Seismic Vulnerability Assessment of Buildings in Rajshahi City

M.T. RAHMAN[1], N.H.M.K. SERKER[2]

[1]Executive Engineer, Pabna Municipality, Pabna and Ex. Master's student of RUET, Bangladesh (tabibur_rahman@yahoo.com)
[2]Department of Civil Engineering, RUET, Bangladesh (kamrujjaman.serker@ruet.ac.bd)

Abstract

Rajshahi is one of the largest cities of Bangladesh and is lying under the seismic zone-I (BNBC-1993). The city is not free from seismic and other disaster related threats because of high growth of population and construction of building structure considering a little and no seismic loading. It is obvious to update the building and infrastructure inventory to evaluate the seismic risk and to establish proper mitigation management plans for disaster reduction. Therefore field survey and inspection were used to develop an inventory of buildings in the selected areas of Rajshahi City Corporation. The study results indicate that most of the buildings are older than thirty years that is buildings were constructed before adopting Bangladesh National Building Code of 1993. Overall field inventory data are analyzed by Rapid Visual Screening method. The result shows that most buildings have probability of Grade 1 damage, i.e. very low risk, considering the limitation of RVS in the context of Bangladesh.

Keywords: *Vulnerability Assessment; Rapid Visual Screening Method; Seismic Risk; Infrastructure Inventory.*

1 Introduction

Bangladesh is one of the seismically vulnerable countries in the world and continuously facing potential earthquake threat and damage (Alam et al, 2009). Earthquake is one of the most devastating natural hazards and in recent years it has become more frequent in Bangladesh. An earthquake of even medium magnitude on Richter scale can produce a mass graveyard in major cities of the country because of rapid and unplanned urbanization with high population density and defiance of Building codes are also increasing the vulnerability against earthquake. Earthquake risk of any place largely depends on its topography, population density, geology, building density and construction quality, and finally the coping strategy of its people. Thus, to address these issues, vulnerability assessment against earthquake is a unique approach.

The urban areas have experienced very rapid population growth during the last few decades due to economic factors such as decrease in economic opportunities in rural areas and consequent migration to the urban areas. The rapid urbanization has led to proliferation of slums and has adversely impacted the resources in urban areas. Most recent constructions in the urban areas consist of poorly designed and constructed buildings (Ahmed et al, 2010). The older buildings even if constructed in compliance with relevant standards at that time, but may not comply with the more stringent specifications of the latest standard. There is an urgent need to assess the seismic vulnerability of buildings in urban areas of Bangladesh as an essential component of a comprehensive earthquake disaster risk management policy. Detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can only be performed on a limited number of buildings (Sinha and Goyal, 2013). It is therefore very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings.

The main objectives of this study are to develop a data base of seismically vulnerable buildings in some part of Rajshahi city. The specific objectives are (i) to classify buildings depending on structural form (ii) to develop an inventory of existing buildings in the study area (iii) to assess the seismic vulnerability of buildings by Rapid Visual Screening (RVS) method.

2 Seismic Vulnerability Assessment Techniques

There exist a good number of techniques or methodologies to assess the seismic vulnerability building such as RVS, Turkish method, FEMA 310, Euro code 8, New Zealand guide lines, NCR Guide lines, Damage probability matrices, Analytical method etc. In each method, different vulnerability factors (e.g. number of storey, age, structure type, occupancy classes, pounding effect, plan and vertical irregularity, presence of short column, soft storey, heavy overhang and mobile phone tower, soil condition and physical condition of building etc) are considered. In this study RVS method was chosen and vulnerability assessment was done.

2.1 Rapid Visual Screening Method

Rapid Visual Screening was first proposed in the US in 1988, which was further modified in 2002 to incorporate latest technological advancements and lessons from earthquake disasters (FEMA 154, 2002). These screening procedures have been widely used in many countries over the world even though it was developed for typical construction in the US. The most important feature of this procedure is that it permits vulnerability assessment based on walk-around of the building by a trained evaluator. The evaluation procedure and system compatible with GIS-based database and also permits use of the collected building information for a variety of other planning and mitigation purposes. The screening method is performed without any structural analysis. The inspection, data collection and decision making occurs generally on site and takes little time to complete the operation. RVS techniques can be implemented in both rural and urban areas. The RVS technology is only acceptable for the buildings not for the bridges or lifeline structures.

Basic structural hazard scores for various building types are provided on the RVS form. The screener modifies the basic structural hazard score by identifying and circling score modifiers which are then added to the basic structural hazard score to arrive at a final structural score, S. The basic structural hazard score, score modifiers, the final structural scores (S), all are related to the probability of building collapse. The result of screening procedure is a final score that may range above 10 or bellow 0, with a high score indicating good expected seismic performance and low score indicating a potentially hazardous structure. If the score is 2 or less, a detail evaluation is recommended. On the basis of detailed evaluation, engineering analysis and other detailed procedures, a final determination of seismic adequacy and need for rehabilitation can be made.

2.2 Damage Level as Function of RVS Score

The probable damage can be estimated based on the RVS score and is given on Table 1. However, it should be realized that the actual damage will depend on a number of factors that are not included in RVS procedure. As a result, this table should only be used as indicative to determine the necessity of carrying out simplified vulnerability assessment of the buildings.

Table1. Expected damage level as function of RVS score

RVS Score	Damage Potential
S<0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3<S<0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7<S<2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0<S<3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S>3.0	Probability of Grade 1 damage, negligible to slight damage

3 Description of the Study Area

Rajshahi city corporation (RCC) is located in the northern region of Bangladesh (Figure 1) and is the fourth metropolitan city of Bangladesh located on the bank of the river Padma. Rajshahi city was simply a district town prior to 1947 that had become a divisional headquarter in 1947. Rajshahi town gained municipal status in 1876 during British reign and finally achieved the status of City Corporation in 1987. Over the years, it grew as the administrative headquarter of the Rajshahi Division. Total area of Rajshahi city is 96.69 sq.km. and population are 491,425 (BBS, Census 2011).

3.1 Base of Economic Activities in RCC area

Industries, informal sector, public sector institutions and service sector provide the major bases for economic activities in the study area. Markets are the important centers of the economic activities in Rajshahi city.

Industrial base

Rajshahi Textile Mills, Rajshahi Jute Mill and Rajshahi Sugar Mill are the major industries in the study area. The Bangladesh Small and Cottage Industries Corporation industries estate established at Sopura is an important industrial base in the study area.

Markets

Shaheb Bazar area, RDA market and adjacent areas, New Market and Hawkers' Market are the major shopping centres in the city. Markets at Harogram, Talimari and Binodpur and Katakhali are important local shopping centres. The shops in the city markets and shopping centres deal in all sort of consumer goods, both durables and daily necessities. Major item are textile goods, ready-made garments, grocery articles, crockery's, stationeries and books, jewelries, electronics and hardware etc.

3.2 Existing Land Use pattern of RCC Area

The Rajshahi City Corporation area is mainly the built up part of the urban area of Rajshahi. Though it is a municipal area a large part of it is used for agriculture purpose. According to the report of physical feature survey by (DDC, 2003) land space used for residential purposes is about 33% of the total urban space. Water bodies like river, pond, ditch etc. occupy 10.78%, while 18.74% land is still being used for agriculture. A little over 11% land is lying vacant. Road infrastructure covers 5.62% of RCC area. Education is an important use with 10.50% of the RCC area. Industries and storage together comprises only 0.81%, while business and mercantile use constitute 1.98% of the total RCC area reflecting a low profile of economic activities in the city.

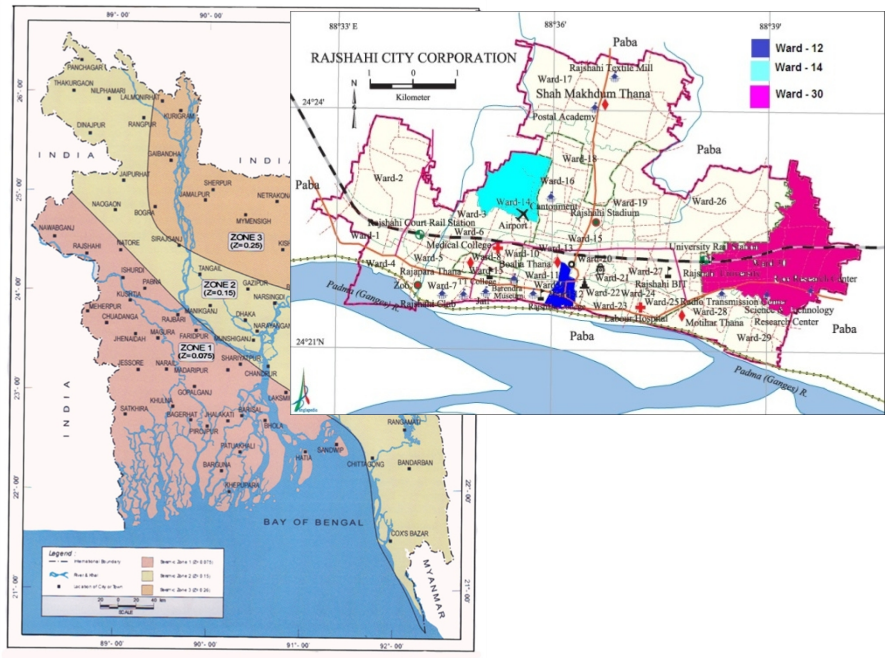

Figure 1. Location of the study area

3.3 Seismicity of Rajshahi District

On 5 July 2008 at 22:55 PM in Bangladesh, a light earthquake occurred on the Bangladesh-India border. It had magnitude of M =4.1(IMD) and was felt in parts of Rajshahi in Bangladesh as well as in parts of West Bengal in India, the earthquake was centred 6.4 km WNW of Rajshahi, 25.7 km east of Lalgola (West Bengal), India, 31.7 kms south-east of Chapi Nawabganj, 34.8 km north-east of Murshidabad, India, 49.3 kms west of Natore, 68 km north-east of Kandi (West Bangal), 87.4 kms north-west of Pabna, 110 kms north of Krishnanagar of India. In Rajshahi division in Bangladesh, it was strongly felt and rushed many people from home at Chapi Nawabganj, Naogaon, Natore and Rajshahi. At least 30 buildings developed cracks (Figure 4.3) and a six-storey building tilted in the division.

3.4 Hazard & Geological Profile of the Study Area

From hazard assessment report, following maps (Figure 2) have been found for Rajshahi City Corporation. From the provided maps, it is found that, for a design level of earthquake (475-y), the expected peak ground acceleration would be in a range of 0.18 g- 0.21 g, which may produce very strong shaking resulting moderate potential damage to infrastructure according to U.S. Geological Survey (Source: CDMP II).

3.5 Focused Study Areas

A part of the Rajshahi City Corporation was considered as the study area and inventory including field data collection was applied on that area. The study area consists of three Wards namely Ward No.12, 14 and 30. These three Wards, selected for this study, are not same in terms of economic and building pattern. Ward No.12 is the most densely populated, commercially important and the oldest area of Rajshahi city. Ward No.14 is consists of planned residential and industrial area with a central stadium of Rajshahi city. Ward No.30 is mostly covered by Rajshahi University campus, Budhpara, and Mirjapur.

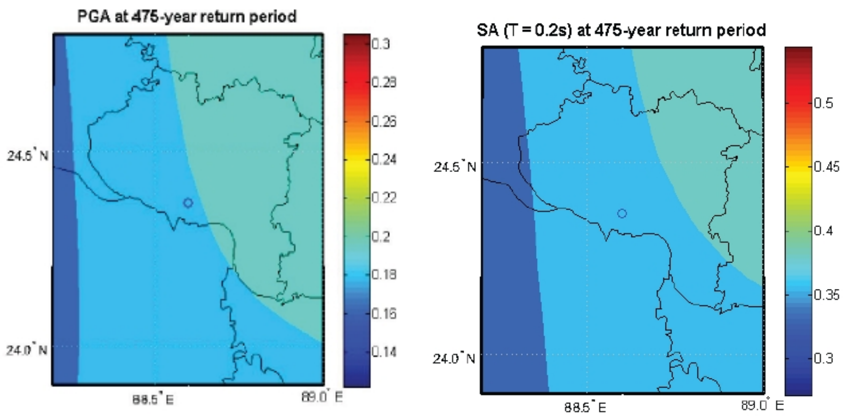

Figure 2. Hazard profile of Rajshahi City Corporation.

3.6 Data collection of the Study

A building inventory is essential for the assessment of seismic vulnerability. To this purpose relevant information regarding the buildings (such as number of storey, age, structure type, occupancy classes, pounding effect, plan and vertical irregularity, presence of short column, soft storey, heavy overhang and mobile phone tower, soil condition and physical condition of building etc.) was collected from direct field survey. Collected data were complied and analyzed in MS Excel. Total number of building found in Ward No. 12, 14 and 30 are 2352, 1822 and 558 respectively. After the collection of data, a standard format was prepared in tabular form to analyze the data obtained from the selected Wards.

4 Results and Discussions

In this study, three Wards (Ward No. 12, 14 and 30) of Rajshahi city have been selected as shown in Figure 4.01. In order to make proper seismic vulnerability assessment of the existing buildings, field survey and inspection were conducted in each Ward. The purpose of the survey is to know about the seismic impact on the existing building stock of the selected Wards of Rajshahi city. This survey included building storey, construction age, building structure, occupancy classes, soft storey, heavy overhang, pounding effect, mobile phone tower effect, presence of short column and physical appearance etc. of buildings of the selected Wards.

The survey covered 2352 no. buildings of Ward No.12, 1822 no. buildings of Ward No.14 and 558 no. buildings of Ward No.30 from February to December in 2014.

(a) (b)

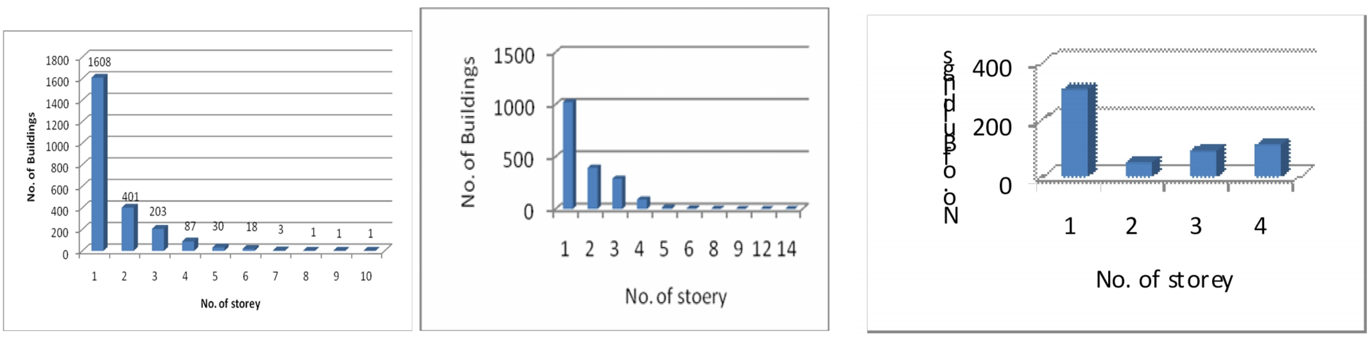

Figure 3. Classification of buildings based on storey height (a) Ward No. 12 (b) Ward No. 14 (c) Ward No. 30

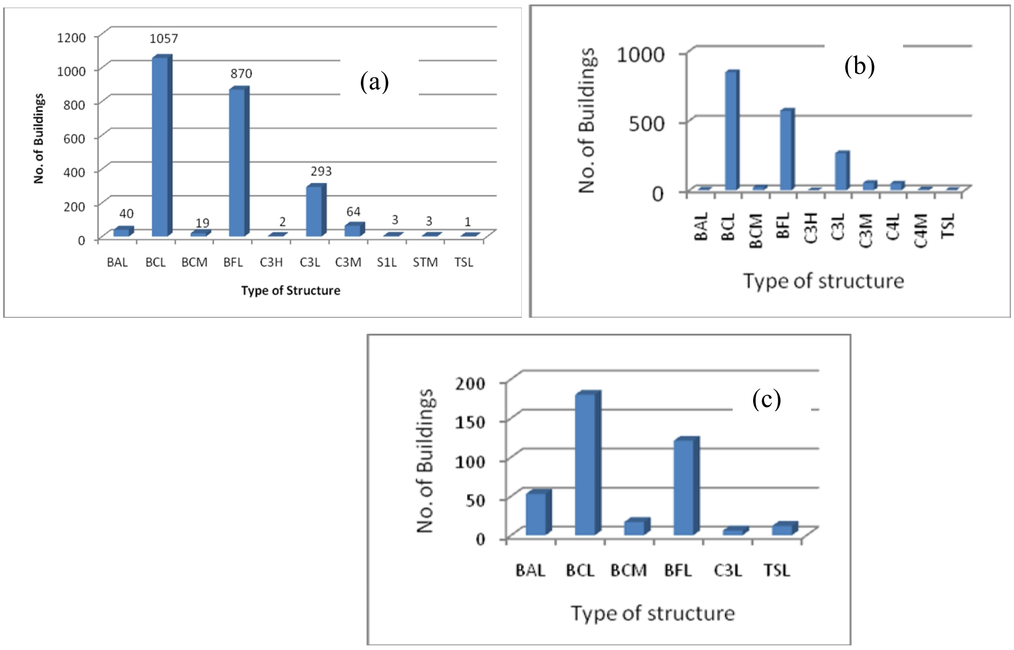

Figure 4. Classification of buildings based on storey height (a) Ward No. 12 (b) Ward No. 14 (c) Ward No. 30

Figure 5. Typical buildings in the study area (a) unreinforced masonry (b) reinforced concrete frame building (c) building near pond (d) building with mobile phone tower and over-hang (e) building with soft-story

From the survey data, a wide variety of buildings found in the study area and single storey buildings are the highest in number in all three wards. In ward No. 12 about 61% buildings were found to be older than 30 years. In Ward No. 14, 72% and 15% of buildings were constructed in between 10-30 year and 30 years earlier respectively. The number of newly constructed buildings was found minimum in Ward No. 30. In this ward, 59% buildings are aged between 10-30 year and 37% buildings are of more than 30 years older. It is evident that most of the buildings were constructed before adopting the building Code of Bangladesh. According to building structure types and buildings materials used most of the buildings fall into unreinforced load bearing masonry structure (URM) group. Particularly 45%, 47% and 46% brick in cement mortar masonry with concrete floor buildings (BCL) are respectively found in Ward No. 12, 14 and 30. Unreinforced masonry buildings usually have poor performance during an earthquake.

Buildings are also classified based on types of occupancy such as residential, commercial, industrial and educational etc. Though there are some commercial institutions in Ward. No 14. single family dwelling (RES1) type houses are the most common (about 41%) depicted from the survey study. Multi family dwelling (RES3) type apartments/condominiums (about 40%) are predominant in Ward No.14 and where as the predominant building type found in Ward No.30 was small shop and market (COM1) type buildings are predominantly 30% of total buildings in the. Some buildings are also found with heavy overhang components and some buildings are found with mobile phone towers on the roof top. Pounding effect is also an important factor considered in the seismic vulnerability study and Ward No. 14 was found to have most number of buildings with possible pounding effect. Besides a few number of buildings found with possible soft story and short column effect. Building classifications for the study area are presented in Figures 3 and 4 and some typical photographs are presented in Figure 5. Finally, vulnerability of buildings based on RVS score, described in Table 1, was calculated for each of the buildings using the formula

$$Final\ Score \quad = (Initial\ Score - \sum (Vu \ln erability\ Parametr\ X (Vu \ln erability\ Score))$$

It is found that all buildings of the study area have only seismic vulnerability of grade G1 based on RVS method. The seismic vulnerability grade G1 is negligible to slight damage, i.e. no structural damage and slight non-structural damage.

Conclusions

In this study, seismic vulnerability of buildings of some selected areas of Rajshahi City Corporation is assessed on the basis of rapid visual screening method. A building inventory for the selected areas was developed to this purpose. The building inventory was developed on the basis of field survey data. Several important factors were considered in the survey process. Finally, RVS score was calculated to assess the vulnerability of the buildings. Following conclusions can be made from the survey study and vulnerability assessment results

(i) With a few exceptions, existing earthquake resistant building codes are not applied uniformly to new construction. Most of the newly constructed buildings belong to private owners and unsafe building practices are favoured to reduce building costs.
(ii) Most of the buildings (almost 100%) have no provision of emergency exit. This may cause harm to the buildings occupants because of panic during an earthquake.
(iii) Buildings below 6-story height have no additional lateral load resisting system. Some buildings were found having lift core in the plan which makes them stronger against earthquake.
(iv) Building classification was done considering the classification system of FEMA 154 (2002) which may have affected the final vulnerability score. A proper building classification may provide much accurate result. Also the quality of the construction work was not considered in the vulnerability assessment process.

References

Ahmed, M.Z., Islam, K., Roy, K.S., Arafat, M.S. and Al-Hussaini, T.M. (2010).“ SeismicVulnerability assessment of RCF buildings in old town of Dhaka city.” Proc. 3rd International Earthquake Symposium, Bangladesh, pp. 439-446

Alam, M.J., Khan, M.A.R., and Paul, A. (2009). “ Seismic Vulnerability Assessment of Existing RC Buildings in GIS Environment”, Earthquake Research Centre (EERC), Department of Civil Engineering, Chittagong University of Engineering & Technology(CUET),Bangladesh.

BBS(Bangladesh Bureau of Statistics) (2011). “Bangladesh Population Census 2011”, vol-3, Urban Area Report, Chittagong: Statistics Division, Ministry of Planning, Govt. of Bangladesh.

DDC (Development Design Consultants Limited). 2003. Social and Municipal Services: Working Paper for the Rajshahi Metropolitan Development Plan. Bangladesh, Dhaka.

FEMA 154 (2002). Rapid Visual Screening of Buildings for Potential Seismic Hazards,Washington, D.C., USA.

Sinha, R.and Goyal, A. (2013). “A national policy for seismic vulnerability assessment of buildings and procedure for rapid visual screening of buildings for potential seismic vulnerability”. Report to Ministry of Home Affairs, Government of India.