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Research Article

A Study on Seismic Capacity Evaluation of Existing RC Buildings by Visual Rating Method in Sylhet City

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Abstract

Bangladesh is in a very seismically susceptible region of the southern part of Asia. Bangladesh is facing a high risk of moderate to strong earthquakes that may result in widespread damage and loss of thousands of lives and horrendous structural damage. Sylhet district is also vulnerable in this situation. If a massive earthquake with seven or greater magnitude occurs in this district, it will lead to a major human tragedy due to the faulty structures of many existing buildings. In this study, the seismic capacity of twelve RC buildings have been evaluated by Visual Rating method and a Simplified method for seismic evaluation of RC buildings presented by Hassan & Sozen. Here, the Visual Rating method is a rapid visual screening type method and Hassan & Sozen's method is an elaborate method which requires design of the buildings. Results of both methods have been compared to judge the result of the Visual Rating method. Then evaluated RC buildings were categorized according to their vulnerability from less vulnerable to more vulnerable. Vulnerable buildings are recommended for further evaluation. In this thesis, among twelve evaluated RC buildings, two RC buildings were found to be vulnerable in both methods. Those two buildings were suggested for further evaluation with Detail Seismic Evaluation Method-1 & 2 by Japan to take proper steps towards the right solution for those buildings.

Keywords: Earthquake Vulnerability, Visual Rating Method, Rapid Visual Screening, Seismic Capacity, Visual Rating Index, RC Wall Ratio, Masonry Infill Ratio

List of Notations and Abbreviations:

VR	Visual Rating
RVS	Rapid Visual Screening
RC	Reinforced Concrete
I_{VR}	Visual Rating Index
I_S	Seismic Capacity
L_s	Average Span Length
R_{cw}	RC wall Ratio
R_{inf}	Masonry Infill Ratio
F_{IV}	Vertical Irregularity
F_{IH}	Horizontal Irregularity
F_D	Deterioration of Concrete
F_Y	Year of Construction
FEMA	Federal Emergency Management Agency

1. Introduction

1.1 Background

The risk of seismic tremor in Bangladesh could be a broadly acknowledged reality presently, especially after devastating impacts of seismic tremors in nearly all the neighboring nations (e.g., India, Pakistan, Sri-Lanka, Afghanistan) and numerous others inside South-east Asia [1]. In 2001, the Gujarat earthquake also known as the Bhuj earthquake, occurred on 26 January, India's 52nd Republic Day, at 08:46 am IST. The earthquake killed between 13,805 and 20,023 people (including 18 in southeastern Pakistan), injured another 167,000 and destroyed nearly 340,000 buildings. Nepal earthquake of 2015, also called Gorkha earthquake, severe earthquake that struck near the city of Kathmandu in central Nepal on April 25, 2015. About 9,000 people were killed, many thousands more were injured, and more than 600,000 structures in Kathmandu and other nearby towns were either damaged or destroyed [2]. Topographical location of Sylhet district is also prone to seismic tremor, over the time a few seismic tremors have happened in this district, but the time history records of seismic tremors are not recorded legitimately due to restriction in seismic recording instruments. There's been no major seismic tremor within the past years, but experts are worried that it may be a clear sign of something horrifying that's coming. Within the background of such devastating seismic tremors, there's growing need for genuine hypotheses and test works to reduce the seismic vulnerability [3].

1.2 Statement of the Problem

Bangladesh is a developing country. A huge number of buildings are being constructed every year. To reduce casualties during seismic tremor, existing RC buildings should be able to withstand the lateral force produced by earthquakes. Therefore, the structural condition of existing

RC buildings ought to be assessed and tested by utilizing a viable method. To evaluate all the existing RC buildings a less time-consuming method is needed, the results of which are accurate. Several methods and strategies, such as FEMA rapid visual screening (RVS) method, Turkish rapid RVS method and Indian RVS method, Japanese Index Method are accessible for quick distinguishing proof of helpless buildings based on visual inspection [4-7]. In any case, these existing RVS strategies give a score which doesn't have a great relationship with the genuine seismic capacity of existing RC buildings as appeared in a past study. Therefore, in this thesis to evaluate the existing RC buildings, Visual Rating (VR) method has been applied [8]. This method has been applied to 12 RC buildings located in different locations in Sylhet City. Some important data were collected by surveying those RC buildings to apply VR method such as average column size (excluding 50mm for plaster work and 75mm for tiles work), average span length (the size equivalent to square floor area carried by a single column), RC wall ratio (R_{cw}), masonry infill ratio (R_{inf}), etc. All the collected data were calculated to determine the value of Visual Rating Index (IVR). The lower the value of I_{VR} the more vulnerable the building is. By determining the value of I_{VR}, all the surveyed and evaluated RC buildings have been classified form the most to the least vulnerable buildings and the value of Visual Rating Index (I_{VR}) have also been compared with the value of Seismic Capacity (I_S) [9].

1.3 Justification of the Study

In this study, vulnerability of existing RC buildings have been measured through VR method. In the VR method, the values of IVR were determined. By those values, RC buildings were categorized in different zones. Some of those evaluated buildings were selected for further evaluation, some of those buildings were recommended for retrofitting and some of those buildings were in good condition which needed no further evaluation or retrofitting. By using this method, the vulnerability of RC buildings can be calculated easily and effectively. This method is less time consuming and easy to execute.

1.4 Objectives of the Study

- To find out RC buildings which are vulnerable to earthquakes.
- To identify various factors causing those RC buildings to be vulnerable to earthquakes.
- To categories existing RC buildings according to their seismic

2. Literature Review

2.1 Overview

Earthquakes are common natural disasters. Generally, the location of tectonic plates in a region determines the susceptibility to earthquakes [10,11,12]. Also, the impact of earthquakes on existing infrastructure and the damage to infrastructure caused by earthquakes are being evaluated. In this paper the impact on existing RC buildings have been considered. To reduce the vulnerability of existing RC building need to be evaluated. To evaluate the existing RC buildings various RVS methods are available [13,14,15]. But most of those RVS methods are comparatively more time consuming to work with. On the other hand, the VR method is more accurate, less time-consuming and easy to work with [9].

2.2 Origin

The main concept of the Visual Rating method originates from Shiga Map [16]. Shiga map considers two simple parameters: ratio of the average shear stress of columns to RC walls based on their cross-section area and RC wall area ratio (a ratio of the total cross-sectional areas of RC walls to total floor area). This method is applicable only for RC buildings with RC shear walls, which does not consider the effects of masonry infill. Later on, Hassan and Sozen presented a simplified method for seismic evaluation of RC buildings using fundamental parameters such as column and wall area ratio to rank existing RC buildings for detailed evaluation [7]. According to their vulnerability against seismic damages, the Seismic Capacity (IS) is the summation of the lateral strength of RC column, masonry infill and concrete wall normalized with total building weight as expressed by following Equation (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 [9].

Seismic Capacity,

$$I_S = \left[\tau_c \frac{A_c}{n A_f w} + \tau_{inf} \frac{A_{inf}}{n A_f w} + \tau_{cw} \frac{A_{cw}}{n A_f w}\right] \quad (1)$$

Here,

τ_c = Average shear strength of RC column
τ_{inf} = Average shear strength of masonry infill
τ_{cw} = Average shear strength of RC wall
A_c = Cross-sectional area of RC column
A_{inf} = Cross-sectional area of masonry infill
A_{cw} = Cross-sectional area of RC wall
n = Number of stories
A_f = Floor area
w = unit weight of per floor area of buildings

Where,

$$\text{Column area ratio} = \frac{A_c}{n A_f}$$

$$\text{Masonry infill area ratio} = \frac{A_{inf}}{n A_f}$$

$$\text{RC wall area ratio} = \frac{A_{cw}}{n A_f}$$

However, screening large numbers of existing buildings, it is quite challenging to apply the aforementioned methods, because it requires detailed architectural drawings. If architectural drawings are not available, then as-built drawing preparation is necessary, which takes much time for seismic evaluation procedure. Visual Rating method proposes a score, hereafter reported as Visual Rating Index (I_{VR}), which is the approximated seismic capacity of existing buildings. The calculation procedure of I_{VR} is described by the following Equation (2) [9].

Visual Rating Index,

$$I_{VR} = \frac{1}{nW}\left[\tau_c \frac{b_c^2}{l_s^2} + \tau_{inf}\left(\frac{t_{inf}}{l_s} R_{inf}\right) + \tau_{cw}\left(\frac{t_{cw}}{l_s} R_{cw}\right)\right] F_{IV} F_{IH} F_D F_Y \quad (2)$$

b_c = Average column size
l_s = Average span length
t_{inf} = Masonry infill thickness
R_{inf} = Masonry infill ratio = $\frac{\text{Number of solid masonry panel in a direction}}{\text{total no. of span in a direction}}$
t_{cw} = RC wall thickness
R_{cw} = RC wall ratio = $\frac{\text{Number of solid RC wall panel in a direction}}{\text{total no. of span in a direction}}$
F_{IV} = Modification factor for vertical irregularity
F_{IH} = Modification factor for horizontal irregularity
F_D = Modification factor for deterioration of concrete
F_Y = Modification factor for year of construction

Where,
Simplified column area ratio = $\frac{b_c^2}{l_s^2}$
Simplified masonry infill area ratio = $\frac{t_{inf}}{l_s} R_{inf}$
Simplified concrete wall area ratio = $\frac{t_{cw}}{l_s} R_{cw}$
Irregularity index = $F_{IV} F_{IH}$
Time index = $F_D F_Y$

3. Methodology of the Study

This study was divided into three major steps which includes site selection, site visit and analysis. All the twelve RC buildings in Sylhet City were selected depending on the owner's availability and design availability. To observe and collect the required data to calculate IVR and IS, those twelve RC buildings were inspected thoroughly. All the collected data were calculated and evaluated precisely. Then a graph was plotted to compare the value of IVR with IS. Accuracy of IVR can be judged through this graph [9].

3.1 Flow Diagram of Methodological Steps

The flowchart describing the total procedure of the thesis work is shown below:

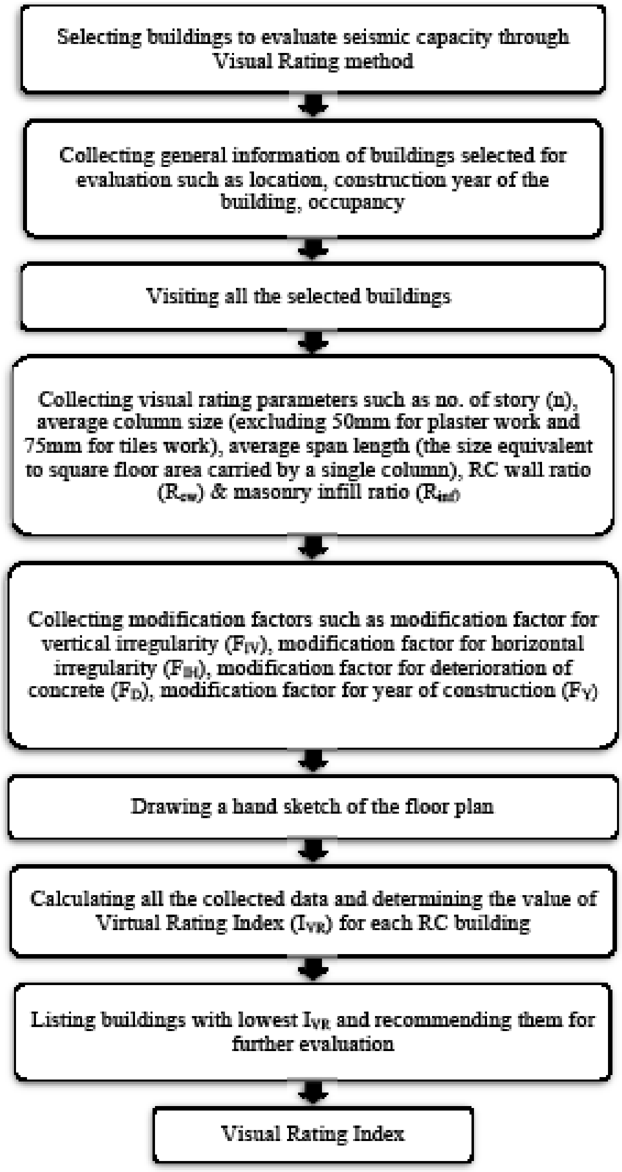
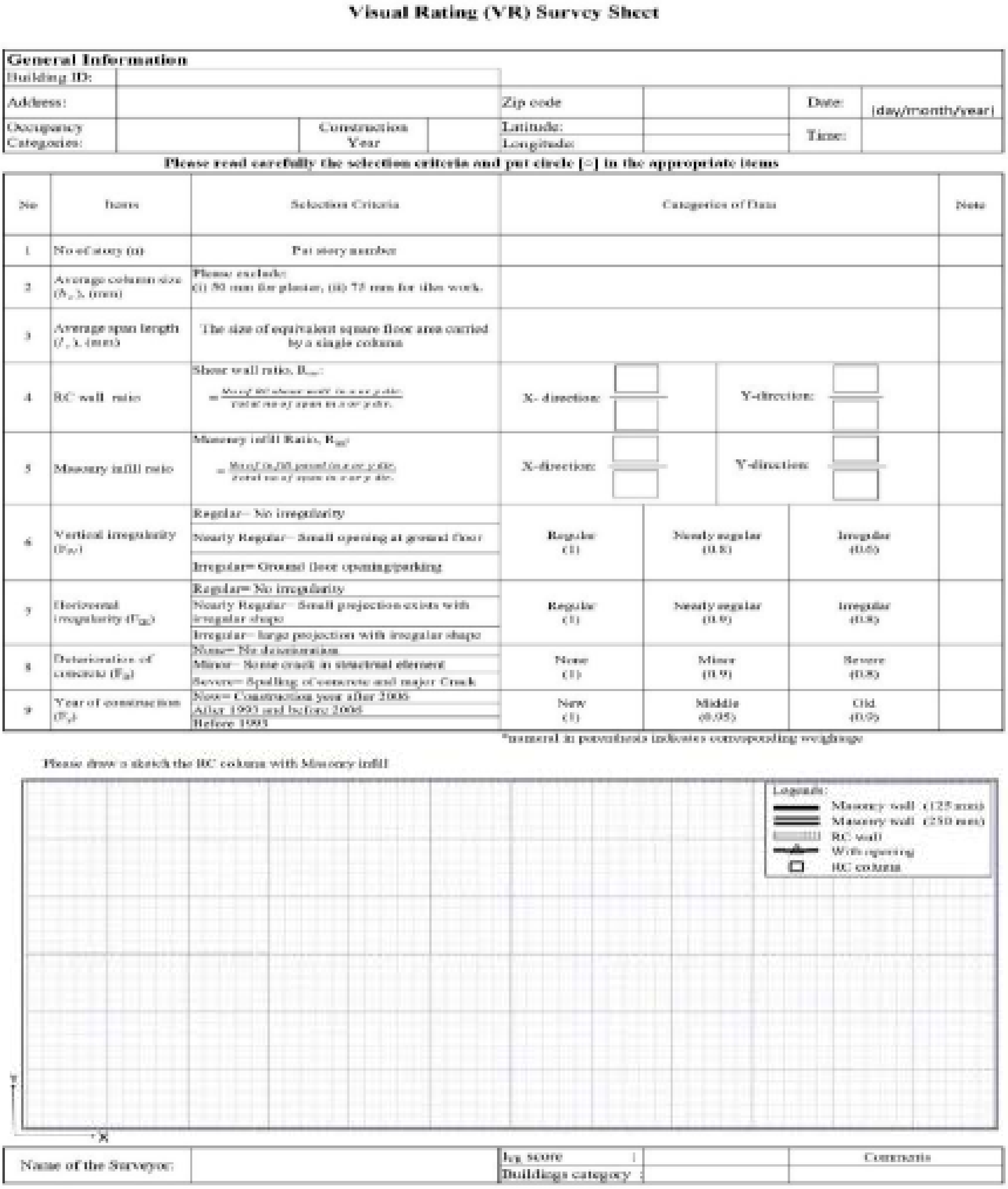


Figure 1: Flow Diagram of Methodological Steps Followed in this Study

3.2 Data Collection Procedure

Data collection is an important step for getting reasonable results, otherwise it will not bring reliable results in the analysis step. An accurate database is necessary for both microscopic and macroscopic perspective. To collect all the data precisely a hard copy of the VR survey sheet was kept with all the surveyors [9]. The VR survey sheet is shown below:



Visual Rating (VR) Survey Sheet

General Information							
Building ID:							
Address:				Zip code		Date:	(day/month/year)
Occupancy Categories:		Construction Year		Latitude: / Longitude:		Time:	

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

No	Items	Selection Criteria	Categories of Data			Note
1	No of story (n)	Put story number				
2	Average column size (b_c), (mm)	Please exclude: (i) 50 mm for plaster, (ii) 75 mm for tiles work.				
3	Average span length (l_c), (mm)	The size of equivalent square floor area carried by a single column				
4	RC wall ratio	Shear wall ratio, R_{sw}: = No. of RC shear wall in x or y dir. / Total no. of span in x or y dir.	X- direction:		Y-direction:	
5	Masonry infill ratio	Masonry infill Ratio, R_{MI}: = No. of infill panel in x or y dir. / Total no. of span in x or y dir.	X-direction:		Y-direction:	
6	Vertical irregularity (F_{VI})	Regular= No irregularity Nearly Regular= Small opening at ground floor Irregular= Ground floor opening/parking	Regular (1)	Nearly regular (0.8)	Irregular (0.6)	
7	Horizontal irregularity (F_{HI})	Regular= No irregularity Nearly Regular= Small projection exists with irregular shape Irregular= large projection with irregular shape	Regular (1)	Nearly regular (0.9)	Irregular (0.8)	
8	Deterioration of concrete (F_d)	None= No deterioration Minor= Some crack in structural element Severe= Spalling of concrete and major Crack	None (1)	Minor (0.9)	Severe (0.8)	
9	Year of construction (F_y)	New= Construction year after 2006 After 1993 and before 2006 Before 1993	New (1)	Middle (0.95)	Old (0.9)	

*numeral in parenthesis indicates corresponding weightage

Please draw a sketch the RC column with Masonry infill

Name of the Surveyor:		I_S score :		Comments
		Buildings category :		

Figure 2: VR survey sheet

3.3.1 Number of story (n)

The number of stories surveyed RC buildings were noted including information about soft stories. A relation between the number of surveyed buildings and their no. of story is plotted in figure 3.3:

Citation: Islam, A. Md., Sarkar, M. A. A., Mahzuz, H. M. A., Alam, J. B. Md. (2024). A Study on Seismic Capacity Evaluation of Existing RC Buildings by Visual Rating Method in Sylhet City. *J Adv Civil Mech Eng, 1*(1), 1-12.

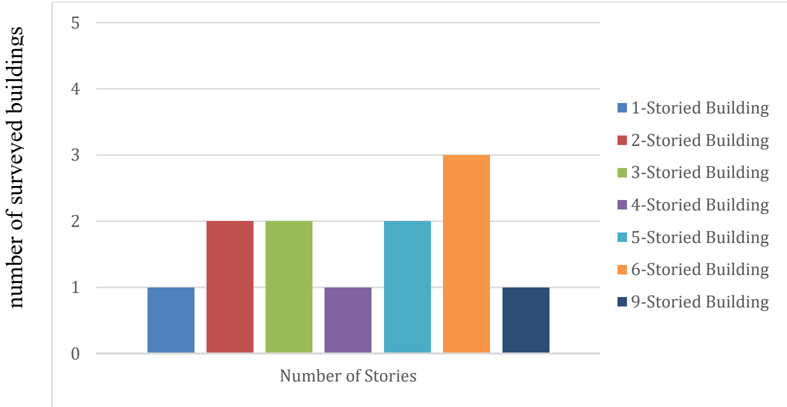


Figure 3: Distribution according to number of stories

3.3.2 Average Column Size (bc)

All the visible columns of the surveyed buildings were measured using a measurement tape. From all the measured column size an average column size was calculated excluding 50mm for plaster and 75mm for tiles work by following Equation (3) (Md.Islam et al., 2020):

Average ColumnSize(mm), $b_c = \sqrt{\frac{a_1+a_2+a_3}{3}}$ (3)

Here,

a_1, a_2, a_3 = cross sectional area of column (measured using measurement tape)

Note that, a_1, a_2, a_3 can be interior or exterior or corner column.

Figure 4: Images taken during surveying

3.3.3 Average Span Length (L_s)

Average span length is mainly the size of the equivalent square floor area carried by a single column. Average span length was calculated by following Equation (4) (Md. S. Islam et al., 2020):

Average Span Length(mm), $L_s = \sqrt{\frac{L\times B}{n_c}}$ (4)

Here,

L = Length of building

B = Width of building

n_c = Total number of columns in a story

3.3.4 RC Wall Ratio (R_{cw})

Shear wall ratio was calculated by analyzing the floor plan of the RC building. It was calculated by following Equation (5) and the minimum value was taken into [9].

Shear wall ratio,

$$R_{cw} = \frac{No\ of\ RC\ shear\ wall\ in\ x\ or\ y\ direction}{Total\ no\ of\ span\ in\ x\ or\ y\ direction} \quad (5)$$

3.3.5 Masonry Infill Ratio (R_{inf})

Masonry infill wall ratio was calculated analyzing the floor plan of the RC building. It was calculated by following Equation (6) and the minimum value was taken into consideration [9].

Masonry infill ratio,

$$R_{inf} = \frac{No\ of\ infill\ panel\ in\ x\ or\ y\ direction}{Total\ no\ of\ span\ in\ x\ or\ y\ direction} \quad (6)$$

3.3.6 Vertical Irregularity (F_{IV})

Through inspecting the RC building, whether the RC building has any soft story or not, the value of FIV was assumed [9].

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Item	Regular	Nearly regular	Irregular
Criteria	No Irregularity	Small opening at ground floor and set back	Ground floor opening or parking
Points (FIV)	1	0.80	0.60

Table 1: Factor for F_{IV}

3.3.7 Horizontal Irregularity (F_{IH})

Through inspecting the floor plan of the RC building, whether the RC building has any irregularity shaped or not, the value of FIH was assumed [9].

Item	Regular	Nearly regular	Irregular
Criteria	No Irregularity	Small projection exists with irregular shape	Large projection with irregular shape
Points (FIH)	1	0.90	0.80

Table 2: Factor for F_{IH}

3.3.8 Deterioration of Concrete (F_D)

Through inspecting the RC building properly, whether the RC building has any deteriorating concrete or not, the value of FD was assumed [9].

Item	None	Minor	Severe
Criteria	No deterioration	Some crack in structural element	Spalling of concrete and major crack
Points (FD)	1	0.90	0.80

Table 3: Factor for F_D

3.3.9 Year of Construction (F_Y)

As the RC Building gets older, it loses its strength gradually. By judging the construction year of the RC building, the value of FY was assumed [9].

Item	New	Middle	Old
Criteria	Construction year after 2006	After 1993 and before 2006	Before 1993
Points (FY)	1	0.95	0.90

Table 4: Factor for F_Y

3.4 Data Analysis

After collecting all the data shown above, the value of IV_R (Visual Rating Index) was calculated by Equation (2):

Visual Rating Index,

$$I_{VR} = \frac{1}{nw}\left[\tau_c \frac{\Sigma A_c}{\Sigma A_f} + \tau_{inf}\left(\frac{t_{inf}}{l_a} R_{inf}\right) + \tau_{cw}\left(\frac{t_{cw}}{l_a} R_{cw}\right)\right] F_{IV} F_{IH} F_D F_Y$$

To calculate I_{VR}, some basic assumptions for material properties are considered. These assumptions are shown below [9]:

τ_c = Average shear strength of column = 1.0 MPa

τ_{nf} = Average shear strength of masonry infill = 0.2 MPa

τ_{cw} = Average shear strength of concrete wall = 1.0 MPa

w = The unit weight = 11 KN/m^2

t_{cw} = Thickness of concrete wall = 250 mm

t_{inf} = Thickness of masonry infill = 125 mm

There are some proposed boundaries for I_{VR} which is shown below [9].

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Range	Categories	Description
$0.25 \leq I_{VR}$	A	No damage
$0.20 \leq I_{VR} < 0.25$	B	Light damage
$0.15 \leq I_{VR} < 0.20$	C	Less possibility of collapse
$0.10 \leq I_{VR} < 0.15$	D	Moderate possibility of collapse
$I_{VR} < 0.10$	E	High possibility of collapse

Table 5: Proposed boundaries for Visual Rating Method

After calculating I_{VR}, the value of IS was calculated by Equation (1):

Seismic Capacity,

$$I_S = [\tau_0 \frac{A_c}{\sum A_f W} + \tau_{inf} \frac{A_{inf}}{\sum A_f W} + \tau_{cw} \frac{A_{cw}}{\sum A_f W}]$$

To calculate IS, A_c (Cross-sectional area of column), A_{inf} (Cross-sectional area of masonry infill), A_{cw} (Cross-sectional area of RC wall) and A_f (Floor area) are considered according to the building floor plans.

There are some proposed boundaries for IS which are shown below [9].

Range	Categories	Description
0.50~	A	No damage
0.40 – 0.50	B	Light damage
0.30 – 0.40	C	Less possibility of collapse
0.20 – 0.30	D	Moderate possibility of collapse
<0.20	E	High possibility of collapse

Table 6: Judgment Criteria According to Seismic Index

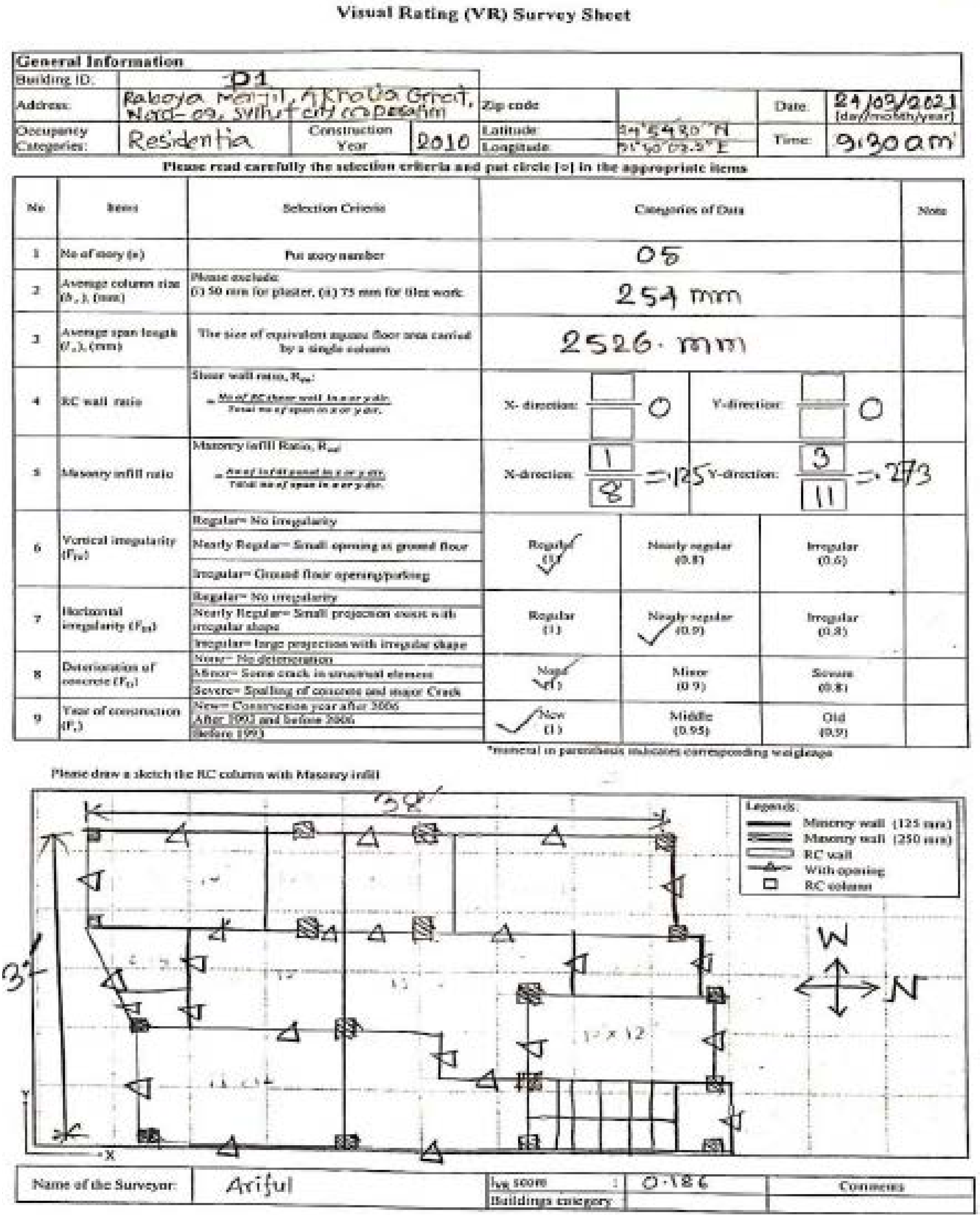
After calculating the value of I_{VR} and the value of IS both of those values were compared by putting their values on a graph to evaluate the accuracy of I_{VR}

4. Results and Discussions

4.1 Calculation of I_{VR} (Visual Rating Index)

Twelve VR survey sheets were plotted during surveying those RC buildings. In those survey sheets, floor plans of the buildings were drawn by hand roughly through visual inspection. All the measurements were measured using measurement tape and all of the calculations were done by hand calculation to use the time effectively as well as some information had been collected from building drawings if needed. Finally, the value of IVR was determined on the data sheet on-site. All the VR survey sheets of those twelve RC buildings are taken safely from field inspection to desk for proper calculation. As a sample, the survey sheet no. 1 for first building is shown below [9].

Citation: Islam, A. Md., Sarkar, M. A. A., Mahzuz, H. M. A., Alam, J. B. Md. (2024). A Study on Seismic Capacity Evaluation of Existing RC Buildings by Visual Rating Method in Sylhet City. *J Adv Civil Mech Eng, 1*(1), 1-12.



Visual Rating (VR) Survey Sheet

General Information							
Building ID:	D1						
Address:	Raboya Manjil, Akhalia Great, Ward-09, Sylhet city corporation		Zip code			Date:	24/03/2021 [day/month/year]
Occupancy Categories:	Residentia	Construction Year	2010	Latitude / Longitude	24°54'30" N / 91°50'03.5" E	Time:	9:30 am

Please read carefully the selection criteria and put circle [o] in the appropriate items

No	Items	Selection Criteria	Categories of Data			Note
1	No of story (n)	Put story number	05			
2	Average column size (b,), (mm)	Please exclude: (i) 50 mm for plaster, (ii) 75 mm for tiles work	254 mm			
3	Average span length (l,), (mm)	The size of equivalent square floor area carried by a single column	2526 mm			
4	RC wall ratio	Shear wall ratio, R_{sw}: = No of RC shear wall in x or y dir. / Total no of span in x or y dir.	X-direction: 0	Y-direction: 0		
5	Masonry infill ratio	Masonry infill Ratio, R_{mi}: = No of infill panel in x or y dir. / Total no of span in x or y dir.	X-direction: 1/8 = .125	Y-direction: 3/11 = .273		
6	Vertical irregularity (F_{vi})	Regular= No irregularity; Nearly Regular= Small opening at ground floor; Irregular= Ground floor opening/parking	Regular (1) ✓	Nearly regular (0.8)	Irregular (0.6)	
7	Horizontal irregularity (F_{hi})	Regular= No irregularity; Nearly Regular= Small projection exists with irregular shape; Irregular= large projection with irregular shape	Regular (1)	Nearly regular (0.9) ✓	Irregular (0.8)	
8	Deterioration of concrete (F_d)	None= No deterioration; Minor= Some crack in structural element; Severe= Spalling of concrete and major Crack	None (1) ✓	Minor (0.9)	Severe (0.8)	
9	Year of construction (F_y)	New= Construction year after 2006; After 1993 and before 2006; Before 1993	New (1) ✓	Middle (0.95)	Old (0.9)	

*numeral in parenthesis indicates corresponding weightage

Please draw a sketch the RC column with Masonry infill

Name of the Surveyor:	Ariful	Avg score / Buildings category	0.186	Comments

Figure 5: VR Survey Sheet of Building no.1

All the collected data are shown below:

Building No.	Location	Usage	No of story (n)	Year of Construction	Avg. col Size (bc) (mm)	Avg. Span Length (L) (mm)	RC wall Ratio (Rcw)	Masonry infill ratio (Rmi)	F_w	F_g	F_p	F_r
1	Akhalia Ghat	Residential	05	2018	254	3526	0	0.135	1	0.9	1	1
2	Topoban	Residential	06	2009	254	2854	0	0.12	0.6	1	0.9	1
3	Upashahar	Residential	03	2001	311	3803	0	0	1	1	1	0.95
4	Chowkidekhi	Residential	04	2019	304	3873	0	0	0.8	0.9	1	1
5	TV gate	Residential	09	2015	344	3864	0.33	0	0.6	1	1	1
6	Upashahar	Residential	03	1989	293	3103	0	0	0.8	1	0.9	0.9
7	Shibbari Bazar	Residential	06	2007	341	3525	0	0.1	0.8	0.8	1	1
8	Shibbari Bazar	Residential	05	2018	278	3120	0	0	1	1	1	1
9	Shibbari Bazar	Residential	02	2011	250	3813	0	0.06	0.8	1	1	1
10	Lakmatiya	Mosque	01	2017	373	4423	0	0	1	1	1	1
11	Lakmatiya	Academic	02	2019	341	3371	0	0	1	0.9	1	1
12	Amberkhana	Residential	06	2016	350	3980	0.5	0	0.6	1	1	1

Table 7: Datasheet of 12 RC Buildings

Values of IVR for twelve RC buildings by Equation (2):

Building No.	1	2	3	4	5	6	7	8	9	10	11	12
I_{VR}	0.18	0.07	0.19	0.18	0.24	0.17	0.09	0.14	0.28	0.64	0.42	0.35

Table 8: Calculation of I_{VR} for 12 RC Buildings

From the Calculation from table 4.2, it is visible that two buildings have I_{VR} values less than 0.10. Therefore, those two buildings fall into E category which indicates those two buildings have a 'high possibility of collapse'. It is also seen that one building has an I_{VR} value in between 0.10 - 0.15. So, this one building falls into D-category and indicates a 'moderate possibility of collapse'. Four of those twelve buildings have I_{VR} values in between 0.15 - 0.20. Which falls into C-category and indicates a 'less possibility of collapse'. There is only one building that has an I_{VR} value in between 0.20 - 0.25. Which falls into B-category and indicates 'light damage'. Four of those twelve surveyed buildings have I_{VR} values greater than 0.25. Which falls into A-category and indicates 'no damage'.

4.2 Calculation of IS (Seismic Capacity)

I_S was calculated by inspecting the floor plan of all the RC buildings. Some necessary data such as A_c (Cross-sectional area of column), A_{inf} (Cross-sectional area of masonry infill), A_{cw} (Cross-sectional area of RC wall) and A_f (Floor area) were taken into account from the floor plans of the buildings. All the collected data from the floor plans of 12 surveyed RC buildings are shown below:

Building No.	No. of story	Cross-sectional Area of Column (A_c) (mm^2)	Cross-sectional Area of masonry infill (A_{mw}) (mm^2)	Cross-sectional Area of RC Wall (Acw) (mm^2)	Floor Area (A_f) (mm^2)
1	05	1161288	1277366	0	112959246
2	06	1677416	3367659	0	211811616
3	03	2322576	1316101	0	343513410
4	04	1300642	1199134	0	68504367
5	09	2023222	2280666	1748942	150216230
6	03	2322576	2728595	0	240606072
7	06	2090318	2438527	0	185330897
8	05	1858060	4069385	0	234104688
9	02	1625803	3328797	0	183945276
10	01	2508382	2651633	0	242651097
11	02	4180637	8941943	0	409965750
12	06	3987088	6347968	1628832	474726000

Table 9: Datasheet of 12 RC Buildings for Calculating I_S

Values of I_S for twelve RC buildings by Equation (1).

Building No.	1	2	3	4	5	6	7	8	9	10	11	12
Is	0.51	0.16	0.23	0.16	0.22	0.28	0.21	0.21	0.58	1.14	0.66	0.22

Table 10: Calculation of I_S for 12 RC Buildings

From the Calculation shown above, it is visible that only one building has a IS value less than 0.20. Therefore, that one building falls into E-category which indicates the building has a 'high possibility of collapse'. It is also seen that six buildings have IS values in between 0.20 - 0.30. So, those six buildings fall into D-category and indicate a 'moderate possibility of collapse'. Only one of those twelve buildings has IS value in between 0.30 - 0.40. Which falls into C-category and indicates a 'less possibility of collapse'. Four of those twelve surveyed buildings have IS values greater than 0.25. Which falls into A-category and indicates 'no damage'.

4.3 I_S (Seismic Capacity) vs I_{VR} (Visual Rating Index) Graph

A graph was plotted by taking the values of I_S and I_{VR} which is shown below [9].

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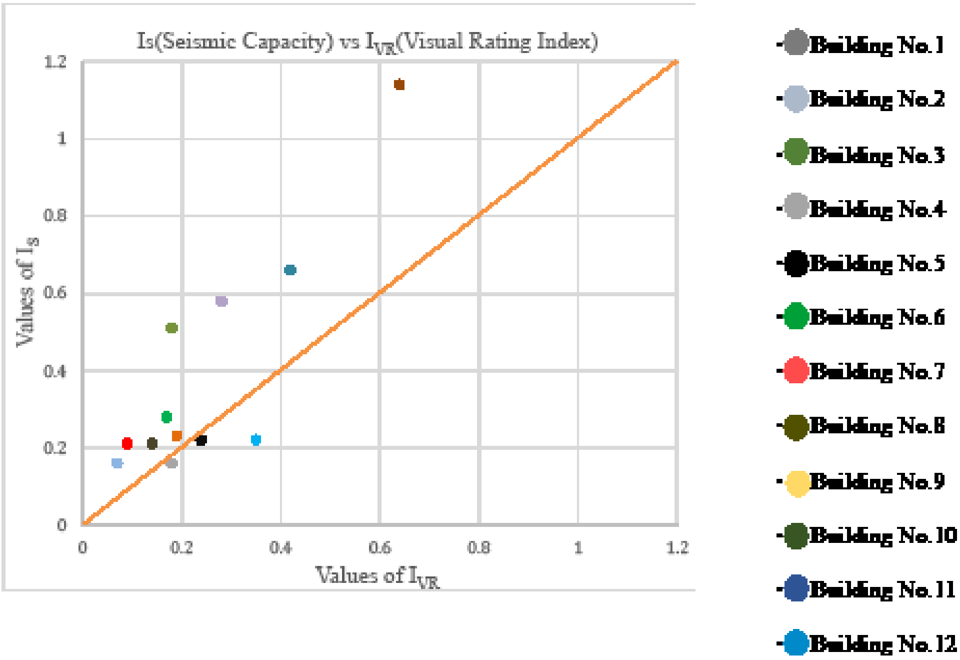

Figure 6: Comparison of I_{VR} with I_S

The graph above indicates that, building no.2 and building no.7 have a high possibility of collapse. In both I_{VR} and I_S those two buildings show least values. In the graph above, it implies that some values of I_{VR} stay in an agreement with the values of I_S. In this thesis, by calculating seismic capacity for twelve RC buildings, building no.2 and building no.7 were found vulnerable in the Visual Rating method. On the other hand, building no.2, building no.4, building no.7 & building no.8 were found vulnerable in Hasan & Sozen's method [17]. It is seen that buildings which are vulnerable in the Visual Rating method are also vulnerable in Hasan & Sozen's method. It indicates that values of I_{VR} are acceptable as a Visual Screening method. Calculation of I_S requires availability of structural design and consumes more time. On the other hand, calculation of I_{VR} does not require any design and consumes less time also. From the graph above, it is proven that we can use values of I_{VR} for initial filtration of vulnerable RC buildings from a large number of RC buildings and categorize them from less to more vulnerable buildings for further evaluation such as Detail Seismic Evaluation Method-1 and Detail Seismic Evaluation Method-2. Both methods have been developed by Japan [18]. For Detail Seismic Evaluation Method-1 needs less data and Detail Seismic Evaluation Method-2 needs more data. But both methods need RC buildings drawing.

5. Conclusion and Recommendations

The resilience of reinforced concrete structures is a critical factor in evaluating the seismic capacity of existing RC buildings [19-21]. Based on visual inspection, this study on existing RC buildings proposes a simple screening approach for RC buildings with masonry infill. This method calculates the I_{VR} which is a rough estimation of a building's seismic capabilities. By analyzing of existing RC buildings for seismic capabilities in Sylhet City as a case study in a developing country, the I_{VR} has been verified with I_S evaluation. So, from this thesis, we can conclude that,

1. In first-level evaluation, the I_{VR} score has a moderate association with I_S.
2. The I_{VR} judgment criteria are divided into five categories: A, B, C, D, and E, with A being the least vulnerable and E being the most vulnerable. Buildings with an I_{VR} of less than 0.20 are considered vulnerable, while those with an I_{VR} of less than 0.10 are the most vulnerable and have a high priority for full seismic study.
3. A large number of buildings can be easily filtered from seismic risk by I_{VR} versus I_S graph with an effective and time-consuming way.
4. For initial filtration of vulnerable RC buildings recommended for further evaluation.
5. Further evaluation can be performed with Detail Seismic Evaluation Method-1 & 2 which have been developed by Japan.

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