CRITICAL ELEMENTS FOR EARTHQUAKE DISASTER IN DHAKA CITY

TAHMEED M. AL-HUSSAINI
Bangladesh University of Engineering & Technology, Bangladesh

ABSTRACT

Dhaka, the capital of Bangladesh, due to its high population growth is about to become a megacity. Various seismic hazard assessment studies based on earthquake catalogues have placed Dhaka in a seismic zone with a design earthquake intensity of around VIII (EMS scale) and an equivalent peak ground acceleration value of 0.15g. This requires a good level of earthquake resistant design in buildings and other infrastructure, and urban planning to minimize earthquake losses. Unfortunately, such practice and planning is nonexistent to a great extent. This paper addresses the different issues that are putting the capital at a great risk for a probable earthquake scenario and proposes some remedial measures.

1. INTRODUCTION

Dhaka, founded during the 10th century, became the Mughal capital of Bengal in 1608 and flourished by becoming a centre of trade and commerce for textiles. Many beautiful buildings, mosques, gardens were built. This was Dhaka's golden age and the population in the town and its suburbs is said to have reached 900 thousand at that time. But in 1715 the capital was shifted to Murshidabad. Dhaka came under British rule around 1765. Its textile industry was ruined. There were also famine occurrences. As a consequence the population of Dhaka declined drastically. Fortunately, by the middle of 19th century, Dhaka established itself as a trading centre for jute. In 1905 it was made the capital of East Bengal and Assam for few years. In 1947 at the end of British rule it became the provincial capital of the then East Pakistan. After independence of Bangladesh in 1971, it naturally became the capital of the new nation. People moved towards the capital in search of living and the population of the city soared. In 1876, the population of Dhaka city was only 52 thousand. It became 125 thousand in 1911, 239 thousand in 1941, 336 thousand in 1951, 1.68 million in 1974, 3.44 million in 1981. The 1991 population census puts the population of greater Dhaka metropolitan area to be 6.89 million. The greater Dhaka comprises the central city, nearby municipalities and some intermittent rural areas. By 2006 the population of Dhaka is projected to be around 12 million (Rajuk, 1995). The population may thus have already crossed the 10 million mark, if not it is expected to do so very soon. The rapid population growth of Dhaka city has made it one of the highest urban population densities of the world. Construction of buildings have taken place in an unregulated manner, many of them do not have earthquake resistant features.

Bangladesh, being located close to the plate margins of Indian and Eurasian plates, is susceptible to earthquakes. In the past, several strong earthquakes have occurred in and around Bangladesh. Some of these earthquakes have caused significant damage to buildings within the country, including Dhaka. However, the present generation of people in Bangladesh hasn’t witnessed any major earthquake. As a result the population has been generally complacent about the risk of earthquakes. In recent years, this has changed to some extent by the occurrence of earthquakes (Magnitude between 4 and 6) in the country and the damage caused by them. The damage has been mainly restricted to rural areas or towns near the epicentre, but there has been some instances of damage in urban areas 50 to 100 km away. Small to moderate earthquakes are occurring regularly in the region comprising Bangladesh, neighbouring India and Myanmar. It should be realized that stronger earthquakes can strike Bangladesh as history suggests.

A moderate shaking of intensity around VIII on EMS Scale (ESC, 1998), or maybe more, in Dhaka is a likely event. In a recent study by Cardona et al. (2001) on 20 cities of the world, Dhaka appeared to have one of the highest values of earthquake disaster risk index (EDRI) mainly due to its inherent vulnerability of building infrastructure (lacking earthquake resistant features), high population density, and poor emergency response and recovery capability. A major earthquake shaking in the city might result in a huge disaster. This paper addresses the potential dangers posed by a probable earthquake.

2. SEISMIC HAZARD ASSESSMENT

During the last 150 years, seven earthquakes of large magnitude (Richter magnitude $M \geq 7.0$) with epicentres in India and Bangladesh have affected Bangladesh. The 1897 Great Indian Earthquake with a magnitude of 8.7 had its epicentre at a distance of only 230 km from Dhaka. Extensive damage to masonry buildings occurred in many parts of the country, including Dhaka. Oldham’s (1899) report on the effect in Dhaka states that “Almost all the pucca buildings in the place being badly damaged, some have entirely collapsed and very many were uninhabitable”. From the reported damage, Sabri (2001) estimated the intensity in Dhaka for this earthquake to be around VIII. The 1885 Bengal earthquake (M=7.0, 170 km from Dhaka) and the 1918 Srimongal earthquake (M=7.6, 150 km from Dhaka) had their epicentres within Bangladesh. Fortunately they were shallow earthquakes causing considerable damage locally and they did not affect much far off places such as Dhaka. According to Bolt (1987), Bangladesh can be affected by earthquakes generated in four tectonic zones, namely the Assam fault zone to the north, Tripura fault zone to the east, Sub-Dauki fault zone in the north-east and the Bogra fault zone in the west. Dhaka, located in the central region of Bangladesh, could be affected by any of these sources. Another point of major concern is that there are active faults near the city also. This was realized during the Dec. 19, 2001 Dhaka earthquake that caused panic among many city residents. Frightened people in several high rise buildings rushed down the stairs, as they felt considerable shaking in the upper floors. The magnitude was small (around 4.2 to 4.8 based on Indian and Nepalese sources), USGS sources placed the epicentral location around 16 km from Dhaka city with a focal depth of 10 km. Accuracy of reported magnitude and other parameters for this particular earthquake has been affected by the lack of earthquake recordings inside the country. At that time there was only one analogue seismometer in the port city of Chittagong around 190 km southeast of Dhaka with one component not functioning. Earthquake catalogues show past occurrence of small earthquake at distance of around 50 km from Dhaka. Whether nearby sources can produce a major earthquake needs to be carefully investigated.

Studies by several researchers based on earthquake catalogues and historical data have revealed the significant seismic risk befalling this country. The 1993 Bangladesh national building code has adopted a seismic zoning map (Ali and Choudhury, 1994), where the country is divided into three zones. The zoning map is based on ground accelerations predicted by Hattori (1979) for earthquakes having different return periods. The most severe zone (Zone 3) lies in the central north and north-east of the country representing a peak ground acceleration of 0.25g (Z=0.25). Next to Zone 3 is Zone 2 having a Z value of 0.15, which includes the major cities of Dhaka and Chittagong. In a recent study, Ansary et al. (2000) made an extensive compilation of an earthquake catalogue and performed a seismic hazard analysis for the whole country. They obtained a Z value of 0.15 for Dhaka city, but suggested increase of Z values for certain areas of the country. Their seismic hazard estimation methodology was based on the assumption that the peak ground acceleration (PGA) at a particular site maintains a recurrence frequency relationship similar to the Gutenberg-Richter magnitude-frequency relationship. The author is of the opinion that this assumption is generally not justified. Very recently, Al-Hussaini (2002) formed an earthquake catalogue for 1841-1990 using some published data and performed a seismic hazard assessment for Dhaka city using a different method. He considered multiple (five) independent earthquake source zones and took into account in a simplified manner the effect of varying distances of earthquake epicentres. He obtained a design intensity of VII to VIII (EMS scale) for Dhaka, this may be considered to be in agreement with the PGA value of 0.15g. The work suffered from the lack of instrumental records inside the country since without such records reliable attenuation laws for Bangladesh cannot be developed. As a result, in all these studies attenuation laws developed for other countries had to be used.

3. BUILDING VULNERABILITY

In the absence of legal enforcement of building code in the country and lack of earthquake awareness, many buildings have been constructed without proper earthquake consideration. The building stock in the city may be broadly classified into two groups: unreinforced brick masonry (URM) buildings and reinforced concrete frame (RCF) buildings. URM buildings have been observed to behave very poorly during earthquakes and they can be more dangerous if they are 4 or more stories high, or built on 5 inch walls, which is not uncommon in Dhaka. RCF construction can also pose equivalent danger if earthquake resistant design provisions are not followed, this has been amply demonstrated in recent earthquakes of Bhuj and Izmit. Economic reasons, lack of quality control in construction and use of poor quality of materials, all contribute to the high vulnerability of buildings. Foundation problems such as earthquake induced settlement of foundations, liquefaction of loose sandy deposits under water or amplification of ground motion in certain soft soil areas of the city may also contribute to the damage of buildings. Some areas of the city may have greater damage (i.e., greater intensity) than other areas due to local soil effect causing amplification of ground motion in certain frequency range or liquefaction. A recent building survey, funded by Bangladesh Ministry of Science and Technology research grant, in parts of Sutrapur, Lalbagh and West Dhanmondi reveals concentration of multi-storied URM buildings in the older part of the city. While the percentage of URM buildings in Sutrapur area of the old city was found to be around 65%, the same in the relatively new West Dhanmondi was found to be around 42%. Using Chinese building damage data and considering three building classes, Al-Hussaini (2002) estimated that an intensity VIII earthquake could result in complete or partial collapse of more than 5% and serious damage to around 15% buildings. This is a preliminary estimate, detailed vulnerability analysis is necessary for reliable damage and loss estimation. Local soil effects can lead to intensity greater than VIII in certain areas causing more damage.

Figures 1 to 6 present some examples of building types and structural configurations that demand detail vulnerability assessment for earthquakes. Fig.1 shows an old multi-storied brick masonry (URM) building in a distressed condition with no plaster and cracks on the exterior wall. Fig.2 shows a five story brick masonry building with no plaster (red bricks used) on inside and outside of many of its walls. Also there is no continuous lintel or any other reinforced concrete band in the walls around the building.

Figure 1: Old masonry building

Figure 2: 5 storied brick masonry building

Of particular concern are hundreds of newly constructed multi-storied RCF apartment buildings, 6 stories or more, with a possible soft story action at ground level due to open parking space (such as shown in Fig.3). In the absence of walls in the ground floor with the exception of the lift core, the design to prevent soft story failure could be critical. High rise buildings of irregular shape exist which may be subjected to high shear stress concentrations during an earthquake (example shown in Fig.4). Multistoried buildings in the city's commercial area, constructed immediately next to one another and with varying heights and levels (Fig.5), could also cause problems. Pounding between adjacent buildings could occur if they are separated, otherwise they might behave as a setback structure causing stress concentrations at the vertical or horizontal discontinuities. Fig.6 shows a RCF building with a high slenderness ratio that could result in large overturning effects.

Figure 3: Open car parking in ground floor

Figure 4: Irregular high rise building

Figure 5: Adjoining buildings of various structural configurations

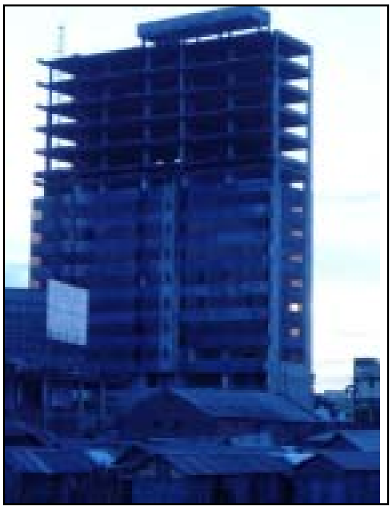

Figure 6: Slender high rise building

4. SECONDARY EFFECTS

Secondary effects such as earthquake induced fire from short circuits and gas explosions can create huge loss of life and property especially in the congested residential areas of the city. The electric lines and distribution systems in many places (see Fig.7) could be at risk of developing fire during an earthquake due to short-circuit. Rupture of gas lines and connections may also result in fire hazard. Fig.8 shows typical connection of gas oven with the gas pipeline in residential houses which may not be strong enough to sustain the earthquake shaking. Narrow lanes in parts of the city (particularly the old city) may prevent fire-fighting vehicles to reach certain areas, also there are no dedicated water lines in the city to fight fires.

Figure 7: Electrical wiring

Figure 8: Connection of oven with gas pipeline

High rise buildings all over the city are making the skyline to accommodate the increasing population, but many of them have narrow staircase and exits. This raises the possibility of stampede when frightened residents might want to flee the building during an earthquake. During the Dec.19, 2001 Dhaka earthquake, about 100 prisoners of Dhaka Jail were injured as they tried to rush out of their building, breaking the stairs and subsequent stampede. Ratan (2003) during a recent survey of several multistoried office buildings in the city's Dilkusha commercial area found that most buildings had only one staircase and did not have a fire exit. In many cases, the width of the staircase was only 2.5 ft or 3 ft with little or no lobby space. This exit may not be sufficient to accommodate the people who would need to escape from the building at the same time. Also in some densely populated residential areas particularly in the old city there is very little space between adjacent multistoried buildings, this can seriously impede the exit of residents or rescue operations during a disaster.

Very recently in Chittagong, components of a power substation transformer broke putting it out of operation due to a 5.5 (M_s) magnitude earthquake at an epicentral distance of around 70 km. News reports stated that it would need costly replacement and it could take about a month. This is a simple example what could possibly happen if a significant shaking hits a major city. Disruption of utility services for weeks or months caused by an earthquake can cause immense sufferings to the quake victims and jeopardize the local economy.

5. POST-EARTHQUAKE RESCUE AND RECOVERY

In the absence of a post-earthquake disaster management plan in Bangladesh, there is very limited rescue and recovery equipment and lack of preparedness for swift action. After the collapse of a faulty reinforced concrete frame building in Chittagong city in 1997 due to an earthquake, it took a long time to rescue an injured minor girl trapped in the collapsed building, subsequently she died in the hospital. Narrow lanes of the city may be easily blocked by falling debris, and the already inadequate road network in the affected areas may be in disarray during an earthquake, thereby disrupting rescue and recovery operations. Whether the buildings housing the fire fighting vehicles and other rescue vehicles and equipment will be able to sustain the earthquake is another question, since many of these buildings may have little earthquake resistance.

During an intensity VIII (or more) earthquake in Dhaka city, casualty figures could easily reach tens of thousands due to widespread collapse and serious damage of buildings. What happens when all on a sudden there are thousands of critically injured people due to an earthquake, where will they be treated and how, that also remains a burning question. There is hardly any room in the casualty wards or even other wards of the very few government hospitals in the city for such an emergency. Affected people will also have to be provided with shelter, protection and food.

The sudden destruction and casualties caused by an earthquake demands swift action on the part of the nation’s earthquake disaster management authority. This will require careful co-ordination of different groups viz. the police, armed forces, volunteers, professionals, engineers, fire-fighters, rescue personnel, utility personnel, medical personnel, media, social workers and post-disaster relief personnel. There is lack of organization and trained manpower to deal with such a crisis.

6. EARTHQUAKE DISASTER MANAGEMENT IN BANGLADESH

While Bangladesh has achieved remarkable success in disaster management for other frequently occurring hazards such as cyclone, tornado and floods, very little has been done to face earthquakes. Important changes may be required in government and non-government organizations involved in disaster management at national and local levels to efficiently implement countermeasures before and after an earthquake event. The Ministry of Disaster Management and Relief, Govt. of Bangladesh has begun its program to include earthquake in its program of disaster management. The Disaster Management Bureau working under the ministry has been recently working for training volunteers and officials for earthquake prone areas, checking inventory of rescue and recovery equipment, forming national coordination committee and generating earthquake awareness among the public. Bangladesh Earthquake Society has been recently formed to assist in this regard and to promote research and development. Earthquake engineering research centres have been initiated at Bangladesh University of Engineering and Technology, Dhaka and at Bangladesh Institute of Technology, Chittagong. Some non-governmental organizations involved in community development and disaster management have shown enthusiasm in working towards earthquake vulnerability reduction. Some digital ground motion measuring equipment and GPS units have been recently installed in the country. Workshops and seminars are being regularly organized to increase earthquake awareness and also for training engineers to adopt earthquake resistant design.

For earthquake disaster mitigation, the following measures should be given top priority:

- Increase public awareness about earthquakes through mass media, education (at school), training, earthquake drills, publications etc.
- Refined seismic hazard assessment using local ground motion data, geophysical data and seismic source modelling.
- Reliable vulnerability assessment of buildings and other structures using advanced testing and structural analysis methods.
- Microzonation of urban areas identifying local soil effects.
- Legal enforcement of building code and its regular updating.
- Building insurance to promote earthquake resistant construction.
- Seismic strengthening of vulnerable structures on a priority basis starting with the most critical structures and facilities.
- Developing laboratory and testing facilities for related research.
- Developing low-cost seismic strengthening techniques so that individual house owners are encouraged to adopt them.
- Training of engineers, planners, architects and construction workers.
- Automatic safety shutdown system for gas and electricity whenever the ground shaking exceeds a certain recommended value.
- Developing facilities for post earthquake rescue and recovery.
- Urban planning of the city to mitigate earthquake effects.
- Implementation of national earthquake disaster management plan involving different professionals, officials and volunteers.

7. CONCLUSIONS

Critical issues concerning a probable earthquake scenario in Dhaka city have been presented. While thousands of buildings may collapse, serious casualties could be in tens of thousands. Economic loss can be catastrophic. Identified problems include lack of earthquake awareness, lack of enforcement of building code, economic limitations, lack of construction quality control, poor quality of construction materials, inherent vulnerability of masonry and reinforced concrete buildings due to absence of earthquake resistant features, foundation problems such as settlement and site amplification, soil liquefaction, fire hazard due to electric short-circuit or gasline rupture, absence of a national post earthquake disaster management plan, lack of rescue and recovery equipment, inadequate road width, lack of medical treatment facility, and lack of trained manpower. A comprehensive and well-coordinated earthquake disaster mitigation plan for the city should, therefore, be developed without further delay and implemented on a priority basis with available resources. The participation of various government, non-government, voluntary organizations, academic institutions, community leadership and media should be encouraged and integrated for maximum benefit.

REFERENCES

Al-Hussaini, T.M., 2002. Seismic Hazard and Risk of Dhaka City, paper presented at *ASC 2002 Symposium on Seismology, Earthquake Hazard Assessment and Risk Management*, Kathmandu, Nepal.

Ali, M.H. and Choudhury, J.R., 1994. Seismic Zoning of Bangladesh, paper presented at the *Seminar on Recent Developments in Earthquake Disaster Mitigation*, Institution of Engineers, Dhaka.

Ansary, M.A., Sharfuddin, M. and Choudhury, J.R., 2000. *Report on Earthquake Hazard Analysis for Bangladesh*, Research Report No. BUET/CE/EQE-2000-01, Bangladesh University of Engineering and Technology, Dhaka.

Bolt, B.A., 1987. *Site Specific Study of Seismic Intensity and Ground Motion Parameters for Proposed Jamuna River Bridge, Bangladesh*, Report prepared for Jamuna Bridge Project, Bangladesh.

Cardona, C., Davidson, R. and Villacis, C., 1999. *Understanding Urban Seismic Risk around the World*, A Final Report on the Comparative Study: A project of the United Nations RADIUS Initiative, IDNDR, published by GeoHazards International.

ESC, 1998. *European Macroseismic Scale 1998*, Edited G. Grunthal, European Seismological Commission, Luxembourg.

Hattori, S., 1979. Seismic Risk Maps in the World (Maximum Acceleration and Maximum Particle Velocity) (II) – Balkan, Middle East, Southeast Asia, Central America, South America and Others, *Bulletin of the International Institute of Seismology and Earthquake Engineering*, Building Research Institute, Ministry of Construction, Tokyo, 17, 33-96.

Oldham, R.D., 1899. Report on the Great Earthquake of 12th June, 1897, *Memoirs of the Geological Survey of India*, Vol. XXIX.

Rajuk, 1995. *Dhaka Metropolitan Development Plan 1995-2015,* report prepared by Rajdhani Unnayan Kartripakha, Dhaka.

Ratan, M.A.A., 2003. *Personal communication*

Sabri, M.S.A., 2002. *Earthquake Intensity-Attenuation Relationship for Bangladesh and its Surrounding Region*, M.Engg. Thesis, Bangladesh University of Engineering and Technology, Dhaka.