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Investigation of Urban Earthquake Disaster Shelter and Relief Base in Bangladesh

MD ARIFUL HOSSAIN[1*], HAIWANG LI[2], TIANE LI[3], VINAY SANI[4], SAID IKRAM SADAT[1]

[1]College of Civil Engineering, Taiyuan University of Technology, China

[2]Professor, College of Civil Engineering, Taiyuan University of Technology, China

[3]Assistant Professor, College of Civil Engineering, Taiyuan University of Technology, China

[4]College of Civil Engineering, Taiyuan University of Technology, China

[5]College of Civil Engineering, Taiyuan University of Technology, China

Corresponding author

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***Abstract**: Bangladesh is a south Asian developing country which is used to struggle with various natural disasters and the earthquake is one of them. Bangladesh is of the most earthquake venerable countries of the world[1] but Bangladesh is ill prepared to tackle the aftermath of any strong earthquake. 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.[2] It is also the site of the Dauki Fault system along with numerous subsurface active faults and a flexure zone called Hinge Zone.[2] These weak regions are believed to provide the necessary zones for movements within the basin area. 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. Here, I have tried to discuss about the risks of earthquake disaster in Bangladesh and the historical earthquakes that occurred in Bangladesh.*

***Keywords**: Disaster, earthquakes, tectonic plates, Earthquake history in Bangladesh, government plan, earthquake proof structure.*

1. Introduction: Earthquakes are one of the most devastating of all natural disasters. Earthquakes are very difficult to predict as events that lead to these disasters happen deep down in the earth. Tectonic plate movements are the primary cause of earthquakes. Volcanic eruptions can also trigger earthquakes but are often, in turn, caused by tectonic activity.

1.1 Some world most earthquake-prone countries: The world's most earthquake-prone countries include China, Indonesia, Iran, and Turkey. [32]

China: China experienced 157 earthquakes from 1900 to 2016, the highest number of earthquakes of any country. Most of these earthquakes happened in the southwest region of the country, where the terrain is highly mountainous. Luckily for China, some of the least populous provinces, namely Sichuan, Gansu, Qinghai, Xinjiang, Tibet, and Yunnan, are located in this region.

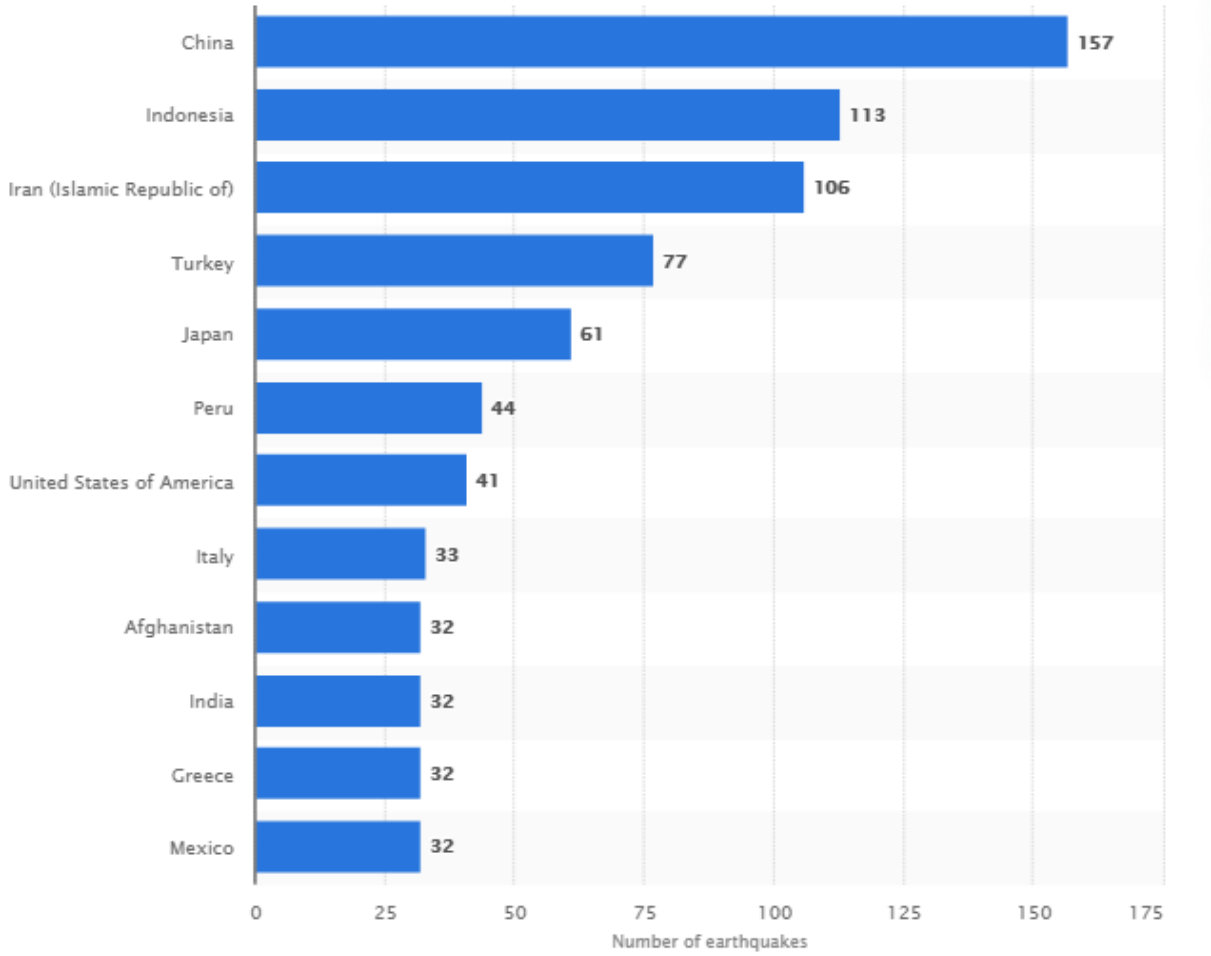
Indonesia: With 113 earthquakes of significant magnitude between 1900 and 2016, Indonesia ranks as the world's second most earthquake-prone country. The primary reason for the high frequency of earthquakes in Indonesia is its location on the Ring of Fire. The majority of the world's earthquakes happen in the Ring of Fire, which encompasses a shoe-shaped area of about 40,000 square km. The movement of tectonic plates in the area, as well as submarine or surface volcanic eruptions, have triggered many earthquakes that have affected Indonesia over the centuries.

Iran: Iran, a country in the Middle East, is located in an area of high seismic activity. It is the third most earthquake country in the world and has experienced at least 106 earthquakes from 1900 to 2016. The country exists where the Eurasian and Arabian tectonic plates meet. The Zagros Mountains, one of the world's youngest mountain range, developed in the area due to the seduction of the Arabian place under the Iranian plate, the latter being a part of the larger Eurasian plate.

Turkey: Like other countries in the list, Turkey also sits atop one of the world's most seismically active spots, the plate boundary between the Eurasian and Arabian plates. The Arabian plate is inching northwards towards the relatively stable Eurasian Plate. Turkey is located at the boundary of impact between these plates. The movement of the Arabian Plate, in turn, is triggered by the formation and spread of new crust along the mid-sea ridges of the Red Sea and the Gulf of Aden.

Japan: Like Indonesia, Japan is near the Pacific Ring of Fire which makes it highly vulnerable to catastrophic earthquakes. The movement and collisions of the continental and oceanic plates in and around Japan are responsible for these disasters. Japan is on the joint of four different tectonic plates. These are the North America plate, Pacific plate, Philippine plate, and the Eurasian plate. The movement and subduction of the Philippine and Pacific plates under the two other plates cause earthquakes.

Countries with the most earthquakes from 1900 to 2016[31]



1.2 Scientific Researches on Earthquakes: The world's most earthquake-prone countries already took some measure and done a lot of research about earthquake disaster. Here we describe about one country "China".

China is one of the countries which have very high seismicity in their continents and have suffered severe damage from past strong earthquakes. [33] More than half of China's land locates in an area with intensity VII or above, which includes 23 provincial capitals and 2/3 of the large cities with population over 1 million people. With many years of hard work, China has built a national network on earthquake observation which covers the whole country and includes seismic, precursory and strong motion observation networks. There are 900 fixed stations for seismic observation which ensures that any earthquake with a magnitude over 3 in over 90% of China can be monitored. It also comes with the capacity to monitor earthquakes with a magnitude as low as 1 in the selected key monitored areas. Currently the researches related to earthquakes have formed

a number of top-rated specialty fields with their own characteristics. A new scientific platform has been built for innovation in observation, experiment, research and development. The broad-band digital seismographs with China's own intellectual property rights
have been developed domestically, which are not only deployed to China's national network for seismic observation, but also exported to many countries and regions. The completion of the national key science project "Crustal Movement Observation Network of Ch ina" has fundamentally changed the landscape of the dynamic observation for crustal layers of the earth system and greatly enhanced the scientific research capabilities in earth monitoring from the space and in crustal movement. A national key research laboratory and fine national key field observation stations have been built. The national key fundamental research programs for large earthquake prediction based on the hypothesis of dynamics of continental active blocks and damage and control of urban engineering have led the elevation in fundamental research activities on earthquake occurrence and its damage control. Extensive exchange programs have been set up for international collaboration. Formal relationships have been formed with over 50 countries and/or regions for collaboration and exchange of research results on earthquake study.

2. Basic concept:

2.1 Disaster: A disaster is a natural or man-made event that negatively affects life, property, livelihood or industry often resulting in permanent changes to human societies, ecosystems and environment. Disasters are highly disruptive events that cause suffering, deprivation, hardship, injury and even death, as a result of direct injury, disease, the interruption of commerce and business, and the partial or total destruction of critical infrastructure such as homes, hospitals, and other buildings, roads, bridges, power lines, etc. Disasters can be caused by naturally occurring events, such as earthquakes, hurricanes, flooding, or tornadoes, or they can be due to man-made events, either accidental (such as an accidental toxic spill or nuclear power plant event), or deliberately caused (such as various terrorist bombings and poisonings).[19]

2.2 Types of disasters: Disasters can take many different forms, and the duration can range from an hourly disruption to days or weeks of ongoing destruction. There are main two types of disasters, such as

Natural disasters: Natural disasters are divided in to following types,[21]

- Geophysical: earthquakes, landslides, tsunamis and volcanic activity.
- Hydrological: avalanches & floods.

- Climatologically: extreme temperatures, drought and wildfires.
- Meteorological: cyclones and storms/wave surges.
- Biological: epidemics and insect/animal plagues.

Man-Made disasters: Man- Made/ Human Induced disasters are divided in to following types,[21] Conflicts, famine, displaced populations, industrial accidents, transport accidents, Terrorism and War. Human are also responsible for environmental degradation, pollution which trigger various disasters.

2.3 Earthquake: An earthquake is an intense shaking of Earth's surface. The shaking is caused by movements in Earth's outermost layer.[4] Most earthquakes are minor tremors, while larger earthquakes usually begin with slight tremors, rapidly take the form of one or more violent shocks, and end in vibrations of gradually diminishing force called aftershocks. Earthquake is a form of energy of wave motion, which originates in a limited region and then spreads out in all directions from the source of disturbance. It usually lasts for a few seconds to a minute. The point within the earth where earthquake waves originate is called the focus, from where the vibrations spread in all directions. They reach the surface first at the point immediately above the focus and this point is called the epicenter. It is at the epicenter where the shock of the earthquake is first experienced. On the basis of the depth of focus, an earthquake may be termed as shallow focus (0-70 km), intermediate focus (70-300 km), and deep focus (> 300 km). The most common measure of earthquake size is the Richter's magnitude (M). The Richter scale uses the maximum surface wave amplitude in the seismogram and the difference in the arrival times of primary (P) and secondary (S) waves for determining magnitude (M). The magnitude is related to roughly logarithm of energy, E in ergs.[3]

2.4 Causes of Earthquake: An earthquake is caused by a sudden slip on a fault. The tectonic plates are always slowly moving, but they get stuck at their edges due to friction. When the stress on the edge overcomes the friction, there is an earthquake that releases energy in waves that travel through the earth's crust and cause the shaking that we feel.[5] Earthquakes are sometimes caused by human activities, including the injection of fluids into deep wells, the detonation of large underground nuclear explosions, the excavation of mines, and the filling of large reservoirs. In the case of deep mining, the removal of rock produces changes in the strain around the tunnels. Slip on adjacent, preexisting faults or outward shattering of rock into the new cavities may occur. In fluid injection, the slip is thought to be induced by premature release of elastic strain, as in the case

of tectonic earthquakes, after fault surfaces are lubricated by the liquid. Large underground nuclear explosions have been known to produce slip on already strained faults in the vicinity of the test devices.[9]

2.5 Types of Earthquake: There are two main types of earthquakes: natural and man-made. Naturally occurring(tectonic) earthquakes occur along tectonic plate lines(fault lines) while man-made earthquakes are always related to explosions detonated by man.[11] Most naturally occurring earthquakes are related to the tectonic nature of the Earth. Such earthquakes are called tectonic earthquakes. "In the past, people never thought that human activity could have such a big impact, but it can," said Christian Klose, a geohazards researcher at Columbia's Lamont-Doherty Earth Observatory.[24] It turns out, actually, that the human production of earthquakes is hardly super villain-worthy. Most of these human-caused quakes are tiny, registering less than four on geologist's seismic scales. But some human actions can trigger much larger quakes along natural fault lines. That's because humans, with the aid of our massive machines, can sling enough mass around to shift the pattern of stresses in the Earth's crust. Faults that might not have caused an earthquake for a million years can suddenly be pushed to failure, as Klose argues occurred during Australia's only fatal earthquake in 1989.[25] The top five ways to create an earthquake are, Build a Dam, Inject Liquid Into the Ground, Mine a Lot of Coal, Drill a Gusher Dry and create the World's Biggest Building[26]

2.6 Tectonic plates: A tectonic plate (also called lithospheric plate) is a massive, irregularly shaped slab of solid rock, generally composed of both continental and oceanic lithosphere. Plate size can vary greatly, from a few hundred to thousands of kilometers across; the Pacific and Antarctic Plates are among the largest. Plate thickness also varies greatly, ranging from less than 15km from young oceanic lithosphere to about 200km or more for ancient continental lithosphere (for example, the interior parts of North and South America). The outer shell of the earth, the lithosphere, is broken up into tectonic plates. The seven major plates are the African plate, Antarctic plate, Eurasian plate, Indo-Australian plate, North American plate, Pacific plate and South American plate.[27]

3. Earthquake in Bangladesh: Bangladesh is positioned at the juncture of several active tectonic plate boundaries. Moreover, it sits a top of the world’s largest river delta at close to sea level, facing both the risk posed by a quake and secondary risks of tsunamis and flooding in the quake’s aftermath. 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.

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.[34]

3.1 Fault Zone: Earthquakes occur on faults. A fault is a thin zone of crushed rock separating blocks of the earth's crust. When an earthquake occurs on one of these faults, the rock on one side of the fault slips with respect to the other. Bangladesh is surrounded by a number of tectonic blocks responsible for many earthquakes in the past. Calcutta, Assam, Tripura are the three very earthquake prone regions that are joined to Bangladesh in the borders in the Northern, Western and North-Eastern part respectively. If we consider the tectonics and geology, five major faults are significant for the occurrences of devastating earthquakes and these are: [1]

- Bogra Fault Zone
- Tripura Fault Zone
- Shilong Plateau
- Dauki Fault Zone
- Assam Fault Zone

3.2 Earthquake zones: In seismology, a seismic zone is an area of seismicity potentially sharing a common cause. It may also be a region on a map for which a common areal rate of seismicity is assumed for the purpose of calculating probabilistic ground motions. An obsolete definition is a region on a map in which a common level of seismic design is required.

Bangladesh can be divided into three main earthquake zones: [2]

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.

3.3 Some example of earthquakes affecting Bangladesh.

Name	Date	Time	Depth	Magnitude	Epicenter	Areas affected	Casualties
Imphal earthquake	4 January 2016	4:35 IST	55.0 km (34.2mi)	6.7 M_w	24.834°N 93.656°E	Bangladesh India Myanmar Nepal	11 dead ~200 injured[14]
Nepal earthquake	25 April 2015	11:56:25 NST	8.2 km (5.1 mi)	8.1 M_w	28.230°N 84.731°E	Nepal India China Bangladesh	8,964 dead in total21,952 injured 3.5 million homeless[15]
Nepal earthquake	12 May 2015	12:50:19 NST	18.5 km (11.5 mi)	7.3 M_w	27.837°N 86.077°E	Nepal India Bangladesh China (Tibet)	218 dead 3,500+ injured [16]
Sikkim earthquake	18 September 2011	18:10 IST	19.7 km (12.1 mi)	M_w 6.9	Taplejung, Nepal 27.723°N 88.064°E	India Bangladesh Nepal Bhutan China	At least 111 killed[17]
Chittagong earthquake	21 November 1997	16:53:07 IST	54 km (34 mi)	6.1 M_w	22.34°N 92.7°E	Bangladesh India	23 dead 200 injured[18]

4. Measures taken in Bangladesh:

4.1 Earthquake risk mitigation in Bangladesh: When earthquake strikes a building is thrown mostly from side to side, and also up and down along with the building foundation the building structure tends to stay at rest, similar to a passenger standing on a bus that accelerates quickly. Building damage is related to the characteristics of the building, and the duration and severity of the ground shaking. Larger earthquakes tend to shake longer and harder and therefore cause more damage to structures. For better understanding of all the possibilities of earthquake risk reduction, it is important to classify them in terms of the role that each one of them could play. Therefore, in the pre-earthquake phase, preparedness, mitigation and prevention are concepts to work on. Post-disaster, immediate rescue and relief measures including temporary sheltering soon after an earthquake until about 3 months later and re-construction and re-habilitation measures for a period of about six months to three years need to follow.

Some immediate measures are suggested below: [34]

- 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.
- Make an inventory of all old buildings which are vulnerable to earthquake, and either repair or evacuate occupants from those buildings.
- Strict application of building codes for all newly constructed buildings, particularly all high-rise buildings.
- Increase public awareness about earthquakes through mass media, education (at school), training, earthquake drills, publications etc.

4.2 Government plan against earthquake: An earthquake so violent that entire cities are largely demolished – this is what national authorities and aid agencies have gathered to prepare for this week, as part of a major disaster-simulation exercise. Jointly organized by the United Nations World Food Programme (WFP) and the Bangladesh Ministry of Disaster Management and Relief, the simulation brings together key emergency-response agencies, including Government officials, NGOs and UN agencies."Identifying areas of improvement and testing coordination mechanisms will help us be better prepared if a powerful earthquake hits," said WFP Bangladesh Representative Christa Rader. Considering the vulnerability to earthquakes in Rangpur, Tangail, Sunamganj and Rangamati, the Department of Disaster Management (DDM) part of the National Resilience Programme (NRP), signed an MoU on 04 September at the DDM conference room with Rangpur City Corporation, and the municipalities of Tangail, Sunamganj, and Rangamati. Bangladesh has already taken important measures in earthquake preparedness, such as risk assessments for 10 major cities, including Dhaka, urban volunteers trainings, contingency plans, training drills, etc.' Mr. Shah Kamal, Senior Secretary, Ministry of Disaster Management and Relief (MoDMR), said in his speech as chair, "With the signing of these MoUs, we work with the municipalities in more depth. Within NRP's plan the local government institutions will have to work more in depth towards earthquake resilience. [28] The government of Bangladesh and the World Bank are engaged in a multi-year process with national decision makers and technical experts to reduce the risks that earthquakes pose to the country's long-term development. The Earthquake Risk Management Program is a multi-phased program, to be financed through two sources of funding, a Global Facility for Disaster Reduction and Recovery Grant from the government of Australia

(AusAID) and a Policy and Human Resources Development Fund Grant (PHRD) from the government of Japan, the total amount being $6 million.[29]

4.3 Earthquake-Proof Structure: Natural disasters are sudden and dangerously powerful, making them a serious threat to communities nationwide. Professionals have learned to anticipate some like hurricanes, blizzards, and tornadoes, but others can still strike with no warning. Earthquakes of any magnitude can occur any time of the year with almost no indications. They can affect small remote areas, or destroy large cities. Experts have discovered specific U.S. areas highly prone to earthquakes, but technically they could happen anywhere. In a country brimming with permanent steel, glass, and concrete structures, earthquakes possibly pose the greatest threat of widespread destruction. To design an earthquake-proof building, we need to reinforce the structure and counteract an earthquake's forces. Since earthquakes release energy that pushes on a building from one direction, the strategy is to have the building push the opposite way. Here are some of the methods used to help buildings withstand earthquakes.[30]

1. Create a Flexible Foundation: One way to resist ground forces is to "lift" the building's foundation above the earth. Base isolation involves constructing a building on top of flexible pads made of steel, rubber, and lead. When the base moves during the earthquake, the isolators vibrate while the structure itself remains steady. This effectively helps to absorb seismic waves and prevent them from traveling through a building.

2. Counter Forces with Damping: shock absorbers reduce the magnitude of shockwaves and help buildings slow down. This is accomplished in two ways: vibration control devices and pendulum dampers.

3. Shield Buildings from Vibrations: Concrete with plastic ring underneath the building channel shockwaves around. Instead of just counteracting forces, researchers are experimenting with ways buildings can deflect and reroute the energy from earthquakes altogether. Dubbed the "seismic invisibility cloak", this innovation involves creating a cloak of 100 concentric plastic and concrete rings in and burying it at least three feet beneath the foundation of the building.

4. Reinforce the Building's Structure: To withstand collapse, buildings need to redistribute the forces that travel through them during a seismic event. Shear walls, cross braces, diaphragms, and moment-resisting frames are central to reinforcing a building. Shear walls are a useful building technology that helps to transfer earthquake forces. Moment-resisting frames provide more flexibility in a building's design.

5. Conclusion: Bangladesh is situated at high risk zone for earthquake and an unprecedented human disaster may occur in the country anytime for even a moderate to heavy tremor. It is apparent that the preparedness to face a major earth quake in Bangladesh is very poor. The policy issues regarding disaster like earthquake could be handled mostly at the national level but planning and implementation issues are to be handled at the local level. Finally proper implementation of national building code and capacity building can reduce the vulnerability and risk of earthquake hazard in Bangladesh.

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Conflicts of Interest

There are no conflicts to declare.