Earthquake Risk Assessment in Hilly Region: A Case Study of Bandarban Municipality, Bangladesh

Jobaidul Alam Boni¹, Riffat Islam¹, Afrin Hossain Anni², Sanzida Sharmin Shoma¹

¹Resilient Cities and Urban Risk Management Department, Asian Disaster Preparedness Center (Bangladesh office), Bangladesh.
²Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology.

*Corresponding Author: Jobaidul Alam Boni

Abstract

Unplanned and haphazard urbanization in Bangladesh has become a major concern over the decades. About 34% populations are now living in urban areas and by 2050 the number will be about 56%. Every year the country is affected by several natural hazards like Flood, Cyclones, Landslides etc. Although there was no major earthquake in the recent past, but due to geographic location, historical evidences and current trend of development the country especially urban centers are vulnerable to Earthquake. It is therefore essential to have a realistic understanding on the nature, severity and consequences of likely damage that a possible event of earthquake may bring upon. Researchers have identified a number of active faults in the country that may generate moderate to major earthquakes. With a view to understanding the possible damage and loss for the major hill towns of Bangladesh, Chittagong Hill Tract Development Facility (CHTDF) of the United Nations Development Programme (UNDP) took an initiative during 2009 for conducting town level Earthquake Risk Assessment. The assessment was conducted using HAZUZ Software Packages developed by United States Federal Emergency Management Agency (FEMA) and National Institute of Building Sciences. In this research paper, it is intended to update the seismic risk assessment results to understand the dynamics of Earthquake risk for Bandarban Municipality. For updating demographics and building inventories, BBS 2011 data for Bandarban and satellite images were used. The hazard scenario, soil classification, liquefaction susceptibility, landslide susceptibility and water depth data for the risk assessment were used as same as the CHTDF analysis. The main focus of the risk assessment is to understand the scenarios for Building damage rates and casualty rate. The updated result will be useful for the Municipality Authority for Preparedness Initiatives in Bandarban.

Keywords: Earthquake, Hazard, Hill Tract, Building Damage Rate, Casualty Rate.

Introduction

Bangladesh has a long history of affecting natural disasters. Tropical cyclones, storm surge and flood have been a common figure for the people of this country. Good news is damage and casualties of these hazards have decreased over the last decade due to strong mitigation and preparedness measure. But there is growing apprehension of another big hazard Earthquake has raised a major concern. Bangladesh is located in the tectonically active Himalayan orogenic belt, which has developed through the collision among the Indian, Arabian, and Eurasian plates over the last 30-40 million years (Ma) [1]. Great Bengal Earthquake or Great Assam Earthquake of magnitude 8.7 in 1897 was originated from this region. The earthquake left masonry buildings in ruins over 400,000 square kilometer area and was felt over 650,000 square kilometer from Burma to Delhi [2]. Greatest earthquake inside Bangladesh ‘The Srimangal Earthquake’ in 1918 was also originated from this region and damaged hundreds of masonry building in the Sylhet and its adjacent districts [3]. Through this region
has not faced a major earthquake in recent years, but several moderate to large earthquake magnitudes are common in this region and will continue to occur as long as the tectonic deformation continues. So there is a major apprehension of a big earthquake from this region and poses a real and serious threat of people, property, economy and development of the country.

Earthquake risk is the probability of encountering a predetermined level of seismic hazard in a given time exposure.

With concentration of population and values in urban centers, earthquake risk assessment using advanced methodologies has become essential for the reduction of seismic risk in urban areas and for effective and efficient mitigation schemes. This study focuses of the seismic risk assessment of Bandarban Municipality of Bangladesh in terms of Building Damage rates and Casualty Rate using HAZUS-MH methodology.

HAZUS-MH is a geographic information system-based natural hazard analysis tool developed by the official Federal Emergency Management Agency (FEMA) in the USA and National Institute of Building Sciences (NIBS) for potential loss estimation and risk evolution of hazard primarily like earthquake, flood and cyclone. Despite the fact that it was created with the US, the HAZUS toolset has been adopted by emergency management organizations worldwide.

To fortify the Earthquake Disaster Management System and more particularly to achieve an exemplar shift from reactive response to a preemptive risk reduction culture, the Earthquake Risk Reduction Programme (ERRP) under Chittagong Hill Tract Development Facility (CHTDF) of the United Nations Development Programme (UNDP) was being implemented in order to conduct town level earthquake risk assessment during 2009. As a continuation and upgradation of this project, this research has been performed to achieve the earthquake risk situation of Bandarban Municipality by a survey conducted in 2011.

Objective of the Study

The main objective of this study is to update the seismic risk assessment result attained previously and show a clear comparison between the two. Estimating losses is vital to decision-making at all levels of government, giving a premise to creating mitigation plans and policies, emergency preparedness and response and recovery planning. Therefore this study aims to focus the present scenario of Bandarban municipality by evaluating building damage rates and casualty rates using advanced methodology.

Methodology

Risk assessment is the most operational tactic to addressing the impact of natural hazards in a region. Understanding the statistics of plausible losses and reconstruction costs due to earthquake creates powerful incentives to develop planning options and tools to cope with risk. The scope of work conducts the risk assessment of general building stock and essential facilities (hospitals, emergency operation centers, schools) of Bandarban Municipality to update the previous assessment conducted by CHTDF project. Comparing the risk assessment results so obtained enables to depict a better scenario of earthquake risk in Bandarban municipality.

The risk assessment has been executed using HAZUS-MH 2.1 software package. For risk assessment analysis of Bandarban municipality, default database for United States has been replaced with Bangladesh database for that particular municipality. Peak Ground Accelerations and Spectral Response Accelerations are used to characterize ground shaking quantitatively. HAZUS methodology combines the general building stocks on a cluster basis, yet is site-specific for essential facilities and lifelines. The framework of the HAZUS risk assessment methodology comprises six interdependent major modules.

They are Potential Earth Science Hazard, Direct Physical Damage, Inventory, Induced...
Physical Damage, Direct Economic/ Social Losses, Indirect Economic Losses respectively [4]. Among these, following three modules have been considered in this study:

1. **Potential Earth Science Hazards**
   - **Ground Motion**
   - **Ground Failure**

2. **Inventory**
   - (General Building Stock, population)

3. **Direct Physical Damage**
   - **General Building Stalk**
   - **Building Damage**

Fig 1: Flowchart showing risk assessment methodology using HAZUS.

**Potential Earth Science Hazards (PESH)**

PESH module estimates ground motion and ground failure. Ground motion demands, for example, peak ground acceleration and spectral acceleration, are estimated based on earthquake source parameters, attenuation relations and geological data. Ground failure which is caused by landslides, liquefaction and surface fault rupture are quantified by permanent ground deformation (PGD). This PGD is determined based on topological data, geological data and ground water depth.

**Geological Data for Bandarban**

For risk assessment, Hazus requires several hazard maps as input like Site Class Map (NEHRP – 1997), Ground Water Table, Liquefaction Susceptibility Map, Landslide Susceptibility Map. Hazus Requires this input hazard maps in a specific format and in shapefiles. Geological maps for Bandarban are shown below (Fig 2, Fig 3, Fig 4).
Hazard Scenario

According to research there are five major fault zone- Madhupur fault (MF), Dauki Fault (DF), Plate Boundary Fault -1 (PBF-1), Plate Boundary Fault -2 (PBF-2) and Plate Boundary Fault -3 (PBF-3) which has the potential to cause an earthquake of more than 7.5 magnitude [5]. In this study we considered three scenarios- first scenario is the special scenario where a magnitude-6 earthquake is occurring directly beneath the city to simulate shallow crustal earthquake. The second Scenario earthquake is from fault PBF1 [6]. The Third scenario is from PBF2. PBF3 , MF, DF are not considered as they are further away from study area. The following table shows earthquake scenario for Bandarban municipality.

| Table 1: Earthquake Scenarios for Bandarban Municipality |
|----------------|---------|--------|----------|------------|-----------------|
| Lat            | Long    | Mw     | Depth    | Dip Angle | Fault type      | Description     |
| 22.64          | 92.18   | 6      | 6.5      | 143        | Reverse         | Mw6.0 beneath city |
| 22.47          | 91.58   | 8.5    | 3        | 160        | Reverse         | Plate Boundary Fault -1 |
| 23.39          | 91.14   | 8      | 3        | 40         | Reverse         | Plate Boundary Fault -2 |

Figure 3: Hazus Compatible Liquefaction Map for Bandarban Municipality

Figure 4: Hazus Compatible Landslide Susceptibility Map for Bandarban Municipality

Source: Damage Estimation Maps and Reports and Identification of High/Moderate/Low Risk and Vulnerable Zone of Rangamati, Bandarban and Khagrachari Municipality Area
Inventory

The inventory contains tools for describing the physical infrastructure and demographics of the study area. It uses standardized classification systems for the groups of components at risk: general building stock. These groups are defined to address distinct inventory and modeling characteristics. An extensive amount of GIS database is utilized to develop dataset for these groups.

The general building stock is classified by occupancy (residential, commercial, etc.) and by model building type (structural system and material, height). Characteristic relationships between occupancy and structure types are developed based on building survey data. Population data is derived from the average of building occupants per unit building floor area, which is obtained from the building survey. Estimates for building exposure are based on for building replacement costs (dollars per square foot) for each model building type and occupancy class that has been modified to local/Bangladesh cost. Dataset of essential facilities lifelines are developed from GIS database and secondary sources (service provider authority), clarified and enhanced through the field survey.

It has been estimated that in Bandarban Municipality there are a total of 8170 buildings. Among them about 22% of them are concrete buildings, 58% of them are masonry buildings and 20% of the buildings are bamboo and masonry structure. According to BBS 2011 total population of Bandarban is 41434 among which 23221 are male and 18213 are female.

Direct Physical Damage

This module provides damage estimates in terms of probabilities of occurrence for specific damage states given in a specified level of ground motion and ground failure.

For buildings, the capacity-demand spectrum method as implied by HAZUS is utilized for the estimation of seismic demand. The estimated seismic demand is, thus, used to determine the probability of being in a particular damage state through fragility functions. However, the seismic performance of buildings in Bangladesh is different from that of United States.

As a result, a new set of building capacity spectrum and fragility functions were developed in CHTDF based on the field survey data and comprehensive numerical analyses. In this study the capacity spectrum and fragility functions were used as CHTDF report on Damage Estimation Maps and Reports and Identification of High/Moderate/Low Risk and Vulnerable Zone of Bandarban Municipality Area.

Hazus Calculation and Analysis Result

Scenario 1: For scenario 1 Hazus estimates that about 67% buildings will be at least moderately damaged. Also 1336 building will be damaged beyond repair. Among the building types masonry buildings will be damaged heavily. Almost 53% of the masonry building will be extensively damaged and 23% of the masonry building will be completely damaged. Following table (Table 1) shows Expected Building Damage by Building Type in Bandarban Municipality Area for Scenario Case 1

<table>
<thead>
<tr>
<th>Structure type</th>
<th>None</th>
<th>Slightly Damaged</th>
<th>Moderately Damaged</th>
<th>Extensively Damaged</th>
<th>Completely Damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Structures</td>
<td>667</td>
<td>310</td>
<td>269</td>
<td>406</td>
<td>138</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>157</td>
<td>790</td>
<td>1260</td>
<td>1447</td>
<td>1086</td>
</tr>
<tr>
<td>Tin shed houses and bamboo</td>
<td>292</td>
<td>430</td>
<td>418</td>
<td>391</td>
<td>112</td>
</tr>
<tr>
<td>Total</td>
<td>1116</td>
<td>1530</td>
<td>1947</td>
<td>2244</td>
<td>1336</td>
</tr>
</tbody>
</table>

Scenario 2: For scenario 2 Hazus estimates that about 70% buildings will be at least moderately damaged. Also 1336 building will be damaged beyond repair. Among the building types masonry buildings will be damaged heavily. Almost 59% of the masonry building will be extensively damaged and 27% of the masonry building will be completely damaged.
Table 3: Expected Building Damage by Building Type in Bandarban Municipality Area: Scenario Case 2

<table>
<thead>
<tr>
<th>Structure type</th>
<th>None</th>
<th>Slightly Damaged</th>
<th>Moderately Damaged</th>
<th>Extensively Damaged</th>
<th>Completely Damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Structures</td>
<td>721</td>
<td>269</td>
<td>234</td>
<td>462</td>
<td>101</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>290</td>
<td>616</td>
<td>1050</td>
<td>1502</td>
<td>1282</td>
</tr>
<tr>
<td>Tin shed houses and bamboo structure</td>
<td>384</td>
<td>364</td>
<td>365</td>
<td>432</td>
<td>98</td>
</tr>
<tr>
<td>Total</td>
<td>1395</td>
<td>1249</td>
<td>1649</td>
<td>2396</td>
<td>1481</td>
</tr>
</tbody>
</table>

Scenario 3: For scenario 3 Hazus estimates that about 3% buildings will be at least moderately damaged. Also 1 building will be damaged beyond repair. Among the building types masonry buildings will be damaged heavily.

Table 4: Expected Building Damage by Building Type in Bandarban Municipality Area: Scenario Case 3

<table>
<thead>
<tr>
<th>Structure type</th>
<th>None</th>
<th>Slightly Damaged</th>
<th>Moderately Damaged</th>
<th>Extensively Damaged</th>
<th>Completely Damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Structures</td>
<td>1733</td>
<td>43</td>
<td>9</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Masonry Structures</td>
<td>4213</td>
<td>359</td>
<td>153</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Tin shed houses and bamboo structure</td>
<td>1583</td>
<td>51</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>7529</td>
<td>453</td>
<td>170</td>
<td>17</td>
<td>1</td>
</tr>
</tbody>
</table>

Summary of Findings

Findings from Analysis of Hazus calculation, seismic risk assessment of three individual cases can be understood for Bandarban Municipality. The following figure (Fig:5) shows comparison of total number of building damage (Concrete structures, Masonry Structures, Tin Shed houses and Bamboo Structures among these three scenarios. From Fig 5, it can be found that earthquake has least effect on damage of structures for the case of Scenario 3, whereas, the damage situation for both scenario 1 and scenario 2 is quite similar.

![Fig 5: Comparison graph showing damage situation for different types of earthquake scenarios.](image)

Analysis of seismic risk in Bandarban municipality with updated data shows a different damage scenario of various types of structures (Concrete, Masonry, tin and bamboo) from the previously estimated data of CHTDF. The following figures (Fig 6, Fig 7, and Fig 8) delineate the clear difference between the two analyses obtained so far. Fig 5, Fig 6 and Fig 7 shows comparison graph in case of Scenario 1, Scenario 2 and Scenario 3 respectively. In some cases, damage of a particular type of structure is higher in 2009 whereas in cases damage rate is higher in 2011. Several parameters may create such deviation, for example, a previously held hazard.
Fig 6: Comparison graph showing damage scenario (Scenario 1) of structures between CHTDF analysis 2009 and 2011 review.

Fig 7: Comparison graph showing damage scenario (Scenario 2) of structures between CHTDF analysis (2009) and 2011 review.

Fig 8: Comparison graph showing damage scenario (Scenario 3) of structures between CHTDF analysis (2009) and 2011 review.
Conclusion

Bandarban municipality is developing a lot recent years and lots of new structures and facilities are introduced to its infrastructure inventory every day. It also lies close to Plate Boundary Fault-1 and Plate Boundary Fault-2. Both research stated that hundreds of buildings are at great risk in case of a big earthquake event from Plate Boundary Fault-1. So necessary preparedness and mitigation step are required for the Bandarban Municipality. Detailed structural vulnerability assessments of the existing buildings are necessary to identify the more vulnerable ones and retrofitting and renovation procedures need to be taken immediately. A spatial contingency plan showing the evacuation routes and open places is needed to mitigate the casualties and losses in case of a major event. A shortcoming of this research is the damage assessment was done only for buildings, but a detailed damage assessment including life lines and transportation infrastructure will show more realistic result of the current condition.

References