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Institute of Industrial Science, The University of Tokyo

Potentiality of Road Blocking to Improve Evacuation Environment from Tsunamii

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INTRODUCTION

By the Great East Japan Earthquake of March 11, 2011, a tsunami with unimaginable proportions was induced and it assailed the region, killing many lives. In its aftermath, tsunami evacuation procedures came under review. The Japanese Government had set evacuation on foot as the basic rule for tsunami evacuation. However, when a tsunami warning was issued in Ishinomaki City, Miyagi Prefecture, following the strong earthquake at the end of 2012, many people attempted to evacuate to a higher ground by cars, 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, 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.

DESCRIPTION OF THE STUDY

This study analyzes the possible reduction of the total time required to evacuate by closing key roads (links) in the network. We take Shizuoka

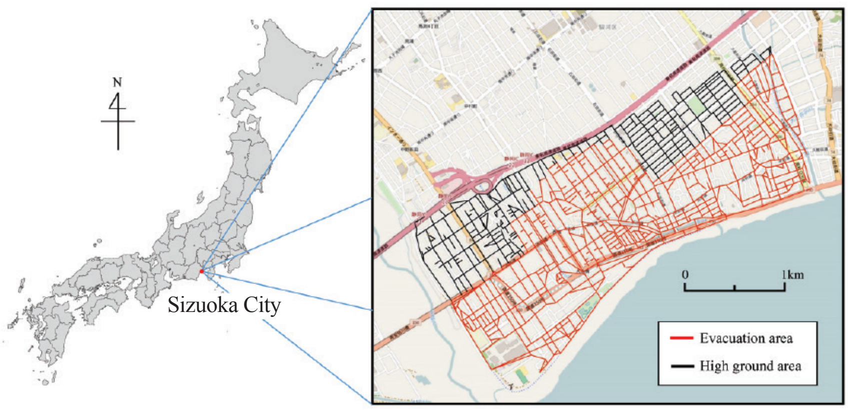


Figure 1: Details of the road network in the subject area

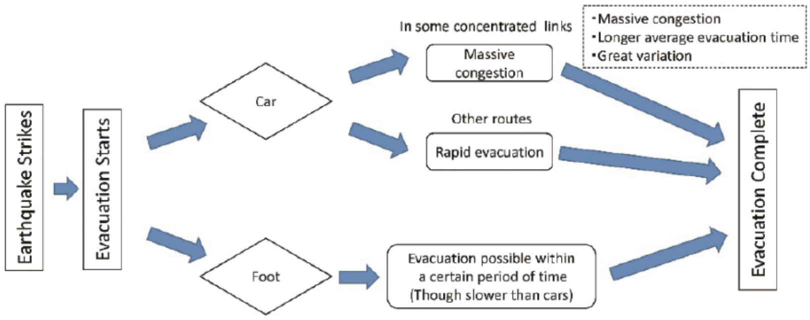
City as our example, where tsunami disaster by a Nankai megathrust earthquake is anticipated.

When a major earthquake strikes, evacuees will start to evacuate from a point in the red-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.

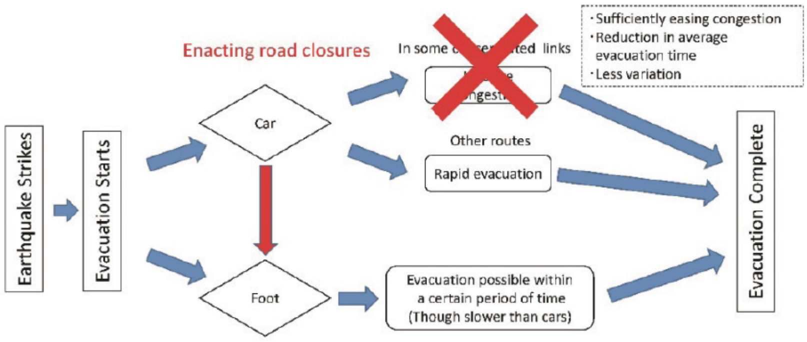
It is assumed that people will choose the shortest evacuation route and evacuation time by car and by foot. This was modeled using a logit model, which is a method to predict the selection behavior of a means of transportation.

If there were no road closures, a large percentage of people would choose car, as that would allow them to evacuate more quickly while fewer people would choose to walk. Although evacuation speed on foot is slower than that by car, because of the absence of congestion, 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 longer.

For this reason, road closures are 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



(a) Where road closures are not enacted



(b) Where road closures are enacted

Figure 2: Easing congestion by enacting road closures

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 for evacuation (Figure 2).

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 would not take congestion into account and assigned movement speeds for each link using the Bureau of Public Roads (BPR) function.

Ultimately, we can calculate several road closure combinations which optimize various factors. It should be closely discussed what factor should be optimized. For example, maximum evacuation time is one of the factors when we focus on the worst person. In this study, we weighted all of people equally, and minimize the average evacuation time. It is compared to the situation with no road closures.

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, this 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.

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 by 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.

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 blue lines are the links that are subject to road closure. Generally, people are supposed to evaluate in a north-westward and north-eastward directions, so it is effective to enclose the roads toward such directions. Actually, we can confirm that relatively long northwestward roads are closed.

Figure 3: Network showing road closure locations

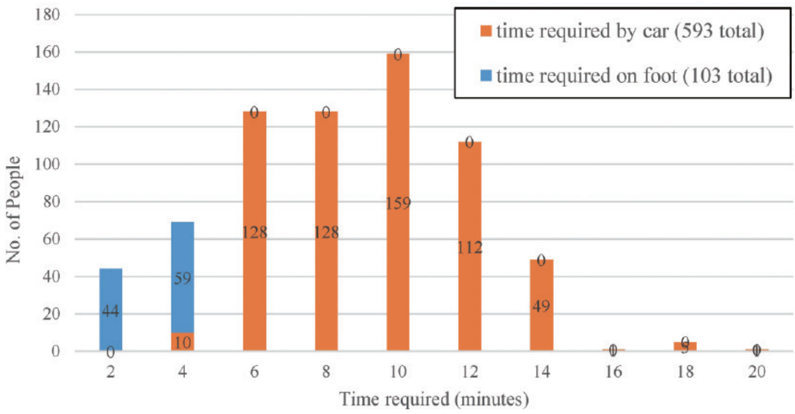


Figure 4: Time distribution in generation 0 (no road closures)

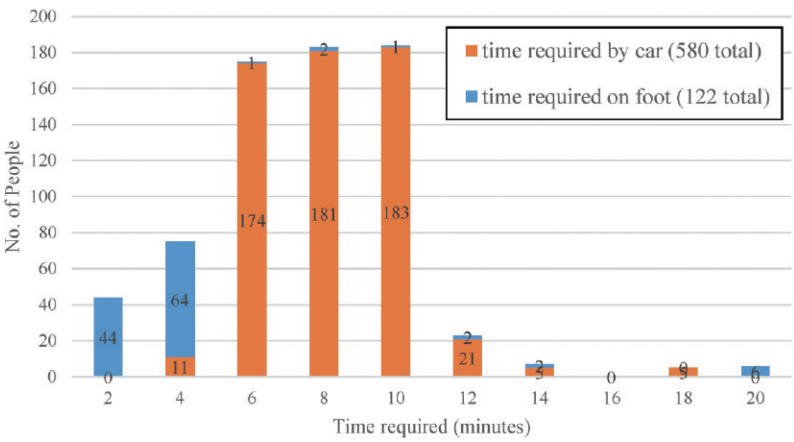


Figure 5: Time distribution in generation 100 (optimal solution)

The distribution graphs of evacuation times from each node to their evacuation sites are shown in Figures 4 and 5. These figures show comparisons of car traffic before and after road closure, respectively. It can be seen that there are roads with reduced traffic volumes and that vehicles have taken detours.

FUTURE PLANS

These trial calculation results still leave some issues unresolved. 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. However, in reality, the flow of car traffic is dynamic; hence, by extending the model to evaluate dynamical flows, we are able to calculate more accurate evacuation time. This extension also enables us to derive the number of people who are captured by tsunami by overlapping tsunami rushing and dynamical traffic flows, which is the most important evaluation factor in such analyses.

7th Joint Student Seminar on Civil Infrastructure: Bangkok, Thailand

By Y.Honma

The 7th Joint Student Seminar on Civil Infrastructure was held on August 19th, 2015 at Sasa International House of Chulalongkorn University, Thailand. The seminar was composed of invited professor section and student presentations. Three professors made invited lectures about leading topics of civil engineering, and fourteen students from universities in Thailand, Japan, and Korea gave presentations on their researches in different fields. Three students from the University of Tokyo were awarded "Excellent Presenters". Owing to the tragic bomb accidents which was happened at the same time in Bangkok, planed fieldtrip tour was cancelled for safety reason. Through the seminar, all of seminar participants shared not only research perspectives, but also, most importantly, a platform to develop a network of friendship that is invaluable as an informal platform to exchange ideas and information in the future.

Photo of seminar participants

SATREPS: 1st JCC and Kick-off Meetings

By A.Kodaka

On September 18th 2015, the 1st Joint Coordination Committee (JCC) meeting was held at Grand Amara Hotel in Nay Pyi Taw, Myanmar. JCC is the highest decision making body of the project and it approves an annual work plan, reviews overall progress, and exchanges opinions on major issues that may arise during the implementation of the project. A Kick-off meeting was also held at the opening of JCC meeting to celebrate the launch of the project. The meeting was opened with addresses from H.E. U Ko Ko Oo, Union Minister of Science and Technology (MOST), Prof. Aye Myint, Rector of Yangon Technological University, and Prof. Kimiro Meguro, Director of ICUS. Subsequently, JCC meeting chaired by H.E. U Ko Ko Oo was opened and following topics were discussed and agreed: Revised Project Design Matrix and Plan of Operation, six research groups progress reports and future activity plans, necessary data, and project members. The meetings were successfully closed with signing of Minutes of Meetings (M/M). A total of 41 people participated in JCC meeting from major counterpart ministries and organizations including MOST, Ministries of Transportation, Agriculture and Irrigation, Construction, and Yangon City Development Committee.

Signing of M/M (From left: Prof. Kimiro Meguro, H.E. U Ko Ko Oo, and Prof. Aye Myint)

Student research: Seismic Retrofitting of Unreinforced Masonry Houses with Abaca Fiber Reinforced Mortar and Abaca Rope Mesh

By: Suhelmidawati Etri

In the last hundreds years, there were many earthquakes have occurred in around the world, including developing countries, which caused a big amount of fatalities. Mainly, these fatalities are due to the collapse of unreinforced masonry (URM) buildings, which were very common in developing countries. Most URM buildings are built with little or no consideration of seismic loading, and these are not capable of resisting the expected seismic ground motion. Regarding these facts, retrofitting of URM buildings is the key issue for earthquake disaster reduction, especially for reducing human casualty. For this reason, there are many kinds of retrofitting materials and methods have been developed and used to strengthen URM houses, such as Fiber Reinforced Polymers (FRP), steel mesh cage, surface treatment, etc. They can contribute somehow to increase strength and modulus for structural applications. However, they are relatively expensive and not available in many parts of the world, which is of prime importance in the third world countries. Therefore, we propose to use a natural fiber called Abaca fiber as reinforcement in cement lime mortar, Abaca Fiber Reinforced Mortar (FRM) and Abaca fiver rope in mesh style, Abaca Rope Mesh (ARM). Abaca is a locally available and inexpensive material with high tensile strength. In order to investigate the effectiveness of these methods, the experimental tests were conducted consists of the axial tensile tests, in-plane tests, out-of-plane tests, and shake table tests. Based on the results obtained by the above tests, it can be concluded that FRM and ARM methods have high potential for retrofitting URM houses in developing countries by showing the larger deformation capacities and bigger energy dissipation capacities.

Shake table test

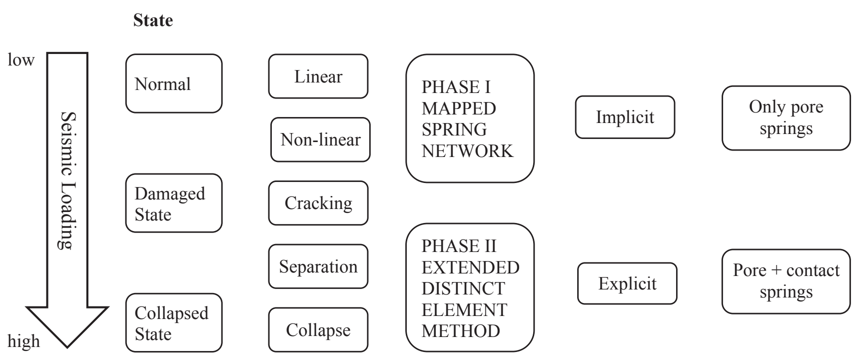
The 3rd International Conference on Urban Disaster Reduction held in US, 2015

Development of Simplified Numerical Model for Seismic Collapse of RC Frame Structures

By Rajasekharan Shanthanu Menon

Collapse of buildings due to an earthquake is completely unacceptable. The combination of wide usage of Reinforced Concrete (RC) framed structures for residential buildings in earthquake prone areas and shoddy design and construction practices, exposes the high vulnerability of this type of buildings to a seismic hazard. Assessing the collapse capacity of such buildings in advance is very important for disaster reduction. There are various methods to assess the collapse capacity of buildings but there always seems to be a stand-off between the applicability/ reliability of these methods and the computation effort involved. Moreover, for better reliability, a large number of simulations have to be performed to compensate for the epistemic/aleatoric uncertainties, further increasing the computation effort required, sometimes, rendering most numerical methods impractical.

Considering the above problem, an effective two-phase numerical collapse simulation of structures can be performed, which can predict the initial behavior of RC structures (elastic/nonlinear/crack initiation/ stiffness degradation/ maximum load capacity) through a finite element mapped nonlinear RC spring network (implicit numerical integration) and predict the final behavior of structures (geometric non-linearity, instability, separation, and collision) through the Extended Distinct Element Method (explicit numerical integration). By using the proposed scheme, large number of simulations can be performed in moderate computing environments, which is useful for practical vulnerability assessment of buildings, especially in developing countries.



SATREPS activity report: Infrasfrucfure (management) group

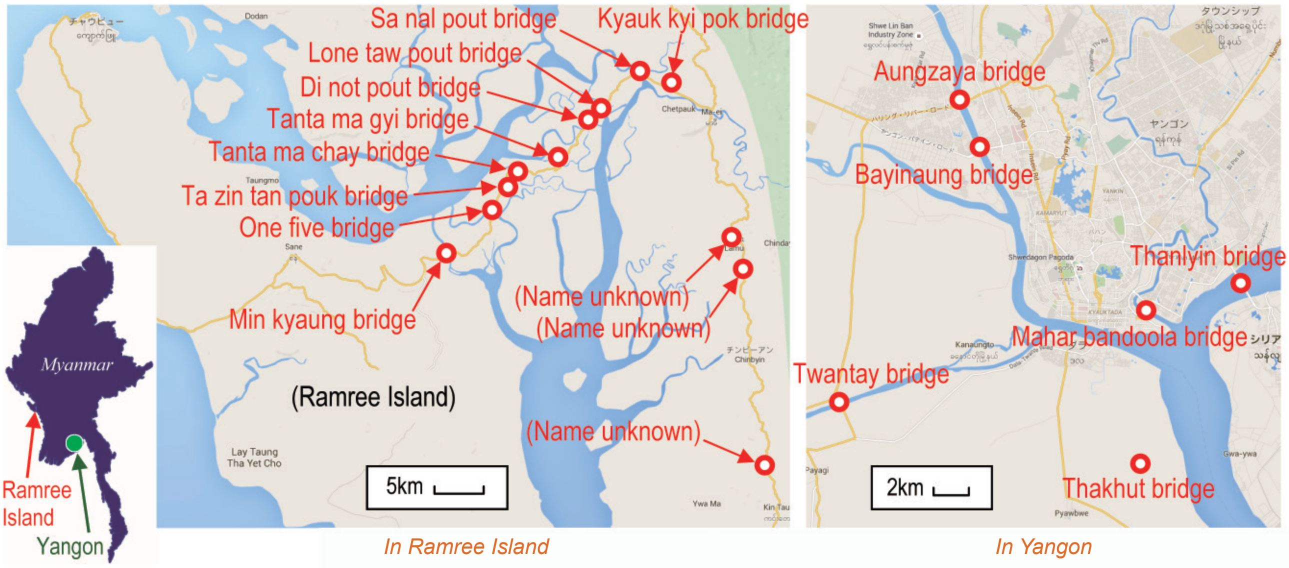
By K. Matsumoto

The infrastruture (management) group of SATREPS conducted the site investigation on deteriorations of road bridges in Myanmar from 7th to 11th September, 2015. The investigators were Prof. Yokota, Dr. Nagai, Dr. Miyashita, Dr. Henry and the author. Figure 1 shows the target bridges. Bridges in Yangon City and Rakhine State were investigated.

Photo 1 shows Thakhut bridge, which is a simply-supported RC girder bridge located in southern region of Yangon City. As shown in Photo 1(a), the girder moved from the center of piers and falling of the girder is concerned. It is considered that the movement of the girder is caused by soft ground condition in Yangon region and insufficient strength of the foundation. Photo 1(b) shows the bottom side of the slab of Thakhut bridge. Severe damage due to corrosion of reinforcing bars can be seen, while almost no damage was observed in the neighbor girders. One of the possible causes of the damage to these slabs is inner chlorides induced by improper materials such as sea water.

Photo 2 shows bottom side of RC slabs of the bridge, which is located in the national road in Rakhine State near the Ramree Island. Even though only around 10 years have passed after the construction, significant steel corrosion occurs in the briges in this region. The person of MOC (Ministry of Construction, Myanmar) explained that the severe corrosion occurred due to the use of sea water and sea sand in the concrete.

As a conclusion of this site investigation, it is noticed that movement of substructures due to soft ground condition in Yangon region and initial defects due to low construction quality are one of the primary factors of the recent deterioration problem of bridges in Myanmar.



In Ramree Island *In Yangon*

Figure 1: Target bridges of the site investigation

(a) The girder moved from the pier (b) Significant damage to the slab vs. less damage in girder

Photo 1: Damage to Thakhut bridge (Yangon)

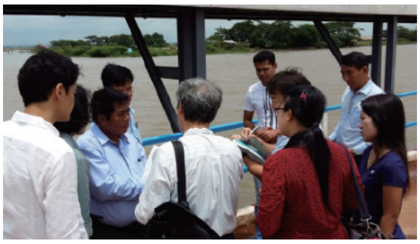
Photo 2: Damaged RC slabs of the bridge (Rakhine)

SATREPS Activity report: Water-related disaster group

By A. Kodaka and A. Kawasaki

From August 17 to 24, 2015, Water-related disaster group conducted a workshop and a joint field survey with stakeholders in Myanmar. The workshop led by Keio University's team was held at Yangon Technological University (YTU) on 18th and 19th August 2015 with the title of "Stakeholders workshop for designing water–related disaster management system". The purpose of the workshop was to elicit requirements of stakeholders for water resource management system in Myanmar. A total of 32 people participated in the workshop from various governmental agencies: Irrigation Department (ID), Ministry of Agriculture and Irrigation (MAI), Department of Meteorology and Hydrology (DMH), Ministry of Transportation (MOT), Directorate of Water Resources and Improvement of River System (DWIR), MOT, and Relief and Resettlement Department (RRD), Ministry of Social Welfare, Relief and Resettlement (MSWRR). The workshop was successfully closed with active discussion on issues and solutions for sustainable use of the system. Subsequently, we conducted the field survey to Bago River basin with Myanmar project members including YTU, ID, and DMH, to understand a situation of flooding, response and flood relief operation by government agencies. Firstly, we investigated operations of water-related infrastructures managed by IDI such as weir, sluice/lock gate, and cannels. We also visited hydro-metrological observation stations of ID and DMH to understand their situation of data acquisition and data sharing among government agencies. Secondly, we visited Bago offices of RRD, and General Administration Department (GAO) to investigate flood relief operation of Myanmar government. We also could investigate storage of flood aid which was located in a temple. Lastly, we visited flood prone areas to investigate flood response behavior of local residents including interview survey to temples that take important roles on evacuation. In total of 11 people attended the field survey. The results of the workshop and the field survey will be summarized as one of the outputs of the project. For more information about the flooding, please refer the official situation reports published by National Natural Disaster Management Committee (NNDMC).

Bago office of RRD



A sluice gate managed by ID

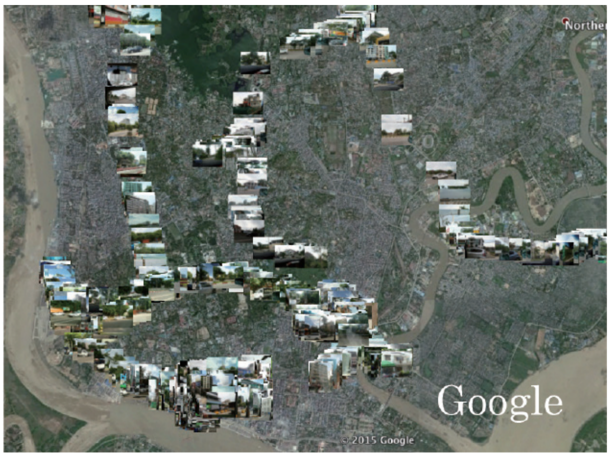
Interview to a monk

SATREPS activity report: Earthquake-related disaster group

By H. Gokon

Building team of Earthquake-related disaster group in the SATREPS project visited Yangon City from September 15 to 25, 2015 to have a discussion with the counterparts in Yangon Technological University (YTU) and Yangon City Development Committee (YCDC) on future plan, and to conduct field surveys for understanding the fundamental vibration characteristics of buildings in Yangon City and ground condition. From Japanese side, researchers from the University of Tokyo and Tohoku University participated in the trip.

As one of our missions is to assess the vulnerability of buildings in Yangon City to natural disasters, we investigated the types of building structures and their features. Photo in



Distribution of sites visited by the building team the right shows the sites visited by this team members. We took photos of building facade by GPS camera, and all the data were displayed on Google earth. We could find that main structures in the urban area, not only in the downtown but also in the residential area, were made of reinforced concrete (RC) with brick wall. We could also have an opportunity to enter the a century-old RC buildings, and survey the current condition from the inside of the structure.

As a preliminary survey to investigate the ground condition and the building characteristics in the future, we tried microtremor measurements at some locations in Yangon City. We could learn several types of problems for deploying the survey in the whole Yangon City, and once again, understood the importance of the corporation with counterparts.


Members joined site survey in September, 2015


Round table discussion among members

In the discussion with YTU and YCDC, we mainly discussed the data needed for the vulnerability assessment and how to map the information. That was the first meeting for some members, and was good opportunity to know each other, especially background of the members (see above photo).

Editor's note...

SATREPS project has been actively carried out by ICUS members and partners. During the time of this volume, each research group performed field survey. To visit the sites and have discussion among members, counterpart and local engineers are very important to understand the real situation correctly and share the image of the project target. I am a member of infrastructure group and visited Rakhine region, west part of Myanmar, where the severely damaged bridges exist due to the use of salt water from sea in concrete causing the corrosion of steel. Why did it happen despite it should not be used? Local engineer explained the difficulty of getting fresh water there because that region faces sea and lowland so that even the river water contains salt. To proceed the project, it becomes important to consider the real local situation like this issue. Establishment of good partnership and communication will be a key to make the project successful.

by K.Matsumoto

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PRINTED MATTER

The International Center for Urban Safety Engineering (ICUS) is a research center located at the Institute of Industrial Science, The University of Tokyo.

The purpose of ICUS is to identify, investigate, and resolve issues towards the realization of sustainable urban systems for the prosperity and safety of society considering challenging socio-economic problems.