日本建築学会大会学術講演梗概集
（東北） 2018 年 9 月

Seismic assessment of existing RC buildings with masonry infill in Bangladesh
Part 3: Proposal of Visual Ranking Method and its application to existing RC buildings

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Keyword:
Seismic evaluation RC building
Masonry infill Column and masonry area

1. Introduction:

In developing countries such as Bangladesh, there exist much volume of stock of seismically vulnerable existing buildings. Therefore, a simple assessment and screening of retrofit target is necessary for quick and effective promotion of seismic improvement. This paper proposes a procedure of visual ranking (VR) method using the fundamental parameters, focusing on the cross-sectional areas of the columns and its tributary area, and masonry infills quantity as well as taking into account the influence of structural configuration and also present condition of buildings. The proposed procedure has been applied on the six existing buildings evaluated in Part 2 as a case study. Finally, this approach is verified with first and second level evaluation procedure in order to investigate the efficacy of the proposed method.

2. Development of Visual Ranking (VR) method

2.1 Visual Ranking (VR) survey sheet:

VR considers a rapid building inspection for a short duration only to record the information using a common survey sheet as shown in Table 1 which contains basic parameters of a building. These basic parameters are considered based on past literature and past earthquake damage database [8,9]. The basic consideration and selection criteria for each items are explained in next the section.

Table 1. A sample of VR survey sheet

Visual Ranking (VR) Survey Sheet

Name of Building: Date:

(Please read carefully the selection criteria and put circle [○] in the appropriate items)

No	Items	Selection Criteria	Descriptions			
1	No of story	Put story number				
2	Average column size, b_c (mm)	Very High = 500mm~ High = 400~500 mm Medium = 300~400 mm Small =250~300 mm	Very High	High	Medium	Small
3	Average span length, l_s (m)	Short= 2~ 3 m Medium = 3~4 m Long = More than 4 m	Short	Medium	Long	
4	Volume of masonry infill	Masonry infill ratio (R_{inf}): $=\frac{No\ of\ infill\ panel\ in\ x\ or\ y\ direction}{No\ of\ span\ in\ x\ or\ y\ direciton}$	x-direction: ☐/☐	y-direction: ☐/☐		
5	Irreguality in vertical (F_{IV})	Regular = No irregularity Nearly Regular = Small opening at ground floor Irregular = Ground floor parking	Regular	Nearly Regular	Irregular	
6	Irregulality in horizontal (F_{IH})	Regular = No irregularity Nearly regular = Irregular in Plan Irregular = Irregular in Plan and frame	Regular	Nearly Regular	Irregular	
7	Deterioration and Spoiled in Concrete (F_D)	None = No deterioration Minor = Some crack in structrual element Severe = Spalling of concrete	None	Minor	Severe	
8	Year of construction (F_Y)	New = less than 15 years Middle =15~30 years Old = More than 30 years	New	Middle	Old	

Name of investigator:

2.2 Basic Concept and Calculation procedure of VR score:

Visual Ranking (VR) procedure intends to prioritize the buildings for preliminary and also detailed evaluations. A VR score for classifying buildings is calculated by Eq. (1):

$$I_{VR}=\left[\tau_c \frac{A_c}{A_f.n.w}+\tau_{inf}\frac{A_{inf}}{A_f.n.w}\right]\times F_{IV}.F_{IH}.F_D.F_Y \qquad \text{Eq. 1}$$

Where, τ_c and τ_{inf} are average shear strength of column and masonry infill; A_c *and* A_{inf} 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), column area ratio (A_c/A_f) can be roughly estimated using average column size (b_c) and average span length (l_s). Masonry infill area ratio, (A_{inf}/A_f) can be calculated from masonry infill thickness (t_{inf}), average span length (l_s), and masonry infill ratio (R_{inf}). Where, R_{inf} is the ratio of number of masonry infill panels to the total no of spans for each direction as shown in Eq. (2):

$$R_{inf}=\frac{Number\ of\ masonry\ panel\ in\ a\ direction}{Total\ no\ of\ span\ in\ a\ direction} \qquad \text{Eq. 2}$$

Therefore, Eq. (1) can be rewritten as:

$$I_{VR}=\left[\tau_c.\left(\frac{b_c^2}{l_s^2}\right).\frac{1}{n.w}+\tau_{inf}\left(\frac{t_{inf}}{l_s}.R_{inf}\right).\frac{1}{n.w}\right]\times F_{IV}.F_{IH}.F_D.F_Y \qquad \text{Eq. 3}$$

The following assumptions have been made regarding materials and building weight as described below:

(a) τ_c ; The Japan Building Disaster Prevention Association (JBDPA) standard [1] proposed shear strength of column is 1.0 MPa which is roughly assumed in this study.

(b) τ_{inf} ; For shear strength of masonry infill (τ_{inf}), ASCE 41-06 seismic guideline [5] estimated 34 psi (0.24 MPa) for good masonry condition. From the reference above, considering material properties for other countries, a conservative value of 0.2 MPa, is adopted as lower boundary of the lateral shear strength (τ_{inf}) of masonry infill.

(d) t_{inf} ; The usual thickness of masonry infill is 125 mm, according to common construction practice in Bangladesh.

(c) w; The average weight per unit area ($w=W/A_f$) is approximately set 11 kN/m^2, according to common design practice.

Each VR parameter in the Eq. (3) are described as follows:

(1) No of story (*n*): No of story directily related to the total building weight by increasing total floor area and weight of a building.

(2) Average column size (b_c): It is considered excluding the concrete cover which is about 50mm. The ranges of b_c are mentioned in the data sheet in Table 1, based on analysis of the existing RC building [10] in Bangladesh as shown in Figure 1.

バングラデシュにおける組積造を有する既存 RC 造建築物の耐震性能評価、その 3

(3) Average span length (l_s): Average span length, l_s is considered as the size of equivalent square floor area carried by column as shown in Figure 2. It has been categorized as small, medium and long shown in survey sheet in Table 1, based on the characteristics of existing buildings in Bangladesh [10] as shown in Figure 1.

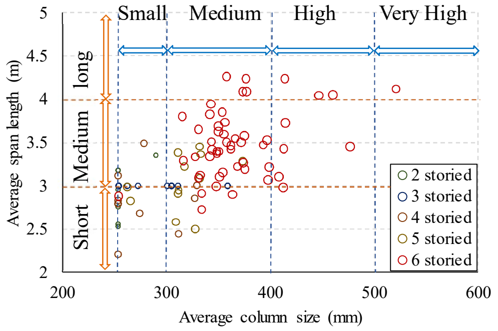

Figure 1. Average span length vs. average column

(4) Masonry infill ratio (R_{inf}): It indicates the quantity of masonry infill expressed as the ratio of total number of masonry infill panel to the total number of span for each direction of building. Masonry infill panel with opening due to door and window are not considered during calculation of R_{inf}.

R_{inf} shall be calculated for both orthogonal directions by using Eq. (2). The minimum value is to be considered. Figure 2 shows a typical sketch of surveyed building. For calculation of R_{inf}, the total number of masonry panels to be counted for each orthogonal direction. It is seen that the total masonry infill panels are counted as 2 and 3 in x and y direction, respectively. On the other hand, the total number of spans are obtained as 12 and 15 in x and y direction, respectively. Therefore, R_{inf} are to be found 2/12 and 3/15 for x- direction and y-direction respectively. Here, minimum value should be considered.

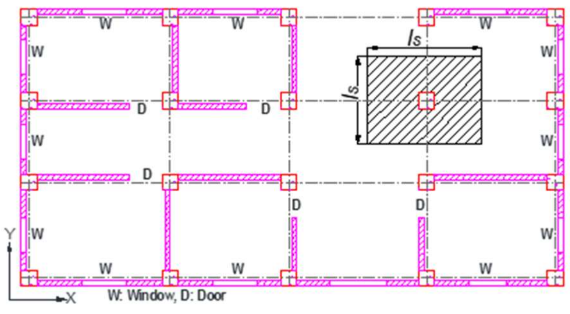

Figure 2. Typical sketch for RVS method

(5) Vertical irregularity factor (F_{IV}): The F_{IV} involves to check balance of story stiffness distribution along the height, the inconsistency between adjacent floor, ground floor parking etc.

(6) Horizontal irregularity factor (F_{IH}): This factor accounts for unbalanced stiffness in floor, investigation of the aspect ratio, different possible shaped plan (like L, T or U). In addition, frame discontinuity is also to be considered during visual inspection. Table 2 shows the basic criteria and values for F_{IH} as per the JBDPA [1].

(7) Deterioration factor (F_d): This factor reflects the cracks and/or spoiled concrete of any structrural element. JBDPA [1] considers the reduction factor for the deterioration of building as shown in Table 2.

(8) Building year of construction factor (F_y): The building age affects its overall seismic capacity. Material deterioration, corrosion of reinforcement might be encountered in old buildings. The values for F_y are shown in Table 2.

Table 2. Items according to values of factors [1]

	Category-1	Category-2	Category-3
F_{IV}	Regular (1)	Nearly Regular (0.8)	Irregular (0.6)
F_{IH}	Regular (1)	Nearly Regular (0.8)	Irregular (0.6)
F_D	None (1)	Minor (0.9)	Severe (0.8)
F_Y	New (1)	Middle (0.95)	Old (0.9)

*numeral in parenthesis indicates corresponding grades/weightage

3. Application and comparison with 1st and 2nd level evaluation:

The proposed VR method has been applied on 6 (six) existing RC buildings in Bangladesh. The details information is described in Part 2. Table 3 shows the results for VR scores, 1st and 2nd level seismic evaluation of these buildings. The seismic evaluation procedure and results have been described in Part 1 and Part 2.

Table 3: VR score with minimum I_s in 1st and 2nd level evaluation

Building ID	Seismic Index		VR score
	1st level	2nd level	
Bldg. # 1	0.09	0.21	0.12
Bldg. # 2	0.21	0.24	0.22
Bldg. # 3	0.47	0.61	0.38
Bldg. # 4	0.23	0.25	0.32
Bldg. # 5	0.23	0.45	0.26
Bldg. # 6	0.20	0.36	0.25

Figures 3(a) and 3(b) show the comparison of VR score with the minimum value of seismic index of 1st and 2nd level evaluation. It has been observed that the VR scores show good agreement with both evaluation procedures. Therefore, it has been underlined that VR score can be an alternate way to assess the seismic capacity which can be obtained with less effort than that of in details evaluation.

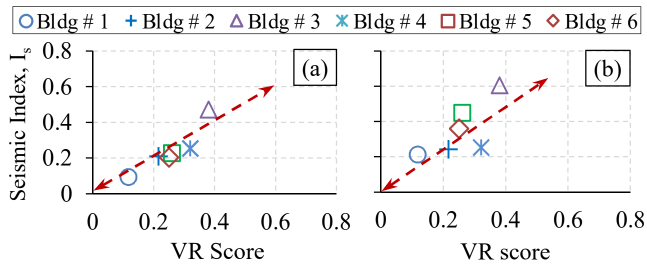

Figure 3. VR score vs. minimum I_s: (a) 1st, (b) 2nd level evaluation

4. Conclusions:

This study proposes a visual ranking (VR) method and application of 6 (six) existing RC with masonry infill buildings in Bangladesh. The VR scores indicates a rough seismic capacity of existing buildings which provides a judgement for further detail evaluation.

However, the values for different modification factors needs further investigations based on structural properties.

References: Please see in Part 4.

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