ESTIMATED DAMAGES AND CASUALTIES IN DHAKA CITY DUE TO POSSIBLE EARTHQUAKE

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ABSTRACT

Earthquake risk at any location depends on the seismic hazard as well as the vulnerability of its structures. For old city like Dhaka, a larger portion of building is very old and consequently vulnerable and local construction practice also has a strong bearing on the seismic vulnerability. Dhaka City Corporation, which has a population of about 6 million in 90 wards. Most of the wards are in older part of the city, which has a population density exceeding 60,000 per square kilometres. For the city, a building inventory of 3668 buildings from eight wards was compiled. Together with BBS data, data from Geological of Bangladesh (GSB) and Dhaka City Corporation, this building inventory is used in different analysis purpose. A soil database of 253 boreholes is developed which are used to develop site amplification and soil liquefaction potentials assessment of the city. Three past historical earthquakes are used as scenario events namely 1885 Bengal Earthquake, 1897 Great Indian Earthquake and 1918 Srimongal Earthquake. Earthquake damage of buildings of different typologies was estimated by using fragility curves proposed by Arya. Human casualty (death and injury) was estimated by a morbidity model proposed by Coburn. If the 1897 Great Indian Earthquake occurs again, on an average 28% of buildings will be estimated to be damaged and 3.7% of total population will be dead and injured.

Keywords:

1.0 INTRODUCTION

Earthquake is one of the most deadly natural disasters that affect the human environment severely. Even a relatively moderate earthquake can lead to very large number of deaths. Although earthquakes may affect rural as well as urban areas, damage due to earthquake is usually maximum when urban areas are affected. There are records of whole cities being destroyed by earthquakes.

Bangladesh is vulnerable to earthquake activities. A series of recent tremors that shock parts of the country including the capital Dhaka indicates that Bangladesh sits on one of the major earthquake zones of the world.

The 1993 Killari and 2001 Gujrat earthquakes in India and 2003 Bam earthquake in Iran have amply demonstrated that inappropriate construction technology may lead to high casualty levels even for moderate earthquake. Dhaka and Tehran are the cities with the highest relative earthquake disaster risk (Cardona e4t al., 1999). Dhaka, the capital of Bangladesh is the center for economy, commerce, politics and society, with a large population of more or less 12 million. Once a great earthquake occurs, Dhaka will suffer immense losses of lives and properties. This will have very severe long term consequences for the entire country.

The earthquake records for 250 years suggests more than 100 moderate to large earthquakes occurred inside Bangladesh since 1900, out of which more than 65 events occurred after 1960. More than 125 earthquakes occurred in and around Bangladesh since the beginning of the new millennium. This clearly indicates an increase in frequency of earthquakes in Bangladesh. The 1869 Cachar earthquake, 1885 Bengal earthquake, 1897 Great Indian earthquake, 1918 Srimangal earthquake, 1930 Dhubri earthquake and 1950 Assam earthquake are quite matured enough to recur any time and may create devastation in Dhaka City.

Bangladesh lies on an active seismic zone ranging from Java- Myanmar – Himalayas – Iran and Turkey, where many large earthquakes occurred in the past. The historical earthquake catalogue shows the high seismicity along the Himalaya and also the occurrence of large earthquakes. **Figure 1** Shows the estimated slip potential along the Himalaya.

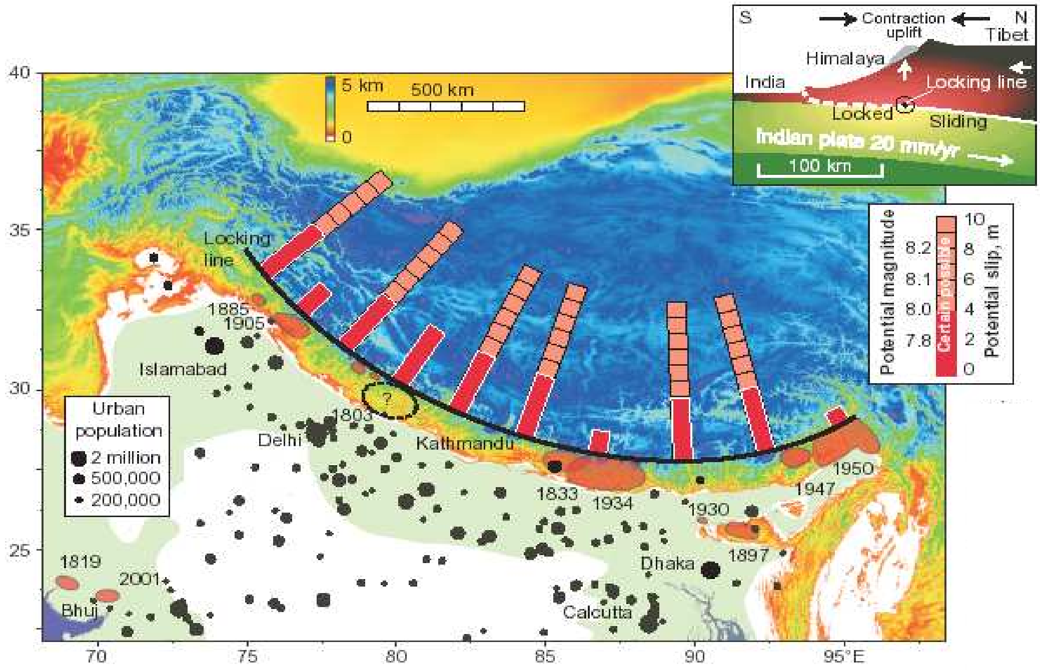


Figure 1 Estimated slip potential along the Himalaya (after Bilham et al., 2001)

Dhaka suffered damage due to earthquakes several times in the past; among them the 1897 Great Indian Earthquake caused most serious damage. The total area over which the shock was felt amounts 45,50,000 sq km, while the area over which known serious damage to masonry buildings occurred not less than 3,77,000 sq km(Oldham, 1899). **Figure 2** Shows the map of Dhaka City.

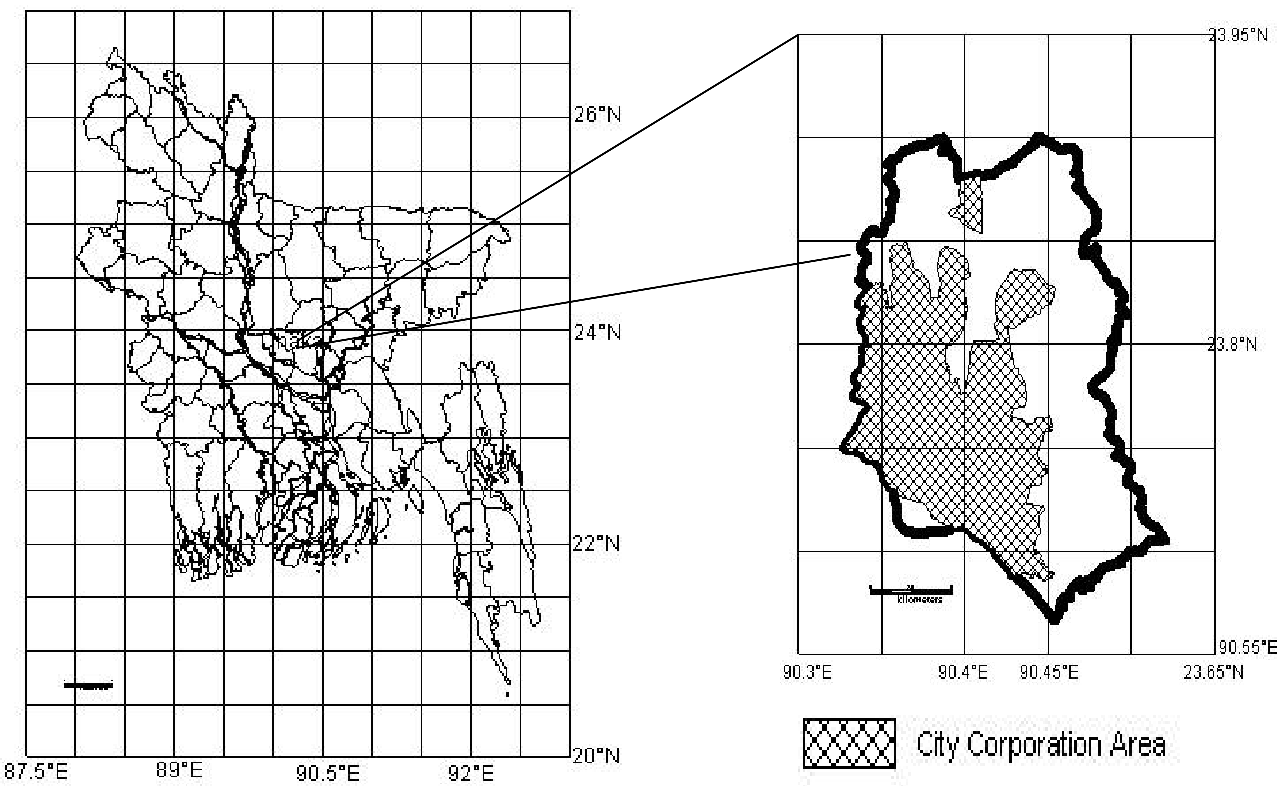


Figure 2 Map of Dhaka City

In 1897, Dhaka's population was approximately 1,00000. No significant earthquake events have occurred since the early 1900s, but the city has grown several folds and the population of core Dhaka has become around 12 million and it has 90 wards with more than 2,50,000 structures.

2.0 EARTHQUAKE DAMAGE ESTIMATION

2.1 Results of the Sample Site Survey

A sample site survey of the area is important for building damage estimation due to earthquakes. Dhaka City has 90 wards. Among these, eight wards such as ward number 73, 74 and 77 of Sutrapur (old town) area; ward number 47, 48 and 49 of Dhanmondi area; ward number 14 and 16 of Kafrul (Mirpur) area were selected based on their construction types, settlement age and locations. These are widely apart and represent the different settlement pattern of the city. The main target was estimating the likely building damage due to the scenario earthquakes with a certain level of ground shaking: how the buildings are constructed and the likely response of the buildings to such shaking. The site survey covered mostly urban area and also covered the commercial and industrial (light industry) areas.

A total 3,668 buildings (only 1.5% of the total) were selected from the eight wards. The distributions of building inventory samples are presented in **Table 2.1**.

Area	Ward	Land Use Type	Settlement Type		Number of Wards	Number of Buildings Studied
			Main	Sub		
Dhanmondi	47,48, 49	Originally Residential now mixed	Urban	Core	3	754
Kafrul (Mirpur)	14, 16	Mixed	Sub-urban	Fringe	2	619
Sutrapur (Old Town)	73, 74, 77	Originally Residential, now mixed	Urban	Core	3	2295

Table 2.1 Sample sites and number of buildings

2.2 Building Typology and Classification

The sample sites survey helped to classify all buildings in Dhaka into six types based on their definition in European Macro Seismic Scale (Grunthal, 1998). **Table 2.2** shows the description of each typology.

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

Table 2.2 Definition of building typologies in Dhaka

2.3 Damage Estimation Considering Site Effect

The damage is represented as a damage ratio and is computed through expected damage ratio curves.
The damage estimation has been done based on intensity variation at each ward level. This intensity has been later converted into PGA values to obtain damage ratio for different building types. At first, the total number of buildings in each ward is divided according to the proportion of area of each intensity classes. Then building typology presented has been used to obtain building types for each ward. Using a particular intensity and it's corresponding number and types of buildings, building damage for particular intensity has been estimated. Finally, total building damage in a ward has been obtained by summing different building damages for different intensities in a particular ward. **Table 2.3** also presents building damage estimation for this particular ward. Estimated building damage of 90 wards for combined hazard is calculated.

Ward No	EMS_A	EMS_B1	EMS_B1	EMS_C	EMS_D	EMS_F	Total Damage
1.	95	159	128	112	3	35	532

Table 2.3 Damage of different types of buildings at wards 1 considering site effects

Total estimated damage is about 70,169 structures out of 2, 50,000 housing units in Dhaka City Corporation. On an average 28% of buildings were estimated to be damaged. **Figure 3** Shows building damages considering site effects.

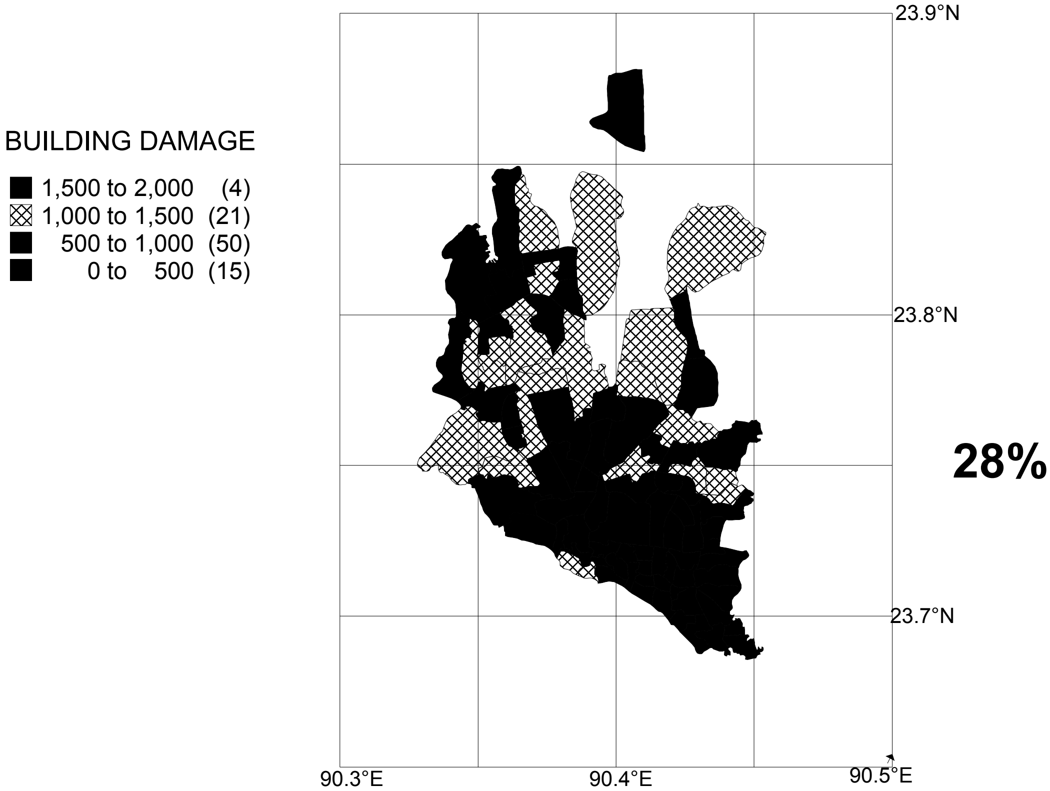


Figure 3 Building damage considering site effects

Among different building types, A-type suffered 77%, B1 type suffered 53%, B2 type suffered 61%, C type suffered 23%, D type suffered 11% and F type suffered 3% damage. As can be seen, the numbers of buildings that may be damaged are high and their repair and rehabilitation is likely to impose a heavy burden on the economy of Bangladesh. **Table 2.3.1** presents percentage of building damage of different types of buildings at 90 wards considering site effects.

Wards	EMS_A	EMS_B1	EMS_B1	EMS_C	EMS_D	EMS_F	Average
90	77%	53%	61%	23%	11%	3%	28%

Table 2.3.1 Percentage of damage of different types of buildings at 90 wards considering site effects

If the 1897 Great Indian Earthquake occurs again, on an average 28% of buildings were estimated to be damaged due to combined hazard. Maximum area will be affected with intensity VIII but some other areas will have intensity IX and X. As expected, the damage for EMSB type, which comprises of single storey and two or more storied brick masonry structures was the highest (about 18% of the total damage).

It is interesting to note that during the 2001 Bhuj earthquake (maximum EMS intensity X), over 9,80,000 masonry structures experienced medium to severe damage and 2,30,000 were Collapsed in Gujarat (Jain et al., 2002) located 70 km from the epicenter with a population of only 150,000 experienced around 10,000 deaths, 90% of masonry structures of old Bhuj collapsed and most of the reinforced concrete structures were badly damaged.

Even many mid to high-rise buildings of Ahmedabad (EMS intensity VII), a city 300 km away, experienced collapse and heavy damages. Since Dhaka is a much larger city and the building stock is larger than Ahmedabad and Bhuj, the expected damage will be consequently much higher.

For this study, based on some previous findings from damaging earthquakes in India (Arya, 2000; Jain et al. , 2002; NSET, 2000), 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%.

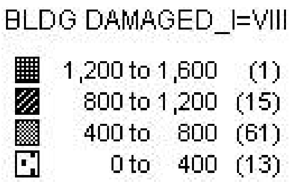
2.4 Damage Estimation Considering Earthquake Ground Motion

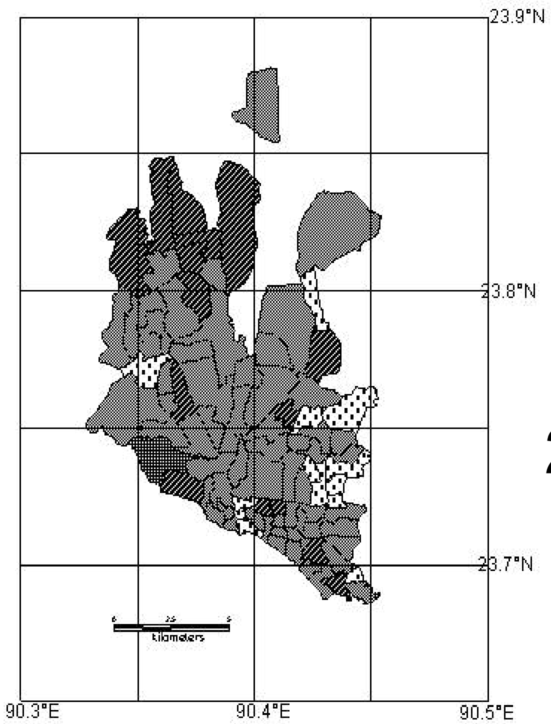
If the earthquake intensity VIII is considered without the effect of any collateral hazard, the damage estimation for different types of structures for ward 1 is shown in **Table 2.4**. Estimated building damage of 90 wards for earthquake intensity VIII is calculated.

Ward No	EMSA	EMSB1	EMSB2	EMSC	EMSD	EMSF	Total Damage
1	278	208	38	26	0	3	553

Table 2.4 Damage of different types of buildings at ward 1 considering earthquake ground motion.

Total estimated damage is about 57,186 structures out of 2,50,000 housing units in Dhaka City Corporation. On an average 23% of buildings were estimated to be damaged. **Figure 4** Shows damage of building considering earthquake ground motion.





23%

Among different building types, A type suffered 72%, B1 type suffered 47%, B2 type suffered 56%, C type suffered 13%, D type suffered 6% and F type suffered 1% damage.

As expected, the damage for EMSB type, which comprises of single storey and two or more storied brick masonry structures was the highest (about 17%of the total damage).

Wards	EMS_A	EMS_B1	EMS_B1	EMS_C	EMS_D	EMS_F	Average
90	72%	47%	56%	13%	6%	1%	23%

Table 2.4.1 Percentage of damage of different types of buildings at 90 wards considering earthquake ground motion

3.0 HUMAN CASUALTY

3.1 Considering Site Effects

The Dhaka building inventory, census information, earthquake hazard and vulnerability data and the mortality information were combined to estimate the number of possible injuries and the corresponding deaths that may occur due to earthquakes of different strengths.

The predictions in the current investigations of human casualty are based on consistent mortality prediction models (Coburn et al., 1992) and can be applied to any area with sufficient hazard, vulnerability and demographic information. **Table 3.1** shows the values of M1, M2, M3 and M4 for different types of household.

Building Types	M1	M2			M3			M4	
		Morning	Night	Noon	I=X	I=IX	I=VIII	Killed	Injured
A	5	0.62	0.78	0.42	0.40	0.30	0.20	0.15	0.25
B1	5	0.62	0.78	0.42	0.30	0.20	0.10	.20	0.25
B2	5	0.62	0.78	0.42	0.60	0.40	0.20	0.40	0.50
C	5	0.62	0.78	0.42	0.60	0.40	0.20	0.40	0.50
D	5	0.62	0.78	0.42	0.60	0.40	0.20	0.40	0.50
F	5	0.62	0.78	0.42	0.10	0.05	0.00	0.00	0.00

Table 3.1 Values of M1, M2, M3 and M4 for different types of buildings

Combining all the effect, the total number of estimated fatalities and injuries in 90 wards of Dhaka City Corporation according to different times of the day are calculated.

Total estimated number of fatalities for the scenario earthquake is 76,936 in the morning, 96.036 in the night and 53.119 in the noon. It is about 1.3%, 1.6% and 0.9% of the total population of Dhaka City Corporation.
Total estimated number of injuries for the scenario of earthquake is 1,00,894 in the morning 126.935 in the night and 68.342 in the noon. It is about 1.7%, 2.1% and 1.1% of the total population of Dhaka City Corporation. **Table 3.1.1** shows the percentage of human casualties during different times of 24 hours.

Casualty	Morning	Night	Noon
Dead	1.3%	1.6%	0.9%
Injured	1.7%	2.1%	1.1
Total	3.0%	3.7%	2.0%

Table 3.1.1 Percentage of human casualties during different times of 24 hours.

3.2 Considering Earthquake ground Motion

The estimated fatalities and injuries during different times of 24 hours are calculated. The total numbers of fatalities in the morning are estimated 43,005, in the night it is 54,106 and in noon it is about 29,131. Again the total numbers of injuries in morning are about 55,631, at night about 69,989 and in noon it is about 37,688.

Casualty	Morning	Night	Noon
Dead & Injured	1.6%	2.1%	1.1%

Table 3.2 Percentage of human casualties during different times of 24 hours.

If an earthquake of intensity VIII hits Dhaka City and if no collateral hazards are considered, 1.6% of total population in the morning, 2.1% in night and 1.1% at noon will be estimated to be dead and injured.

4.0 CONCLUSION

This paper presents a complete damage scenario of buildings and human casualty for a potentially catastrophic earthquake in Dhaka City Corporation area. Dhaka City Corporation with 90 wards has a population of about 6 million. Most of the wards are in older part of the city, which has a population density exceeding 60,000 per square kilometres.

In estimation of damage, three past historical earthquakes are used as scenario events namely 1885 Bengal earthquake, 1897 Great Indian earthquake and 1918 Srimangal earthquake. Bedrock Peak Ground Acceleration (PGA) value were estimated using different attenuation laws. PGA value is converted into intensity values to integrate the effect of site amplification as well as liquefaction.

Earthquake damage of buildings of different typologies was estimated by using fragility curves proposed by Arya. Human casualty (death and injury) was estimated by morbidity model proposed by Coburn.

The final results for damage and loss in Dhaka City can be used to check the overall reasonableness of the models and methodologies. The estimated average damage for building stock is 28%. As expected, the damage for EMSB type, which comprises of single storey and two or more storied brick masonry structures was the highest (about 18% of the total damage).

The influence of collateral hazards was also illustrated. The estimated average damage for building stock is 23%, when the effects of liquefaction and soil amplification are ignored in the analysis.

This paper will give some foods for thought for our planners and policy makers about the catastrophic effects due to possible earthquakes and take appropriate steps to mitigate the sufferings of people & reduce the losses of lives and properties.

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