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Evaluation of Seismic Capacity and Expected Damage of RC Buildings in Bangladesh
Part 1: Study on characteristics of existing RC buildings in Bangladesh

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1. Introduction

Developing countries such as Bangladesh, have a huge stock of seismically vulnerable existing buildings. At present, Bangladesh has been adopting Japanese seismic evaluation standard (JBDPA) [1] in CNCRP seismic evaluation manual [2] for seismic evaluation of existing RC buildings. However, JBDPA standard [1] proposed seismic demand index (i.e. $I_{SO}=0.6$) based on study of past earthquake damage database. On the other hand, CNCRP standard [2] proposed criteria for seismic demand index of 0.28 to 0.36 based on seismic demand correlation of Bangladesh National Building Code (BNBC) [3] and JBDPA [1]. However, due to lack of past earthquake database in Bangladesh, the proposed judgement criteria by CNCRP [2] needs further verification. Criteria setting for identification of vulnerable building is a key issue regarding seismic evaluation and/or retrofitting of existing RC buildings in Bangladesh.

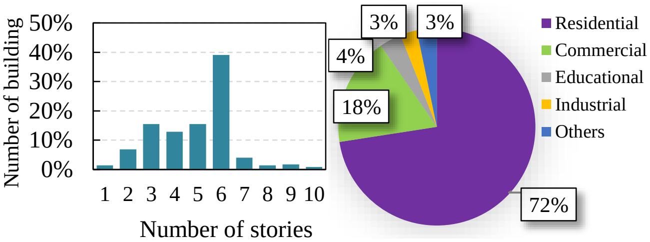
This study intends to develop the correlation between expected damage and seismic capacity based on I_s index for existing buildings in Bangladesh using analytical model and performance based seismic analysis. This study has been subdivided into two parts (part 1 and part 2). Part 1 consists of understanding the buildings' characteristics (e.g. number of stories, column size etc.) and seismic capacity of existing RC buildings located at Dhaka, Bangladesh. Then based on the investigated characteristic, several RC frames are designed to represent the case of typical existing buildings and using design criteria of BNBC [3]. Part 2 describes the seismic evaluation results of those designed RC frames, correlation of damage level with I_s index based on pushover analysis on mathematical models.

2. Study on existing RC buildings in Bangladesh

2.1 Overview of the Database

Total of 583 RC buildings located in Dhaka city have been investigated in order to understand the characteristics of typical existing buildings in Bangladesh. The building information with as-built architectural drawing along with location of masonry infill are collected from field survey conducted by Comprehensive Disaster Management Program (CDMP) [4].

Most of the surveyed buildings are residential buildings with four to six storied as shown in Figure 1(a) and 1(b). Figure 2 shows distribution of average column size and average span length with number of stories for 110 investigated buildings out of 583 buildings. The usual practice for least dimension of typical column is 250 mm and average span length is 3 to 4 m as shown in Figure 2.



(a) According to Story number (b) Occupancy catergories

Figure 1: Distribution of buildings in percentage

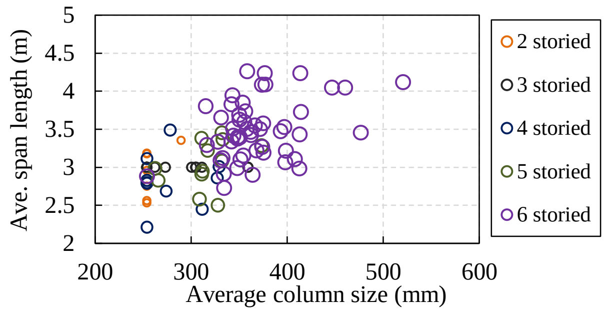


Figure 2: Average span length vs average column size

2.2 Seismic capacity evaluation of existing buildings

In this study, a simplified way of seismic evaluation has been done based on the concept of Shiga map [5]. This is because of seismic evaluation procedures (such as first level and second level) require information about reinforcement and material properties which are not available in the CDMP database [4]. Seismic capacity is the summation of lateral strength of RC column, masonry infill and concrete wall normalized with total building weight [6] as expressed by following Eq. (1). The lateral capacity of each structural element (i.e. RC column, masonry wall and concrete wall) refers to the product of cross-sectional area and corresponding shear strength.

$$Seismic\ capacity\ index = \tau_c \cdot \frac{A_c}{n.\ A_f . w} + \tau_{inf} \cdot \frac{A_{inf}}{n.A_f.w} + \tau_{cw} \cdot \frac{A_{cw}}{n.A_f.w} \qquad (1)$$

where, τ_c, τ_{inf}, and τ_{cw} are average shear strength of column and masonry infill; A_c, A_{inf}, and A_{cw} are cross-sectional areas of column and masonry infill; A_f, n, and w are the floor area, number of story, and average building weight, respectively.

In Eq. (1), (A_c/A_f), (A_{inf}/A_f), and (A_{cw}/A_f) are column area ratio, masonry infill area ratio, and RC wall area ratio respectively. Figure 3 (a) and 3 (b) show the distribution of column and masonry infill area ratio, respectively. In about 65 % of total buildings showed 0.2~0.3% column area ratio which is relatively low compared to Japan. Besides, about 60 % of total buildings have lower masonry infill wall area ratio ranges 0.1% to 0.2%, as shown in Figure 3(b).

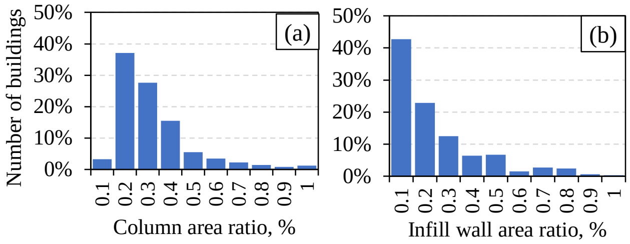


Figure 3: Distribution:(a) column area ratio, (b) infill wall area ratio

Due to lack of material tests in CDMP [4] database, the following assumptions have been made regarding materials and building weight as described below:

(a) Average shear strength of RC column (τ_c): JBDPA standard [1] considers the average shear stress for column is 1.0 MPa for first level screening procedure based on shear span ratio, where h_o/D ranged between 2 to 6 (h_o is the clear height of column, D is the depth of column). In this study, therefore, τ_c is assumed 1.0 MPa as conservative value.

(b) Average shear strength of masonry infill (τ_{inf}): ASCE seismic guideline [7] prescribes shear strength as 34 psi (0.24 MPa) for masonry infill wall. In this study, average shear strength of masonry infill, τ_{inf}, as 0.2 MPa has been adopted as lower boundary of the lateral shear strength.

(c) Average shear strength of concrete wall (τ_{cw}): JBDPA standard [1] considers τ_{cw} as 1.0 MPa considering without boundary column. Therefore, τ_{cw} has been assumed 1.0 MPa as lower boundary.

(d) Average unit weight per floor area (w): The unit floor weight of existing buildings has been found from 10 to 12 kN/m^2 based on study of existing RC buildings. In this study, the average unit weight per floor area, w, is set as 11kN/m^2.

The seismic capacity index has been calculated using Eq. (1), and shown in Figure 4.

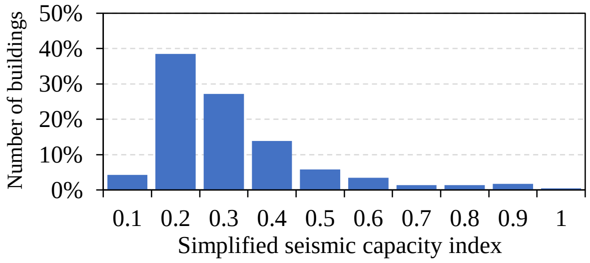


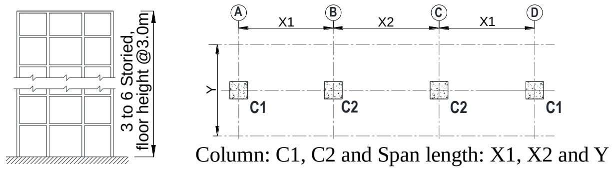
Figure 4: Simplified seismic capacity index

It is important to set boundary line for judgement criteria for retrofitting of the buildings with lower seismic capacity. From Figure 4, it can be estimated that if boundary line has been set at 0.2, about 40% building need to be retrofitted. Alternatively, if boundary line has been set at 0.30, more than 60% buildings are needed for retrofitting. Due to lack of past earthquake damage database, it is difficult to set up boundary line for retrofitting. Therefore, damage evaluation corresponds to local seismicity is one of the way for identifying approximate damage status of existing buildings. Detail drawings and information are necessary for performing such evaluation procedure. As CDMP [4] database does not have detail structural drawing, therefore, several representative RC frames have been design based on BNBC [3]. The detail consideration of design procedure has been described in the following sections.

3. Design of RC frame

3.1 Parameter selection

Total thirty-five RC frames have been designed as per BNBC [3] as shown in Figure 5. Those frames have been selected varying in different parameters as shown Table 1. Material properties has also considered to represent construction practices as shown in Table 2.



(a) Elevation (b) Plan

Figure 5: Typical designed RC frame

Table 1: Selection of parameters

Variables	Ranges
Number of stories	3 to 6 storied
Span length	2 m to 5 m
Column size	250 mm to 500 mm

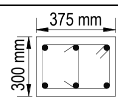
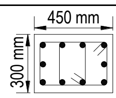
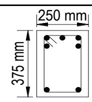
Table 2: Materials properties

Building type	f'_c (MPa)	f_y (MPa)
New building	25	414
Old building	13.5	275

3.2 Load Consideration and structural design

All studied frames sustain total load of 10 kN/m^2 as per BNBC [3] including dead load, and live load. In addition, the seismic load has been applied using equivalent static force method. All RC frames are designed as per BNBC [3] and typical sections are shown in Table 3.

Table 3: Typical column and beam sections

Item	Column: C1	Column: C2	Beam
Section			
Main rebar	6-D22	10-D25	7-D25
Tie bar	D10@200 mm		D10@250 mm

4. Summary of part 1

Seismic capacity evaluation has been done for existing RC building to understand the basic characteristics. Then, several RC frames have been designed based on BNBC [3] and buildings characteristics. Seismic evaluation and damage ratio of RC frame have been described in part 2. The flow of study is shown in Figure 6.

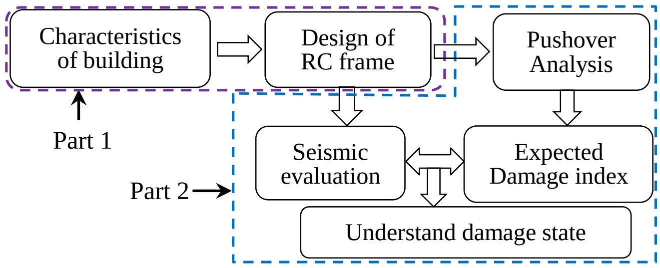


Figure 6: Flow of study

References: Attached in part 2.

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