SEISMIC VULNERABILITY ASSESSMENT OF EXISTING BUILDINGS IN CHITTAGONG CITY: A CASE STUDY ON RAMPUR WARD

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ABSTRACT
A strong earthquake affecting a major urban area like Chittagong city may result in destructions of massive proportions and may have disastrous consequences for the entire nation. Chittagong, located in the south eastern part of Bangladesh, is a strategically and commercial capital of the country. The study area situated at no.25 Rampur ward of Chittagong City Corporation with more than 30,000 populations. The study methodology comprised of the most popular method of modern Turkish, where about eight individual parameters were surveyed like soft story, pounding effects, apparent quality etc. at level I survey. Based on the selected parameters, performance score has been assigned to individual buildings by which the buildings have been classified as damage category of safe, moderate and unsafe at level I survey. A total of 400 buildings have been surveyed in the study area of interest. Among those 400 buildings 179 buildings are safe, 39 buildings are unsafe and 182 buildings are of moderate category after level I survey. The important outcome of the study is the complete building inventory of the study area identifying the damage category.

Keywords: Seismic vulnerability assessment; Turkish method; Rampur ward; Chittagong city

INTRODUCTION
By its geographical position, Bangladesh is being treated as one very vulnerable country with its high risk of earthquake hazard. The Indian plate is moving ~60 mm/yr in a northeast direction and sub ducting at the rate of 45 mm/yr under the Eurasian and 35 mm/yr under the Burmese plates in the north and east, respectively (Bilham, 2004).
When the rocks along a weak region in the earth’s crust reach their strength, a sudden movement takes place and opposite sides of the fault suddenly slips and release the large elastic strain energy stored in the interface rocks. The sudden slip at the fault causes the earthquake. A violent shaking of the earth when large elastic strain energy released spreads out through seismic waves that travels through the body along the surface of the earth. Most earthquakes in the word occur along the boundaries of the tectonic plates. Earthquakes can also occur far from the edges of plates, along faults. They are more common near the edges of the plates (UPSeis, 2016).
Bangladesh stands on the northeastern corner of the Indian plate while Chittagong is situated over Chittagong-Tripura Fold Belt (CTFB). Most of the active faults within CTFB is thought to be secondary faults and deformations related to the rupture of the Tripura segment shown in [Fig. 1]. However, a part of these faults may generate large earthquakes separately from the plate boundary fault like the 1918 Srimongal earthquake. However, it is difficult to separate active structures from the secondary structures (Morino et. al., 2013). Some active faults within Chittagong have been shown in [Fig. 2] among which Sitakund fault, Patia fault, Sitapahar fault, Kalabunia fault have potentials to produce some significant earthquakes. Sitakund fault zone is located at Northwest side of Chittagong city and the nearest fault from main city.

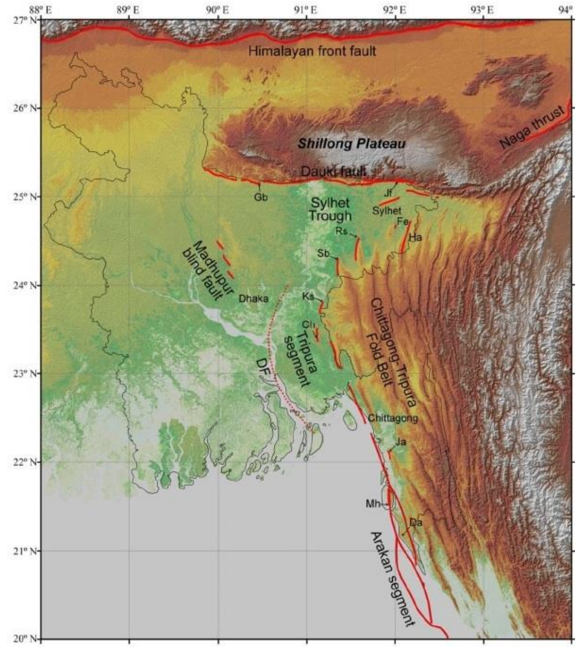

Fig. 1: Active faults in and around Bangladesh (Morino et. al., 2013)

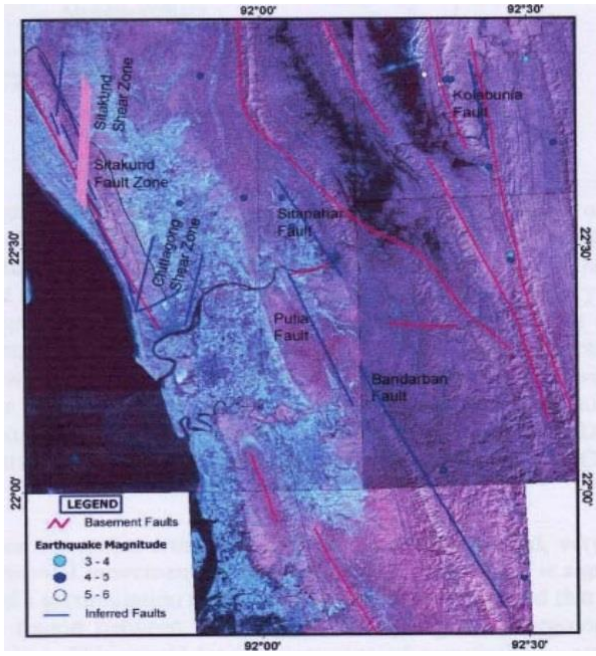

Fig. 2: Active faults in and around Chittagong (Alam, 2011)

In the seismic zoning map of Bangladesh, provided in BNBC (Bangladesh National Building Code), Chittagong has been shown under Zone II with basic seismic zone coefficient of 0.15. But recent repeated study reveals shocking value around this region indicating the possibilities of potential threat of even much higher PGA like 0.28g than projected, which has already been proposed in BNBC draft 2012 as for Chittagong under Zone III with basic seismic zone coefficient of 0.28 (Al-Hussaini et. al., 2012).

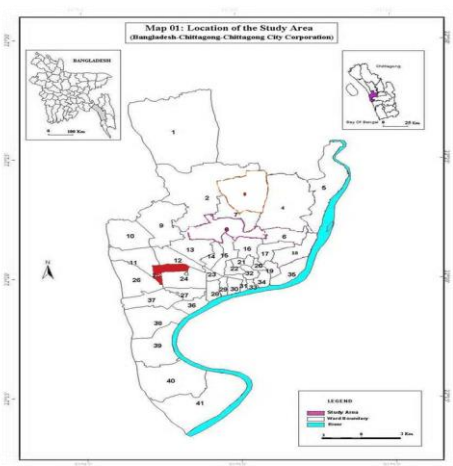

Fig. 3: Chittagong City Corporation map

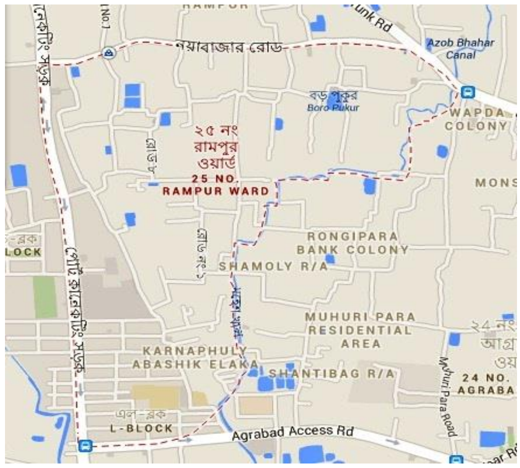

Fig. 4: 25 Number Rampur ward map

The study area is ward no.25 of Chittagong City Corporation known as Rampur ward situated near the Bay of Bengal. This ward is one of the densely-populated wards of Chittagong city and has a residential of more than 30,000 people shown in [Fig. 3] and [Fig. 4]. Some typical buildings of study area are shown in [Fig. 5] and [Fig. 6]. This study has been carried out to identify the vulnerable structures in the study area so that highly vulnerable structures can be retrofitted on the priority basis. In order to develop an earthquake preparation program, earthquake vulnerability has been assessed on the basis of potential Vulnerability of Structures.

Fig. 5: Building ID 01

Fig. 6: Building ID 56

SEISMIC VULNERABILITY ASSESSMENT

Current approaches in seismic vulnerability evaluation methods can be classified in three main groups depending on their level of complexity. The first, most simple level is known as "Walk down Evaluation." Evaluation in this first level does not require any analysis and its goal is to determine the priority levels of buildings that require immediate intervention. The procedures in FEMA 154 (1988), FEMA 310 (1998) Tier 1 and the procedure developed by Sucuoglu and Yazgan (2003) are examples of walk down survey procedures. The second level or Preliminary assessment methodologies (PAM) are applied when more in-depth evaluation of building stocks is required. In this stage, simplified analysis of the building under investigation is performed based on a variety of methods. These analyses require data on the dimensions of the structural and non-structural elements in the most critical story. The procedures by FEMA 310 (1998) Tier 2 and Ozcebe et al. (2003), later complemented by Yakut et al. (2003) can be listed as the examples of preliminary survey procedures. It is possible to survey large building stocks by employing the preliminary evaluation methodologies within a reasonable time span. The procedures in third level employ linear or nonlinear analyses of the building under consideration and require the as-built dimensions and the reinforcement details of all structural elements. In the present study only first level has been covered for seismic vulnerability assessment of buildings in study area.

Walk down Evaluation (Level – I)

For level-I assessment the procedure developed by Sucuoglu and Yazgan (2003) has been used. The first survey level is conducted from the sidewalk by trained observers through walk-down visits. A street survey procedure must be based on simple structural and geotechnical parameters that can be observed easily from the sidewalk. The time required for an observer for collecting the data of one building from the sidewalk is expected not to exceed 10 minutes. The parameters that are selected for representing building vulnerability in this study are the following:

1. The number of stories above ground (1 to 7)
2. Presence of a soft story (Yes or No)
3. Presence of heavy overhangs, such as balconies with concrete parapets (Yes or No)
4. Apparent building quality (Good, Moderate or Poor)
5. Presence of short columns (Yes or No)
6. Pounding between adjacent buildings (Yes or No)
7. Local soil conditions (Stiff or Soft)
8. Topographic effects (Yes or No)

Each parameter reflects a negative feature of the building system under earthquake excitations on a variable scale (Sucuoglu and Yazgan, 2003)

The intensity of ground motion at a particular site predominantly depends on the distance of the causative fault and local soil conditions. As there exists a strong correlation between PGV and the shear wave velocities of local soils (Wald, 1999), in this study the PGV is selected as to represent the ground motion intensity. As for Chittagong no PGV map is available, the intensity zones are expressed accordingly, in terms of the associated PGV ranges as developed for Istanbul.

Zone I: $60<PGV<80$ cm/s^2

Zone II: $40<PGV<60$ cm/ s^2

Zone III: $20<PGV<40$ cm/ s^2

Based on their number of stories and the seismic hazard level at the site buildings are assigned different base scores as shown in Table 1.

Table 1: Base Scores and Vulnerability Scores for Concrete Buildings (Ahmed et al. 2012)

Number of Stories	Base Scores(BS)			Vulnerability Scores(VS)					
	Zone I (60<PGV<80)	Zone II (40<PGV<60)	Zone III (20<PGV<40)	Soft Story	Heavy Overhang	Apparent Quality	Short Column	Pounding Effects	Topography Effects
1or 2	100	130	150	0	-5	-5	-5	0	0
3	90	120	140	-15	-10	-10	-5	-2	0
4	75	100	120	-20	-10	-10	-5	-3	-2
5	65	85	100	-25	-15	-15	-5	-3	-2
6or 7	60	80	90	-30	-15	-15	-5	-3	-2

Building Seismic Performance

Once the vulnerability parameters of a building are obtained from walk down surveys and its location is determined, the seismic performance score PS can be calculated by using Eq. (1). The base scores (BS), the vulnerability scores (VS) and the vulnerability score multiplies (VSM) to be used in Eq. (1) are defined in Tables 1 and 2, respectively

$$PS = (BS) - \Sigma\, (VSM) \times (VS) \qquad (1)$$

Table 2: Vulnerability Parameters (VSM) (Ahmed et al. 2012)

Soft story	Does not exist=0	Exists=1
Heavy overhangs	Does not exist=0	Exists=1
Apparent quality	Good = 0;	Moderate = 1; Poor =2
Short columns	Does not exist=0	Exists=1
Pounding effect	Does not exist=0	Exists=1
Topographic effects	Does not exist=0	Exists=1

Buildings are classified into three risk groups in this study based on the calculated Seismic performance score (PS) as shown in following Table 3.

Table 3: Risk Groups Based on Seismic Performance Score (PS)

Risk Groups	Performance Score Range
Unsafe	$PS \le 30$
Moderate	$31<PS \le 60$
Safe	$61<PS \le 100$

RESULTS AND DISCUSSIONS

Total number of structure in this area is almost residential, where most of the percentages are moment resisting RC frame. A total of 400 RC buildings were surveyed in case of Level I survey. Among 400 buildings 34 two storied, 77 three storied, 139 four storied, 102 five storied and 48 six storied buildings exist in the study area as shown in [Fig. 7]. After assessing the overall survey parameters, among 400 buildings 277 buildings have heavy overhangs problem, 11 buildings have short column problem, 110 buildings have soft story problem, 186 buildings have pounding possibilities and in terms of apparent quality 53 buildings are poor, 91 building are good and 256 building are average as shown in [Fig. 8]. At end of Walk down evaluation survey, according to their seismic performance score building are classified into three categories of safe, unsafe and moderate as shown in [Fig. 9]. Finally, [Fig. 10] shows that among 400 buildings 179 buildings are safe, 39 buildings are unsafe and 182 buildings are of moderate category after level I survey.

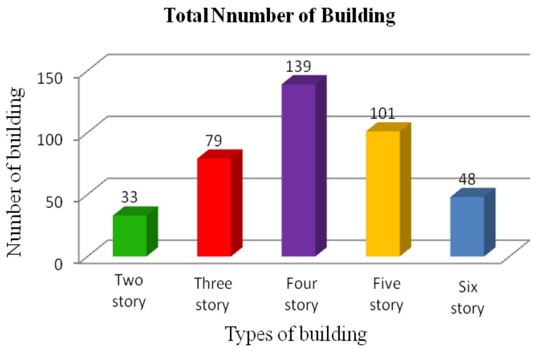

Fig. 7: Total Number of different storied Buildings

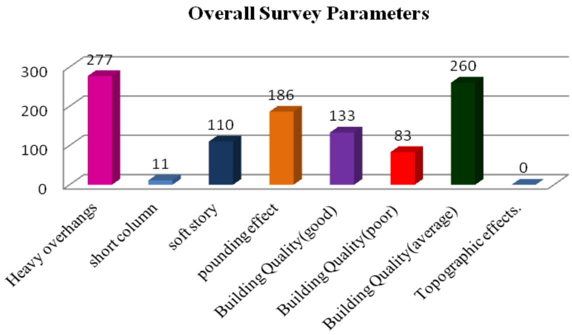

Fig. 8: Vulnerability Parameters after Walk down Evaluation

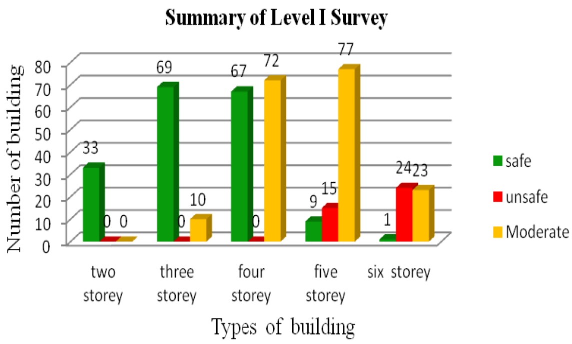

Fig. 9: Summary of Level I Survey

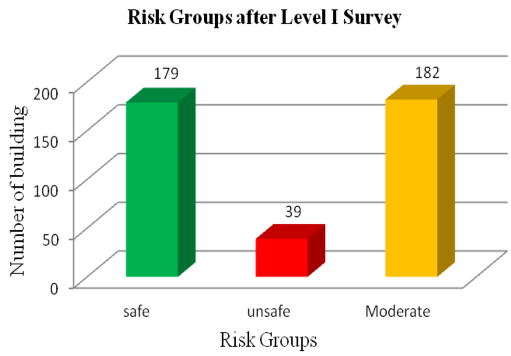

Fig. 10: Risk Groups after Level I Survey

CONCLUSIONS

- From this assessment, soft story in 27.5%, pounding effect in 46.5%, short columns in 2.75%, and heavy overhanging in 24% building among 400 buildings in study area have found at level I survey.
- From the level-I survey results we found Apparent Building Quality (Average) in 64% building, Apparent Building Quality (Good) in 23% building, and Apparent Building Quality (Poor) in 13% building.
- Among 400 buildings 179 (45%) buildings are found to be safe, 39 (10%) buildings are found to be unsafe and 182 (45%) buildings are found to be moderate in terms of their performance score (PS) value after level I survey.
- Those 39 unsafe buildings and 182 moderate buildings should be taken under further assessment to identify their vulnerable structural component and retrofit thereafter as early as possible on priority basis.

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