GIS APPLICATION IN DISASTER MANAGEMENT

Humaira Zahir\textsuperscript{1}, Mohammad Ahmeduzzaman*\textsuperscript{1}

\textsuperscript{1}Lecturer, Department of Civil Engineering, Stanford University, Dhaka, Bangladesh.

ABSTRACT

Over the past decades, urbanization in Bangladesh has been rapidly taking place without proper guidance. As a result many of the urban centers have developed haphazardly. These urban centers are fast growing and influence the economic developments of the country. It is therefore essential to have a realistic understanding on the nature, severity and consequences of likely damage or loss that a possible event of earthquake could cause. A strong earthquake affecting a major urban center like Dhaka may result in damage and destructions of massive proportions and may have disastrous consequences for the entire nation. The objective of this study is to determine the major type of disasters occurring in different times, to identify the disaster prone areas of Bangladesh, major damages due to disaster, probable loss estimation and develop maps describing the seismic vulnerability characteristics of the existing building stock, essential facilities, and lifeline facilities in Dhaka city corporation area. The base map of Dhaka has been developed in a GIS database for further vulnerability assessment. The building inventory was developed as a tool for assessing the seismic vulnerability of existing building. The building inventory consists of data that will be used to calculate the seismic vulnerability, such as building structural type, the building occupancy class, the number of building occupants during the day and the night, the seismic vulnerability characteristics of building etc. From the collected database and vulnerability maps, the major findings regarding to the seismic vulnerability of building, lifeline and essential facilities can be summarized as the followings: The vulnerability factor which is the most common in Dhaka city is soft story (52\%). Among occupancy classes in all city corporation areas, residential class is the major proportion. Their proportions are 81.3\%, in Dhaka most buildings with concrete slab-column frames are constructed less than 10 years. On the other hand, most masonry buildings with concrete floors ages more than 10 years. Also, light reinforced concrete buildings are found to be older than reinforced concrete buildings.

Keywords: Vulnerability, earthquake, disaster, GIS, consequence.

1. INTRODUCTION

1.1 Background Information

Over the past decades, urbanization in Bangladesh has been rapidly taking place without proper guidance. As a result many of the urban centers have developed haphazardly. These urban centers are fast growing and influence the economic developments of the country. It is therefore essential to have a realistic understanding on the nature, severity and consequences of likely damage or loss that a possible event of earthquake could cause. A strong earthquake affecting a major urban center like Dhaka may result in damage and destructions of massive
proportions and may have disastrous consequences for the entire nation. This study presents the vulnerability mapping of Dhaka city corporation area. The objective of this study is to develop maps describing the seismic vulnerability characteristics of the existing building stock, essential facilities, and lifeline facilities in Dhaka City Corporation. This study is limited to the City Corporation area of Dhaka, though a significant number of areas outside the jurisdiction of City Corporation areas are densely populated and unplanned & haphazard development is taking place over there. For example, Keraniganj, one of the densely populated areas in Bangladesh with a population of more than one million, is not covered by this study despite of its adjacent location to the DCC area.

1.2 Study Area

For determining disaster intensity, whole Bangladesh is considered as study area. For vulnerability assessment Dhaka is considered as the study area. Dhaka has an area of 136.4 sq. km covering 90 wards of DCC and cantonment and Zia International Airport areas. The cantonment and airport areas are defined as ward 91. The city current population is 7.2 million (projected based on 2001 census). Dhaka is the capital city of Bangladesh located on the banks of the Buriganga River. The city is the center for political, economic and cultural life in Bangladesh. Dhaka and its surrounding metropolitan area has a total population of 11 million, spread over a total area of 815.85 sq. km., with a population density of 14,608 persons per sq. km. The city has become the 11th most populous city in the world. However, the population within the DCC area stands at approximately 7 million. This population is growing by an estimated 4.2% per annum, one of the highest rates amongst Asian cities. The continuing growth reflects an ongoing migration from rural areas to the Dhaka urban region, which accounted for 60% of the city’s growth in the 1960s and 1970s. Although Dhaka has never had any experience of earthquake disasters in the past, even then the earthquake of December 19, 2001 with a magnitude of 4.5 certainly is an indication of its earthquake source and vulnerability. In addition, micro-seismicity data also supports the existence of at least four earthquake source points in and around Dhaka. The earthquake disaster risk index has placed Dhaka among the 20 most vulnerable cities in the world. Dhaka with its population of around 11 million and enormous poorly constructed and dilapidated structures signifies extremely vulnerable conditions for massive loss of lives and property in the event of a moderately large earthquake.

2. METHODOLOGY

2.1 Base Map Development

The data are collected from different sources. At first the shape file of Bangladesh is made from JPG image. This shape file is used for determining the disaster intensity of Bangladesh. For Dhaka, the base map has been developed from existing maps of Dhaka City Corporation. In Dhaka, base maps have been developed by a number of organizations for their respective purposes. Dhaka City Corporation (DCC), for example, has developed ward-level base maps showing building footprints and road layout. But there is no attribute information attached with these base maps. Moreover, the DCC ward-level base maps cover 75 out of 90 wards within its jurisdiction. RAJUK, the capital development authority, has developed base maps
for its entire jurisdiction (590 sq. miles), but RAJUK does not have detail footprints of Uttara, Gulshan, Baridhara, Banani and Cantonment areas of City Corporation Boundary. Moreover, the building use categorization developed by RAJUK lacks sufficient details required for vulnerability assessment. Survey of Bangladesh (SOB) has spot level and building footprint maps. Spot level maps of SOB were used for generating contour maps, but building footprint maps of SOB is not as informative as required. Considering the availability of base maps from various different sources, initiatives were taken to develop a comprehensive base map of Dhaka City Corporation area for vulnerability assessment by compiling base maps from various sources with satellite images.

2.2 Building Inventory Development

To properly assess the seismic vulnerability of existing building stock, it is required to know the building structural type, the building occupancy class, the number of building occupants during the day and the night, the total floor area, the seismic vulnerability characteristics of building, etc. Some of the above listed information can be obtained from the existing building databases, but the rest cannot. Three level building surveys have been carried out in this study. The building attributes collected at this survey level were: Number of story, Occupancy class, Structural type, Number of occupants during the day and the night, Age of the building, number of soft story, number of heavy overhangs, number of short columns, visible physical condition (poor/average/good) etc.

3. RESULTS AND DISCUSSION

The major disasters of Bangladesh are flood, cyclone, tsunami, river erosion etc. Data are collected about when and where these disasters occur and about their intensity. It was observed that the most disaster prone area of Bangladesh are Chittagong, Rangpur, Rajshahi and Sylhet. A Digital Elevation model is also developed for the disaster intensity.

3.1 Relationships between Occupancy and Number of Building Occupants

Number of building occupants is an important parameter for earthquake loss estimation of a number of casualties, a number of refugees and etc. Due to difference in number of building occupants during day and night, it is also important to know the number of building occupants in the different period of time. Idealistically, we would prefer to use the exact
number of occupants in each occupancy class however such a data is not exist in Bangladesh and it is impossible for the scope in this project to conduct such a survey for every building. Because data of occupancy class is available in building stock of the study areas, we can alternatively approximate the number of building occupant if we know the relationship between number of building occupants and occupancy class. In this study, number of occupants in each building occupancy classes is calculated using an average number of occupants per floor area times the building floor area.

Figure 3: Frequency of the Number of Occupants in Single House at Day and Night in Dhaka

3.2 Relationships between Structural Type and Building Age

In the local construction practice, the popularity in application of each structural type is varied by era. For example, most of concrete slab-column frames (C4) were built during the last decade while masonry buildings with concrete floor (BC) were constructed more than 30 years ago. Relationships between structural type and building age for the three cities are demonstrated in Graph.

Figure 4: Relationships between Structural Type and Building Age for Dhaka

3.3 Relationships between Structural Type and Apparent Building Quality

The level of building damage during earthquakes depends on the apparent building quality which is, in turn, related to the quality of construction materials, workmanships and building maintenance. Well-trained observers can classify a building’s quality as roughly good,
moderate, or poor. From the survey results, relationships between apparent building quality and structural type in the three cities are illustrated in figure.

3.4 Relationships between Structural Type and Vulnerability factors

For concrete buildings, 5 significant vulnerability factors are observed including (1) soft story, (2) heavy overhang, (3) short column, (4) pounding possibility between adjacent buildings, and (5) topographic effects (buildings constructed on slope ground). Relationships between structural type and the presence of the above vulnerability factors are shown in figure.

Soft first story buildings are one of the most vulnerable structures during severe earthquakes. A soft story in a building happens when the ground story has less stiffness and strength compared to the other stories. Normally, this situation can be resulted from the building that locates along the side of the main street because the first story is used for a commercial space that has opening between the frame members for customer circulation. Besides, further irregularity can be caused by having taller clearances and different axis systems. Hence, the soft story buildings exhibit a less safe behavior than the similar regular structures during moderate and severe earthquake. Heavy overhanging floors in multistory buildings lead to irregularity in stiffness and mass distributions. From the view point of earthquake engineering, these irregular plan shapes are undesirable because they cause an inappropriate dynamic behavior when subjected to horizontal earthquake ground motion. For example, torsional moment in buildings can be increased during earthquakes due to non-symmetric distribution of mass and stiffness. Short columns can be created by the arrangement of infill walls or other non-structural, architectural members. Sometimes, the infill walls are shorter than the columns and windows may be opened at the top of the periphery shear walls at the basement of the structures. In such cases, the column length becomes shorter and stiffer. Due to the increase in stiffness, the columns share more flexural moment and this causes the increase in shear forces. Therefore, these columns usually sustain heavy damage during strong earthquake.
Figure 6: Relationships between Structural Type and Presence of Vulnerability Factors for Dhaka

Among the surveyed buildings in Dhaka, about 53% were found with soft story. Soft story is commonly present in the recently constructed buildings where ground floor is used as a car park. Among the surveyed buildings under this project, about 41% of buildings in Dhaka were found with heavy overhangs. These buildings were found in both old and new city areas. Earthquake damage in short columns is pretty common. During this study, the presence of short columns was found in 34% in Dhaka. There might be a substantial short column effect in the city as well, if a major earthquake event occurs. The building density of Dhaka city and the types of buildings are shown in the following figure.

Figure 7: Building density  Figure 8: Types of buildings

3.5 Occupancy Class and Essential facility

Occupancy class is an important factor determining economic loss, since the building value is primarily a function of building use (i.e., hospitals are more valuable than most commercial buildings, primarily because of their expensive nonstructural systems and contents, not because of their structural systems). Occupancy class also relates to the number of occupants, for example, a lot of people (workers) work for industrial buildings in the daytime while a few people stay in residential buildings in this time. In the three cities, 27 occupancy classes are grouped into residential, commercial, industrial and essential facilities.

Figure 9: Dhaka city building types
3.6 Vulnerability Factor

A vulnerability map shows the degree of loss to a given element at risk resulting from the occurrence of the specified earthquakes. Based on the developed database for the general building stock, vulnerability maps showing the ward-wise distribution of the following vulnerability factors are created: occupancy class, structural type, building age, visible physical condition, and population at risk. In addition to the above, the maps showing vulnerability of concrete buildings (only for C3L, C3M, LCL and LCM structural type) in the city is developed. The statistics obtained from the field survey including presence of soft story, presence of heavy overhang, apparent building quality, presence of short columns, pounding possibility between adjacent buildings, and topographic effects are used in the development of this map.

![Figure 10: Vulnerability Value](image)

4. CONCLUSION

Based on the developed database for the general building stock, vulnerability maps are created. Each map shows the ward-wise distribution of the following vulnerability factors including occupancy class, structural type, building age, visible physical condition, and population at risk. Moreover, the maps showing vulnerability of concrete buildings in the three cities are developed by using the statistics obtained from the field survey including presence of soft story, presence of heavy overhang, apparent building quality, presence of short columns, pounding possibility between adjacent buildings, and topographic effects. The significant findings from the building vulnerability assessment are concluded as followings:

- Among occupancy classes in all city corporation areas, residential class is the major proportion. Their proportion is 81.3% in Dhaka.
- Among structural type of non-engineered buildings from the survey results, BF (brick in cement mortar masonry with flexible roof) is the most common type in all cities. For engineered buildings, C3 (concrete frame with masonry infill walls) is the most common class.
- From the survey results, age of buildings has been related to structural types. For example, it was found that most buildings with concrete slab-column frames (C4) are constructed less than 10 years. On the other hand, most masonry buildings with concrete floors (BC) ages more than 10 years. Also, light reinforced concrete buildings (LC) are found to be older than reinforced concrete buildings (RC).
As expected, all residential types have an average number of occupants per floor area in the daytime less than the nighttime; nevertheless, the other occupancy classes as commercial, industrial, government and education have the number of occupants in the daytime more than the nighttime.

The vulnerability factor which is the most common in Dhaka city is soft story (52%).

REFERENCES

Cauzi C, Faccioli E. Broadband (0.05 to 20 s) prediction of displacement response spectra based on worldwide digital records. Journal of Seismology. 2008.


Vukazich SM, Selvadurai A, Jessica T. Conducting a Soft First-Storey Multi-family dwelling survey: An Example using Santa Clara County, California.