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EARTHQUAKE, CAUSE SUSCEPTIBILITY AND RISK MITIGATION IN BANGLADESH

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ABSTRACT

Bangladesh, a densely populated country in South Asia, is located in the northeastern part of the Indian sub-continent at the head of the Bay of Bengal. Geographical location of Bangladesh makes it ideally suited to earthquake. Bangladesh is surrounded by the regions of high seismicity which include the Himalayan Arc and shillong plateau in the north, the Burmese Arc, Arakan Yoma anticlinorium in the east and complex Naga-Disang-Jaflong thrust zones in the northeast. It is also the site of the Dauki Fault system along with numerous subsurface active faults and a flexure zone called Hinge Zone. These weak regions are believed to provide the necessary zones for movements within the basin area. The historical seismicity data of Bangladesh and adjoining areas indicate that Bangladesh is vulnerable to earthquake hazards. As Bangladesh is the world's most densely populated area, any future earthquake shall affect more people per unit area than any other seismically active regions of the world. So that proper hazard mitigation measures may be undertaken before it is too late.

Keywords: earthquake, seismicity, vulnerability, mitigation.

INTRODUCTION

Bangladesh is an earthquake-prone country. It is one of the largest deltas of the world situated at the confluence with the Bay of Bengal of the Padma-Meghna-Jamuna river system. As a result occurrence of Floods, cyclones and tornadoes are yearly phenomenon and considerable loss of lives and properties take place every year due to these disasters. Tectonic framework of Bangladesh and adjoining areas indicate that Bangladesh is suited adjacent to the plate margins of India and Eurasia where devastating earthquakes have occurred in the past. Bangladesh is surrounded by a number of tectonic blocks which have produced earthquakes in recent times. 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. During the last seven or eight years, the occurrence and damage caused by some earthquakes (magnitude between 4 and 6) inside the country or near the country's border, has raised the awareness among the general people and the government as well. However occurrences of earthquakes both inside and outside of the country and around major cities indicate that earthquake hazard exists for the country in general and the cities in particular. Consideration of earthquake forces in structural design, city planning and infrastructure development is therefore a prerequisite for future disaster mitigation.

Scope of the study

This study analyzed the causes, effects and probability of earthquake in Bangladesh. This study will also provide earthquake condition and hazard mitigation measures in order to reduce the existing problems for earthquake in Bangladesh.

Aim of the study

The main aim of this research is to analysis the Earthquake vulnerability and risk mitigation in Bangladesh.

Objectives

- To find out the causes of earthquake in Bangladesh
- To find out the effects of earthquake in Bangladesh
- To identify the earthquake probability in Bangladesh
- To investigate the earthquake risk zone in Bangladesh

METHODOLOGY OF THE STUDY

The research is based on secondary information including a literature survey. In doing so, a conceptual understanding of research problem and theoretical framework was made first and then on analyzing and identifying the causes, effects, probability, risk zone and earthquake risk mitigation. Then these data and information are organized and processed. This research comprises four major stages of work:

- Conceptualization
- Collection of secondary data from different sources
- Analysis of the collected data
- Mitigation and conclusion

Literature review

The scope of the research is vast and earthquake is one of the most important issues of Bangladesh. There are a number of researches carried out on earthquake. There are mentioned some such types of literature which is related to this topic.

Akhtar (2010), in his study he focuses the vulnerability and risk mitigation of Dhaka city. Dhaka, a fast growing and densely populated (12.8 million as of 2008) mega city, poses an extremely high risk because

of its population density (45, 508 per km^2) and innumerable high-rise apartments.

Lahiry A. Kumar (2010), in his study "Possible Disastrous Earthquake in Bangladesh and its Precautions" from various authentic sources have presented the various important aspects of earthquake and its threats, risks, vulnerability, preparations, precautions and rescue tasks with special vulnerability information on Rural Electrification (RE) Program in Bangladesh. This article is for creating earthquake awareness among vulnerable people and for preparing necessary action plan and contingency plan of any sector corporation.

A. Hossain (1998), his study reveals much information in the fields of tectonics, earthquake, occurrence, ground motion attenuation etc are to be added continuously to the existing database for updating the seismic zoning map in the future. He also said that northeastern cities of Bangladesh are more vulnerable to earthquake hazards than the central, eastern, southern and western cities. The most vulnerable cities in the northeast are Mymensingh, Kishorgonj and Sylhet. Finally he gave some mitigation measures in order to reduce the existing problems for earthquake in Bangladesh.

Jamilur R. Choudhury (1993), in his study about earthquake is discussed geography and geology of Bangladesh. He showed the major earthquakes that affecting Bangladesh and different natural disasters that occurred in Bangladesh in different times. In his research he showed different maps which indicate seismic zone, seism tectonic, isoseismics etc. An outline of a code for earthquake resistant design was also prepared.

Professor Jamilur Reza Chowdhury, A multidisciplinary research-based group, said the CDMP survey made significant progress with a successful fault-line search aided by modern technology and foreign experts. "The survey is the first of its kind in our country," he said. In course of the survey conducted from February 2008 to August 2009, a database of all the buildings and maps of roads, electricity, water and gas pipe lines were developed to assess possible damages that could occur during an earthquake.

Basic definitions

Earthquake

Vibrations of the earth caused by the rapture and sudden movement of rocks that have been strained beyond their elastic limit.

Focus

The point within the earth where the initial slippage occurs to generate earthquake energy.

Epicenter

The point on the earth's surface directly above the focus.

Causes of earthquake

Earthquakes originate due to various reasons, which fall into two major categories via non-tectonic and tectonic. The origin of tectonic earthquakes is explained with the help of 'elastic rebound theory'. Earthquakes are distributed unevenly on the globe. However, it has been observed that most of the destructive earthquakes originate within two well-defined zones or belts namely, 'the circum-Pacific belt' and 'the Mediterranean-Himalayan seismic belt'. Earthquakes can happen along any type of plate boundary. They also occur along faults which are large cracks in the earth's crust. Most faults are associated with large plate boundaries where violent earthquakes usually occur. Causes of earthquake are described below.

Plate tectonics

Most Earthquakes are caused by Plate Tectonics. The earth's crust consists of a number of sections or plates that float on the molten rock of the mantle. These plates move on convection currents caused by heat rising from the center of the earth. The hot magma rises and spreads out on the surface, creating new crust. The crust spreads out forming a new plate until it meets another plate. One of the plates will be pushed down into the interior of the earth and reabsorbed into the mantle. Plates can also be compressed to push up mountains when they collide or move sideways along transform faults. The plates are the Earth's crust that floats on the molten rock in the center of the Earth.

Volcanic eruptions

Earthquakes are one of the indicators of increased volcanic activity leading up to an eruption. As magma forces its way up into a volcano, it pushes aside the rocks in its way, causing bulges in the ground and a flurry of earthquakes.

The meteor theory

Every day tiny meteors hit the earth, as we move through space. The vast majority of them burn up in the atmosphere, leaving no more trace than a shooting star across the sky. Once in a while, a meteorite will reach the surface of the earth. Very rarely a great meteorite will hit, causing the ground to shake and creating a large crater. The Meteor Crater in Arizona is an excellent example of this type of crater. The moon is full of meteor craters that we can see because they have not eroded away. The earth also has been struck many times over its history. Erosion by wind and rain wear down the craters so we can't see most of them anymore. Scientists studying the earth have found traces of many meteor impacts around the world. Each impact creates an earthquake.

Nuclear explosions

On a larger scale an explosion can cause the earth to shake for a considerable distance. Scientists use seismographs to monitor nuclear tests. People in Las Vegas could feel the shaking caused by underground nuclear tests in the desert miles away. The government

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analyzes the shock waves (earthquakes) produced by nuclear explosions to study the effects of nuclear tests and to monitor tests elsewhere in the world.

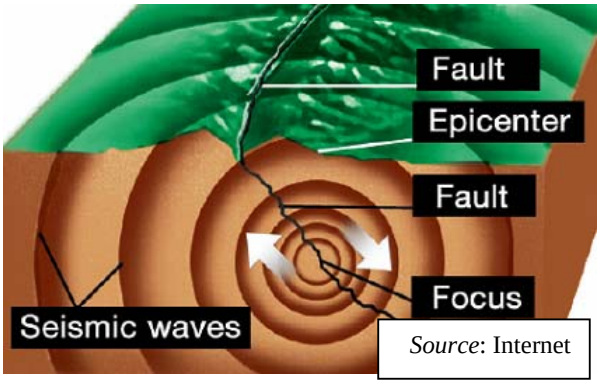


Figure-1. Causes of earthquake.

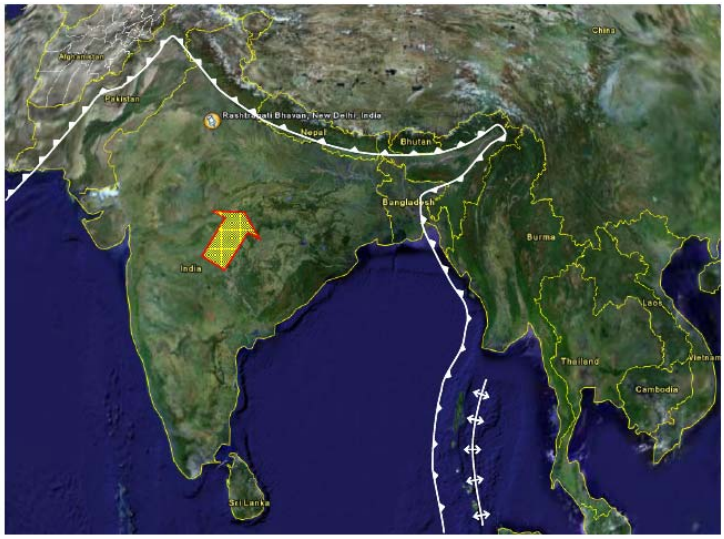
Induced earthquake

While most earthquakes are caused by movement of the Earth's tectonic plates, human activity can also produce earthquakes. Four main reasons contribute to this phenomenon: constructing large dams and buildings, drilling and injecting liquid into wells, and by coal mining and oil drilling.

Earthquake threat for Bangladesh

Bangladesh, being located close to the plate margins of Indian and Eurasian plates, is susceptible to earthquakes. The collision of the Indian plate moving northward with the Eurasian plate is the cause of frequent earthquakes in the region comprising Bangladesh and neighboring India, Nepal and Myanmar. Historically Bangladesh has been affected by five earthquakes of large magnitude (M) greater than 7.0 (Richter scale) during the 61 year period from 1869 to 1930. Among them, the mighty 8+ magnitude 1897 Great Indian earthquake in Shillong, Assam had an epicentral distance of about 230 km from Dhaka. That earthquake caused extensive damages to masonry buildings in many parts of Bangladesh including Dhaka. The 1885 Bengal earthquake (M=7.0, 170 km from Dhaka) and 1918 Srimongal earthquake (M=7.6, 150 km from Dhaka) had their epicenters within Bangladesh and they caused considerable damage locally. Two great (M>8) earthquakes occurred in Bihar in 1934 and in Assam in 1950, but they were too far to cause any damage in Bangladesh. It should be noted that large earthquakes in the region have not been occurring for quite a long time (around 75 years) and hence, the possibility of a major earthquake occurring soon is quite high. According to Prof. Bruce Bolt of University of California at Berkeley, a world-renowned seismologist, large magnitude earthquakes generated in four tectonic zones can affect Bangladesh.

Dhaka, one of the oldest historical cities in the Indian sub-continent and now the capital of Bangladesh, is vulnerable to earthquakes. In broad terms, Bangladesh is an earthquake-prone country; its northern and eastern regions in particular are known to be subjected to earthquakes of magnitudes greater than 5 on the Richter scale. The geotectonic set-up of the country, which is located along two of the planet's active plate boundaries, suggests high probabilities of damaging future earthquakes and the possibility of rarer but extraordinarily large earthquakes that can cause damage far from their epicenters. The juxtaposition of the Himalayan origin along with its syntax is northeast of Bangladesh and the convergent Burma Arc plate boundary in the east make this land and Dhaka, in particular, vulnerable to high-magnitude earthquake events.



Source: Internet

Figure-2. Regional tectonic setup of Bangladesh with respect to plate configuration.

Causes of earthquake in Bangladesh

- Bangladesh at high quake risk for its geographic location.
- Tectonic frame work of Bangladesh and adjoining areas indicate that Bangladesh is situated adjacent to the plate margins of India and Eurasia where devastating earthquake have occurred in the past and still now Bangladesh is seismically active.
- The geologist, however, said the Indian plate is moving 6 cm each year towards the northeast, and sub-ducting under the Eurasian plate at 45 mm and the Burmese plate at 35 mm in the north and east respectively each year. This continuous motion is taken up by active faults.
- The probability of an earthquake from a given fault depends on the rate of motion and on the time since the last rupture. Active faults of regional scale capable of generating moderate to great earthquakes are present in and around Bangladesh.
- The Dauki fault, about 300 km long trending east-west and located along the southern edge of the Shillong Plateau (Meghalaya- Bangladesh border), the 150 km long Madhupur fault trending north-south situated between Madhupur Tract and Jamuna flood plain, the Assam-Sylhet fault, about 300 km long trending northeast to southwest located in the southern Surma basin, and the Chittagong-Myanmar plate boundary fault, about 800 km long running parallel to the Chittagong-Myanmar coast.
- The various factors contributing to the earthquake risk in the urban and rural areas of Bangladesh. The urban areas in Bangladesh have developed in a fast pace to accommodate the increasing population resulting in extensive construction of multi-storied buildings. In the absence of legal enforcement of the building code in the country and lack of earthquake awareness in the country, many multistoried buildings have been constructed without proper earthquake consideration.
- Human activity can also produce earthquakes. Four main reasons contribute to this phenomenon: constructing large dams and buildings, drilling and injecting liquid into wells, coal mining and oil drilling.
- The urban areas in Bangladesh have developed in a fast pace to accommodate the increasing population resulting in extensive construction of multi-storied buildings. In the absence of legal enforcement of the building code in the country and lack of earthquake awareness in the country, many multistoried buildings have been constructed without proper earthquake consideration. The various factors contributing to the earthquake risk in the urban and rural areas of Bangladesh may be summarized below:

- Absence of earthquake
- Awareness
- High population density and construction lacking earthquake resistant design.
- Absence of legal enforcement of building code and its seismic design provisions.
- Poor quality of construction materials and improper construction method.
- Economic limitation.
- Possibility of fire outbreaks due to rupture of gas pipelines or electric short-circuit during an earthquake and inadequate fire fighting facilities.
- Inadequate road width and space between buildings preventing rescue operations and fire-fighting vehicles to reach certain areas.
- Inadequate exit (at the same time) for the occupants of a building during an emergency.
- Lack of facilities (rescue equipment, trained staff, medical personnel, and medical facilities) and preparedness for emergency response and recovery operations following an earthquake.
- Lack of earthquake resistant design of life line facilities which include power plants, power stations, bridges, communication control stations, gas and water supply stations etc.

Effects of earthquake

Primary effects occur immediately, and are all due to the shaking of the ground e.g. buildings collapsing, destruction of roads and bridges. Secondary effects happen afterwards, but can be even more devastating e.g. fire, tidal waves and disease and landslides. Effects of earthquakes can be classified into various classes.

Ground rupture

It is the main result of an earthquake strike. Shaking of ground causes severe damage to the buildings or other structures on the ground including houses etc. Shaking of ground at a particular place depends upon the distance of that place from the epicenter. Severe shaking of ground causes destruction of all the buildings of a city and many people die by burring into the building materials.

Landslides

Earthquakes causes instability of land results into landslides. This claims many lives in the effected zone.

Fire

Earthquake causes breaking of electrical power lines or gas supply lines which causes incidents of fires. Water lines also got ruptured and decreased pressure makes it impossible to control the spread of fire. In earthquake of San Francisco in 1906, more deaths happened because of fire as compared to earthquake itself.

Soil liquefaction

When severe shaking occur then soil or sand loses their strength for a temporary period and gets converted from solid to liquid. This liquefaction causes sinking of buildings, bridges etc.

Tsunami and floods

When epicenter of an earthquake is located near sea, then the traveling of seismic waves below the sea causes generation of Tsunami waves, which can travel at a speed of 600-800 kilometers per hour. For creation of Tsunami earthquakes are needed to be highly intensified. In general earthquakes having reading of less than 7.5 on the Richter scale are not able to generate Tsunami waves. But stronger earthquakes can are comfortable enough to create.

Table-1. Effects of Earthquake.

	Social Impacts (impact on people)	**Economic Impacts (impact on business in the area)**	**Environmental Impacts (impact on the landscape)**
Primary effects	Death, Homes destroyed, Services e.g. water disrupted, Transport systems damaged	Businesses & property destroyed,	Landscape destroyed,
Secondary effects	Diseases	Looting, Economic effect of restoring businesses	Fires, Tidal Waves, Landslides

Effects of earthquake in Bangladesh

Significant damaging historical earthquakes have occurred in and around Bangladesh and damaging moderate-magnitude earthquake occur every few years. The country's position adjacent to the very active Himalayan front and ongoing deformation in nearby parts of south-east Asia expose it to strong shaking from a variety of earthquake sources that can produce tremors of magnitude 8 or greater. The potential for magnitude 8 or greater earthquakes on the nearby Himalayan front if very high, and the effects of strong shaking from such an earthquake directly affect much of the country. In addition, historical seismicity within Bangladesh indicates that potential for damaging moderate to strong earthquakes exist throughout much of the country. Large earthquakes occur less frequently than serious floods, but they can affect much larger areas and can have long-lasting economic, social, and political effects.

Liquefaction is another source of earthquake related damage. During sustained strong shaking, poorly consolidated, water saturated sediments can liquefy and loose their ability to support loads. The foundations and supports of structures built on liquefiable sediments can fail, causing damage or destruction. Much of the country is of loose sandy soil and most of it remains in saturated condition round the year, thereby vulnerable to liquefaction in case of sustained ground motions.

Based on the above discussions, the probable scenario for an earthquake to a scale of M 6.5 or above in Dhaka city could cause:

- Panic among the city dwellers and no knowledge of what is to be done during and immediately after the earthquake occurrence.
- Possible sinking of many of the buildings on filled earth with shallow foundations due to the liquefaction effect.
- If the earthquake occurs during monsoon time possible damage of the Dhaka flood protection embankment due to liquefaction effect causing sudden submergence of a large area.
- Large scale damage and some collapse of poorly constructed and old buildings.
- Possible outbreak of fire in most of the buildings from the gas lines (the residential ovens are mostly in burning condition from morning to mid-night)
- Possible damage of power installations and power cut off for indefinite period.
- Water supply failure as almost all the deep tube wells are run by power, and possible water line damage
- Damage of roads and blockage of traffic due to falling of debris from collapsed buildings and other installations on or near roads.
- Some of the hospital buildings may collapse killing a large number of inmates and stopping medical facilities for the disaster victims.
- Some of the school building may collapse killing and injuring a large number of students
- An after shock may cause further collapse of many of the already damaged buildings.
- A few rescue equipment whatever is available, can not be operated due to the lack of guidance, availability of operators, some will be non-functional, some will be under the rubbles, some can not find access to rescue spots due to road blockage, etc.

Earthquake probability in Bangladesh

The historical seismicity data of Bangladesh and adjoining areas indicate that this area is vulnerable to earthquake hazards. During the last 150 years, seven major earthquakes (with M >_7) have affected Bangladesh.

Table-2. Major earthquakes affecting Bangladesh.

Date	**Name of earthquake**	**Magnitude** (Richter)	**Epicentral distance from Dhaka** (km)	**Epicentral distance from Sylhet** (km)	**Epicentral distance from Chittagong** (km)
10 January 1869	Cacher	7.5	250	70	280
14 July 1885	Bengal	7.0	170	220	350
12 June 1898	Great Indian	8.7	230	80	340
8 July 1918	Srimongol	7.6	150	60	200
2 July 1930	Dhubri	7.1	250	275	415
15 January 1934	Bihar-Nepal	8.3	510	530	580
15 August 1950	Assam	8.5	780	580	540

Source: A. Hossain, February 1998

- Geological framework and adjoining areas shows a number of tectonic blocks which may produce damaging earthquake in Bangladesh.
- Study of worldwide frequency suggests that the more severe an earthquake, the less it occurs. A catastrophic earthquake with a magnitude more than 8.0 on Richter scale usually occurs once in every 5-10 years; disastrous on local scale with magnitude 6.2-6.9 about 100 or more in a year, and moderate (magnitude 4.3-4.8) more or less 5000 per year. Earthquake with magnitude less than 3.4 recorded only by seismograph, the annual number of such tremor is about 800,000. So far at least 12 large-to-great earthquakes occurred in and around Bangladesh.
- Kamal, a professor of geological sciences at Dhaka University, said, "We have faced two or three severe earthquakes within the last 150 years... But because of the long interval since the last major tremor, the possibility of a dangerous strike in the near future is rising."
- The active fault studies under the survey revealed five different segments as potential to be source of earthquake in the future. Sylhet, for the Dauki fault, and Chittagong, for the Plate Boundary fault- 1, 2 and 3 in the Bay, are among the most vulnerable cities.

Earthquake risk zone in Bangladesh

As Bangladesh is located in a tectonically active much of the country including Chittagong, Sylhet, Dhaka, Rangpur, Bogra, Mymenshing, Comilla, Rajshahi are very much vulnerable to major earthquake disaster. Considering geology and tectonics of Bangladesh and neighborhood five tectonic blocks can be identified which have been active in producing damaging earthquakes. These are

- Bogra fault zone
- Tripura fault zone
- Sub Dauki fault zone
- Shillong fault zone
- Assam fault zone

Considering fault length, fault characteristics, earthquake records etc the maximum magnitude of earthquakes that can be produced in different tectonic blocks are given below:

Table-3. Maximum earthquake magnitude in different tectonic blocks.

S. No.	Tectonic block	Maximum magnitude of earthquake
01	Bogra fault zone	7.0
02	Tripura fault zone	7.0
03	Sub Dauki fault zone	7.3
04	Shillong fault zone	7.0
05	Assam fault zone	8.5

Source: Bolt, 1987

As Bangladesh is located close to the boundary of two active plates (Indian plate in the west and Eurasian plate in the east and north) the country has always been under threat of an earthquake that might be so catastrophic it will kill people in less than a minute. With the frequency of earthquakes on the increase, it is natural for people to be scared as experts consider them to be advance warning of what lies ahead. And with tremors in the Chittagong region increasing in frequency, experts believe we can expect a major one any day.

Bangladesh can be divided into three main earthquake zones:

- **Zone-1:** Syleht-Mymensingh is with the possible magnitude of 7 on Richter scale.
- **Zone-2:** Chittagong-Comilla-Dhaka and Tangail are with the possible magnitude of 6 on Richter scale.
- **Zone-3:** Rest of the country is with possible magnitude of 6 on Richter scale.

The entire northern region from Lalmonirhat to Bogora and greater Mymensingh and Syleht are prone to powerful earthquake. The recent rise and mushroom growth of high-rise buildings in and around Dhaka and other main cities could be great disaster, if a major tremor of the magnitude is over 7 on richter scale. There has been no effective post-quake disaster management program that could tackle emergence.

For determining zone coefficients, comparisons of acceleration contour maps with earthquake risk map of the USA indicate that Bangladesh is comparatively less seismic than California. This indicates that lower values of zone coefficients are appropriate in Bangladesh. But unplanned urbanization and rapid growth of population make this zone more vulnerable than that of USA.

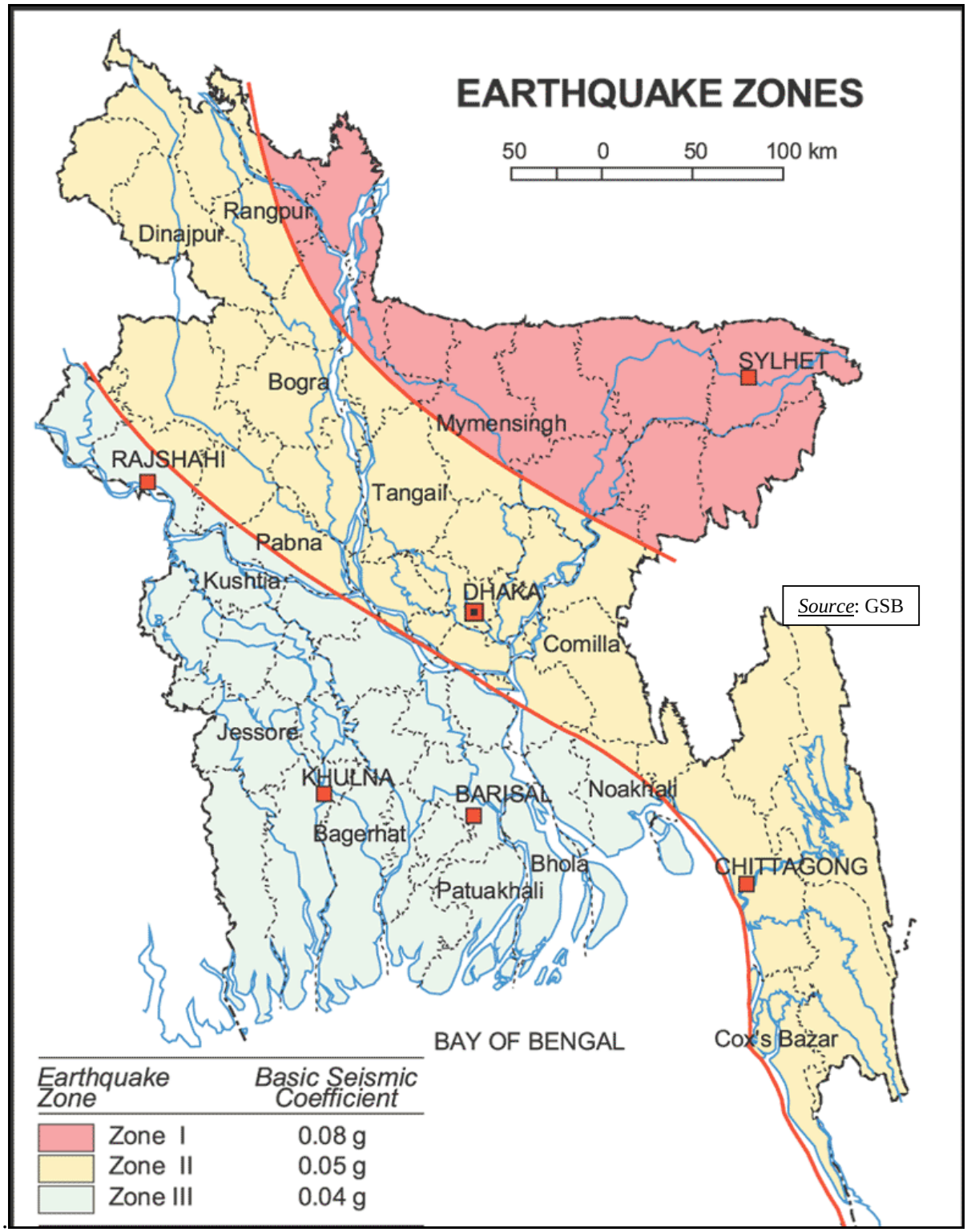


Figure-3. Earthquake zones of Bangladesh.

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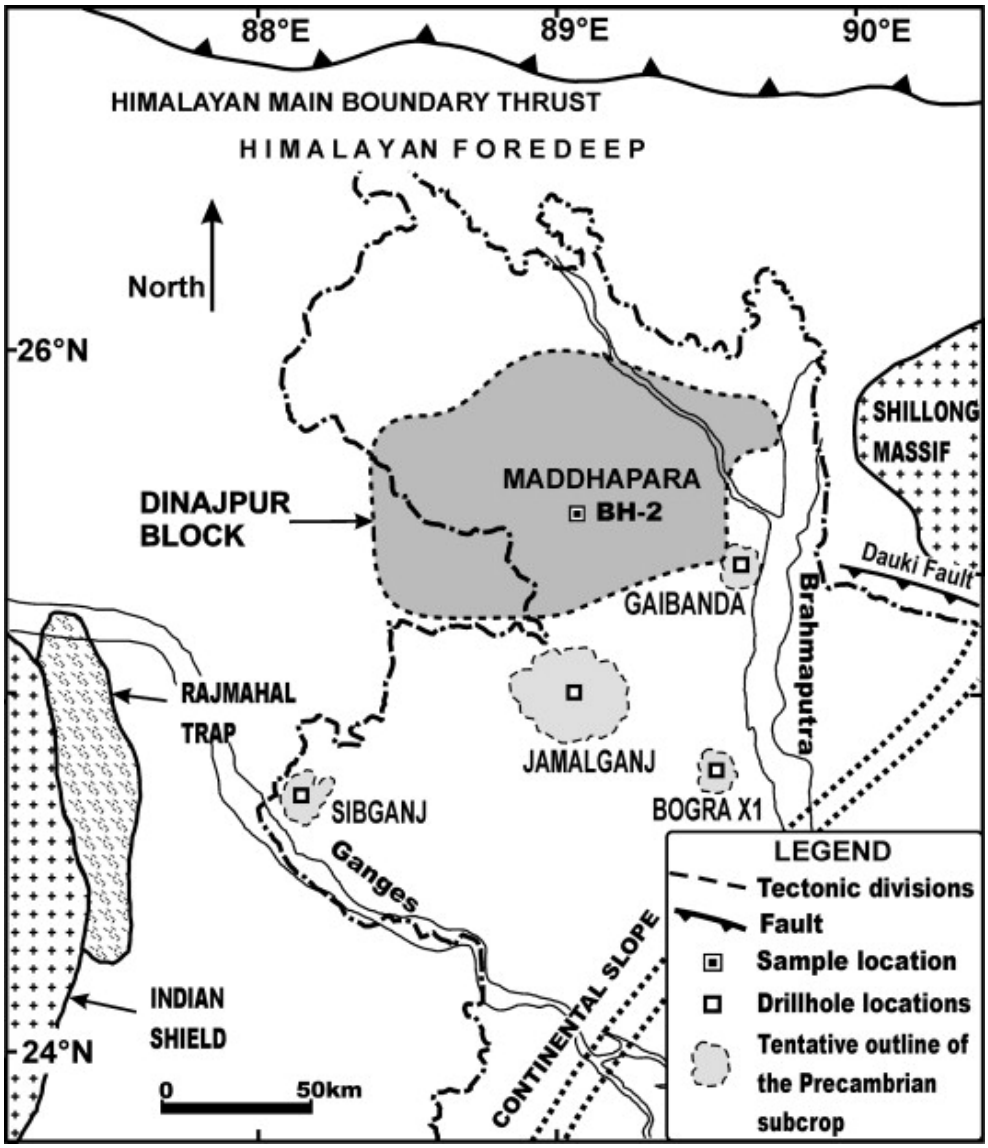

Source: Internet

Figure-4. Tectonic Fault in Northern Part of Bangladesh.

A recently published UN report identifies Dhaka as earthquake-prone cities and makes the ominous prediction that if these cities are hit by earthquake reaching 6 on the Richter scale then the death toll would reach up to 8 million. If Dhaka experiences a major earthquake, then the most vulnerable area would be the old part of the city. Unplanned construction, dilapidated buildings and narrow alleys make this part a high danger zone.

One-third of Dhaka is most vulnerable to tremor

A recent research has found that about one-third area of the Dhaka city is "most vulnerable" to earthquake, and high-rise buildings, especially those between 9 and 14 storeys in height, will not be able to withstand a mid-level earthquake because of the city's typical soil characteristics. Even 5-8 storey buildings will be vulnerable in some areas, including Bashundhara, low-lying parts of Rampura, Rupnagar to Duaripara in Mirpur, and Gabtoli to Rayerbazar embankment areas, because these areas have been recently filled with clay and silty materials.

The earthquake disaster risk index has placed Dhaka among the 20 most vulnerable cities in the world. Recently plate motions measured that Dhaka is moving 30.6 mm/year in the direction North-East. Micro-seismicity data supports the existence of at least four earthquake source points in and around Dhaka. Thirty-five per cent of Dhaka, including middle and North part and Old Dhaka, is on red soil and it is less susceptible to an earthquake, whereas the East and West areas, built on landfills and more susceptible to earthquake.

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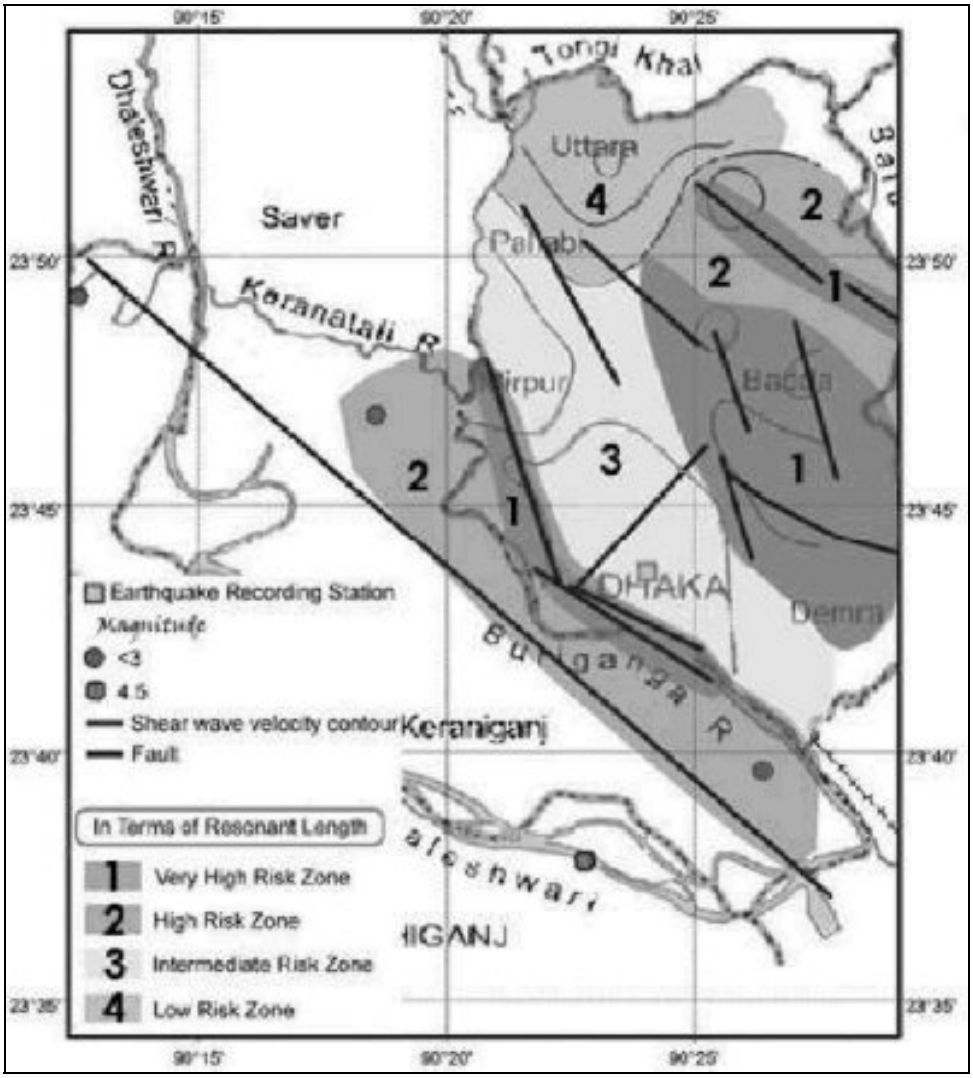

Source: Aftab Alam Khan, 2006

Figure-5. Earthquake hazard zoning map of Dhaka Megacity.

For 9-14 storey buildings, the high-risk areas are Kamrangir Char, Rayer Bazar, Adabar, the lower part of Mirpur, Uttarkhan, Dakkhinkhan, Bashundhara, Badda, Banasri (Rampura), Meradia, Bashabo, Madhubagh, and part of Begunbari and Gulshan. The buildings of 5-8 stories are also very vulnerable to earthquake, especially in the filled sites of deep marshy land. The buildings up to four stories are relatively safe in Dhaka.

The major faults of Dhaka city

- Along Bagunbari KhaL, trending east-west in the southern part of the city.
- Along an abandoned channel, in the Uttara area, across Zia Interna tional Airport, trending north-south in the northern part of the city.
- Along the Turag River, in Mirpur near Dhaka Zoo, trending north-south in the western part of the city.

The lineaments are

- Along the edge of the depression from Khilkhet to Jatrabari, trending north-south in the central part of the city.
- Along the edge of the depression in the southern part of Dakhin Khan, trending south-west in the eastern part of the city -Along the edge of the depression in the western part of Uttara, trending north-south in the northern part of the city.
- Along the edge of the depression in the Pallabi area, trending north-south in the northern part of the city.
- Along the branch of the Turag River, trending northeast-southwest.
- Along Tongi Khal, in the Tongi-Uttar Khan area, trending east-west at the northern limit of the city.
- Along the Buriganga River at the southern limit of the city, trending southwest-northeast.

- Along the old natural levee, in the Mohammadpur area, trending north-south

Earthquake risk mitigation in Bangladesh

Earthquake cannot be prevented. But certainly it is high time to be much more concerned about the probable impending earthquake in order to minimize the loss of lives and property in national interest. It is of prime importance to set a national institute of earthquake research to develop high skilled manpower that can perform the task for earthquake risk assessment and management. We should remember that one earthquake of moderate intensity would kill thousands of people and destroy enormous national property. Death is certain for all human beings but painful death is not desirable.

Bangladesh is possibly one of the most vulnerable countries to potential earthquake threat and damage. An earthquake of even medium magnitude on Richter scale can produce a mass graveyard in major cities of the country, particularly Dhaka and Chittagong, without any notice. Construction of new buildings strictly following building code or development of future controls on building construction are the activities which will be functional in future. However, under the present stage of human occupancy, buildings, infrastructures and other physical structures of different areas of a city will not be equally vulnerable to any such shock. Earthquake vulnerability of any place largely depends on its geology and topography, population density, building density and quality, and finally the coping strategy of its people and it shows clear spatial variations. It is thus necessary to identify the scale of such variations and take necessary measurements to cope with that.

Although the earthquake tremors cannot be stopped or reduced, the human casualties and loss of properties can be reduced with the help of an earthquake vulnerable assessment atlas. An earthquake atlas is the presentation of facts relating to earthquakes and the guideline for earthquake mitigation measurements at regional scale in the form of map, graphs, pictures and text.

However, some immediate measures are suggested below:

- Make an inventory of all old buildings which are vulnerable to earthquake, and either repair or evacuate occupants from those buildings.
- Make an inventory of houses, which are constructed at the foot of steep hillsides, particularly where hill slopes have been cut, even ten years back. Relocate those families to suitable places.
- Make earthquake vulnerability atlas of major cities, which will show in detail the list of vulnerable sites, their possible consequences and possible measurements of mitigation at different scales of earthquake events.
- Strict application of building codes for all newly constructed buildings, particularly all high-rise buildings.
- Development of awareness program to educate people regarding the causes and consequences of earthquakes and also to disseminate knowledge to them regarding their responsibilities before, during and after the earthquake through seminar, symposium and workshop, and also through non-formal education by GO and NGOs.

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 assessment of probable ground motion and identifying local soil effects.
- Reliable assessment of probable damage to buildings and other structures.
- Survey and identification of risky buildings
- Updating of the building code.
- Legal enforcement of building code.
- Building insurance to promote earthquake resistant construction.
- Seismic strengthening of critical structures and facilities.
- Developing laboratory and testing facilities for 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 during a major earthquake
- Developing facilities for post earthquake rescue and recovery.
- Urban (including transport) planning of the city to mitigate earthquake effects.
- Implementation of national earthquake disaster management plan involving various professionals, officials and volunteers.

CONCLUSIONS

Earthquakes pose a gigantic threat to the economy and well being of this country. While thousands of buildings may collapse in the cities, serious casualties could be in tens of thousands. Seismic risks should be correctly assessed and subsequently mitigated to the extent feasible. A comprehensive and well-coordinated earthquake disaster mitigation plan for the urban as well as rural areas should be developed without further delay and implemented on a priority basis with available resources. Earthquake engineering research centers should be promoted to be focal points for providing expert technical guidance to the country for earthquake disaster mitigation. Building codes need to be updated and improved.

Effective interaction and dialogue between the technical professionals and the government authorities should be ensured. Success of earthquake disaster mitigation efforts will depend on the blending of technical and political solutions into best practices for the reduction of unacceptable risk and sustainable development. Priorities should be established for strengthening the most critical structures and lifeline facilities. The participation of various government, non-government and voluntary organizations, academic institutions, community leadership and media should be encouraged and integrated for maximum benefit.

REFERENCES

Akhter S.H. 2010. Earthquakes of Dhaka. In: Environment of Capital Dhaka - Plants Wildlife Gardens Parks Air Water and Earthquake. M.A. Islam (Ed.). Asiatic Society of Bangladesh. pp. 401-426.

Ali M.H. 1998. Earthquake Database and Seismic Zoning of Bangladesh. Department of Civil Engineering, BUET, Dhaka, Bangladesh.

Ameen S. The Earthquake Scenario in Bangladesh. Senior Programme Manager, USAID.

Choudhury J.R. 1993. Seismicity in Bangladesh. Bangladesh University of Engineering and Technology (BUET) Dhaka.
http://bangladeshandproblems.blogspot.com

Khan A.A. 2004. Earthquake hazard: Dhaka city perspective. The Daily Star. 5(40).

Lahiry A.K. 2010. Possible Disastrous Earthquake in Bangladesh and its Precautions" from "National Power (electricity) Week-2010: Power Sector: Progress and Development Strategy. Power Division, Ministry of Power, Energy and Mineral Resources (MoPE and MR), Dhaka, Bangladesh.