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Analysis of Earthquake Readiness, Damage Scenarios, and Pre-and Post-Preventive Measure Techniques: A Comprehensive Review of Dhaka City

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Abstract

Earthquakes can have devastating effects on communities worldwide, and understanding the trends in seismic activity can help reduce the impacts of future earthquakes. The necessity for better building design and earthquake preparedness has been brought to light by recent earthquakes. This paper includes a thorough analysis of earthquake readiness and damage scenarios, as well as pre-and post-preventive methods for responding to seismic events. It assesses the existing level of earthquake preparedness and its effects on the built environment while considering design principles, surrounding considerations, and zoning of Bangladesh. It also incorporates the wide range of damage scenarios that might occur to buildings, and the vulnerability of buildings with secondary effects, as well as the numerous pre- and post-preventive measure procedures. The consequences of these findings and their possible recommendations are discussed, in the paper's conclusion. Analyzing earthquakes can help researchers understand the effects of earthquakes on the environment, and can help to inform emergency response plans.

Keywords: *Seismic Activity; Earthquake Readiness; Damage Scenarios; Pre-and Post-Preventive Measures; Implications.*

1 Introduction

Bangladesh, a nation in South Asia, is well-known for both its distinctive topographical features and susceptibility to natural calamities. Even though the country has many environmental issues, earthquakes seriously threaten its infrastructure and population. Seismic activity is crucial in Dhaka City, a city with a high population density and rapid urban growth. A 7.8-magnitude earthquake that struck Turkey and Syria on February 6, 2023, claimed the lives of more than 50,000 people(Kanwal, 2023). The objective of this critical evaluation is to assess Dhaka's present level of earthquake readiness, as well as the potential damage scenarios and the effectiveness of pre- and post-preventive actions.

This review's first section will examine Bangladesh's geographic and geological features, which render it susceptible to earthquakes. To create effective mitigation plans and ensure the resilience of infrastructure and populations, it is essential to understand the seismic risk profile of the nation(Rahman et al., 2021). The subsequent sections will concentrate on Bangladesh's earthquake readiness and preparedness efforts, evaluating the efficacy of current laws, rules, and construction norms. This analysis will examine possible earthquake damage scenarios and assess how they can affect vital industries like housing, education, healthcare, and transportation systems. It tries to pinpoint weaknesses and inadequacies in infrastructure design and building methods. The analysis will also take into account the socioeconomic effects of earthquake damage, such as community relocation, business interruptions, and difficulties with long-term rehabilitation(Jahan et al., 2011). Lastly, this analysis will focus on Dhaka's pre- and post-preventive measures, assessing the efficiency of tactics such as earthquake-resistant building designs, retrofitting of existing buildings, emergency response procedures, and disaster risk reduction activities.

2 Geographical Characteristics

The first section of this review will delve into the geographical and geological characteristics of Bangladesh that make it susceptible to earthquakes. Understanding the country's seismic risk profile is crucial in formulating effective mitigation strategies and ensuring the resilience of infrastructure and communities.
Due to its geographical location, Bangladesh faces a significant risk of earthquakes. The tectonic structure of Bangladesh and its surrounding regions suggests that the country is situated near the boundaries of the Indian and Eurasian plates. Even today, Bangladesh remains prone to seismic activity. Figure-1 below shows the earth zoning of Bangladesh based on the frequency of earthquakes, and Figure-2 shows the listing of recent earthquakes and the likelihood of a devastating earthquake in the future.

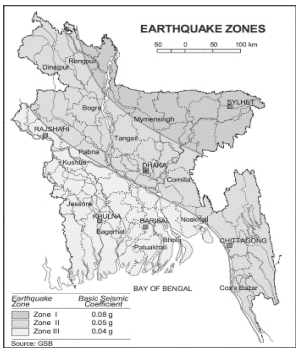

Figure 1. Earthquake Zones of Bangladesh (Hossain et al., 2018)

a. Magnitude: 4.3; Depth: 61 km Chhatak, Sylhet, Bangladesh

b. Magnitude: 4.3; Depth: 10 km Karimganj, Assam, India (30/10/2022)

c. Magnitude: 3.9; Depth: 10 km Bogura, Rajshahi (30/07/2022)

d. Magnitude: 4.2; Depth: 10km Dohar, Dhaka, Bangladesh (04/05/2023)

Figure 2. Recent earthquake activity in Bangladesh (Hossain et al., 2018)

3 Earthquake Readiness in Dhaka City

3.1 Structural failure

In the event of an earthquake, structural failure causes the most fatal injuries and death. In the 6.1 million buildings that comprise Dhaka City, 67 percent of the commercial and 51 percent of the industrial structures do not adhere to the Detailed Area Plan (DAP), and about 10 percent of the commercial, 9 percent of the industrial, and 6 percent of the residential structures were built on conservation areas (such as water bodies, flood-prone areas, open space) (Rahman et al., 2021).

3.2 Risk map of the capacity of open space to be used in emergencies in Dhaka city

The map provided in Figure-3 displays the Population Coverage Ratio (PCR) in open space for the city of Dhaka. These conclusions are supported by the region's high population density and dearth of open space. For having a high danger (2.5%-19% evacuation capacity in open space), Shayampur, Sutrapur, and Hazaribagh in the southern portion of Dhaka are placed 30th, 31st, and 32nd, respectively (Omar et al., 2021). Due to its numerous parks and open spaces, the city's central area, including Ramna, Shahbagh, and Azimpur, is ranked 2nd, 3rd, and 5th, respectively. (Omar et al., 2021)

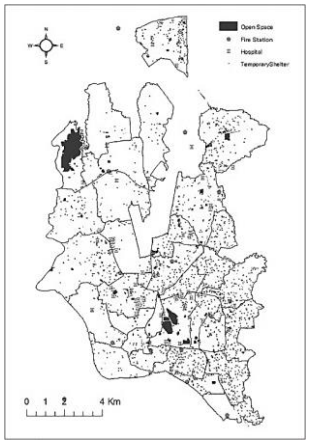

Figure 3. Location of emergent facilities (Omar et al., 2021)

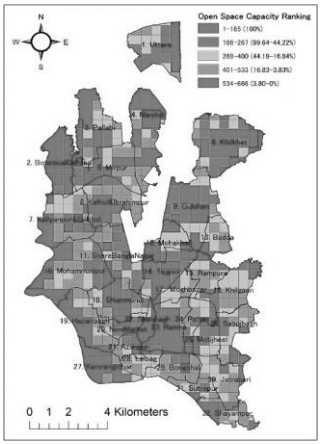

Figure 4. Population coverage ratio (PCR) by open space (Omar et al., 2021)

3.3 Building Service

To reduce casualties during an earthquake, a building must include additional services such as an alert system and emergency departure strategy. These building characteristics aid in escape and give directions (Malla, 2015). Among the 202 respondents, 101 were male and 101 were female (Figure-5). The fire equipment condition, exit point, and utility services are shown.

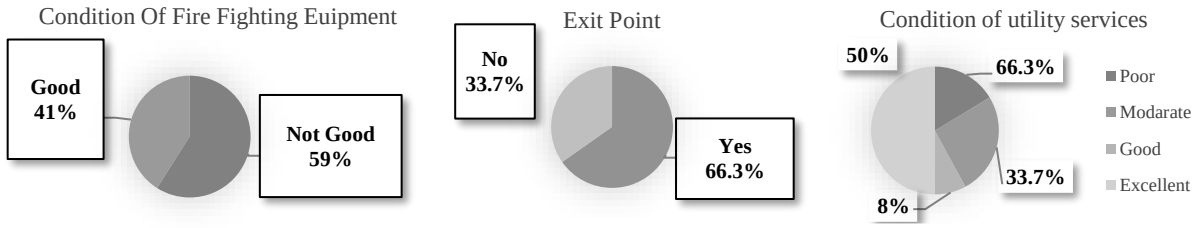

Figure 5. Condition of Fire Equipment; Exit Point; Condition of Utility Services (IEEE Region 10 et al., n.d.)

3.4 Organizational Efforts and Fire Service Readiness

The DEEP project intends to increase both the resilience of the impacted populations and the response capacities of the Dhaka administration. It was overseen by the German Red Cross and ran for a total of 21 months with assistance from Christian Aid Bangladesh, the Action Contre La Faim, and Bangladesh Red Crescent. Several training sessions and simulations were held over the course of the 21-month project to prepare first responders, volunteers, and the general public for earthquakes and the hazards they represent. According to this project, the following results had been coming out (Red Cross EU Office, 2017):

Project Title	Dhaka Earthquake & Emergency Preparedness- Enhancing Resilience (DEEPER)
City & Country	City: Dhaka; Country: Bangladesh Areas: 18 administrative areas, Dhaka South City Corporation
Duration	July 2019 through December 2020
Sectors	Urban Disaster Risk Reduction, Preparedness, Strengthening of Response, Strengthening of Resilience, and Building of Capacity
Specific Objectives	Through integration with cutting-edge emergency systems, the 18 target wards in Dhaka City have improved resilience and raised readiness to respond to significant earthquakes and other catastrophes.
Results	**Volunteers and systems:** Disaster preparedness, response systems, and volunteer capacities are strengthened. **Planning and Systems**: The targeted 3 zones and 18 wards now have improved reaction readiness capabilities. **Safety of schools and health systems**: Target wards now have 36 schools and 6 health institutions that are better prepared for emergencies.
Target Groups	"The project's 43,390 direct beneficiaries are individuals who receive training from it and participate in its activities directly. This comprises: • 80 master facilitators/trainers from the BDRCS. • The 18 Ward Disaster Management Committees have 360 members (where WDMCs are replaced, the project will aim for a WDMC composition with 50 percent women). • 36,000 school teachers and students in 36 participating schools were assisted by 3.600 city volunteers spread over 18 wards.36,000 school teachers and students in 36 participating schools were assisted by 3.600 city volunteers spread over 18 wards. (Existing Red Crescent Youth RCY members – new additional recruitment will aim for 50% females). • 300 employees across 6 healthcare institutions • 3,000 participants in market and neighborhood associations.
Applicant/Donors	German Red Cross (GRC) & European Civil Protection and Humanitarian Aid Operations (ECHO)

(Bangladesh Red Crescent Society, 2023)

According to information from the Director General of the Disaster Management Department, the Bangladesh Air Force is now using two rescue helicopters. They are now working on the third phase of a project to purchase tools for search and rescue operations as well as emergency communication in earthquakes and other catastrophes. Equipment for evacuating during earthquakes was previously purchased and stored by the Fire Service and Civil

Defense (Bangladesh Red Crescent Society, 2023). Ten organizations, each receive a portion of the equipment purchased under the program. Along with primary care and personal safety gear, the equipment includes life jackets, hard helmets, outerwear, hard hats, gum boots, and flame-resistant vests.
Following the earthquakes in Turkey and Syria, the Fire Service and Civil Defense called a divisional emergency meeting and prepared a proposal with roughly 14 points under the national plan for disaster management (2021–2025). They then sent the proposal to the ministry, which is now awaiting Cabinet approval. According to the Fire Service Division, about 500,000 buildings—or 60% of all buildings in Dhaka city—would collapse if an earthquake of magnitude 7 occurred right now and with the existing capacity (Mamun Abdullah, 2023). To fight any crisis, 13,000 volunteers from the Fire Service and Civil Defence as well as a reserve force from the Arms Forces Division serve as frontier rescue teams. The government had established a goal of educating 66,000 volunteers, of which 46,000 have already received post-earthquake situational awareness training (Mamun Abdullah, 2023). Additionally, there are 25,000 BNCC volunteers, 76,140 responders under the Cyclone Preparedness Program, and Red Crescent volunteers. The Fire Service wants to train 30,000 more emergency personnel (Mamun Abdullah, 2023).

4 Damage Scenarios

4.1 Vulnerability of Building

The rapid Visual Screening (RVS) Method was used to evaluate the earthquake susceptibility of the existing structures (residential, commercial, educational, religious, etc.), and it covered around 85% of the structures. Buildings that have value over the threshold are regarded as seismically secure. When the Federal Emergency Management Agency's cut-off score of "2" is taken into account, the number in the study area drops to 44 percent from 65 percent when the cut-off score of "1.5" is taken into account in terms of this country's economic potential (Jahan et al., 2011).

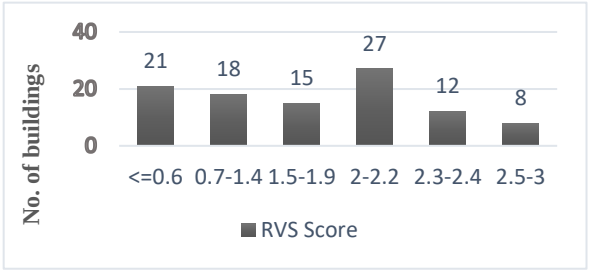

Figure 6. Analysis of vulnerability of building (Jahan et al., 2011)

4.2 Secondary Effects

Particularly in the crowded residential districts of the city, an earthquake-induced fire caused by short circuits and gas explosions can result in significant loss of life and property. Fire risks could also emerge from gas lines and connection ruptures (Al-Hussaini et al., 2003). There are no designated water lines for fighting fires in the city. (Al-Hussaini et al., 2003). When occupants seek to evacuate the building after an earthquake out of fear, restricted staircases and exits in high-rise buildings increase the risk of a stampede (Al-Hussaini et al., 2003). There is extremely little space between adjacent multistory buildings in some densely populated residential neighborhoods, especially in the ancient city, which can substantially obstruct rescue efforts in the event of a disaster or the ability of occupants to leave their homes (Al-Hussaini et al., 2003). Utility service interruptions brought on by an earthquake that lasts for weeks or months can be extremely painful for those affected and dangerous for the local economy (Al-Hussaini et al., 2003). The loss of a productive labor force, and infrastructure, forced emigration, disruption of supply lines, and reduction in individual earning capacity are all long-term detrimental effects of the earthquake on agricultural and national growth (Gauchan et al., 2017).

5 Pre-disaster preparedness

5.1 Long-Term Measures

Bangladesh needs to create an accurate seismic risk map that includes micro- and macro-zoning based on the frequency and intensity of seismic activity. Given its weak physical construction and dense population, Dhaka city in particular needs a precise seismic risk map (Islam, 2016). Schools, madrasas, hospitals, and prayer halls should all be constructed in a way that is earthquake-resistant because they will be used for large-scale gatherings during or after an earthquake. (Islam, 2016). Making all public facilities earthquake-proof, including water supply

systems, communication networks, and electricity lines, and installing earthquake-resistant elements in all structures in high-risk zones (Islam, 2016).

5.2 Medium-term measures

Increasing community members' awareness is needed of what to do in the event of an earthquake is a good place to start the process of community-based earthquake risk management. (Islam, 2016). Retrofitting of unstable constructions in seismically active areas should be done. It is crucial for the city of Dhaka because 60% of its buildings cannot withstand earthquakes (Islam, 2016).

5.3 Short-term measures

In an emergency, each family member should be able to turn off the gas and electrical mains. Due to the possibility of a delay in outside assistance, every family should always have a first aid kit on hand and ensure that every member is trained in its use (Islam, 2016). Liquids that can catch fire must be stored safely away from the flame. Large and hefty items should be placed on the floor or the lower shelves of storage shelves (Islam, 2016).

6 Pre-and Post-preventive measure techniques to reduce earthquake damage

6.1 Before Earthquake

Fire-fighting equipment should be checked and routine practice of the disaster prevention and rescue strategy should be followed. Consultation with authorized engineers or organizations is needed to inspect and repair any issues with the building (Islam, 2016). Routes to the shelters near the house and elsewhere should be known. The billboard, the sunshade, and any other potentially loose objects should be checked frequently (Islam, 2016).

6.2 Duties after an earthquake

Get rid of any fire risks. Small fires should be put out as soon as possible with the resources at hand to stop them from spreading. During an earthquake, objects may have moved and could fall, causing more damage or injuries (Islam, 2016). Aftershocks from earthquakes can worsen existing damage to shaky structures and everyone should get out of the damaged home as soon as possible to avoid aftershocks (Islam, 2016). To get the most recent emergency instructions and information, a portable, battery-operated radio should be followed which can be the main information source if the power is out. Aftershocks need to be anticipated and distance should be kept from damaged areas and observation of downed power lines or ruptured gas lines should be kept. (Islam, 2016). Animals should be observed. Utmost caution should be used when entering buildings. (Islam, 2016).

7 Recommendations

After reviewing all these papers, we would like to forward some recommendations on this topic to reduce the damage and losses from earthquakes.

- Create awareness: There should be widespread awareness of earthquakes among city people. Additionally, it ought to organize seismic demonstrations to teach people how to flee a catastrophic earthquake. Radio and television should take the necessary precautions to broadcast information on how to prepare for earthquakes as well as basic dos and don'ts.
- Computerized Data Warning System: To acquire a more precise forecast of the earthquake, a computer-based earthquake prediction modeling system needs to be built.
- Simulation Exercises: The Armed Forces Division intends to conduct drills that simulate combat situations. To assess and enhance the preparedness of the agencies concerned for earthquakes, similar exercises may be carried out.
- Separate Department for Earthquake Study: A separate department for earthquake study might be planned in any university or other educational setting. On this, both students and scientists can conduct research.
- Produce government organizations: The implementation of sensible disaster management policies and plans, community education and training initiatives, proper observance of the national building code, effective coordination between governmental and non-governmental organizations, and the expansion of adequately staffed rescue teams can all contribute to keeping the impact within manageable bounds.
- Medical Team: It is necessary to designate distinct mobile medical teams at the district level. The Health Ministry and the Ministry of Disaster and Relief can collaborate on this.

8 Conclusion

This critical assessment underlines the significance of Dhaka's earthquake preparedness and the demand for efficient preventative measures. In the context of Dhaka city, it has highlighted many significant conclusions. To identify high-risk locations seismic hazard assessment and mapping methodologies are crucial. This information helps policymakers and urban planners to create tailored earthquake readiness measures. To guarantee the construction of structurally sound structures and infrastructure in Dhaka's earthquake-prone areas, building standards and regulations are crucial. Preventive measures in Dhaka city should include land-use planning and zoning regulations, education and awareness programs, and post-preventive measures such as search and rescue operations, medical response, temporary shelters, and rehabilitation efforts to support affected communities and facilitate recovery. The given recommendations in our paper need to be studied more for a better response. Overcoming challenges such as limited resources, urbanization, and dense population necessitates collaboration among the government, stakeholders, and external support. Capacity building, knowledge sharing, and continuous research are crucial to enhancing Dhaka's preparedness for earthquakes.

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