Judgement criteria for Visual Rating method of existing RC buildings in Bangladesh

Md Shafiul ISLAM[1], Zasiah TAFHEEM[2], Debasish Sen[3], Hamood ALWASHALI[4], Masaki MAEDA[5]
[1]Tohoku University,shafiul@rcl.archi.tohoku.ac.jp
[2]Tohoku University,zasiah@rcl.archi.tohoku.ac.jp
[3]Tohoku University,dsendip@rcl.archi.tohoku.ac.jp
[4]Tohoku University,hamood@rcl.archi.tohoku.ac.jp
[5]Tohoku University,maeda@rcl.archi.tohoku.ac.jp

Abstract— **Visual Rating method is a simple way to identify the most vulnerable buildings and prioritize for detailed evaluation. This study presents judgement criteria for prioritization of existing RC buildings. A capacity spectrum method is applied on model RC buildings, representing existing RC buildings in Bangladesh, to calculate the capacity-demand ratio. Judgement criteria for detailed evaluation is set based on capacity-demand ratio. The Judgment criteria of Visual Rating method are proposed based on the correlation between Visual Rating method and seismic index.**

I. INTRODUCTION

A rapid seismic evaluation method defined as Visual Rating (VR) method has been developed for identifying the most vulnerable buildings [1] and prioritization for detailed seismic evaluation. However, judgement criteria for prioritization based VR score is not yet decided.

In Bangladesh, CNCRP [2] manual proposed the seismic demand index (I_{SO}) ranging from 0.28 to 0.36 based on Bangladesh National Building Code (BNBC) [3] and JBDPA [4] for detailed evaluation. However, I_{SO} by CNCRP [2] needs further verification before using in VR method due to lack of past earthquake database in Bangladesh.

This study aims to propose judgement criteria for categorization of existing RC buildings. Several model RC buildings, representing the existing RC building in Bangladesh, are chosen for setting judgement criteria for detailed evaluation. Further, judgement criteria for VR method has been proposed using the judgement criteria of detailed seismic evaluation and the VR results.

II. INTRODUCTION OF VISUAL RATING METHOD

The Visual Rating (VR) method [1] is a simple way for screening of existing RC buildings based on visual inspection. The VR method estimates seismic capacity of a building in terms of Visual Rating index (I_{VR}) based on lateral strength of RC column and infill wall. The detailed procedure of I_{VR} is discussed by the author [1]. The VR method is applied on several existing RC buildings located at Dhaka, Bangladesh, under a project called SATREPS-TSUIB [5] and I_{VR} is compared with the detailed seismic evaluation results of those investigated RC buildings [6]. Since, the main intention of the VR method is to screen and categorize the existing RC buildings, it is necessary to set criteria for categorization of detailed evaluation.

This study considers several model RC buildings, representing existing RC buildings in Bangladesh. A judgment criteria detailed evaluation are set based on a correlation between capacity demand ratio and seismic capacity of model RC buildings. The following sections discuss about the procedure of judgement criteria based on capacity demand ratio and seismic capacity in details.

III. JUDGEMENT CRITERIA FOR DETAILED EVALUATION

A. Outline of Model Buildings

A total of 105 model RC buildings, representing the existing RC buildings in Bangladesh, are considered. The selection criteria are: story number (n=2 to 6), and strength index (C) and ductility index (F) as shown in Table I. It should be noted that these parameters are set according to investigation of existing RC buildings [7]. The floor height is assumed as 3000mm as commonly found in Bangladesh.

TABLE I
PARAMETERS OF MODEL BUILDINGS

Strength index (C)	Ductility index (F)		
	Case 1	Case 2	Case 3
0.10	1.00	1.27	1.75
0.15	1.00	1.27	1.75
0.20	1.00	1.27	1.75
0.25	1.00	1.27	1.75
0.30	1.00	1.27	1.75
0.35	1.00	1.27	1.75
0.40	1.00	1.27	1.75

Model buildings are converted into ESDOF system for capacity spectrum method. Here, the equivalent mass (w) and equivalent height (h) is calculated by multiplying 0.80 with total mass (W) and 0.70 with total height (H).

B. Capacity Demand Ratio calculation procedure

Fig.1 shows a capacity spectrum method for calculation of capacity demand ratio (CDR), can be estimated by Eq. 1.

$$CDR = \frac{S_a}{S_{ae} \cdot F_h} \tag{1}$$

where, S_{ae}=Spectral acceleration at elastic response acceleration of BNBC [3], S_a= Capacity at safety limit and, F_h= Response reduction factor is calculated by Eq. 2.

$$F_h = \frac{1.5}{(1+10*h_{eq})} \tag{2}$$

The equivalent damping ratio (h_{eq}) of ESDOF system, is calculated using Eq. 3.

$$h_{eq} = 0.05 + 0.25 * 1 - \frac{1}{\sqrt{\mu}} \tag{3}$$

where, μ is the ductility factor is calculated using Eq. 4:

$$\mu = \frac{\Delta_u}{\Delta_y} \tag{4}$$

where, Δ_u and Δ_y are the ultimate and yield deformation, respectively. In this study, yield drift is assumed as 1/150.

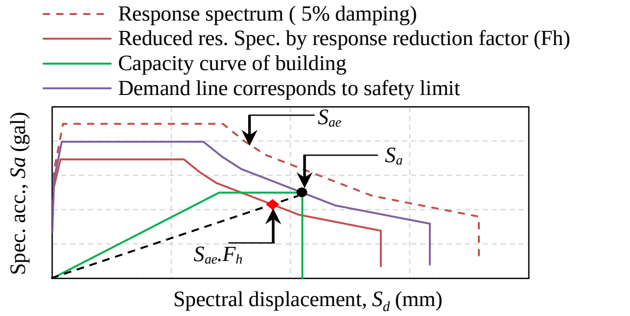

Fig. 1 A typical diagram showing calculation of CDR of model buildings

C. *Capacity-Demand Ratio (CDR) and Seismic Index (I_{S2})*

The calculated CDR is plotted with I_{S2} as shown in Fig. 2. It has been observed that the seismic index greater than 0.40 shows the buildings contain the capacity demand ratio greater than 1. It indicates that these building has sufficient seismic capacity to resist seismic demand during earthquake.

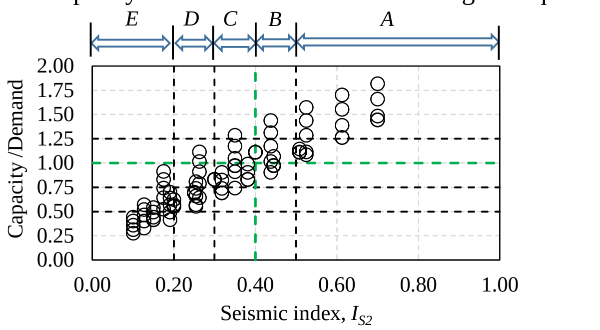

Fig. 2 Proposal of boundary for seismic index (I_{S2}) according to CDR

D. *Judgment Criteria for Seismic Index (I_{S2})*

Table II shows judgement criteria for I_{S2} and buildings are categorized into 5 groups namely A, B, C, D and E depending CDR as shown in Fig. 2. In the criteria, the buildings have lower seismic capacity (i.e. I_{S2} less than 0.40) are considered as most vulnerable buildings. Besides, E are the most vulnerable buildings and A are to be considered less vulnerable.

TABLE II
JUDGEMENT CRITERIA ACCORDING TO CDR AND I_{S2}

CDR	Seismic index (I_{S2})	Categories	Description
1.25<	0.50~	A	No damage
1.00~1.25	0.40~0.50	B	Light damage
0.75~1.00	0.30~0.40	C	Less possibility of collapse
0.50~0.75	0.20~0.30	D	Moderate possibility of collapse
~0.50	<0.20	E	High possibility of collapse

IV. JUDGEMENT CRITERIA FOR VISUAL RATING METHOD

A correlation between I_{S2} and I_{VR}, is obtained in another study [6] as shown in Fig. 3, is considered to propose judgement criteria for VR method. The judgement criteria for I_{S2}, as shown in Table III, is plotted in Fig. 3.

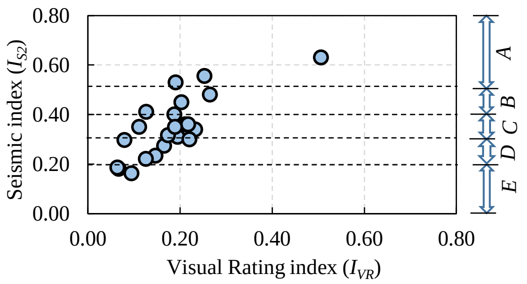

Fig. 3 Correlation between I_{S2} and I_{VR}

It has been that it is not easy to set boundary for I_{VR} due to variation of I_{VR} for each the range of I_{S2}. However, judgement criteria for I_{VR} is proposed by setting the number of buildings (in percentage) to be screened of each category of I_{VR}. Hence, distribution of buildings in percentage for each range of I_{S2} has been plotted according to I_{VR} as shown in Fig.

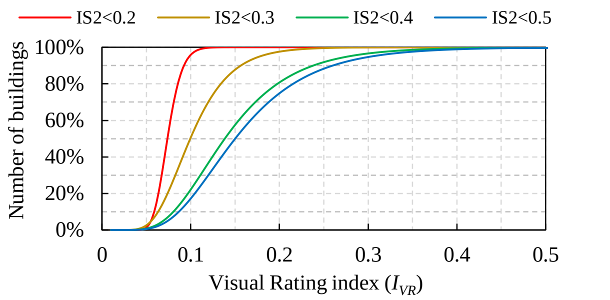

Fig. 4 Cumulative percentage of buildings according to I_{VR}

Based on Fig. 4, judgement criteria for I_{VR} are set assuming 90% target screening of each categories. Table III shows the proposed judgement criteria and the buildings are at E category, considered as the most vulnerable buildings and detailed evaluation is highly recommended.

TABLE III
JUDGEMENT CRITERIA FOR VISUAL RATING INDEX (I_{VR})

Range	Categories	Description
$0.26 \le I_{VR}$	A	No damage
$0.24 \le I_{VR} < 0.26$	B	Light damage
$0.16 \le I_{VR} < 0.24$	C	Less Possibility of collapse
$0.10 \le I_{VR} < 0.16$	D	Moderate possibility of collapse
$I_{VR} < 0.10$	E	High possibility of collapse

V. CONCLUSION

The main conclusions are stated as follows:

(i) This study proposes I_{SO} =0.40 for detailed evaluation which is close to the value (I_{SO}=0.36) by CNCRP manual [3].

(ii) The criteria for I_{VR} are set into 5 (five) classes such as A, B, C, D and E from less to most vulnerable buildings.

(iii) I_{VR} lower than 0.24 are regarded as vulnerable buildings, and the buildings with I_{VR}<0.10 are the most vulnerable and high priority for detailed seismic evaluation.

However, additional existing RC buildings survey is recommended to increase accuracy and effectiveness of the proposed judgement criteria.

ACKNOWLEDGMENT

This research is supported by SATREPS-TSUIB project (Prin. investigators: Prof. Yosiaki Nakano, U. Tokyo and Md. Shamim Akhter, Director General, HBRI, Bangladesh) (https://www.jst.go.jp/global/english/kadai/h2712_bangladesh.html) and JSPS KAKENHI Grant Number JP18H01578 (Prin. investigator: Prof. Masaki Maeda, Tohoku University).

REFERENCES

[1] Islam, M.S., Alwashali, H., Sen, D., Maeda, M., Bulletin Earthquake Engineering (2019)

[2] CNCRP, Technical manual of Government of Bangladesh, 2015

[3] Bangladesh National Building Code, Housing and building research institute, 2015

[4] Japan Building Disaster Prevention Association (JBDPA), 2001, Tokyo, Japan

[5] Science and Technology Research Partnership for Sustainable Development (SATREPS), 2015

[6] Islam, M.S., Sen, D., H., Alwashali, Maeda, M., JCI, Vol. 41(2) 1009-1014, July 2019

[7] Islam, M.S., Ph.D. dissertation, Tohoku University, September, 2019