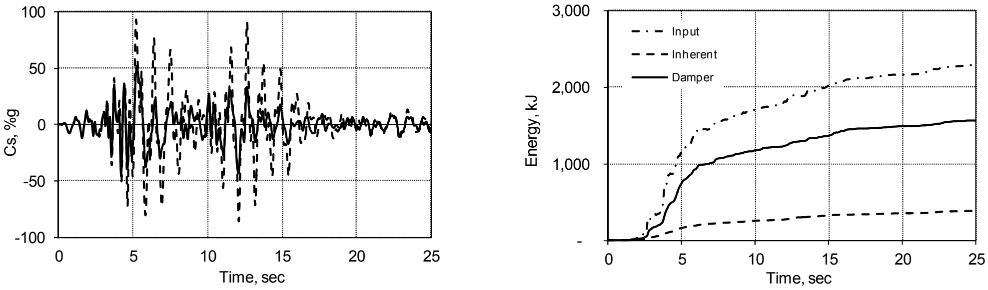
Figure 3. Architectural rendition

Figure 4. Mathematical model

Nonlinear response history analysis was performed to evaluate performance. Components of the ground motion were aligned with building principal axes. Maximum response quantities, such as, building floor displacement and accelerations, story shears, FVD forces, and member stresses, were extracted for evaluation.

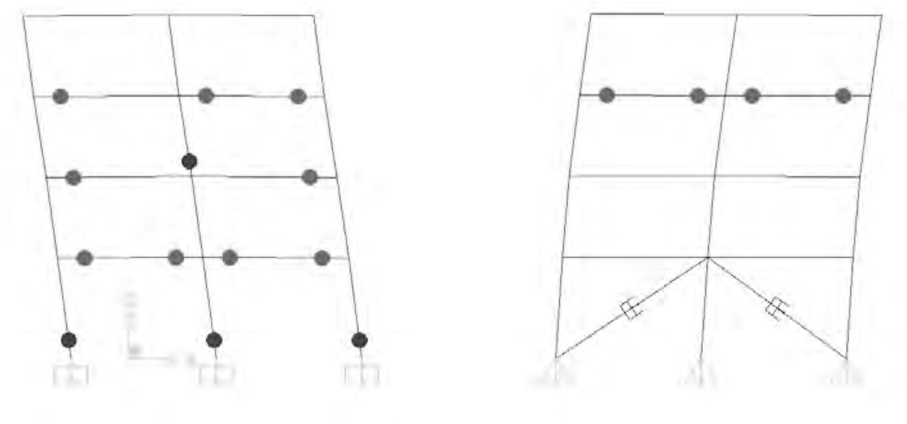
2.1. Analysis results

Figure 5 presents example of responses. The damped model had smaller base shear and floor accelerations because it has a longer period and larger effective damping ratio. **Error! Reference source not found.**. As seen in the figure, the dampers dissipated a large portion of seismic energy. Figure 6 shows the snap shot of the conventional and damped models at maximum deformation. Both models meet their performance goal of life safety. However, the damped model meets the higher essentially elastic performance goal, and the plastic rotations in the damped model (1.3% radian for beams) were smaller than those (1.7% radian in beam and 2.6% radian in column) of conventional model.



Base shear coefficients　　　　Components of seismic energy

Figure 5. Response histories



Conventional design　　　　Model with dampers

Figure 6. MCE plastic hinge rotations

2.2. Cost-Benefit Analysis

The damped structure has superior long-term performance and lower maintenance costs. Following a design earthquake, the conventional building should provide life safety, but will sustain significant damage and could require replacement. The additional initial cost of the dampers is offset by the savings in steel tonnage and foundation concrete volume. Sample data is presented in Table 1.

Table 1. Cost comparison for conventional and damped structures

Item	Conventional	Damped	Differential cost

Moment Frames	274 Ton	223 Ton	- $150,000
Foundation	RC grade beams	No grade beams	- $200,000
Dampers	None	$200,000	+ $200,000
Net			-$150,000

3. COLLAPSE ANALYSIS OF BUILDINGS WITH DAMPERS

3.1. Modeling of viscous dampers

In most applications, the dampers are modeled as simple Maxwell model. Such model is adequate for most design applications, but is not adequate for large earthquake analysis Damper limit states are governed by a few elements. The dampers bottoms out, once the piston motion reaches its available stroke. This is the stroke limit and results in transition from viscous damper to a steel brace with stiffness equal to that of the cylinder wall. The force limit states in compression and tension are governed by the buckling capacity of the driver brace and the tensile capacity of the piston rod, respectively. **Error! Reference source not found.** presents the proposed limit-state model for viscous dampers. This model is developed to incorporate the pertinent limit states and consists of five components. The damper components are modeled: a) the driver used to attach the damper to the beams and columns is modeled as a nonlinear spring, b) the piston rod and undercut is modeled as a nonlinear spring. In tension, the undercut section of the piston can yield and fracture, c) dashpot is used to model the viscous component, d) gap element and linear springs, e) hook elements and linear springs are used to model the limit state when the piston extension reaches the damper stroke.

3.2. Ground Motions

The input histories used in analysis were based on the two components of the 22 far-filed (measured 10 km or more from fault rupture) NGA PEER (2009b) records. These 44 records have been identified by FEMA P695 (FEMA 2009) for collapse evaluation analysis. The selected 22 records correspond to a relatively large sample of strong recorded motions that are consistent with the code (ASCE/SEI 7) and are structure-type and site-hazard independent. For analysis, the 44 records were normalized to remove the record-to-record variation in intensity.

3.3. SMF Connection

Steel SMFs with reduced beam sections (RBSs) are one of the prequalified connections for seismic applications and were used in this analysis. The constitutive post-yield relation for the RBS plastic hinges developed by Lignos (2008) was used in this subject study. Those authors used experimental data from a database of 42 RBS connections tested in laboratories using regression analysis; they identified the plastic hinge properties as a function of flange slenderness, web slenderness, lateral bracing, and yield strength of beams. The moment-rotational definitions, the multilinear moment-rotation constitutive relation for the RBS plastic hinges was thus defined. FEMA 350 (FEMA 2000) recommends the introduction a reduction in the flexural stiffness to account for the effect of the reduced beam flanges. Such reduction will result in an increase in the story drifts by 3% to 7% in typical applications. FEMA 350 also recommends increasing story drifts by 10% to account conservatively for this effect. This approach was used to scale up the computed inelastic drifts:

3.4. Model Properties and IDA

Program OpenSees (PEER 2009a) was used to conduct the nonlinear analyses. For collapse analysis, the normalized records are scaled upward or downward to obtain data points for the nonlinear incremental dynamic analysis (IDA) simulations (Vamvatsikos and Cornell, 2004).

4. APPLICATION TO STEEL BUILDINGS

To illustrate the concepts described in this paper, design and analysis of a group of archetypes with viscous damping was conducted. Fifteen archetypes are currently under consideration. The basic geometry and distribution of dampers for these models are summarized in Table 2. The selected building models will be regular in plan and elevation with a dominant first mode response. The period of tall buildings is limited to approximately 5 sec to ensure sufficient energy is present in the input histories. The investigations for all but the 20- and 30-story structures have been completed. The frames were designed using the code provisions and special requirements for SMRFs. The ASCE 7 maximum period used to compute base shear period is used for evaluation. A typical 5-story archetype is shown in Figure 7.

Table 2. Archetypes analyzed in this study

Archetype	Stories	Drift Ratio	Damper FS

O1	1	2.5%	1.0
O2	1	1.0%	1.3
O3	1	2.5%	1.0
O4	1	1.0%	1.3
A1	2	2.5%	1.0
A2	2	1.0%	1.3
A3	2	2.5%	1.0
A4	2	1.0%	1.3
B1	5	2.0%	1.0
B2	5	1.0%	1.3
C1	10	2.0%	1.0
C2	10	1.0%	1.3
D1	20	2.0%	1.0
D2	20	1.0%	1.3
E1	30	1.0%	1.0

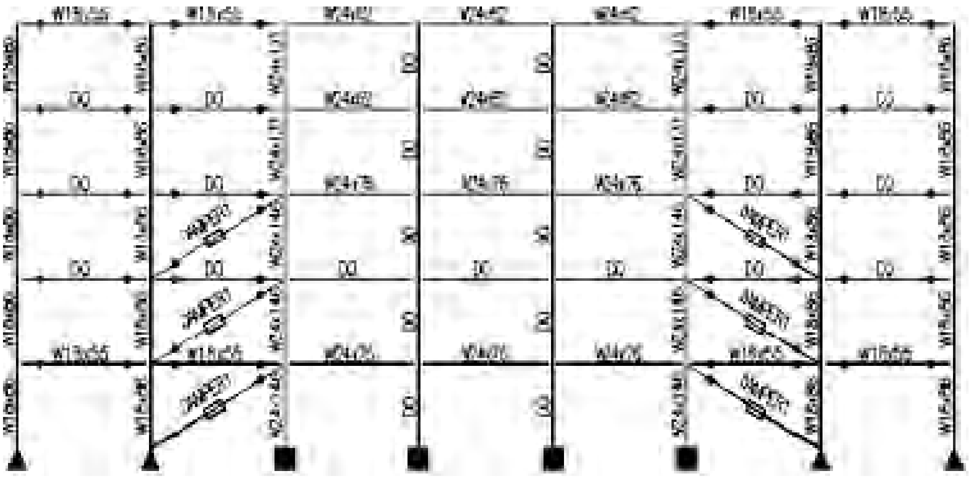


Figure 7. Five-story archetype B1

4.1. Damper property selection

Following the design of moment frames according to ASCE/SEI 7 requirements for strength, dampers were sized to limit story drift ratios. ASCE/SEI 7 presents recommendations for the design of dampers. This approach was used to provide an approximate damper size, assuming stiffness proportional to damping. However, because dampers had a velocity coefficient (α of 0.5 and because they did not extend throughout the full building height, the damper constant was then computed more accurately by conducting nonlinear analysis at the design earthquake (DE) level. Three sets of spectrum-compatible records that matched the DE spectrum were developed. Northridge, Kobe, and Newhall records were used from the Pacific Earthquake Engineering Research Center (PEER) Next Generation Attenuation (NGA) database (PEER 2009b). Additionally, the Kobe record was scaled such that the ordinate of its response spectrum matched the DE spectrum at the building's fundamental period

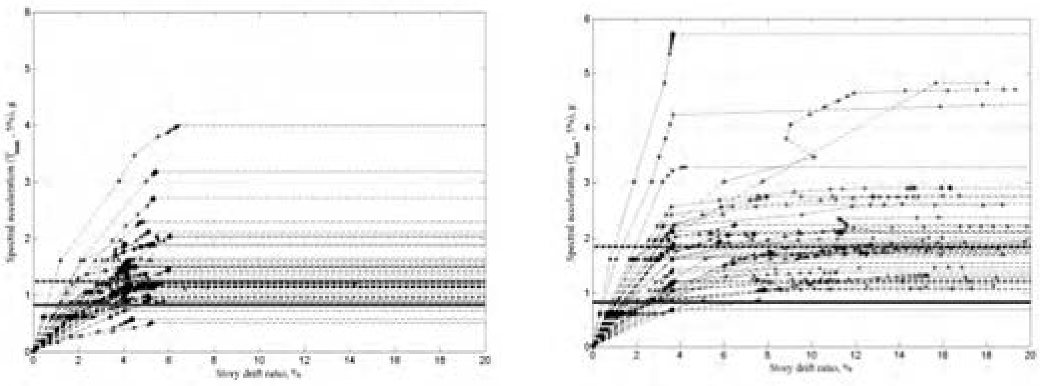
5. ANALYSIS RESULTS

The analysis results for the five-story archetypes are presented in Figure 8. For the IDA plots, the solid and dashed red lines correspond to the MCE (SMT) and the median collapse capacity (SCT), respectively. Note that the addition of small damper factor of safety significantly increases collapse margin. For the fragility plots, the 44 collapse data are statiscally organized and a lognormal curve is filled to the data (dashed lines in the figures). The plot was then rotated to correspond to a total uncertainty of 0.55 (solid line) per FEMA P695. Finally the curve was shifted to account for the effect of the SSF (dark solid lines in the figures). The probability of collapse at MCE intensity was then be computed. The probability of collapse at MCE level was reduced by a factor of approximately 4 when an additional damper factor of safety of 30% is included. The probability of the damper reaching its limit state at the MCE intensity can then be computed from the damper fragility plots. Note that the probability of damper reaching a limit state is significantly reduced when a damper factor of safety of 30% is included in design.

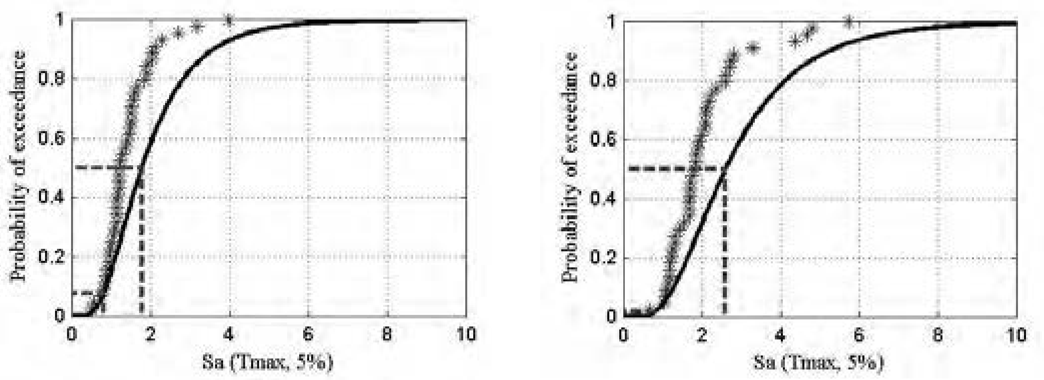
Table 3 summarizes the analysis results. The collapse margin ratio (CMR) is defined as the ratio of SCT and SMT. The adjusted collapse margin ratio (ACMR) is then computed as the product of SSF and CMR. FEMA P695 specifies a minimum ACMR of 1.59 for acceptable performance. Both archetypes have significantly larger collapse margins and therefore pass easily.

Table 3. Collapse fragility data

							MCE probability	
Arch.	**SCT**	**SMT**	**CMR**	**SSF**	**ACMR**	**P/F**	**Collapse**	**Damper capacity**
B1	1.24	0.82	1.51	1.34	2.20	Pass	8.0%	22%
B2	1.81	0.82	2.25	1.34	3.10	Pass	2.0%	10%



Static pushover curves



Fragility plots

Figure 8. Analysis results

6. CONCLUSIONS

New steel buildings were designed using performance based engineering (PBE) and provisions of ASCE 7. SMRFs were used to provide strength; dampers were used to control story drifts. PBE design using dampers is superior to the conventional design. The demand on both structural and nonstructural components is reduced. To date, a model of viscous dampers with limit states has been formulated that includes damper limit states. Current research using IDA and limit states of dampers is currently underway. The outcome of this study will provide a more realistic assessment of the performance of moment frames with dampers. All the archetypes had significant margin against collapse and thus had satisfactory performance. When a damper factor of safety is included in design, additional protection for the structures and dampers is provided. As one of the research deliverables, pertinent information will be provided for the designers to assist in seismic design using this approach

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Comprehensive Seismic Risk Reduction Program for Public Buildings in Metro Manila, Philippines

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ABSTRACT

Under the auspices of the World Bank, a multi-step risk assessment project has been recently completed for Metropolitan Manila, Philippines, the country's primary commercial and business center, the 11th most populous metropolis in the world, with 12 million. This area is susceptible to multihazard natural disasters such as earthquakes, floods, and typhoons. To address this vulnerability, a risk assessment and mitigation program was undertaken. A prioritization and seismic retrofit program was developed and focused on public schools and hospitals that have suffered disproportional damage and casualties in past disasters worldwide. The key steps in the program were to: a) prioritize vulnerable structures, b) conduct cost-benefit analysis to assess retrofit options, and c) prepare a seismic retrofitting guidelines including design examples and details. Approximately, 4,000 structures were evaluated. The probabilistic evaluation platform was utilized and retrofit options were developed based on the state of art but simple seismic retrofit methods and modified for local construction.

Keywords: *metro Manila, multihazard prioritization, probabilistic risk assessment, cost-benefit analysis, seismic retrofit*

1. INTRODUCTION

As evidenced by the M7.2 Bohol earthquake on October 15, 2013, and Super Typhoon Yolanda on November 8, 2013, the Philippines is considered to be a natural hazards global hot spot—ranking eighth among the most exposed countries in the world. Geographically positioned on the Ring of Fire in the Southeast Asia region of the Pacific Ocean, the Philippines is particularly vulnerable to natural hazards such as earthquakes, typhoons, floods, volcanic activity, and tsunamis. In addition to the risk of human life loss and suffering, it is estimated that 85% of the national GDP activity occurs in at-risk areas, such as Metro Manila (MM), which further emphasizes the need for a robust natural hazards risk mitigation program.

To address the vulnerabilities stated previously, it was vital to develop a multihazard evaluation and strengthening program for this area. The key components of the program were: a) Hazard assessment, b) Development of an appropriate mitigation and strengthening solution, and c) Prioritization, of public buildings for earthquake strengthening and hazard mitigation. Such prioritization is necessary to help ensure that available funds are optimally allocated.

Data collection from the initial pool of buildings included site visits, visual surveys, and photos of the buildings for documentation. The data was then reviewed, assessed, and categorized, and then aggregated with available facility and structural data from the various agencies. The data was then assembled into a database and processed by using risk assessment algorithms that correlate earthquake hazards to probable loss (that is, fatalities), and a ranking for each building was developed.

The information from the database was then used to develop effective earthquake strengthening methodologies for these types and other types of vulnerable structures in the pool of buildings. Retrofit techniques (such as adding shear walls or braced frames, and improving the existing component detailing) and innovative methods were investigated and presented. The selection of upgrade techniques incorporated both earthquake engineering and risk management (in terms of cost-benefit analysis), and were specific to the building types identified in the pool that are known to be vulnerable to earthquake damage. Finally, an implementation program was provided that outlined the next steps in advancing a multihazard risk mitigation program, using the findings, methodologies, and guidelines developed by this project team.

2. PRIORITIZATION APPROACH

Computer models, such as FEMA HAZUS (2001), to estimate portfolio losses from different natural hazards. The results are used for disaster response planning, policy making, and other planning exercises. For this project, a prioritization methodology was developed to highlight the disaster impacts at a qualitative level, with the goal of showing that, if earthquake upgrades are not performed, earthquake-caused life losses will be orders of magnitude greater than from other natural disasters. A first-order analysis of the natural hazards and potential consequences to schools and hospitals is presented in Table 1, which highlight the significantly greater threat that is presented by earthquakes. The consequences are based on a review of Philippine natural hazard loss history.

Table 1. Natural Hazard Impact to MM Schools (Hospitals)

Hazard	Earthquake	Tsunami	Typhoon/Flood	Volcanic
Property Damage	High	Mod.	Mod.	High
Business Interruption	High	Mod.	Mod.	High
% of Sites Affected	>50%	≈30%	5–20%	0%
Injuries	High	Mod.	Low	Low (Mod.)
Deaths	High	Mod.	Low	Low (Mod.)

3. EVALUATION OF BUILDINGS FOR SEISMIC HAZARD

3.1. Building construction

Typical school and hospital buildings are comprised of reinforced concrete–frame construction with infill walls. For some public buildings reinforced concrete shear walls are used. Figure 1 presents a typical school building. Elevation and plan view for a typical school building is shown in Figure 2. As shown in the figure, school buildings are comprised of row rows of classrooms and a walkway in the longitudinal direction. Individual classrooms approximately measure 10 x 10 m in plan, the walkway is approximately 3-m wide and typical floor height is approximately 3 m tall.

Figure 1. Typical school building

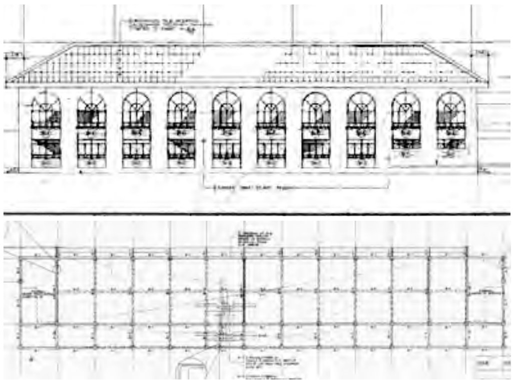


Figure 2. Elevation and plan view

3.2. Building codes

In the Philippines, the governing code for the design and construction of buildings is the National Building Code of the Philippines (NBCP). The codes were actually both adopted from the 1970 Uniform Building Code. The NBCP has since evolved into the National Structural Code of the Philippines (NSCP) and National Structural Code of the Philippines (NSCP). Similar to the first edition, the second through sixth editions of the code has also been adopted from later UBC editions, see Table 2.

Table 2. History of seismic codes for Philippines

Ed.	Issued	Title	Code basis
1	1972	NBCP	UBC 1970
1	1977		
2	1982	NBCP	UBC 1979
3	1987	NSCP	UBC 1985
4	1992	NSCP Vol. 1	SEAOC 1988 UBC 1988
4	1996		
5	2001	NSCP Vol. 1	UBC 1997
6	2010	NSCP Vol. 1	UBC 1997

4. COST-BENEFIT ANALYSIS FOR EARTHQUAKE RETROFITTING

4.1. Description

The CBA used a modified version of the standard Boardman (2010) multistep approach. Given that the focus of this project is on public schools and hospitals in Metro Manila, the major stakeholders for this project include the Philippine Department of Education (DepED) and Department of Health (DOH), and the students, patients, employees, friends, and families associated with these institutions. Generally speaking, however, the Philippine government, the Philippine local government units (LGUs), and the Philippine citizenry at large are also stakeholders in this project. The main goal was to identify whether the buildings studied need to be retrofitted and, if so, what the costs and benefits would be. The status quo (no strengthening) was used as the baseline, and the benefits derived from an earthquake strengthening program and the costs associated with such an approach were quantified.

4.2. Earthquake Hazard Prioritization

Earthquake hazard prioritization and selection of the highest-risk buildings for earthquake upgrade were based on building vulnerability and expected casualties from the M7.2 West Valley Fault scenario. Because most of the school and hospital buildings are of similar construction (reinforced concrete frame with masonry infill walls), the vulnerability ranking is directly correlated to the resulting casualties (that is, fatalities) from structural damage and collapse. Vulnerability and fatality calculations were based on the probabilistic methods developed in ATC-13 and FEMA HAZUS (2001), and were used to rank the buildings under investigation. To estimate vulnerability and fatalities for a particular building, the following distinct parameters were used as input: a) Seismic hazard, b) Exposure , c) Building vulnerability, d) consequence function (casualty index in this paper). For this project, a database of buildings was developed that incorporated these parameters. Following is a summary of the definitions and procedures that were used to determine these variables.

4.3. Seismic Hazard

The seismic hazard used in the analysis was based on the design response spectrum as defined in the National Code. Development of the elastic response spectrum was based on the procedure outlined in the National Code, and included factors such as the seismic zonation (equal to 4 for Metro Manila), the classification of subgrade soil at the site, and the shortest distance from the building site to the fault. Data for the type of soil (typically Class D or E) at various campuses was determined from the available PHIVOLCS liquefaction maps. Geographic coordinates (latitude and longitude) were provided in the database of school buildings that was furnished by DepED. Because the geometric coordinates of the West Valley Fault are known, the normal distance to the fault line was computed for each school campus. With this value, the near-field effects for various campuses could be computed. The design spectrum for an individual building was then developed based on the procedure listed in the National Code, modified for the site class and near-field effects. The obtained site-specific spectrum comprised the seismic hazard for each building.

4.4. Exposure

The exposure for each building was based on its student population (used to estimate fatalities), floor area (in square meters), and construction characteristics used to estimate structural damage. The DepED database was updated on an independent survey of 130 random buildings. The database entries were modified as follows:

4.5. Building Vulnerability

The structural vulnerability was based on fragility data from FEMA HAZUS, which shows the probability of exceeding a damage state as a function of the building drift ratio. The parameters (means and variances of the lognormal curves) for the fragility functions of a given building included the following factors: Construction material, Lateral-load-resisting system, Number of stories, Construction date, and Construction practices

4.6. Damage states and causality index

The definitions of these damage states for a reinforced concrete moment–frame building (C1) were used. The FEMA HAZUS indoor casualty rates for concrete moment-frame low-rise (C1L) and concrete moment-frame mid-rise (C1M) buildings were used in this paper.

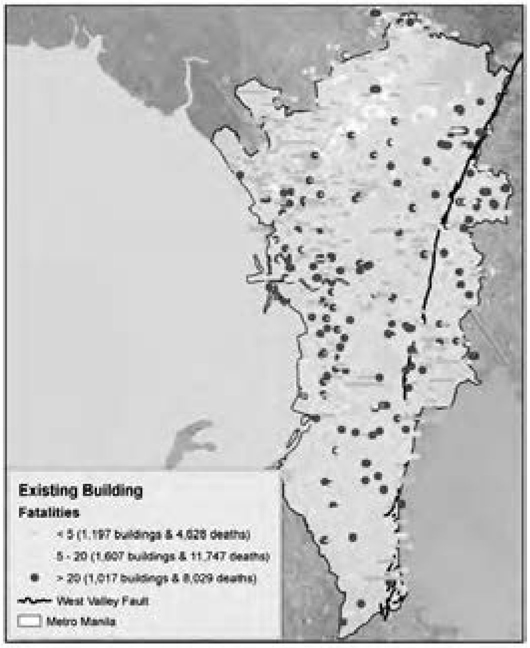
FEMA HAZUS building collapse rates for “Complete Structural Damage” are 13% for C1L and 10% for C1M. Collapse rates for unreinforced masonry are 15% for URML and for URMM. FEMA HAZUS casualty rates are uniform across all building types, so casualty estimates must factor in the collapse rates. Based on this logic, casualty rates for reinforced concrete buildings should be slightly lower than for unreinforced masonry buildings. However, MMEIRS findings on the relationship between casualty and building damage are quite different from HAZUS findings. The MMEIRS report shows that casualty numbers in reinforced concrete buildings are actually between 5 and 100 times (an average of 20x) those of unreinforced masonry buildings. Therefore, the casualty numbers and the collapse rate were adjusted accordingly.

5. ANALYSIS RESULTS

Figure 1 presents the distribution of the number of fatalities associated with individual buildings. It is noted that there are a percentage of buildings with large expected fatalities. The geographic distribution of buildings based on the number of fatalities is shown in Figure 3. In this figure as the legend indicates:

- Red dots correspond to buildings with fatalities of more than 20
- Yellow dots indicates fatalities of 5 to 20
- Green dots represent buildings with less than 5 fatalities

The buildings can thus be ranked based on the number of fatalities as shown in Figure 4. The data in this figure are based on 3,821 buildings and 2.15 million students and the fatalities in the event that the design-level earthquake, as defined in the building code struck Metro Manila. The key findings of this figure are summarized in Table 3.



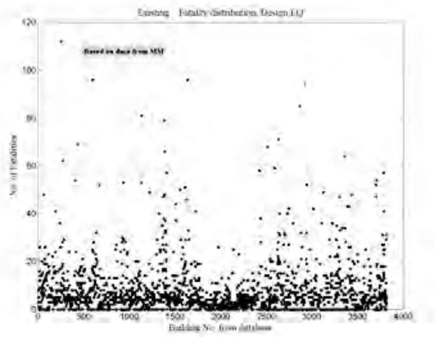


Figure 1. Fatality distribution for school buildings

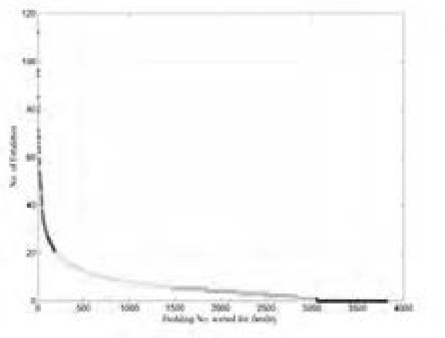


Figure 3. Geographical distribution of schools based on the estimated fatalities

Figure 4. Ranking of buildings based on the number of fatalities

Table 3. Fatality values from probabilistic evaluation

% Number of buildings	% Fatalities
Worst 100 (Magenta)	18%
5% (186) (Red+)	26%
38% (Yellow+)	80%
100% (3821)	100% (24,000)

Note the following:

- By retrofitting worst 5% buildings, fatality risk will be significantly reduced for 26% of total population.
- By retrofitting worst 38% buildings, fatality risk will be significantly reduced for 80% of population.
- Systematic seismic upgrade of certain vulnerable structures and will have a significant impact on casualty risk and damage

It was estimated that the total inventory (replacement) cost of all buildings to equal $US1.0 billion and the total loss anticipated from a design earthquake to be $US 820 million. By contrast, the seismic upgrade cost is significantly less as shown in Table 4.

Table 4. Seismic upgrade costs from probabilistic evaluation

% Number of buildings	Seismic upgrade cost in $US million
Worst 100 (Magenta)	$US25-50
5% (186) (Red+)	$US40-80
38% (Yellow+)	$US180-360
80% (3000) (Green+)	$US300-600
100% (3821)	--

Therefore, as an example, seismic upgrade of the worst 100 buildings (3% of inventory) will cost $US25-50 million dollars. However, such program will not only result in saving of over 4,000 lives but also preserve the infrastructure that is substantially more valuable than the cost of the seismic upgrade. It is further noted that such a seismic upgrade will ensure that these facilities are available to serve as shelters for other natural disasters such typhoons. Furthermore, such an upgrade program can be expanded to the entire country.

6. EARTHQUAKE STRENGTHENING GUIDELINES

The Guidelines for Earthquake Strengthening and Upgrading of Public Schools and Hospitals in Metro Manila have been developed to assist in addressing the seismic design requirements for public hospital and school buildings in Metro Manila. It is recommended that the Guidelines be used as a supplement to the 2010 edition of the Philippine Earthquake Code (ASEP 2010). In the Guidelines, the Life Safety (LS) performance level at the design earthquake is used for evaluating existing buildings. The Guidelines are divided into three volumes. Volume I of the Guidelines provides a prescriptive methodology for evaluating and upgrading school and hospital buildings. Volume III provides design examples for use in evaluating typical Metro Manila school and hospital buildings. The examples show the upgrade methods prescribed in Volume I.

The proposed seismic strengthening scheme for the lateral force resisting system (LFRS) members is presented in Table 5. For deficient buildings, either new reinforced concrete shear walls or BRBF systems are proposed. The use of BRBF will limit the foundation upgrade and preserve the open space in front of the classrooms.

Table 5. Proposed upgrade matrix for vertical elements of LFRS

LFRS	Constructed	Option
RC framing with or without CHB infill walls	Pre-2001	Add new RCSWs or BRBFs
	Post-2001	Add new shotcrete , if necessary

7. CONCLUSIONS

Metro Manila Philippines is one of the most populated cities in the world and the economic and commercial center in Philippines. The area is also subject to frequent natural disasters with grave consequences. To assess the natural hazard risk and advance mitigation schemes, a risk assessment and management program was undertaken. The results showed that:

- The earthquake hazard is the governing risk for the area resulting in annualized fatality rate of 1% ort population; an order of magnitude larger than any other natural hazard for the area.
- A ranking algorithm was developed and implemented using the available database from Philippines supplemented by field surveys. The fatality and structural loss were used as the ranking parameters of interest. The algorithm showed that a subset of small number of buildings contributed the most to fatalities; approximately 25% of fatalities occurred in 5% of buildings.
- It is projected that the strengthening of these 200 buildings can be achieved at accost of US $40-80 million and will result in saving over 6000 lives in the event of the design earthquake.
- Guidelines for seismic strengthening were developed. The guidelines included strengthening details (drawings) and examples based on MM construction for use by local engineers.

8. REFERENCES

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