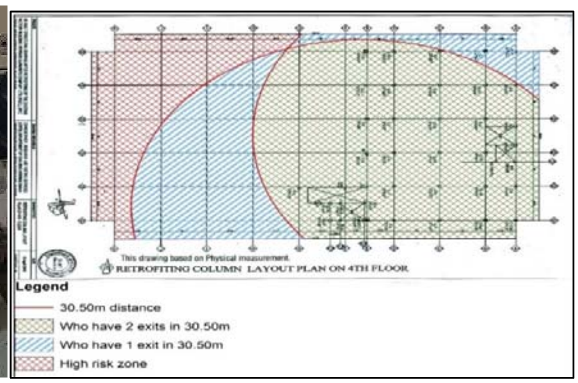
BNUS ANNUAL REPORT-2017

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY

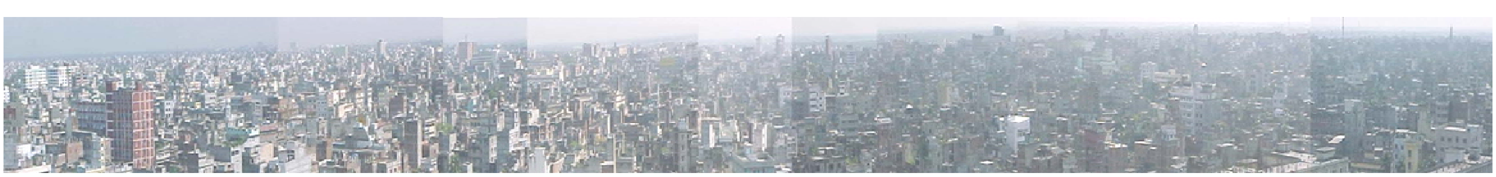
BUET, DHAKA, BANGLADESH

Edited By:

Mehedi Ahmed Ansary



April 2018



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BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

PART-I

REPORT ON RECENT (2015-2017) STRONG GROUND (EARTHQUAKE) MOTION RECORDS IN AND AROUND BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Mehedi Ahmed Ansary

1. INTRODUCTION

The 4.8 km long Jamuna Multipurpose Bridge connects the eastern and western parts of Bangladesh. Being the only road and rail link between the two regions, the bridge bears immense economic and strategic importance for the whole country. But the bridge is located in a seismically active region that can be subjected to moderately strong earthquakes from a number of sources and special earthquake protection devices have been used in the bridge. The bridge has been designed for a peak ground acceleration of 0.2g due to a 7.0 magnitude earthquake in the Bogra fault zone, which is about 25 to 40 kms from the west end of the bridge, based on study by Bolt (1987).

Jamuna Multipurpose Bridge Authority (JMBA) took necessary steps for the installation of seismic instruments on and around the Jamuna Bridge. JMBA employed Bangladesh University of Engineering & Technology (BUET) as the technical consultant for this project. The Installation of the seismic instruments on the bridge structure and six other free-field (ground) stations was completed by Kinemetrics, Inc. USA on July 10, 2003 (BUET, 2003). The Operating and Monitoring Phase of the project started on July 11, 2003.

In this report the earthquake data recorded by different SMAs for the period (2015 to 2017) has been compiled for future references.

2. STUDY LOCATIONS

29 SMAs have been deployed by BUET from 2003 to 2005 and these entire digital seismic measuring devices are located at free-field stations in and around of Bangladesh as shown Figure 1. Location of Digital Seismic Measuring Device at free-field Station (ETNA) are shown Table 1. Table 2, Figures 2 and 3 lists and show sensors and recorders installed on the bridge and bore-hole.

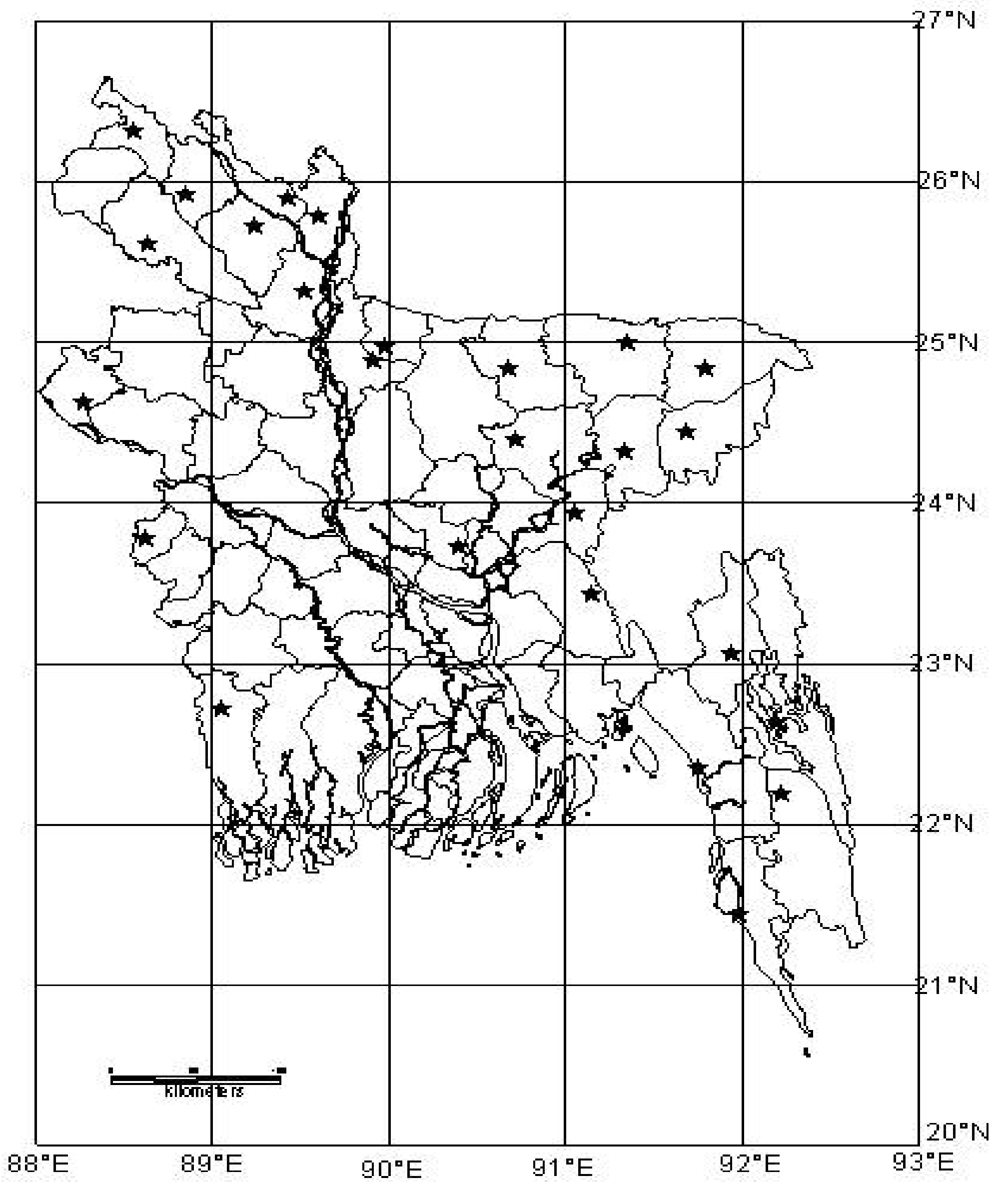


Figure 1 Location of Digital Seismic Measuring Devices (29-ETNA) in and around of Bangladesh

Table 1 Location of Digital Seismic Measuring Device Station (ETNA)

SL.No	Model	Location	Latitude	Longitude
*1	ETNA (BUET)	LGED, Bogra	23.32^0N	88.45^0E *
*2	ETNA (BUET)	LGED, Natore	23.22^0N	88.35^0E *
3	ETNA (BUET)	Jamuna Bridge West-End	23.28^0N	88.25^0E
*4	ETNA (BUET)	Jamuna Bridge East-End	23.25^0N	88.20^0E *
5	ETNA (BUET)	LGED, Mymensingh	25.43^0N	90.65^0E
*6	ETNA (BUET)	BUET-Dhaka	23.92^0N	90.25^0E *
7	ETNA (GSB)	PWD Office, Satkhira	23.85^0N	88.52^0E *
*8	ETNA (GSB)	PWD, Ashkona-Hajji camp	23.71^0N	90.38^0E *
*9	ETNA (GSB)	Pollice Staff College	23.72^0N	90.25^0E
10	ETNA (GSB)	GSB-Dhaka	23.75^0N	90.35^0E
11	ETNA (GSB)	GSB-Chittagong	22.15^0N	91.80^0E
12	ETNA (GSB)	PWD, Cox's-bazar	21.42^0N	91.89^0E
13	ETNA (GSB)	PWD, Bandarban	22.25^0N	92.32^0E
14	ETNA(JIDPUS)	PWD, Rangamati	22.72^0N	92.38^0E
15	ETNA (GSB)	PWD, Sunamganj	25.07^0N	91.32^0E
16	ETNA (GSB)	PWD, Sylhet	25.15^0N	91.25^0E
17	ETNA (GSB)	PWD, Moulvibazar	24.35^0N	91.72^0E
18	ETNA(JIDPUS)	PWD, Comilla	23.22^0N	91.35^0E
19	ETNA (GSB)	PWD, B.Baria	23.92^0N	91.25^0E
20	ETNA (GSB)	PWD, Kishoreganj	24.35^0N	90.92^0E
21	ETNA (GSB)	PWD, Netokona	24.72^0N	90.65^0E
22	ETNA(JIDPUS)	Haluaghat, Mymensingh	25.05^0N	90.25^0E
23	ETNA(GSB)	PWD, Jamalpur	25.15^0N	90.12^0E
24	ETNA(GSB)	PWD, Rangpur	25.80^0N	89.20^0E
25	ETNA (GSB)	PWD, Lalmonirhat	25.90^0N	89.35^0E
26	ETNA(JIDPUS)	PWD, Kurigram	25.60^0N	89.80^0E

SL.No	Model	Location	Latitude	Longitude
27	ETNA (GSB)	PWD, Panchagarh	26.15^0N	88.25^0E
28	ETNA(GSB)	PWD, Meherpur	23.75^0N	88.62^0E
29	ETNA(JIDPUS)	AEC, Ruppur	23.42^0N	88.75^0E
30	ETNA	Inside the Jamuna Bridge		

***Note** shaded ETNAs are out of order and needs replacement*

Table 2: List of sensors and recorders installed on the bridge and bore-hole

K2 Data Recorder Label	Sensor Type	Channel Label	Orient-ation	Sensor Location
JAMUNA located inside bridge deck near Pier P10	Displacement	D1	X	Across Isolation System at Pier P10
	Displacement	D2	Y	
	Displacement	D3	Y	Across Expansion Joint between Piers P7 and P8
	EPI Uniaxial Accelerometer	BR9	Z	Pile Cap at Pier P9
	EPI Biaxial Accelerometer	BR10	X	Deck at Pier P9
		BR11	Y	
MEGHNA located inside bridge deck near Pier P10	EPI Uniaxial Accelerometer	BR4	Z	Pile Cap at Pier P10
	EPI Uniaxial Accelerometer	BR8	Z	Deck at Pier P10
	EPI Uniaxial Accelerometer	BR12	X	Deck at Midspan between Piers P9 and P10
	EPI Uniaxial Accelerometer	BR13	X	Deck at Midspan between Piers P10 and P11
SURMA located inside bridge deck near Pier P10	EPI Triaxial Accelerometer	BR1	X	Pile Cap at Pier P10
		BR2	Y	
		BR3	Z	
	EPI Triaxial Accelerometer	BR5	X	Deck at Pier P10
		BR6	Y	
		BR7	Z	
PADMA located at west abutment	EPI Triaxial Accelerometer	AB1	X	West Abutment
		AB2	Y	
		AB3	Z	
	Borehole Triaxial Accelerometer	BH1	EW	Borehole near West End (58 m depth)
		BH2	NS	
		BH3	Z	

Note:

X means orientation across the bridge (transverse direction)

Y orientation parallel to the bridge (longitudinal direction)

Z means vertical direction

3. EARTHQUAKE DATA ANALYSIS

There are some custom-made softwares that came with the instruments to operate and monitor the whole system. One can also interact with the instruments (i.e., K2s) using the software called Quick Talk and change the settings. Quick Talk and Quick Look may be also used for downloading or viewing the incoming data without any processing. After the sensors were connected, they had to go through the Functionality Test done with the operating software. Then they had to be corrected for any offsets in the readings. Once all of these are done for each of the sensors, the system was ready. It was tested to see if data from all the channels are reaching the recorders, if they are set at real time through GPS. The GPS are set at UTC time as stated in the original documents. The system is such that each of the sensors can be configured separately, but they were kept the same at the beginning. Each sensor can be set to trigger the whole system. The trigger value for the twenty two free-field ground accelerometers was set at 0.5% of g (5 cm/sec^2). Whenever the acceleration exceeds the trigger value, automatic data recording will take place. To process, analyze and interpret the data, the software called Strong Motion Analyzer (SMA) is used. One can perform necessary filtering, corrections and plotting of the signals received from the sensor. This accelerometer gives data in North-South, East-West and Up-Down direction. Also Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), Peak Ground Displacement (PGD) and Ground Motion Orbit are shown for all the earthquake recorded by the SMAs and ETNAs according to the Table 3 and Figure 4.

Table 3: Some recent (2015-2017) earthquakes in and around Bangladesh

SL No.	Date	Name of the Earthquake	Epicentre	Magnitude	Depth (km)	Stations Recorded in Bangladesh
1	25-04-2015 (6:11:25 UTC)	Nepal EQ	28.100N,84.600E36 km E of Khudi, Nepal	7.8	8.2	BR1-BR7 on the bridge, Bogra, ~~BUET,~~ JMB West, Natore, ~~PSC~~, Ruppur and Sylhet
2	25-04-2015(6:45:21 UTC)	Nepal EQ (after shock)	44km E of Lamjung, Nepal	6.6	10	Natore
3	26-04-2015 (7:09:10UTC)	Nepal EQ (after shock)	27.771N, 86.017E21 km SSE of Kodari, Nepal	6.7	22.9	Bogra, ~~BUET~~, JMB West, ~~PSC~~ and Ruppur
4	27-04-2015(12:35:53UTC)	Nepal EQ (after shock)	26.864N 88.055E 13 km ESE of Ilam, Nepal (Near Darjheeling)	5.1	31.7	Bogra
5	12-05-2015	Nepal EQ	27.809N 86.066E	7.3	15	Bogra, JMB West,

	(07:05:19UTC)	(after shock)	19km SE of Kodari, Nepal			Natore and Ruppur
6	02-06-2015 (22:09:08UTC)	Assam EQ	25.800N 89.900E Dubri, Assam	3.9	10	Kurigram
7	03-01-2016 (23:05:22 UTC)	Monipur EQ	24.804N,93.650E 30km W of Imphal, India	6.7	55	BR9-BR11 & D1 on the bridge and Netrokona
8	13-04-2016 (13:55:17 UTC)	Myanmar EQ	23.094N, 94.865E 75 km SE of Mawlaik	6.9	136	Bogra, JMB West, Kurigram and Ruppur
9	24-08-2016 (10:34:54 UTC)	Myanmar EQ	20.923N, 94.569E 26 km W of Chauk	6.8	82	Bogra and Khagrachari
10	03-01-2017 (9:09:02 UTC)	ID-BD Border	24.015N, 92.018E20 km ENE of Ambasa, India	5.7	32	Comilla and Hazicamp

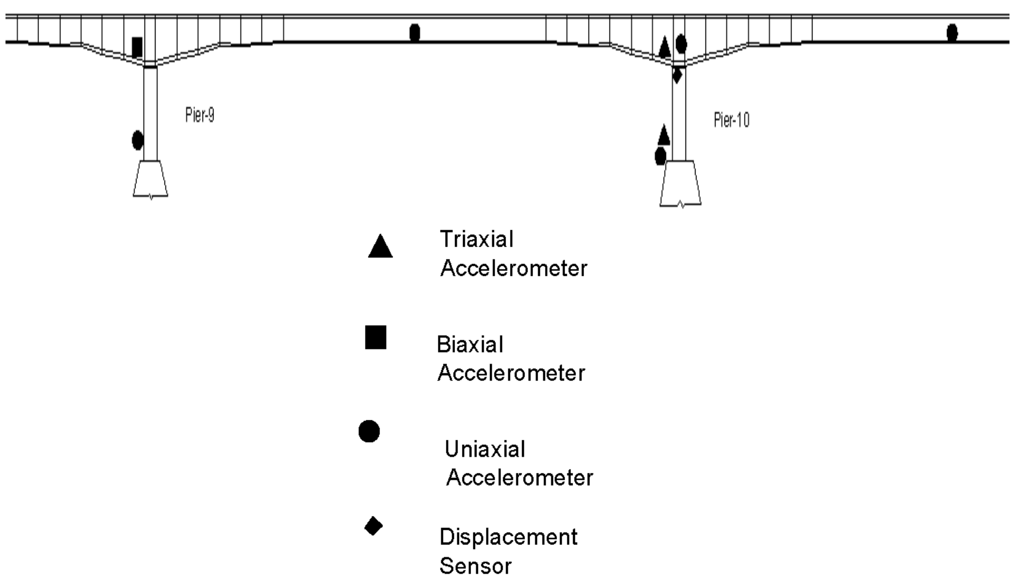


Figure 2: Location of sensors on the bridge

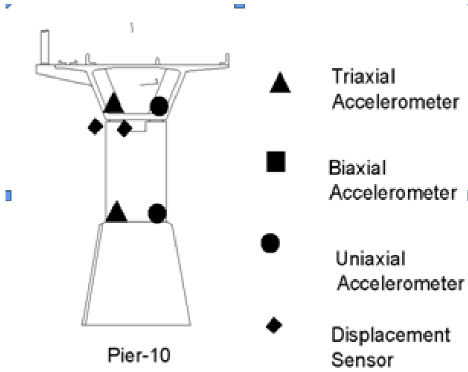


Figure 3: Location of different types of accelerometer

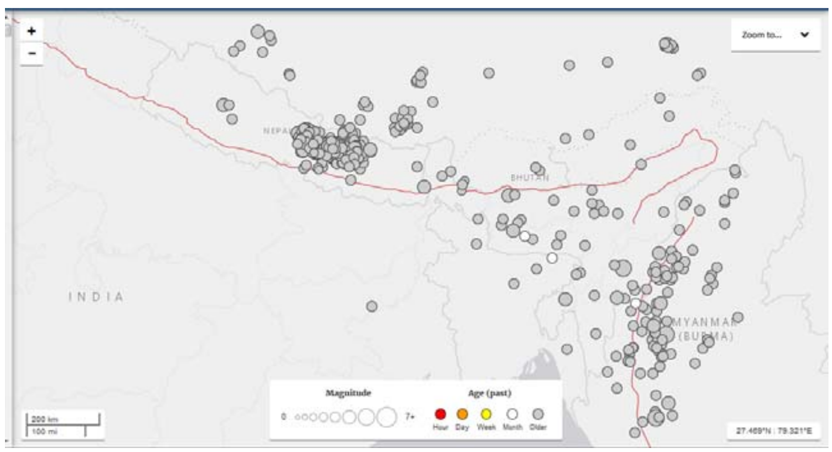
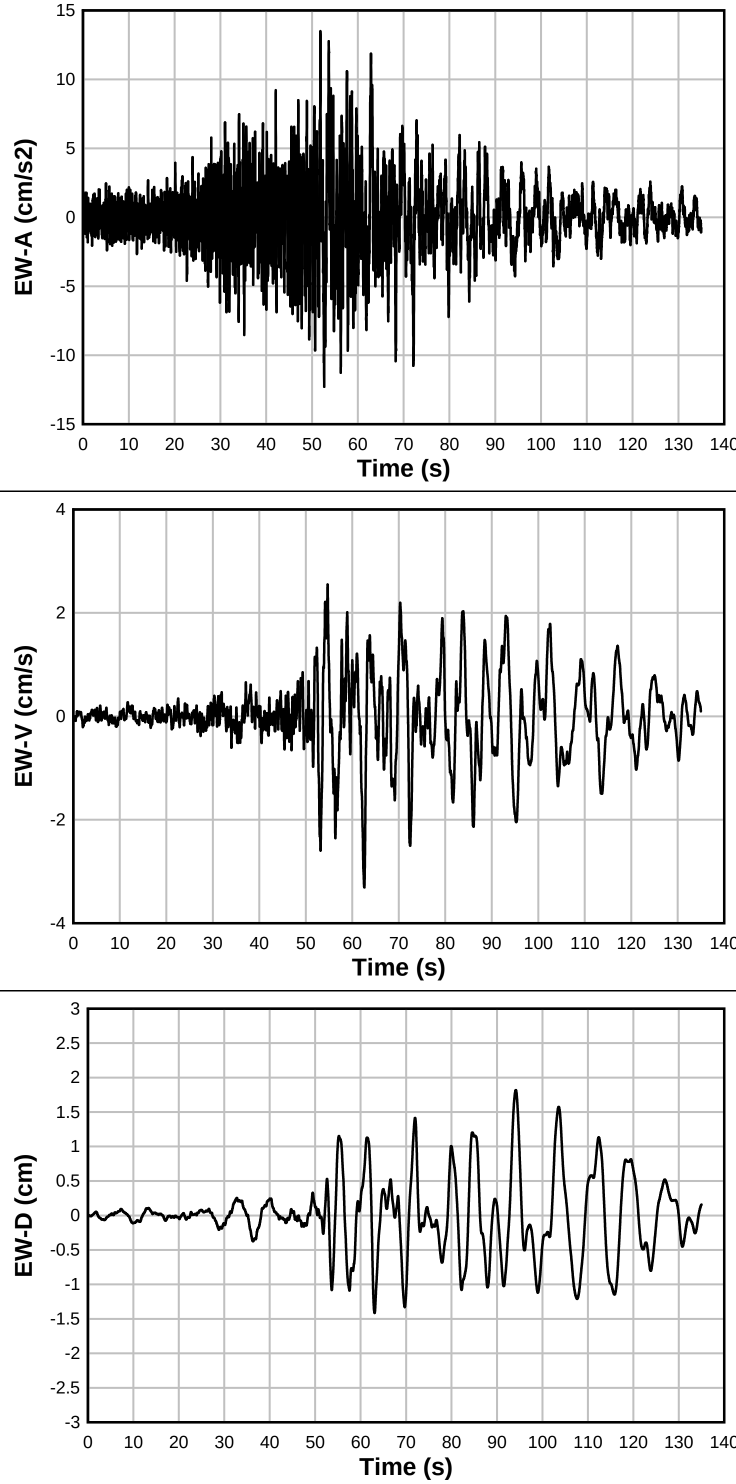
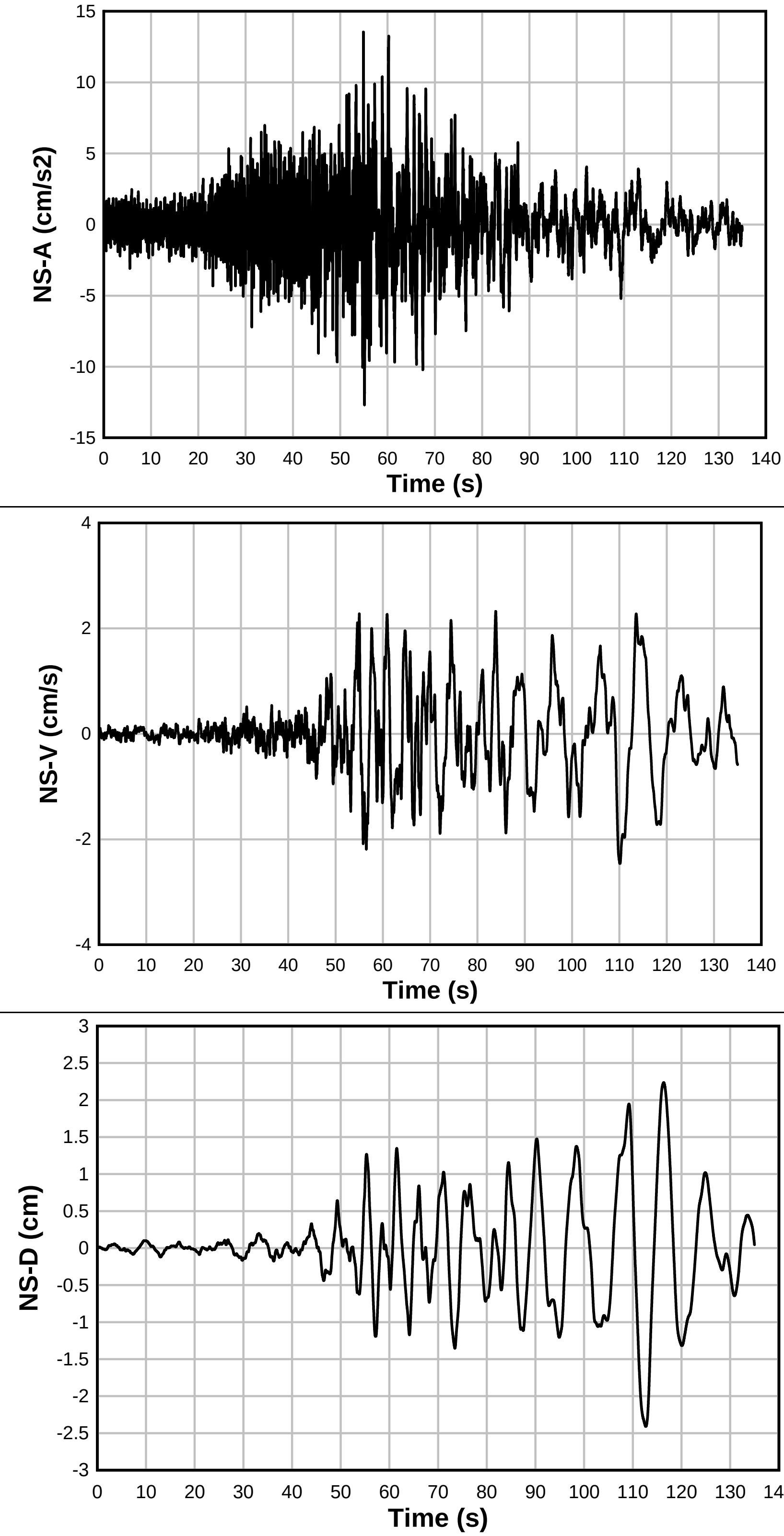


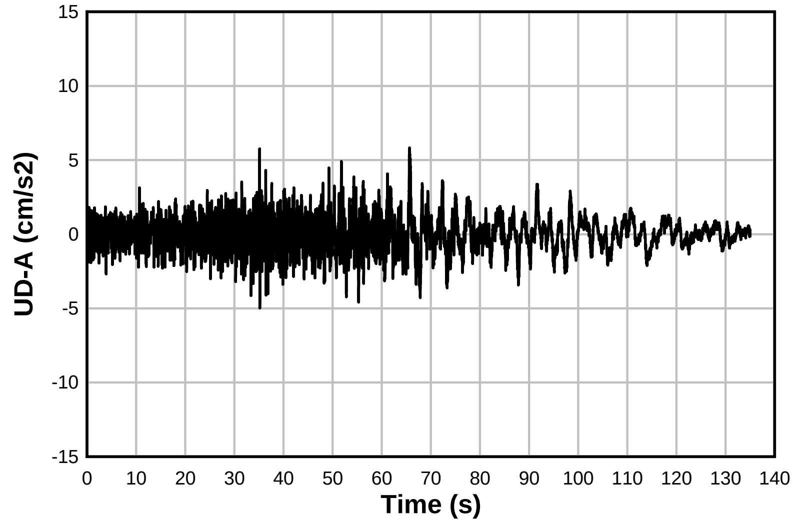
Figure 4. Locations of the recorded earthquakes

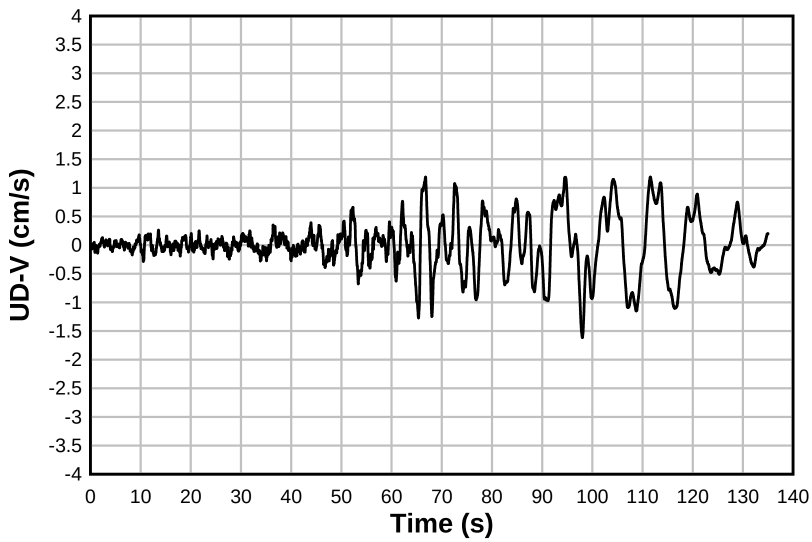


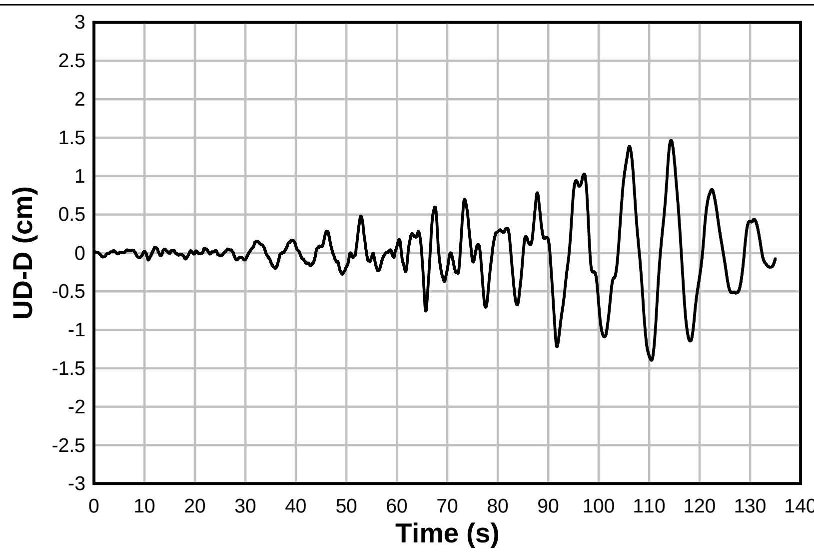
Recorded ground motion at Bogra due to 25th April Nepal EQ (EW component)



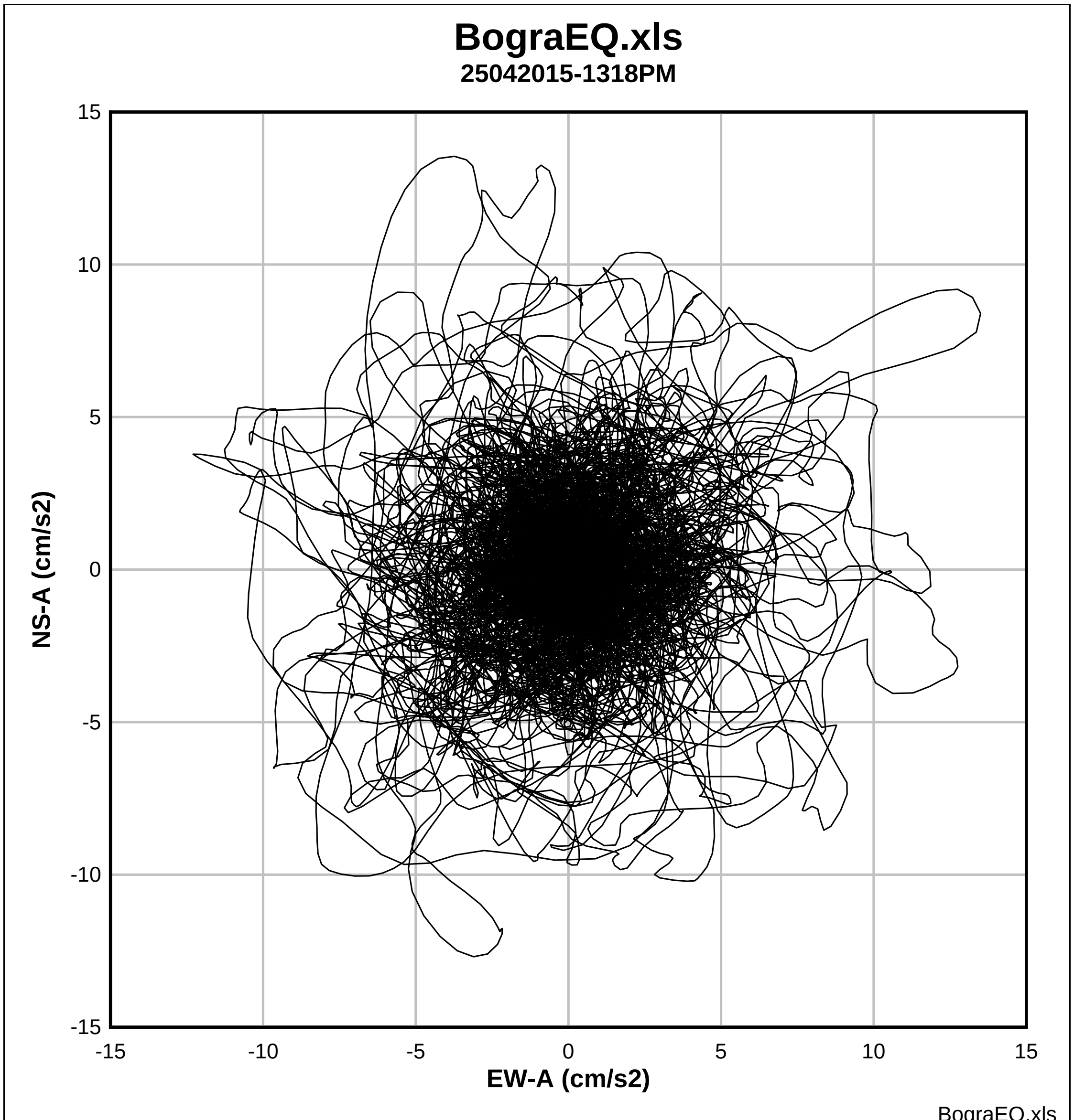
Recorded ground motion at Bogra due to 25th April Nepal EQ (NS component)



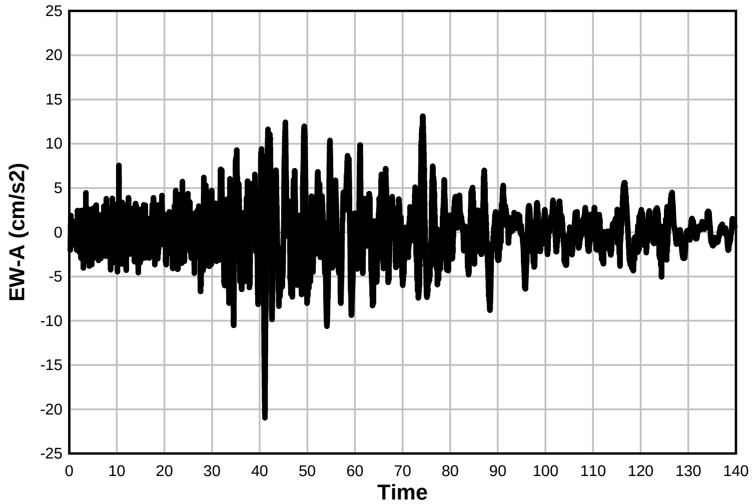


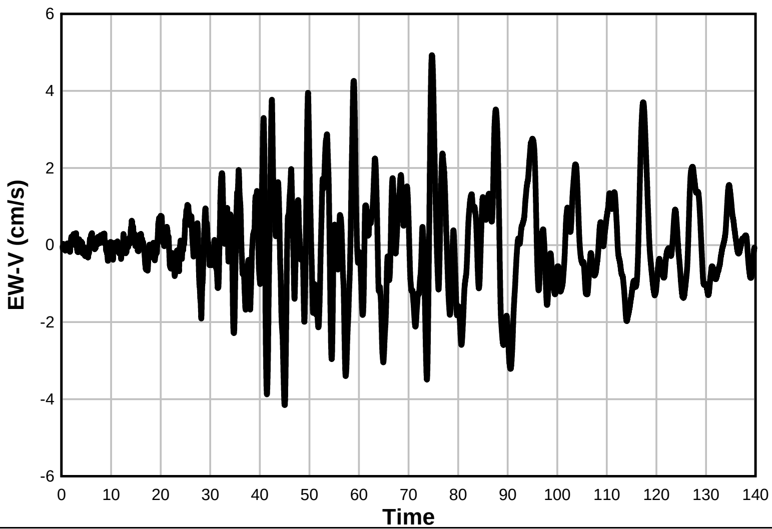


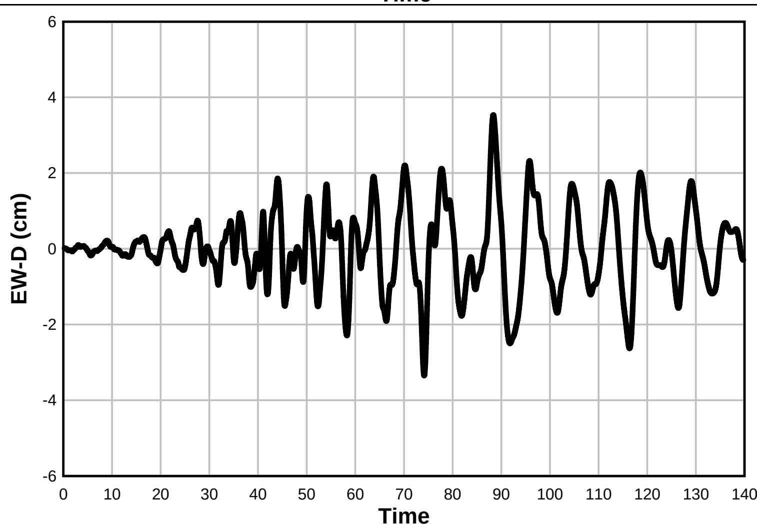
Recorded ground motion at Bogra due to 25th April Nepal EQ (UD component)



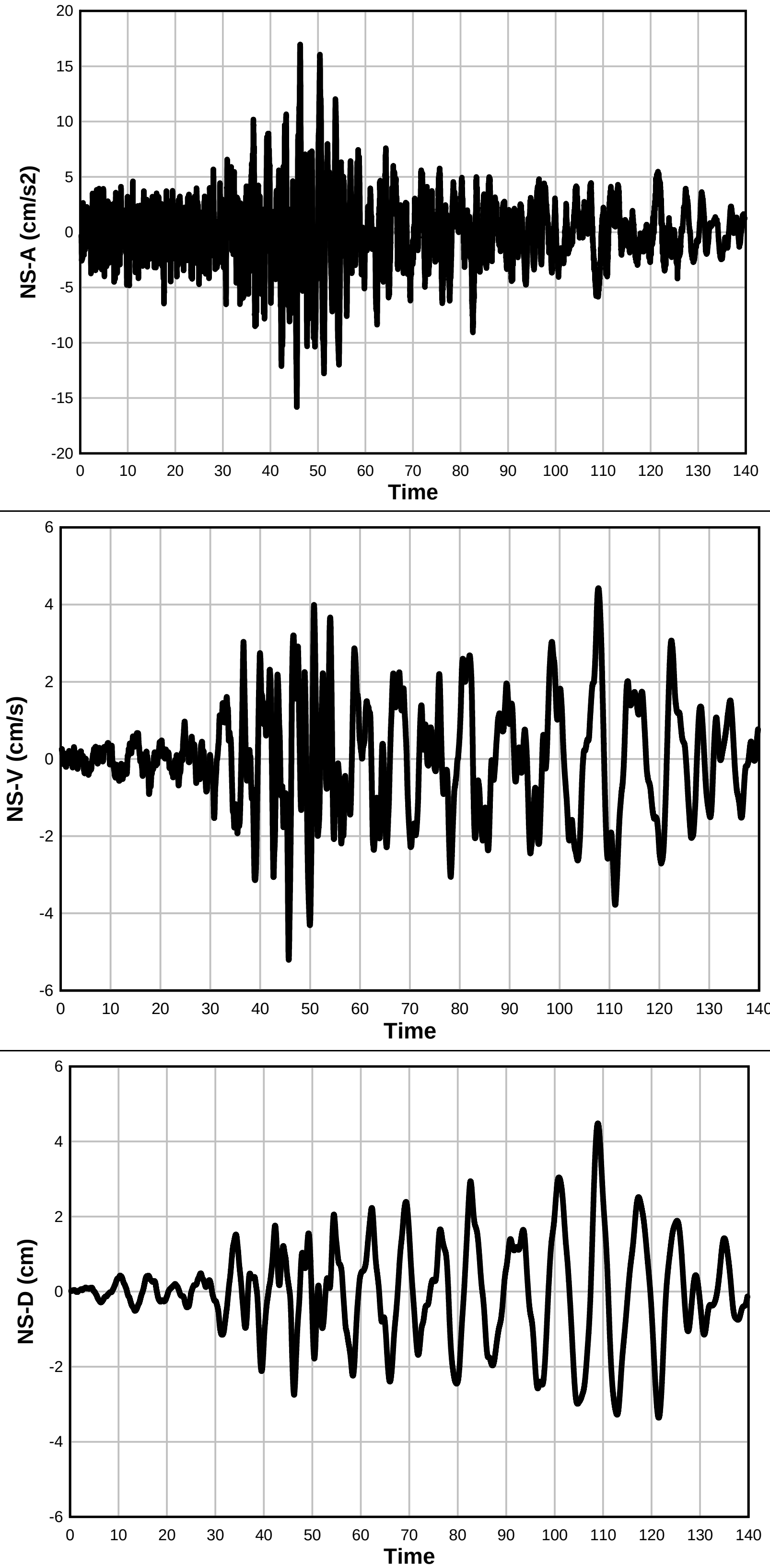
Recorded ground motion orbit at Bogra due to 25th April Nepal EQ



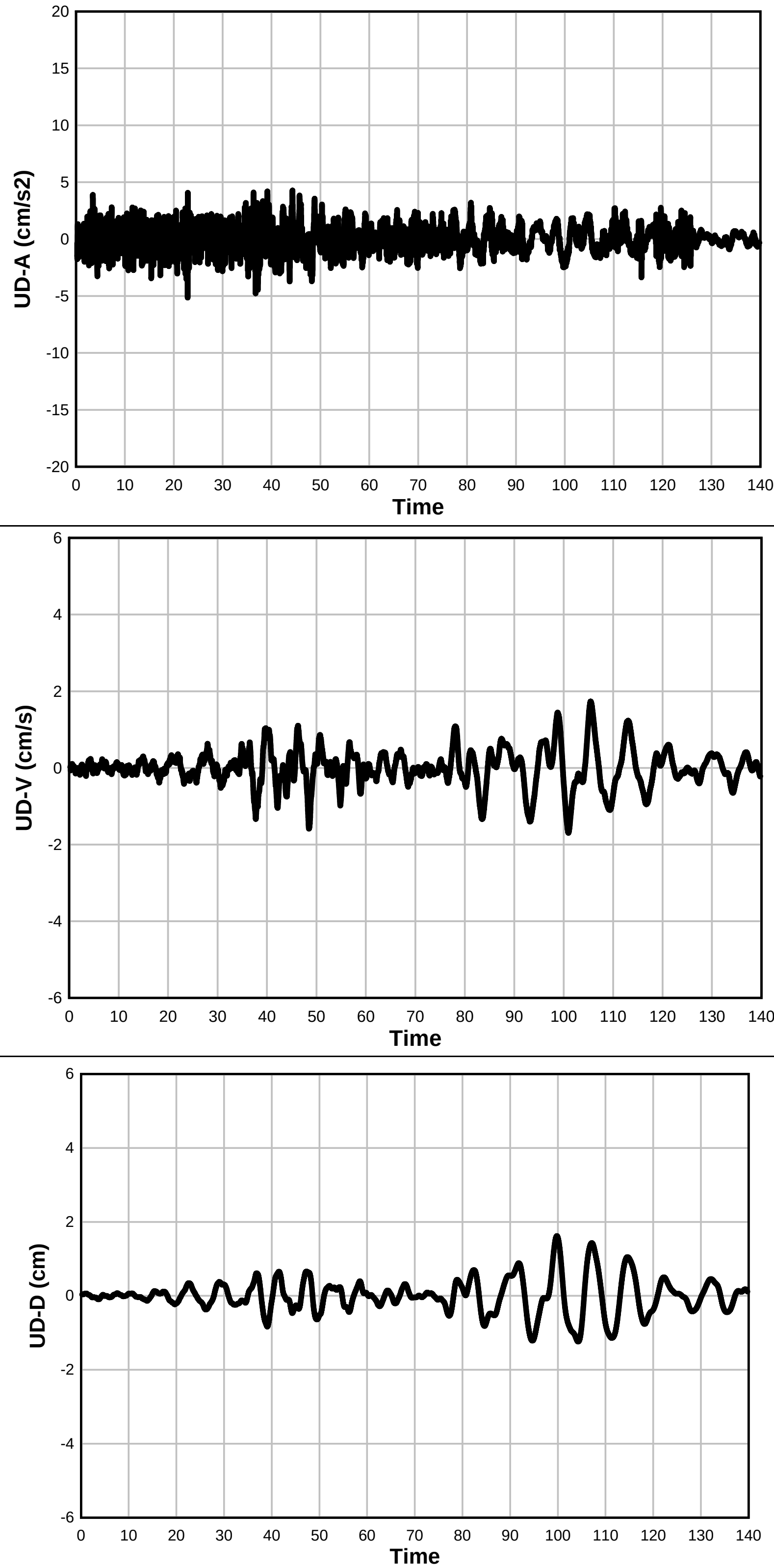




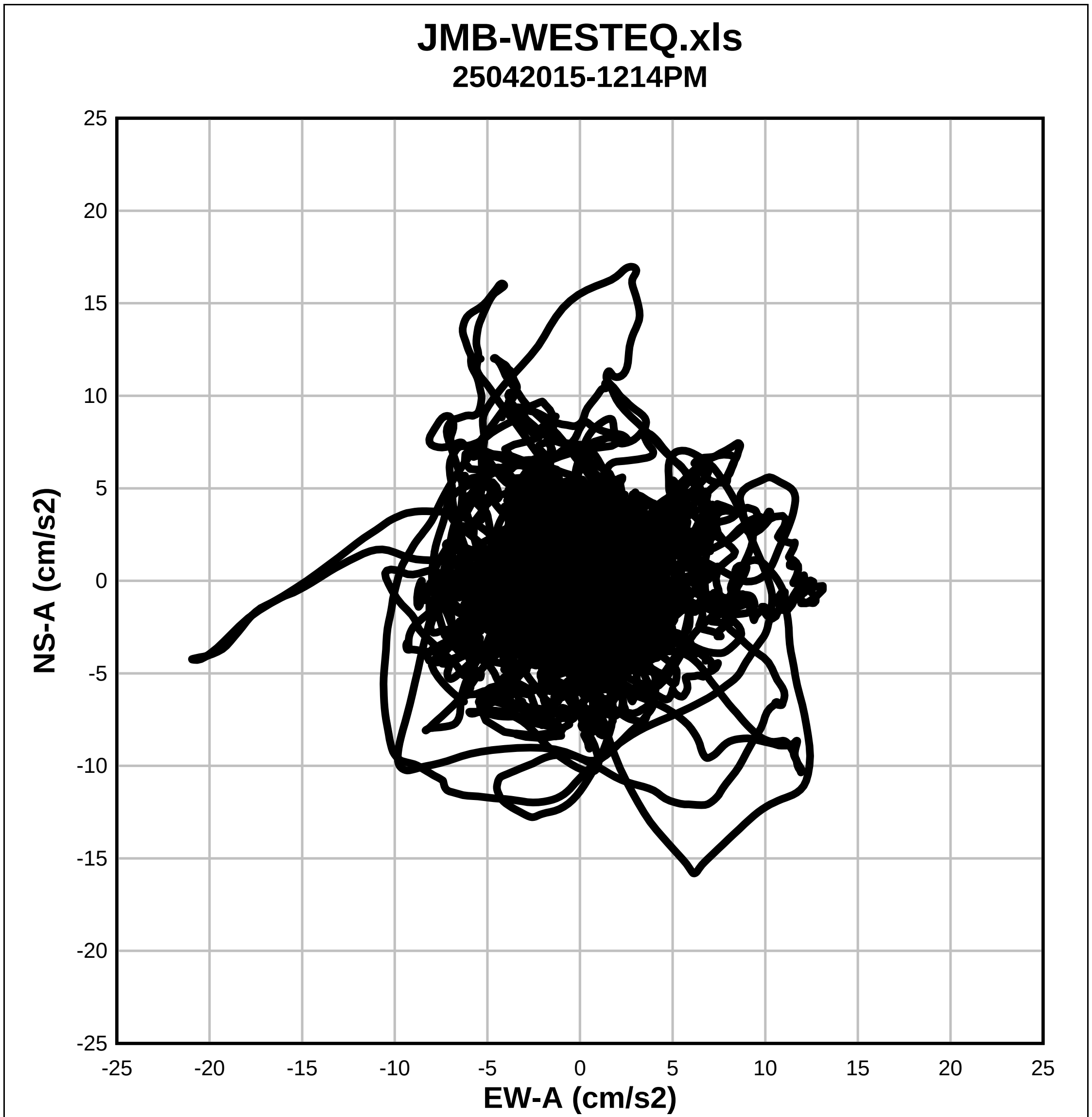
Recorded ground motion at JMB West due to 25th April Nepal EQ (EW component)



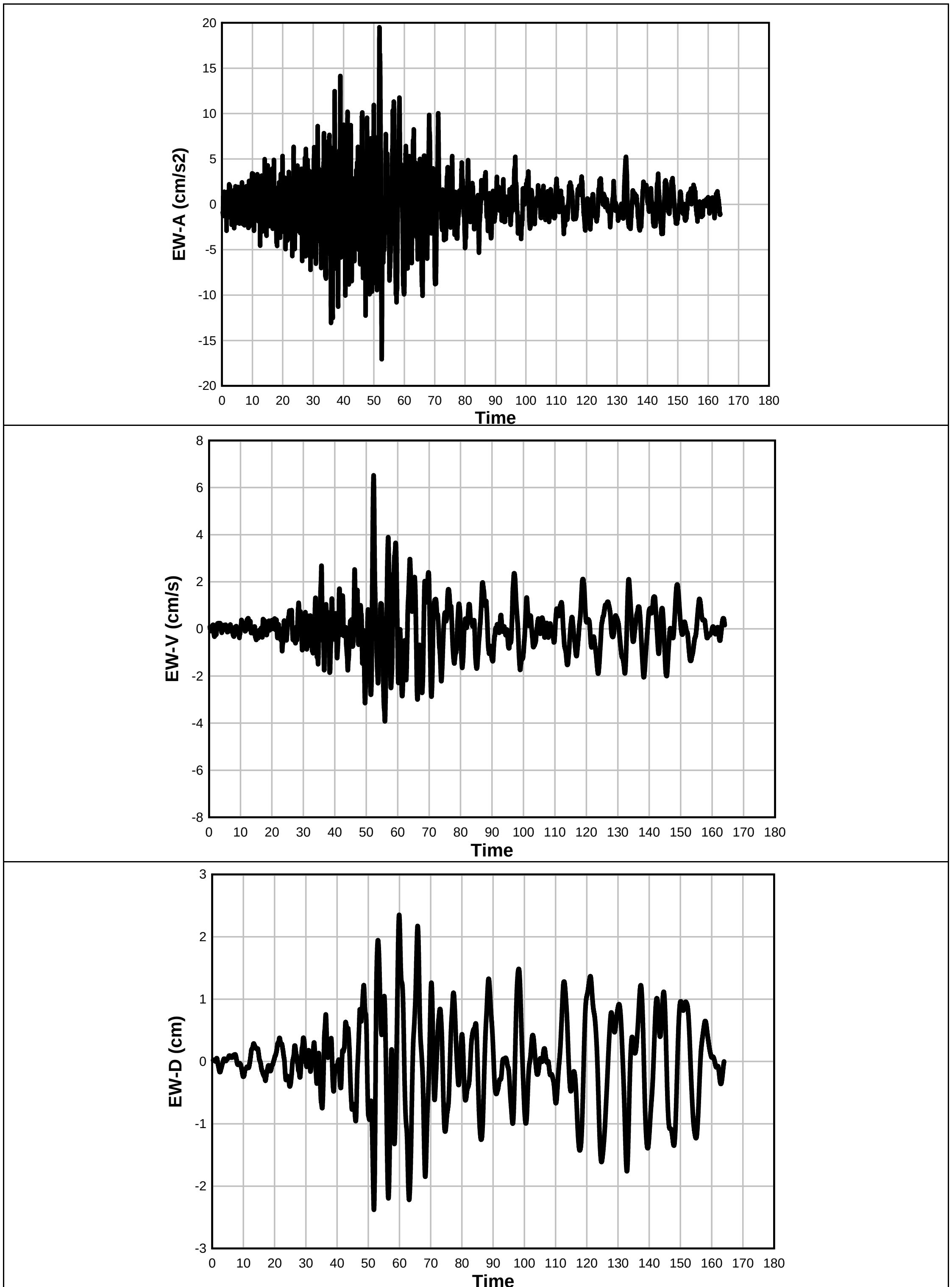
Recorded ground motion at JMB West due to 25th April Nepal EQ (NS component)



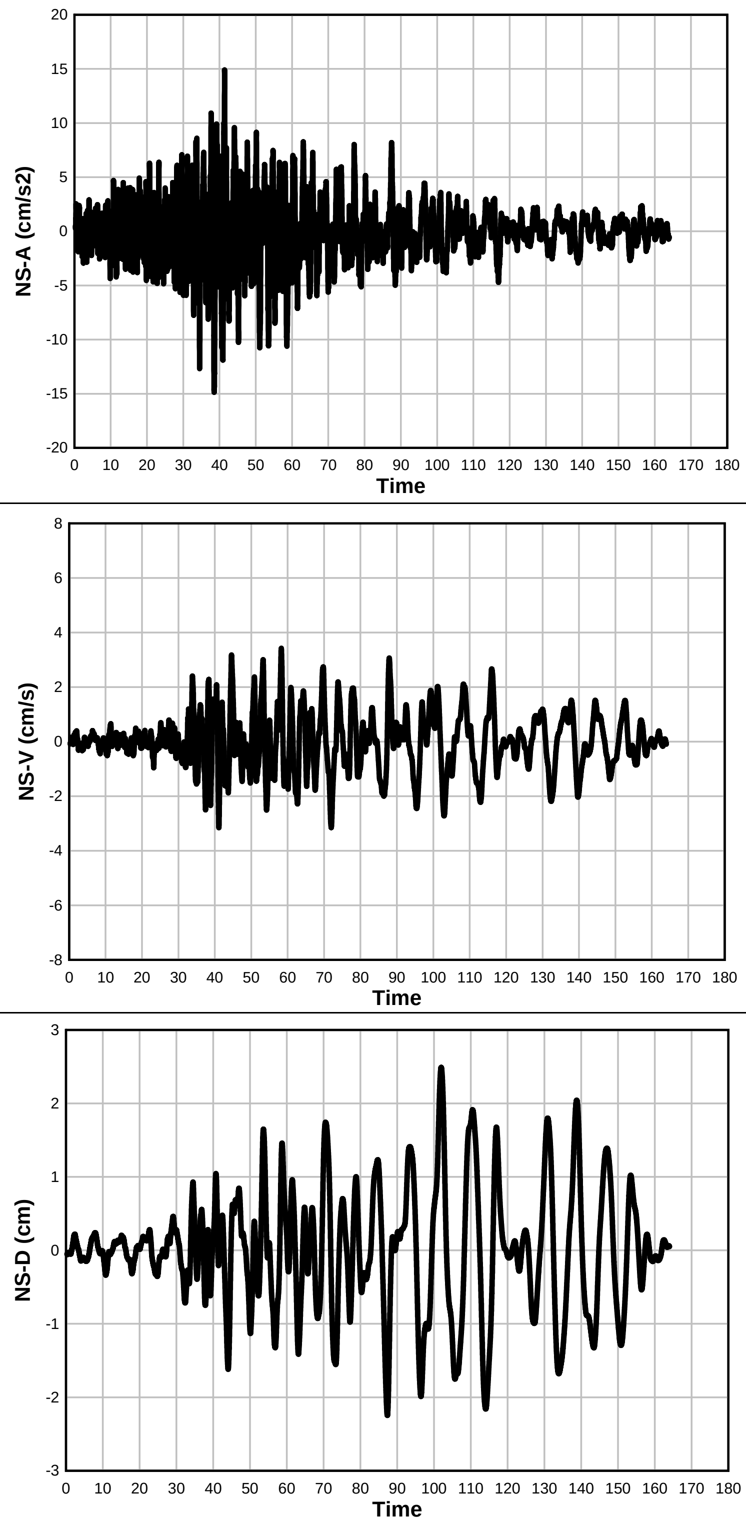
Recorded ground motion at JMB West due to 25th April Nepal EQ (UD component)



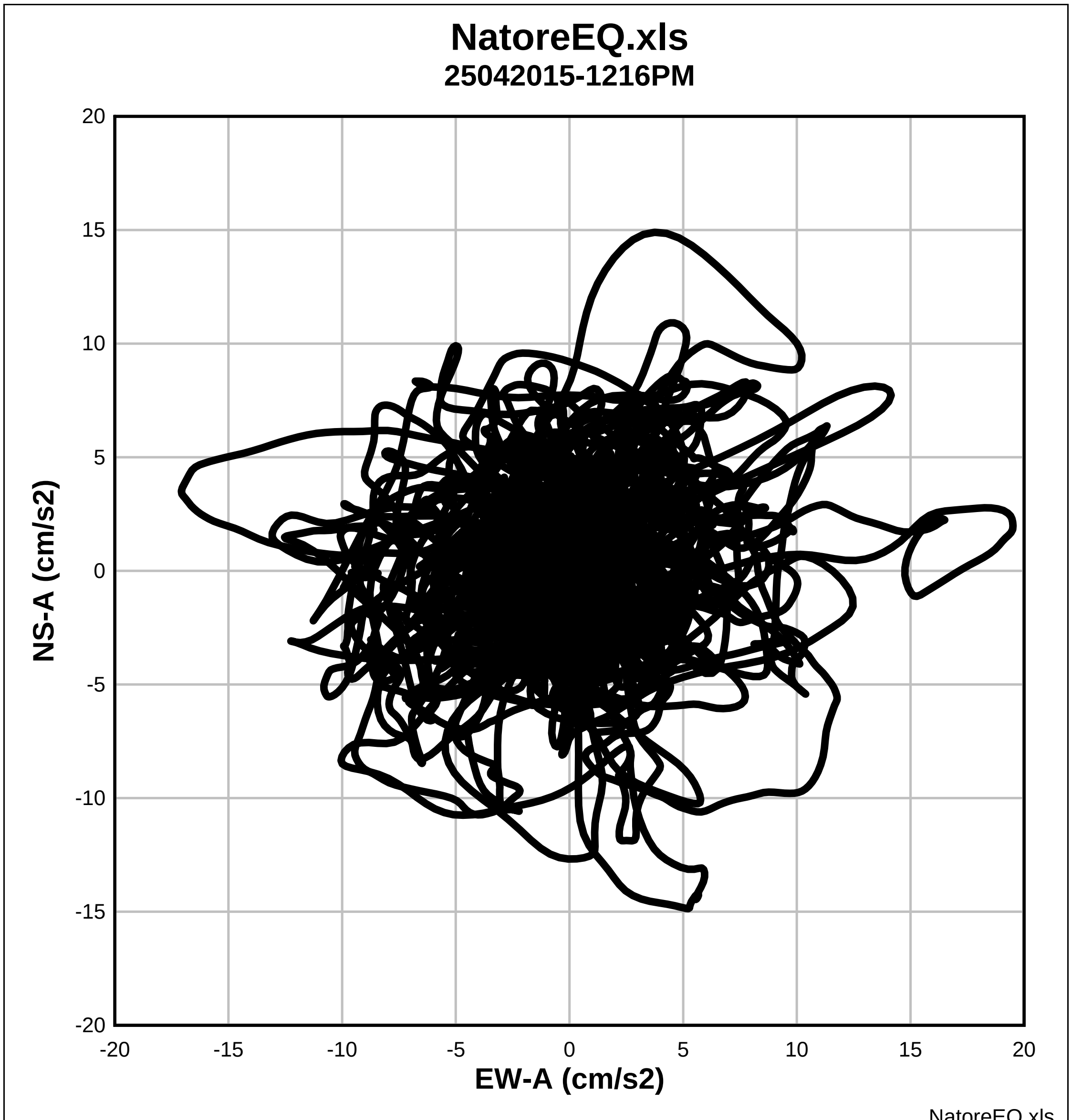
Recorded ground motion orbit at JMB West due to 25th April Nepal EQ



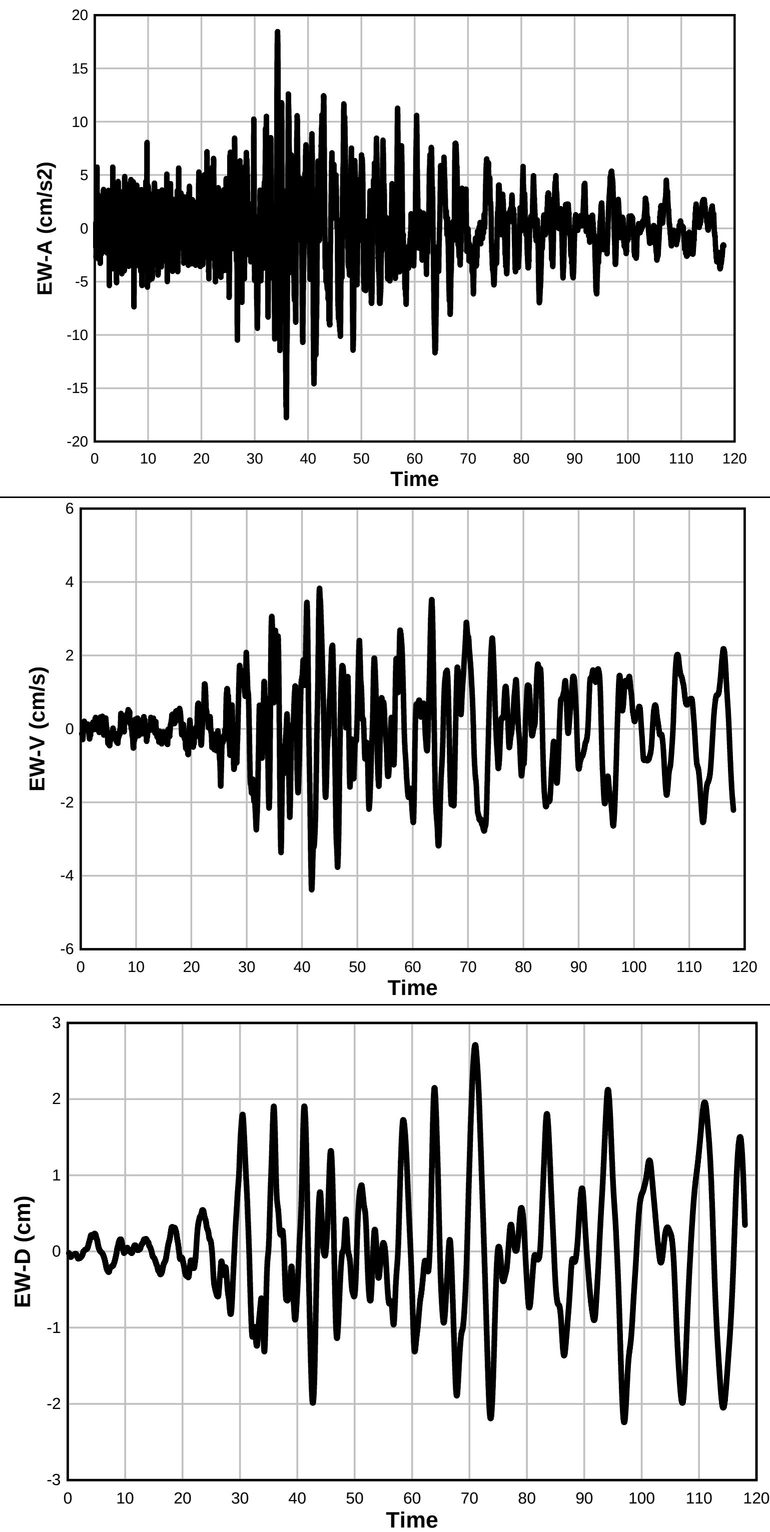
Recorded ground motion at Natore due to 25th April Nepal EQ (EW component)



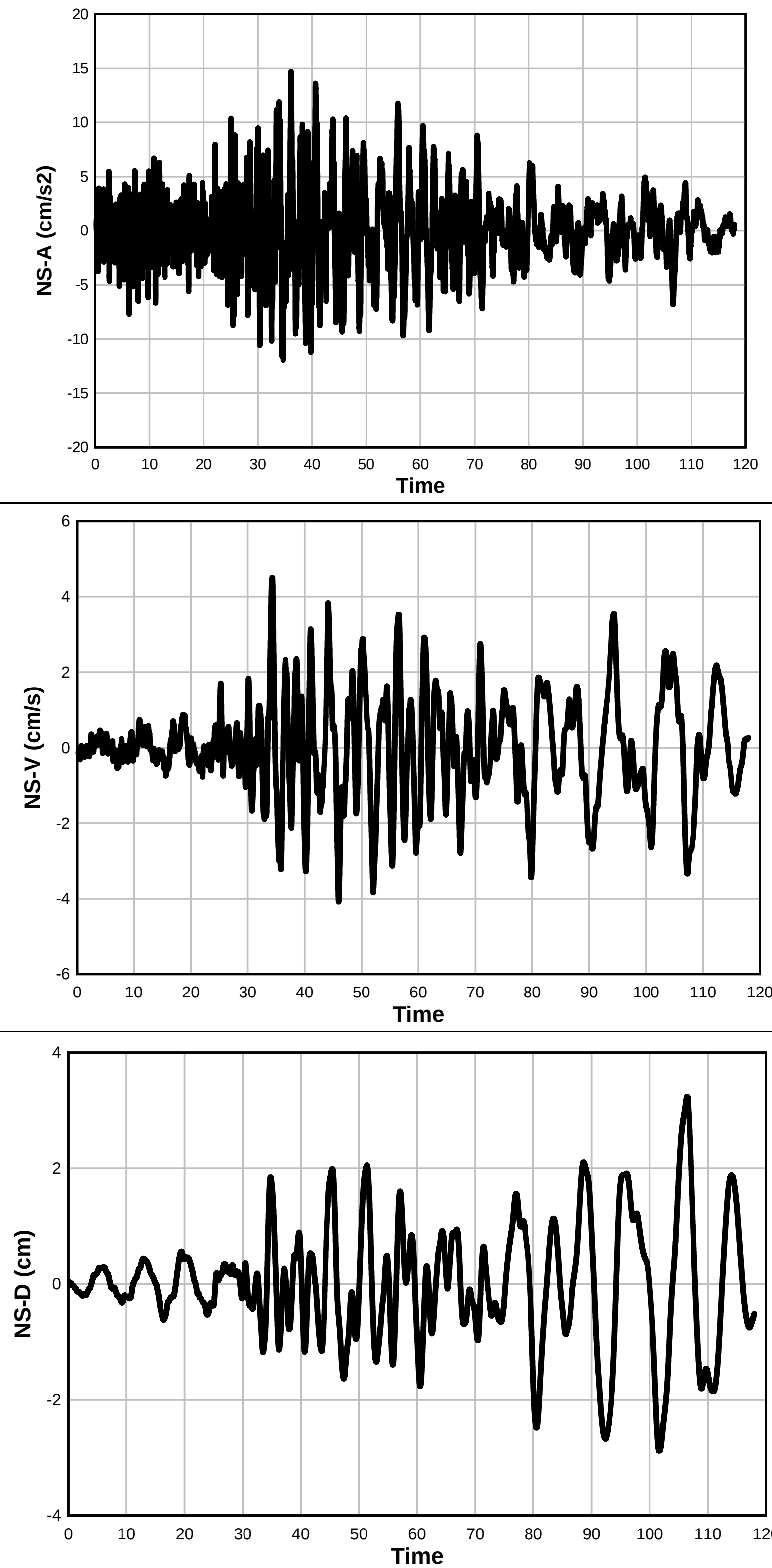
Recorded ground motion at Natore due to 25th April Nepal EQ (NS component)



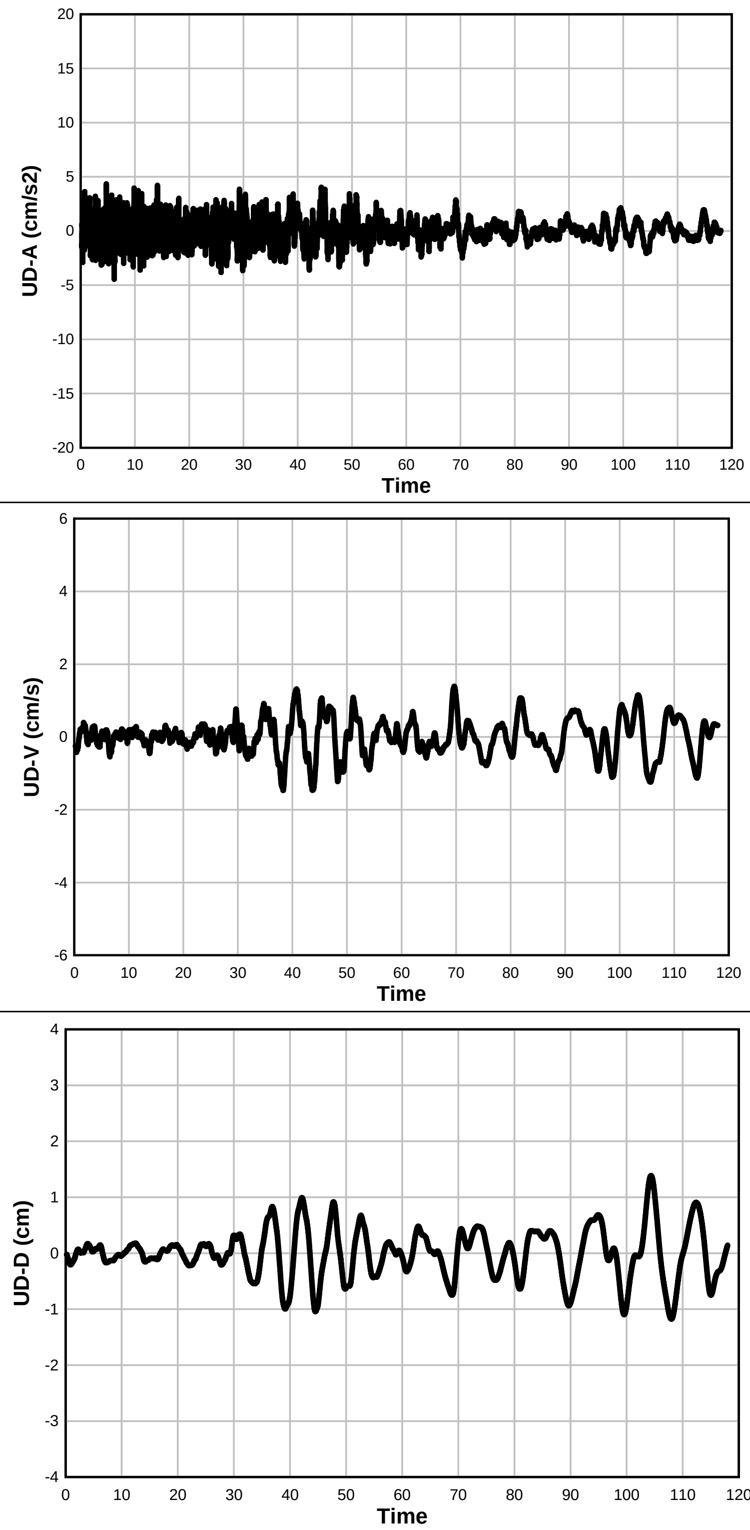
Recorded ground motion orbit at Natore due to 25th April Nepal EQ



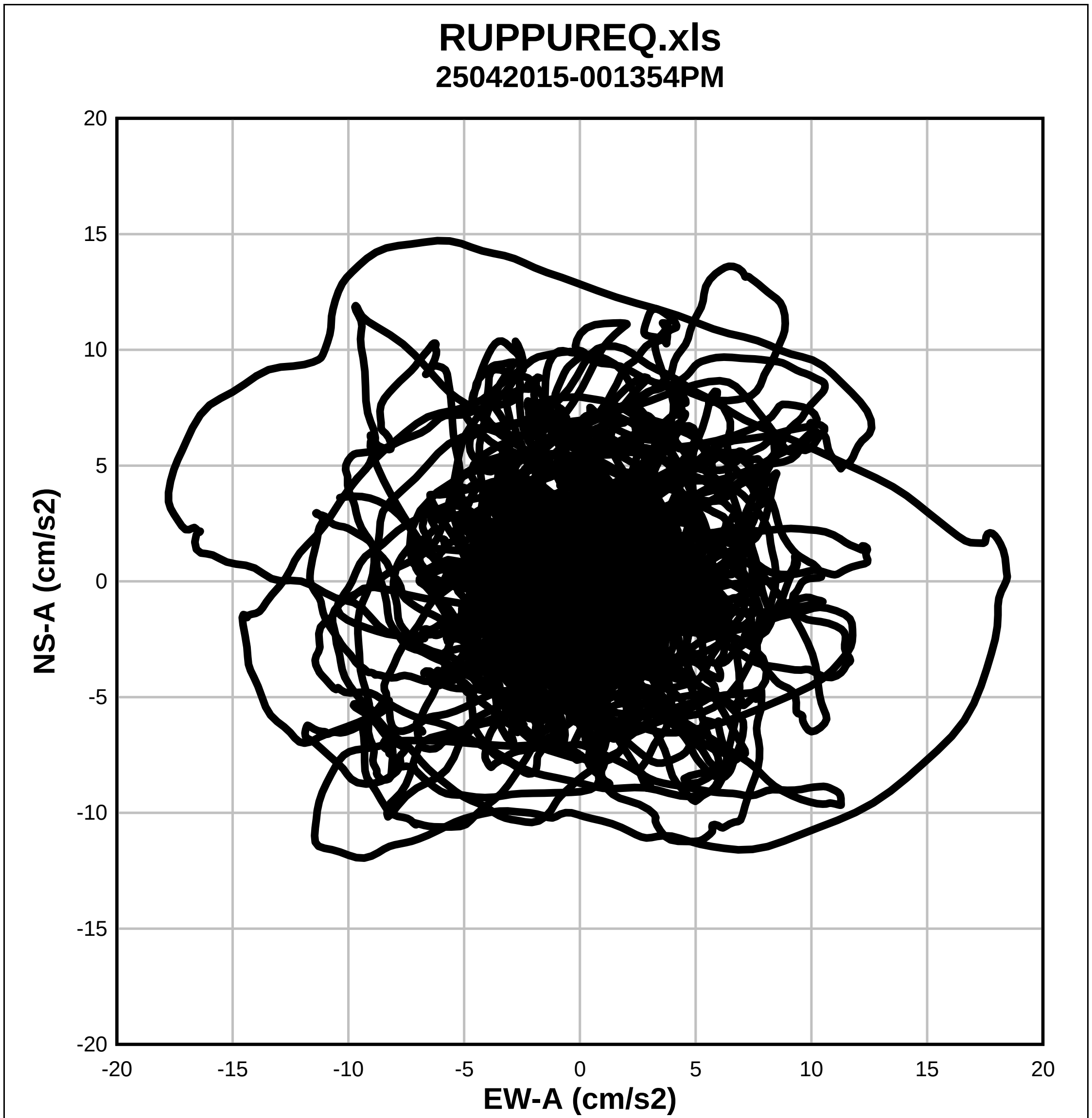
Recorded ground motion at Rooppur due to 25th April Nepal EQ (EW component)



Recorded ground motion at Rooppur due to 25th April Nepal EQ (NS component)



Recorded ground motion at Rooppur due to 25th April Nepal EQ (UD component)



Recorded ground motion orbit at Ruppur due to 25th April Nepal EQ

PART-II

FLASH FLOOD SITUATION DUE TO SUNAMGANJ FLOOD MARCH 28, 2017

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Maruf Billah

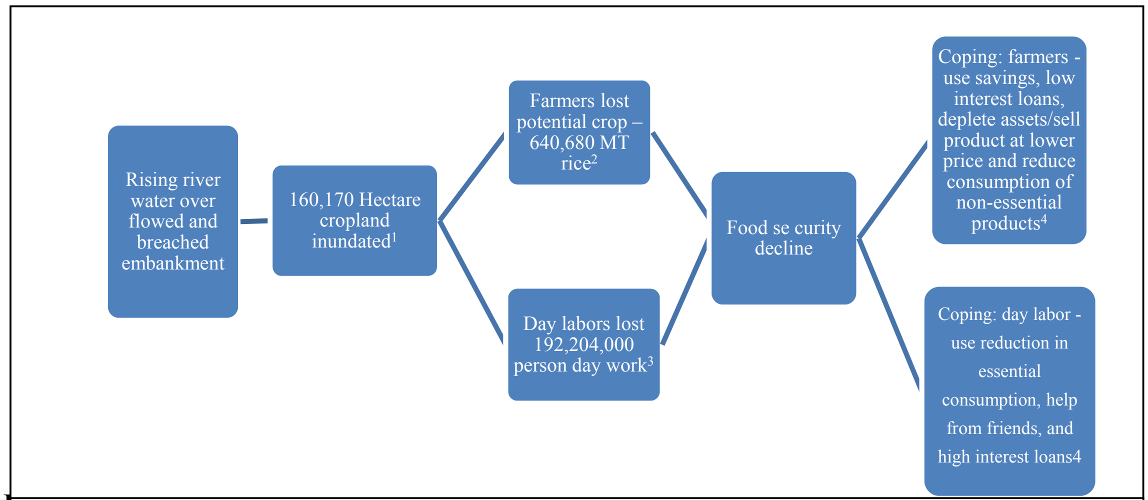
Mehedi Ahmed Ansary

Heavy rainfalls as well as onrush of water from the upstream Meghalaya hills in India have led to the inundation of a vast areas of croplands of Haors and low-lying areas of the northeast. Flood started on 28th March affecting six districts (Sylhet, Moulavibazar, Sunamganj, Habiganj, Netrokona and Kishoreganj) in the north east region. Rising water overflow and breeched embankment in many places and inundated vast areas of croplands.

Figure 1: Flash Flood Affected Districts (Source DDM report)

Impact of Flash Flood:

This flood caused huge damage to crop production.



1 Source- Reports of DDM, DAE April 01, 04 and 05, 2017, national dailies (the daily Star, Dhaka Tribune, Daily Janakantha, Samakal, April 08, 12 and 13, 2017.
2 Estimated production of 4 T per hectare as suggested by the Ministry of Agriculture
3 Estimated 120 person/day for harvesting boro rice from one hectare of crop field (Situation repot of nirapod).
4 Final Draft National Social Security Strategy (NSSS) of Bangladesh 2015

Table 1: Detail impact scenario of flash flood 2017

District name	No. of Upazilla	No. of affected Upazilla	Impact on Agriculture (hac)	No. of affected family(non ag)	No. of affected family (farmer)	No. of affected family (fisher man)	House hold damage		
							Partial	Full	Total
Kishoreganj	13	8	47347	50000	152481	51092	-	-	-
Habiganj	8	8	57020	29000	77066	-	1308	248	1556
Sylhet	13	13	64454	50000	108541	9653	-	-	-
Sunamganj	11	11	166612	150000	277188	44445	-	-	-
Moulavibazar	7	7	18898	1000	50620	13400	5910	891	6801
Source: department of Disaster Management Report, 28 April 2017									

Sunamganj district has been affected most extensively. The Department of Agricultural Extension of Sunamganj has published the details of crop damage in the district

Table 2: Detail Impact of flash flood in Sunamganj district

Upazila	Total area under boro cultivation (Hec.)	Damage of standing crop in boro fields (Hec.)	Remark
Dharmapasha	31,800	18,610	Ajarkhali, Shoytankhali, Marardair, Haldirbodh, Ulashkhali and Balrampur embankments were damaged
Sadar	16,200	10,300	Tolakhalu and Teukhali embankment were damaged
Tahirpur	18,400	7,610	Alamkhali, Doronbadh and Mahalia were affected
South Sunamganj	22,275	5,560	Shallardair embankment was damaged
Jagannathpur	20,207	12,190	Burakhali, Tanguar, Betauka, Falgida, Demakhali and Katagang embankment collapsed and water logged
Dirai	28,000	6,740	Kadirpur, Tufankhali, Baram, Tangni and Boishakhi embankment were damaged
Shalla	22,000	2,120	Joaria embankment were damaged
Doara Bazar	13,680	6,930	
Chatak	14,240	9,830	Water logged due to damage of Lakhsmibaul

			embankment
Jamalganj	25,190	6,010	Water logged due to damage of Kalibari Point
Biswamvarpur	11,090	5,790	Gondamara and Jiragtaherpur embankment collapsed
Total	**229,082**	**91,690**	
Source: Department of Agriculture Extension, Sunamganj, April 04, 2017			

Government Response of Flash Flood in 2017

The Government's assistance to the flood affected people included cash grant, food aid and other materials. DDM report on Government response is given below:

Table 3: Government responce of flash flood 2017

Districts	Response
Sylhet	500 MT. G.R. rice and BDT. 1,000,000 G.R. cash have been supplied in response to the Demand Note
Sunamganj	60,000 M.T, of G.R. rice, BDT. 255,000 G.R. cash and 185 bundle of Corrugate iron sheet have been stored in Sunamganj district
Habiganj	50 MT. G.R. rice and BDT. 100,000 G.R. have been supplied in response to the Demand Note
Kishoreganj	100 MT. G.R. rice and BDT. 200,000 G.R. cash is sent. 100 MT. G. R. rice have been supplied in response to the Demand Note
Netrokona	100 MT. G.R. rice and BDT. 500,000 G.R. cash is sent. BDT 1.0 million have been supplied in response to the Demand Note
Moulavibazar	50 MT. G.R. rice and BDT. 100,000 G.R. cash have been supplied in response to the Demand Note
Source: DDM Reports, April 05 and 07, 2017	

Role of Water Development board During This Incidence:

The people set afloat by the flash floods of the haor areas are not blaming their luck and blaming the Water Development Board. They were supposed to build embankments before the rains came but they did not. (The Daily Star, 3th May 2017)

This claim is definitely easy to believe once anyone drive a few kilometers away from the tiny provincial town of Sunamganj and see the water. The water stretches on as far as the eyes can see, brilliant in the summer sun. Calmer towards the mainland, crashing in waves the deeper into the haors one go. Where are the dykes the government doled out crores to reconstruct? The Star Weekend could not independently verify the total budget allocated, but documents obtained show that the Water Development Board floated tenders worth Tk. 48 crores 49 lakhs at least, to contractors, solely for the purpose of rebuilding the dams.

Mohammed Siddik Ali, a farmer of Tahirpur Upazila, had waited for the promised dykes before he realised they weren't happening, and picked up the shovel himself. (The Star Weekend, 5^{th} may 2017).

But at first the water development board totally ignored the blame. In 23th April 2017, Water Resources Minister Anisul Islam Mahmud said his ministry has nothing to do at this moment but learn lessons from the catastrophe in the haor areas. Terming the flash flood “completely different”, the minister said the flood happened as water overtopped the dam. Although flash floods happen in this region, this time the flood hit earlier than usual, he added.

Regarding allegation of corruption through various projects of the Water Development Board in the haor area, the minister said “We are working on it. Especially with the paperwork whether there are any irregularities in payment and other issues. If we find any allegation to be true, stern action will be taken.” (The Prothom Alo, 23th April 2017).

But earlier Deputy Assistant Engineer of Water Development Board in Dharampasha upazila Ali Reza said they gave budget allocation in time, but the work could not start as the members of the project committee were changed (The daily Star, 27^{th} February 2017).

Then in 5th may the director general of Anti- Corruption Commission claims Bangladesh Water Development Board (BWDB) officials for irregularities in the construction and maintenance of embankments in Sunamganj haor that eroded in early flash floods about a year ago. “We've been able to find through our quizzing that in the construction of embankments, Bangladesh Water Development Board showed gross negligence,” he added. The Anti- Corruption boss also added that, for years, embankments in hoar areas have been damaged by floodwater, submerging low-lying areas and affecting crops. Locals often blame negligence and corruption in the construction of the embankments. The ACC sent a letter to the water resources ministry in April last year when the eroded embankments gave way to floodwater. It asked the ministry to investigate the matter. The ministry was also asked to submit a report in this regard within 10 working days.

The the ministry, in its reply sent to the ACC in the last week of February this year, said the embankments were damaged by rats making holes. The commission didn't find the reply satisfactory. (The Daily Star, 5^{th} May 2017).

Conclusion

Floods in these haor areas caused huge damage to boro crop. Since the area significantly contributes to the national food production, overall food security of the country may experience negatively as a consequence. Whatever the reason is, focuses should be on helping the affected people to cope with the losses.

Sunamganj Flood on Frame



Media Coverage

Sunamganj farmers face Tk1,500cr loss due to flash flood

Sunamganj district Agricultural Extension Department’s Deputy Director Jahedul Haque has said the Haor famers have incurred around Tk1500 crore losses as the flash flood damage the Boro paddy of 1,50,000 hectares.

See details: http://www.dhakatribune.com/bangladesh/nation/2017/04/27/sunamganj-farmers-face-tk1500cr-loss-due-flash-flood/

At least a 100,000 hectares of Boro has gone under water in the flash flood in the last few days'

Traders believe the high price of rice is set to continue after recent flash floods in the northeastern wetlands destroyed more than 200,000 hectares of mature Boro paddy.

See details: http://www.dhakatribune.com/bangladesh/nation/2017/04/08/flash-flood-haors-may-worsen-rice-price-hike/

Flash flood ravages Sunamganj's Paknar Haor backswamp

"The backswamp was in precarious condition due to the flash flood and heavy rains. The embankment collapsed after the water level rose," said Jahedul Haque, deputy director of Department of Agricultural Extension in Sunamganj.

See details: http://bdnews24.com/bangladesh/2017/04/24/flash-flood-ravages-sunamganj-s-paknar-haor-backswamp

Paddy production hit by flood in the Haors

Paddy production is at peril in the Haors and low-lying areas of of the northeast as heavy rainfalls as well as onrush of water from the upstream Meghalaya hills in India have led to the inundation of a vast areas of croplands.

See details: http://www.dhakatribune.com/bangladesh/nation/2017/04/08/paddy-production-hit-flood-haors/

BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

PART-III

CYCLONE MORA, 31 MAY 2017

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Tasnim Tarannum Isaba
Mehedi Ahmed Ansary

Introduction:

Severe Cyclonic Storm Mora (Thai, meaning "agate")(Royal institute dictionary) was a tropical cyclone that caused widespread impacts across Sri Lanka, Andaman and Nicobar Islands, Bangladesh, Myanmar and Northeast India in May 2017. The second named storm of the annual cyclone season, Mora developed from an area of low pressure over the southeastern Bay of Bengal on May 28. It quickly strengthened and was named *Mora* early the next day. Heading north-northeastwards towards Bangladesh, Mora continued to intensify and was upgraded to a severe cyclonic storm before May 31. Soon after, Mora reached peak strength with maximum sustained winds of 110 km/h (70 mph). Maintaining its intensity, the cyclone made landfall near Chittagong on the morning of May 30 and steadily weakened over land, dissipating early on the next day.

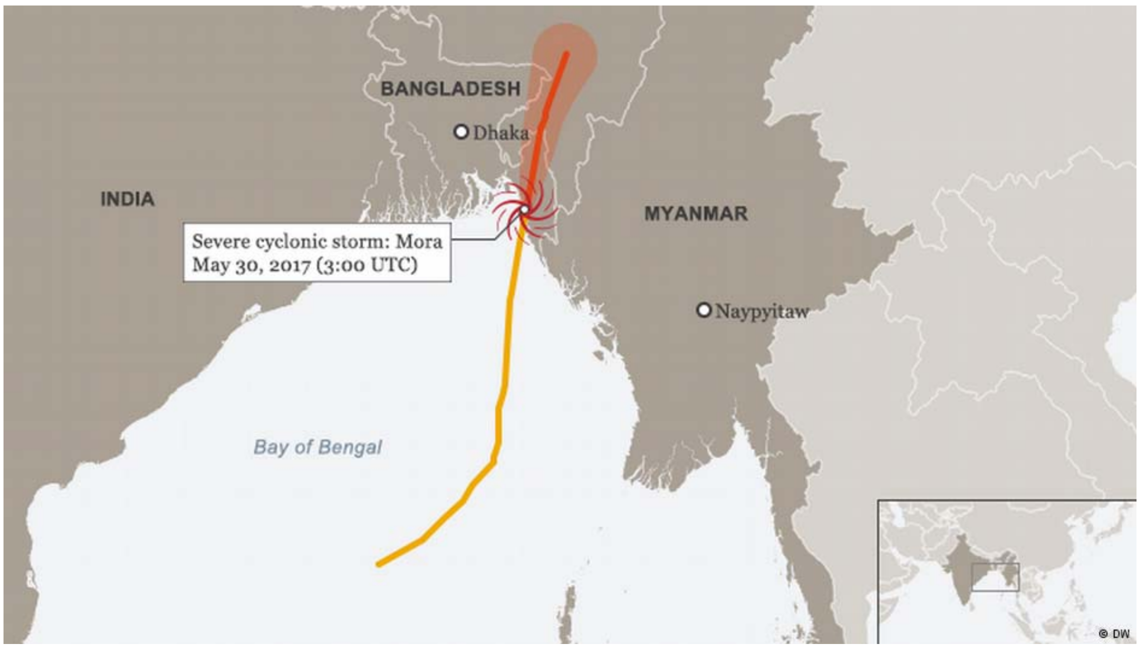


Figure 2: Projected track of cyclone mora

Meteorological History of Mora

In late May 2017, an area of convection began to organize in the Bay of Bengal under favorable conditions characterized by low wind shear and warm sea surface temperatures (Joint Typhoon Warning Center, May 26, 2017). The conducive environment allowed for the development of rain bands and the beginnings of a circulation on May 27 (Joint Typhoon Warning Center, May 27, 2017).That same day, the Indian Meteorological Department (IMD) noted the high likelihood of the low pressure area organizing into a tropical depression (Tropical Weather Outlook 27 May 2017). Similarly, the Joint Typhoon Warning Center issued a tropical cyclone formation alert on the disturbance at 14:30 UTC May 27, citing the persistent thunderstorm activity and consolidating center of circulation; (Joint Typhoon Warning Center, May 27, 2017) the JTWC classified the disturbance as a tropical cyclone roughly six hours later as it continued to intensify. At the time, the storm's motion was influenced primarily by a nearby subtropical ridge, forcing the system to take a north-northeasterly track

It rapidly strengthened on 28 May with the IMD classifying it as a Depression and subsequently as a Deep Depression on the same day, designating it BOB 02. In the early hours of 29 May, the IMD reported the storm to have reached Cyclonic storm intensity, naming it Mora. The storm followed a north-northeasterly track parallel to Myanmar coast. Shortly before landfall, the storm reached its peak intensity as a severe cyclonic storm with winds of 70 mph (110 km/h) and a minimum central pressure of 978 hap (mbar).The JTWC analyzed it having reached category 1 hurricane strength with winds of 75 mph (120 km/h) on the same day. The storm made landfall at peak intensity on the southern coast of Bangladesh near Chittagong at 11:30 UTC (IST 6:00 am). After landfall the storm steadily weakened due to land interaction and dissipated into a well-marked low pressure area over Meghalaya on 31 May.

Preparedness

With Mora's relatively rapid intensification, Bangladeshi authorities were hard pressed to carry out evacuations and prepare for the storm. Maritime weather alerts were issued for the Bangladeshi ports of Chittagong, Cox's Bazar, Mongla and Payra, under the anticipation of a 1.2 to 1.5 m (4 to 5 ft) storm surge (The Daily Star. May 29, 2017). All flights out of the Shah Amanat International Airport of Chittagong were suspended (BBD News, May 29, 2017). City-wide, 500 shelters were opened. Authorities attempted to evacuate 1 million people prior to landfall (British Broadcasting Company, May 29, 2017) though as of May 29, only 300,000 had done so (CNN, Retrieved May 29, 2017).

Figure 3: Dissemination of early warning by CPP volunteers

A total of 500,000 people managed to move out of coastal areas before the storm made landfall on May 31. A multitude of tropical cyclone warnings and watches were issued for much of southern Bangladesh and the districts of Northeast India. Strong winds and storm surge battered buildings and destroyed farmlands across Chittagong, Cox's Bazar, and Rangamati, with at least 20,000 houses damaged in refugee camps for Rohingya Muslims displaced by conflict in neighboring Myanmar. As of May 31, nine people were reported to be killed across Bangladesh, mostly due to falling trees (CNN, 30 May 2017).

Response and Relief

Just days before Cyclone Mora struck Bangladesh's South West coastline, the Red Crescent initiated its cyclone contingency plan and activated its emergency control room to respond to the imminent disaster. Around 55,000 Cyclone Preparedness Programme volunteers and 800 Red Crescent Youth volunteers were out in full force in 15 of the country's coastal districts to disseminate early warnings in communities and help evacuate those living in the path of the storm. A day before the Cyclone struck Bangladesh, the national society also distributed a cash grant of 5000 takas (60 euros) to 2,300 households in Noakhali district under a Forecast Based Financing project supported by the German Red Cross. The Red Crescent distributed dry food supplies to around 25,000 people after the cyclone made landfall on 30 May 2017. The International Federation of Red Cross and Red Crescent Societies (IFRC) earlier released its Disaster Relief Emergency Fund (DREF) to provide food and other emergency relief items to people taking refuge in temporary shelters (IFRC report, 15 June 2017).

Figure 4: People evacuated to cyclone shelter after the warning arise

Figure 5: Dissemination of relief by Red Cross

United Nations agencies were also on the ground and actively supporting the Government and civil society to restore services and provide emergency supplies to those affected. The United Nations High Commissioner for Refugees (UNHCR) provided emergency hospital tents to the affected camps, and was aiming to provide waterproof plastic sheeting to affected families. The International Organization for Migration (IOM) provided shelter and emergency healthcare, and was supervising repairs to damaged health facilities and sanitation services (latrines). The World Food Programme

(WFP) provided emergency food rations and large quantities of dry biscuits until regular food supplies resume. The United Nations Children's Fund (UNICEF) supplied hygiene kits, water purification tablets, and recreation kits for affected refugee and migrant children. The United Nations Population Fund (UNFPA) continues to provide high-quality medical care to pregnant women, new mothers and their newborn children in the camps (WFP report, 13 June 2017).

The Government of Bangladesh has already allocated 15,000,000 BDT (USD 8.53 million) and 1,400 MT of rice to cyclone-affected districts. The Bangladesh navy deployed two ships to remote islands to distribute aid. The World Food Programme has 122 metric tons of biscuits available in the region, and is distributing these in makeshift camps and settlements. The International Organization for Migration is distributing plastic sheets, rope and other items to people with severe shelter damage in Balukhali. UNHCR is distributing plastic sheeting and other items in camps housing refugees and other displaced persons. The International Federation of the Red Cross and Red Crescent (IFRC) has mobilized USD $107,000 from its Disaster Relief Emergency Fund (DREF) to provide emergency food, drinking water, storage, and shelter materials.

Impact of Cyclone Mora

Cyclone Mora made landfall on Bangladesh's coastal region at 6 am on 30 May, with heavy rain and winds estimated at 160 km/h. Initial assessments are that 2,811,465 people have been affected across 12 high-risk costal districts. Nearly 350,000 people were evacuated on 29 May from affected areas on the southern coast. Houses and properties have been damaged, and roads and telecommunications were partially disrupted in Cox's Bazar. Continued rain is expected which will exacerbate the situation for those whose homes have been destroyed. Two villages in Cox's Bazar and three villages in Chittagong have been flooded.

Figure 6: water entrance in the affected areas

According to the National Health Crisis Management Centre and Control Room of the Directorate General of Health Services (DGHS), there have been reports of two casualties so far. It is reported that 70% of the houses in Saint Martin Island and around 3,000 houses in Ukhiya and Teknaf have been damaged. Eleven children are reported to have been injured during the cyclone due to the falling trees and torn tin roofs.

Cox's Bazar hosts approximately 400,000 Undocumented Myanmar Nationals (UMN) including 74,000 newly arrived Rohingyas following the recent tensions in Myanmar. According to a UMN community leader, around 10,000 huts in Kutupalong camp and Balukhali settlement have been destroyed. Many UMNs have taken shelter at learning centres supported by UNICEF and UNHCR in makeshift settlements and official camps (UNICEF, 1 June 2017).

Figure 7: Cyclone destroyed rohingya refugee camp

According to the National Health Crisis Management Centre and Control Room of the Directorate General of Health Services (DGHS), reports the casualties to have at 6 lives lost, 136 injured, and Government report figured around 200,000 people displaced. The Indian navy ship Sumitra rescued 27 people who were found adrift at sea over 100 miles away from Chittagong. Government sources have estimated that approximately 52,000 houses were damaged or destroyed, leaving 260,000 people in possible need of shelter. Cox's Bazaar district was particularly heavily hit, with approximately 17,000 residences damaged. Housing for undocumented Myanmar nationals near Cox's bazaar was severely damaged. Rohingya refugees are currently without reliable shelter, food, and fuel, and may also lack dry space to cook. Electricity has been disrupted in Bandarban district and many upazillas. Roads and communication networks in remote parts of Bandarban district have been interrupted and will take additional days to recover.

PART-IV

ASSESSING EMERGENCY EVACUATION BEHAVIOR OF READY MADE GARMENTS WORKERS: CASE STUDY OF DHAKA AND CHITTAGONG, BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Maruf Billah

Mehedi Ahmed Ansary

Background

Bangladesh is a developing country with many challenges and profitable sectors. Among all the other sectors readymade garments industries are the most highlighted one in recent decades. Despite such phenomenal success in remittance earning and employment potential, this sector has experienced some worst industrial accidents in the history. The loss of 1,136 lives when Rana Plaza collapsed on 24 April, 2013 created a worldwide concern for workplace safety in Bangladesh (ILO, 2015). In addition to building characteristics, the behavioral and socio-economic characteristics of the occupants or workers can also have a strong influence on the evacuation strategies during complex situations, including fire and earthquake events. Most evacuation models focus primarily on evacuation movement, ignoring the prediction of behaviors that occupants perform before and during evacuation movement that can delay their safety, such as fighting the fire or helping others (Kuligowski, 2008). The time to start the evacuation is highly dependent on the ability of occupants to hear the alarm. The characteristics of gender, age and limitations presented little impact on the timing and movement during evacuation (National Research Council Canada, 1994). On building exits, evacuation time can be reduced by utilizing a high flow rate in the exit design (National Bureau of Standards (USA), 1935). Based on the purported successful evacuation time in a 1911 theatre fire in Edinburgh, evacuation time for buildings was specified to be 2.5 min (Her Majesty Stationery Office, 1952). In Bangladesh negligence of the authorities in preparing an emergency situation work plan and rehearsing it in regular basis came out as major reasons for such catastrophic disasters (Qurratul-Ain-Tahmina and Khadiza Khanam (2001). It is also found that cause of death is usually not the fire directly. Most of workers have died due to stampede, locked exit route, inadequate number of stairs, deliberately blocked pathways, smoke and suffocation (Akther, Salahuddin, Iqbal, Malek, & Jahan, 2010). Different studies have been conducted based on the structural assessment of garments factories, especially after the Rana Plana incident. Evacuation behavior for the garments industry workers during fire or earthquake has not been analyzed yet. A comprehensive human behavior model is needed to simulate occupant behavior during fire or earthquake evacuation. This study has taken an approach to analyze the socio-economic characteristics of workers in RMG industries in relation to their evacuation behavior during fire or earthquake events with analyzing the existing evacuation arrangements and vulnerability of garments workers. The perception of workers on earthquake or fire events has been included and data has been collected from questionnaire survey.

Sample Size Calculation

The Study follows a sampling method named as Yamane's formula for collecting data in two respective readymade garments industries.

Yamane's formula is: $n = \frac{N}{1+N*(e)^2}$

Where, n= Sample size

N= Population size

e= Level of precision or sampling error.

According to the formula, sample size of two garments industry is $n = \frac{3200}{1+3200*(0.042)^2} =$

482

For sampling level of precision or sampling error up to 5% is considerable but here 4.2% has been used for more accuracy. As the sample size was 482 respondent but 490 respondent have been surveyed to avoid messing data.

Study Area Profile

The study area of the research is two different garments factories from two different locations Dhaka and Chittagong, major two cities of Bangladesh. One of them is in the EPZ area with better facilities and another is outside the EPZ.

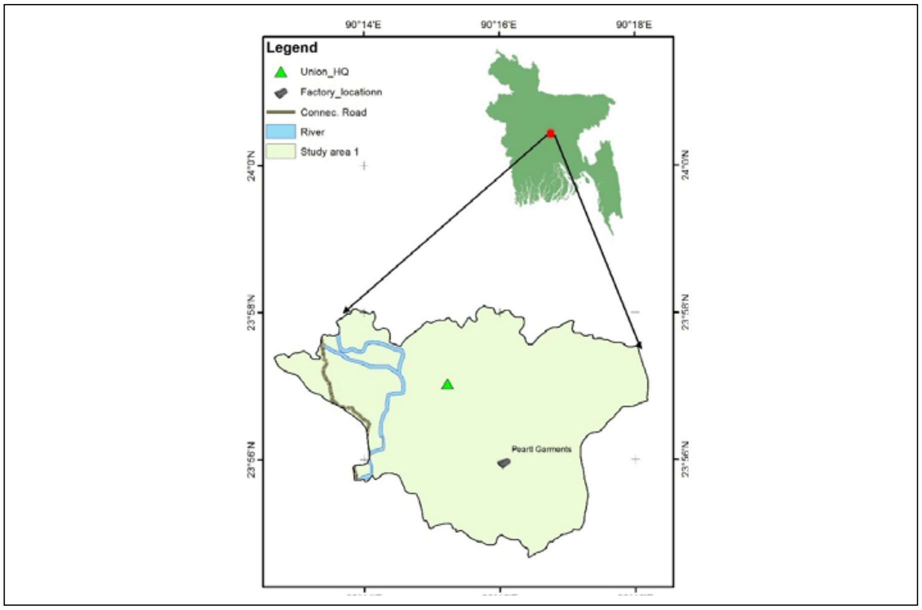


Fig: Location of Pearl Garments Savar Dhaka.

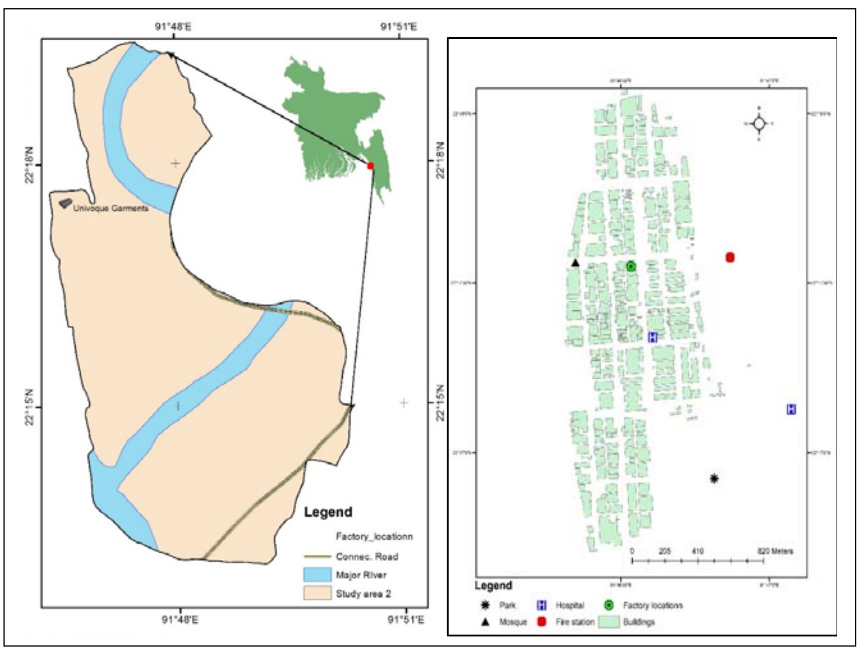


Fig: Location of Univogue garments EPZ Chittagong

Socio Economic Condition and Education Level

Socio economic condition and level of education have great influence on human behavior in garments sector like Bangladesh, where garments sector has become so popular for availability of cheap labor. Most of the worker either have come from low or middle income family to develop their economic condition nor have come from the rural part of the country for better living condition. As an over populated country job opportunity in Bangladesh is so difficult and garments are the common target for those jobless who have less qualification and badly in need of economic support. On the other hand garments industries taking this opportunity to have some cheap labor. The respondent from two surveyed industries reflect the real condition of the garments workers in Bangladesh.

Table: Description of livelihood income of respondents

Description		Less than Tk. 60,000	Tk. 60,001 to Tk. 120,000	Tk 120,001 to Tk. 180,000	Tk. 180,001 to Tk. 240,000	Tk. 240,001 to Tk. 300,000	Over Tk. 300,001
Pearl garments Dhaka	Male	.0%	75.3%	14.1%	3.5%	3.5%	3.5%
	Female	1.0%	94.7%	3.9%	.0%	.5%	.0%
	Total	.7%	89.0%	6.9%	1.0%	1.4%	1.0%
Univogue garments Chittagong	Male	1.3%	33.3%	22.7%	14.7%	12.0%	16.0%
	Female	1.6%	50.8%	16.9%	9.7%	10.5%	10.5%
	Total	1.5%	44.2%	19.1%	11.6%	11.1%	12.6%

Among the respondents 70.8% is female in Pearl garment Dhaka and 62.30% is female in Univogue garment. And most of the women workers are here to support their low or middle income families.

Education level is another major issue which have a great influence in human behavior. The education level of the respondents of two garments industries shows that most of them have little or no educational back ground.

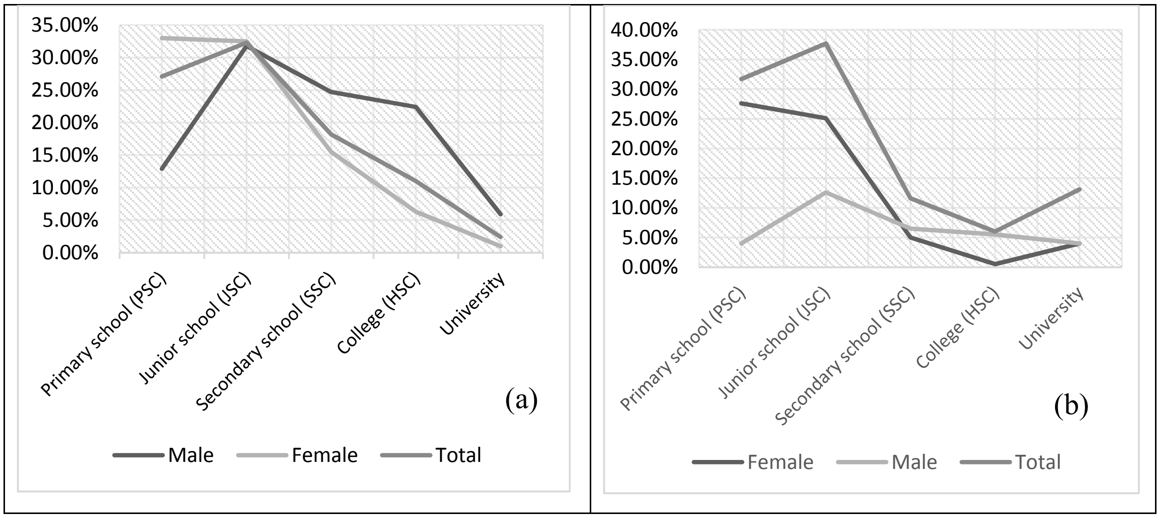


Fig: Education level of respondents in Pearl garments Dhaka (a) and Univogue garments Chittagong (b)

Most of them are from the primary and junior school level who have no or a little knowledge about occupational health safety, disaster, evacuation and other scientific terminology and only the training and workshop can help them to skill up themselves. Awareness level of these workers should be developed so that they can understand the need of evacuation training and procedures and can be conscious what the garments owner are doing for their safety.

Vulnerability Profiling of Working Space Using Venn diagram

For distance calculation from the emergency exit Maximum 30.50 meter has been considered as it mentioned in EPZ building rules which meant specifically for factory building to be constructed in the EPZ zone. It is written as a code specifically for factory buildings, although less elaborate than Bidhimala 2008 in many dimension.

Venn diagram analysis has been conducted to analysis the working space vulnerability. Here maximum option to reach emergency exit has been considered as less vulnerable. The vulnerability profiling has been classified into four part. The high risk zone, where there is no emergency exit within 30.50 meter, another portion only 1 emergency exit within 30.50 meter, some space has 2 exits within 30.50 meter and the safest portion has more than 2 exits within 30.50 meter. So the workers who perform their duty in the high risk space of the working floor have to be faced more difficulty to evacuate. After performing the vulnerability profiling it can be estimated that, in Univogue garments most of the working space have at least 1 exits within 30.50 meter except a little portion near the left and official area, where the garments worker are prohibited. On the other hand most of the working places are in the ground floor which consumes less time during evacuation. But in the Pearl garments a different scenarios have been seen. Only 2 exits in each floor left a considerable portion of working area in high risk zone which mean a portion of the total workers have to perform their duties in those areas where they have to struggle to evacuate when an emergency arise. More time will be consumed as 5 storey of working building.

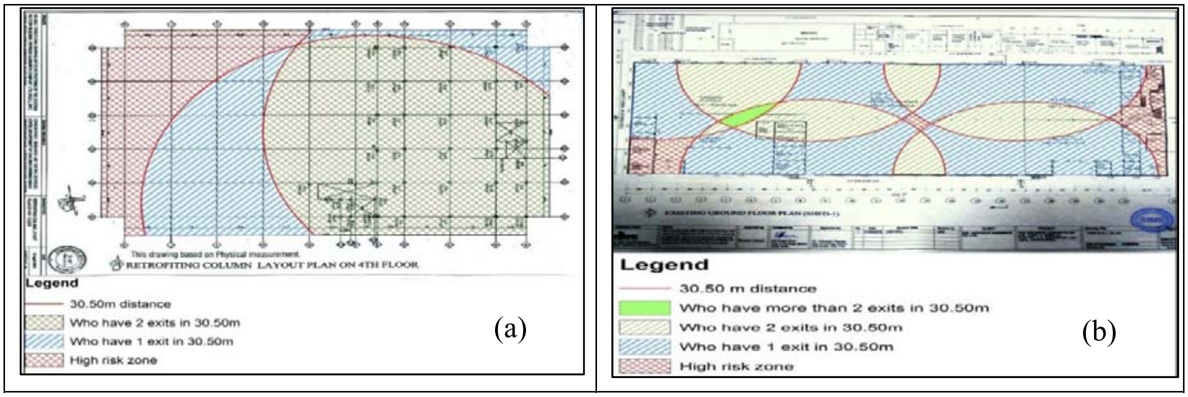


Fig: Vulnerability Profiling of Working Space Using Venn diagram in Pearl garments (a) and in Univogue garments Chittagong (b).

Evacuation Behavior of garments workers

An independent investigation carried out by the Bangladesh Occupational Safety, Health and Environment Foundation (OSHE) attempted to identify the reasons behind Tazreen fire incident. In the study it is clear that evacuation behavior of the garments worker have an influence by mid-level workers and supervisors during the time of emergency evacuation procedure. If the evacuation behavior of the garments worker is strengthened then a large portion of casualties and damage can be reduced. To analyze the existing evacuation behavior of the garments workers, an assessment of awareness level, evacuation plan and evacuation time has been carried out in respective two garment industries.

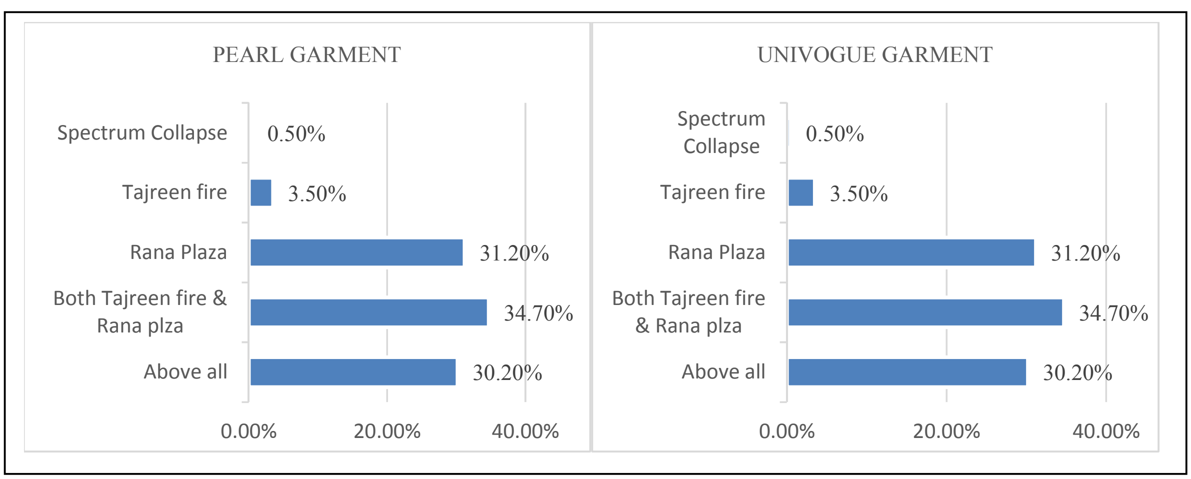


Fig: Awareness about the recent garments incidence

In garments awareness of recent garments industry incidences can have an impact on the evacuation behavior of workers. Figure reveals that, majority of the workers (56%) are aware of all recent garments industry incidences, with 36% being aware of both Tazreen fire and Rana Plaza collapse. In Univogue garments most of the workers are well known about the Rana Plaza as it was a national issue but other incidence like Sectrum collapse have been slip through from the eyes of most of them, a little are known with all the three incidence they have been asked for. Aware ness level should be more developed so that the worker can be conscious about their safety and what the garments owner are doing for them which will useful to develop their evacuation plan.

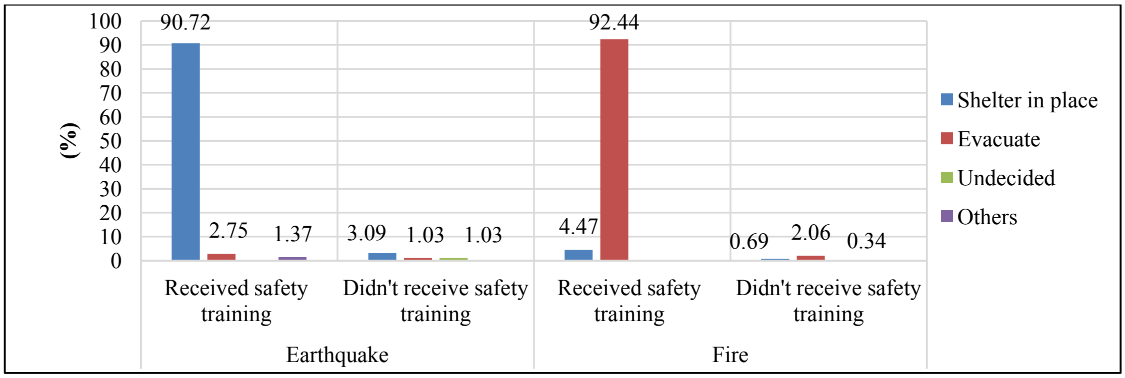


Fig: Distribution of respondents according to evacuation plan and status of receiving safety training in fire and earthquake in Pearl garments

It is evident that, maximum respondents said they have received safety training from their employer in case of earthquake (95%) and fire (97%). In case of an earthquake, maximum respondents (90.72%) who have received safety training preferred to take shelter in place. The percentage of being undecided in both fire and earthquake is higher when respondents didn't receive any safety training.

But in case of Univogue garments in Chittagong almost 100% respondent prefer to evacuate immediately in terms of any kind of disaster, no matter what kind of disaster it is. This variation of reaction of the responded have come due to difference of structural conditions of two garments. In case of pearl garments, it is high rise so in term of earthquake works prefer to take shelter in place because they may not have enough time to evacuate as earthquake has no early warning. On the other hand in Univogue garments, most of the workers work in the ground floor so it is easier for them to evacuate no matter what kind of emergency it is.

Structural vulnerability or difference not only have the influence on evacuation plan but also on evacuation time and the assessment which has been carried out is an example of that.

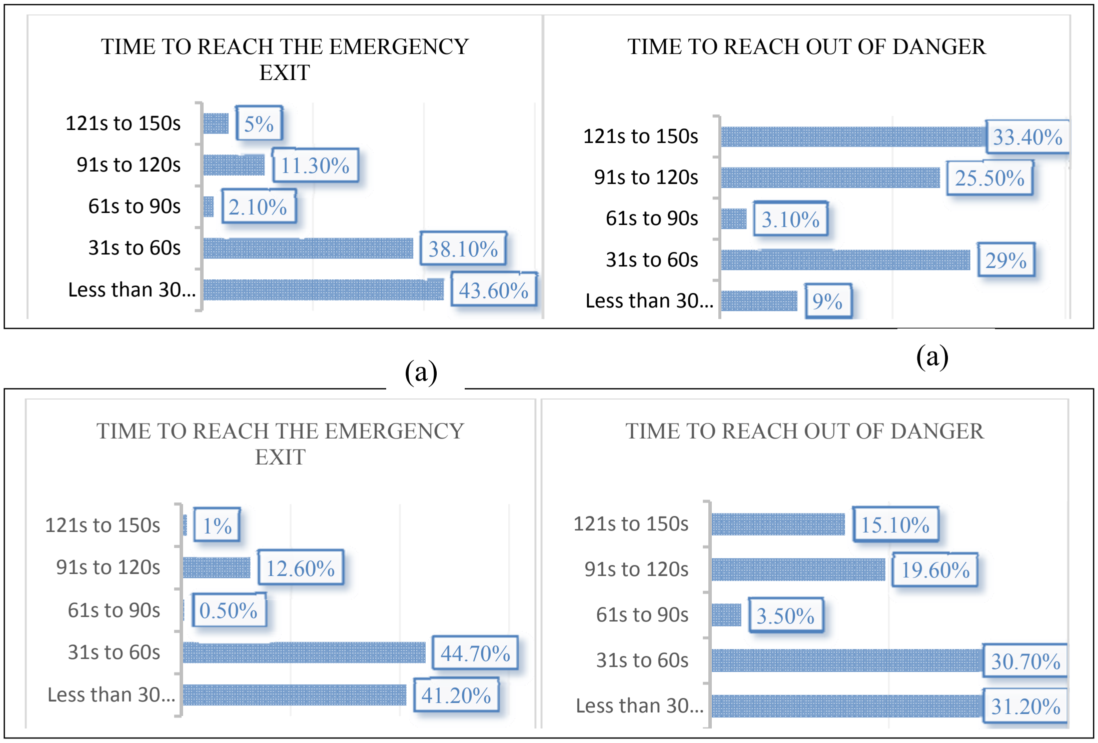


Fig: Evacuation time of respondent in Pearl garments (a) and in Univogue garments (b)

The time consumed by the Pearl garments worker to reach emergency exits are almost similar to the time that has been used up by the workers of Univogue garments in Chittagong. But in case of going out of danger there is a huge different has been seen where 31.20% (largest portion of workers) workers in the Univogue garments use less than 30 seconds to go out of danger then in Pearl garments 33.40% of the total workers use 121 to 150 seconds to get out of danger which means a huge difference has been seen in two garments workers in terms of consumed time to get out of danger. Structural difference of two garments are playing a major part here. As the pearl garments is high rise so the workers consumes more time to come down from the upstairs. Sometimes the female workers have to face more obstacles than male workers during evacuation due to physical, mental and other surrounding conditions.

To assess the evacuation behavior on gender perspective ANOVA test has been conducted to identify the difference between male and female behavior.

Table 4: Significance test through ANOVA analysis for Pearl garments Dhaka (Gender of respondents and evacuation time)

Description		Sum of Squares	df	Mean Square	F	Sig.
Time to reach the emergency exit	Between Groups	15.160	1	15.160	11.675	**.001**
	Within Groups	375.259	289	1.298		
	Total	390.419	290	-		
Time to reach out of danger	Between Groups	11.855	1	11.855	5.906	**.016**
	Within Groups	578.062	288	2.007		
	Total	589.917	289	-		

If the p-value is less than 0.1, then it can be concluded that there is a significant variation among the means of evacuation times. Here the p-values are .001 and 0.016, which indicates that the mean values between male and female are significantly different.

Table 5: Significance test through ANOVA analysis for Univogue garments Chittagong (Gender of respondents and evacuation time)

Description		Sum of Squares	df	Mean Square	F	Sig.
Time to reach emergency exit	Between Groups	2.868	1	2.868	2.898	.090
	Within Group	194.991	197	.990	-	-
	Total	197.859	198	-	-	-
Time to reach out of danger	Between Groups	38.810	1	38.810	19.503	**.0001**
	Within Groups	392.024	197	1.990	-	-
	Total	430.834	198	-	-	-

The ANOVA test shows that while reach to the emergency exit there is no difference between the time duration of male and female because there the p-value is .09>.01 but in terms of get out of danger from the emergency exit there is a significant difference between the time consumed by man and woman because the p-value is .00<.01. Most of the garments worker in Univogue garments works in the ground floor and most of them have 2 or more emergency exits nearby so there is no significant difference of consumed time between man and women to reach to the emergency exit but to get out of danger they have to follow a common direction in the lead of the building structure and the difference is there.

3.3 Conclusion

Evacuation planning is complex because there are many stakeholders with different perspectives, there are multiple requirements, and evacuations are nearly always surrounded by uncertainty and confusion. In Dhaka and Chittagong city must have an evacuation vulnerability assessment to provide effective and worker involved evacuation road map. This study will be a great instrument for the policy makers to rethink about further research on technology for earthquake and fire response. It has been estimated that structural condition has a great influence on the evacuation behavior. As every garments industry has different structural condition so different evacuation plan is needed. It will be sustainable if workers can take part in the decision making of evacuation plan.

BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

PART-V

RECENT LANDSLIDE EVENTS IN BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Tasnim Tarannum
Mehedi Ahmed Ansary

1. INTRODUCTION

Landslide is becoming a concern of great priority because of its devastating nature worldwide. It is one of the most significant natural damaging disasters in hilly environments (Evans *et al.*, 2007; Kyoji, Wang and Fukuoka, 2004; Ahmed and Rubel, 2013). A landslide can be defined as the movement of mass of rock, earth of debris down a slope (Cruden, 1991).

Bangladesh is a multi-hazard prone country and landslide is not a new phenomenon in Bangladesh. Landslide is a regular geologic hazard in the country, especially in Chittagong, the Southeastern Part of the country (Sarwar, 2008). The physiography of the country denotes that most of the area of Bangladesh is floodplain and only 18% is hilly area (Islam and Uddin, 2001). According to geological time scale, hilly area of Bangladesh developed in tertiary age. The bedrock and soil structure of these hills are not stable and are highly prone to landslide. Bangladesh hills are basically composed of unconsolidated sedimentary rocks such as sandstone, siltstone, shale and conglomerate. Unsustainable land use and alteration in the hills including indiscriminate deforestation and hill cutting are two major factors in Bangladesh that aggravated the landslide vulnerability in the hilly areas. Effects of climate change and excessive rainfall within shorter time span often cause landslide specifically in the areas composed of unconsolidated rocks. This situation is further aggravated if the slopes are steep and exposed because of indiscriminate hill cutting (Mahmood and Khan, 2010).

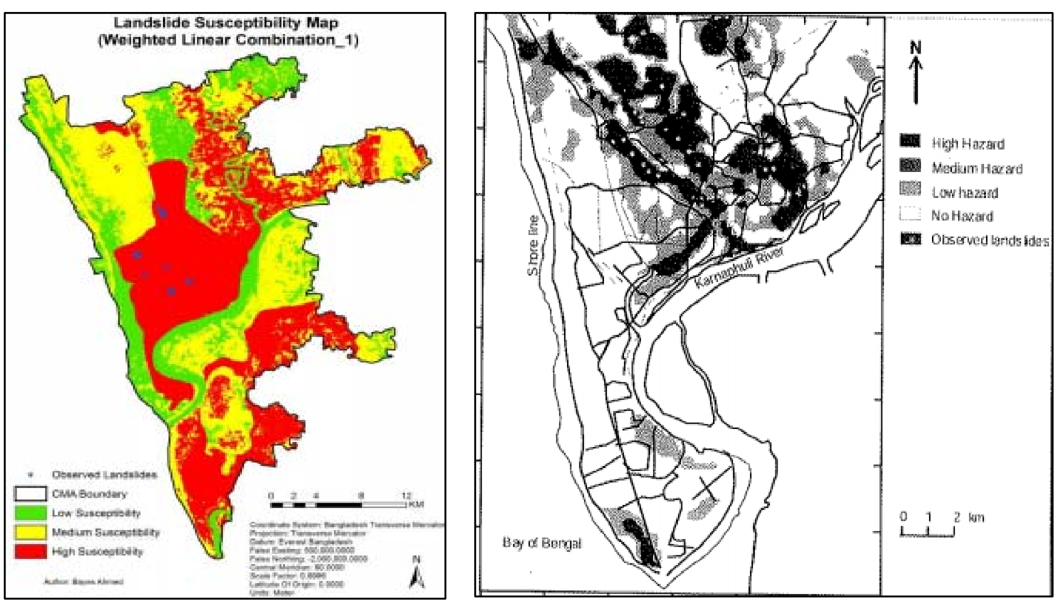


Figure 8:Landslide hazard susceptibility map in Chittagong City (Source: Rubel and Ahmed, 2013; Khan and Chang, 2007)

2. PREVIOUS LANDSLIDE EVENTS IN BANGLADESH

Table 1: Previous landslides in Bangladesh

Year and Date	Death and injuries	Affected areas	Damages
30 May, 1990	-	Jhagar beel area, Rangamati	-
July, 1997	-	Charaipada, Bandarban	-
11 and 13 August, 1999	17 dead	Bandarban and Chittagong	• At least 50 houses were completely vanished under the solid earth and 300 houses were partly damaged. • About 283.50 ha of cultivated land, 810 ha of household garden, and 50 km unmetalled road were crushed. • Road communication between Bandarban headquarters and remote thanas became snapped.
24 June, 2000	13 dead and 24 injured	Chittagong University Campus	• The landslide damaged property worth several lacs of taka in those places.
11 June, 2007	135 dead and 213 injured	Motijharna of Lalkhan Bazaar, Power Colony, Kushumbagh Residential area, Taragate, Devpahar, Shaheed Minar area of Chittagong area, and Lebu Bagan of Chittagong Cantonment area.	• A total of 5,072 families were homeless • Food grain storage of Majheerghat, Sagorika road, Chaktai, and Patharghata were degraded because of water logging situation.
03 July, 2008	19 dead	Teknaf and Ukhia Cox's Bazar district	• Five houses were damaged.
14 July, 2008	2 dead	Himchari, Cox's Bazar district	-
22 July, 2008	10 injured	Kalo Pahar in Sunamganj	• About 100 homes destroyed and covered around 100 acres of land
18 August, 2008	24 dead	Hossain Colony in Chittagong city and neighboring Sadar sub district of Cox's Bazaar	• Some areas were water-logged due to heavy rainfall. • The landslide destroyed 13 cottages within sudden moment in Hossain Colony.

(Source: Sarwar, 2008; SAARC Disaster Management Workshop, 2010; Banglapedia, 2015)

3. RECENT LANDSLIDE EVENTS

Table 2: Overview of recent landslides in Bangladesh (2017)

Date	Location	Primary cause	Outcome	Death	Property damage
23 January, 2017	Companiganj, Sylhet	Illegal hill cutting	_	6	_
09 February, 2017	Bichanakandi, Sylhet	Illegal stone extraction	_	3	_
12 June, 2017	Rangamati, Chittagong, Bandarban	Heavy monsoon rain	Power cut and telecommunication disruption	160	$223 million

Figure 9: The part of Shah Arefin Tila where workers were killed in a landslide

3.1. Landslide in 23 January, 2017

At least six people were killed and several others injured in a landslide during an illegal hill cutting in Companiganj upazila of Sylhet. The incident happened at Matiar Tila, a part of Shah Arefin Tila in Bholaganj area of the upazila. The hillock used to be leased as a stone quarry to stone extractors. Following a writ petition of Bangladesh Environment Lawyers Association (BELA), the High Court ordered stopping of the leasing system and illegal hill cutting in 2012. But a syndicate of local influential people continued hill cutting and extracting stones. After the landslide at 6.00am, local people claimed that six workers were killed while extracting stones.

3.2. Landslide in 09 February, 2017

Three stone quarry workers were killed when part of a hillock collapsed on them while lifting stones from Bichanakandi in Gowainghat upazila, Sylhet. Part of the hillock collapsed on some workers while lifting stones from Bichanakandi stone quarry near the kheyaghat area at the dead of night, leaving the three workers dead. According to Gowainghat Police Station, an influential gang has long been involved in lifting stones illegally from there. Police could not yet recover the bodies as those are believed to have been removed from the place.


5.5: Landslide in 12 June, 2017

Figure 3: Hillock collapse in Bichanakandi stone quarry, Gowainghat upazila

On 12 June 2017, heavy monsoon rain triggered a series of landslides and floods in Chittagong division. Reports indicate that approximately 80,000 people across five districts of Chittagong Hill Tract (CHT)- Bandarban, Chittagong, Cox's Bazar, Khagrachari and, Rangamati were affected. The landslide resulted in 160 deaths and 187 injured.

Impact on property and infrastructure: About 6,000 structures have been destroyed, and other key infrastructure have been damaged. The worst-hit district was Rangamati, where landslides buried hillside houses where people were sleeping. At least 20 separate landslides hit the district. Up to 105 deaths were reported until 15 June, 2017 and 5,000 homes were damaged. Roads in Rangamati remained inaccessible and many roads in the district were washed away, leaving craters up to 15 meters (50 feet) deep, or blocked with debris. The district's power grid was also destroyed. There were also fuel and food shortages according to the district chamber of commerce and industry.

Response and rescue operation: Immediately after the landslides, rescue workers were having trouble reaching victims as roads were blocked with mud and rain continued. The weather also caused power cuts and telecommunication disruptions, making the rescue operation more difficult. Heavy digging equipment could not reach remote areas. Rescuers were using boats to reach some areas where roads were cut off. Elsewhere, villagers joined firefighters and soldiers in cutting fallen trees and clearing debris in remote areas where rescuers have been unable to get heavy machinery. Power and cell service were completely off in the affected areas and doctors worked by candlelight to help the injured. Thousands of Bangladesh army soldiers were already stationed in the area because of a long-standing insurgency, and they were directed to help in the rescue effort. Two officers and two soldiers of the Bangladesh Army (Major Mohammad Mahfuzul Haq, Captain Md.

Tanvir Salam Shanto, Corporal Mohammad Azizul Haq and soldier Md. Shahin Alam) were killed after a second landslide struck a highway-clearing operation in Rangamati. The body of a fifth army personnel, soldier Md. Azizur Rahman, was found 15 June, 2017. According to the head of Bangladesh Disaster Management Department, the landslides were the worst in the country's history.

Figure 4: Level of damage in Rangamati, one of the worst-affected districts

Figure 5: Rescue operations carried out by Bangladesh Army and volunteers

4. Lessons Learned

Illegal cutting of hills: Illegal cutting of hills and extraction of stones were the primary reasons of landslides in 23 January and 9 February, 2017. Greedy influential people and muscle-men invade the government hills and build temporary houses on them to earn money by renting them to the poor people. Poor people who live in those houses are highly vulnerable to landslide. Because of hill cutting, the slopes become instable and prone to landslide.

The legal base of preventing illegal hill cutting is the Building Constriction Act (1952). The purpose of the Act was to prevent haphazard erection of buildings, excavation of tanks and cutting of hills and hillocks in Bangladesh. According to the provision of section 3C of the Act, no person shall cut or raze any hill without the previous sanction of the authorized officer. The Act also provides for specific provisions for punishment and legal actions against the persons transgressing the law. As per section 3D and 10A of the Act, the authorized officer can serve a show cause notice to any person who is cutting hills illegally; seize all the vehicle, instrument, material used for cutting the hills and may get the person arrested by a police officer without warrant. Violation of section 3C is an offence punishable with imprisonment which may be extended to seven years or fine or with both.

The Bangladesh Environment Conservation Act (1995) has empowered the Department of Environment (DoE) to impose restriction on hill cutting and razing. According to the provision of this Act, no person or institution can be entitled to cutting and/ or razing of hills which under the authority of government, semi-government, autonomous institution or under the ownership of a private person without receiving clearance certificate from the DG of DoE.

Unfortunately, there is lack of implementation of these laws. The District Administration should pro-actively conduct Mobile Court by Executive Magistrates for taking cognizance of hill cutting as an offence under its jurisdiction for immediate and effective action. GIS-based surveillance can be done with aerial photographs taken at an interval of time to monitor hill cutting.

Rainfall and landslide vulnerability: Landslide in Chittagong is influenced by heavy rainfall. When it rains, water dissolves the minerals of the soil of the hills that loosen its compaction. Soils of the hills also become heavy by absorbing rainwater. If rain intensity is too high, minerals of soil dissolve very quickly and the soil turns into mud and becomes very heavy. The steep slope of the hill cannot bear the mass weight of the wet soil or mud that results the landslide. A detailed scientific study is needed to understand the threshold of rainfall for landslide potentiality in the region. Information technology and database management in Bangladesh is still it its infant stage. Most of the data available from Bangladesh Meteorological Department (BMD) is error prone, inaccurate, and incomplete. At the same time, Detailed Area planning (DAP) of the city and a better management of government owned land are needed to minimize landslides and its hazards in Chittagong. Landslide vulnerability area need to be identified and highly vulnerable area should be declared as ‘Red Zone’ for housing or any other settlement activities. Relocation of present inhabitants of dangerous hill slope is another issue to be considered. A landslide database is essential to have a better understanding of causes, impacts and trends of landslide in Bangladesh.

Coordinated rescue operations: Rescue operations in recent landslides had an experience of poor coordination and inadequate rescue tools. Landslide disaster contingency plan at both government and community level should be formulated with definite coordination body and trained manpower equipped with necessary tools. Chittagong City Corporation should have plan in place to evacuate its residents in case of emergency situation

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PART-VI

RISK ASSESSMENT OF DISPLACED INHABITANT DUE TO RIVER EROSION AND LOOKING FOR RELOCATION AS A SUSTAINABLE SOLUTION IN LEBUKHALI UNION, PATUAKHALI, BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Maruf Billah

Tasnim Tarannum

Mehedi Ahmed Ansary

Introduction

“The only way to explain to people who know nothing about our problem of river bank erosion is this - those who had a very happy and healthy life, with beautiful houses, and fields full of crops and cattle are now like beggars. They sleep in the markets and in the open," said Ahmad Ali (a refugee due to river erosion at Kaijuri, near the city of Sirajganj, north-west of Dhaka) [Source: BBC NEWS, Sunday, 30 August 2009: “Help for victims of Bangladesh river erosion”]

These common pictures can be shown all over the Bangladesh since it is a low-lying deltaic country in South Asia formed by the Ganges, the Brahmaputra and the Meghna rivers. More than 700 rivers and tributaries have made this country a land of rivers. Over 92 percent of the annual runoff generated in the GBM area flows through Bangladesh, which is only about 7 percent of the total catchment (Ahmad, 2000). Thus, a vast amount of water flows through Bangladesh. It is estimated that every year an average of 870 Million Acre Feet (MAF) of water flows into the country from India. The amount of rainfall received within the country is estimated at 203MAF, with evaporation, evapotranspiration, and deep percolation losses probably accounting for about 120MAF. This means that about 953MAF flows out to sea–from that 914MAF flows through the Ganges Brahmaputra delta (within Bangladesh) (Rashid 1991).

Riverbank Erosion and common and recurrent natural hazard in Bangladesh. Every year, millions of people are affected by erosion that destroys household, industries, standing crops, farmland and homestead land. In the country as a whole, between 15 to 20 million people are at risk from the effects of erosion (Rogge and Haque, 1987). The Flood Plan Coordination Organization (FPCO) reports that 4.3 million inhabitants of the charland in the major river systems comprise the most vulnerable group in Bangladesh. In addition, ‘about 9,000 hectares of mainland and 5,000 ha of char land are reworked each year by erosion’ (FPCO, 1995:7) and over 60,000 people become landless due to river-bank erosion problems along the main rivers of Bangladesh. It has been estimated that tens of thousands of people are displaced annually by river erosion in Bangladesh, possibly up to 100,000 (Faruque, 2007). River erosion is the on-going phenomenon in our country’s geo-morphological context, and hence we have selected the topic related to assessing damage and loss resulting from riverbank erosion. When disasters strike, the poor usually survive by selling off land, livestock, housing material and personal belongings (Haque, 1997). Some researchers have reported that bank erosion is taking place in about 94 out of 489 upazilas of the country.

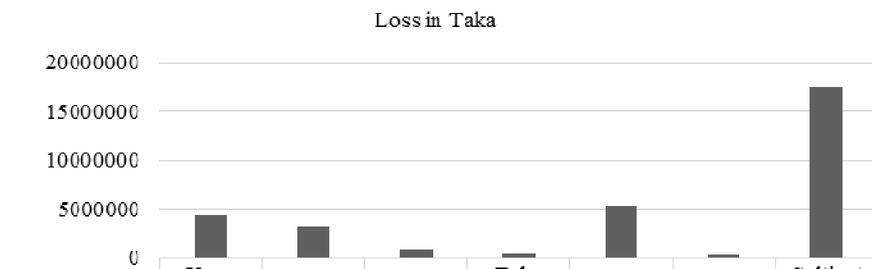
As situated in the coastal region, the Lebukhali union at Dumki upazila is also prone to Payra river erosion. About sixty-five families are displaced to Gucchagram area and their miseries causes by the river erosion. They lost the rhythm of live, livings and livelihoods, the status. The effects of the Payra river erosion make them homeless, penniless and peace less. So, the total assessment of the damages and losses will give a minimum idea about their vulnerability.

A part of Bakergong and Lebukhali union on the bank of the Payra river have been facing the river bank erosion. The gucchagram of the Lebukhali union has been selected as the study area due to massive bank erosion since last six years. Assessing the damages and losses of economic resources due to Payra riverbank erosion at Lebukhali as well as making a comparison with previous situation is the main focus point of this study. To conduct the damage and loss assessment study involves both primary and secondary data source; where the primary sources have direct and dominant contribution to meet the need of the objectives.

Result and discussion

Assessment of Economic Damages and Losses

Economic damages and losses which are directly related to economic costs included losses and damages of houses, homestead areas, trees, ponds, tube-wells, latrines and cultivated lands in context of Gucchagram area in Lebukhali union. Here the total estimated damages and losses costs about 317,24,000 BDT. It has been assumed that the monetary value of per satangsa homestead area is about 7000 taka, per house 40000 taka, per pond 15000 taka, per tube well 20000 taka, per tree 7000 taka, per latrine 3000 taka and per satangsa of cultivated land is about 5000 taka. Obviously it's not a lower amount in profile that lost their last piece of land and came to the Gucchagram with a bare hand. The largest portion of losses has been seen on cultivated land because the most of the local people were farmers who lost their lands by the river erosion. Figure 1 represents the approximate estimations of their economic losses.



	Home stead	House	Pond	Tube well	Tree	Latrine	Cultivat ed land
■ Loss in Taka	4284000	3280000	840000	340000	5285000	210000	17485000

Figure 1. Estimation of economic damage and loss in taka

Impacts on Agriculture

In the country's context, it has been estimated that more than one-half of rural households have virtually no direct access to land, even though the majority are dependent on agriculture (Januzzi and Peach, 1980; Rogge and Haque, 1987). Since agricultural land losses shows the greatest portion of economic loss, we assess particular vulnerability in this sector resulting from riverbank erosion. Declining of crop production, damage to the standing crops, changing in crop diversity and cropping pattern are the aspects where losses and damages occurs. Effects of riverbank erosion can be seen on both sides of Payra River due to erosion and deposition. Comparing the two events, (Figure 2, (a)) it can be concluded that on agricultural sector aspects on Payra river erosion damaging crop ranks from 2 to 5, which means the river erosion has made the standing crops most vulnerable. There seen a little variation in crop diversity and cropping pattern before and after the river erosion.

Assessment of Non-Economic Damages and Losses

Besides the economic losses, the affected people have faced some non-economic losses which have a great impact on their livelihood and other consequences. Social degradation, impact on environment, levels of generated vulnerability always play a big role in this community. Non-economic damages make them vulnerable to access a better life quality. It makes them hold an unhygienic environment with a lower health profile and malnutrition.

Generated Vulnerability

In the worldwide scenario, no community can be declared as 100% resilient because man has the ability to cope with disasters not to prevent them. When disasters strike, the poor survive by selling off land, livestock, housing materials and personal belongings — all of which further their impoverishment (Islam, 1998). As a community, the people of the selected area have some vulnerability before and after the occurrence of the riverbank erosion which makes them more vulnerable than before. Women are generally assumed to be most vulnerable to the impacts of natural disasters. Women worldwide are more likely than men to be poor, own less, work longer hours and earn less income (Ahooja-Patel, 1992). Comparing the generated vulnerability before and after the event (Figure 2(b)), it can be seen that vulnerability of child marriage and school dropout rate increases after river erosion indicating the vulnerability of women.

Social Degradation

Social degradation due to Payra riverbank erosion can be identified as the breakdown in social interaction as broken social and family bondage, lowering their social status, migration to the city, ruin of peace as well as occupational change (Figure 2(c)). It fosters strong interdependent kinship and neighborhood networks that promote survival strategies based on the obligatory exchange of physical, financial and material supports during times of need (Novak, 1993; Zaman, 1989). Against these, worse situation cases make them fragile. It may be the indirect cause but the assimilated effects affected the community. Though there was violation of the social justice and equilibrium before the riverbank erosion, it was negligible. The rural power structure is dominated by members of the larger landowning class, and they determine the settlement of alluvial land upon re-emergence from the riverbeds (Malik, 1983; Zaman, 1991). The newly formed chars are settled upon by people of both banks as new settlement frontiers and remain sources of perennial dispute among conflicting claimants (Zaman, 1989). The assessment shows that situations have been completely changed after the erosion.

Impact on Environment

Every disaster has a negative impact on the environment and sometimes the human disturbance makes it worse. As a part of the disaster-prone country, the selected area was already under the impact on climate change but the riverbank erosion has amplified the negative effects even more. The respondents express their view regarding the effects of sand deposition on the crop land. As a result, the crop production is disrupted. Bank erosion and char formation are ongoing process in the Payra River which changes the soil characteristics of the area. The depth of the river is slowly decreasing and the habitat of fishes like the famous Payra's Hilsha fish is destroyed. The respondents claim that some fish species have become rare today. As seen from Figure 2(d), access to safe drinking water has decreased and cropland affected by sand deposition has increased due to river erosion.

Received Relief Measures

Some steps have been taken by the government to reduce the impact of the massive riverbank erosion during the last six years. The government has replaced the victims who lost their land due to river erosion and has developed the resilient community named Gucchagram with sixty-five families. There is a common large pond called (Dighi) with a co-operative fish farming system in the community. They have received 10 kg rice relief for the first two years or more. But at present they only receive little commodities twice a year during the holy EIDs. In the existing price-hiking circumstances, that's not enough against their needs. Besides, there is a hope that few families got a piece of land in the Char area as compensation for losing their land. Though these may be a forwarding step from the government, it doesn't make the local people satisfied as 44% of the respondents are dissatisfied with the amount of compensation they have received. The activities of the NGO sectors are very much negligible to meet their needs. Only few NGO's are working with them and trying to rebuild the capacity of the affected people.

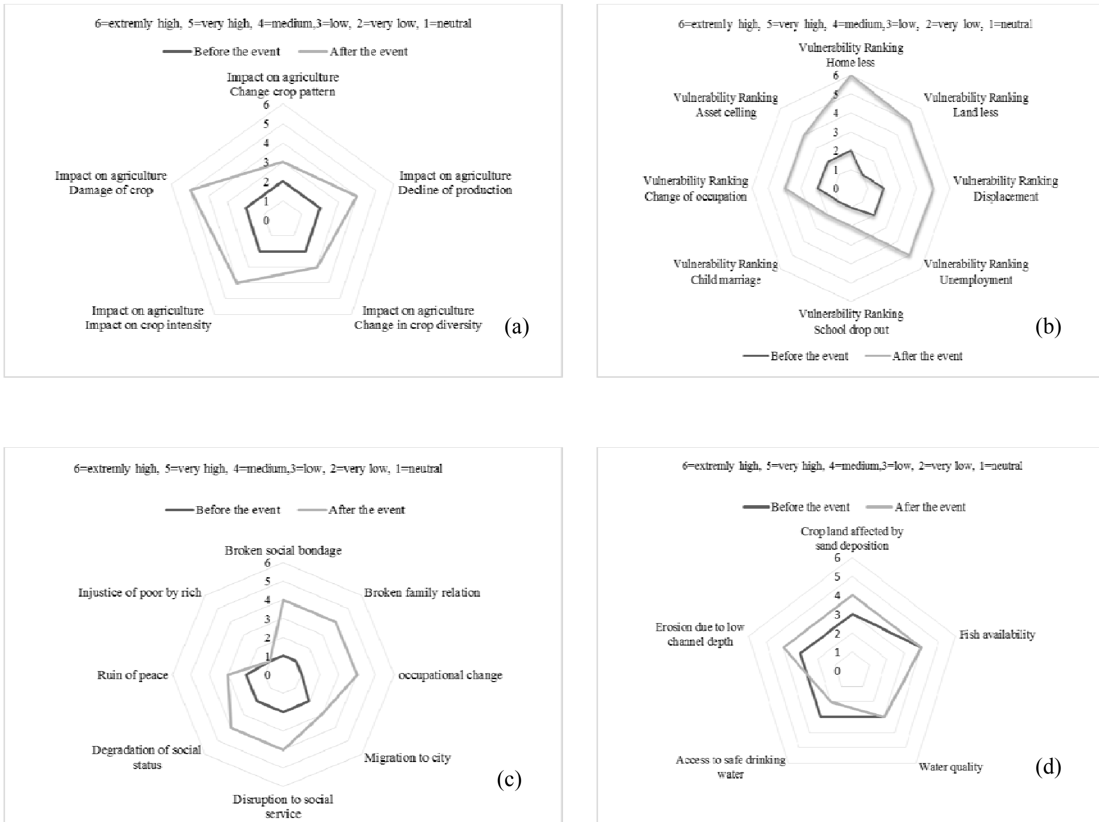


Figure 2. Risk ranking or situation analysis of the affected community before and after the event. (a) Impact on agriculture, (b) generated vulnerability, (c) social degradation, (d) impact on environment.

Relocation as a Sustainable Solution

Many steps have been taken by the government to replace the affected people in the safer location but some long-term preparedness measure should be taken to reduce the vulnerability and enhance the capacity of the affected people, like:

• Strengthening and supporting the capacity of the community to cope with the erosion event with community preparedness plan, emergency plan, increasing the participatory process etc.

• Developing and supporting basic infrastructure service (water, health, housing, cultivated land etc.) and enable poor people to access existing Govt. Services

• Providing alternative livelihood opportunities through skills development and small enterprise development

• Raising awareness on basic rights of the community, with particular emphasize on land rights and rights of women and trained them about the basic knowledge about what they should do during the emergency moment

• Constructing a cyclone shelter is also needed since the nearest shelter situated very far from the community.

• Providing security of their shelter and maintaining proper administrative plan because there is now a burning issue about constructing an Army camp there, it'll make them again homeless.

Conclusion

This study has been conducted to estimate the damage and loss due to river bank erosion at Gucchagram in Lebukhali union in which we have seen a big divergence on the life leading styles before and after the event. Their miseries have no bound and it's also hampering their social status, they live a life in unhygienic environment and it makes them vulnerable to sanitation, health, education etc. The direct losses arise from losing agricultural land, household, homestead, trees etc. Total economic loss is about 3,17,24,000 taka, among them the most affected areas cultivated land about 1,74,85000 taka and homestead damage is about 42,84,000 taka. In the non-economic sector, the social sector and the capacity of that community has been affected more. But an alarming factor is they had a climate change impact before the event and now existing as a superior muscle. While conducting the study we have to face some limitation like lack of experience, insufficient time, as well as we have to face problem to collect data from the women while the male members were absent on the home. We hope that the farther study can help to understand the sufferings of the affected people of that area and find proper steps to turn the vulnerable community to a resilient one.

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APPENDIX 1: Questionnaire

Risk Assessment for River Erosion at Gucchagram in Lebukhali Union, Patuakhali, Bangladesh

Flood and River Bank Erosion Management, Department of Disaster Resilience and Engineering, Faculty of Disaster Management, Patuakhali Science and Technology University

Questionnaire

Please answer the following Question

Serial no:

Date:

Basic information of the study area

Name…………………………………..village……………ward no….......................

Union…………………………………….upazila…………………………….District…

Age	sex	education	occupation	Service less

How many member of your family

Male	Female	Child	Others

What is the source of your income?

agriculture	job	business
Farmer	Bank job	Shopkeeper
Fish cultivator	Private job	Blacksmith
Dairy farmer	Government job	Potter

What do you think how this riverbank erosion is form?

Failure of Embankment	Excessive raining	Excessive water from upward	Poor drainage system	Riverbank erosion

Did you have any shelter nearby of your house?

Yes		No	

Distance of the nearby shelter from the house ……………..

Losses of Livelihoods

	Yes	No	If yes then amount in number
Homestead			
House			
Pond			
Dug well			

Tube well			
Tree			
Latrine			
Factories			

Loss of Cultivated Land

Cultivated land (ha)	Mark with (*)
0-2	
2-4	
4-6	
6>	

Generated vulnerability

5= extremely high, 4= very high, 3= medium, 2= low, 1= very low, 0= neutral.

Before event	0	1	2	3	4	5		After	0	1	2	3	4	5
Homeless														
Landless														
Displacement														
Unemployment														
School drop out														
Child marriage														
Change of occupation														
Asset selling														

Social Destruction

5= extremely high, 4= very high, 3= medium, 2= low, 1= very low, 0= neutral.

Before event	0	1	2	3	4	5		After	0	1	2	3	4	5
Broken social bondage														
Broken family relation														
Occupational change														
Migration to city														
Disruption to social service														
Broken social network														
Degradation of social status														
Ruin of peace														
Injustice of poor by rich														

Impact on Agriculture

5= extremely high, 4= very high, 3= medium, 2= low, 1= very low, 0= neutral.

Before event	0	1	2	3	4	5		After	0	1	2	3	4	5
Change crop pattern														
Decline of production														
Change in crop diversity														

Impact on crop intensity														
Damage of crop														

Impact on Environment

5= extremely high, 4= very high, 3= medium, 2= low, 1= very low, 0= neutral.

Before event	0	1	2	3	4	5		After	0	1	2	3	4	5
Crop land affected by sand deposition														
Fish availability														
Water quality														
Access to safe drinking water														
Erosion due to low channel depth														

Relief and benefit of Erosion Victims

5= extremely satisfied, 4= very satisfied, 3= Satisfied, 2= Dissatisfied, 1= very Dissatisfied,

Before event	1	2	3	4	5		After	0	1	2	3	4	5
Receive relief service													
Development service from NGO													
Land from accreted char													
Aid in raising homestead													

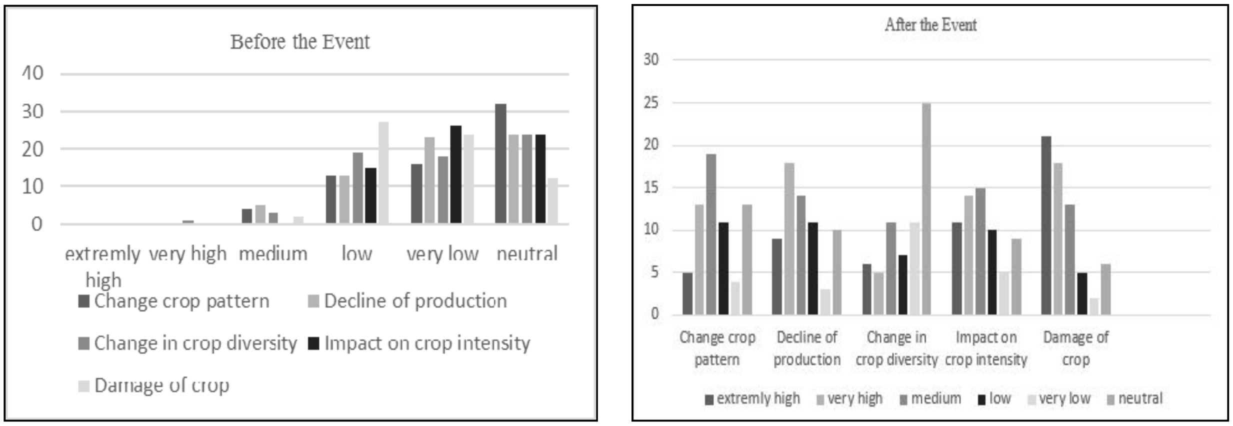


Figure: Impact on agriculture before and after river erosion

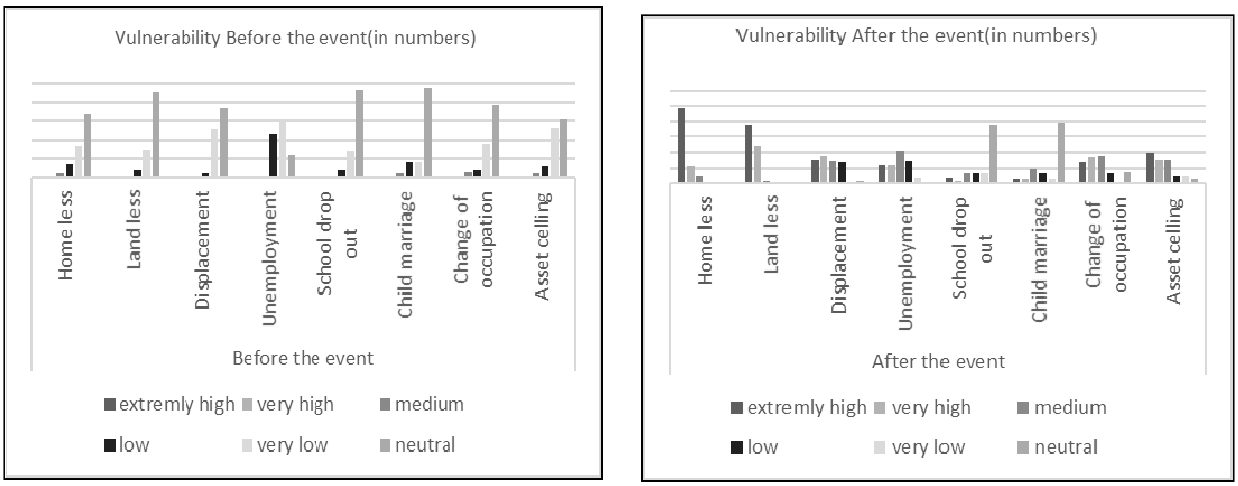


Figure: The level of vulnerability of the selected area before and after river erosion

PART-VII

PERFORMANCE OF REINFORCED CONCRETE FRAME RETROFITTED WITH BUCKLING RESTRAINED BRACE (BRB)

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: MA Islam

Raquib Ahsan

Mehedi Ahmed Ansary

Introduction

In Bangladesh, BNBC-1993 is being implemented still now for the design of reinforced concrete structure. But, many advances in earthquake engineering research have been taken place over the last few decades. There is a considerable concern regarding the reinforced concrete buildings around the world, which have been built prior the enactment of modern building codes in seismically active region (Z. Al-Sadoon et. al., 2015). These structures which have been mainly designed and constructed for gravity loads only, are vulnerable to earthquake. In addition, these structures do not confirm the ductility provision which is necessary for survive of design level earthquake. Moreover, most of the buildings are damaged due to large lateral displacement in earthquake. To alleviate such problem or to satisfy the displacement limit some ductile materials having sufficient lateral strength and stiffness need to be incorporated into the structures. Performance of conventional bracing system is poor (Sabelli et. al., 2001) and recent research findings suggested that those bracing system may not be a reliable solution (Uriz et. al., 2004). Buckling Restrained Braces (BRB) initially developed by Watanabe (1988) and further examined in the United States through testing (Z. Al-Sadoon et. al., 2015). The reduction in RC member sizes and increased lateral stiffness and energy dissipation, reduction of the building weight and greater architectural flexibility, reducing the drift of the structure during a severe earthquake are the benefits of using BRBs in RC moment frame.

Design of Concrete Frame and Experimental Setup

The concrete frame that is investigated in this study is a representative of a typical six storey reinforced concrete moment resisting frame building (residential) in Dhaka, Bangladesh. Figure 1, 2, 3 show the RC frame. The left and right columns were identical and provide a cross section of 120 × 120 mm. The top beam was 710 mm wide, 2160 mm long and 120 mm deep. The height of the frame was 1050 mm and width was 1370 mm center to center of column. The slab was 2160 mm long, 710 mm wide and 75 mm thick. The superimposed loads were placed on the slab. The foundation was 1800 mm long, 405 mm wide and 255 mm deep. The vertical column reinforcement consists of four 12 mm diameter. The column stirrups using 10 mm diameter, spaced at 250 mm. The beam consists of 4 – 10mm bar and stirrups using 10 mm diameter, spaced at 250 mm. Properties of BRB is shown in Table 1. Four bolts were used to anchor the BRB with column. Total 2.4 ton load (one-third of total load) is superimposed on the frame. Loads are calculated considering bottom column of a six storey building.

Figure 1: BRB and RC frame connection

Figure 2: RC frame connection without BRB

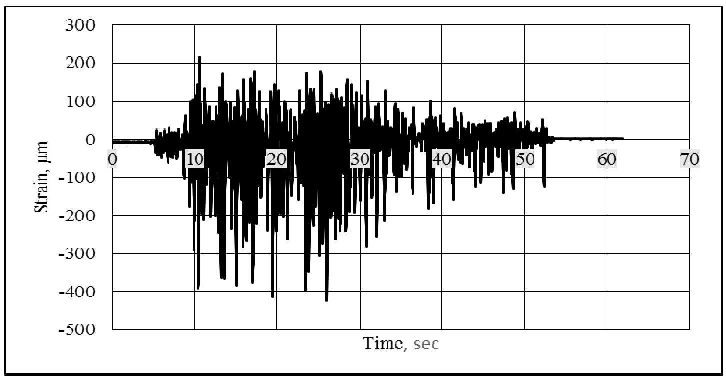


Figure 3: RC frame with superimposed loads (with BRB)

Figure 4: Strain in bottom reinforcement of column (with BRB)

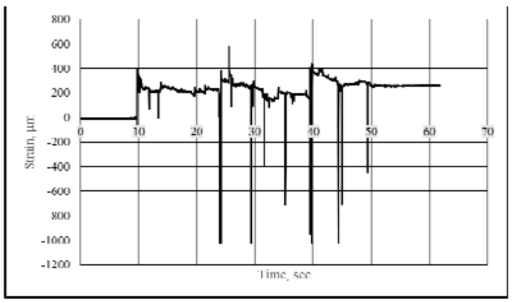
The frame was tested in the earthquake engineering lab of BUET-JIDPUS. In plane test was performed in the shake table of BUET-JIDPUS. The specification of shake table is shown in Table 2.

Test Result and Discussion

To obtain the strain of reinforcement strain gauge was attached to the bottom reinforcement of column and slab. Figure 4, 5, 6 shows the recorded strain. A displacement transducer was attached to the slab level for recording the lateral displacement. Maximum experienced acceleration of the frame was recorded attaching accelerometer in the shake table. Figure 7, 8 shows the maximum acceleration that the reinforced concrete frame endured. Figure 9 shows the displacement over time.

Table 1: Properties of Buckling Restraint Brace

Properties of BRB			
Length	55 inch	Anchor Plate Thickness	12 mm
Diameter	3.5 inch	Anchor Bolt Dimension	11 mm



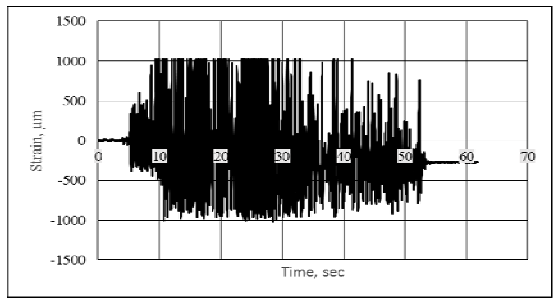


Figure 5: Strain in slab (main) reinforcement (with BRB)

Figure 6: Strain in column tie rod (with BRB)

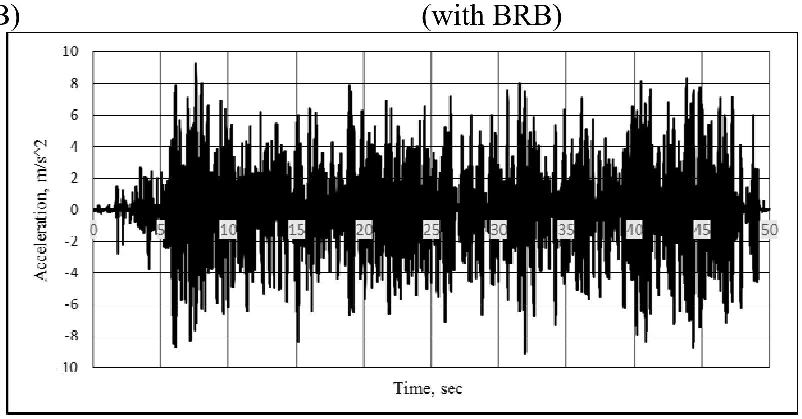


Figure 7: Maximum recorded acceleration (with BRB)

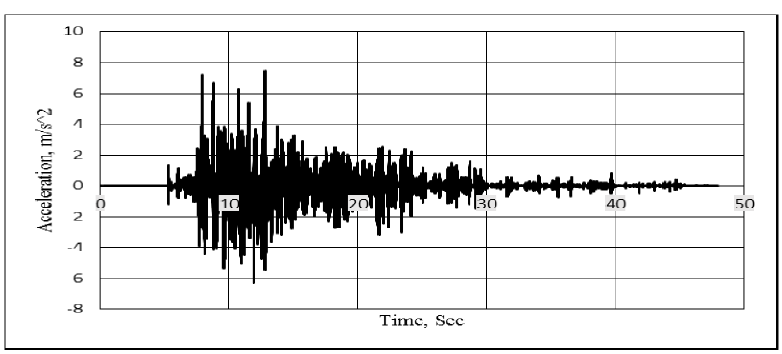


Figure 8: Maximum recorded acceleration (without BRB)

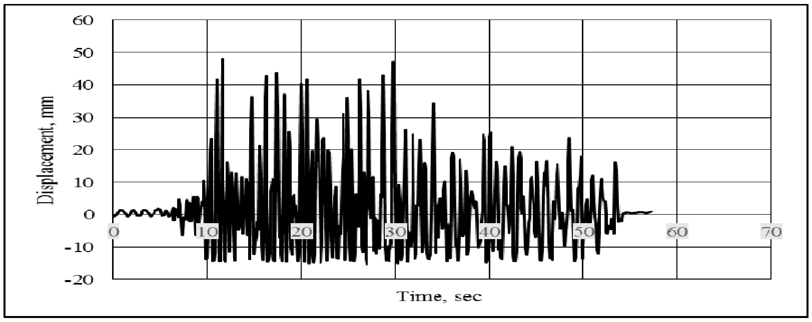


Figure 9: Maximum recorded displacement (with BRB)

Table 2: Specification of Shake Table

Shake Table Specification
Size: 3m x 3m **Actuator:** 25 ton Servo Hydraulic Actuator **Acceleration Capacity:** 1.3g maximum acceleration with 10 ton payload **Bare table Acceleration:** 4.0g **Velocity Capacity:** 100 cm/s **Displacement Capacity:** +/- 100mm

Conclusions

From the test result it is clear that reinforced concrete frame without BRB can sustain 0.24g acceleration before failure whereas RC frame with BRB can sustain 0.31g acceleration before failure (with one-third superimposed load of total load). RC frame retrofitted with BRB can sustain a lateral displacement of 47mm (1.85 inch) before failure. From strain diagram it is clear that, the bottom reinforcement of column experienced 400 micrometer/meter strain (0.015 inch/inch). Slab main reinforcement and column tie rod experienced the same amount of strain which is around 1000 micrometer/meter strain (0.0394 inch/inch). Therefore it is clear that, BRB performed better and this bracing system was effective at preventing buckling.

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PART-VIII

SOFT GROUND IMPROVEMENT AT THE RAMPAL COAL BASED POWER PLANT CONNECTING ROAD PROJECT IN BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Sudipta Chakraborty

Ripon Hore

Mehedi Ahmed Ansary

1. INTRODUCTION

Fields of transportation plays a significant role in the progress of a country. In the construction of road, railway, airway, the alignment may have to be fixed through the soils which may not bear the traffic loads. In most cases, ground improvement is required. In a broad sense, ground improvement refers to the incorporation of different techniques employed for modifying the properties of a soil to improve its engineering performance.

Colombo–Katunayake Expressway (CKE) is the first major highway in Sri Lanka; where Preloading, Preloading with surcharging, prefabricated vertical drains (PVD), sand compaction piles (SCP), stone columns (SC) and composite treatments have been used as soft ground treatment (Cooray, 1984). The composite treatment has been used at three locations-Peliyagoda (Ch 1+500–1+850) and Muthurajawela (Ch 11+250–11+930 and 12+050–12+450).

Wei-Bing and Jia-Huan (1989) has reported the consolidation analysis of a foundation at Lianyungang City with sand drain by vacuum preloading. Boring and testing result shows that the site has 10 m thickness of uniform clay. The area preloaded by the vacuum method is 4000 m^2, with 2800 sand drains being 10 m long, 7 cm in diameter and 1.2 m in spacing. Vacuum under membrane has been maintained at above 650 mmHg column. After pre-loading, the mean settlement of ground surface has been found to be 55 cm and bearing capacity has been increased from 3 T/ m^2 to 8 T/ m^2.

Similarly Woo et al. (1989) has explained, geotechnical improvement program for the second Bangkok International Airport project, Thailand. Non-displacement sand drains with preloading by surcharge or vacuum or dewatering have been tried in test section to investigate their effectiveness. The sub-soils at the project site have been fairly uniform. Five different soil strata have been identified within the top 35 m zone. They are weathered clay (up to 1.5 m), very soft to soft clay (1.5-11 m), soft to medium clay (11-15 m), stiff clay (15-25 m) and dense sand (below 25 m). The 40 m by 40 m test section has 460 sand drains installed in triangular pattern, with spacing of 1.75 m center to center. Each sand drain which has been installed by jet-bailer method has a nominal diameter of 26 cm and 14.5 m long. A 60 cm thick sand blanket has been placed on the ground surface to provide a firm working platform.

Sand drain has been used as soil improvement method in the land reclamation project for a steel mill complex construction in Korea. Average depth of sea water has been above 5 m before backfilling with sand. The unit weight of backfill material is about 16.67 kN/m^3 with an average soil friction angle of 30°. The in-situ soil profile can be generally described as about 5 m of very loose alluvial sand and loose silty sand followed by very soft silty clay and clayey silt up to a depth of 20 m. underlying this is 5 m thick dark gray stiff clay. Bedrock and in some places, sandy gravel are located below the clay layer. Standard penetration resistance (N values) have varied from 0 to 29, but more than 80% of the N values are below 10. Most of N values are between 0 and 2 in soft clayey soil and relatively higher N values have been encountered in stiff clay layer. The diameter of sand drains is about 0.5 m with spacing ranging from 1.8 m to 2.5 m for hot strip mill site, and from 2.0 m to 2.5 m for cold rolling mill site. Typical construction pattern of sand drains has been laid out in regular square pattern with an average sand drain length of 25 m (Shin, et al., 1993).

Radhakrishnan, et al (2010) has stated that marine clays has been found in coastal region of Mumbai. A number of Industries, dams, buildings and embankments are being constructed along the inland coastal areas where the soil is of soft clay associated with problems of settlement and stability. In order to analyze the stability of an embankment constructed on these compressible marine clayey deposits, laboratory consolidation testing is the basis for computing the settlement. Providing vertical sand drains (VSD) offers a better solution in accelerating the process of consolidation to eliminate the deleterious post construction settlements and also to acquire sufficient additional shear strength. An embankment has been constructed as an approach to a Railway Bridge, which is underlain by a soft marine clay layer of thickness varying from 3.5m to 15.6m at the critical location, for a length of nearly 600 meters. There is an impermeable weathered rock below the clay layer and the total height of the embankment at the critical location is 14 meters. Construction of the embankment has been done in 3 stages. The total construction time has been 2 years. The construction time for the 1st, 2nd, 3rd, stages are 3 months, 2.5 months, 5 months respectively and there is a rest period after the completion of each stage. Sand drains have been provided in conjunction with the preloading. Sand drains of 300mm diameter have been installed in triangular pattern with an effective spacing of 2.75m.

Indraratna, et al. (2010) has discussed three sites of Muar clay (Malaysia), the Second Bangkok International Airport (Thailand), and the Sandgate railway line (Australia). One of the test embankments on Muar plain has been constructed to failure. The failure is due to a “quasi slip circle” type of rotational failure at a critical embankment height at 5.5 m, with a tension crack propagating through the crust and the fill layer. The Second Bangkok International Airport or Suvarnabhumi Airport is about 30km from the city of Bangkok, Thailand. Because the ground water is almost at the surface, the soil has suffered from a very high moisture content, high compressibility and very low shear strength. The soft estuarine clays in this area often pose problems that require ground improvement techniques before any permanent structures can be constructed. Under railway tracks where the load distribution from freight trains is typically kept below 7-8 meters from the surface, relatively short PVDs have been employed. The rail track of the Sandgate Rail Grade Separation Project is stabilised using short Prefabricated Vertical Drains (PVDs) in the soft subgrade soil. Site investigation included 6 boreholes, 14 piezocone (CPTU) tests, 2 in-situ vane shear tests and 2 test pits. Laboratory testing such as soil index property testing, standard oedometer testing and vane shear testing have been also performed. The groundwater level is at the ground surface.

The Ballina Bypass route in Ballina (New South Wales, Australia) has been built to reduce local traffic jams. To ensure ground stability and improvement, PVDs combined with surcharge and vacuum preloading are being utilized to consolidate the soft soils before the construction (Indraratna et al., 2012). A trial embankment has been built to the north of Ballina to evaluate the effectiveness of the technique in this area.

Long et al., (2013) has discussed three projects namely North-South Expressway (NSEW) project, CaiMep International Terminal (CMIT) project, and 3 test embankments (TS1, TS2 and TS3) at Suvarnabhumi Bangkok International Airport (SBIA) project in Thailand, where prefabricated vertical drain (PVD) with or without vacuum consolidation has been employed.

The railway embankment along the alignment of the project for the construction of double line track from Tongi to Bhairab Bazzar (including signaling on Dhaka- Chittagong main line) in Bangladesh is lying on soft ground between chainage 29+300 m to 64+265 m. Depending on the soft ground treatment, 29 sections have been identified; among which in 13 sections no treatment, surcharge loading in 2 section, remove and replacement technique for 7 sections and PVD installation in 7 section of the embankment is proposed (BRTC, 2013).

Shukla and Kambekar (2013) has proposed embankment for double track broad gauge railway line between Belapur-Seawood-Uran areas in Navi Mumbai for chainage 19000 to 20500. The study of the soil indicates that the top of the stratification contains the yellowish stiff clay. The next layer observed in the stratification contains the soft grayish marine clay which is then followed by yellowish stiff/hard clay with gravels. The next layers of stratification are completely weathered rock which is underlain by moderately weathered rock. The second layer of subsurface profile is identified as grayish soft marine clay. This layer undergoes heavy settlements and the duration required for settlement to take place is also very high. These settlements can be accelerated by prefabricated vertical drains (PVD) with surcharge. With the use of PVD water flows horizontally (radically) as well as vertically i.e. three dimensional consolidations. The time required for consolidation with prefabricated vertical drains is expected to be shorter as compared to the time required for the preloading alone without PVD. The expected consolidation settlement achieved by PVD from the calculation is slightly higher than actual field consolidation settlement. The closer the spacing in between prefabricated vertical drains, the shorter the time required for the consolidation process. The advantages of square pattern are that it is more convenient to lie out and manage on site.

Zein and Elgasim (2014) has investigated on the suitability of staged construction, sand drains and sand compaction piles soil improvement methods for the design of a 12m high earth embankment on weak and compressible alluvial clay deposits. The embankment site chosen for study is the location of the eastern abutment of Alhalfaya Bridge built across River Nile to link Omdurman city and Khartoum North town in Khartoum State, Sudan. The embankment is of the rolled earth type with a maximum

height of 12.0m,30m top width and 78m bottom width with 1:2 (vertical: horizontal) side slopes. The soil profile comprised of a soft silty clay soil layer ranging in depth from 1.0m to 6.0m, underlain by a very loose to medium dense poorly graded fine to medium coarse silty sand or sandy silts extending to a depth of 14.0m. These alluvial deposits rest directly on the highly weathered sandstone formation. The natural moisture content varied from 26% to 42% with most values between 28 and 32%. The natural dry density ranged between 11.0 and 14.5kN/m^3. The use of vertical sand drains in soft clay accelerate the primary consolidation of clay since they bring about rapid dissipation of excess pore water pressure under embankment loading. Vertical drains are normally used where preloading alone will not be efficient. The installation of sand drains into relatively thick clay strata increases the rate of consolidation of the clay under the load by shortening the drainage path.

Bangladesh railway, Rajshahi has taken up a decision to construct a new railway track along Kashiani-Gopalgang-Tungipara section about 32 km in length (BRTC, 2016). The soft soil thickness varies from 4 to 12 m. PVD in triangular pattern with a 2 m spacing has been proposed.

This paper aims to discuss on the soil profile of the Rampal Coal Based Power Plant connecting road project and the suitable soft soil improvement technique for this project.

2. PROJECT DESCRIPTION AND LOCATION

Construction of the Rampal Coal Based Power Plant connecting road consists of 4 lanes and 2 lanes for slow moving vehicle. The connecting road is 5.76 km long resting on soft soil; required soil treatment is the major challenge for this project. Project has started on 01-03-2015 and has fully completed on 28-12-2016. Photograph of the site before starting any construction work is shown in Figure 1.

Figure 1 Panoramic photographic view of the site

The study site is located in the Rajnagar and Gauramba union of Rampal sub-district of Bagerhat. The latitude and longitude of the site are $22^{0}37'00''$N to $22^{0}34'30''$N and $89^{0}32'00''$E to $89^{0}34'05''$E respectively. The location of the site is shown in the Figure 2.

The aim of this project is to facilitate the improvement of sustainable power supply capacity of the Government through improvement and construction of the proposed Khulna 1320MWx2 Coal based Power plant connecting all weather road. The most challenging part of the project is soil improvement of the 5.76 km long soft soil under the road construction, stratify the formation of soil and record the level of the ground water. It is important to provide accessibility and transportation facilities for construction and setting up the proposed Power Plant within the planned projected time. It is also vital to evaluate the safe bearing capacities of the foundation at the different layers, encountered at the different borehole positions.

Figure 2 Project locations on the map.

3. GEOLOGY OF THE SITE

The geology of the project site comprises of Paludal Deposits (ppc) and Tidal Deltaic Deposits (dt). Geologically the site comprises Tidal deltaic deposits-light to greenish grey, weathering to yellowish grey, silt to clayey silt with lenses of very fine to fine sand along active and abandoned stream channels, including crevasse splays. This contains some brackish-water deposits. Numerous tidal creeks crisscross the area; large tracts are submerged during spring tides. Also this site consists of soft marsh clay and peat-grey or bluish grey clay, black herbaceous peat, and yellowish grey silt. Alternating beds of peat and peaty clay common in bils and large structurally controlled depressions; peat is thickest in deeper parts.

4. SUB-SOIL INVESTIGATION

The soil test report has been prepared on the basis of an agreement between of the proposed Khulna coal based plant connecting road of Local Government Engineering Department (LGED) at Rampal, Bagerhat and the Development Survey Consultant, a sub-soil investigation firm in Dhaka. The sub-surface investigation work includes execution of eleven borings extending to the depth of 11.0 m to 40.0 m, performance of the required field and laboratory tests, evaluation of the Bearing capacity and finally recommending for the safe and appropriate type of foundation suited to the subsoil conditions. The wash boring method has followed in drilling the boreholes after driving the casing pipe. Grain size analysis, specific gravity and direct shear tests has been performed in the laboratory for proper evaluation of the soil parameters. The disturbed soil samples are normally collected during the operation of SPT. These samples are those in which the natural soil structure gets disturbed during sampling. The samples represent the composition and the mineral content of the soil.

The top formation of soil existing roughly to the depth of 2.65 m (BH-6), 3.10 m (BH-1), 3.55 m (BH-3), 3.70 m (BH-4 and BH-5), 4.70 m (BH-2), 5.55 m/5.70 m (BH-7, BH-8 and BH-9), 6.65 m (BH-10) and 7.60 m (BH-11) is predominated by plastic nature consisting of grey and occasionally yellowish grey soft silty clay. Further below, a layer of grey non-plastic sandy silt occasionally mixed with trace clay exists to a variable depth of 7.85 m/ 8.0 m (BH-1 and BH-6), 9.00 m/10.0 m (BH-2, BH-3, BH-4 and BH-5), 12.0 m (BH-7), 13.65 m (BH-10), 15.70 m (BH-9), 16.50 (BH-11) and 17.70 (BH-8) measured from existing ground level of the investigated boreholes. The subsequent layers of soil existing to the depth of the investigation are also non-plastic by nature. The above non-plastic soil comprises grey sandy silt, sand silt mix and very fine sand with some/ little silt. The SPT Value with soil profile of 11 boreholes against respective interval of the depth is shown in Figure 3.

The consistency of the top layer of clayey silt existing roughly to the depth of 2.65 m (BH-6), 3.10 (BH-1), 3.55 m (BH-3), 3.70 m (BH-4 and BH-5), 4.70 m (BH-2), 5.55 m/5.70 m (BH-7, BH-8 and BH-9), 6.65 m (BH-10) and 7.60 m (BH-11) is usually very soft and soft and occasionally medium. Further below, the layers of the non-plastic sandy silt existing roughly to the depth of 7.85 m/8.00 m (BH-1 and BH-6), 9.00 m/ 10.00 m (BH-2, BH-3, BH-4 and BH-5), 12.00 m (BH-7), 13.65 (BH-10), 15.70 m (BH-9), 16.50 m (BH-11) and 17.70 m (BH-8) generally have been observed in a very loose and loose state. The subsequent deep layers of the non-plastic sand-silt mix, silty fine sand and fine sand existing to the depth of the investigation, generally have been observed in a medium dense to dense and finally to a very dense state. Moreover, the consistency of the layer of clayey silt existing in between the depths of 13.65 m and 16.50 m (BH-10) is usually stiff.
Unconfined compressive test value varies between 30 to 40 kPa for the underlying soil beneath the embankment. According to the Laboratory test result the specific gravity of the investigated soil usually varies from 2.60 to 2.65. The engineering properties of the investigated layers of soil, particularly, the values of the angle of the internal friction, obtained from the performance of the direct shear tests, vary from 19.0^{o}-39.0^{o}. Several consolidation tests have also been carried out in the depth of 4 m at different locations. Following data have been obtained from one dimensional consolidation tests: initial void ratio ranges between 0.70 and 0.90, compression index ranges between 0.25 and 0.35 and coefficient of consolidation for vertical drainage ranges between 0.005 and 0.015 m^2/day.

5. SOIL IMPROVEMENT METHODOLOGY AND DATA ANALYSIS

Vertical drains are installed under a surcharge load of 65 kPa to accelerate the drainage of impervious soils and thus speed up consolidation. These drains provide a shorter path for the water to flow through to get away from the soil. Time taken to drain clay layers can be reduced from years to a couple of months. A sand column of 250 mm diameter and 5 m was used. The column is then filled with sand and connected to a free-draining blanket of granular soil. Because of its low permeability, the consolidation settlement of soft clays takes a long time to complete. To shorten the consolidation time, vertical drains are installed together with preloading either by an embankment or by means of vacuum pressure. Vertical drains are artificially-created drainage paths which are inserted into the soft clay subsoil. Thus, the pore water squeezed out during consolidation of the clay due to the hydraulic gradients created by the preloading can flow faster in the horizontal direction towards the vertical drains. It is taken advantage of the fact, that most clay deposits exhibit a higher horizontal permeability compared to the vertical. Subsequently, these pore water can flow freely along the vertical drains vertically towards the permeable layers. Therefore, the vertical drain installation reduces the length of the drainage path and, consequently, accelerates the consolidation process and allows the clay to gain rapid strength increase to carry the new load by its own.

The alignment of this road project is situated on a marshy land. This land remains water logged throughout the year and shrimp culturing occurs there. Oceanic ebbs and tides caries sediment and silted, formed alluvium types land. As per soil profile presented in the Figure 3, up to 3.5m consists of very soft silty clay and from 3.5-9.0m contains loose to very loose sandy silt. SPT value varies from 1-4 up to a depth of 5m which indicates that the soil condition is poor (very soft soil). Atterberg limits are 35-56 (LL), 25-28 (PL) respectively and moisture content is 42%. Under this circumstance, Vertical Sand Drain technique has been employed for this project. In the foundation level of the road, total number of 1, 10,000 vertical sand drain has been used. Depth of Vertical Sand Drain (with a 250mm diameter) is 5m from excavated ground level that means 5.6m from original ground level (OGL). Fineness modulus (FM) of sand (fine aggregate) is an index number which represents the mean size of the particles in sand. It is calculated by performing sieve analysis with standard sieves. The cumulative percentage retained

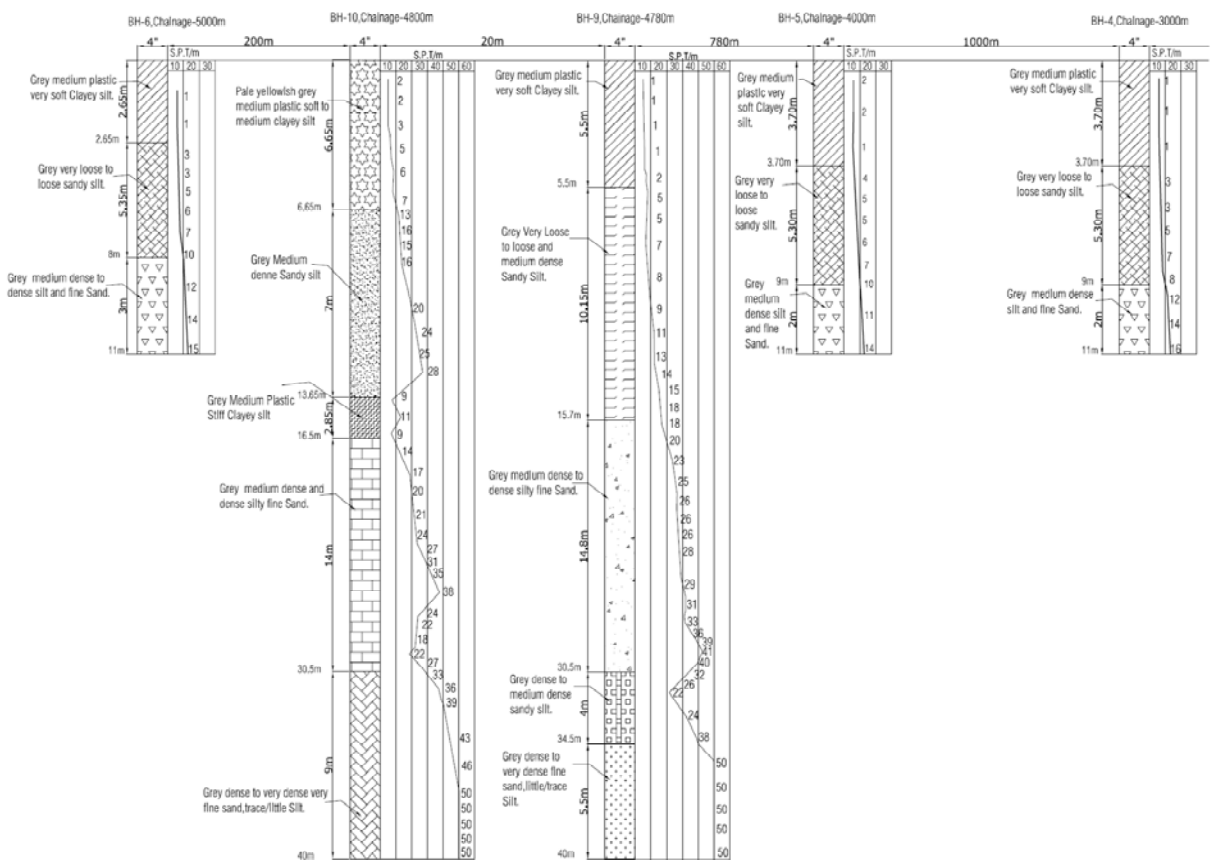

Figure 3 Soil profile with SPT values in the 11 boreholes

on each sieve is added and subtracted by 100 gives the value of fine aggregate. FM of sand has been used 1.8 for the vertical sand drains. Spacing between each sand drain is 1000 mm (1 m) and drains have been placed in a square pattern as presented in Figure 4.

Figure 4 Figure shows square pattern of VSD after completion of the work

Two layers (L1 and L2) have been considered for estimation of consolidation settlement. Thickness of layer 1 and layer 2 were 0-5 m and 5-10 m respectively. Unit weights of L1 and L2 in saturated phase are 16.50 kN/m^3 and 17.40 kN/m^3 respectively. Initial void ratio (e_o) of L1 and L2 were 0.81 and 0.8 respectively. Unit weight (γ_w) and Dry unit weight (γ_d) were 9.81 kN/m^3 and 15 kN/m^3 respectively. The estimated value of compression index C_C is 0.29. The location of the water table is assumed to be at the EGL. The load coming from the vehicular traffic has been assumed to be 65 KN/m^3. 552 mm primary consolidation has been estimated in the consolidation test. Due to high primary consolidation, square sand drain with double drainage condition has been selected. Coefficient of consolidation for vertical drainage (C_v) and coefficient of consolidation for radial drainage (C_{vr}) was 0.010 m^2/day. Drain radius 0.125 m has been considered. Average longest drainage path during consolidation (H_{dr}) was 5 m. 1 m of centre to centre spacing between two sand drains has been considered. In this site, theoretically using sand drain takes 90 days of time for 100% settlement and without sand drain only 236.33 mm settlement can be achieved in 90 days, as can be observed in Figure 5.

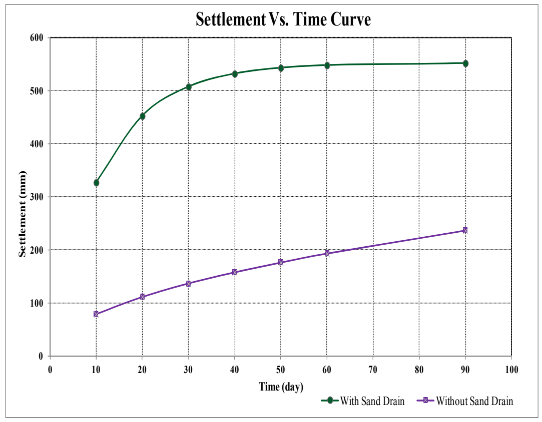

Figure 5 Settlement versus time curve for both with and without sand drain

It is always difficult to create the working field. The construction of ring bund is a complicated task for bringing the soil from outside. Removing the water through dewatering process and excavating the upper soft soil layer are challenging. The construction processes of the VSD are described in the Figure 5. To construct the VSD, forty five tripods have been used in this project as presented in Figure 6.

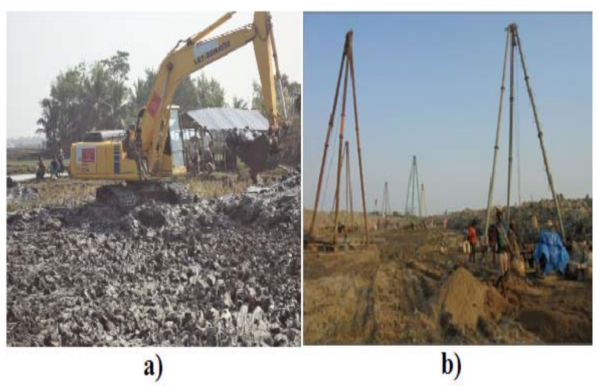

Figure 6 Figure a) shows that removing of soft clay before construction of the VSD pile and b) the construction of the VSD

Figure 7 shows the as built drawing of the road cross-section. After completion of the VSD, 600 mm of drainage layer (sand blanket) has been provided on top of the VSD. These layers have been composed of sand with FM 1.2, which have been compacted in layers of 150 mm thickness. Sylhet sand with one inch sizes of stone gravel were mixed in the ratio of 1:1 and have been provided as the filter layers at both side of the 600 mm of the drainage layer. Filter layers have been provided to prevent sand to come out along with the emerged water due to capillary action from the VSD and flow out to the outer side of the road.

The total height of the road embankment is 3m. This embankment has been constructed using compacted dredged soil filling (sandy clay, silty clay and silt, PL<20) in 150 mm layers. 150 mm base course, 150 mm sub-base and 250 mm improved sub-grade (ISG) have been used for slow moving road. 25 mm bituminous carpeting with 7 mm seal coat has been used for the slow-moving road. 175 mm base course, 250 mm sub-base course and 300 mm ISG have been used in 2 lanes of road. 80 mm bituminous carpeting and 12 mm seal have been used in two lanes of road. 125 mm of brick on end of ending has been used in two lane road. Turfing on land slope at end of the road is 1:2. In both sides of the road 1.5 thickness of turfing slope protection have been provided with clay. Top and bottom width of the six lane road including two slow moving roads are 30.40 m and 44.20 m respectively.

6. EMBANKMENT FILLING AND FINAL ROAD CONSTRUCTION

Dredged sand of the Mongla-Ghoshiakhali channel has been used as the embankment filling (around 3 m thick). Embankment has been filled in layer by layer with proper compaction as presented in Figure 8.

The improved subgrade layer (ISG) has been provided with sand of FM 0.8. The CBR value of ISG has been found 14% instead of 8%. Sub base layer of 250 mm thickness has been provided with 1:1 mixture of bricks khoa and sand for which CBR value has been found to be 80% instead of 30%.

At the top of the sub base layer, wet mix macadam has been constructed. Confirming the optimum moisture between khoa and sand; a mixture of khoa and sand (1.5 inch down khoa 60%, 1 inch down khoa 30% and local sand 10%) has been used for construction of the hard bed and 110% compaction has been found. Different stages of road construction after the VSD has been carried out are presented in Figure 9.

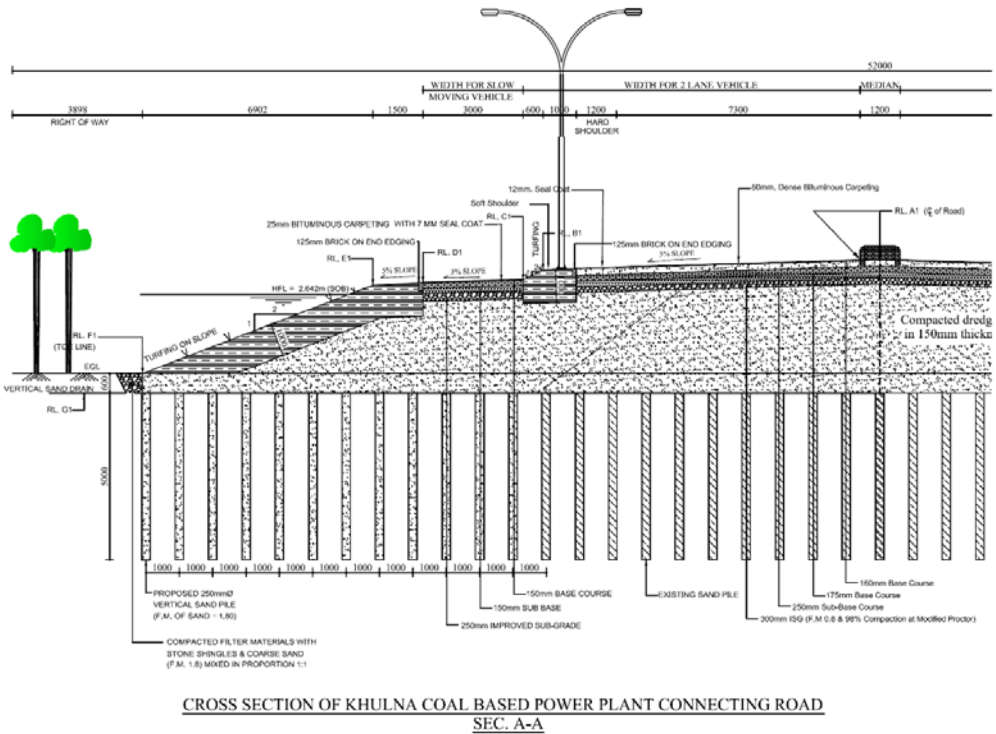

Figure 7 Final design for 4 lanes and 2 lanes slow moving road

a) b)

Figure 8 Figure a) shows embankment filled with Dredged sand of the Mongla-Ghoshiakhali channel and b) shows Embankment filling final layer (ISG bottom)

7. DISCUSSION

In the Khulna-Mongla highway project, the construction work is very challenging because of soft soil foundation layer. Due to low SPT value of soil, preloading with VSD technique has been employed to treat the soil. Sand has been used in the VSD having a FM value of 1.8. In total, 1, 10,000 VSDs have been used in this project. 600 mm of sand (FM-1.2) blanket has been provided at the top of the VSD. For preloading, no extra load has been applied; self-weight of the embankment has been used as the load. In an average 3 m height of embankment has been constructed. In different layers of pavement ISG, sub-base, WMM, bituminous carpeting, dense carpeting and also in the both sides of the lane hard shoulder and soft shoulder have been used.

To measure the soil improvement, SPT have also been carried out after almost 100 days of VSD installation at three chainage locations. Figure 10 compares the SPT values at those locations

Figure 9 Figure a) shows that mixture of aggregates close to OMC, b) shows compaction in progress, c) shows base course and d) shows completed road

before and after VSD installation. It has been observed that the SPT value improved significantly due to the installation of VSD. To measure the settlement, two settlement measuring plates have been placed in each kilometer. In total twelve settlement plates have been placed in the 5.76 km of road. After full completion of the embankment, the measured settlement has been found between 500 and 600 mm. According to the one dimensional consolidation test of undisturbed sample, the theoretical estimate of the settlement has been estimated to be around 552 mm.

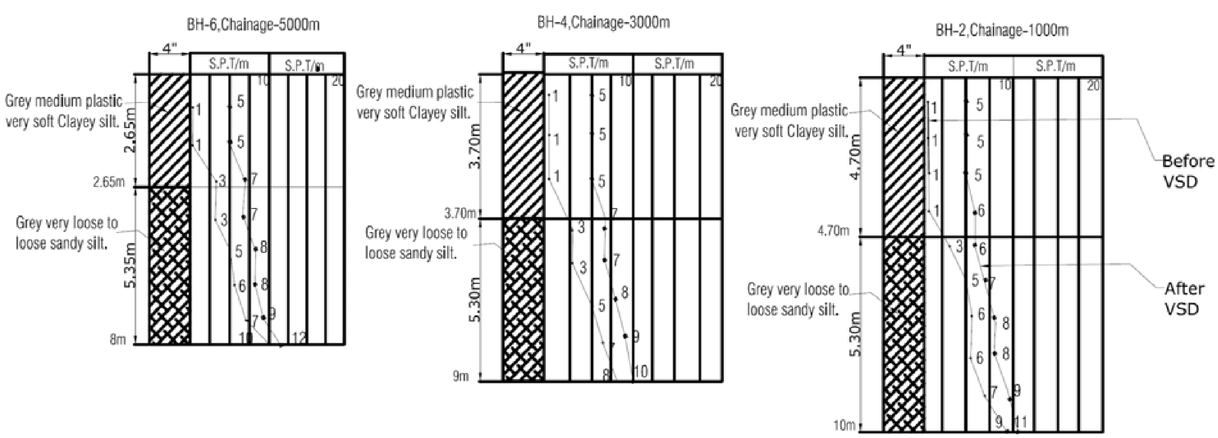

Figure 10 Comparison of SPT value before and after the soil improvement

8. CONCLUSIONS

The application of preloading with vertical sand drain (VSD) technique, as a soil stabilization method has been presented in this paper. Regarding the time consumption aspects and value of required work, soil strengthening by forming vertical sand drain is a more preferable technique. In this Rampal coal based power plant connecting road project 1, 11,000 number of VSD has been installed at 1 m center to center spacing in square pattern upto a 5 m depth. Due to the installation of VSD, time for settlement has been reduced from almost one year to only 90 days. SPT values also improved due to the VSD installation. In twelve locations along the embankment, settlements have been measured. Measured settlement varies from 500 to 600 mm along the embankment profile. The concept of the soil improvement using VSD beneath the road embankment with tripod for installation purpose is not only cost-effective but also safe, reliable and time-saving as shown through the success of the project.

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PART-IX

GEOTECHNICAL STABILITY OF COASTAL POLDER OF BHOLA DISTRICT IN BANGLADESH COAST AGAINST CYCLONIC STORM SURGES USING PLAXIS

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Md. Saddam Hossain

Mehedi Ahmed Ansary

1. Introduction

Coastal region of Bangladesh, the most low-lying part of the country, is the homeland of 50 million people, nearly one-third of huge population of densely populated Bangladesh (Marziya 2010-11).The Ganges, the Brahmaputra and the Meghna that constitute one of the largest river systems in the world drain through the coastal region into the Bay of Bengal has made the region more complex and unstable. Additionally, coastal region of Bangladesh is highly susceptible to tropical cyclones and storm surges due to its geographical location. The destruction due to the storm surge flooding is a serious concern along the coastal regions of the countries, for example along the coasts of Bangladesh, India and Myanmar. Bangladesh is on the receiving end of about 40% of the impact of total storm surges in the world (Murty 1992). The most deadly cyclones of the modern era struck Bangladesh in 1970 and 1991. Cyclone SIDR struck Bangladesh in November 2007, killing over 3,000 people, injuring over 50,000, damaging or destroying over 1.5 million homes, and affecting the livelihoods of over 7 million people (Dasgupta 2009).Moreover, the adverse effects of Climate Change – especially High Temperature, Sea-level Rise, Cyclones and Storm Surges, Salinity Intrusion, Heavy Monsoon Downpours etc. has aggravated the miserable conditions of people living here. From 1960 to 1980 a total of 123 coastal polders were constructed to protect low-lying coastal areas from tidal floods and salinity intrusion in southern Bangladesh (Ahmed 2011). The failure of these earth embankments due to cyclone and storm surges makes the scenario more vulnerable which results in more causalities and economical loss.

Lack of proper construction, poor maintenance after a natural calamity, climate change effects making the embankments less effective to withstand the region from strong water and wind thrust and making the inhabitants exposure to the natural calamities. The aim of our study is to investigate the present stability conditions of the embankments around coastal polders. The soil profile and construction technique of the embankments of polders more of less same. We have selected Bhola zone as a prototype for investigation .Finite element (PLAXIS 3D)(Vilas, Moniuddin 2015) modeling of Bhola embankment considering primary soil parameters of earth embankment and sub-soil has been analyzed for investigation of global factor of safety encountering different levels of water level and wind thrust forces.

2.Geometry

5m wide embankment has been considered for modelling. River side slope is 2H: 1V and road side slope is 1H: 1V considered in the model based on field visit scenario. Both position and intensity of surge height and thrust force (cumulative effect of water thrust and wind force) have been varied to find out the worst condition for which embankments are less susceptible to withstand the forces responsible for failure and make the polders vulnerable for cyclones and storms.

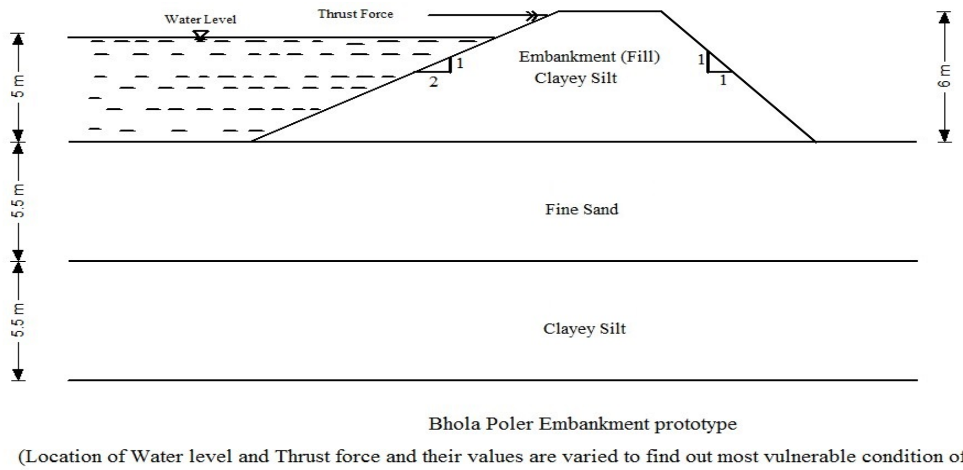

Fig.1: Embankment prototype of Bhola polders

3. Data collection

Standard penetration test (SPT) has been performed at 3 locations of Bhola polder embankments and soil has collected from the locations to perform Tri-axial test and consolidation test to find out basic parameters of embankment fill soil and sub-soil. SPT soil profile and results from laboratory testing shows the soil properties of embankments of Bhola polder is more or less same. Figure2 shows SPT profile from the top of the embankment. SPT values varies from 1 to 7 up-to a depth of 18m indicating very soft to loose consistency. The embankment fill soil is Clayey Silt which is about 6m height from the top. The subsoil is Fine Sand up to 5.5m below the ground level then another 5.5 m subsoil is Clayey Silt. The fill and the entire soil material were modeled as Mohr Coulomb. Table 1 summarizes soil properties used in the PLAXIS-3D modeling. Standard penetration test (SPT) has been performed at 3 locations of Bhola polder embankments and soil collected from the locations to perform Tri-axial test and consolidation test to find out basic parameters of embankment fill soil and sub-soil. Table1 includes the basic parameters need to make model of Bhola polder embankment to find out global stability.

SPT soil profile of one embankment at Taltoli Ghat, Charfashion, and Bhola is presented below.

Table1: Soil parameters

Material	γ_{unsat} $KN/_{m^3}$	γ_{sat} $KN/_{m^3}$	E_{ref} $KN/_{m^2}$	C $KN/_{m^2}$	ϕ (Degree)	K m/day Permeability
Embankment(Fill) (Clayey Silt)	17	19	40380	5	43	0.01

Fine Sand	17	19	25000	3	30	0.04
Clayey Silt	18	20	50000	0	28	0.2

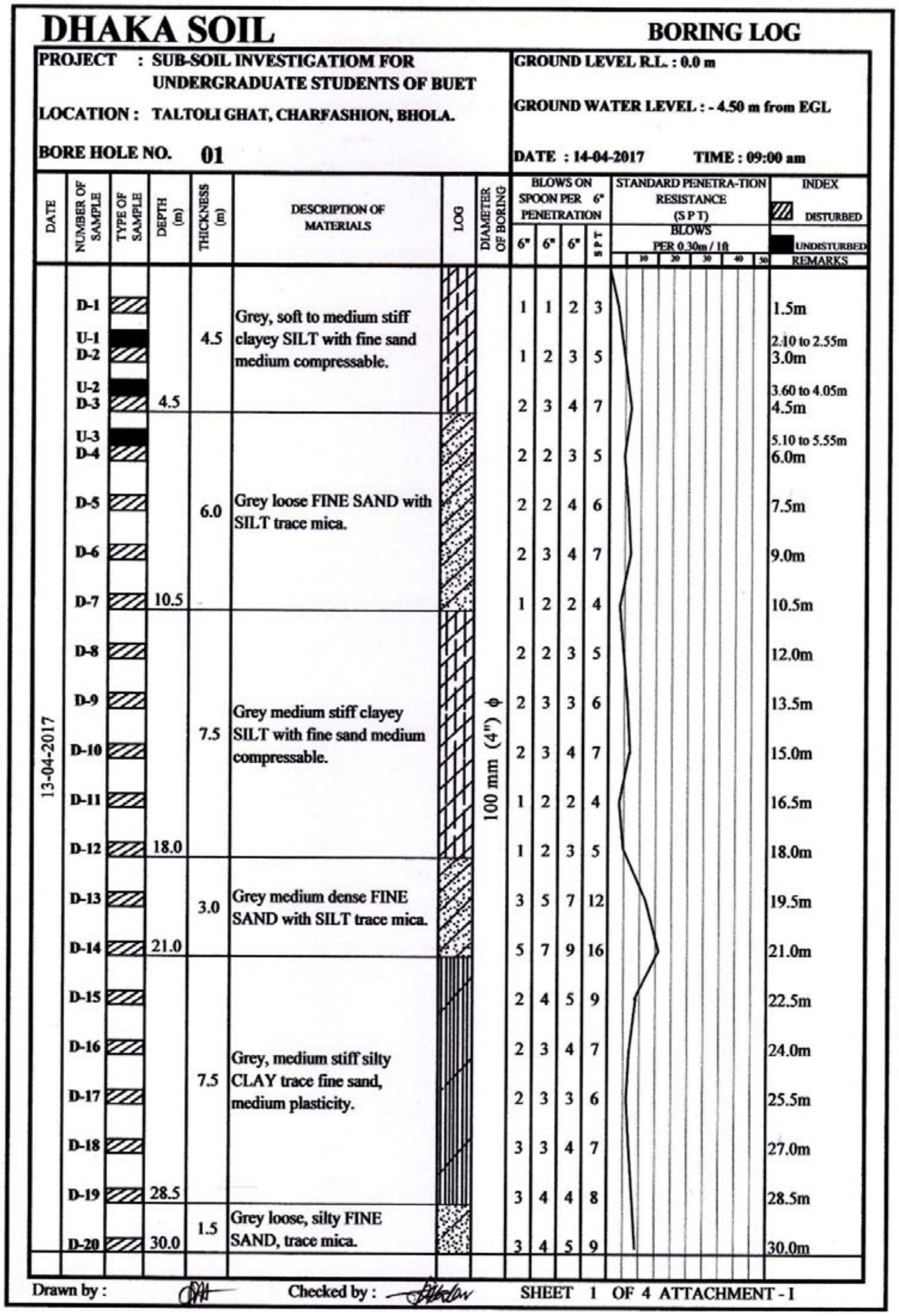

Fig2. Soil profile of embankment at Charfashion, Bhola Polder.

Strom surge height and thrust force (both for wind and water) of two mighty Cyclone in Bangladesh, Cyclone-1991 and Cyclone-2007(SIDR) (Akter, M 2014), are considered in Plaxis-3D model for evaluation of factor of safety due to these scenario. Surge height and thrust force for different Thana of Bhola district is enlisted below at table 2.

Table.2: Storm surge depth and thrust force of two desperate cyclone of Bangladesh

District Name	Thana Name	Cyclone wind speed (Km/hr)	Surge Depth (m)	Thrust Force (KN/m)	Surge Velocity (m/s)
1991 Cyclone					
Bhola	Bhola Sadar	77.52	1.53	7.28	0.74
Bhola	Burhanuddin	96.62	0.88	4.52	0.68
Bhola	Char Fasson	113.34	1.67	17.04	1.37
Bhola	Daulatkhan	87.80	2.20	1.40	0.30
Bhola	Lalmohan	109.84	0.33	4.43	0.59
Bhola	Manpura	142.11	3.08	8.27	1.08
Bhola	Tazumuddin	112.42	4.09	8.59	0.77
SIDR- 2007 Cyclone					
Bhola	Bhola Sadar	146.04	1.81	33.42	1.44
Bhola	Burhanuddin	164.16	1.01	37.30	1.68
Bhola	Char Fasson	179.96	1.81	49.36	2.33
Bhola	Daulatkhan	149.24	2.10	9.41	0.37
Bhola	Lalmohan	173.34	0.36	25.75	1.17
Bhola	Manpura	142.43	3.14	25.20	1.72
Bhola	Tazumuddin	148.28	3.91	13.67	1.15

4. Method of Analysis

In order to determine minimum factor of safety which indicates vulnerability of embankment, we have considered 13 combination of surge height and thrust force (cumulative effect of water thrust and wind force) for Bhola polder embankment enlisted at Table 2 experienced during two major cyclone in 2007 and 1991. Flow diagram below shows the combinations considered for embankment safety analysis at Plaxis-3D model.

Embankment in normal condition (without water and wind)
Water at top of embankment
Water at mid-level of embankment
Water at low-level of embankment
Water at top + Thrust at top
Water at mid + Thrust at top
Water at mid + Thrust at mid
Water at low-level + Thrust at top
Water at low-level + Thrust at mid
Water at low-level + Thrust at bottom
Wind at top level
Wind at mid-level

Fig 3. Combinations considered for embankment safety analysis at Plaxis-3D model.

5. Result of Analysis

As the soil of embankment fill material is fine grained Silty clay and their permeability is low as .01m/day,Undrained (Merifield 2009) characteristics would govern during storm surge and short period of inundation. Figure 4. Shows the deformation of embankment due to Undrained behavior with the combination water at mid-level and then both water and thrust force acting at mid-level of polder embankment, which are the worse condition of embankments encountering cyclone hazards enlisted at table2.

Deformed embankment shows unstable condition of embankment where the maximum value of displacement of a soil particle is about 3.5m which indicates certain failure of polder.

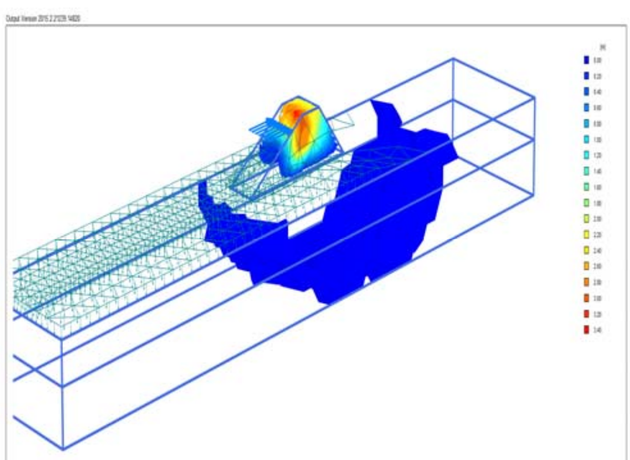

Fig4. Deformation of embankment due to Undrained behavior for the combination both water and thrust force acting at mid-level of polder embankment

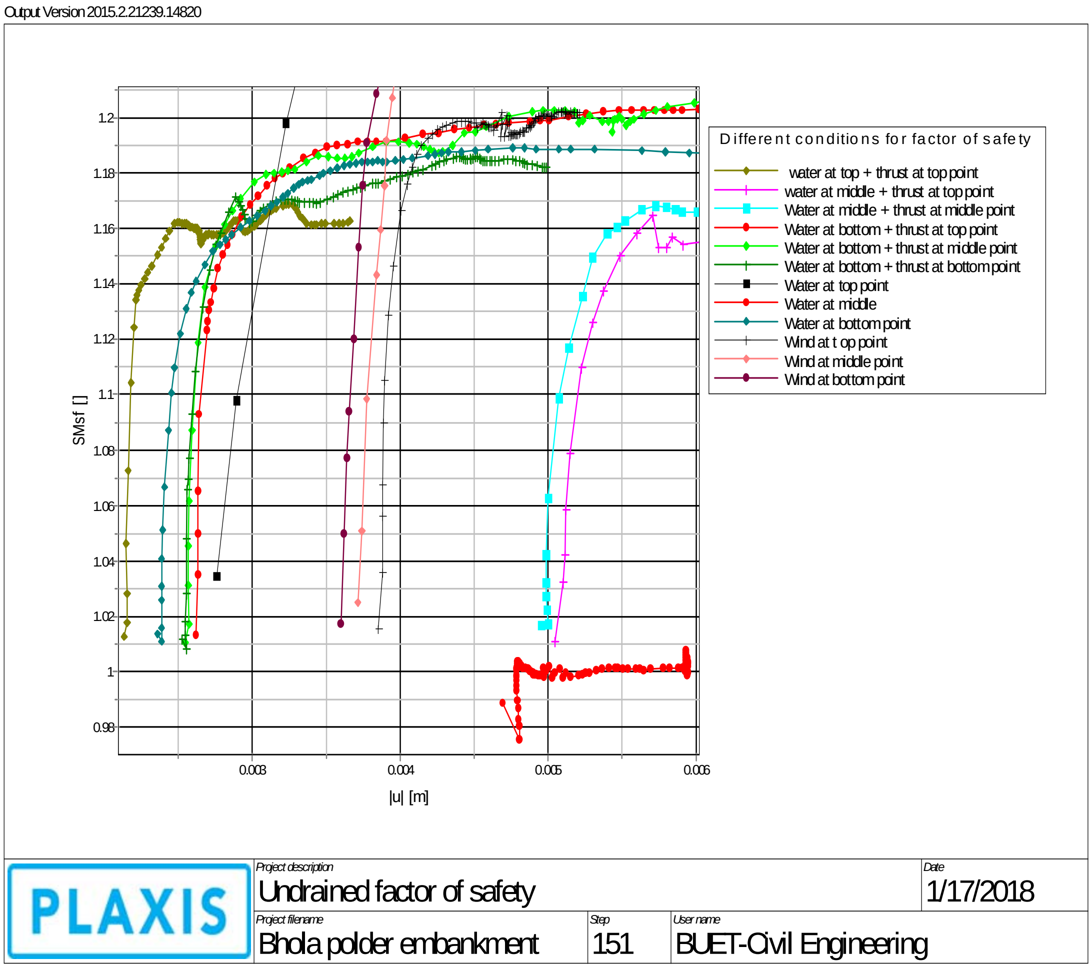

Fig5. Global factor of safety of embankment due to Undrained behavior for the combination both water and thrust force acting at mid-level of polder embankment

Factor of safety curves shows global factor of safety of embankment is from 0.95 to 1.2 mostly whereas minimum factor of safety of embankment as 1.5 is considered safe for stable condition. This result indicates the polder might not be able to withstand the thrust forces during cyclones like Sidr.

5. Discussion and Recommendation

We have taken an embankment section of Charfashion to evaluate the condition of Bhola polder. Model results show poor consistency of the embankment encountering cyclones that Bangladesh has already experienced. It's high time to conduct rigorous soil testing at every polder in coastal region of Bangladesh to evaluate their condition and take engineering steps to make them stabilize so that embankments can withstand cyclonic storm surges like SIDR, which are common at coastal region of Bangladesh at a regular interval due to it's tropical geographic location.

Acknowledgements

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BANGLADESH NETWORK
OFFICE FOR URBAN SAFETY

PART-X

DEVELOPMENT OF A RATING SYSTEM FOR RMG FACTORIES OF BANGLADESH BASED ON ACCORD AND ALLIANCE DATA

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Zahid Hasan Khan
Mehedi Ahmed Ansary

Introduction

Workplace safety and security in Bangladeshi garment factories attracted widespread international scrutiny after the Tazreen fashion factory fire on November 24, 2012 and the Rana Plaza collapse on April 24, 2013. Various transnational labor organizing bodies, corporations, and the Bangladesh government developed different governance mechanisms to monitor working conditions in garment factories. The Accord on Building and Fire Safety in Bangladesh and the Alliance for Bangladesh Worker Safety are the two most significant transnational private governance structures that received extensive attention worldwide. Transnational labor rights groups and corporations introduced two governance structures popularly known as the "Accord" and "Alliance". So two different factory inspection programs have been established to make work place safer in Bangladesh:

1.1 The Bangladesh Accord on Fire and Building Safety in Bangladesh, and the Alliance for Bangladesh, where ILO fulfills the role of neutral chair. The Accord on Fire and Building Safety in Bangladesh (the Accord) was signed by over 190 Apparel Company from over 20 countries in Europe, North America, Asia and Australia; two global trade unions, Industry ALL and UNI Global; and eight Bangladeshi trade unions on May15, 2013. It is a 5-year independent and legally binding agreement designed to build a safe and healthy Bangladeshi RMG Industry (Ansary et. al. 2015).

1.2 The Alliance for Bangladesh Worker Safety (the Alliance) officially launched its local operation in Dhaka on December 9, 2013, which is also a 5-year independent and legally binding agreement founded by a group of North American apparel companies and retailers and brands (26 North American retailers and brands) to develop and launch the Bangladesh Worker Safety Initiative (Ansary et. al. 2015).

The GoB has already upgraded Chief Inspector of Factories and Establishment office to Department of the Inspection for Factories and Establishments (DIFE), sanctioning 679 new staff positions including 392 new inspectors and also started organizing training programme for the newly recruited inspectors for capacity building. Bangladesh University of Engineering and Technology (BUET) and two private engineering firms TUV SUD Bangladesh (Pvt.) Ltd. and Veritas Engineering & Consultant on behalf of the NTC, the Accord, and the Alliance are responsible for conducting the assessments of the structural integrity and fire safety of RMG factory buildings. To undertake the structural assessment of factory buildings with common approach, Guidelines for Assessment of Structural Integrity and Fire and Safety including harmonized standards were developed by the technical experts (structural engineers, fire safety experts, etc.) from the BUET on behalf of the NTC, the Accord, and the Alliance. A review panel along with a review mechanism was also established to handle urgent safety issues in garment factories. Finally, in November 2013, assessments of the structural integrity and fire safety of RMG factory buildings officially commenced, led by engineers from BUET (Ansary et. al. 2015).

Various factors adversely affect structural condition and hence the performance of RC structures. These factors may include inadequate material selection, poor workmanship, severe environments, and exposure to harmful chemicals, unexpected loadings, fatigue, and catastrophic events (Jain et al 2012). Safety management of structures for public and property security must be performed regularly throughout the structures life cycle. Visual inspection provides important information on performance and durability of structures (ACI 201 2008). In deteriorating structures, several visible distresses may develop with time, of which the commonly detected ones are cracks, leaching/staining, sapling, delamination, and efflorescence. In line with this, inspection activities and condition evaluations are done to assess the current serviceability and structural function of existing structures. Condition assessment and visual inspection are concerned with estimating the likely future safety and performance of an existing structural system. Many buildings in the Bangladesh use reinforced concrete, in whole or in part, as the structural system. Proper inspection procedures, based on a visual investigation, can help identify deficiencies in concrete before they become critical to the overall stability of the structure. This Tool provides engineers with background information and a systematic methodology for inspecting reinforced concrete buildings, focusing on deterioration conditions that can be seen and, more importantly, those conditions that can lead to a structural failure.

There exist different levels of investigation when it comes to condition survey of reinforced concrete structures. In seismic evaluation of structures, for example, FEMA 310 which is one of the "most advanced seismic evaluation procedure" for buildings categorizes the levels of inspection to a three-tiered process as enumerated by Rai (1998). Tier 1 is the screening phase in which the inspection is mainly visual. In this phase, the engineer looks on potential deficiencies and expected behavior of the structure. This screening helps provide evaluation statements for structural, nonstructural and foundation aspects in the form of checklist. Tier 2 is the evaluation phase where complete analysis of the building is made while Tier 3 is the more detailed evaluation phase.

Building performance can be measured in many ways, the most common being condition. Condition survey is defined as the "examination of concrete for the purpose of identifying and defining areas of distress". (ACI 201) The buildings condition gives a measure of the effectiveness of current maintenance programs because it determines the remaining useful life of components or systems and compares it with the full economic life expected, given good maintenance. In terms of condition survey of in-service concrete for the purpose of rehabilitation, the American Concrete Institute (364) classifies condition assessment of concrete structures under two categories: preliminary investigation and detailed investigation. The preliminary investigation develops an initial assessment of the concrete structures behavior, condition and existing performance. A preliminary investigation is not intended to be a comprehensive study and is visual in nature. The tasks was done by Accord and Alliance through their inspection team over their member factories.

A detailed investigation is performed when the initial site visit or preliminary investigation has identified a need for more in depth assessment of concrete structures behavior. A detailed investigation includes additional filed observation, measurements and field and laboratory testing.

2. Implementation mechanism of the structural assessment

The common steps for structural assessment of buildings housing RMG factories by team of expert are described below:

2.1 Visual inspection

Visual inspections of factory building were done for identification of existence of any distress in the structure of a building.

2.2 Review of current use and loading pattern

The design drawings and soil investigation reports of the factory buildings (if available) are reviewed to assess the current use and loading pattern.

2.3 Assessment of immediate threat of collapse from current building use

Assessment of immediate threat of collapse from current building use is done to take decision about further initiatives required to make the factory buildings resilient. For the assessment of immediate threat of collapse from current building use, the surveyors firstly highlight key columns and carry out simple calculations of working stresses to find out Factor of Safety (FOS), which is Column Ultimate Strength, divided by the Column Working Stress (Ansary et. al. 2015). Here, the Column Working Stresses are calculated comparing data set values and trigger points developed. Column Ultimate

Strengths of the key columns of RMG factory buildings are calculated using Eq. (1) according to Bangladesh National Building Code (BNBC 1993)

$$P_n = 0.85\varphi\,[\,0.85f'_c(A_g - A_{st}) + f_y A_{st} \quad \ldots\ldots(1)$$

where

P_n is the ultimate strength of a column,

Φ is the strength reduction factor (¼0.7),

f'_c is the compressive (cylinder) concrete strength,

A_g is the gross area of concrete section,

A_{st} is the area of reinforcement and

f_y is the steel strength.

To decide on Column Ultimate Strengths, firstly the key columns are checked for brick or stone aggregate concrete. In case of unknown column material, brick aggregate is assumed. Due to the absence of any compressive strength data for existing RMG factory buildings, equivalent compressive (cylinder) concrete strengths (f'c) are used for preliminary analysis. For the key columns with stone aggregate concrete and brick aggregate concrete, equivalent compressive (cylinder) concrete strength (f'c) are assumed to be 16.3 MPa (2365 psi) and 14.1 MPa (2045 psi), respectively. These two equivalent concrete strengths were estimated on the basis of the cylinder test results conducted at BUET Concrete Laboratory between 2003 and 2009 using Eq. (2).

f'c = mean of concrete strengths - 1.34 * standard deviation of concrete strengths................(2)

After deciding on concrete strengths of the key columns, the order of reinforcement is checked with a ferro-scanner to calculate the area of reinforcement (Ast). In case of unknown number of reinforcement bar, it is assumed as 1 percent of gross area of concrete section. For the buildings constructed before 2005 and after 2005 the steel strengths (fy) are assumed 40 ksi (276 MPa) and 60 ksi (414 MPa), respectively. After deciding on all these information, Column Ultimate Strength is calculated. Finally, FOS is calculated from Column Ultimate Strength and Column Working Stress. Based on FOS, four colour codes have been proposed to be used indicating the level of vulnerability of the factory buildings and the required actions within certain time frame to overcome the vulnerable condition. Table 1 shows the colour codes based on FOS of columns along with required actions within time frame. Thus, preliminary assessment of immediate threat of collapse from current building use is carried out.

Table 1 Colour codes based on FOS of columns along with required actions within time frame structural assessment of buildings housing RMG factories (Ansary et. al. 2015).

FOS of column	Color Code	Description	Required action	Actions with time frame
Below 1.25	Red	Critical visible defects resulting in immediate danger to structure and workers.	Require careful review. Take actions to increase FOS by reducing load less than the minimum load on any floor,i.e.1kN/m² or 20psf. If FOS is still below1.25, then evacuate the facility immediately considering expert opinion.	Require Detailed Engineering Assessment (DEA) along with core test immediately.
Between 1.50 and 1.25	Amber	Significant visible defect swith no immediate danger to structure or workers.	No reason to suspend operations in the facility. Production may continue subject to agreement to address issues raised and actions prioritized locally in report	Require DEA along with core test within 6 weeks.
Between 1.86 and 1.5	Yellow	Limited visible defects with no immediate danger to structure or workers.	Production may continue subject to agreement to address issues raised and actions prioritized in report	Require actions and core test within 6 months.
Better than 1.86	Green	No critical visible defects or structures and no visible immediate risks to workers.	Generally all clear subject to agreement to address prioritized comments. Production can continue.	No immediate actions required.

3. Outline of Methodology

The tool was developed from a review of documentation on deterioration conditions in concrete and of accepted industry recommendations and practices. For the development of this tool, review and full consideration of the following were given to:

i. American Concrete Institute 201.1: Guide for Making a Condition Survey of Concrete in Service

ii. American Concrete Institute 364: Guide for Evaluation of Concrete Structures before Rehabilitation

iii. ASCE 11 Guidelines for Structural Condition Assessment of Existing Buildings

iv. US Army Corps of Engineers: Guide for Visual Inspection of Structural Concrete Building Components

3.1 Components of the Tool

The tool consider both the structural and nonstructural deficiencies in concrete. It focuses on specific building elements for condition evaluation. These elements primarily include columns, slabs and beams.

Brick Walls are also considered but because it is load bearing in nature, it is not included in the overall rating of the building. Also, because there are a number of defects in concrete, only the major defects and visible deteriorations are considered. The tool can be divided into six parts: plan frame, critical areas, visible deterioration, building component, condition rating and the recommendations part.

3.2 Nonstructural deficiencies

Nonstructural deficiencies in general are surface deficiency resulting from the conditions of the design, construction or service life of the building. These deficiencies are not immediately critical to the structure but they can cause further deterioration, which can eventually lead to structural deficiencies. Examples of nonstructural deficiencies are: abrasion, blistering, chemical reaction cracking, cracking due to construction practice, crazing, discoloration, efflorescence, flaking, honeycombing, pop-out, etc.

3.3 Structural deficiencies

Structural deficiencies on the other hand indicate a breakdown of the material to a point that threatens the structural capacity of the members. Common structural deficiencies are chemical deterioration, corrosion cracking, distortion, reinforcement corrosion, scaling, sapling, shear cracking, moment cracking, etc. For a detailed explanation and corresponding photographs in CAPs of Accord & Alliance investigations can be seen from their websites.

3.4 Scoring System

The adopted scoring system is based on the proposed methodology by Coronelli (2007). This rating system is a modification of the evaluation procedure by the CEB (1998): Condition Rating. This methodology was proposed for wide variety of structures to identify the most deteriorated cases by a damage index and plan more detailed analysis and repair interventions. Because the procedure of Coronelli considers several factors that are non-existent in the Bangladesh condition such as freeze thaw, etc it is further modified taking into account local conditions.

The scoring system begins by first examining the structural configuration and its division or components and subsequently judging the relative importance of these components. In general, more importance is given to columns since its failure is brittle and could trigger incremental collapse of more parts of the structure. The failure of the floor however has limited effects with a beam failure. The structural factor, as adopted from the study of Coronelli, which gives the relative importance of each structural element, is shown in Table 2. After examining the structural component, damage of each individual element will be rated.

Table 2 Structural element factor values for framed buildings (Coronelli, 2007).

Structural Element	Factor
Columns	1.25
Beams	1.1
Slabs	0.3

Element factor from column was taken from table 1 (Ansary et. al. 2015)

Table 3 Factors for estimating LCR & GCR

1	CONCRETE	B1	COLUMNS			SLABS			BEAM		
			K2	K3	K4	K2	K3	K4	K2	K3	K4
1.1	Poor workmanship: peeling, stratification, honeycomb, voids	1									
1.2	Cracking caused by direct loading, imposed deformations and restraint	3									
1.3	Efflorescence, exudation, popout	1									
1.4	Mechanical damage: erosion, collision	1									
1.5	Wet surfaces	1									
1.6	Cover defects caused by reinforcement corrosion	2									
1.7	Sapling caused by corrosion of reinforcement	3									
1.8	Open joints between segments	2									
2	**REINFORCEMENTS**										
2.1	Corrosion of stirrups	1									
2.2	Corrosion of main reinforcing bars, reduction of steel area in the section	3									
		18									
			LCR'Column			LCR'Slabs			LCR'S Beam		
	LCR = (∑ B1*K2*K3*K4)/72 =										

GCR = (1.25*LCR Column + 1.1 LCR Beam + 0.3 LCR Slabs)/2.65

Factors

a) B1 is the basic value of ith damage type, b) K1 is the structural element factor , c) K2 is the intensity factor for the ith damage, d) K3 is the extension factor for the ith damage, e) K4 is the urgency of intervention factor for the ith damage

Cut-off Score

i) GCR < 15 , No further investigation required. Only some repair is necessary

ii) GCR > 15 , Detail Engineering Assessment is required and immediate steps should be taken as per DEA

3.5 Condition Rating

The condition rating is a numerical score given to the structure relative to its most deteriorated case. The score can range from 0 to 100 with 100 representing the worst case scenario or the case in which all members are deteriorated. A brief description of each of the deterioration case is shown in Table 4.

Table 4 Condition rating and corresponding deterioration class with description (Coronelli, 2007).

Class	Description of the condition	Rating
i	No defect, Only construction deficiencies.	0-5
ii	Low degree deterioration, which only after a long period of time might be the cause for reduced serviceability or durability of the affected structural component, if not repaired in proper time	6-10
iii	Medium degree deterioration, which can be the cause for reduced serviceability and durability of the affected structural component, but still not requiring any limitation of use of the structure	11-15
iv	High degree deterioration, reducing the serviceability and durability of the structure, but still not requiring serious limitation of use	16-25
v	Very heavy deterioration, requiring limitation of use, propping of most critical components, or other protective measures	26-30
vi	Critical deterioration, requiring immediate propping of the structure and strong limitation of use, for example, closing	>30

The form includes two condition ratings as follows:

3.5.1 Local Condition Rating (LCR)

The local condition rating or LCR is the rating for each of the building component. This includes individual ratings for beams, columns, floor slabs and walls. The LCR is computed as:

LCR = ∑ B1 K2 K3 K4/72 X 100

B1 is the basic value of ith damage type, expressing its potential effect on the safety and durability of the structural component under observation; values range 1–4(Coronelli, 2007).

K1 is the structural element factor characterizing its importance for the safety of the whole structure or one of its parts;

K2 is the intensity factor for the ith damage, determined by qualitative visual criteria and experimental measurements in a scale of four degrees, with the corresponding numerical values K2 = 0.5, 1, 1.5, 2(Coronelli, 2007).

K3 is the extension factor for the i^{th} damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K3 = 0.5, 1.0, 1.5, 2 (Coronelli, 2007).

K4 is the urgency of intervention factor for the i^{th} damage, with values varying from 1 to 5 (Coronelli, 2007), grouped into four classes on the basis of direct consequences of the deterioration type on the safety of the structure and the users, and related to an indication of time for intervention.

3.5.2 Global Condition Rating (GCR)

The global condition rating gives the condition index of the structure as a whole considering all the structural components. It is the condition rating for the whole building. It is computed as:

GCR = (1.25* LCR Column + 1.1 LCR Beams + 0.3 LCR Slabs) /2.65...............................(2)

3.7 Recommendations

Data was collected from problems of every industries observed by Accord and the Alliance & recorded as CAP on their websites. Corresponding industries were also visited by authors for the accuracy of scoring systems.

Industries	GRC	Deterioration Class	Description of the condition (Coronelli, 2007).	As on Accord & Alliance CAP
4A Yarn Dyeing Ltd.	5	I	Low degree deterioration, which only after a long period of time might be the cause for reduced serviceability or durability of the affected structural component, if not repaired in proper time	Repair Slab crack within six months
Arcorp Denim Ltd..	7.5	II	Low degree deterioration, which only after a long period of time might be the cause for reduced serviceability or durability of the affected structural component, if not repaired in proper time	Building Engineer to check cantilever design & confirm control of deflection within six weeks
A & B Outerwear Ltd.	11	III	Medium degree deterioration, which can be the cause for reduced serviceability and durability of the affected structural component, but still not requiring any limitation of use of the structure	Repair Slab & Beam crack within six weeks

Alfa Textile Ltd	12	III	Very heavy deterioration, requiring limitation of use, propping of most critical components, or other protective measures	Repair Beam crack within six weeks
Abanti Color Tex Ltd.	20	IV	High degree deterioration, reducing the serviceability and durability of the structure, but still not requiring serious limitation of use	Repair Slender RC Column, Slab & Beam crack immediate now (DEA recommendation)
AKH Apperals Ltd	26	V	Very heavy deterioration, requiring limitation of use, propping of most critical components, or other protective measures	Repair Slender RC Column, Slab & Beam crack immediate now (DEA recommendation)
Apparel Gallery Ltd.	37	VI	Critical deterioration, requiring immediate propping of the structure and strong limitation of use, for example, closing	Repair RC Column, Slab crack & Control Corrotion of reinforcement immediate now (DEA recommendation)

Table 5: Comparison of developed rating system with Accord & Alliance observation

According to Table 3 it is clearly identified that Global Rating Condition/point up to 15, (Deterioration Class I, II & III) the structural condition of corresponding industries is not very critical (example: 4A Yarn Dyeing Ltd., A & B Outerwear Ltd., Alfa Textile Ltd Arcorp Denim Ltd). Accord & Alliance observation for corresponding industries can be compared along with this result from table 5.

When Global Rating Condition/point increases above 15 (Deterioration Class IV, V & VI) the structural condition of corresponding industries is very critical (example: Abanti Color Tex Ltd., AKH Apperals Ltd & Apparel Gallery Ltd.). Accord & Alliance observation for corresponding industries can be compared along with this result from table 5. For these industries DEA is recommended from Accord & Alliance along with recommendation of “Repair should be conducted immediate now “. Following result can be summarized as findings,

Two recommendations can be made upon computation of the condition rating of the building such as:

a. For 4A Yarn Dyeing Ltd., A & B Outerwear Ltd., Alfa Textile Ltd Arcorp Denim Ltd no further investigation required. Only some repair is necessary.

b. For Abanti Color Tex Ltd., AKH Apperals Ltd & Apparel Gallery Ltd Detail Engineering Assessment is required and immediate steps should be taken as per DEA.

This recommendation is based on the computed local and global condition rating. If the condition rating is greater than 15 a detailed investigation is recommended. This value is based on the fact that at 15 deterioration condition, a building is already considered medium to high degree deteriorated (Coronelli, 2007).

3.8 Conclusion

This rating system has been developed to evaluate the deterioration condition of a moment-resisting reinforced concrete frame for industrial building in Bangladesh. Seven RMG factory building data from Accord and Alliance have been assessed based on the proposed method. DEA. GCR value of RMG factory building greater than 15 is considered to be unsafe. Out of the seven assessed building four were found to be ok. Three were found to be not ok and need detail engineering assessment (DEA). So this rating system can be used to evaluate the deterioration condition of a moment-resisting reinforced concrete frame of Factory Building of Bangladesh as well as other occupancies anywhere in Bangladesh.

APPENDIX

Table 6 .List of factors for computation of condition rating (Coronelli, 2007).

	Factor	Description	Reference Table
B1	Basic value	Expresses its potential effect on the safety and durability of the structural component under observation;	Table 10
K1	Structural Element Factor	Characterizes its importance for the safety of the whole structure or one of its parts;	Table 1
K2	Intensity Factor	Intensity factor for the ith damage, determined by qualitative visual criteria and experimental measurements in a scale of four degrees, with the corresponding numerical values K2 = 0.5, 1, 1.5, 2	Table 7
K3	Extension Factor	Extension factor for the ith damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K3 = 0.5–1.0–1.5–2 ;	Table 8
K4	Urgency of Intervention Factor	Extension factor for the ith damage within the elements under consideration, defined uniquely by descriptive criteria and applied in a scale of K4 = 1,2-3,3-5,5 ;	Table 9

Table 7. General criteria for the intensity degree of a damage type(Coronelli, 2007).

Degree	Criterion	K2
Low - initial	Damage of small size, generally appearing on single localities 0.5 of a member	0.5

Medium–propagating	Damage is of medium size, confined to single localities, 1.0 or damage is of small size appearing on few localities or on a small area of a member (eg< 25%)	1.0
High – active	Damage is of large size, appearing on many localities or 1.5 on a greater area of a member (25 and 75%)	1.5
Very high – critical	Damage is of a very large size, appearing on a major part 2.0 of a member (>50%)	2.0

Table 8. General criteria for the extent of a damage type(Coronelli, 2007).

Criterion	K3
Damage is confined to a single unit of the same type of member	0.5
Damage is appearing on several units (eg less than 1/4) of the same type of member	1.0
Damage is appearing on the major part of units (eg 1/4 to 3/4) of the same type of member	1.5
Damage is appearing on the great majority of units (more than 3/4) of the same type of member	2.0

Table 9. Factor to stress the urgency of intervention (Coronelli, 2007).

Criterion	K4
Intervention is not urgent because the damage does not impair either the overall safety and/or durability 1 (service life) of the structure or the durability of the affected member	1
Damage must be repaired within a period not longer than five years, to prevent further impairment of the 2–3 overall safety and/or durability of the structure, or, solely, the durability of the affected member exposed to the aggressive attack	2-3
Immediate repair is required, as the damage is already jeopardizing the overall safety and/or durability of the 3–5 structure (especially in aggressive environment), or, if there is direct danger to people from falling pieces of disintegrated concrete	3-5
Temporary propping or limitation of traffic loads is require	5

Table 10. Damage types to be evaluated, associated basic values B1 and special criteria for the evaluation of the class of types (Coronelli, 2007).

Damage type		B1	Degree of Damage			
			I (K2=0.5)	II (K2=1.0)	III (K2=1.5)	IV (K2=2.0)
1.0 CONCRETE						
1.1	Poor workmanship: peeling, stratification, honeycomb, voids	1	Single small defect	Several different small defects	Few stronger defects	Several different stronger defects
1.2	Cracking caused by direct loading,	3	Single < 0.5 mm	Several <0.5mm	Single >0.5mm	Several >0.5mm

	imposed deformations and restraint					
1.3	Efflorescence, exudation, popout	1	General criteria (Table 2)			
1.4	Mechanical damage: erosion, collision	1	General criteria (Table 2)			
1.5	Wet surfaces		Light	Medium	Heavy	Severe
1.6	Cover defects caused by reinforcement corrosion	1	Rust stains, light	Rust stains, heavy	Cracks over stirrups	Delamination over stirrups
1.7	Sapling caused by corrosion of reinforcement	2	Finer cracks along reinforcing barsin corners	Finer cracks along other reinforcing bars and/or wider longitudinal cracks or exposed reinforcement along corners	Wider cracks along other bars, or exposed reinforceme nt	Hollow areas and surface spalling
1.8	Open joints between segments	3	1mm	1–3 mm	3-5 mm	>5mm
2.0REINFORCEMENT						
2.1	Corrosion of stirrups	1	General criteria (Table 3)			
2.2	Corrosion of main reinforcing bars, reduction of steel area in the section (if in critical section, *K*4=2)	3	Uniform < 10%	Pitting <10%	Uniform >10%	Pitting >10%

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PART-XI

SLOPE STABILITY ANALYSIS OF EMBANKMENTS OF GAIBANDHA AREA, BANGLADESH

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Sirazhum Monera Asha

Mehedi Ahmed Ansary

1. Introduction

In Bangladesh, the most common problems are embankment failure and river bank erosion which happens almost every year. The most serious problems seen in the river banks and embankments are erosion and breaching. The main causes for slope failure are erosion, rainfall, earthquakes, geological factors, external loading, construction activities such as excavation of slopes and filling of slopes, rapid drawdown, increment of pore water pressure and the change in topography etc. Furthermore, insufficient supervision during construction results in poor-quality works with the use of low quality soil materials, insufficient compaction and or inadequate laying of topsoil layers.

Gaibandha is situated on the bank of river Brahmaputra which is the fifth strongest river in the world. This river has often required earthen embankments at various places to prevent river erosion. Consequent flood and excessive rainfall accelerated the failure process which results immense damage to agriculture and infrastructures every year. In this study the soil of district Gaibandha of Bangladesh has been considered. The soil mostly consists of sandy silt or fine sand with silts. The soil layers have been drawn in the similar manner found in the bore log and slope stability has been analyzed for the different embankment heights, each with three different water level conditions using the program GEO5 slope stability.

2. Literature Review

Harabinova and Panulinova (2017) in "Assessment of slope stability", have assessed the slope stability on the road II/595 near the village Zlatno, Slovakia before and after the landslide of 2010 using the GEO 5 slope stability software. The critical factors of safety has been determined by the methods of Petterson, Bishop and Sarma. They have used four variants- original condition (dry state), condition after landslide (saturated state) and reinforced slopes with ground anchors. By finding the most unfavorable slip surface the proposal of remedial measures has been given, which is using geogrid with tensile strength 173 KN/m.

Michalski (2016) in "Slope stability analysis with GEO 5 software for 'Laski' landslide in Miedzybrodzie Bialskie" has computed the factor of safety by using the slide surfaces which have been identified in drill cores. He has carried out the calculations in three scenarios- first with normal water level, second with water level lowered to 5 m and third one was without the water level with the worst courses of sliding surfaces. It has been found that despite of water lowering and stabilization of the existing surfaces, there was a considerable risk of a new sliding surface occurrence.

Santosh et al. (2016) in “Slope stability analysis with GEO5 software for Malin landslide in Pune, Maharashtra” has analyzed the slope stability of the landslide to find out the causes of the landslide and remedial measures to avoid landslide by applying the GEO5 slope stability software.

Mahbub et al. (2013) in “Slope stability analysis of embankment of Jamuna River” have analyzed the stability of different slopes and to find the pattern of slope failure under different field conditions. They have used the program STB2010 to analyze the slope stability. It has been concluded that the safety factors at high flood level for slope 1:2 were found significantly less than the desired point of the factor. The highest flood level conditions were the most vulnerable and threatening for the embankment. They have advised a slope of 1:1.5 and considered that slope to be a balanced design for embankment slope.

Hossain et al. (2010) in “River embankment and bank failure in Bangladesh: A study on geotechnical characterization and stability analysis” has investigated the geotechnical properties of failed Jamuna and Padma river embankment materials. The study result has shown that the soil of Jamuna river embankment was not well graded sand and the permeability was moderately high which increased rapidly in submerged condition. Also the slope was not well protected which made the embankment vulnerable to erosion. The study has shown that the factor of safety has been over estimated by about 22-24% if seepage analysis has not been considered in designing embankment.

3. Case Study

A portion of the flood control embankment at Bhatpara in Koizuri union of Shahzadpur upazila under Sirajganj district suddenly collapsed into the Jamuna River. The embankment was made with GO bags and CC blocks. The bags of the right side protection embankment got displaced which caused the collapse of the embankment. The 12-kilometre protection embankment was constructed by WDB in 2011. (The Daily Star, January 20, 2015)

Kurigram district, through which three of the major rivers and 12 of their tributaries flow, was guarded by a 210-kilometre-long embankment. 23 kilometres of this embankment completely washed away, and more than 60 percent of it was severely damaged. In total, 280 kilometres of embankment was damaged and 35 kilometres was wiped out by the recent floods of 2017 in the rest of the northern districts. (The Daily Star, September 08, 2017)

A portion of the riverbank protection embankment went into the Padma River in last couple of weeks of October 2015. Water Development Board (WDB) built 1800-metre-long embankment for Tk 20 crore to protect the upazila town on the Padma riverbank from the erosion. The 1200 metre embankment between Bhelabad and the upazila headquarter was built with CC blocks in 2007, followed by 600-metre-long embankment between Andharmanik and the upazila headquarters in 2008. (The Daily Star, November 03, 2015)

About 180-feet area of Sirajganj Town Protection Embankment went into the Jamuna due to erosion by the turbulent river on July 19, 2010. At least 180 feet area of Sirajganj town protection embankment collapsed. Workers of Water Development Board put sand bags and CC blocks immediately after the collapse to prevent further damages but their attempts went in vain because of strong current in the Jamuna. The embankment began to collapse as sand under the CC blocks moved away about 35 feet off the dyke. The embankment was built with a 100-year warranty, but in 2009 it was damaged twice-on July 10 and on July 17. (The Daily Star, July 20, 2010)

4. Methodology

The analysis in this study has been performed by the program GEO5 slope stability. GEO5 has been used to perform slope stability analysis (embankments, earth cuts, anchored retaining structures, MSE walls, etc.). The slip surface has been considered as circular (Bishop, Fellenius/Petterson, Janbu, Morgenstern-Price or Spencer methods) or polygonal (Sarma, Janbu, Morgenstern-Price or Spencer methods).

The respective soil profile has been drawn for two boreholes of Gaibandha and factor of safety has been analyzed for three cases- high water table, low water table and rapid drawdown. Bishop's method has been used considering a circular slip surface. Next, geogrid restrictions have been inserted in the soil and factor of safety has been calculated for all three cases. The bore log of Gaibandha borehole 1 (Figure 1a) depicts the three soil layers namely silt with fine sands, loose to medium dense silty fine sand and medium dense silty fine sand along with the SPT N values per 1.5 meters of soil depth. Same information has been obtained from the bore log of Gaibandha borehole 2 (Figure 1b), which contains four layers namely medium stiff silty clay, medium stiff clayey silt with fine sand, fine sand with silt and lastly medium silty dense fine sand with the SPT N values per 1.5 meters of soil depth.

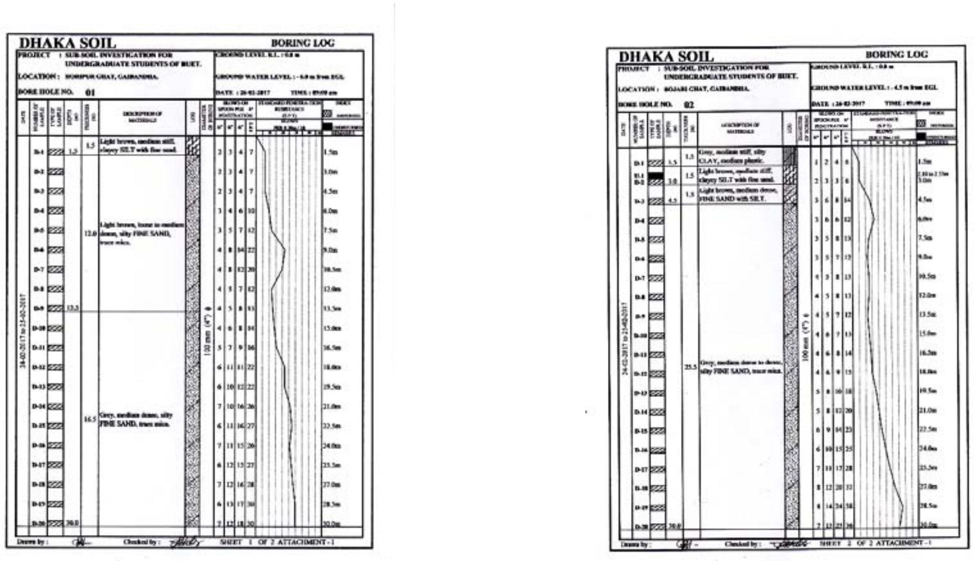

Figure 1: Bore logs collected from Gaibandha

In the GEO5 software, the angle of friction, Φ value has to be input along with the soil properties and coefficient of reduction of pore pressure. The corresponding internal angle of friction (Φ) values for each of the layers have been deduced from the following chart shown in Figure 2 by Peck et al., (1974).

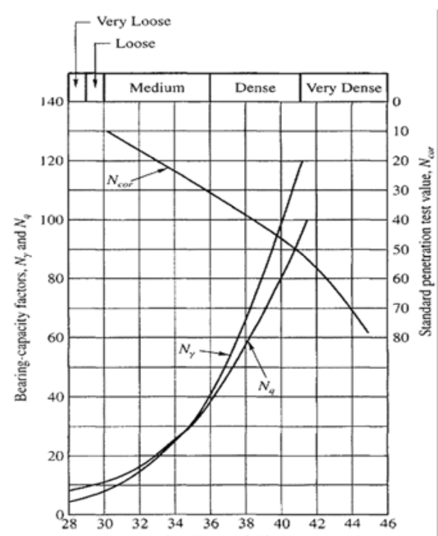

Figure 2: SPT N value vs angle of friction Φ (after Peck et al., 1974)

Influence of Water: Ground water can be assigned to the slope plane section using one of the five options in GEO5, of these five options, two have been considered in this study namely- Ground water table and rapid drawdown.

1) *Ground water table:* The ground water table is specified as a polygon. It can be arbitrarily curved, placed totally within the soil body or introduced partially above the ground surface.

Presence of water influences value of pore pressure acting within a soil and reducing its shear bearing capacity.

For embankment height 10, 7.5 and 5 meters, high water table has been considered at 1 meter below the embankment surface for each of the embankments and low water tables were at 8, 5 and 3 meters from the embankment top surface respectively.

2) Rapid draw down: Original table can be introduced above the input ground water table. Original water table simulates state before rapid draw down. For the case of rapid drawdown in the study, original water level and ground water level has been specified to imitate the case of floods. For embankment height 10, 7.5 and 5 meters, original ground water table has been considered at 1 meter below the embankment surface for each of the embankments and ground water tables have been considered at 8, 5 and 3 meters from the embankment top surface respectively.

Rapid draw down analysis: The coefficient of pore pressure R_u represents the ratio between the pore pressure and geostatic pressure in a soil body. In the area, where R_u is positive, entered unit weight of saturated soil γ_{sat} is considered; in other case unit weight of soil γ is used. In this study, the coefficient of reduction of pore pressure R_u has been taken as 0.4.

Circular Slip Surface: All methods of limit equilibrium assume that the soil body above the slip surface is subdivided into blocks (dividing planes between blocks are always vertical). Individual methods of slices differ in their assumptions of satisfying the force equations of equilibrium and the moment equation of equilibrium with respect to the center O. The methods allowed by the program are Fellenius / Petterson, Bishop, Spencer, Janbu, Morgenstern-Price, Shahunyants and ITF Method.

Introducing anchor forces and water above the ground surface into the analysis: Anchor forces are considered as external load applied to the slope. They are taken with respect to one running meter [kN/m] and introduced into the moment equation of equilibrium. These forces should contribute to additional stability, if that cannot be achieved in a different way. There is no limitation to the magnitudes of anchor forces and therefore it is necessary to work with realistic values. Influence of water above the ground surface is considered as set forces acting perpendicular on the ground surface together with pore pressure along the slip surface, which is derived depending on the depth of slip surface measured from the ground water table. The forces acting on the ground surface enter the moment equation of equilibrium as forces acting on respective arms measured towards the center of the slip surface.

Optimization of Circular Slip Surface: The goal of the optimization process is to locate a slip surface with the smallest factor of slope stability SF. The circular slip surface is specified in terms of 3 points: two points on the ground surface and one inside the soil body. Each point on the surface has one degree of freedom while the internal point has two degrees of freedom. The slip surface is defined in terms of four independent parameters. Searching for such a set of parameters that yields the most critical results requires sensitivity analysis resulting in a matrix of changes of parameters that allows fast and reliable optimization procedure. The slip surface that gives the smallest factor of slope stability is taken as the critical one. The optimization process can be restricted by various constraints. Optimization restrictions are specified as a set of segments in a soil body. The optimized slip surface is then forced to bypass these segments during optimization.

Bishop Method: The simplified Bishop method assumes zero X_i forces between blocks. The method is based on satisfying the moment equation of equilibrium and the vertical force equation of equilibrium.

The factor of safety SF is found through a successive iteration of the following expression:

$$FS = \frac{1}{\sum_i W_i . \sin\alpha_i} . \sum_i \frac{c_i . b_i + (W_i - u_i . b_i) . \tan\varphi_i}{\cos\alpha_i + \frac{\tan\varphi_i . \sin\alpha_i}{FS}} \quad \text{... (1)}$$

Where, u_i - pore pressure within block

C_i, φ_i - effective values of soil parameters

W_i - block weight

A_i - inclination of the segment of the slip surface

B_i - horizontal width of the block.

5. Result

The factors of safety obtained without any reinforcements for three different water level are presented below in a tabular form in Tables 1 to 6. These have been calculated for three different slopes, 1:1, 1.5:1 and 2:1 and three different embankment heights, 5 meters, 7.5 meters and 10 meters.

Table 1: List of Factor of Safety for embankment height 5 meters of Gaibandha borehole 1

Embankment height 5 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	1.19	3	0.97	1	3	0.7

1:1.5	1	1.41	3	1.15	1	3	0.89
1:2	1	1.64	3	1.34	1	3	1.06

Table 2: List of Factor of Safety for embankment height 7.5 meters of Gaibandha borehole 1

Embankment height 7.5 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	0.94	5	0.77	1	5	0.41
1:1.5	1	1.2	5	0.99	1	5	0.64
1:2	1	1.46	5	1.2	1	5	0.84

Table 3: List of Factor of Safety for embankment height 10 meters of Gaibandha borehole 1

Embankment height 10 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	0.58	8	0.56	1	8	0.12
1:1.5	1	1.11	8	0.87	1	8	0.33
1:2	1	1.39	8	1.06	1	8	0.62

Table 4: List of Factor of Safety for embankment height 5 meters of Gaibandha borehole 2

Embankment height 5 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	1.03	3	0.58	1	3	0.62
1:1.5	1	1.29	3	0.87	1	3	0.87
1:2	1	1.52	3	1.11	1	3	1.06

Table 5: List of Factor of Safety for embankment height 7.5 meters of Gaibandha borehole 2

Embankment height 7.5 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	0.55	5	0.54	1	5	0.16
1:1.5	1	0.83	5	0.79	1	5	0.42
1:2	1	1.11	5	1.03	1	5	0.64

Table 6: List of Factor of Safety for embankment height 10 meters of Gaibandha borehole 2

Embankment height 10 m							
slope	HWT from GL	FS (opt)	LWT from GL	FS (opt)	Rapid drawdown		Rapid drawdown FS
					original	GWT	
1:1	1	0.56	8	0.54	1	8	0.15
1:1.5	1	0.84	8	0.80	1	8	0.41
1:2	1	1.11	8	1.11	1	8	0.60

The failure of soil mostly depends on the factor of safety. The more the safety factor the more would be the assurance of soil strength along with the less of failure possibility. The factors of safety obtained from analyzing the soil samples as per in field condition in GEO5 slope stability, have been found factor of safety values lower than the optimum factor of safety value 1.50, which means the embankments were highly unstable. To remedy this problem, geogrid has been installed at 2 meter intervals and the tensile strength of the geogrids has been selected by trials. The new factors of safety are presented in Tables 7 to 12.

Table 7: List of Factor of Safety with geogrid for embankment height 5 meters of Gaibandha borehole 1

Embankment height 5 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (3 m from GL)	HWT (1 m from GL)	Rapid Drawdown
1:1	60	1.75	2.24	1.50
1:1.5	50	1.79	2.31	1.53

1:2	50	1.93	2.50	1.66

Table 8: List of Factor of Safety with geogrid for embankment height 7.5 meters of Gaibandha borehole 1

Embankment height 7.5 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (5 m from GL)	HWT (1 m from GL)	Rapid drawdown
1:1	120	1.76	2.32	1.45
1:1.5	120	1.89	2.51	1.55
1:2	90	1.90	2.63	1.56

The values of tensile strength for slope 1:1 and 1:1.5 has been taken as 120 KN/m by trial. The previous tensile strength value taken was 90 KN/m but the factors of safety of the mentioned slopes have been obtained 1.30 and 1.42 respectively for the case of Rapid drawdown, which did not satisfy the required value 1.50.

Table 9: List of Factor of Safety with geogrid for embankment height 10 meters of Gaibandha borehole 1

Embankment height 10 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (8 m from GL)	HWT (1 m from GL)	Rapid drawdown
1:1	140	1.84	2.55	1.42
1:1.5	120	1.91	2.69	1.51
1:2	90	1.91	2.72	1.49

The value of tensile strength for slope 1:1 has been taken as 140 KN/m by trial. The previous tensile strength value taken was 120 KN/m but the factor of safety of the mentioned slope has been found 1.37 for the case of Rapid drawdown, which did not satisfy the required value 1.50. Similarly, value of tensile strength for slope 1:1.5 has been taken as 120 KN/m. The previous tensile strength value taken was 90 KN/m but the factor of safety of the mentioned slope has been found 1.36 for the case of Rapid drawdown.

Table 10: List of Factor of Safety with geogrid for embankment height 5 meters of Gaibandha borehole 2

Embankment height 5 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (3 m from GL)	HWT (1 m from GL)	Rapid drawdown
1:1	68.7	1.75	2.09	1.53
1:1.5	54	1.73	2.11	1.52
1:2	54	1.87	2.30	1.65

Table 11: List of Factor of Safety with geogrid for embankment height 5 meters of Gaibandha borehole 2

Embankment height 7.5 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (5 m from GL)	HWT (1 m from GL)	Rapid drawdown
1:1	160	1.82	2.26	1.52
1:1.5	120	1.81	2.37	1.52
1:2	80	1.78	2.32	1.49

The value of tensile strength for slope 1:1 has been taken as 160 KN/m by trial. The previous tensile strength value taken was 140 KN/m but the factor of safety of the mentioned slope has been found 1.47 for the case of Rapid drawdown, which did not satisfy the required value 1.50. Similarly, value of tensile strength for slope 1:1.5 has been taken as 120 KN/m. The previous tensile strength value taken was 90 KN/m but the factor of safety of the mentioned slope has been found 1.40 for the case of Rapid drawdown.

Table 12: List of Factor of Safety with geogrid for embankment height 5 meters of Gaibandha borehole 2

Embankment height 10 m (Factor of Safety with geogrid)				
slope	tensile strength (KN/m)	LWT (8 m from GL)	HWT (1 m from GL)	Rapid drawdown
1:1	200	1.87	2.45	1.48

1:1.5	140	1.84	2.46	1.50
1:2	120	1.91	2.58	1.56

The value of tensile strength for slope 1:1 has been taken as 200 KN/m by trial. The previous tensile strength value taken was 180 KN/m but the factor of safety of the mentioned slope has been found 1.41 for the case of Rapid drawdown, which did not satisfy the required value 1.50. Similarly, value of tensile strength for slope 1:1.5 has been taken as 140 KN/m. The previous tensile strength value taken was 120 KN/m but the factor of safety of the mentioned slope has been found 1.43 for the case of Rapid drawdown. The value of tensile strength for slope 1:2 has been taken as 120 KN/m by trial. The previous tensile strength value taken was 90 KN/m but the factor of safety of the mentioned slope has been found 1.44 which was also for the case of Rapid drawdown.

6. Conclusion

From the results of the study, it is observed that the soil is pretty unsafe in the field condition and it is evident that the most vulnerable state for the slope was the rapid drawdown. To increase the factor of safety values, geogrid has been inserted in the soil and the results are well within the range of optimum factor of safety value 1.50. So, for building an embankment in the river bank, soil treatment is imperative. The highest flood level conditions should be given the most importance. The flatter slopes are more stable, which is also noticeable from the results. But considering the economic aspects of possible solutions, a slope of 1:1.5 is advised to be a balanced design for embankment slope. To construct the embankments protection by some kind of reinforcements or soil treatments is as significant as following proper designs and construction procedures.

7. Acknowledgements

The authors would like to acknowledge the JST-JICA for the fund to undertake *Research on Disaster Prevention/Mitigation Measures against Floods and Storm Surges in Bangladesh* (Component C3) which provided data for this paper.

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PART-XII

REPORT ON STRONG MOTIONS RECORDED BY BRIDGE SENSORS AND OTHER ACCELEROMETERS NEAR THE BRIDGE

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By:

Mehedi Ahmed Ansary

1. INTRODUCTION

The 4.8 km long Jamuna Multipurpose Bridge connects the eastern and western parts of Bangladesh. Being the only road and rail link between the two regions, the bridge bears immense economic and strategic importance for the whole country. But the bridge is located in a seismically active region that can be subjected to moderately strong earthquakes from a number of sources and special earthquake protection devices have been used in the bridge. The bridge has been designed for a peak ground acceleration of 0.2g due to a 7.0 magnitude earthquake in the Bogra fault zone, which is about 25 to 40 kms from the west end of the bridge, based on study by Bolt (1987).

Jamuna Multipurpose Bridge Authority (JMBA) took necessary steps for the installation of seismic instruments on and around the Jamuna Bridge. JMBA employed Bangladesh University of Engineering & Technology (BUET) as the technical consultant for this project. The Installation of the seismic instruments on the bridge structure and six other free-field (ground) stations was completed by Kinemetrics, Inc. USA on July 10, 2003 (BUET, 2003). The Operating and Monitoring Phase of the project started on July 11, 2003.

In this report, the earthquake data recorded by different bridge sensors have been compiled for future references. Also the Acceleration Response Spectrum (ARS) curve proposed by Prof. Bolt during the feasibility study of the bridge has been compared with the data of the West Bridge Free-free data for the last few years.

2. STUDY LOCATIONS

Location of Digital Seismic Measuring Device at free-field Station (ETNA) near the bridge are shown Table 1. Table 2, Figures 1 and 2 lists and show sensors and recorders installed on the bridge and bore-hole.

Table 1 Location of Digital Seismic Measuring Device Station (ETNA) near and inside the bridge

SL.No	Model	Location	Latitude	Longitude
3	ETNA (BUET)	Jamuna Bridge West-End	23.28^0N	88.25^0E
30	ETNA	Inside the Jamuna Bridge	-	-

Table 2 List of sensors and recorders installed on the bridge and bore-hole

K2 Data Recorder Label	Sensor Type	Channel Label	Orient-ation	Sensor Location
JAMUNA located inside bridge deck near Pier P10	Displacement	D1	X	Across Isolation System at Pier P10
	Displacement	D2	Y	
	Displacement	D3	Y	Across Expansion Joint between Piers P7 and P8
	EPI Uniaxial Accelerometer	BR9	Z	Pile Cap at Pier P9
	EPI Biaxial Accelerometer	BR10	X	Deck at Pier P9
		BR11	Y	
MEGHNA located inside bridge deck near Pier P10	EPI Uniaxial Accelerometer	BR4	Z	Pile Cap at Pier P10
	EPI Uniaxial Accelerometer	BR8	Z	Deck at Pier P10
	EPI Uniaxial Accelerometer	BR12	X	Deck at Midspan between Piers P9 and P10
	EPI Uniaxial Accelerometer	BR13	X	Deck at Midspan between Piers P10 and P11
SURMA located inside bridge deck near Pier P10	EPI Triaxial Accelerometer	BR1	X	Pile Cap at Pier P10
		BR2	Y	
		BR3	Z	
	EPI Triaxial Accelerometer	BR5	X	Deck at Pier P10
		BR6	Y	
		BR7	Z	
PADMA located at west abutment	EPI Triaxial Accelerometer	AB1	X	West Abutment
		AB2	Y	
		AB3	Z	
	Borehole Triaxial Accelerometer	BH1	EW	Borehole near West End (58 m depth)
		BH2	NS	
		BH3	Z	

Note:
X means orientation across the bridge (transverse direction)

Y orientation parallel to the bridge (longitudinal direction)
Z means vertical direction

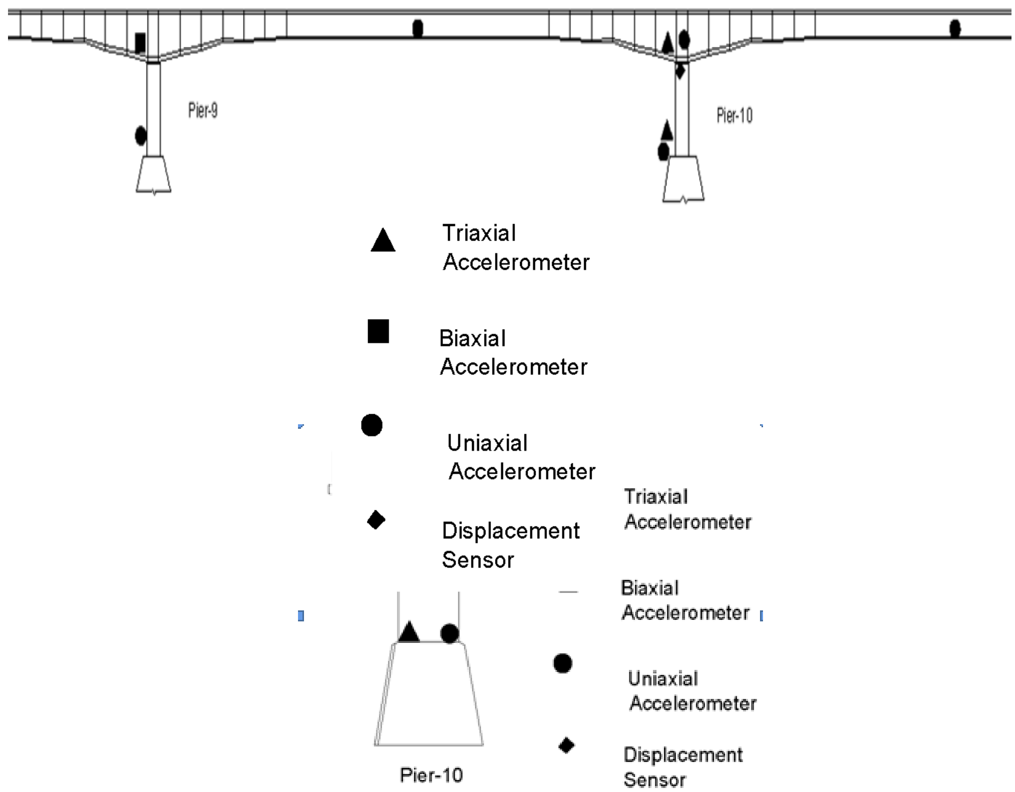


Figure 2: Location of different types of accelerometer

3. SOME RECENT EARTHQUAKES IN AND AROUND BANGLADESH AFFECTING THE BRIDGE SITE

Table 3 and Figure 3 show the earthquake data recorded by the free-field station and bridge sensors during recent times.

Table 3 Earthquakes recorded by the free field stations and the bridge sensors

SL No.	Date	Name of the Earthquake	Epicentre	Magnitude	Depth (km)	Stations Recorded near and inside the bridge
1	25-04-2015 (6:11:25 UTC)	Nepal EQ	28.100N,84.600 E36km E of Khudi, Nepal	7.8	8.2	BR1-BR7 on the bridge and JMB West
2	26-04-2015 (7:09:10UTC)	Nepal EQ (after shock)	27.771N, 86.017 E21km SSE of Kodari, Nepal	6.7	22.9	JMB West
3	12-05-2015 (07:05:19 UTC)	Nepal EQ (after shock)	27.809N 86.066 E 19km SE of Kodari, Nepal	7.3	15	JMB West
4	03-01-2016 (23:05:22 UTC)	Monipur EQ	24.804N,93.650 E 30km W of Imphal, India	6.7	55	BR9-BR11 & D1 on the bridge
5	13-04-2016 (13:55:17 UTC)	Myanmar EQ	23.094N, 94.865E 75 km SE of Mawlaik	6.9	136	JMB West

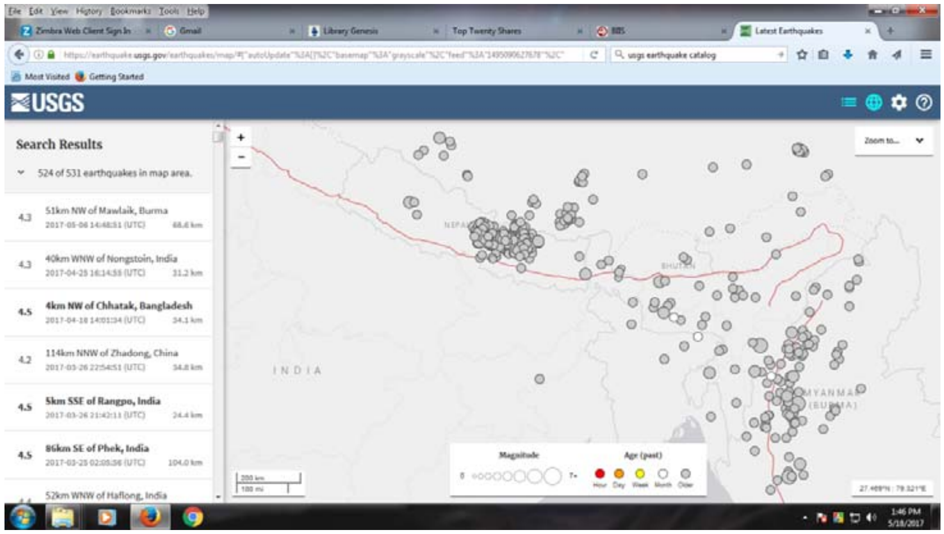


Figure 3: Earthquake locations

4. EARTHQUAKE DATA ANALYSIS

There are some custom-made softwares that came with the instruments to operate and monitor the whole system. One can also interact with the instruments (i.e., K2s) using the software called Quick Talk and changes the settings. Quick Talk and Quick Look may be also used for downloading or viewing the incoming data without any processing. After the sensors were connected, they had to go through the Functionality Test done with the operating software. Then they had to be corrected for any offsets in the readings. Once all of these are done for each of the sensors, the system was ready. It was tested to see if data from all the channels are reaching the recorders, if they are set at real time through GPS. The GPS are set at UTC time as stated in the original documents. The system is such that each of the sensors can be configured separately, but they were kept the same at the beginning. Each sensor can be set to trigger the whole system. The trigger value for the twenty two free-field ground accelerometers was set at 0.5% of g (5 cm/sec^2). Whenever the acceleration exceeds the trigger value, automatic data recording will take place. To process, analyze and interpret the data, the software called Strong Motion Analyzer (SMA) is used. One can perform necessary filtering, corrections and plotting of the signals received from the sensor. This accelerometer gives data in North-South, East-West and Up-Down direction. The strong motion data recorded by the sensors together with their orbital motions are presented in the Appendices.

5. SITE RESPONSE ANALYSIS

Acceleration Response Spectrum developed by Prof. Bolt for Jamuna Bridge is presented in Figure 4. Figure 5 shows the ARS for different earthquake motion recorded by West Strong Motion Recorder at the bridge site. Figure 6 compares those ARS values with Bolts' ARS. We can conclude from Figure 6 that Bolt's ARS is relatively lower than the ARS values of different earthquake motion recorded at the bridge site. Also, a new ARS has been proposed which may be used for a future bridge in the vicinity of the existing one.

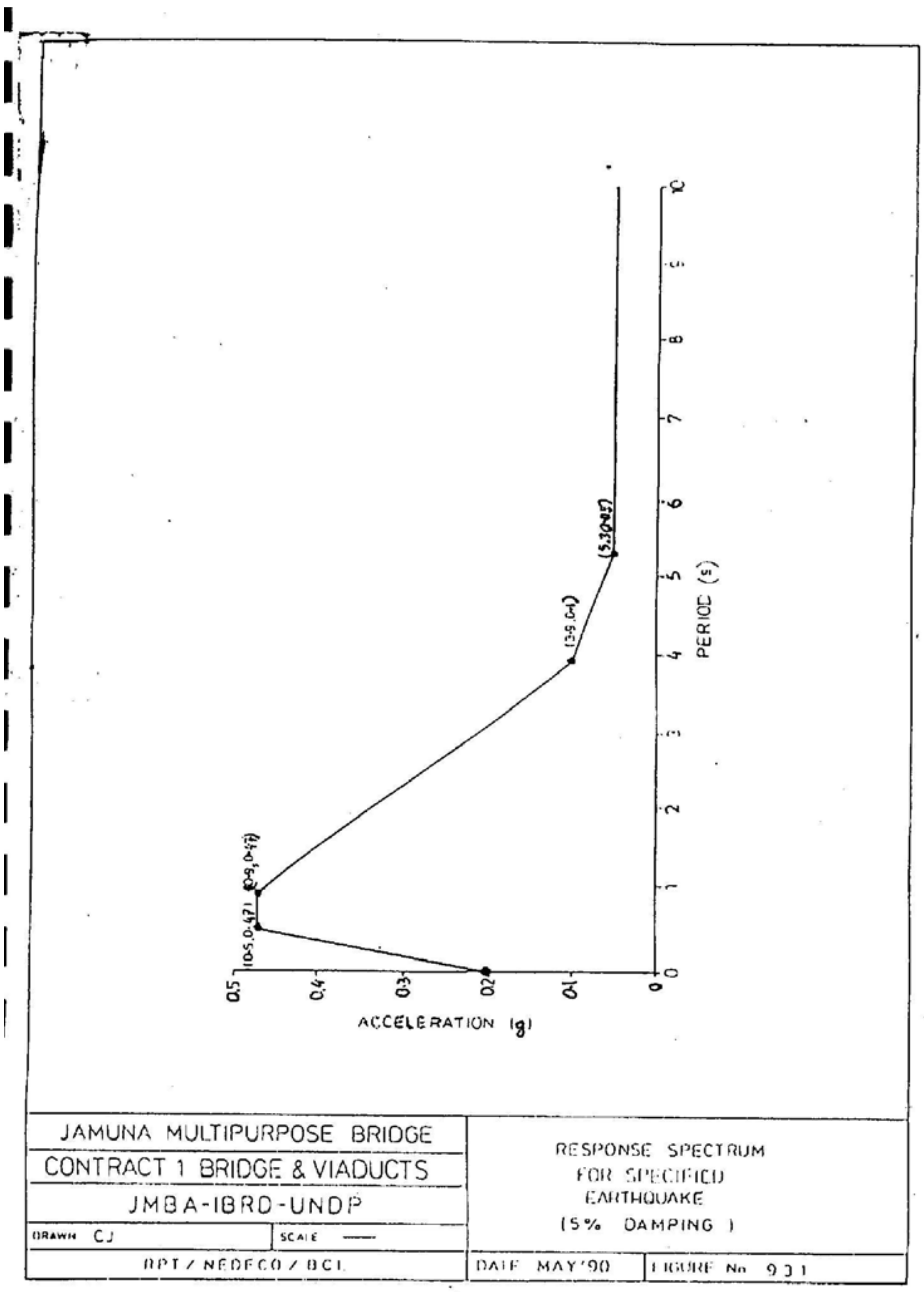
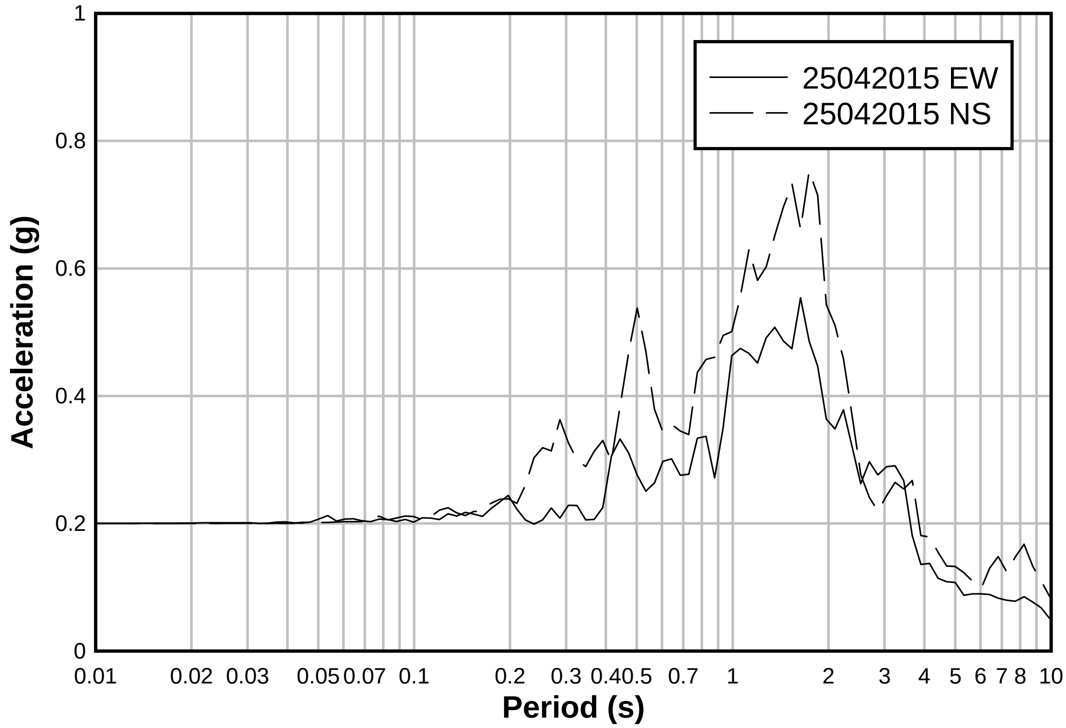


Figure 2 Response spectrum for specified earthquake (5% damping) [Bolt, 1987]

Figure 4 Bolts Acceleration Response Spectrum for Jamuna Bridge



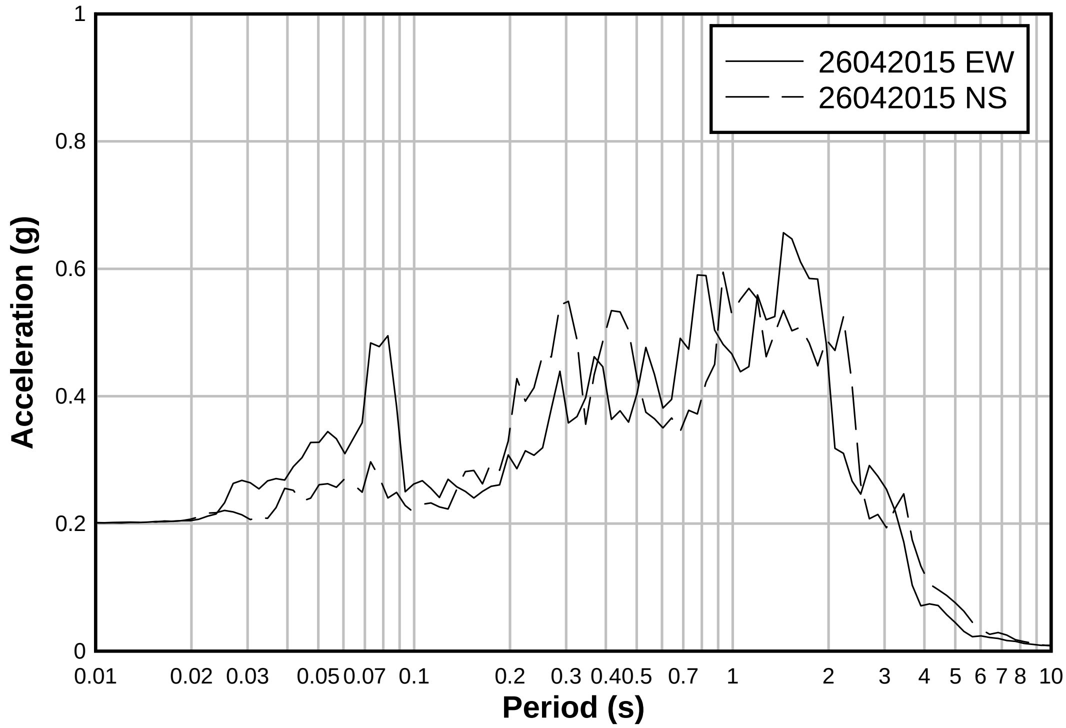
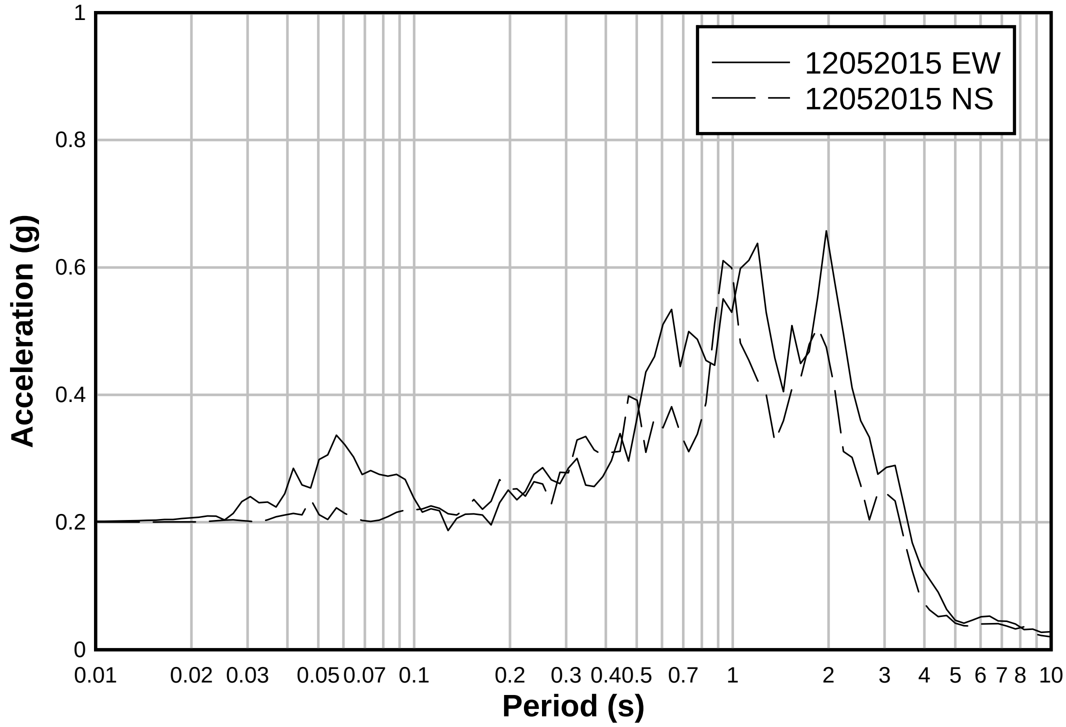


Figure 5 Acceleration Response Spectra for West Jamuna Bridge Recorder



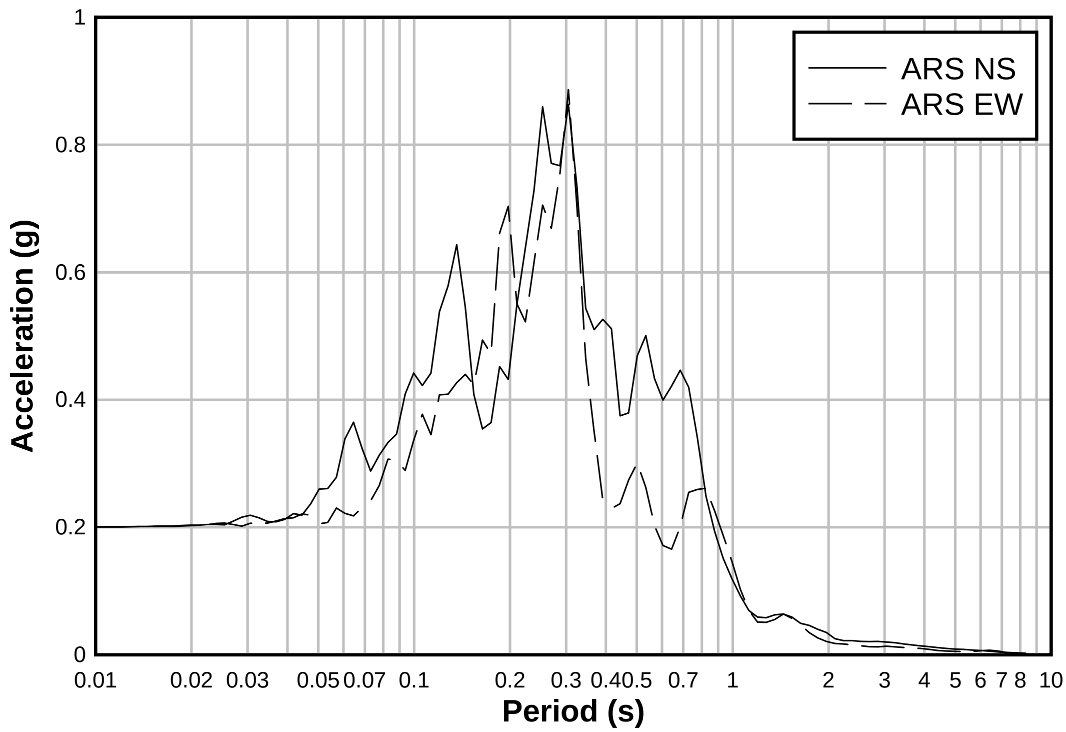


Figure 5 (Contd.) Acceleration Response Spectra for West Jamuna Bridge Recorder

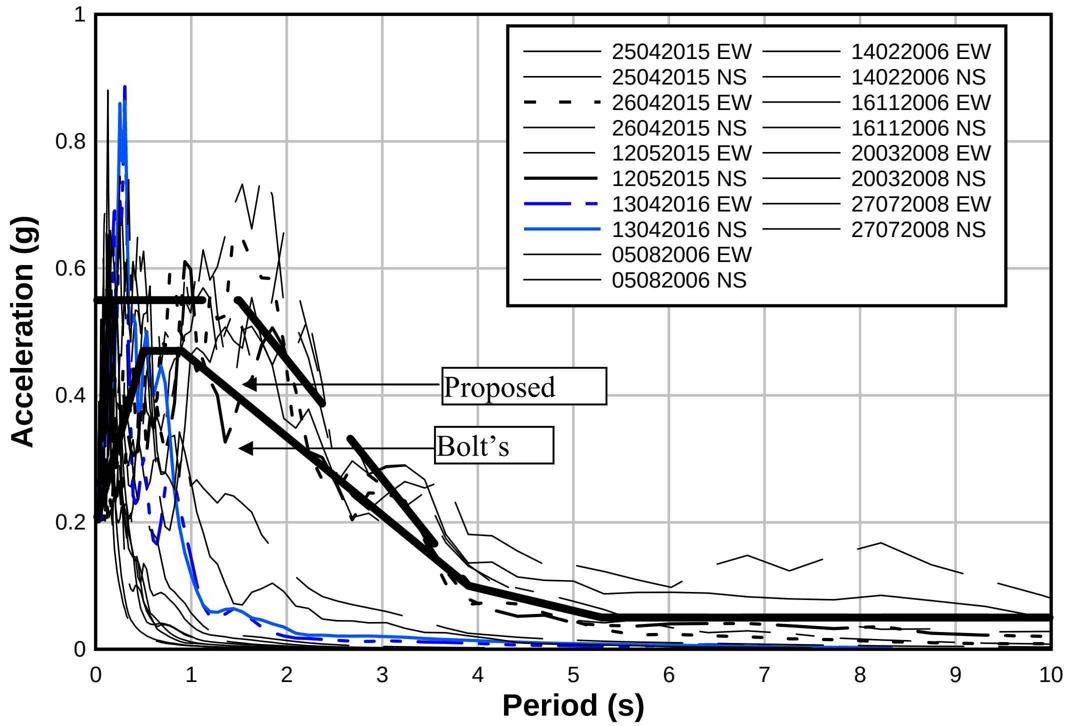
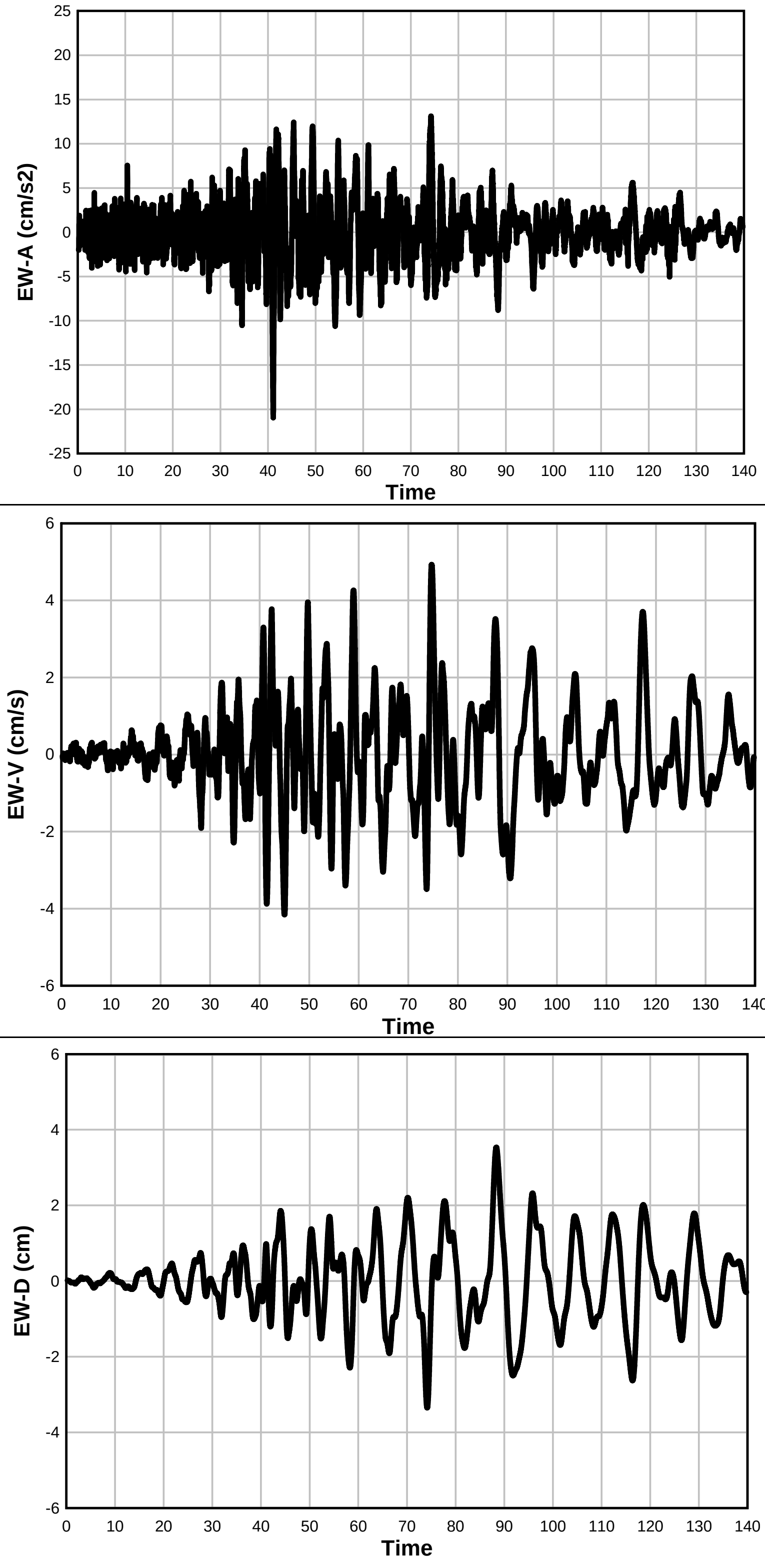
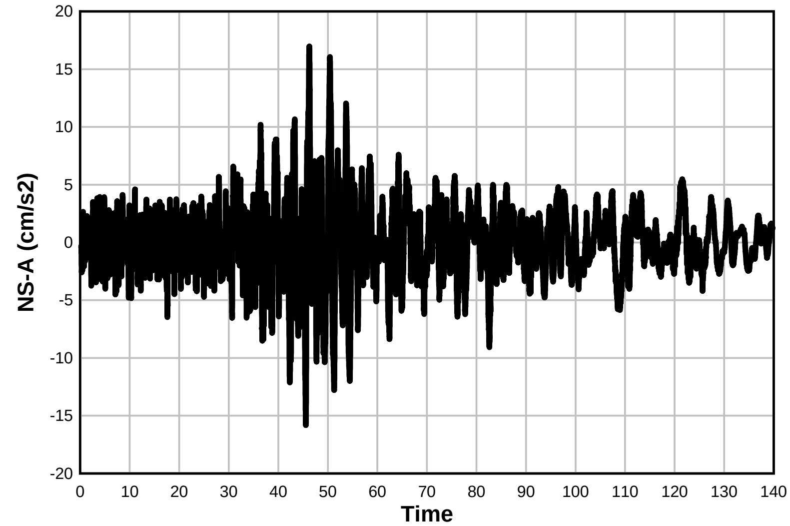
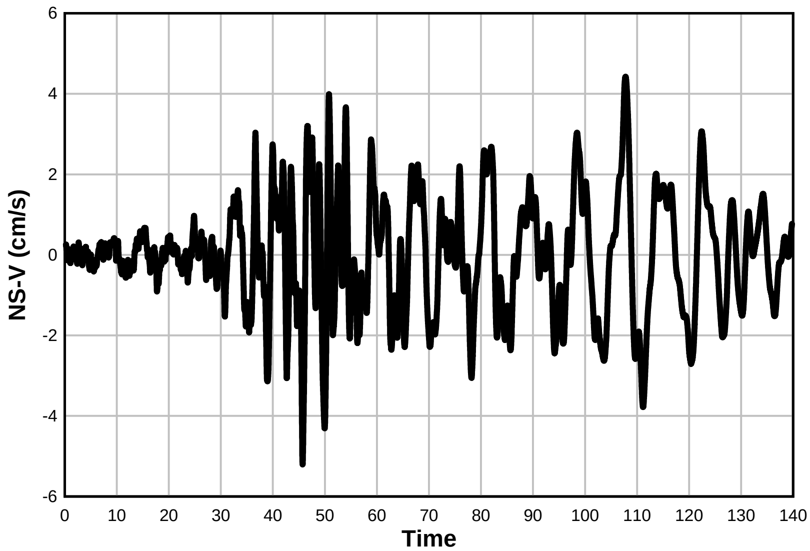


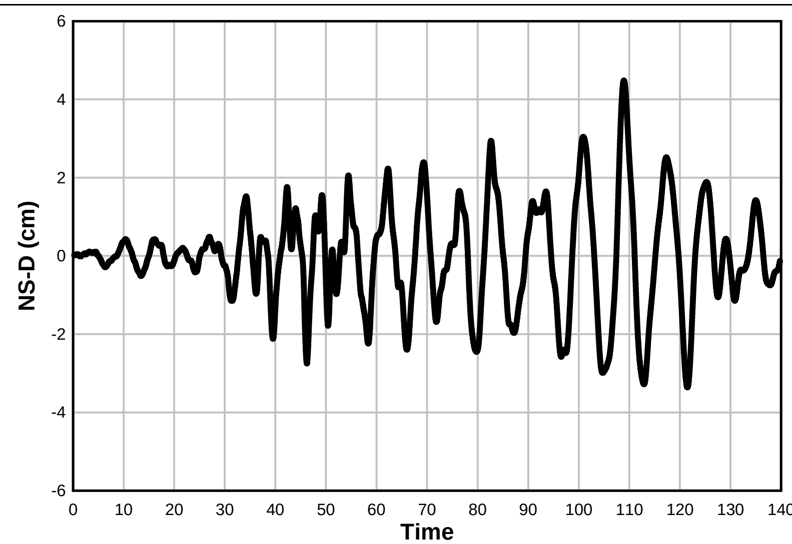
Figure 6 Acceleration Response Spectra for West Jamuna Bridge Recorder compared with Bolt's ARS



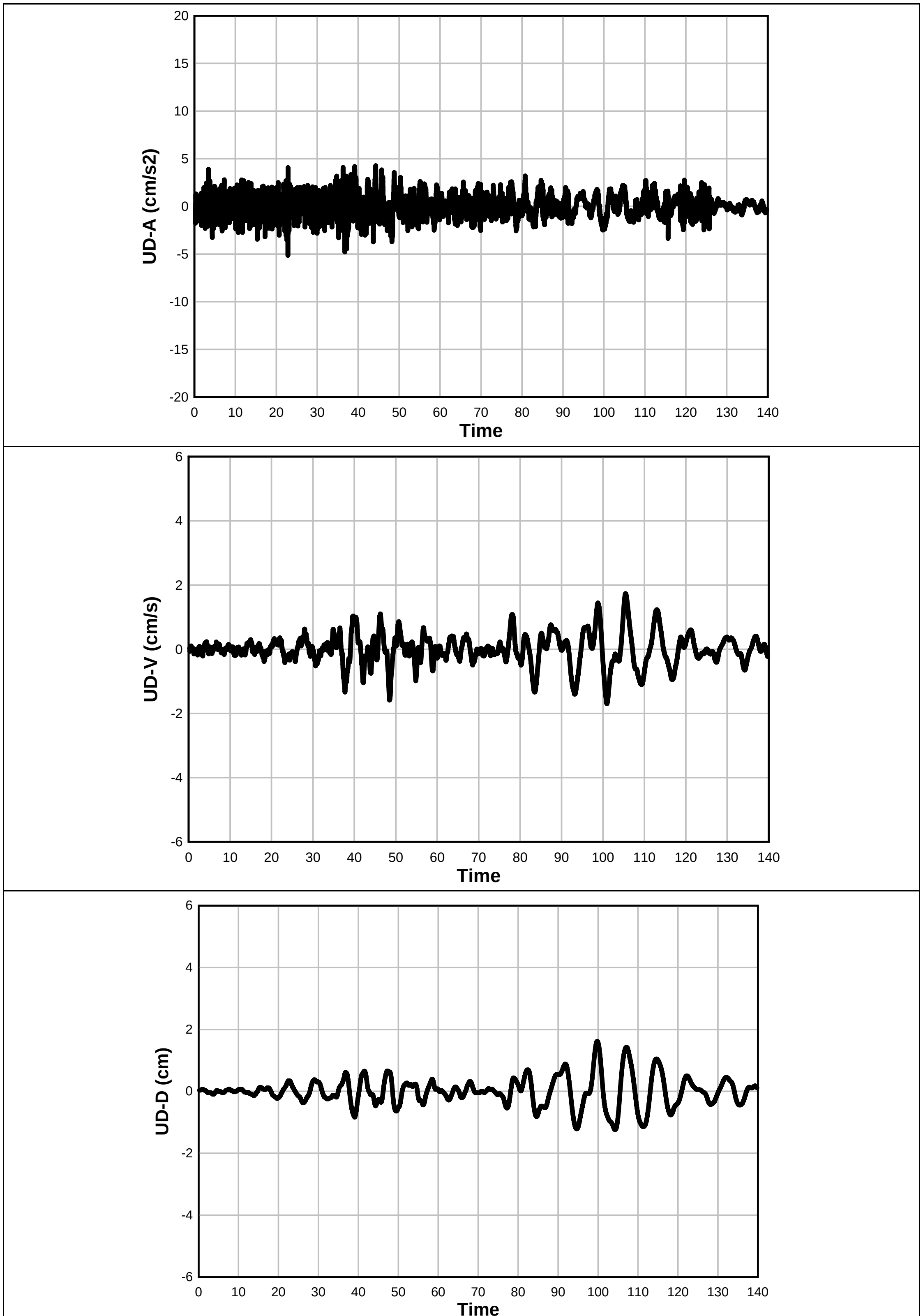
Recorded ground motion at JMB West due to 25th April Nepal EQ (EW component)



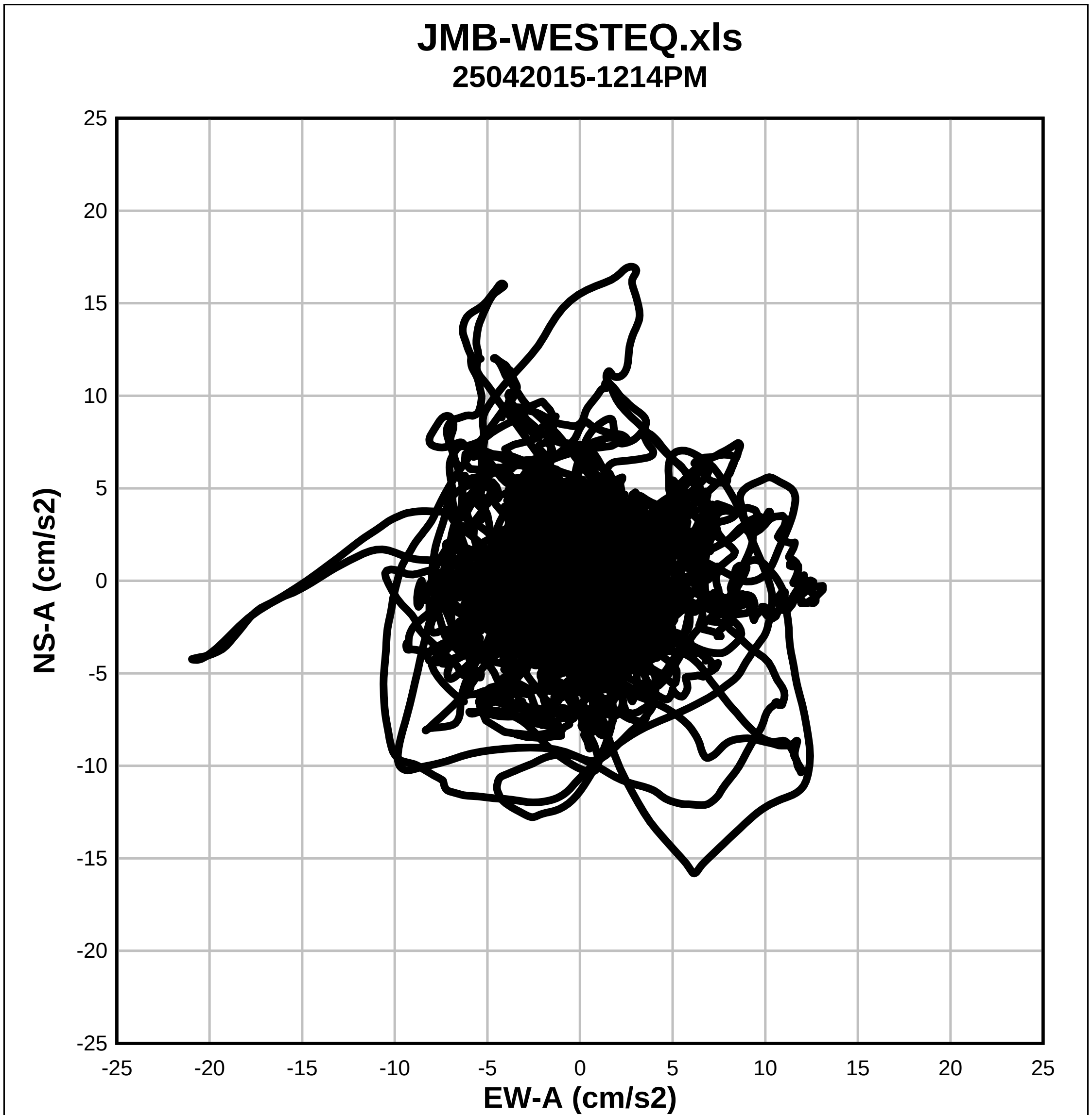




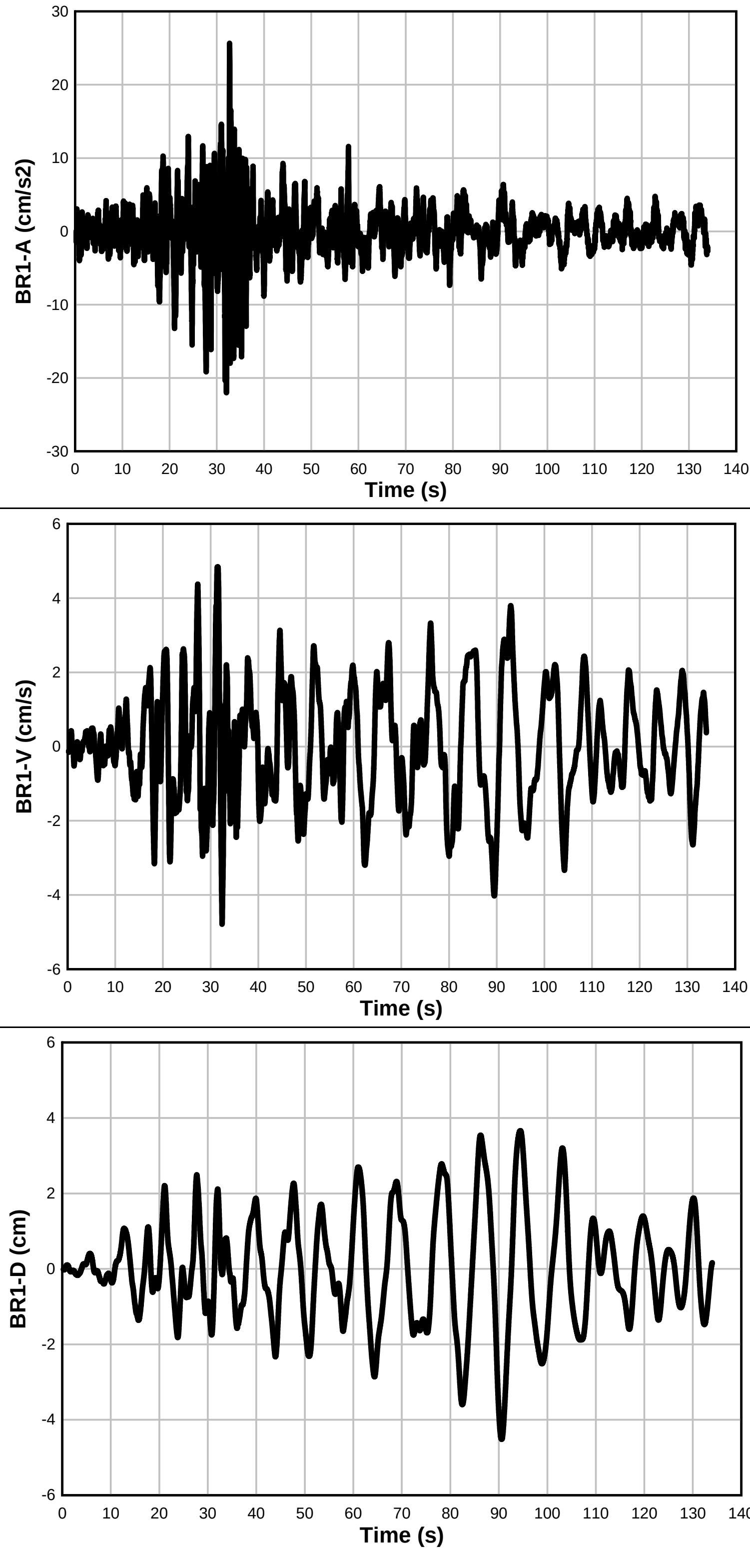
Recorded ground motion at JMB West due to 25th April Nepal EQ (NS component)



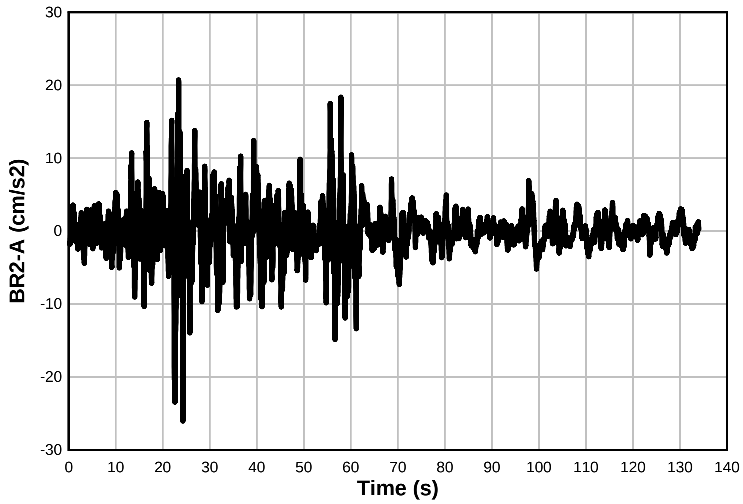
Recorded ground motion at JMB West due to 25th April Nepal EQ (UD component)

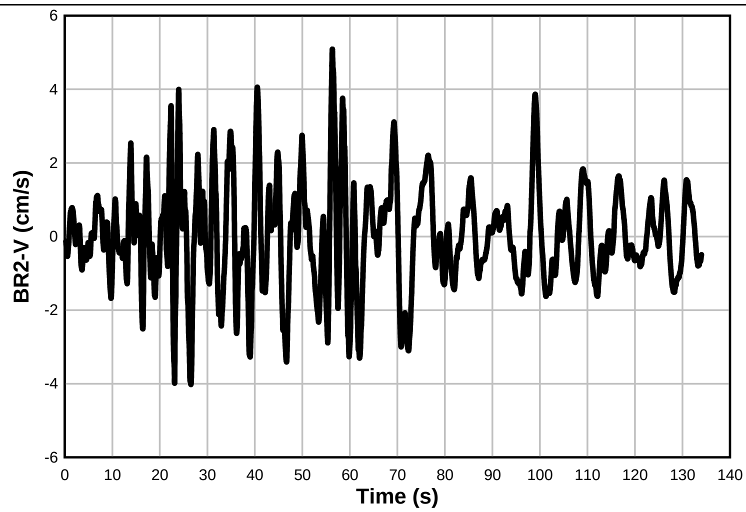


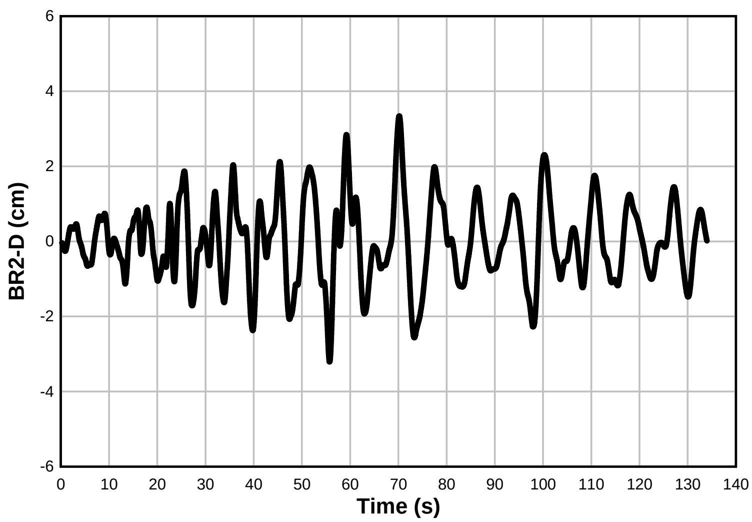
Recorded ground motion orbit at JMB West due to 25th April Nepal EQ



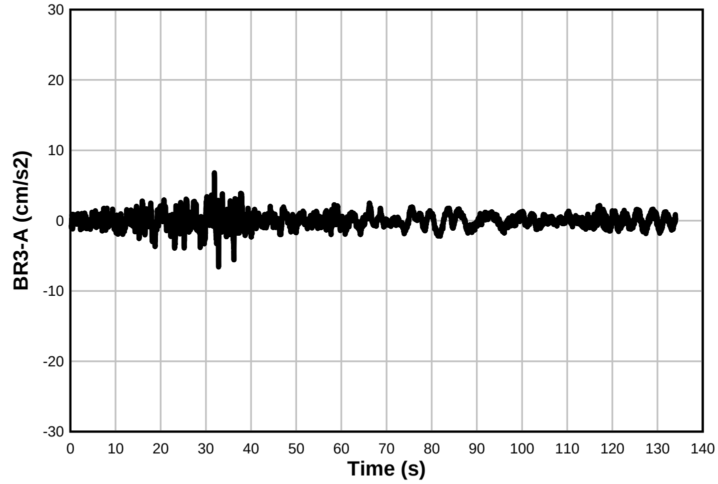
Recorded motion at BR1 due to 25th April Nepal EQ

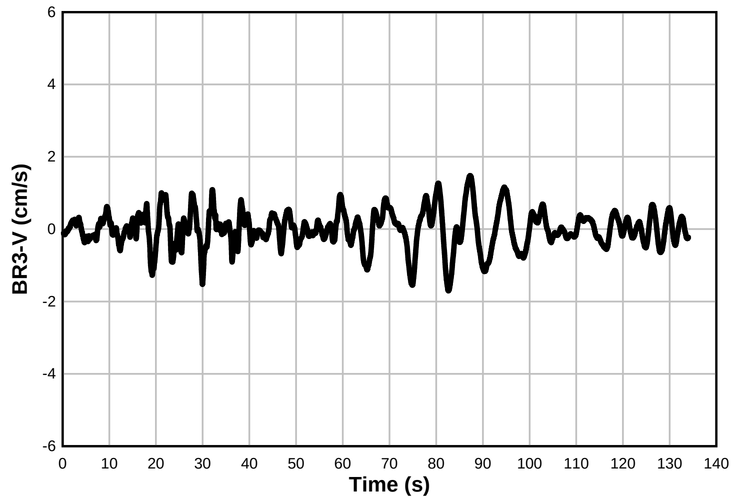


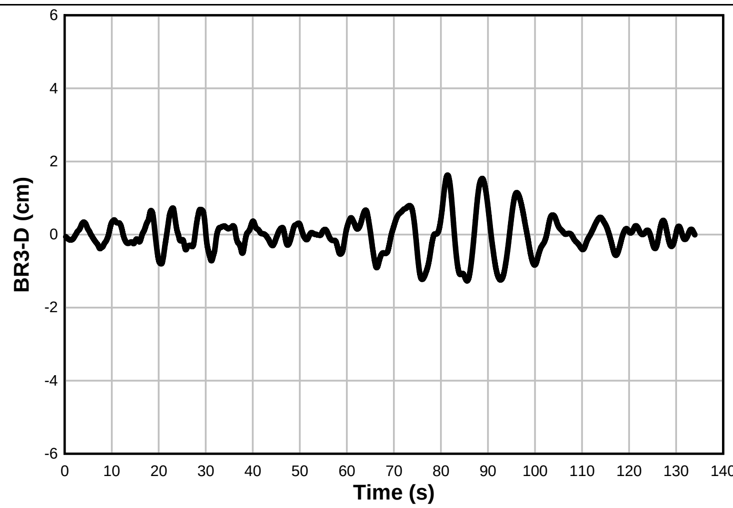




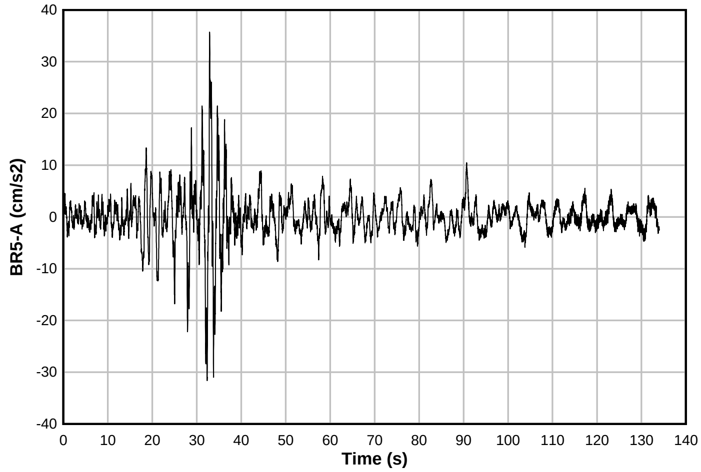
Recorded motion at BR2 due to 25th April Nepal EQ

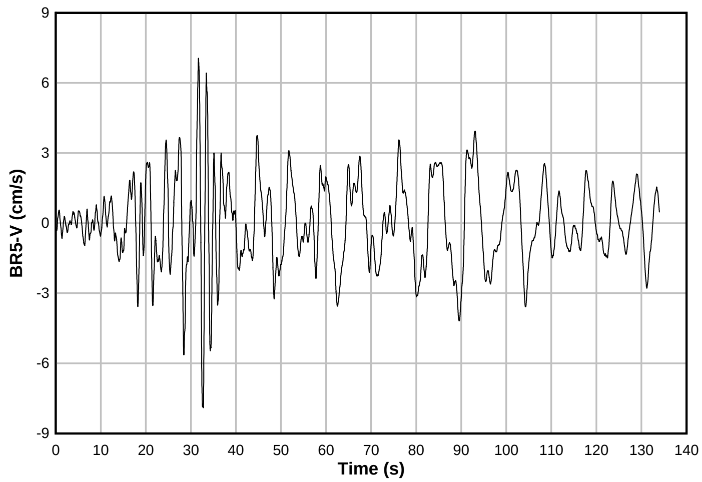


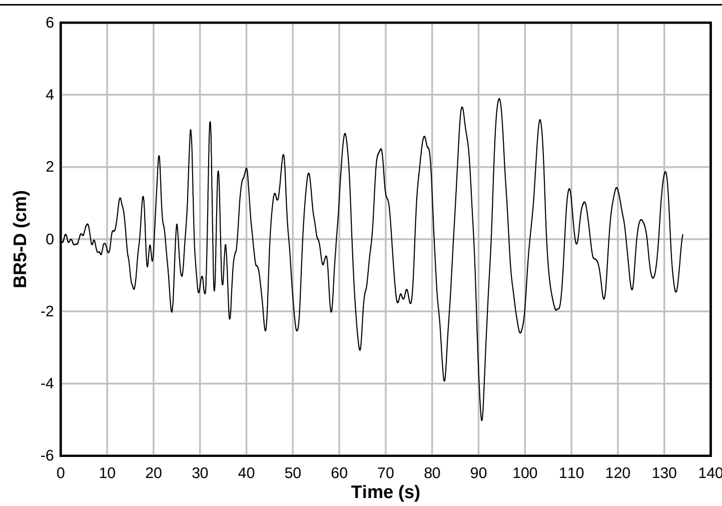




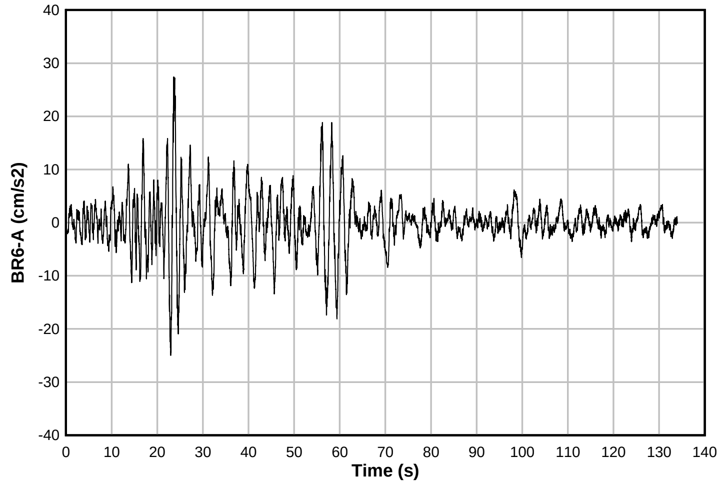
Recorded motion at BR3 due to 25th April Nepal EQ

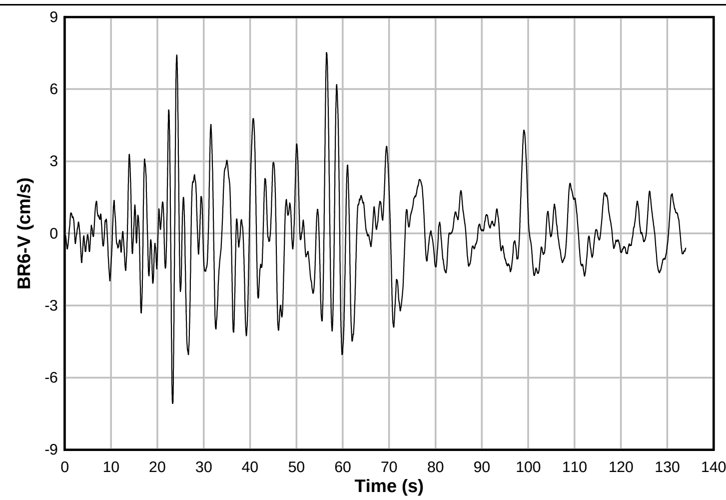


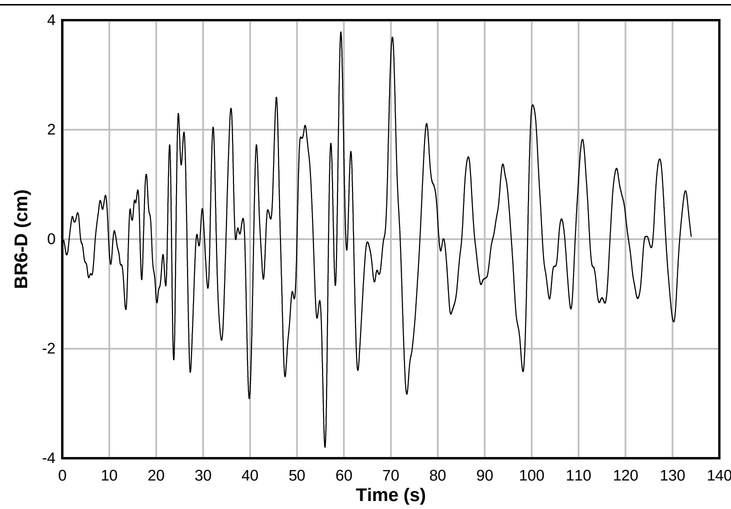




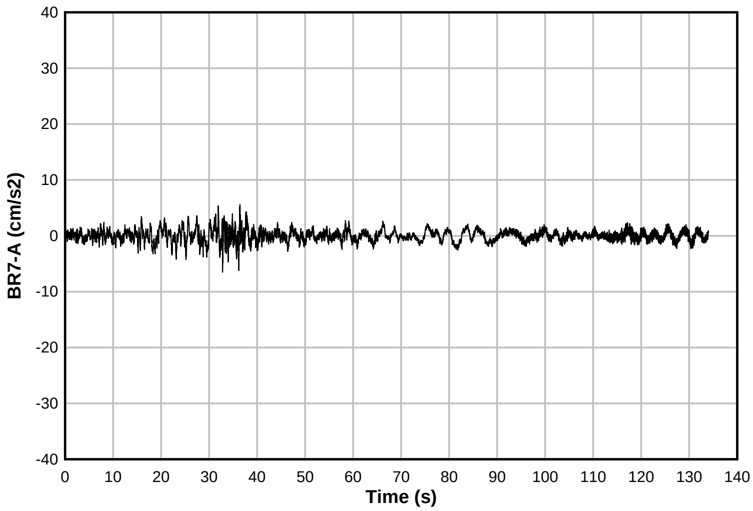
Recorded motion at BR5 due to 25th April Nepal EQ

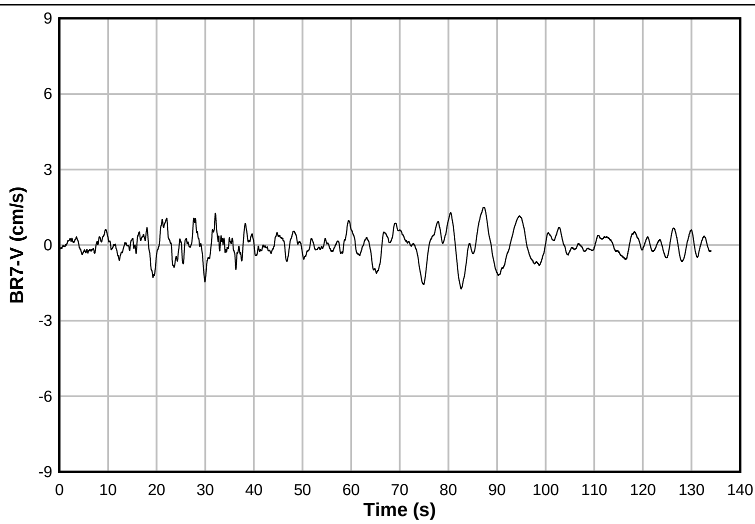


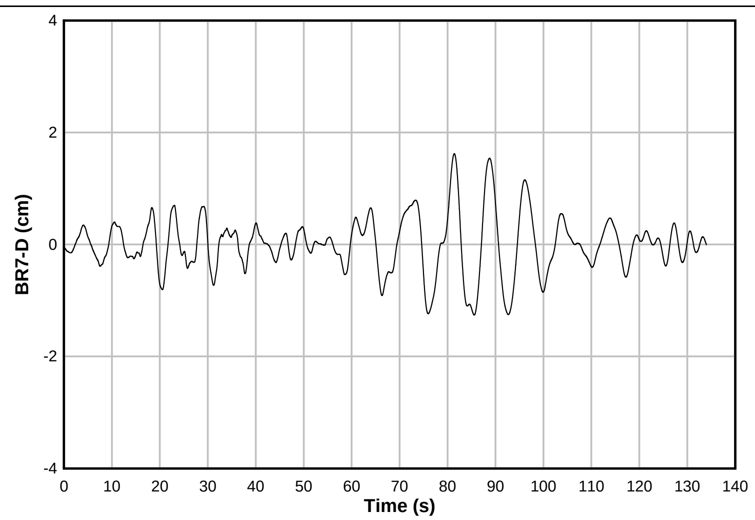




Recorded motion at BR6 due to 25th April Nepal EQ







Recorded motion at BR7 due to 25th April Nepal EQ

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY

PART-XIII

FIRE AND EARTHQUAKE EVACUATION OF READYMADE GARMENTS (RMG) FACTORIES IN DHAKA: AN ANALYSIS FROM SOCIO-ECONOMIC AND BEHAVIORAL PERSPECTIVE OF THE WORKERS

BANGLADESH NETWORK OFFICE FOR URBAN SAFETY (BNUS), BUET, DHAKA

Prepared By: Tasnim Tarannum Isaba

Mehedi Ahmed Ansary

1. INTRODUCTION

Readymade garments (RMG) sector is a great prospect for the economy of Bangladesh. It is the largest exporting industry of Bangladesh which experienced phenomenal growth during the last 25 years. This sector contributes for 75% of foreign currency earning for Bangladesh. Textiles and readymade garments sector contributes 13% of GDP and employs more than 3,000,000 people (Firoz, 2011). The industry also play a great role in employment generation, especially for economic empowerment of women. RMG exports total US $24.5 billion in FY 2013-14 accounting for over 80% of the nation's export earnings and employing around 4 million workers, an estimated 55-60% of whom are women (International Labor Organizations- ILO, 2016). Therefore, readymade garment manufacturing and export have become a lifeline for a major portion of both urban and rural people.

Despite such phenomenal success in remittance earning and employment potential, this sector has experienced some worst industrial accidents in the history. The loss of 1,136 lives when Rana Plaza collapsed on 24 April, 2013 created a worldwide concern for workplace safety in Bangladesh (ILO, 2016). Fire hazards are also common which is prevalent from many of the recent fire hazard incidents in factories. More than 500 workers lost their lives in the last five years due to fire hazard, including the fire incident at Tazreen Fashions of Ashulia, Dhaka. The fire resulted in the deaths of 111 workers and more than 300 workers were injured. This accident also created an uproar against the existing work conditions in the RMG sector globally (AMRC-Asia Monitor Resource Centre, 2013).

In addition to building characteristics, the behavioral and socio-economic characteristics of the occupants or workers can also have a strong influence on the evacuation strategies during complex situations, including fire and earthquake events. Most evacuation models focus primarily on evacuation movement, ignoring the prediction of behaviors that occupants perform before and during evacuation movement that can delay their safety, such as fighting the fire or helping others (Kuligowski, 2008). Human behaviors must be considered in order to identify workers' response to alarm operation or other forms of crisis. When carrying out fire risk assessment, the assessor must not only consider issues such as ignition sources, causes of fire spread, active and passive protection, fire alarm systems, emergency lighting etc. but they must consider how the occupants are likely to react when the alarm is raised (Fire Risk Consultancy, 2017).

In Bangladesh, different studies have been conducted based on the structural assessment of garments factories, especially after the Rana Plana incident. Evacuation behavior for the garments industry workers during fire or earthquake has not been analyzed yet. A comprehensive human behavior model is needed to simulate occupant behavior during fire or earthquake evacuation. This study has taken an approach to analyze the socio-economic characteristics of workers in RMG industries in relation to their evacuation behavior during fire or earthquake events. The perception of workers on earthquake or fire events has been included and data has been collected from questionnaire survey. After analyzing the behavioral and socio-economic characteristics of the workers, the study will further conduct evacuation modelling.

2. MAJOR INDUSTRIAL ACCIDENTS IN RMG SECTOR OF BANGLADESH

Case 1: Fire at Tazreen Fashion Limited

Tazreen Fashions is a sister concern of a large business corporation in Bangladesh named “Tuba Group” and was established in 201 with 1500 workers (Document Cloud, n.d). On 24 November 2012, fire broke out in the factory at around 7 p.m. during operation. Although the total number of people who were killed and injured due to the accident cannot be verified due to the inconsistent reports of journalists and the media, researchers and investigators later estimated these to have been 111-124 deaths and 200-300 people injured (Ahmed, 2012; Bergman and Rashid, 2012; AMRC - Asia Monitor Resource Centre, 2013; Ross, 2013; Zaman et al., 2013; BBC, 2013a).

According to a report of the Asian Network for the Rights of Occupational and Environmental Victims, more than 1200 people were working inside when the fire broke out (AMRC, 2013). The factory didn’t have any fire sprinkler of fire exit, therefore many workers tried to escape via interior stairways. Many workers continued to work even after hearing the fire alarm, assuming it as a fire drill. With the doors locked on most floors of the nine-storey factory and smoke-filed staircases, most workers were trapped inside the building. Some desperate workers broke windows and jumped from the upper floors to the ground, leaving them badly injured or dead. According to the Bangladesh Fire Service and Civil Defense official Abu N M Shahidullah and operations director Mahbubur Rahman, most of the workers who died due to the lack of adequate exits and suffocation by smoke were on the first and second floors (Chowdhury and Tanim, 2016).

Case 2: The Collapse of Rana Plaza

Rana Plaza Rana Plaza is a nine-storey commercial building located at Savar. It housed five separate RMG factories, employing around 5,000 people on different floors. The first three floors of the building contained around 300 shops and the bank whereas the five RMG factories occupied the higher floors, and the ninth floor was under construction. The building collapsed at about 9 a.m. on 24 April 2013 due to poor structural condition, with a death toll of 1,129 lives and approximately 2,51 injured (Alam and Hossain, 2013; Butler, 2013). Majority of the victims were women (Wallace, 2015). After the collapse, government authorities of Bangladesh refused international assistance and local rescuers played major role in recuing victims and provision of foods, water and oxygen. The preliminary results of a government inquiry found that heavy machinery, high-capacity generators, and the use of substandard materials during the construction of the building were largely responsible for its collapse (Chowdhury and Tanim, 2016).

3. REASONS BEHIND INDUSTRIAL ACCIDENTS IN RMG SECTOR BASED ON PAST INCIDENTS

An independent investigation carried out by the Bangladesh Occupational Safety, Health and Environment Foundation (OSHE) attempted to identify the reasons behind Tazreen fire incident. The provision of only one main entrance and exit on the ground floor which was itself insufficiently wide to accommodate the number of workers in the factory was one of the root causes (AMRC, 2013). Other causes include-

1) Inadequate fire extinguishers or fire defense materials
2) Locked collapsible gates on different floors
3) Expired fire safety certificate and irregular inspection
4) Lack of adequate fire training
5) Mid-level workers and supervisors preventing the workers during evacuation.
6) Negligence of the factory owners regarding building code and raw material storage.

In case of collapse of factory buildings, results found from a preliminary government inquiry revealed that placement of heavy machinery, high-capacity generators and use of substandard materials during construction were largely responsible for Rana Plaza collapse. It was also found that there was a huge deviation from the original building design and layout as top three floors were added without the permission of planning authority and the factory building was constructed on marshland, being the principal reason for its faulty failure e (Campbell, 2013; Than, 2013; Watkins and Ahmed, 2013). Lack of fire escape and complete absence of building safety standards also contributed to the incident. Investigations by BGMEA also identified similar results (Chowdhury and Tanim, 2016). Managers of Rana Plaza forced workers to go to work despite seeing the large crack on the building, otherwise a strong trade union might have been able to evacuate Rana Plaza (Hoskins, 2015).

4. METHODOLOGY

The study conducted questionnaire survey in Dhaka. The questionnaire has been included in the appendix. 291 garments workers from Pearl Garments Co. Ltd. (PGCL) located at Nabinagar, Savar were surveyed from Dhaka. Data has been collected on their contact information, evacuation plan in case of fire or earthquake and demographic information. Later the collected data has been inputted and analyzed using SPSS (Statistical Package for Social Science) and Microsoft Excel.

5. ANALYSIS OF SOCIO-ECONOMIC CHARACTERISTICS OF WORKERS

5.1. Gender and age group:

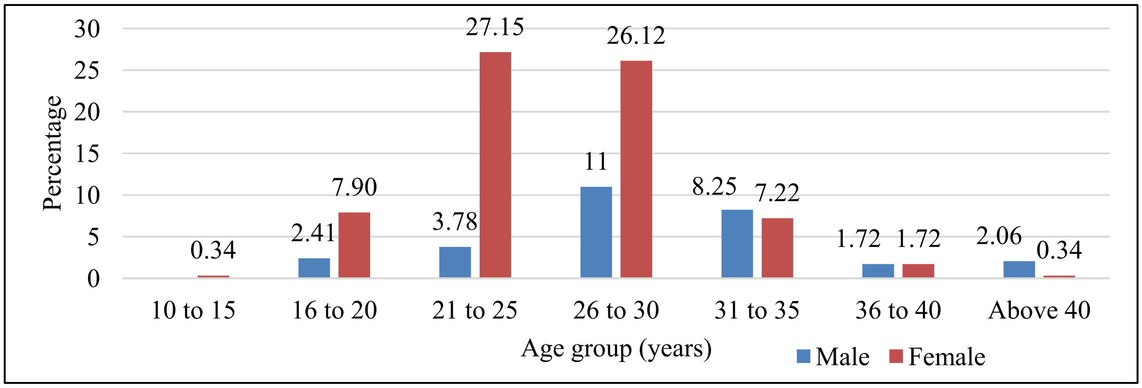


Figure 10: Age group distribution of respondents according to gender (Source: Field Survey)

Among the respondents, 70.8% are female whereas only 29.2% are male workers. Figure 1 reveals the distribution of respondents according to age group and gender. Maximum female workers (27.15%) are within the age group of 21 to 25 years. On the other hand, maximum male workers (11%) are within the age group of 26 to 30 years. After the age of 30 years and above, the percentage of male workers dominates over the percentage of female workers.

5.2. Job title:

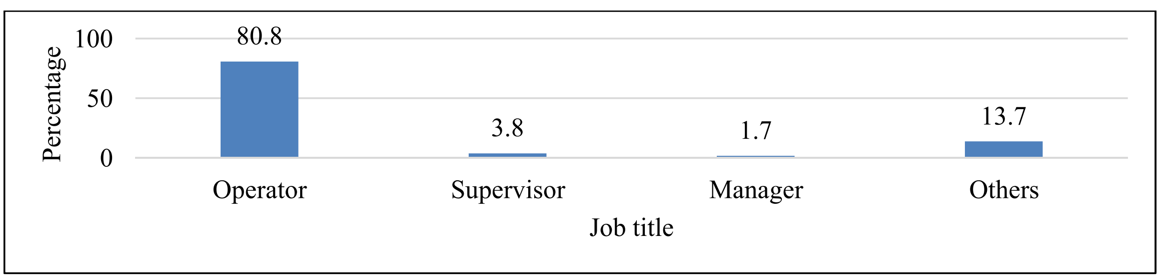


Figure 2: Distribution of respondents according to job title (Source: Field Survey)

Among the respondents, 80.8% of workers are operators which include sewing operators, cutting operators and ironing operators. Figure 3 and 4 represents the distribution of respondents according to their gender and age group respectively.

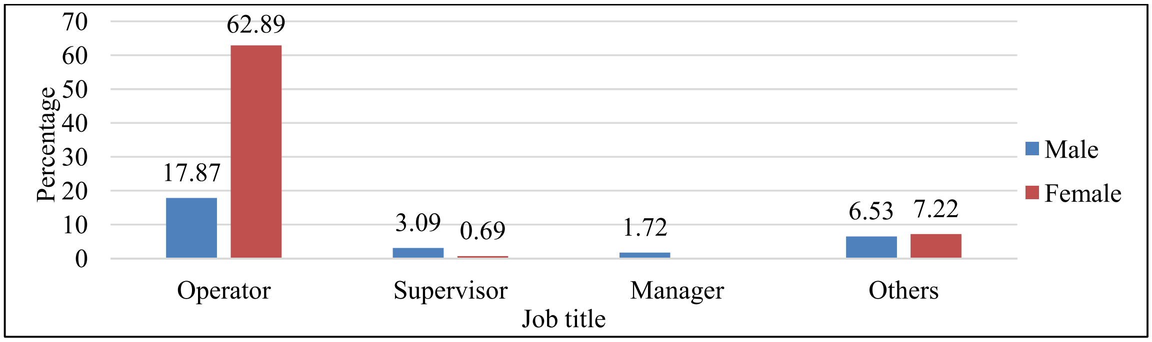


Figure 3: Job distribution of respondents according to their gender (Source: Field Survey)

From figure 3 it is prevalent that; female workers are mostly on the position of operators (62.89%) whereas male workers dominate in supervisor and managerial positions (3.09% and 1.72% respectively).

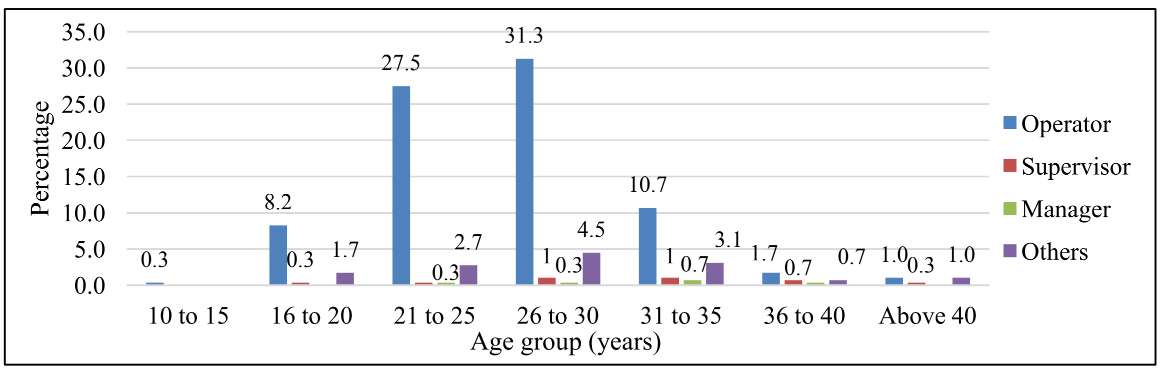


Figure 4: Job distribution of respondents according to their age group (Source: FieldSurvey)

Figure 4 reveals that, operators of garments industry are mainly within the age group of 16 to 31 years, with the highest percentage (31.3%) on the group 26 to 30 years.

5.3. Monthly household income:

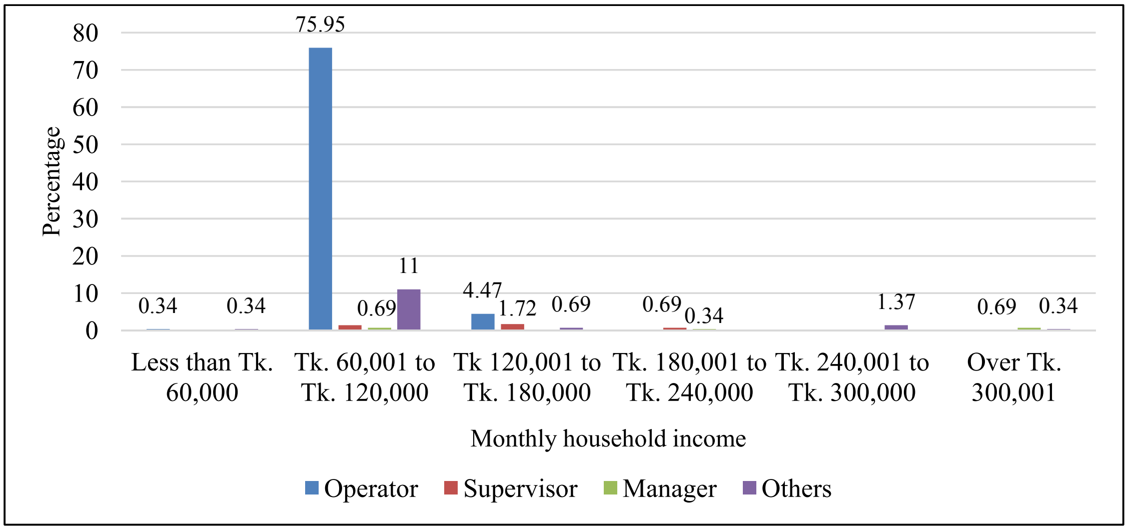


Figure 5: Monthly household income distribution of respondents according to job title (Source: Field Survey)

From figure 5 it can be seen that, maximum garments workers are within the monthly household income range of Tk. 60,001 to Tk. 120,000, especially for operators (75.95%). Maximum supervisors (1.72%) have a monthly household income of Tk. 120,001 to Tk. 180,000. In case of managers, their monthly household income varies from Tk. 60,001 to over Tk. 3000,0001.

5.4. Highest level of education:

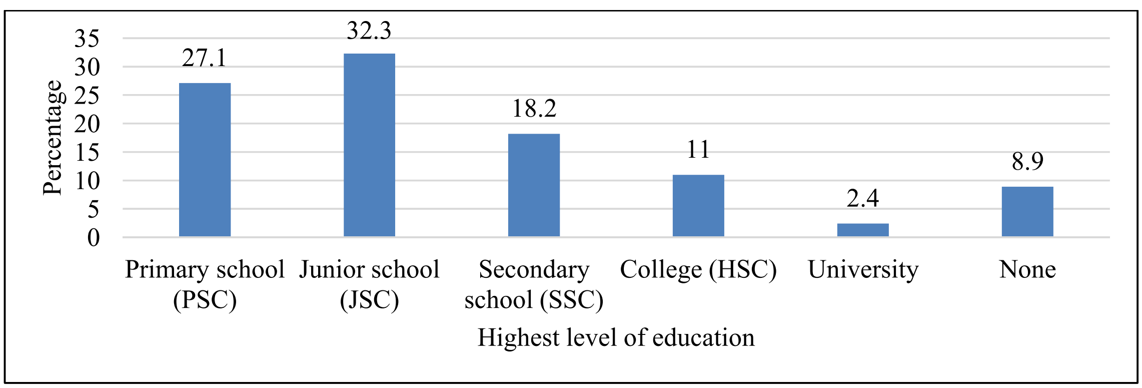


Figure 6: Monthly household income distribution of respondents according to job title (Source: Field Survey)

Maximum workers of the garments industry have an education level up to junior school (32.3%). Almost 78% workers have an education level up to SSC, whereas only 13.4% have passed HSC. 8.9% of the workers didn't receive any education.

6. EVACUATION BEHAVIOR:

6.1. Recent garments industry incidences:

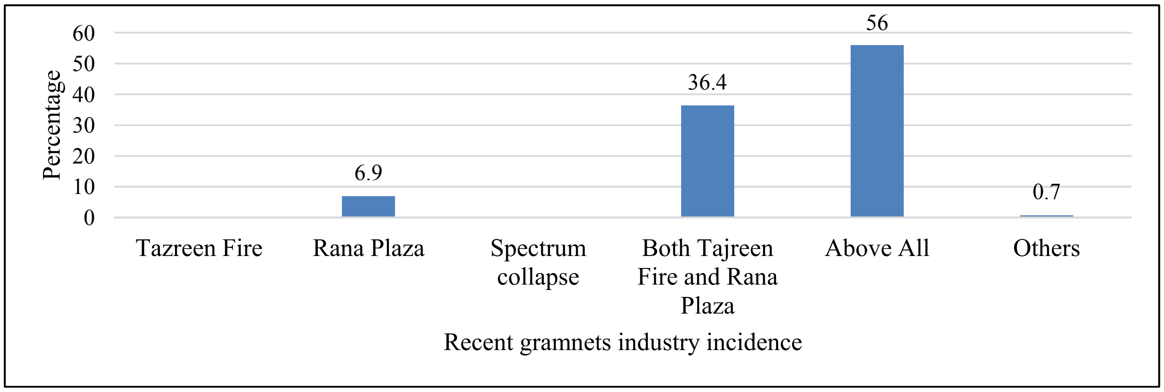


Figure 7: Distribution of respondents according to awareness of recent garments industry incidences (Source: Field Survey)

Awareness of recent garments industry incidences can have an impact on the evacuation behavior of workers. Figure 7 reveals that, majority of the workers (56%) are aware of all recent garments industry incidences, with 36% being aware of both Tazreen fire and Rana Plaza collapse.

6.2. Evacuation plan during fire and earthquake:

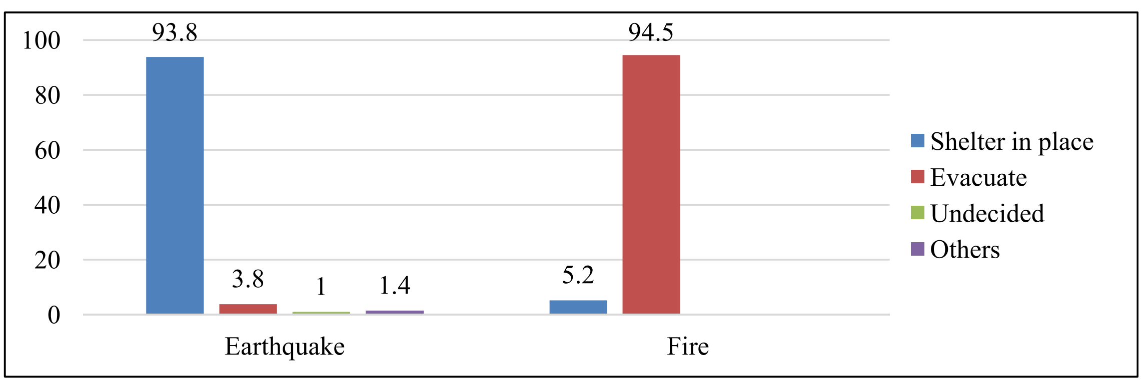


Figure 8: Evacuation plan of respondents during fire and earthquake (Source: Field Survey)

Figure 8 reveals that, in case of an earthquake, almost all respondents (93.8%) preferred to take shelter in place. But in case of a fire, respondents (94.5%) preferred to evacuate instead of taking shelter. 1% remained undecided in case of earthquake, whereas the percentage is only 0.3% in case of fire.

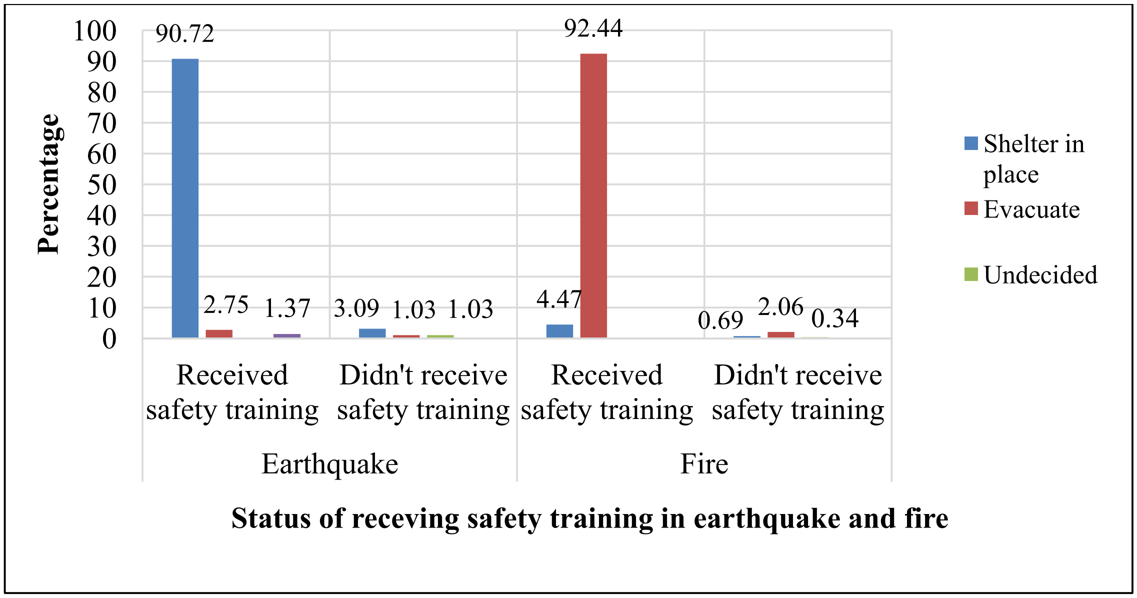


Figure 9: Distribution of respondents according to evacuation plan and status of receiving safety training in fire and earthquake (Source: Field Survey)

From figure 9 it is evident that, maximum respondents said they have received safety training from their employer in case of earthquake (95%) and fire (97%). In case of an earthquake, maximum respondents (90.72%) who have received safety training preferred to take shelter in place. The percentage of being undecided in both fire and earthquake is higher when respondents didn't receive any safety training.

6.3. Evacuation time:

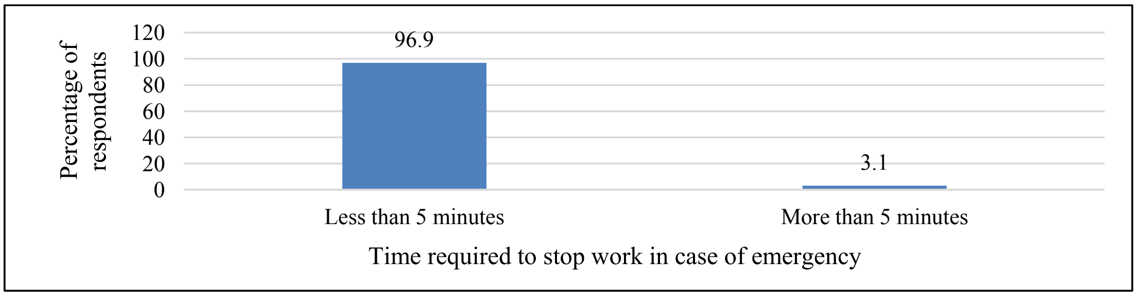


Figure 10: Distribution of respondents according to time required to stop work and leave in case of an emergency (Source: Field Survey)

Figure 10 reveals that, almost 96.9% of respondents reported that they will need less than five minutes to stop work and leave in case of an emergency arises. Only 3.1% reported that,

Table 6: Mean and standard deviation for evacuation time

	From Place of Work to Emergency exit (Seconds)	**From Emergency Exit to Out of Danger (Seconds)**
Mean	56.30	113.12
Standard deviation	39.49	59.37

Table 1 represents the mean and standard deviation of the time required to reach emergency exit from the location of work and the time required to reach out of danger from emergency exit. It has been found that more time is required in reaching out of danger from the emergency exits, compared to the time required to reach emergency exits from the place of work in floor. The survey found that 93.8% respondents reported that they have 3 emergency exit in the floor, and 6.2% respondents reported that they have more than 3 emergency exits in their floor. The adequate number of emergency exits in each floor can be the reason behind less time required to reach emergency exits.

Table 2: Pearson chi-square test between number of emergency exits on each floor and time required to reach the emergency exits

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.359[a]	4	.670
Likelihood Ratio	2.879	4	.578
Linear-by-Linear Association	.063	1	.802
N of Valid Cases	291		

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .37.

But from chi-square test between number of emergency exits on each floor and time required to reach to emergency exit on the respective floor, it has been seen that no significant relationship exists between these two variables (p-value 0.670 which is above 0.05).

Table 7: Gender comparison in evacuation time

Gender	**Average Time to Reach from Place of Work to Emergency Exit (Seconds)**	**Average Time to Reach from Emergency Exit to Out of Danger (Seconds)**
Male	56.30	113.12
Female	56.57	113.70

Table 2 shows the gender comparison of evacuation time, both from place of work to emergency exit in the floor and from emergency exit to out of danger. It can be seen from the table that, males require less time compared to female workers for evacuation but the time difference is negligible.

6.4. Evacuation plan:

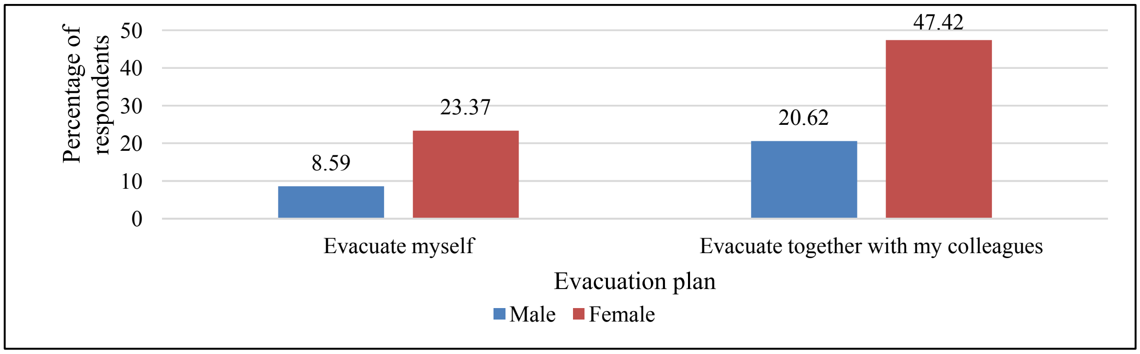


Figure 10: Distribution of respondents according to evacuation plan (Source: Field Survey)

From figure 10 it is evident that, both male and female have tendency to evacuate together with colleagues rather than evacuating alone. Almost 32% of respondents reported that they would like to evacuate by themselves, whereas 68.04% reported that they would evacuate with their colleagues.

Chi-square tests:

Relationship between gender and shelter in place or evacuate

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.236[a]	2	.044
Likelihood Ratio	7.372	2	.025
Linear-by-Linear Association	5.259	1	.022
N of Valid Cases	291		

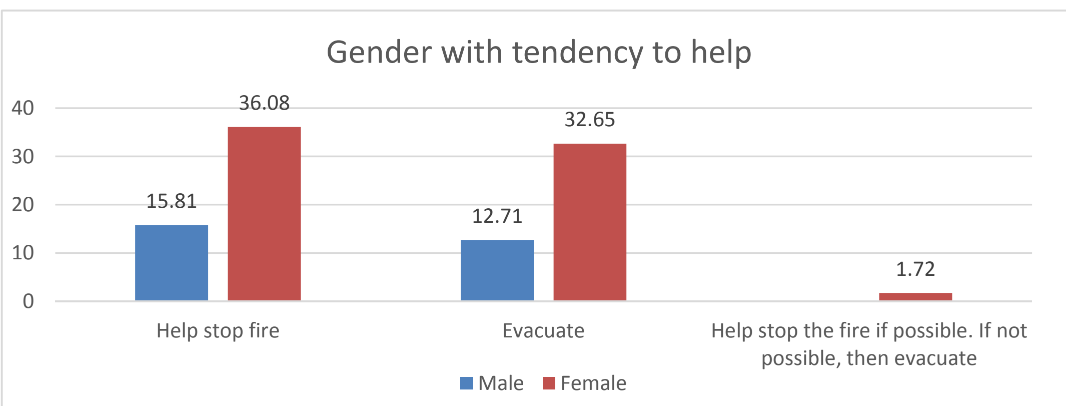
a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is .29.

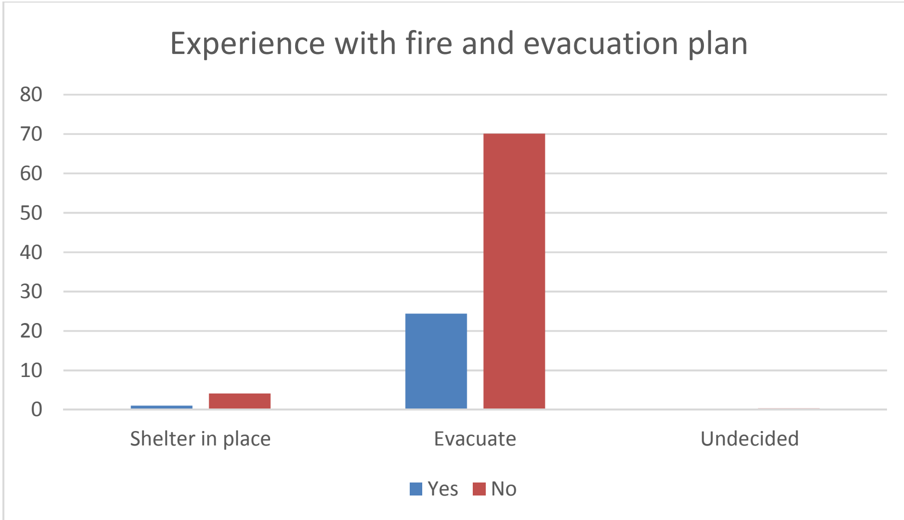
Relationship between gender and tendency to help during evacuate:

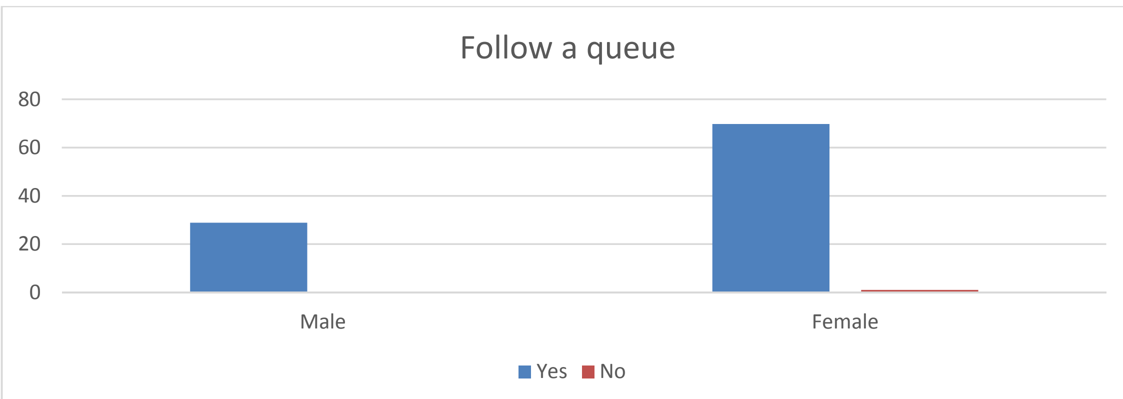
Chi-Square Tests

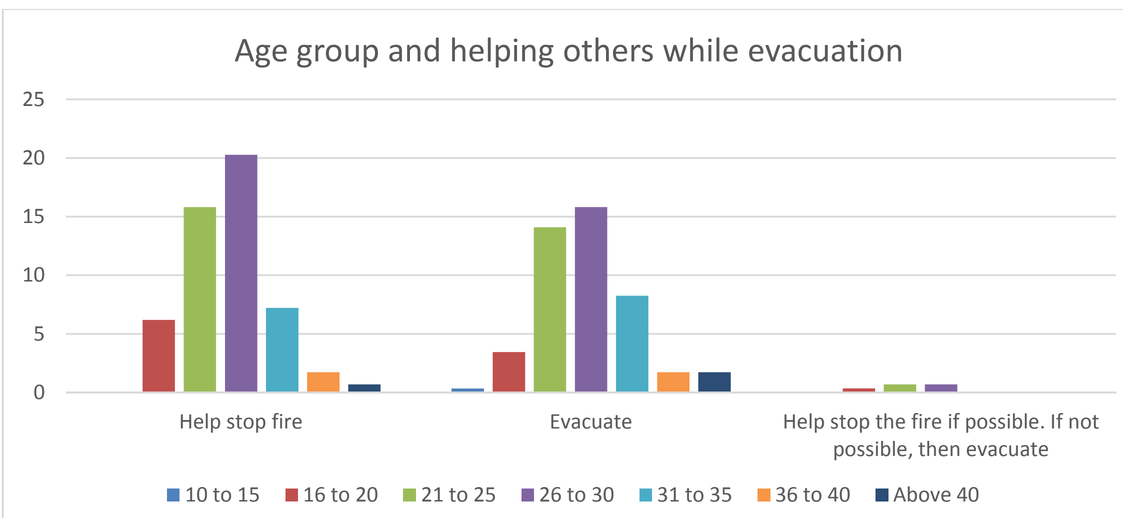
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.302[a]	3	.231
Likelihood Ratio	5.452	3	.142
Linear-by-Linear Association	.059	1	.809
N of Valid Cases	291		

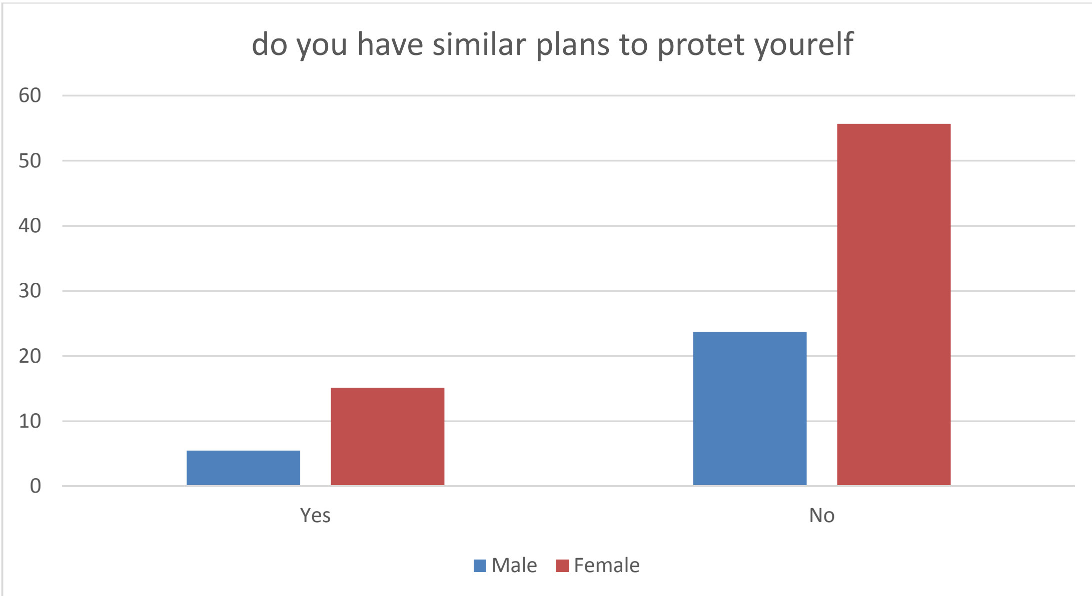
a. 4 cells (50.0%) have expected count less than 5. The minimum expected count is .88.




Experience with fire and evacuation plan
80
70
60
50
40
30
20
10
0
Shelter in place
Evacuate
Undecided
Yes
No


Follow a queue
80
60
40
20
0
Male
Female
Yes
No


Age group and helping others while evacuation
25
20
15
10
5
0
Help stop fire
Evacuate
Help stop the fire if possible. If not possible, then evacuate
10 to 15
16 to 20
21 to 25
26 to 30
31 to 35
36 to 40
Above 40


do you have similar plans to protet yourelf
60
50
40
30
20
10
0
Yes
No
Male
Female