SEISMIC RISK ASSESSMENT OF EXISTING BUILDINGS OF CUET CAMPUS IN CHITTAGONG

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ABSTRACT
Bangladesh is situated in the seismic prone area on the world seismic guide. Existing fault lines are capable of producing moderate to high magnitude earthquake in Bangladesh. The Chittagong city is quite substantial to earthquake according to proposed seismic map of Bangladesh National Building Code (BNBC). Chittagong University of Engineering and Technology (CUET) is located about 27 km away from the center of the city. This study was carried out to identify the condition of existing structures of CUET in terms of seismic risk. Rapid Visual Screening procedure especially FEMA 154 and Turkish two levels risk assessment procedures are applied to assess the seismically vulnerable buildings. A total number of 80 buildings are assessed in the first level investigation. Moreover, seven buildings (administrative and academic) were selected based on importance and considered in the second level investigation. Most of the buildings are found to be performed well during both first and second level assessments.

Keywords: Assessment; CUET; rapid visual screening; risk; seismic vulnerability

INTRODUCTION
Bangladesh is located in the moderate seismic region in the world seismic map prepared by Global Seismic Hazard Assessment Program (GSHAP, 1992). The country is situated close to the boundary of two active plates: the Indian plate in the West and the Eurasian plate in the East and North. An earthquake of even medium magnitude on Richter scale can produce a mass graveyard in major cities of the country. For the existing buildings, it is important to identify the seismically vulnerable building before taking any strengthening measure. To survey all buildings in detail level is neither feasible nor possible. Rapid Screening Procedure is widely accepted before considering any structural detail level of investigation. Chittagong University of Engineering & Technology (CUET) region falls into zone 2 in Bangladesh National Building Code (BNBC 1993) with a seismic coefficient of 0.15 g and zone 3 with a coefficient of 0.28 g in the new seismic map. It has been felt necessary to prepare a structural database of existing buildings in CUET campus. The results of the current study will be a guideline in any future development plan. This study is carried out to assess the seismic safety of existing structures by considering rapid screening and preliminary approach. The first tire includes a simple walk-down assessment by visualizing the structural vulnerability parameters. In the second tire, buildings were assessed by checking structural integrity checks.
This study aims at evaluating the structural vulnerability of existing buildings by means of multiple assessment techniques. The main objectives of this study are to assess the seismic safety of existing buildings and to provide a direction how to judge in a practical way whether the minimum safety requirements are fulfilled.

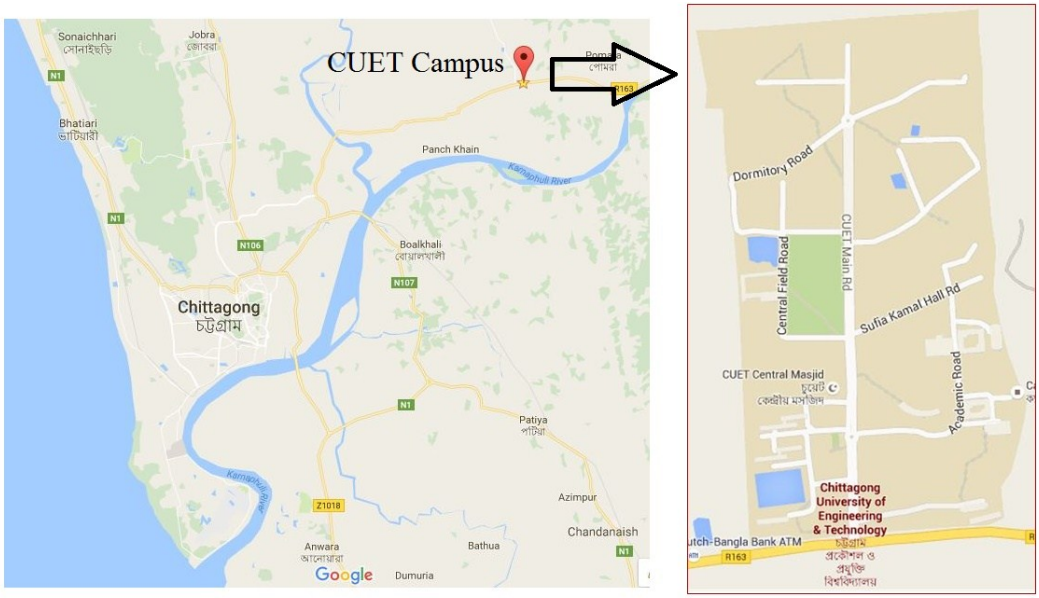

Fig. 1: Google map of CUET Campus

METHODOLOGY

Mainly two major types of structures are present at CUET. Reinforced Concrete (RC) Frame Structures with masonry infill wall and Unreinforced Masonry Buildings with the flexible diaphragm and Unreinforced Masonry Buildings with fixed diaphragm. To evaluate the seismic condition of the existing buildings, two methodologies were mainly used named R.V.S (Rapid Visual Screening) suggested by FEMA (Federal Emergency Management Agency) and Turkish simple screening procedure developed by Ozcebe et al. in 2006.

The FEMA 154 methods assign a basic structural score based on lateral force resisting system of the building. Score modifiers are specified to take into account the effect of number of stories, plan, vertical irregularities, pre-code or post-benchmark code detailing and soil type. This approach enabled users to classify surveyed buildings into two categories: those acceptable as to "risk to life safety" or those that may be seismically hazardous and should be evaluated in more detail by a design professional, experienced in seismic design. Ozcebe et al (2006) developed seismic vulnerability evaluation methods that can be classified into three main groups. The first, the simplest level is known as "Walkdown Evaluation". In this survey, major vulnerability factors are considered as soft story, heavy overhang, apparent quality, short column, pounding possibility and topographic effects. Evaluation of this first level does not require any analysis and its goal is to determine the priority levels of buildings that require immediate intervention. Preliminary assessment methodologies (PAM) are applied when more in-depth evaluation of building stocks is required. The procedures in the third tier employ linear or nonlinear analyses of the building under consideration and require the as-built dimensions and the reinforcement details of all structural elements.

RESULTS AND DISCUSSIONS

There are mainly two types of structures exist in CUET campus. Most of the buildings are Unreinforced Masonry (URM) structure with the flexible and rigid diaphragm. Rest of the buildings are RC frame (C3) structures with masonry infill. A total number of 86 buildings exist in the campus area of which 80 buildings are surveyed and analyzed. However, remaining 6 buildings which are found to be under construction are not taken into consideration. All of the buildings are less than 6 storied. Figure 2 represents the number of buildings exists according to their story numbers. The figure illustrates that 92 percent buildings are less than 4 stories. Among the surveyed buildings, 68 percent buildings are RC structures, 32 percent buildings are Unreinforced Masonry structure (figure 3).

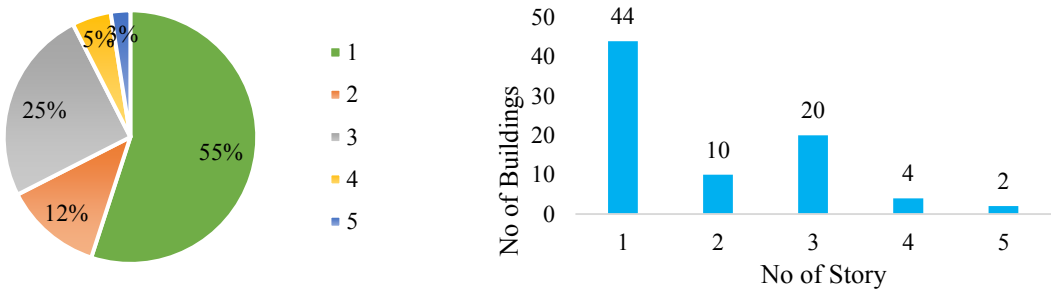

Fig. 2: Proportion of buildings according to no. of stories

Fig. 3: Building structural types and no. of stories

Total buildings are classified into eight categories based on their purpose of uses. Figure 4 reflects existing building use categories in percentage. Majority numbers of the buildings were using for the residential purposes. Only 8 percent buildings are used for the academic purposes, 4 percent buildings are administrative and 1 percent buildings are emergency center.

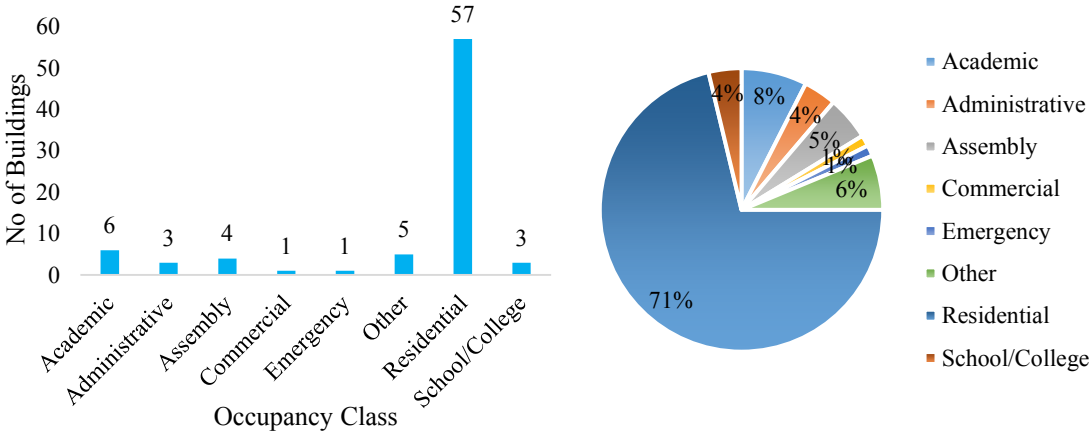

Fig. 4: Proportion of occupancy class of the buildings

Level 1 Assessment

First stage assessment is basically rapid screening procedure including Turkish tier 1 Walkdown Survey and FEMA 154 Rapid Visual Screening. The prior one is followed for the RC structures and later method is used to evaluate unreinforced masonry types of buildings. Turkish level 1 survey method is used for 26 RC structures.

Turkish Walkdown Procedure

In the Turkish level 1 survey, major vulnerability factors are surveyed and shown in tables and figures. Figure 5 represents the existing structural physical visible condition of the buildings in percentile form. Table 1 displays the relationship of the buildings apparent quality varies with

building number of stories. Figure 6 represents number of buildings present having short column effect. Table 2 shows short column presence with respect to different number of stories.

Table 1: Apparent Building Quality

No of Story	Average	Good	Poor	Total
1	3	3	2	8
2	5	2	0	7
3	5	0	1	6
4	3	0	0	3
5	0	2	0	2
Total	**16**	**7**	**3**	**26**

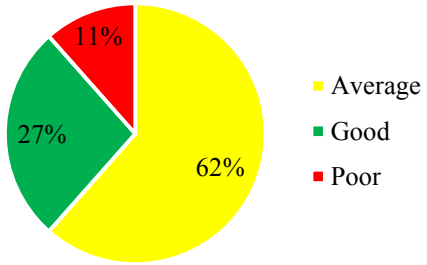

Fig. 5: Proportion of Apparent Quality

Table 2: Short Column Effect

No of Story	Identified	Not Identified	Total
1	2	6	8
2	6	1	7
3	5	1	6
4	3	0	3
5	1	1	2
	17	**9**	**26**

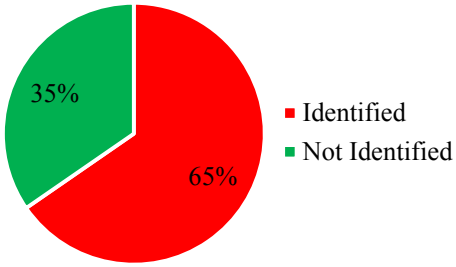

Fig. 6: Proportion of Short Column

There are only two buildings which are identified as pounding possibility with each other. However, three parameters such as soft story, heavy overhang and topographic effects are not found in any of the surveyed buildings. From the level 1 survey, performance scores are calculated for each building. Table 3 shows the performance scores are obtained for RC buildings. The buildings having a score above 80 are classified as low risk building. The building having a score below 60 is considered as high risk buildings. The score ranges from 61 to 80 marked as moderate risk class. Table 3 represents level 1 performance score variations with different number of stories.

Table 3: Summary of Performance Score (PS)

Number of Stories	PS < 60	60 ≤ PS ≤ 80	PS > 80	Total
1	0	0	8	8
2	0	0	7	7
3	0	6	0	6
4	3	0	0	3
5	1	1	0	2
Total	**4**	**7**	**15**	**26**

Rapid Visual Screening

FEMA 154 RVS can be applied for both structures. Turkish method can't be applied for masonry structures, as a result, RVS is conducted for remaining 54 nos. masonry structures. Table 4 and Table 5 shows the no. of buildings having RVS score modifiers plan irregularity and pre-code/post-benchmark. The proportion of these modifiers are shown in figure 7 and figure 8. The modifier vertical irregularity is not considered as all the buildings are vertically regular. As the soil condition was unknown the soil type D is taken as a modifier as per FEMA 154 guideline. From the RVS procedure, final scores are calculated for each building. Table 6 shows the nos. of buildings require detailed evaluation based on cut-off score 2 suggested by the guideline.

Table 4: Plan Irregularity

No of Story	Irregular	Narrow Rectangular	Rectangular
1	19	6	11
2	0	0	3
3	0	2	12
4	1	0	0
Total	**20**	**8**	**26**

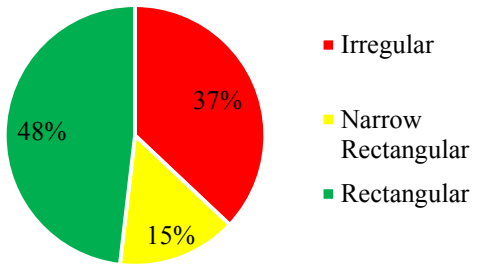

Fig. 7: Proportion of Plan Irregularity

Table 5: Pre-Code and Post-Benchmark

No of Story	Post-Benchmark	Pre-Code
1	17	19
2	0	3
3	1	13
4	1	0
Total	**19**	**35**

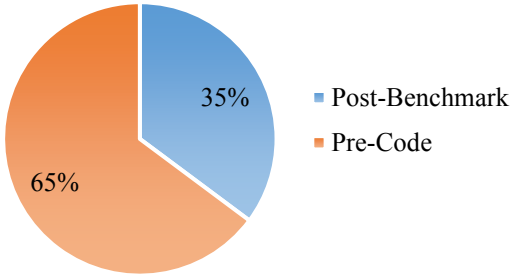

Fig. 8: Proportion of Pre-Code and Post-Benchmark

Table 6: RVS Final Score Summary

No of Story	Detailed Evaluation Required	
	Yes (Final Score ≤ 2)	No (Final Score > 2)
1	18	18
2	0	3
3	2	12
4	0	1
Total	**20**	**34**

Level 2 Assessment

Second level assessment is conducted for the RC buildings following Turkish Tier 2 guideline prepared by Ozcebe et al. in 2006. Seven buildings are analyzed based on building importance level in terms of building use. Academic and administrative buildings are preferred in this stage. Table 7 represents the risk class for each building that is obtained from the Turkish level 2 analysis. The building integrity values are checked after taking detail structural floor sketch and preliminary assessment calculation. Finally Table 7 shows the risk class for each buildings that is obtained from the Turkish level 2 analysis.

Table 7: Summary of assessment results and Risk Class in level 2

ID No.	Building Name	Risk Group
15	Dormitory	Low
57	EME Building	Low
61	Engg. Office Building	Low
63	CE Building	Low
65	Central Library	Low
66	Pre-Engineering Building	Low
68	Admin Building	Low

CONCLUSIONS

It is seen that most of the single story residential building configuration are somewhat similar. Therefore the obtained performance for single story residential URM represents similar results in first level assessment. It is observed that building performance score decreases with increase in number of story. All the buildings in second level assessment procedure lie in the low risk group. The overall findings are summarized in table 1.

Table 8: Summary of findings based on first and second level assessments

Level of Assessment	First		Second
Assessment Approach	Walk-down Procedure	Rapid Visual Screening	Preliminary Assessment Method
Structural Type	RC frame with Masonry Infill	Unreinforced Masonry	RC frame with Masonry Infill
No. of Building Assessed	26	54	7
High	04	20	0
Moderate	07	-	0
Low	15	34	7

Among the applied methods, FEMA 154 covers all the structural types whereas Turkish method are limited to apply for RC frame buildings only in the first level of assessment. In FEMA 154, six parameters are dominated (mid-rise, high-rise, plan irregularity, vertical irregularity, pre-code, post-benchmark and soil condition). Masonry buildings need to be assessed in details for more consistent results. This study contains basic structural vulnerability information which can be employed for any decision making in any future development work. As under construction buildings are not considered in this study, these buildings should be assessed in future.

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