Loss assessment of Sylhet city from an event similar to 1918 Srimangal earthquake

Estimation de la perte de la ville de Sylhet d'un événement semblable du tremblement de terre de Srimangal en 1918

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ABSTRACT

A comprehensive earthquake loss assessment for the Sylhet city of Bangladesh using Geographic Information Technology was performed considering the 1918 Srimangal Earthquake as a scenario event. Site amplification, liquefaction, and landslide microzonation maps for the city were developed for this purpose. For microzonation purpose 167 boreholes with SPT data were used. For the assessment of potential losses, a building inventory was carried out for the Sylhet city. 3040 buildings (12% of the total) were surveyed within the study area. On the other hand for the loss assessment of water and gas pipelines, the water and gas delivery network of the city were digitized and put within a GIS platform. Site amplification, liquefaction and landslide microzonation maps were overlaid and combined with the structural inventory maps, and water and gas supply system maps to produce maps of regional damage distributions. The methods to combine the different hazards are based on weighted average approach. For human casualty estimation a morbidity model was used. Finally economic loss was estimated using the damages expected to be suffered due to the scenario event. The expected damage for buildings is 59%, maximum fatalities 7.0% and maximum injuries 8.3% at night. In case of lifeline, affected length for water pipe line is 118.53 km and total number of damage points is 204 and affected length of gas supply system is 436 km and total number of damage points is 981.

RÉSUMÉ

Une estimation complète de la perte du tremblement de terre pour la ville Sylhet du Bangladesh, en utilisant la Technologie de l'Information Géographique a été effectuée étant donné le tremblement de terre de Srimangal en 1918, comme un événement de scénario. Les cartes de l'amplification du site, la liquéfaction et la microzonation de glissement de terrain, pour la ville ont été développées à cet effet. Pour l'objet de la microzonation, 167 trous de sonde avec les données SPT ont été utilisés. Pour l'estimation des pertes potentielles, un inventaire de bâtiment a été effectué pour la ville de Sylhet. 3040 bâtiments (12% du total) ont été inspectés dans la région de l'étude. D'autre part, pour l'estimation de la perte des canalisations de gaz et d'eau, le réseau de l'approvisionnement de l'eau et du gaz de la ville ont été numérisés et mis dans une estrade GIS. Les cartes de l'amplification du site, la liquéfaction et la microzonation de glissement de terrain ont été recouvertes et combinées avec les cartes de l'inventaire structurel, et les cartes du système de provision d'eau et de gaz pour produire des cartes de distributions des dégâts régionaux. Les méthodes pour combiner les hasards différents sont basées sur approche moyenne équilibrée. Pour l'estimation de la victime humaine, un modèle de morbidité a été utilisé. Finalement la perte économique a été estimée en utilisant les dégâts attendus à être souffert dû à l'événement du scénario. Le dégât attendu pour les bâtiments est de 59%, fatalités maximales est de 7,0% et des blessures maximales est de 8,3% la nuit. En cas de lien vital, la longueur affectée de la pipe-line d'eau est de 118,53 km et le nombre total de points du dégât est de 204 et la longueur affectée du système de provision de gaz est de 436 km et le nombre total de points du dégât est de 981.

Keywords : liquefaction, site amplification, landslide, seismic loss

1 INTRODUCTION

The 2001 Gujarat Earthquake in India and the 2005 Kashmir Earthquake in Pakistan and India revealed the vulnerability of “non-earthquake proof” cities and villages in the Indian sub-continent. In 1897, an earthquake of magnitude 8.0 caused serious damages to buildings in the northeastern part of India (including Bangladesh) and 1542 people were killed. Recently, Bilham et al. (2001) pointed out that there is high possibility that a huge earthquake will occur around the Himalayan region based on the difference between energy accumulation in this region and historical earthquake occurrence. The population increase around this region is at least 50 times than the population of 1897 and cities like Dhaka, Chittagong, Sylhet have population exceeding several millions. It is a cause for great concern that the next great earthquake may occur in this region at any time. Sylhet the most important northeastern district of Bangladesh, experienced earthquakes at regular intervals that had caused large destructions in the past.

Seismic hazard due to local site effects such as soil amplification, liquefaction, and landslide can be anticipated by combining the available soil parameter data with the current hazard models or by making use of existing maps showing estimated levels of these collateral hazards. Regional seismic hazard and risk analysis is used not only for estimation of potential damage and loss to existing facilities, but also for planning locations and construction of future facilities and for analyzing and comparing the regional effects of various retrofit schemes..

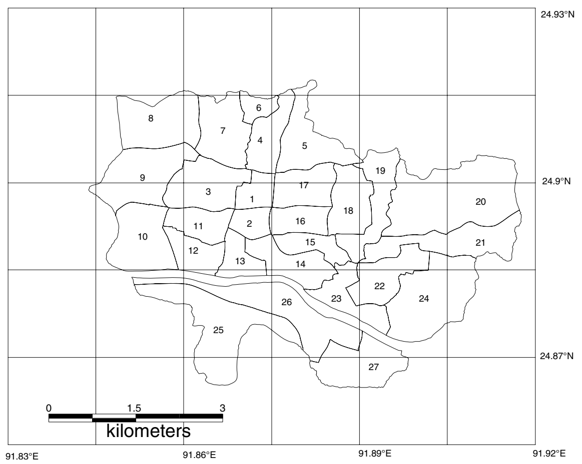

Figure 1 Map of Sylhet City Corporation

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The GIS-based analysis is useful to engineers, planners, emergency personnel, government officials, and anyone else who may be concerned with the potential consequences of seismic activity in a given region. The results of a regional seismic hazard and risk analysis are usually presented in the form of microzone maps that serve as an effective means of conveying information from the scientific community to the professional community of decision makers involved in hazard and risk mitigation. Figure 1 shows the boundary of Sylhet City Corporation.

2 REGIONALTECTONICS

According to Molnar and Tapponnier (1975), for the past 40 million years the Indian subcontinent has been pushing northward against the Eurasian plate at a rate of 5 cm/year, giving rise to the severest earthquakes and most diverse landforms known. In recent times, Bilham et al. (2001) has pointed out that there is high possibility that a large earthquake will occur around the Himalayan region based on the difference between energy accumulations in this region. There is a seismic gap that is accumulating stress, and that a large earthquake may occur someday when the stress is relieved. The major earthquakes that have affected Sylhet since the middle of the last century are presented in Table 1.

Table1. Some historical earthquakes with magnitude, intensities, epicentral distance and focal depth at Sylhet

Name of past Earthquake	Fault	Magn -itude	EMS Intens -ity	Distance (Km)	Focal Depth (Km)
1869 Cachar Earthquake	Tripura	7.5	VIII	92	56
1885 Bengal Earthquake	Bogura	7.0	V	234	72
1897 Great Indian Earthquake	Assam	8.7	IX	151	60
1918 Srimangal Earthquake	Sub-Dauki	7.6	IX	71	14

3 ESTIMATION OF BEDROCK ACCELERATION

In the regional seismic loss estimation analysis it was needed to clarify the bedrock motion in the region. The most common method involves the use of an empirical attenuation relationship. Applying statistical regression analyses to recorded data has developed numerous relationships in the past. To pick the most suitable attenuation law for predicting rock motions, the earthquake events of Table 1 were used. In this study, the engineering bedrock was assumed to be the layer at which the shear wave velocity (V_s) exceeds 300 m/s, which exist almost 30 m deep from the surface of the study area. Distance versus PGA assessment for earthquakes was plotted on log-log paper. From isoseismal maps, the epicentral distances of several locations and their intensities were found. These intensities were converted into PGA by Trifunac and Brady (1975) equation and were plotted along with the attenuation curves. The 1918 Srimangal Earthquake with the highest PGA value 0.18g at bedrock level for Sylhet City was selected.

4 SITE EFFECTS

Vibration characteristics at different points of the study area were anticipated by employing one dimensional wave propagation program SHAKE. The computations were made in the frequency range 0 to 20 Hz at frequencies every 0.05 Hz interval. An estimation of the fundamental frequency and the maximum value of the amplification were obtained of each site. The liquefaction resistance factor, F_L, for the top 20 m of soil, and the resulting liquefaction potential, P_L for the 167 sites were evaluate. More than one thirds (37%) area would be affected severely due to liquefaction Most of the current research for estimating landslide potential has focused on determining the critical level of a given ground motion parameter that will trigger landslide in various geologic deposits The program used for stability analysis was XSTABL, which was a fully integrated slope stability analysis program. XSTABL performs two dimensional limit equilibrium analysis to evaluate the factor of safety for a layered slope using the simplified Bishop Method.

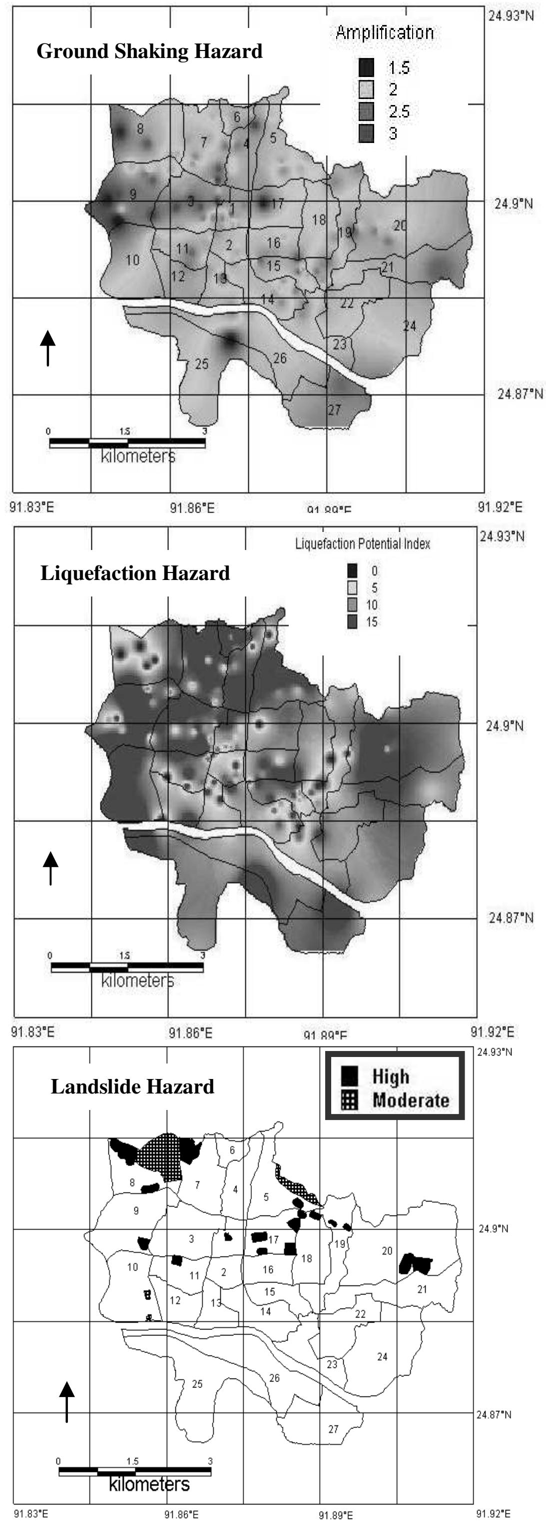

Figure 2. Maps shows site effects for amplification, liquefaction and landslide potential hazard

These critical levels of ground motion values were weighted against to the regional estimates of surface peak ground acceleration to give a prediction for the occurrence of damaging earthquake-induced landslides in the study area. Figure 2 shows site effects for amplification, liquefaction and landslide potential hazard.

5 COMBINATION OF SITE EFFECTS IN THE GIS ENVIRONMENT

Every analysis region is different; for that reason the quantification of the secondary site effects and the weighting scheme for combining the various seismic hazards is heuristic, based on judgment and expert opinion about the impact of local site conditions in the region and the precision of the accessible geologic and geotechnical information. However countries like Japan and the United States have long histories on instrumental seismicity and several models have been proposed there to correlate the various hazard. However that is not the case in Bangladesh. Heuristic rules for quantification and combination were used which was developed by King and Kiremidjian (1994) for other countries. The regional distribution of bedrock-level shaking was estimated as 0.18g. Figure 3 shows ground shaking and combined seismic hazard in the study area.

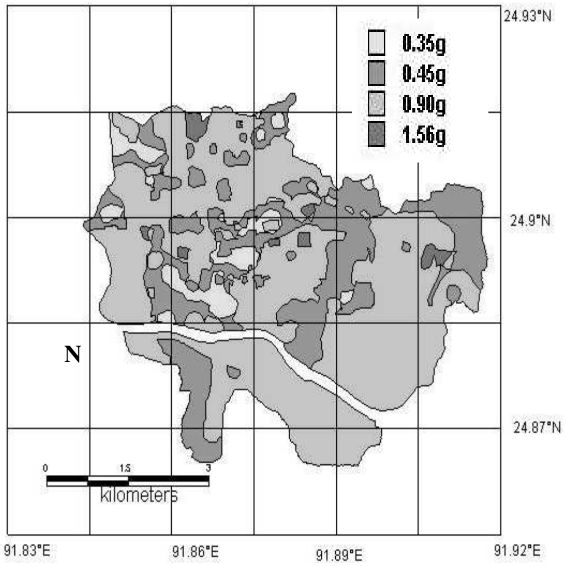

Figure 3. Map showing combined seismic hazard in study area

6 CLASSIFICATION, DISTRIBUTION AND DAMAGE FUNCTION

A building Inventory was carried out by survey to clarify the nature of distribution and strength of buildings in the study area. The area is not uniform in terms of building construction, building typologies, population density, and economic activity. Therefore, for the building survey, the area was categorized in to Core and Fringe areas. There is no statistical data on the number of buildings in Sylhet City Corporation. 3611 buildings (14% of the total) were surveyed in the study area. It was assumed for some ward that number of building is equal to number of household and from survey of some core and fringe wards and together with BBS, 1991 data it was estimated that total number of building is more or less 25992.The sample sites survey results helped to classify all buildings in Sylhet into six types based on their definition in European Macroseismic Scale (Grunthal, 1998) is shown in Table 2.

A number of fragility curves exist for Indian Buildings prepared by Arya (2000) and for Nepalese buildings prepared by Bothara et al. (2000). There also exist a number of fragility curves for different types of structure and for different earthquake intensities but the Indian and Nepalese curves might be the most apposite for Bangladeshi structures, until Bangladeshi researchers develop their own fragility curves. In this study, fragility curves for the buildings were prepared by calibrating the existing fragility curves for Indian buildings prepared by Arya (2000) and for Nepalese buildings prepared by Bothara et al. (2000). Figure 4 shows the fragility curves customized from Arya (2000) and Bothara et al. (2000).

Table 2. Definition of building typologies in Sylhet City Corporation Area

No	Types	Description	% Of Building
1	EMSA	Mud structures; roof material is either of GI sheet or polythyne / straw / bamboo.	6%
2	EMSB1	1-storied brick masonry of fired bricks with cement or lime mortar; roof is either of CI sheet or other materials.	36%
3	EMSB2	1-storied brick masonry of fired bricks with cement or lime mortar with RCC roof. 2-storied or taller brick masonry of fired bricks with cement or lime mortar; roof is generally made of RCC slab. Some weak and old reinforced concrete frame.	3%
4	EMSC	Reinforced concrete frame with low ductility; designed for vertical load only.	38.5%
5	EMSD	Reinforced concrete frame with moderate ductility; designed for both vertical and horizontal loads.	0.5%
6	EMSF	Mainly bamboo, wooden and steel structures.	16%

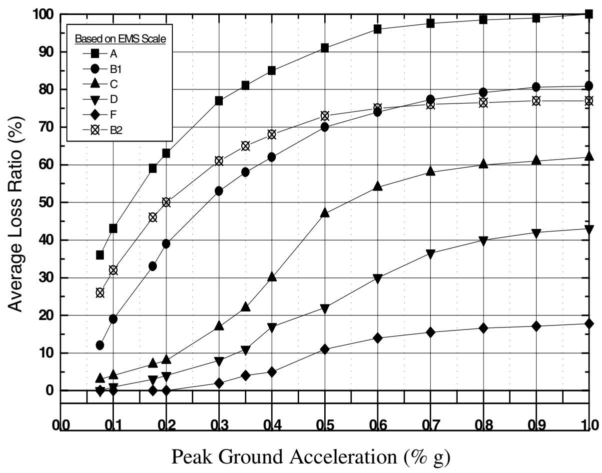

Figure 4. Vulnerability functions based on peak ground acceleration (after Arya, 2000)

From survey results considering building type, building story it is clear that average weighted floor area is 273 m^2. Because of rapid urbanization in Sylhet City, number of slum is increasing. According to the statistics of BBS (1991), 21% population lives in slums in Sylhet City. Huq-Hussain (1996) reported that floor space per household for slum dweller's is 90sft. Merging this information for Sylhet, average floor area for each building was obtained to be 200 m^2. In this study, all buildings are assumed as residential building because this scenario is reflected from Figure 5.

7 DAMAGE ESTIMATION OF BUILDINGS

Damage assessment for a region predictably depends on factors such as the level of seismic hazard in the region, including the effects of local site conditions and the distributions of facilities in the region, according to earthquake engineering class. There are several definitions for damage and also several relationships for estimation of damage due to given levels of seismic hazard for various facility type. The investigation was carried out for based on combined Seismic Hazard (MMI_F) considering local site effects.

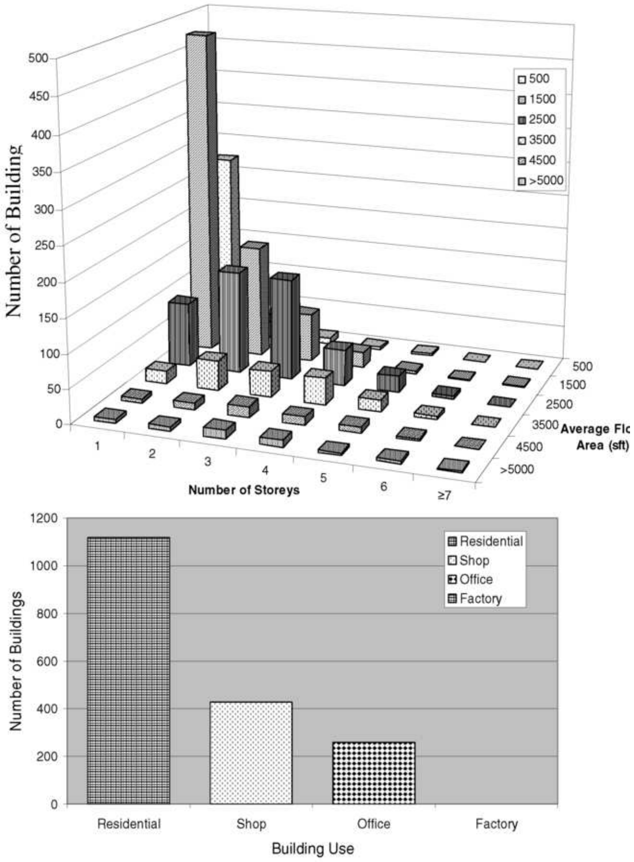

Figure 5. Average Floor Area and Building use pattern in study area

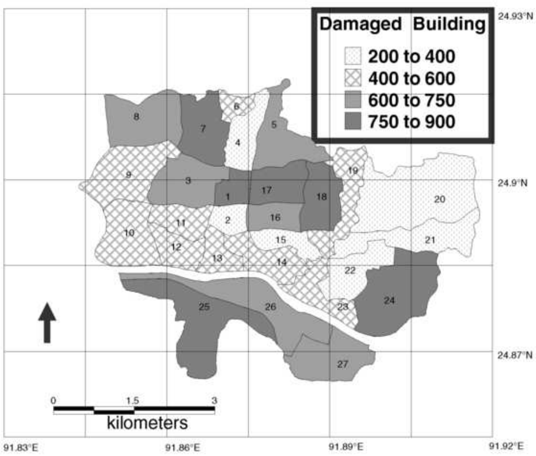

Figure 6. Maps showing building damage due to combined seismic hazard in the study area.

Based on MMI_F, on an average 59% of buildings are estimated to be damaged. Among different building types, A type damaged 96%, B1 type damaged 76%, B2 type damaged 76%, C type damaged 55%, D type damaged 12%, and F type damaged 15%. The damage for EMSB type, which comprises of single story and two or more storied brick masonry buildings is the highest and about 51% of the total damage. Figure 6 shows building damage due to combined seismic hazard in the study area.

8 LOSS ESTIMATION

Loss estimation was based on some preceding findings from damaging earthquakes in India (Arya, 2000; Jain et al., 2002). It was assumed that 25% total damaged buildings will be collapsed (damage grade G5 and G4) and 40% will be heavily damaged (damage grade G3). Also moderately damaged structures (damage grade G2) comprise 15% and low damaged structures (damage grade G1) comprise 20%. Table 3 summarizes the findings of the direct monetary losses. The cost calculations are made based on the following assumptions that are suggested by concerned organizations.

Rebuilding cost per square meter =US dollar 100

Partial rebuilding for heavy damage per square meter=US dollar 40

Repair and retrofit for moderate damage per square meter =US dollar 15

Water pipeline repair per point =US dollar 250

Table 3. Direct monetary losses due to a scenario event equivalent to 1918 Srimangal Earthquake

Building Damage Grade	Physical damage	Loss in Us dollar (Mill)	% Of Loss
Total Collapse (G5)	3683	73.75	34
Partial Collapse (G4)	5886	117.8	54
Heavily damaged (G3)	2297	118.4	8
Moderately damaged (G2)	3064	9.0	4
Water pipe damage point	204	0.051	Negligible
Total		319	100

9 CONCLUSIONS

In this study, three microzonation maps for Sylhet city namely Landslide, Liquefaction and Site Amplification were developed and a final combined hazard map for the city was presented. Total estimated damaged structures are about 15320 out of 25992 housing units (59%). Total direct monetary-loss for all buildings and lifelines was estimated to be 319 million US dollar.

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REFERENCES

Arya, A. 2000. Non-Engineered Construction in developing countries- An Approach toward earthquake Risk Prediction, *Proc. of 12th WCEE*, No. 2824.

Bangladesh Population Census (BBS) 1991. Community Series, Sylhet District

Bilham, R., Gaur, V.K. & Molnar, P. 2001. Himalayan Seismic Hazard, *Science*, Volume 293.

Bothara, J.K., Parajuli, Y.K. Arya, A.S. & Sharpe, R.D. 2000. Seismic safety in owner-built buildings, *Proc. of 12th WCEE*, No. 2130.

Huq-Hussain, S. 1996. Female Migrants in an Urban Setting - the Dimensions of Spatial/Physical Adaptation: The Case of Dhaka, *Habitat Intl*., 20: 93-107.

Jain, S., W.R. Lettis, C.V.R. Murthy & Bardet J.P. 2002. Bhuj India Earthquake of January 26, 2001, Reconnaissance Report, *Earthquake Spectra*, Supplement A to Volume 18.

Molnar, P. & Tapponier, P. 1975. Cenozoic tectonics of Asia, effects of a continental collision, *Science*, Volume 189(8), pp.419-426.

King, S.A. & Kiremidjian, A.S. 1994. Regional Seismic Hazard and Risk Analysis through Geographic Information System.

Trifunac, M.D. & Brady, A.G. 1975. A study of the duration of strong earthquake ground motions, *Bulletin of Seismological Society of America*, Volume 65, pp. 581-626.