SEISMIC VULNERABILITY ASSESSMENT OF EXISTING RC BUILDINGS IN GIS ENVIRONMENT

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ABSTRACT:
With rapid population growth over the past 30 years and no significance seismic activity during this period, the unchecked development of the built environment in Bangladesh has been resulted in little resilience to earthquake. Identifying buildings due to this unchecked development that has high vulnerability is of critical importance both for reliable loss estimation as a result of an expected earthquake and setting priority criteria for strengthening of those buildings. In this study, using GIS-Detailed Area Plan (DAP) of Chittagong Development Authority (CDA), rapid individual building assessment based on statistical method as demonstrated in Istanbul, Turkey has been considered to evaluate seismic vulnerability of reinforced concrete buildings. Number of stories above the ground level, soft story index, pounding effect, topographic effect, existing of short columns, apparent building quality, local soil conditions, overhang ratio, minimum normalized lateral stiffness index, minimum normalized lateral strength index and normalized redundancy score are selected as the basic estimation variables. In this method, the discriminant scores obtained from two discriminant functions are combined in an optimal way to classify existing buildings as “safe”, “unsafe” and “requires detailed evaluation”. This paper presents seismic vulnerability assessment application in GIS environment on a City Ward entitled as “Purbo Madarbari” of Chittagong, the port city of Bangladesh.

KEYWORDS:
Vulnerability, GIS, MRG, LRG

1.INTRODUCTION

Bangladesh is possibly one of the countries most vulnerable to potential earthquake threat and damage. The Seismic activity of Bangladesh is shown in Figure 1. An earthquake of even medium magnitude on Richter scale can produce a mass graveyard in major cities of the country, particularly Dhaka, Sylhet and Chittagong. Construction of new buildings strictly following building code or development of future controls on building construction is the activities, which will be functional in future. However, under the present stage of human occupancy, buildings, infrastructures and other physical structures of different areas of a city will not be equally vulnerable to any such shock. Earthquake vulnerability of any place largely depends on its geology and topography, population density, building density and quality, and finally the coping strategy of its people and it shows clear spatial variations. It is thus necessary to identify the scale of such variations and take necessary measurements to cope with that.

Geographically Bangladesh is located close to the boundary of two active plates: the Indian plate in the West and the Eurasian plate in the East and North. As a result the country 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 shown under Zone II with basic seismic coefficient of 0.15, but recent repeated shocking around this region indicating the possibilities of potential threat of even much higher intensity like 0.35g than projected.

Chittagong City Corporation Area is situated approximately 70 km from above described fault zones in the Bangladesh-Myanmar Boarder zone. According to BNBC-1993 this area lies in zone-II. Moreover hilly terrain of this city corporation area may create huge landslide during a heavy earthquake as most of the buildings contain sloppy ground around them. Yet, no study on seismic vulnerability assessment has carried out at the Chittagong City Corporation Area. Hence, 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.

A pilot application in a ward of Chittagong City Corporation area has been conducted which is situated on the banks of Karnaphuli River and is a most densely populated area of the city. During the project work, existing methodologies were reviewed and verified to the present situation of the existing buildings. Seismic risks of RC structures were evaluated and the concerned authority will be made aware of the probable disaster by providing this information. It is also necessary to find out suitable retrofitting measure for earthquake vulnerable structure.

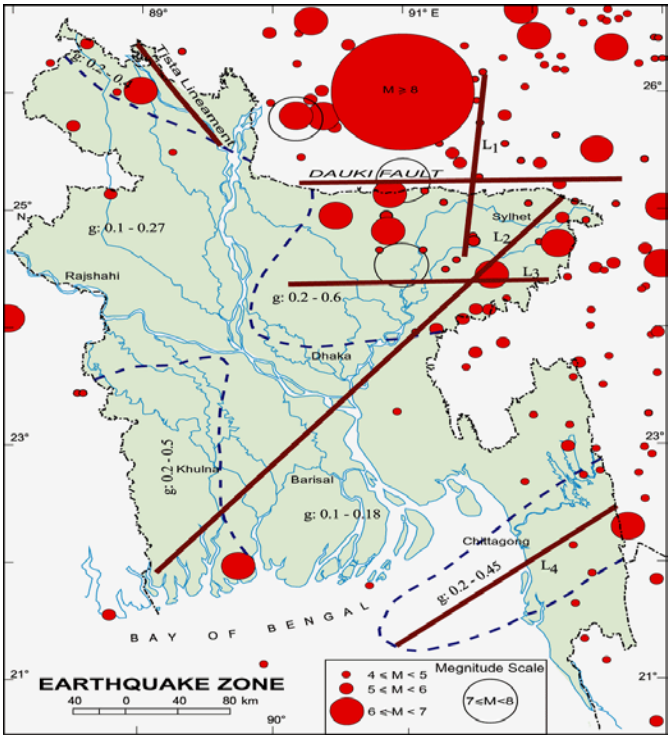

Figure 1: Seismic Activity of Bangladesh

2.STRUCTURAL VULNERABILITY

Structural vulnerability refers to the susceptibility of those parts of a building that are required for physical support when subjected to an intense earthquake or other hazard. This includes foundations, columns, supporting walls, beams, and floor slabs. Strategies for implementing disaster mitigation measures in hospital facilities will depend on whether the facilities already exist or are yet to be constructed. The structural components are considered during the design and construction phase when dealing with a new building, or during the repair, remodeling, or maintenance phase of an existing structure. Unfortunately, in Bangladesh, earthquake-resistant construction standards have not been effectively applied, and special guidelines have not been considered for hospital facilities. For this reason, it is not surprising that each time an earthquake occurs in the region, schools and hospitals among the buildings most affected, when they should be the last to suffer damage. The structural vulnerability of schools and hospitals is high, a situation that must be totally or partially corrected in order to avoid enormous economic and social losses, especially in developing countries. Since many schools and hospital facilities are old, and others have neither been designed nor built to seismic resistant standards, there are doubts as to the likelihood of these buildings continuing to function after an earthquake. It is imperative to use vulnerability assessments to examine the ability of these structures to withstand moderate to strong earthquakes.

2.1 Structural configuration

One of the greatest causes of damage to buildings has been the use of improper architectural-structural configurations. Generally speaking, it may be said that a departure from simple structural forms and layouts tends to be severely punished by earthquakes. Architects and Engineers should have a thorough understanding of the relevant issues. The detrimental issues related to the structural configuration of buildings like concentration of mass, weak column, quality of material and construction, deficiencies in structural layout, soft stories, lack of redundancy, excessive structural flexibility, excessive flexibility of the diaphragm and torsion are considered in this study.

3.METHOD OF SEISMIC RISK ASSESSMENT

In the past, severe earthquakes in this subcontinent and elsewhere have caused extensive losses of life and property. Identification of seismically vulnerable buildings within the existing building stock is therefore a high priority task in the seismic risk reduction of the urban environment. Much effort has been devoted in recent years to the problem of how to devise reliable estimates, given the large uncertainties that exist, (Sozen and Hassan 1997, Gulkan and Sozen 1999 and Yucemen et al. 2004).
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.
Preliminary Assessment Methodology (PAM) is 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 nonstructural elements in the most critical story. The procedures by FEMA 310 (1998) Tier 2, Ozcebe et al. (2003) and Yakut et al. (2003) has been reviewed and documented as the examples of preliminary survey procedures. It is possible to survey large building stocks by employing the preliminary evaluation methodology within a reasonable time span.
The procedures in 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. The procedures proposed in FEMA 356 (2000), ATC 40 (1996), EUROCODE 8 (2004), Sucuoglu et al. (2004) and Park and Ang (1985) are examples of third level assessment procedures.

3.1 Walk down Evaluation-Tier 1

This procedure was developed by Sucuoglu and Yazgan (2003). The details of the procedure are available elsewhere (Sucuoglu 2003). Structural parameters that have to be observed during the field surveys and the value given to each parameter by the observer are number of stories, existence of a soft story, existence of heavy overhangs, apparent building quality, existence of short columns, pounding between adjacent buildings, topographic effects and local soil conditions. Table 3.1 shows the base score and vulnerability score for RC buildings depending on the above parameters.

Table 3.1. Base Scores and Vulnerability Scores for Concrete Buildings

Number of Stories	Base Scores (BS)			Vulnerability Scores (VS)					
	Zone I	Zone II	Zone III	Soft Story	Heavy Overhang	Apparen t Quality	Short Column	Poundin g	Topog. Effects
1 or 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

3.2 Preliminary Assessment- Tier 2

In many instances statistical analysis based on the observed damage and significant building attributes would provide reliable and accurate results for regional assessments. 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 main objective of the procedure is to identify the buildings that are highly vulnerable to damage. The procedure is applicable to RC frames and frame-wall structures, having up to seven stories. Discriminating parameters introduced are number of stories, minimum normalized lateral stiffness index, minimum normalized lateral strength index, normalized redundancy score, soft story index, overhang ratio and performance classification.

3.3 Linear or Non-linear Analysis-Tier-3

The procedures in third stage 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 this evaluation stage, buildings that cannot be classified in the first two stages are considered. This phase of the evaluation usually requires laborious strength and displacement calculations and takes much longer time that the first two evaluation stages. Therefore it is preferred to have small number of buildings to be assessed in this stage.

3.4 Seismic Vulnerability Assessment Procedure

The seismic vulnerability assessment procedure has been summarized in the following ways:

STEP 1: Site investigation and identified the RC building as per GIS map
STEP 2: Walk Down Survey & Evaluation
STEP 3: Calculation of Building Seismic Performance Score
STEP 4: Classification of Buildings according to Building Seismic Performance Score
STEP 5: Selection of Buildings for Preliminary Assessment
STEP 6: Selection of Basic Estimation Parameters
STEP 7: Calculation of the Damage Index and Cutoff Values for each Performance Classifications
STEP 8: Comparison of damage index and cutoff value & Classification of Buildings into different performance group

4.STUDY AREA

The study area in Purbo Maderbari ward no.30 of Chittagong City Corporation Area is situated on the banks of Karnaphuli River and most densely populated area of the Chittagong City. It is one of the most densely populated ward covering residential and commercial areas. Northern side and middle of the ward is commonly used for residential and southern side of the ward, which is situated on the banks of Karnaphuli River, is commonly used for commercial purposes. The GIS location map of the study area with structures collected from CDA (DAP 2007) is shown in Figure 4.1. The soil profile is 21 meters or more in depth and containing more than 6 meters of soft medium stiff clay but not 12 meters of soft clay which site soil characteristics type is S3 as per Bangladesh National Building Code (BNBC-1993).

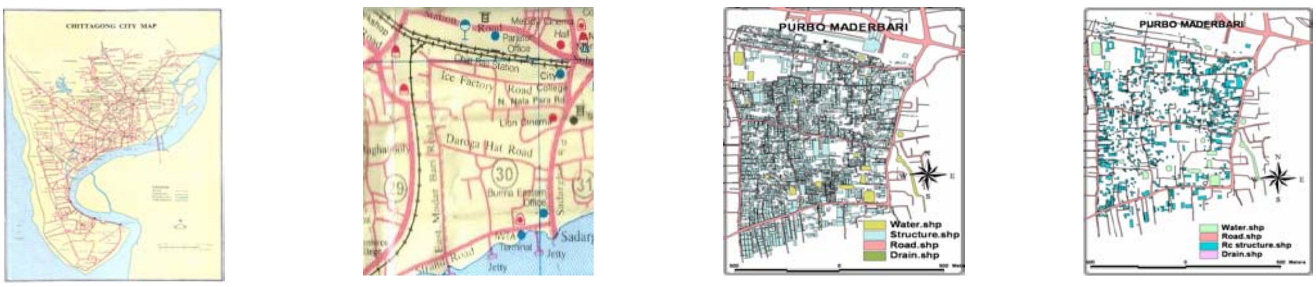

Figure 4.1 Location of Ward 30 with Existing Building Structures in GIS Map

Structures belongs to Ward 30 can be classified into three types depending upon construction material, geometric configuration, construction procedure. These are Katcha (mud house & bamboo house), Semipucca (brick masonry with CI sheet roofing) and Reinforced Concrete buildings. Total number of structure in this ward is 3150 where Katcha structure is 850, Semipucca is1329 and Reinforced Concrete building is 971. This information is given in Figure 4.2.
This paper includes only the RCC structures and is classified according their heights as shown in Table 4.1. A total of 971 RC buildings were surveyed in Tier-1, Walk Down Evaluation and 122 buildings were selected for further investigation in the Tier-2, Preliminary Assessment. At the end of Tier-2 evaluation 80 RC buildings, mostly having 4 stories or more are rated as Moderate Risk Group (MRG) and 42 RC buildings are rated as Low Risk Group (LRG).

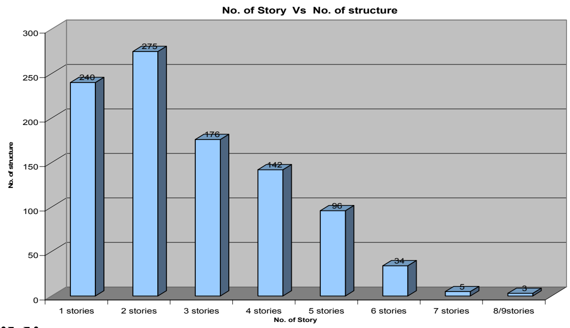

Figure 4.2 Building Distribution Types and Sample RC Buildings

Table 4.1 Classification of RCC buildings

No. of Stories	One stories	Two stories	Three stories	Four stories	Five stories	Six stories	Seven stories	Eight/Nine stories
No. of Structure	240	275	176	142	96	34	5	3

5.DATA ANALYSIS & RESULT

With the different vulnerability parameters necessary for assessment as described in Tier 1 & Tier 2, the existing RC buildings in the study area have been evaluated in two stages.

5.1 Tier-1: The Walk down Evaluation of Existing RC structure

In Tier-1, buildings have been assessed by Walk Down Evaluation method as described in previous sections. Buildings from one storey to nine storey have shown different performance score as they have different vulnerability parameters. The performance score of existing RC buildings have been tabulated in Table 5.1.

Table 5.1 Summary of Walk down Evaluation of existing RC structure in Study Area

	One stories	Two stories	Three stories	Four stories	Five stories	Six stories	Seven stories	Eight/Nine stories
0< Performance Score <= 60	0	0	0	0	80	34	5	3
60< Performance Score <=100	0	0	43	142	16	0	0	0
Performance Score > 100	240	275	133	0	0	0	0	0

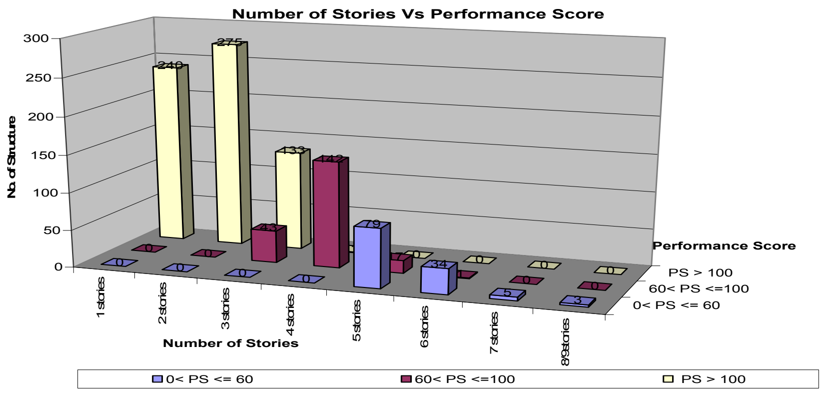

Figure 5.1: **Different Performance group of RC buildings in study area**

5.2 Tier-2: The Preliminary Assessment of Existing RC Structure

In Tier-2, buildings with a seismic performance score of 60 or less were given priority for preliminary assessment. Specific information about the structural system of each building including all dimensions of structural and nonstructural elements was processed. At end of Preliminary evaluation survey, buildings were evaluated according to both the life safety performance classification and the immediate occupancy performance classification performance levels. In each case, the building under evaluation was assigned an indicator variable of "0" or "1". The building was rated in the "low risk group" if both indicator values were zero or in the "high risk group" when both indicator values were equal to unity. In all other cases buildings were classified as the cases "requiring further study." Further investigations have indicated that these buildings generally lie in the "moderate risk group." GIS maps using color-coding of individual building belongs to MRG and LRG are prepared & shown in Figure 5.2.

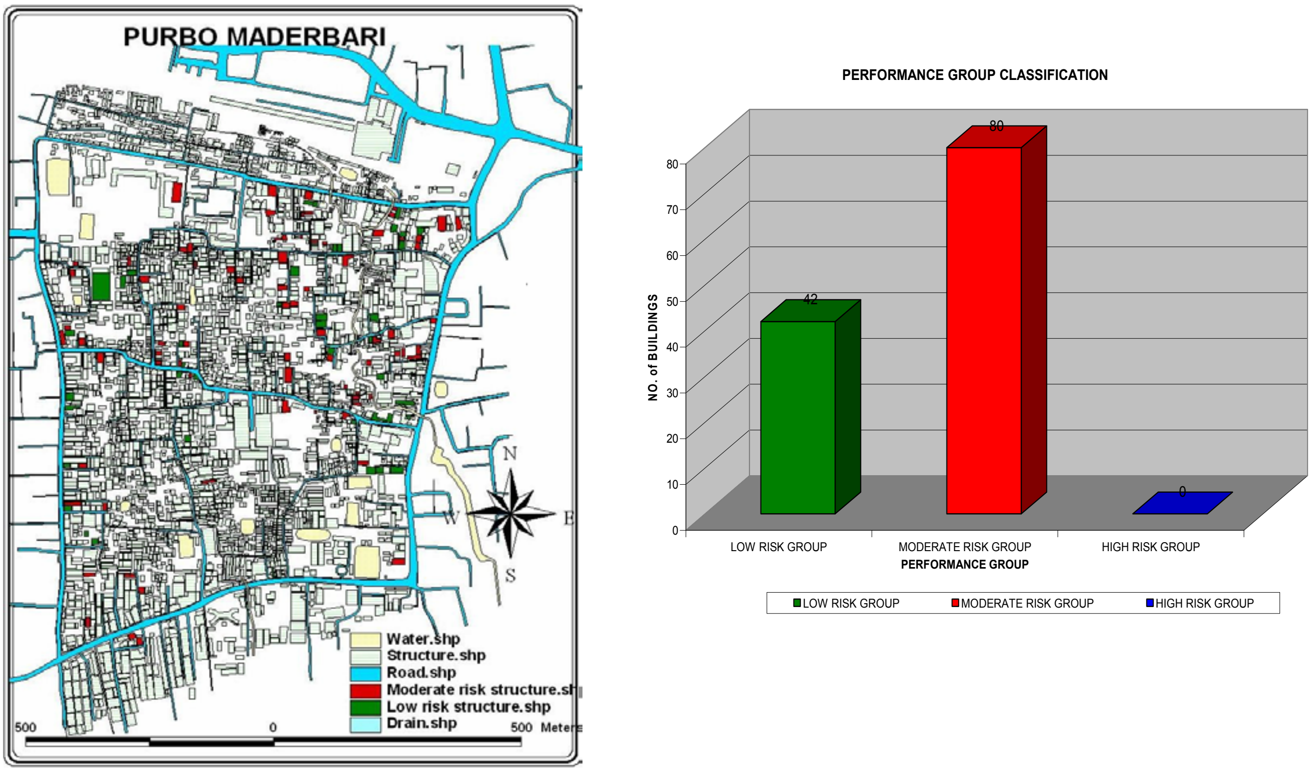

Figure 5.2: Buildings under LRG and MRG

6. CONCLUSIONS

Comparisons made between the results of the Tier-1 and Tier-2 evaluations revealed that, in general, both procedures gave consistent results for the buildings belong to Ward 30 of Chittagong City Corporation. It can be concluded that Preliminary Assessment procedure can complement the Walk Down Evaluation procedure and building with lower performance scores should be given priority for retrofitting scheme and in the long run, the entire building stock of Chittagong City Corporation area should be screened by the use of Preliminary Assessment technique.

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