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Short Communication

ASSESSMENT OF VULNERABILITY OF CRITICAL INFRASTRUCTURES DUE TO EARTHQUAKE IN SYLHET CITY AND MANAGEMENT

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Abstract: In this paper, results are presented on the assessment of seismic vulnerability of buildings in Zone III of Sylhet city, Bangladesh. This study was based on a methodology for earthquake vulnerability analysis using Rapid Visual Screening (RVS) and a structural scoring system (S value >2 indicating Seismic safety). The survey showed that most of the buildings studied in the city fell in the category of seismically moderate to high risk range (S value of 2 or less). Criteria for construction of seismically safe buildings have been proposed.

Introduction

Sylhet, the most important city in the northeastern part of Bangladesh is one the most earthquake prone zones of the country [1]. Bangladesh National Building Code (1993) [2] has placed Sylhet (Latitude: 24.85ºN, Longitude: 91.80ºE) in seismic zone III, the zone of High Seismicity. Kamat and Sengupta [3] used SAP 2000 program to evaluate each building located in seismic zones III and IV (Zone III is vulnerable to earthquake; Zone IV is very vulnerable to earthquake). They assessed each building by equivalent static method, response spectrum method and pushover analysis. The global and local deficiencies for each building were consolidated by them. The authors have presented local deficiencies based on the demand to capacity ratios in the elements from the equivalent static method.

The present work was aimed at measuring how prone the buildings in Sylhet are to seismic force by applying the FEMA 154 Report-Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards [4]. RVS is applicable to all buildings designed and constructed before the adoption of adequate seismic design and provides information on the average behavior of different types of structures. In fact this paper is an effort to make contribution in the judgment of seismic performance of buildings.

Materials and Methods

Selection of RVS "Cut-Off" Score

The selection of RVS cut off score (S) involves the costs of safety versus benefits. The final decision depends also on many non-technical factors, and is not straightforward. In other words, present design practice is such that a value of RVS score (S) of about 3 is appropriate for day-today loadings, and a value of about 2 or somewhat less, is appropriate for infrequent but possible earthquake loadings. Unless the community itself considers the cost and benefit aspects of seismic safety, S value of >2.0 is a reasonable preliminary value to use within the context of RVS to differentiate adequate buildings from those potentially inadequate and thus requiring detailed review. Thus a "Cut-off" S value of >2 was selected in this study for Sylhet City (S ≦1 means high risk, 1-2 means moderate risk, and >2 means no risk). Fig. 1 presents flowchart for Hazardous Building Identifying Methodology. Fig. 2 shows steps to develop an RVS for the study area for assessment [5].

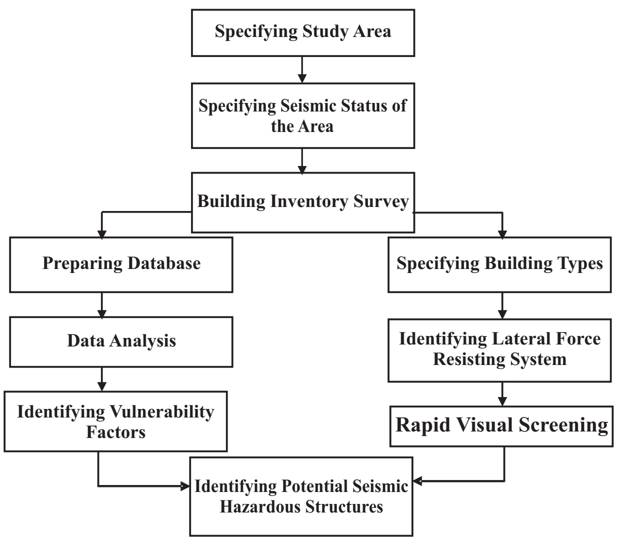

Figure 1. Flowchart for Hazardous Building Identifying Methodology.

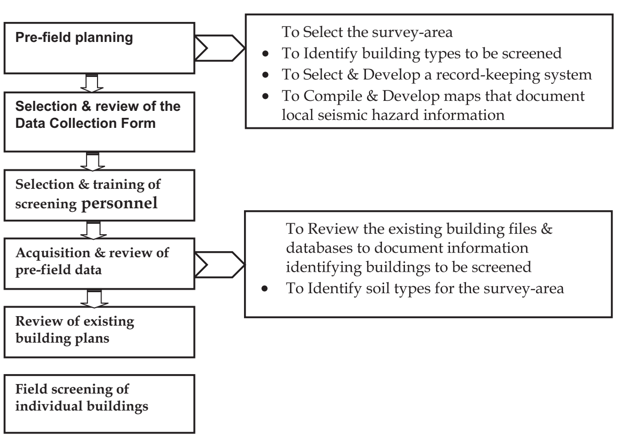

Figure 2. Steps to develop an RVS.

Results

Building Types Considered by the RVS Procedure

The sites survey helped in classification of all buildings in Sylhet into five types, EMSB1 (1-storied brick masonry of fired bricks with cement or lime mortar, roof either of GI sheet or other materials), EMSB2 (2-storied or taller brick masonry of fired bricks with cement or lime mortar, roof generally made of RCC slab and some weak and old reinforced concrete frame), EMSC (reinforced concrete frame with low ductility, designed for vertical load only), EMSD (reinforced concrete frame with moderate ductility, designed for both vertical and horizontal loads) and EMSF (mainly bamboo, wooden structures), based on their definition in European Macroseismic Scale [6]. According to description of Macroseismic Scale and FEMA 154, the lateral-load-resisting system exists only in EMSB2, EMSC, and EMSD as is also true for URM, C2 and C3 types. Thus among the fifteen different types of systems, the buildings in Sylhet City were found to be of C2, C3 and URM types.

The present results show that 30.60% buildings were of RCC frame and 52.15 % of Masonry type. Further, 20.26 % schools, colleges, and particularly the hospitals were of irregular shape. Most of the buildings were constructed without any consideration of soil characteristics and loads and a large portion of buildings were without any foundation. Most buildings were constructed in the last 10 years. Soil type, lateral force resisting system and the buildings' lifelines are essential for RVS method. Distribution of population and road width also impact the scoring method. The population load was large in both schools and hospitals, but relatively greater in schools, thus adding to the stress particularly on the school buildings. On average, only a quarter of the buildings had access to spacious roads. Soil types based on soil intensity [7] were identified as C, D, and E for different geographical locations in Sylhet. Based on these findings the distribution of RVS scores reached in the present work is shown in Table 1**.** It is evident that the majority of the buildings (155 = 105+35+15, i.e. over 66%) were in the moderate to high risk range (S = 2 or less). The seismically safe S value of >2 could be achieved for only 5.36% hospitals, while 31.9% buildings could not be assessed.

Discussion

The present study shows that most buildings in Sylhet city turned out to be seismically unsafe (S=2 or less, moderate to high risk). The primary schools, secondary schools and most hospitals, having a high rise structure fell in this category (only 5.36% hospitals being safe). Low score also implies construction of buildings (74.12% buildings [8,9]) by non-technical persons in Sylhet. Large population load on these buildings increases stress and is cause of potential hazard to human life. Lack of access to wide roads being limited hampers rescue operation. On average only a quarter of the buildings studied were found to have access to wide roads.

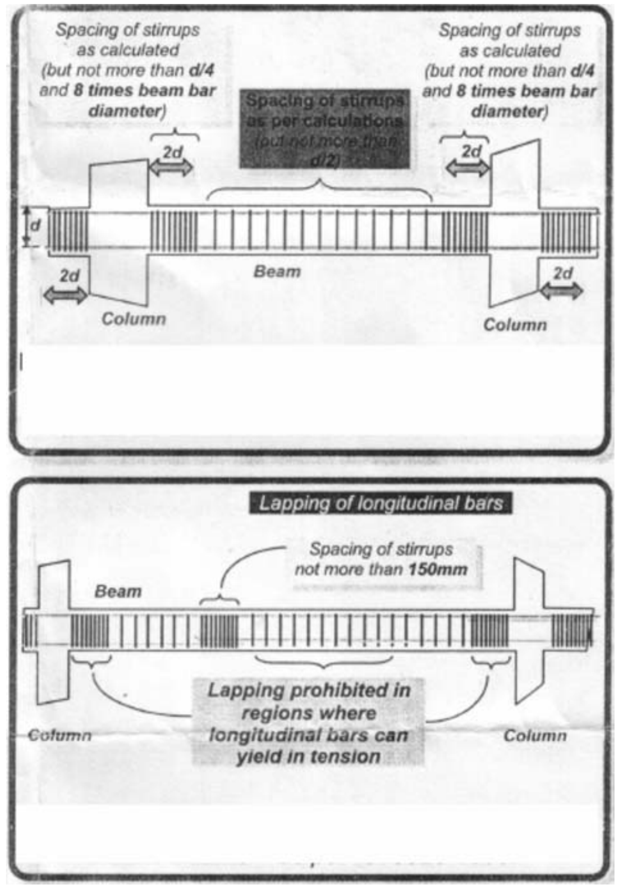

Figure 3. Drawing of reinforcement setup at beam, column and Joint [10].

The earthquake force on a building is a function of mass. Thus, seismic safety demands that the buildings be as light as possible, consistent with structural safety and functional requirements. Cantilever or projected parts

Table 1
Distribution of Building Scores **[**5] **(**S≥2 = no risk; S <1 = high risk, S (1-2) = moderate risk).

Score	Primary School		High School		Hospital		Total	
	Bldg No	%	Bldg No	%	Bldg No	%	Bldg No	%
<0	2	2.86		0.00	13	23.21	15	6.47
0-1	9	12.86	5	4.72	21	37.50	35	15.09
1-2	42	60.00	57	53.77	6	10.71	105	45.26
>=2					3	5.36	3	1.29
No Scoring	17	24.29	44	41.51	13	23.21	74	31.90
Total	70	30.17	106	45.69	56	24.14	232	

should be avoided as far as possible. In order to minimize "torsion and stress concentration", a building should have a simple rectangular plan, and should be symmetrical, both with respect to the mass and the rigidity of the structure [9]. For buildings with a basement, the ties should be placed at the level of the basement floor and should be designed to carry the load of the panel walls. These should also be designed to "tension" and "compression" loads, in addition to the axial load of not less than the earthquake force acting on the heaviest column connected [8]. Basement walls provide a "thrust area" which reduces the lateral force on the foundations. Raft foundations located on the well-compacted soil give added advantage. Furthermore, the bands at the plinth level, the lintel level and the roof level should be joined by the vertical steel (MS bar of 12 mm diameter for a single-storey house, and an 18 mm bar located at the junction of the walls are considered adequate). Mutry [10] has proposed details of reinforcement set up at beam, column and Joint levels (Fig. 3), yielding a higher S value. The criteria suggested here for seismic safety of buildings are expected to be of much value in minimizing seismic hazard.

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