SEISMIC VULNERABILITY ASSESSMENT OF EXISTING RCC BUILDINGS IN CHITTAGONG CITY: A CASE STUDY OF 8 NO. SHULAKBAHAR WARD

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ABSTRACT
Chittagong is the largest port city and commercial capital of Bangladesh which has many development activities as like of planned residential areas, but over the last 30 years the unchecked development in Chittagong has been resulted in little resilience to earthquake. So now-a-days it is very important to identify buildings that are high vulnerable. This paper represents the seismic vulnerability of RCC buildings of 8 no. Shulakbahar ward, Chittagong by using Turkish method based on a number of structural parameters like soft story, pounding effects, apparent quality etc. at level-I survey and two parameters like redundancy and strength index are also calculated at level-II survey that determined on the basis of engineering knowledge and observation. In this method, the discriminate scores obtained from two discriminate functions are combined in an optimal way to classify existing buildings as “safe”; “unsafe”; “moderate” from level-I survey and those moderate group buildings are further analyzed in Level-II survey and obtained the high risk and low risk group, moderate risk group.

Keywords: Turkish method; soft story index; pounding effect; stiffness index; strength index

INTRODUCTION
Earthquake is caused due to tectonic movements in the earth's crust. Earthquake is also occurred away from plate boundaries at weaknesses in the earth's crust known as faults. In case of Bangladesh which is possibly one of the country’s most vulnerable to potential earthquake threat and damage because the location of Bangladesh close to the boundary of two active plates: the Indian plate in the west and the Eurasian plate in the east and north. For this reason the country (e.g. Chittagong) is always under a potential threat to earthquake at any magnitude at any time, which might cause catastrophic death tolls in less than a minute. In the basic seismic zoning map of Bangladesh, Chittagong region has been laid under Zone II, has seismic coefficient of 0.15, which means this area (Chittagong) under the high risk of earthquake. According to Global Hazard Assessment Program (GSHAP), the most hazardous division in Bangladesh is the Port City Chittagong. About 80-90 percent of buildings and physical infrastructures in Chittagong are vulnerable to future massive earthquake measuring 6-7 magnitudes on the RS, as most of these were not designed to withstand against seismic load. Hilly terrain of this city corporation area may create huge land slide during a heavy earthquake. Now evaluation of the seismic resistance and the assessment of possible damage are quite imperative in order to take preventive measures and reduce the potential damage to civil engineering structures and loss of human lives during possible future earthquakes.
The objective of this study is to compile a database of R.C.C. buildings to make a vulnerability analysis of those structures of the selected area in 8 No. Shulakbahar ward, to classify the buildings into seismically safe or unsafe as well as to identify the buildings that are highly vulnerable.

OBSERVED AREA
The study area is Sholokbahar R/C/A at ward no.8 of Chittagong City Corporation situated on the bank of Karnaphuli River.

Fig. 1: Study Area Shulakbahar Ward

METHODOLOGY

There are several methods to determine seismic risk assessment such as FEMA 154 (1988), FEMA 310 (1998), EURO CODE 8, NewZeland Guideline, Modified Turkish Method, NRC guideline, IITK-GSDM method, Japan method. All the methodologies have common objective to determine the risk of building due to earthquake. Among these Turkish Method of simple survey procedure is adopted for this case study for the study area of 8 No Shulakbahar ward.

TURKISH METHOD

In recent times, after the 1999 earthquake in the cities of Kocaeli and Duzce, Government of Turkey and Japan International Cooperation Agency (JICA) came forward for implementing a regional seismic assessment and rehabilitation program. Researchers from various universities were involved in this program supported by the Government of Turkey and JICA. In this method a simple two-level Seismic Assessment Procedure for a building stock was proposed (Sucuoglu and Yazgan 2003). In this most vulnerable buildings that may undergo severe damage in a future earthquake are identified. The first level (Level - I) is known as "Walk Down Evaluation". This simple level does not require any analysis. In this level the street survey procedure based on simple structural and geotechnical parameters that can be observed easily from the sidewalk. In second level (Level - II), the observers enter the basement and ground stories of the buildings for collecting the simplest structural data.

Level – I: (The Walk Down Evaluation procedure)

In this level of observation some structural parameters that have been observed during the field surveys and selected for representing building vulnerability are given below.

Survey Parameters

(a) Number of Stories [Up to seven stories]: This is the total number of floors above the ground level.
(b) Existence of a soft Storey [Yes or No]: A soft storey usually exists in a building when one particular storey, usually employed as a commercial space, has less stiffness and strength compared to the other stories.
(c) Existence of heavy Overhangs [Yes or No]: Heavy balconies and overhanging floors in multistory RC buildings shift the mass center upwards; accordingly give rise to increased seismic lateral forces and overturning moments during earthquakes.
(d) Apparent Building Quality [Good, Moderate or Poor]: A close relationship has been observed between apparent quality and experienced damage during recent earthquakes in Turkey.
(e) Existence of short Columns [Yes or No]: Frames with partial infill's lead to the formation of short columns which sustain heavy damage since they are not designed for the high shear forces due to shortened heights that will result from a strong earthquake.
(f) Pounding Effect [Yes or No]: When there is no sufficient clearance between adjacent buildings, they pound each other during an earthquake as a result of different vibration periods. Uneven floor levels aggravate the effect of pounding.
(g) Topographic Effects [Yes or No]: Buildings on slopes steeper than 30 degrees have stepped foundations, which cannot distribute ground distortions evenly to structural members above.

(h) Local Soil Conditions [Stiff or Soft]: The intensity of ground motion at a particular site predominantly depends on the distance 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. The PGV map in the JICA (2002) report has contour increments of 20 cm/s2. The intensity zones in Istanbul are expressed accordingly, in terms of the associated PGV ranges.
Zone I : 60<PGV<80 cm/s2
Zone II : 40<PGV<60 cm/s2
Zone III: 20<PGV<40 cm/s2
Based on their number of stories and the seismic hazard level at the site buildings are assigned different base scores as shown in Table given below.

Table 1: Base scores and vulnerability scores for concrete buildings, (Sucuoglu et al., 2003)

No. of Stories	Base Scores(BS)			Vulnerability Scores(VS)					
	Zone I	Zone II	Zone III	Soft Story	Heavy Overhang	Apparent Quality	Short Column	Pounding	Topographic 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
6 or 7	60	80	90	-30	-15	-15	-5	-3	-2

Building Seismic Performance
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 the following equation:
PS = (BS) - Σ (VSM) × (VS); Where, *BS* is the Base Score (Defined in Table 1), *Σ (VSM)* is the Summation of Vulnerability Score Multiple (Defined in Table 2), *VS* is the Vulnerability Scores (Defined in Table 1)

Table 2: Vulnerability Parameters, *(VSM)*

Soft storey	Does not exist = 0, Exist = 1
Heavy overhangs	Does not exist = 0, Exist = 1
Apparent quality	Good = 0, Moderate = 1, Poor =2
Short columns	Does not exist = 0, Exist = 1
Pounding effect	Does not exist = 0, Exist = 1
Topographic effects	Does not exist = 0, Exist = 1

Level - II (Preliminary Assessment)
Yucemen et al. 2004, Ozcebe et al. (2003) and Yakut et al. (2003) employed the discriminant analysis technique to develop a preliminary evaluation methodology for assessing seismic vulnerability of existing low- to medium-rise RC buildings in Turkey. The procedure is applicable to RC frames and frame-wall structures, having the stories up to seven. The main objective of the procedure is to find the buildings that are highly vulnerable to damage.
Definition of the discriminating parameters and the procedure to be followed are introduced below:

Table 3: Variation of LSCVR and IOCVR values with number of stories

n	LS_{CVR}	IOCVR
3 or less	0.383	-0.425
4	0.430	-0.609
5	0.495	-0.001
6	1.265	0.889
7	1.791	1.551

Table 4: Variation of CMC values with soil type and distance to fault

Soil Type	Shear Wave Velocity (m/s)	Distance to Fault (km)				
		0-4	5-8	9-15	16-25	>26
B	>760	0.778	0.824	0.928	1.128	1.538
C	360-760	0.864	1.000	1.240	1.642	2.414
D	180-360	0.970	1.180	1.530	2.099	3.177
E	<180	1.082	1.360	1.810	2.534	3.900

By comparing the CV values with associated DI value calculate performance grouping of the building for life safety performance classification (LSPC) and immediate occupancy performance classification (IOPC) as follows:

If $DI_{LS} > CV_{LS}$ take $PG_{LS}=1$
If $DI_{LS} < CV_{LS}$ take $PG_{LS}=0$
If $DI_{IO} > CV_{IO}$ take $PG_{IO}=1$
If $DI_{IO} < CV_{IO}$ take $PG_{IO}=0$

RESULTS & DISCUSSIONS

After analyzing data, among 500 buildings 191 buildings are unsafe, 215 buildings are safe and 94 buildings are moderate category that is shown in Fig. 2.

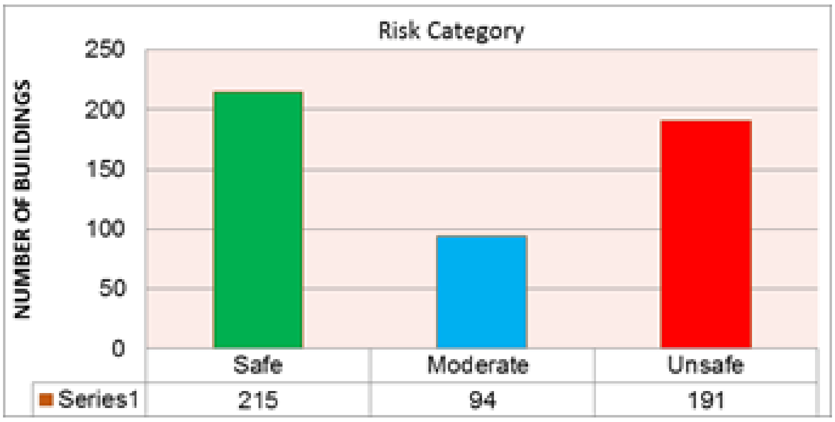

Fig. 2: Number of vulnerable buildings

The study can be summarized as follows:

- The vulnerability factor which is the most severe in study area recognized with soft story in 41.2% and heavy overhanging in 24% building found at level I survey. In case of level II survey 50% buildings have soft storey problem and 26% found heavy overhanging problem.
- The moderate apparent quality of the buildings is ensured by 55% and 12% in level I and II survey respectively. About 14.4% buildings have poor apparent quality found at level II survey.
- From the Level I survey results, the pounding and topographic effects of the buildings covered maximum percentage 6% and 8% respectively. In case of Level II survey these effects were found for 12% and 8% building respectively.
- The redundancy and strength index at level II survey were found in case of 28% and 8% buildings respectively.

CONCLUSION

1) This study mainly targets to attract the interest on the present situation of Chittagong earthquake by seismic vulnerability assessment based on Turkish method.
2) The results of the first level and the second level investigations indicated that, in general consistent results, which further indicated that walk down survey provides a realistic priority ordering for the second level investigations.
3) Some buildings, which were assigned moderate at the end of first level, may be ranked in the high seismic risk group buildings by the second level survey.

REFERENCES

Ahmed, MA; Saha, AR and Dhar, AS. 2008. *Earthquake Vulnerability Assessment of Cox's Bazar District*. *Dhaka*: Ministry of Food and Disaster Management

Ahmed, MM. 2013. *Seismic Vulnerability Assessment of Building and Application of HYDE-System for Retrofitting*. M.Sc. thesis, Chittagong University of Engineering & Technology; Chittagong, Bangladesh

BNBC 1993. Bangladesh National Building code, Housing and Building Research Institute, Mirpur, Dhaka, Bangladesh

BNBC 2006. Bangladesh National Building code, Housing and Building Research Institute, Mirpur, Dhaka, Bangladesh

CDMP. 2009. *Seismic Hazard & Vulnerability Assessment of Dhaka*, *Chittagong & Sylhet City Corporations*. Comprehensive Disaster Management Programme, Bangladesh.

GSHAP. 1992. World Seismic Map. Global Seismic Hazard Assessment Programme. seismo.ethz.ch/GSHAP

Gulkan, P and Sozen, MA. 1999. Procedure for Determining Seismic Vulnerability of Building Structures. ACI *Structural Journal*, 96(3): 336-342.

Sucuoglu, H and Yazgan, U. 2003. Simple Survey Procedures for Seismic Risk Assessment in: Urban Building Stocks. *Seismic Assessment and Rehabilitation of Existing Buildings*, NATO Science Series IV/29, pp. 97-118.