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SEISMIC STRUCTURAL ASSESSMENT OF DAMAGED CHITTAGONG PUBLIC LIBRARY BUILDING DURING 27 JULY 2003 EARTHQUAKE

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ABSTRACT

Seismic structural damage assessment is a part of post earthquake disaster management program. During the Rangamati Earthquake of Chittagong Hill Tracts in July 27, 2003, the only Public Library located at Chittagong was severely affected and undergone various degrees of damages. This paper deals with the physical damages as well as structural strength assessment of the damaged Public Library building. A detailed overview of several seismic damage evaluation documents framed by FEMA 310 has been elaborated and incorporated for seismic structural strength assessment process. Finite element frame analysis is used incorporating Bangladesh National Building Code (BNBC) seismic provisions. The difficulties existing in the structural system planning of the damaged Chittagong Public Library building and design discrepancies are documented and probable suggestive measure are highlighted in this paper.

Keywords: FEMA, Rangmati Earthquake

INTRODUCTION

Bangladesh, being located close to the plate margins of Indian and Eurasian plates, is susceptible to earthquakes. The collision of the Indian plate moving northward with the Eurasian plate is the cause of frequent earthquakes in the region comprising Bangladesh and neighboring India, Nepal and Myanmar. Historically five earthquakes of large magnitude i.e. greater than 7.0 in Richter scale affected Bangladesh. Two of them had their epicentres within Bangladesh and caused considerable damages locally. The 1897 Great Indian earthquake (Magnitude 8.7 in Richter scale) in Shillong, considered to be one of the strongest earthquakes of the world, had its epicenter only 230 km away from Dhaka and caused extensive damage in Bangladesh. Major historical earthquakes affecting Bangladesh are listed in Table 1.

Bangladesh has been divided into three generalized seismic zones as shown in Fig 1: zone-I, zone-II and zone-III. Zone-I comprising the northern and eastern regions of Bangladesh with the presence of the Dauki Fault system of eastern Sylhet and the deep seated Sylhet Fault, and proximity to the highly disturbed southeastern Assam region with the Jaflong thrust, Naga thrust and Disang thrust, is a zone

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of high seismic risk with a basic seismic co-efficient of 0.08. Northern Bangladesh comprising greater Rangpur and Dinajpur districts is also a region of high seismicity because of the presence of the Jamuna Fault and the proximity to the active east-west running fault and the Main Boundary Fault to the north in India.

Table 1. Major historical earthquakes in Bangladesh (After Alam, 2005 and Ansary 2003)

Name of earthquake	Epicenter	Magnitude	Intensity at Dhaka	Distance (km)
1869 Cachar	Jaintia, Assam	7.5	V	250
1885 Bengal	Bogra	7.0	VII	170
1897 Great Indian	Assam	8.1	VIII	230
1918 Srimangal	Srimangal	7.6	VI	150
1930 Dhubri	Dhubri, Assam	7.1	V	250

The Chittagong-Tripura Folded Belt experiences frequent earthquakes, as just to its east is the Burmese Arc where a large number of shallow depth earthquakes originate. Zone-II comprising the central part of Bangladesh represents the regions of recent uplifted Pleistocene blocks of the Barind and Madhupur Tracts, and the western extension of the folded belt. The Zone-III comprising the southwestern part of Bangladesh is seismically quiet, with an estimated basic seismic co-efficient of 0.04. Rangamati Earthquake struck with an intensity of epicenter area was VII-VIII 'damaging type' on EMS scale. The location of epicenter of the Rangamati Earthquake is shown in Figure 2. According to USGS, the magnitude of the earthquake was 5.6. The earthquake's epicenter was located at Rangamati's Barkal area. The shock was also strongly felt in the port city of Chittagong. During this earthquake the Chittagong Public Library building, the only library of Chittagong city was damaged severely.

Chittagong Public Library is the principle library of Chittagong city. Chittagong public library building was established in 1989. After the construction, several earthquakes affected the building.

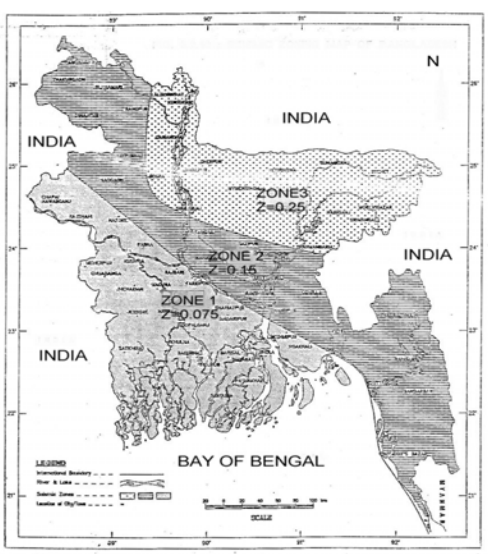

Figure 1. Earthquake Zoning map of Bangladesh

Figure 2. Location of Rangamati Earthquake

The public library located at Chittagong was seriously affected and undergone various degrees of damages resulting with grave risk to human lives during earthquake occurred at Rangamati of Chittagong Hill Tracts on the 27th July of 2003 (Rangamati Earthquake). Fig 2 gives some damage scenarios of the Public Library

This paper deals with the physical damages as well as structural damage assessments of the damage public library building. The difficulties existing in the structural system planning and design discrepancies are also highlighted in this paper.

(a) (b) (c)

Figure 3: Patterns of damages of structural elements (a) Typical wall (b) Typical column (c) Typical beam

PHYSICAL INVESTIGATION OF THE BULIDING AND STRUCTURAL ANALYSIS

The only Public Library located at the heart of Chittagong city is four-storied and Load Bearing Masonry (LBM) wall RC frame type structure. The plinth area of the building is 13805 sq. ft. with the length and width of 125.5 ft and 110 ft, respectively. The architectural plan and typical views of the building are shown in Figure 4 and 6. The key structural plan showing the location of columns and beams are also shown in Figure 5. The existing structure has several key vulnerabilities that are needed to address. About three inches of settlement occurred at the south-east corner of the building during 27 July 2003 earthquake. The unreinforced brick masonry walls around the exterior wall of the building posed another problem. Due to their initial stiffness, they would tend to resist seismic loads. However, because of their limited strength and ductility, they would provide an incompatible and unreliable source of seismic resistance and energy dissipation. Table 2 gives some information on the historical earthquakes occurring at Chittagong during the last few decades.

Table 2. Historical Earthquakes in Chittagong (After Islam, 2005)

Year	Richter Magnitude of the earthquake	Extent of damage
December, 1830	---	Most of the houses were severely cracked
October, 1842	---	Minor losses of resources
1865	---	Most of the buildings were severely cracked
November, 1997	6.1	Sinking of two underground floors of a five storied building and 32 people were died.
July, 1999	5.2	Widespread damage and loss of property and also lives. 8000 people in seven unions were severely affected, seven persons died and 24 persons were seriously injured, 1292 houses were fully damaged with 5662 partially, 10 cyclone centers, hospitals, and other structures were damaged. The estimated financial loss was about 14 million Taka.

Table 2 (Continued). Historical Earthquakes in Chittagong (After Islam, 2005)

Year	Richter Magnitude of the earthquake	Extent of damage
July, 2003	5.6	Six-mile long crack was developed in the ground. Most of the damage was affected by the series of aftershocks. 3 people were killed and 25 injured by this earthquake. A number of structures were damaged as the Fig-2.3 represents. Throughout the region nearly 500 buildings were damaged. Moreover, The only Public library at Chittagong was severely damaged.

The structural member hasn’t sudden change in stiffness along both horizontal & vertical direction, which yields better results to seismic resistance. This building has excessive openings (about 50%) at side masonry walls, which doesn’t yield positive results. Hence the corner where the building changes its direction has become seismically vulnerable, as there is a possibility to occur a stress reentrant phenomenon during an earthquake. Although the length of the building is more than 100 ft, no expansion joint is provided in the building. This also makes the structure seismically vulnerable.

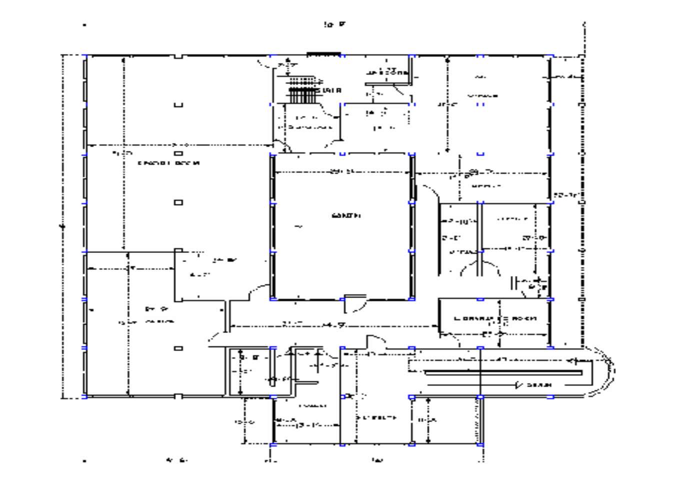

Figure 4. Typical Floor Plan

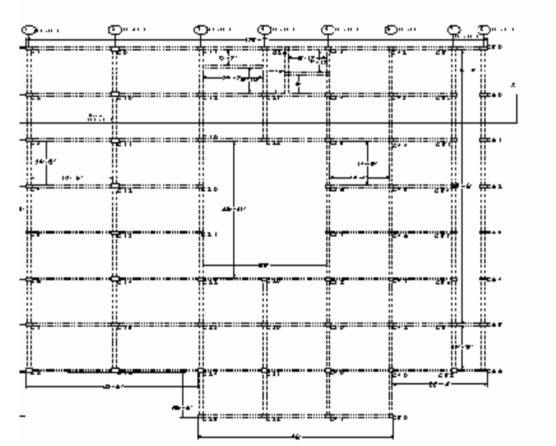

Figure 5. Beam-Column Layout

(a)

(b)

Figure 6: (a) Front view of the damaged building (b) Isometric view of the damaged building

Physical Investigation using FEMA 310

FEMA 310 is a well-known publication on seismic evaluation procedure developed by Federal Emergency Management Agency. The evaluation procedure is based on precise approach to determine existing building conditions. According to the FEMA 310 there shall be one complete load path available through which the inertial forces, induced as a result of the seismic force effects from any horizontal direction are transferred from the mass to the foundation. The strength of lateral force resisting system in any story shall not be less than 80% of the strength in an adjacent story. There shall be no change in the horizontal dimension of lateral force resisting system of more than 30% in a story relative to adjacent stories. It also specifies that, effective mass between adjacent stories shall not vary more than 50%. In order to avoid pounding, the building shall not be located closer than 4% of the height to an adjacent building.

Structural Analysis

The linear static analysis using a Finite Element software namely GRASP), for all typical frames, has been performed to study the strength behavior of the building and subsequently to compare with physical investigation performed using FEMA procedure. The loading combination of 1.0(DL + LL + EL) has been used in the review of the design of structural elements like beam, column and slab using ACI recommended procedure. BNBC 1993 Seismic Codal provision has been used in this study to calculate the lateral loads developed due to an earthquake.

RESULT AND DISCUSSION

Detailed evaluation on the configuration related check on the architectural planning and strength related checks on the structural elements of the building framing system used could be summarized in Table 3 and Table 4.

CONCLUSION

The configuration related and strength related structural investigation have unfold the fact that Chittagong Public Library building was planned and designed without incorporating the earthquake resistant design provisions as described in BNBC-1993 or any other seismic building codal provisions. Earthquake cannot be prevented but the damage they cause can be greatly reduced by following seismic provisions, proper structural planning, design and detailing. In the light of the results and discussion made above, the following are the conclusions can be drawn from this study:

1. The public library building is 125.5 ft long in the EW direction, has no expansion joint.
2. The quality of construction was very poor and the compressive strength of concrete used was in the range of 1500-2000 Psi.
3. Mixed use of structural framing system such as load bearing brick masonry wall with RC frame elements makes the building vulnerable and also excessive opening in all solid brick masonry load bearing masonry walls make the building unsafe with respect to clear load path.
4. The soil under the structure is susceptible to liquefaction and so uneven settlement of column and load bearing wall supports also created undue cracks during the earthquake.
5. Strong Column-Weak Beam is not satisfied.
6. Available column shear capacity is less than the demand shear capacity due to earthquake load.
7. Lack of stirrups in beams, ties in columns and ductile seismic detailing of column-beam joints made the structural farming system vulnerable to the earthquake.

Finally the 27th July 2003 Rangamati earthquake made the Chittagong Public Library Building, one of the hazardous buildings, in the Chittagong city and any frequent small intensity earthquakes will invite a great disaster. So it is suggested that Chittagong Public Library Building should be announced as abandoned structure without any further delay and need proper strengthening scheme to increase its seismic demand strength to protect human lives in future.

Table 3. Summary of the Configuration Related Checks using FEMA 310 Guidelines

Sl. No	Configuration Related Check	Remark
1	Type of the structure	Four storied Mixed RC frame structure with Brick Masonry.
2	Geometry	Horizontal dimension is equal at all the stories.
3	Weak Story	There are no abrupt changes in column sizes from one story to another and no significant geometrical irregularities. So, weak or soft story does not exist.
4	Soft Story	
5	Vertical Discontinuities	Vertical elements in the lateral force resisting system are continuous to the foundation.
6	Symmetry	Asymmetrical.
7	Shape of building	Simple rectangular shape.
8	Cantilever Balcony	Not exists.
9	Torsion	The building being asymmetrical, center of mass and center of rigidity does not coincide.
10	Adjacent Buildings	Not applicable.
11	Short Columns	Short columns do not exist.
12	Height width ratio	Height width ratio = 0.47, which is less than 4.
13	Shear wall	No shear walls exist.
14	Side wall	Solid Brick masonry wall (10 inch thick).
15	Expansion joint	Not exists.

Table 4. Summary of strength related check using FEMA 310 Guidelines

S. No	Strength Related Check	Remarks
1	Moment Resistance of Beam	Check not satisfied.
2	Column Flexural Capacity	Check not satisfied.
3	Strong Column-Weak Beam consideration	Check not satisfied.
4	Column Shear Capacity	Check not satisfied.

The analytical results with physical investigation of the building have been shown in Table-5

Table 5: Comparison of the analytical result with physical investigation

Floor Identification	Analytical Result Check	Physical investigation Check	Photographs in real situation after earthquake
Ground Floor	1. Beam (C29-C30) was damaged due to insufficient moment resisting capacity. 2. Column C8 was damaged due to insufficient shear capacity.	1. Beam (C29-C30) was extensively damaged at the support. 2. Column C8 was damaged at the middle of the column.	1.  2. 
1^{st} Floor	1. Beam (C29-C30) was damaged due to insufficient moment resisting capacity. 2. Column C31 was damaged due to insufficient shear capacity.	1. Beam (C29-C30) was extensively damaged at the support. 2. Column C31 was damaged at the upper portion of the column.	1.  2. 
2^{nd} Floor	1. Beam (C34-C43) was damaged due to insufficient moment resisting capacity. 2. Column C7 was damaged due to insufficient shear capacity.	1. Beam (C34-C43) was extensively damaged at the support. 2. Column C7 was damaged at the middle of the column.	1.  2. 
3^{rd} Floor	1. Beam (C29-C30) was damaged due to insufficient moment resisting capacity. 2. Column C31 was damaged due to insufficient shear capacity.	1. Beam (C29-C30) was extensively damaged at the support. 2. Column C31 was damaged at the upper portion of the column.	1.  2. 

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