SATREPS – TSUIB

User's Manual on Visual Rating (VR) for Potential Seismic Vulnerability Assessment of Existing Reinforced Concrete Buildings in Bangladesh

HOUSING AND BUILDING RESEARCH INSTITUTE (HBRI)
MINISTRY OF HOUSING AND PUBLIC WORKS
PEOPLE'S REPUBLIC OF BANGLADESH

AND

INSTITUTE OF INDUSTRIAL SCIENCE (IIS)
THE UNIVERSITY OF TOKYO
JAPAN

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User’s Manual on
Visual Rating (VR) for Potential Seismic Vulnerability Assessment of Existing Reinforced Concrete Buildings in Bangladesh

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SATREPS-TSUIB Project

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The contents of this book are related to Visual Rating method of existing RC Buildings to Potential Seismic Hazard which has been described hereinafter in brief practical form as guidelines. As such no chapter, article, clause, sub-clause therefore, be referred to as VALID DOCUMENTS in the event of any arbitration, litigation, dispute, claim case, whatsoever secured, made or claimed by any person as the case may be under any circumstances.

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FOREWORD

Developing countries which are located in earthquake prone area, such as Bangladesh, do not have experience of recent major earthquake. Although there have been no recent earthquake disasters, experts are now highly concerned due to repeated occurrence of this catastrophic event in surrounding countries. Therefore, there is an urgent need for seismic screening of the existing RC building for evaluation of seismic capacity and subsequently retrofitting and/or strengthening.

At present, Bangladesh has been applying the seismic evaluation manual (CNCRP 2015), for detailed seismic evaluation of existing RC buildings, which is adopted from the Japanese seismic evaluation standard (JBDPA, 2001). However, detailed evaluation of large buildings stock is quite challenging, especially developing countries, due to lack of professional experts and budget. In this regards, identification of vulnerable buildings by rapid screening method and prioritization of existing RC buildings for detailed evaluation is a way to evaluate a large building stock.

This manual presents development and application procedure of rapid screening method, namely Visual Rating (VR) method, for prioritization of existing RC building for detailed seismic evaluation. The VR method is based on visual inspection of an existing building within 0.3~1.0 hr. and approximate seismic capacity using a few fundamental parameters. This manual discusses judgement criteria for setting priority of detailed evaluation based on VR method score.

This manual presents the starting stage of the proposed VR method. In order to upgrade the applicability and effectiveness of the proposed VR method, further research on local material properties and local seismicity is necessary. It has been suggested to read the manual thoroughly and apply the method with engineering judgement. We, expect feedback form all professional and practicing engineers to future up gradation.

We deeply acknowledge to all members of Working Group (WG) 2 in SATREPS-TSUIB project, for their valuable assistance, support, and cooperation. We also thank to PWD engineers from WG2 for valuable support in application to existing RC buildings. Finally, we are thankful to Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA) for their valuable support and cooperation in all aspects of the SATREPS-TSUIB project.

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PREFACE

In developing countries, such as Bangladesh, an enormous stock of vulnerable buildings is to be considered for detailed seismic evaluation, which requires a rigorous analysis with much expertise, cost, and time. In addition, detailed seismic evaluations are very challenging for a large stock of existing RC buildings due to several reasons, including requirements for detailed architectural and structural drawings along with other necessary information that are not available in most of the existing RC buildings. In this regard, identification of the most vulnerable buildings through rapid visual screening, and prioritization of those buildings to conduct detailed evaluation are the effective ways to reduce the aforementioned limitations. Therefore, it is very essential to develop a rapid seismic evaluation method considering the aforementioned parameters influencing the seismic capacity of an existing RC buildings.

This manual focuses on development of a rapid visual screening method, herein mentioned as Visual Rating (VR) method, for identifying the most vulnerable RC buildings and proposes judgment criteria for prioritization of existing RC buildings for detailed evaluation. The proposed VR method considers cross-sectional area and shear strength of vertical elements such as RC column, masonry infill wall, and RC wall as well as other building attributes such as structural configuration, deterioration and age of building. The presented method estimates the seismic capacity of existing RC buildings in terms of Visual Rating index (I_{VR}) and lower value of I_{VR} corresponds to the most vulnerable building. a lower boundary of seismic capacity of an existing RC buildings comparing with the results of detailed evaluation.

Since the main intention of the VR method is to set priority for detailed seismic evaluation, judgment criteria have been proposed for I_{VR} using the obtained correlation between I_{VR} and detailed seismic evaluation results of investigated buildings. Based on the proposed judgement criteria, the buildings with I_{VR} score less than 0.10 are considered as the most vulnerable buildings and detailed seismic evaluation is highly recommended. Furthermore, the proposed method can be used in other developing country by reconsidering material strength properties and local seismicity in intended region.

The manual will be improved through application in existing RC building. This manual helps to set the strategy for earthquake disaster risk mitigation and to take decision of retrofitting by having an approximate estimation for the vulnerable buildings.

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CHAPTER 1
Introduction

1.1 General Principle

Visual Rating (VR) method has been developed for rapid screening of RC framed buildings with or without infill brick masonry wall or RC walls for potential seismic hazards. This guideline has been prepared to:

- understand the development background of Visual Rating (VR) method
- demonstrate the application procedure of VR method among audience ranging from professional engineers and practitioners to appropriately trained nonprofessionals with general familiarity or background in building design or construction.

This guideline mainly contains the following:

a. Survey datasheet in which each item has been explained in details.
b. Scoring method of RC framed buildings objective to prepare a priority list for potential vulnerability analysis.

This guideline has been developed to facilitate to execute rapid screening of RC framed buildings. VR method is a screening method and it must not be used to declare the final structural vulnerability (or risk). For final decision on vulnerability (or risk) of a building, detail structural assessment shall be done. This VR method provides a very rough idea about the seismic capacity and the judgment for detailed evaluation shall be proposed.

The manual contains four chapters. The first chapter includes the scope of this guideline. In the second chapter, the background of this VR method has been briefly discussed. Third chapter provides the guidance on completing survey data sheet and interpretations of survey results. Finally, the forth chapter covers the judgement criteria of VR index for rating. There are several examples of field survey data sheets and VR Index calculation attached in the supplement part.

1.2 Scope of Applications

The scope of this manual shall be limited to the following conditions:

a. The provisions of this manual shall be applied to RC framed buildings with or without infill brick masonry wall or RC walls.
b. Buildings of 6 stories and less are covered in this manual. Building higher than 6 stories shall be considered with special attention.
c. Building frame with concrete strength not less than 9.0 N/mm^2 are covered in this manual.
d. This manual shall not be applied to severely deteriorated buildings due to fire incident, time deterioration, significant settlement and structural cracks etc.

The Scope of the application has been developed from "The Japanese Technical Manual for Seismic Evaluation and Seismic Retrofit of Existing Reinforced Concrete Buildings, 2001" Published by The Japan Building Disaster Prevention Association (JBDPA) and its adapted version namely, "Manual for Seismic Evaluation of Existing Reinforced Concrete Buildings" for Bangladesh prepared under the CNCRP project funded by The Government of Bangladesh (GoB) and Japan International Co-operation Agency (JICA). The manual has been published by Public Works Department in 2015.

Most importantly, it shall be noted that Visual Rating (VR) method can only be used as a tool to identify the building which requires more attention for further seismic vulnerability assessment.

VR survey can be conducted by the following professionals and non-professionals with basic training on VR method:

i. Project Manager with Civil Engineering background or Management background with in-depth knowledge on VR method.
ii. Professionals in Civil and Structural Engineering discipline.
iii. Appropriately Trained Supervisors (Diploma in Civil Engineering).
iv. Appropriately Trained Surveyors (Diploma in Civil Engineering/High School Graduate).

Among the above listed people, the Project Manager will prepare require numbers of working teams considering the volume of buildings, available fund and time limit etc. The Project

Manager is also responsible to select suitable persons in VR Index calculation level, supervision level and survey level. Only Professionals in Civil and Structural Engineering Discipline can calculate VR Index by their own. Others will supervise and conduct the survey only. Estimated survey time for a 6 storied building with an area ranging from 300 to 400 square meters per floor may require around 30 to 45 minutes for a survey team consisting of two surveyors.

1.3 Definitions

Column area ratio: The ratio between total cross-sectional area of columns in a story and total floor area of a whole structure.

Infill wall area ratio: The ratio between total cross-sectional area of masonry infills in a story and total floor area of a whole structure.

Irregularity index: An index modifying the Visual Rating Index (I_{VR}) for horizontal and vertical irregularity.

RC wall area ratio: The ratio between total cross-sectional area of reinforced concrete (RC) walls in a story and total floor area of a whole structure.

Simplified column area ratio: A simplified way to estimate column area ratio in Visual Rating method.

Simplified infill wall area ratio: A simplified way to estimate infill wall area ratio in Visual Rating method.

Simplified RC wall area ratio: A simplified way to estimate RC wall area ratio in Visual Rating method.

Time index: An index modifying the visual rating index for deterioration and buildings age.

Total floor area: Total floor area of a whole structure.

Visual Rating index: An index representing the score of Visual Rating method.

Visual Rating method: A simplified procedure to estimate seismic capacity of existing buildings.

1.4 Notations

I_{VR}	Visual Rating index
n	Number of stories
τ_c	Average shear strength of column
τ_{inf}	Average shear strength of masonry infill
τ_{cw}	Average shear strength of concrete wall
A_c	Cross-sectional area of all columns in a story
A_{inf}	Cross-sectional area of all masonry infills in a story
A_{cw}	Cross-sectional area of all concrete walls in a story
A_f	Floor area of a story of a structure
w	Unit weight per floor area of a building
I_c	Simplified column area ratio
I_{inf}	Simplified masonry infill area ratio
I_{cw}	Simplified concrete wall area ratio
b_c	Average size of columns
l_s	Average span length
R_{inf}	Masonry infill ratio
R_{cw}	Concrete wall ratio
t_{inf}	Masonry infill thickness
t_{cw}	Concrete wall thickness
F_{IV}	Vertical irregularity factor
F_{IH}	Horizontal irregularity factor
F_D	Deterioration factor
F_Y	Building's year of construction factor
h_o	Clear height of column
D	Width of column
n_c	Total number of columns
L	Length of building
B	Width of building

CHAPTER 2

Visual Rating index (I_{VR})

2.1 General

In this chapter, the theoretical background and development procedure of Visual Rating method has been described. In the beginning, several literatures related to theoretical background of the proposed VR method have been discussed. Afterward, the development and assumptions considered for the proposed Visual Rating method has been discussed in details.

2.2 Visual Rating Index (I_{VR})

Visual Rating index of an existing building, I_{VR}, is calculated by the following Eq. (2.1):

$$I_{VR} = I_{VRB}.F_{IV}.F_{IH}.F_{D}.F_{Y} \quad (2.1)$$

where,

I_{VRB}= Basic Visual Rating index (see section 2.2)

F_{IV} = Modification factor for vertical irregularity (see section, 2.4.1)

F_{IH}= Modification factor for horizontal irregularity (see section, 2.4.2)

F_{D} = Modification factor for deterioration of concrete (see section, 2.5)

F_{Y} = Modification factor for year of construction (see section, 2.6)

2.3 Basic Visual Rating index (I_{VRB})

The basic Visual Rating index (I_{VRB}) is calculated considering column area ratio, RC wall area ratio, masonry wall area ratio and their average shear strength (see commentary 1). Since the proposed method is based on visual inspection, this Visual Rating method approximately estimates column area ratio, RC wall area ratio and masonry infill area ratio by more simplified way thorough visual investigations. Therefore, the simplified seismic capacity index of existing buildings is expressed by following Eq. (2.2).

$$I_{VRB} = \frac{1}{n.w}\left[\tau_c.I_c + \tau_{\inf}.I_{\inf} + \tau_{cw}.I_{cw}\right] \tag{2}$$

where,

I_c=simplified column area ratio, $I_c = \frac{A_c}{A_f} \approx \frac{b_c^2}{l_s^2}$ (see section, 2.2.1)

I_{inf} = Simplified masonry infill wall area ratio, $I_{\inf} = \frac{A_{\inf}}{A_f} \approx \frac{t_{\inf}}{l_s}.R_{\inf}$ (see section, 2.2.1)

I_{cw}= Simplified RC wall area ratio, $I_{cw} = \frac{A_{cw}}{A_f} \approx \frac{t_{cw}}{l_s}.R_{cw}$ (see section, 2.2.1)

n= number of stories of a building (see section, 3.3.1)

b_c= Average size of columns (see section, 3.3.2)

l_s =Average span length (see section, 3.3.3)

R_{inf}=Masonry infill ratio (see section, 3.3.4)

R_{cw}= Concrete wall ratio (see section, 3.3.5)

τ_c= Average shear strength of column (see section, 2.5.1)

τ_{inf}= Average shear strength of masonry infill (see section, 2.5.1)

τ_{cw} = Average shear strength of concrete wall (see section. 2.5.1)

w= Average unit weight per floor area (see section. 2.5.2)

t_{inf}= Thickness of masonry infill (see section. 2.5.2)

t_{cw}= Thickness of concrete (see section. 2.5.2)

[Commentary-1]

(1) Theoretical Background of Visual Rating method and Visual Rating index

The main concept of Visual Rating method originates from Shiga Map (Shiga et al.1968), which has been proposed after investigating the damaged buildings in the 1968 Tokachi-oki earthquake, Japan as shown in Figure 2.1. The Shiga map considers two simple parameters: ratio of the average shear stress of columns and RC walls based on their cross-section area, and RC wall area ratio (A ratio of the total cross-sectional areas of RC walls in the first story to the total floor area).

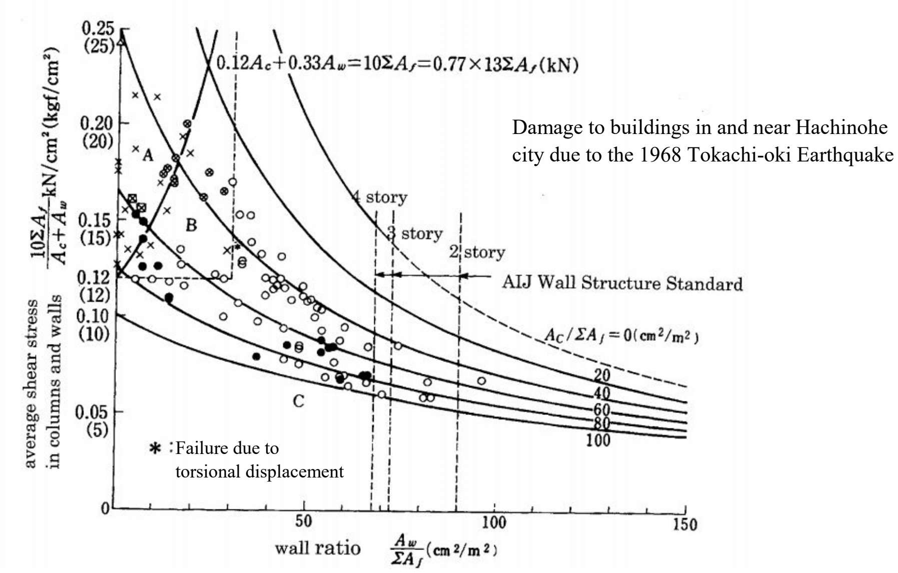


Figure 2.1 Shiga map (Shiga et al. 1968)

Afterwards, this Shiga map showed good agreement with the damage status of RC buildings in the 1978 Miyagi earthquake (Shibata A., 2003). However, this method is applicable only for buildings with RC shear walls, which does not consider the effects of masonry infill. Later on, Hassan and Sozen (1997) presented a simplified method with fundamental parameters such as column and wall area ratio to rank RC framed building according to their vulnerability against seismic damages. This method has been validated by investigation of damaged buildings in the 1992 Erzincan Earthquake, Turkey as shown in Figure 2.2.

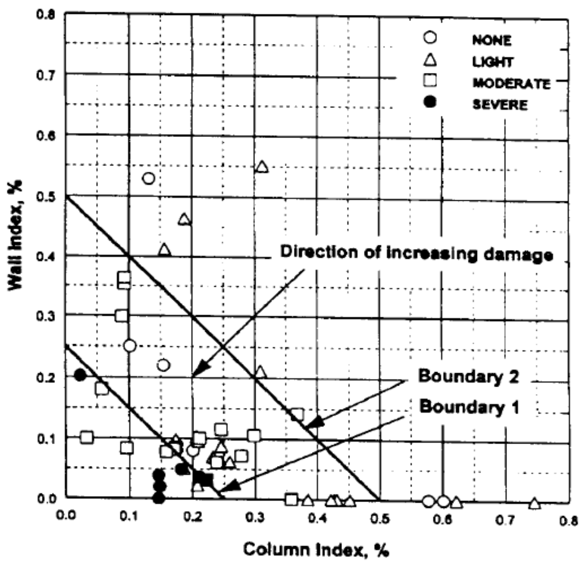


Figure 2.2 Proposed evaluation methods by Hasan and Sozen (1997)

From above discussion, it has been concluded that the simple two parameters such as column area ratio and infill wall area ratio have great influences on seismic capacity. Furthermore, Islam M.S. (2019) studied on several earthquakes damaged database such as the 2015 Nepal Earthquake, the 2016 Ecuador Earthquake, the 2016 Taiwan Earthquake and the 1992 Turkey earthquake. It has been observed that column area ratio and masonry infill area ratio showed good agreement with the damage state of existing buildings, based on past earthquake databases. Thus column area ratio and wall area ratio are the key parameter for estimation of seismic capacity.

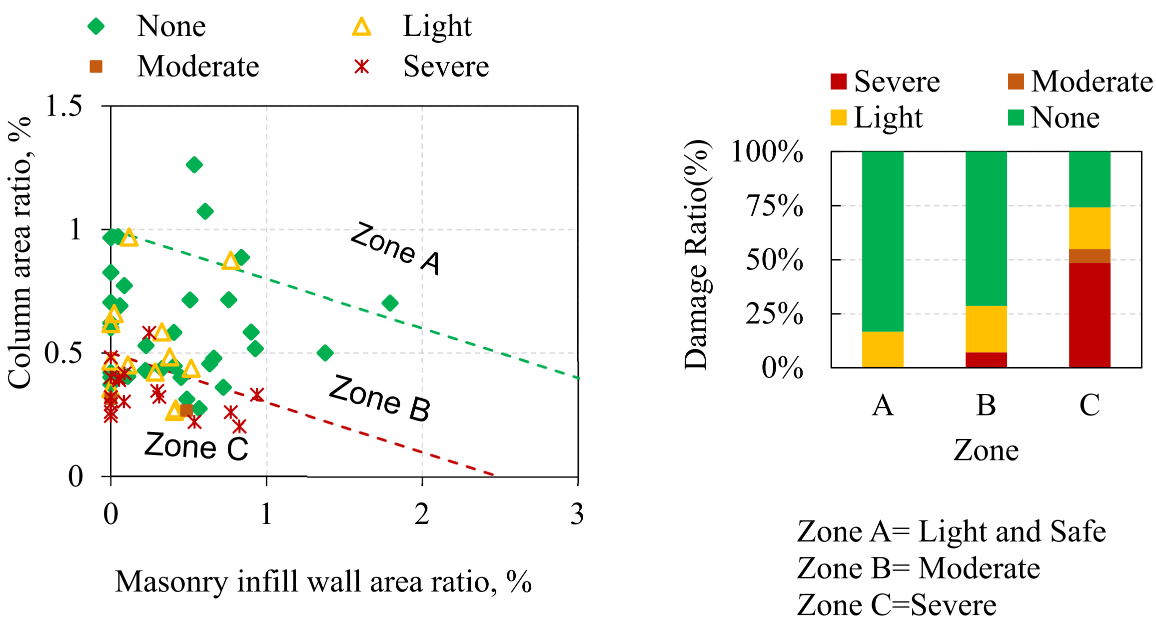


Fig.: Column area ratio and infill wall area ratio with damage ratio [Islam, MS, 2019]

(2) Development of basic Visual Rating index

Based on Shiga map concept, the Japanese seismic evaluation method (JBDPA) [13] proposes a practical way for estimating the seismic capacity of existing RC buildings. The JBDPA standard [13] considers three levels of seismic evaluation procedures to estimate seismic capacity in terms of seismic index (I_S). According to JBDPA standard, seismic index (I_S) is estimated by following Eq. (C2.1).

$$\text{Seismic index } (I_s) = E_0 \times S_d \times T \tag{C2.1}$$

where, E_0= the basic seismic index= C × *F*. C is the strength index which is expressed as base shear coefficient of a RC buildings. *F* is the ductility index based on deformation of existing RC building. S_d is the irregularity index considering both horizontal and vertical irregularity. *T* is the time index considering deterioration of concrete, corrosion of reinforcing steel and buildings year of construction.

In the first level evaluation, strength index (C) can be estimated by lateral strength (V) normalizing with total building's weight (W) as shown in Eq. (C2.2). Here, lateral strength (V) is simply calculated by cross-sectional area of vertical elements and their average shear strength. However, ductility index (F) is considered as 1.0 assuming the building is brittle.

$$\text{Strength index}, C = \frac{V}{W} \tag{C2.2}$$

Second level evaluation procedure considers detailed calculation for estimation of strength index (C) and ductility index (F) based on lateral force-deformation capacity and failure mechanism of each vertical member [13]. However, detailed architectural and structural drawing along with reinforcement detailed is required for both evaluation procedures.

Based on first level evaluation procedure of JBDPA standard [13], strength index (C) of masonry infilled RC building is calculated by Eq. (C2.3) proposed in the previous study [12].

$$C = \frac{1}{w}\left[\tau_c . \frac{A_c}{n.A_f} + \tau_{\inf} . \frac{A_{\inf}}{n.A_f} + \tau_{cw} . \frac{A_{cw}}{n.A_f}\right] \tag{C2.3}$$

where, τ_c, τ_{inf}, and τ_{cw} are average shear strength of RC column, masonry infill, and reinforce concrete wall; A_c, A_{inf}, and A_{cw} are the cross-sectional areas of RC column, masonry infill and reinforced concrete wall. *n* is the number of story, A_f is the floor area, and *w* is the unit weight per floor area of a RC building. In the Eq. (2.3), $A_c/n.A_f$, $A_{inf}/n.A_f$, and $A_{cw}/n.A_f$ are expressed as column area ratio, masonry infill area ratio, and concrete wall area ratio, respectively.

The basic seismic index, E_0, can be calculated by considering C index from Eq. (C2.4) and F index is 1 (one) as follows:

$$E_0 = \frac{1}{w}\left[\tau_c.\frac{A_c}{n.A_f} + \tau_{\inf}.\frac{A_{\inf}}{n.A_f} + \tau_{cw}.\frac{A_{cw}}{n.A_f}\right] \tag{C2.4}$$

Hence, the seismic index (I_s) of first level evaluation as shown in Eq. (C2.1), considering masonry infilled RC buildings, can be estimated by following Eq. (C2.5).

$$I_S = \frac{1}{w}\left[\tau_c.\frac{A_c}{n.A_f} + \tau_{\inf}.\frac{A_{\inf}}{n.A_f} + \tau_{cw}.\frac{A_{cw}}{n.A_f}\right].S_D.T \tag{C2.5}$$

Although the first level evaluation method is very simple and easy to applicable, it is quite challenging to apply on large numbers of existing buildings because it requires architectural drawings. If architectural drawings are not available, as-built drawing preparation are necessary, which takes much time and efforts for seismic evaluation procedure. For this instance, the VR method proposes a simplified way for estimation of column area ratio ($A_c/n.A_f$) masonry wall area ratio ($A_{inf}/n.A_f$) and concrete wall area ratio ($A_{cw}/n.A_f$) by visual inspection instead of measuring of cross-sectional area of all RC column, infill wall, concrete wall, and total floor area. Simplified way considers visual inspection, collection of several parameters which provide approximate estimation of column area ratio, masonry infill area ratio and concrete wall area ratio. This method proposes a score, hereafter reported as Visual Rating index (I_{VR}), which is approximated seismic capacity of existing buildings. The calculation procedure of Visual Rating index (I_{VR}) is described in the following section. Visual Rating index (I_{VR}) indicates the seismic capacity of existing buildings which is expressed by Eq. (C2.6).

$$I_{VR} = \frac{1}{n.w}\left[\tau_c.\frac{A_c}{A_f} + \tau_{\inf}.\frac{A_{\inf}}{A_f} + \tau_{cw}.\frac{A_{cw}}{A_f}\right].S_D.T \tag{C2.6}$$

where, A_c/A_f , A_{inf}/A_f , A_{cw}/A_f can be expressed as simplified column area ratio, simplified masonry infill area ratio, and simplified concrete wall area ratio, respectively. It should be noted that these simplified column area ratio, masonry infill area ratio and concrete wall area ratio are calculated for a single floor of a buildings. The following sections describe about the simplification procedure in details.

2.4 Basic Assumptions for Visual Rating Method

The VR method considers basic assumptions for several parameters such as material properties, buildings unit weight, thickness of masonry infill, and structural wall as well as seismic capacity modification factors.

2.4.1 Basic assumptions for average shear stress

2.4.1.1 Average shear strength of column (τ_c)

Average shear strength is of 1.0 MPa. (see commentary 2-1)

2.4.1.2 Average shear strength of masonry infill (τ_{inf})

The average shear strength of masonry infill, τ_{inf}, is considered as 0.2 MPa. (see commentary 2-2)

***2.4.1.3 Average shear strength of** concrete wall (τ_{cw})*

The average shear strength of concrete wall (τ_{cw}) is assumed 1.0 MPa (see commentary 2-3)

[Commentary 2]

(2-1) Average shear strength of column (τ_c)

Many guidelines and researchers consider a single value for average shear strength of RC column as a conservative approach. In Japan, the Japan Building Disaster Prevention Association (JBDPA 2001) proposed seismic evaluation standard which considers average shear strength of column is 1.0 MPa for the first level screening procedure based on shear-span-to-depth ratio, where h_o/D ranged 2 to 6 (h_o is the clear height of column, D is the column width). Figure 2.3 shows a relationship between shear strength of column and h_o/D ratio based on analyses of existing buildings located in Dhaka, Bangladesh (Islam MS 2019). It has been observed that the shear strength of RC column ranging from 0.60 to 1.75. Lower boundary of shear strength provides more conservative results. On the other hand, upper boundary overestimates the seismic capacity. From the above discussion, this method assumes average shear strength is of 1.0 MPa.

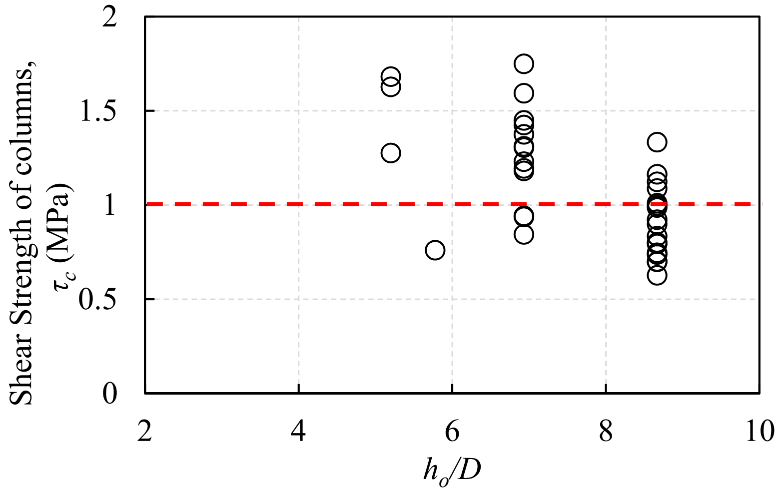


Figure 2.3 Average shear strength for column vs. h_o/D ratio for investigated RC buildings in Bangladesh [Islam MS, 2019]

(2-2) Average shear strength of masonry infill (τ_{inf})

There are several guidelines about consideration of shear strength of masonry infill. ASCE seismic guideline (ASCE/SEI 41-06 2007) prescribed 34 psi (0.24 MPa) for good masonry condition. In developing country such as Nepal, the average lateral strength for masonry infill wall is assumed of 0.28 MPa based on past experimental studies (Karmacharya, U 2018, Pradhan, 2009). Figure 2.4 shows the maximum shear strength of masonry infill corresponding to compressive strength of masonry prism (Alwashali, 2018). From the discussion above, a value of shear strength of masonry infill, τ_{inf}, is considered as 0.2 MPa, which is a conservative value for masonry with compressive strength of less than 10 MPa, as shown in Figure 2.4.

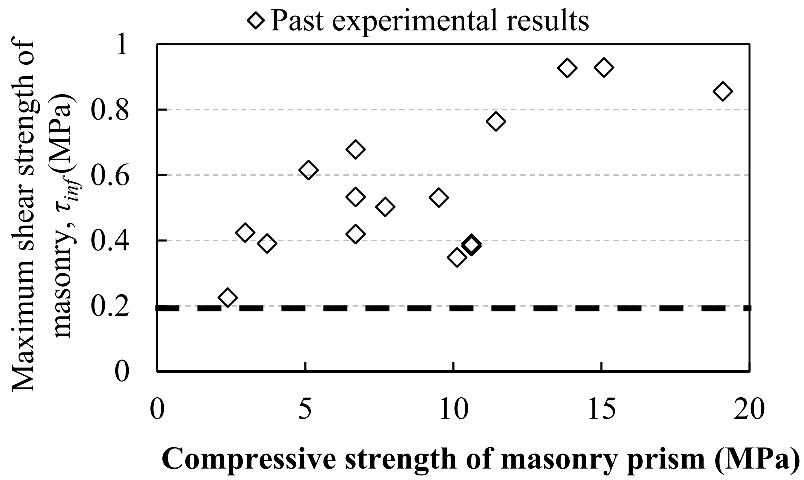


Figure 2.4 Average Shear Strength for Masonry Infill with Compressive Strength of Masonry (Alwashali, 2018)

(2-3) Average shear strength of concrete wall (τ_{cw})

JBDPA standard (2001) proposed the average shear strength of concrete wall without boundary columns is 1.0 MPa based on past damage investigation and experimental data. In this method, the average shear strength of concrete wall (τ_{cw}) has been assumed 1.0 MPa for very preliminary evaluation.

2.4.2 Basic assumptions for buildings properties

2.4.2.1 Thickness of masonry infill (t_{inf})

The masonry infill thickness (t_{inf}) as 125 mm for single layer of infill panel. In case of infill wall thickness of 250 mm, the number of walls should be counted twice of 125 mm thick infill wall. (see commentary 3-1)

2.4.2.2 Thickness of concrete wall (t_{cw})

The minimum thickness of concrete wall (t_{cw}) is assumed 200 mm. (see commentary 3-2)

2.4.2.3 Average unit weight per floor area (w)

*T*he average unit weight per floor area, *w*, is set as 11kN/m^2. (see commentary 3-3)

[Commentary 3]

(3-1) Thickness of masonry infill (t_{inf})

In general, the thickness of masonry infill is about 125 mm which is common practice in masonry infill RC buildings in Bangladesh. Besides, the thickness of masonry infill varies within a range of 125 mm to 250 mm as found in the field survey in Bangladesh (Islam MS 2019). Sometimes for public building such as office building, the thickness of exterior wall and interior wall is 250 mm and 125 mm. This method assumes the masonry infill thickness (t_{inf}) as 125 mm for single layer of infill panel. In case of infill wall thickness of 250 mm masonry wall, the number of walls should be counted twice of 125 mm thick infill wall.

(3-2) Thickness of concrete wall (t_{cw})

The thickness of concrete wall ranges 200 mm to 300 mm as found in existing building in Bangladesh (Islam MS 2019). In this method, the minimum thickness has been conservatively assumed 200 mm as the lower boundary.

(3-3) Average unit weight per floor area (w)

The unit weight per floor area of existing buildings is found ranging from 10 to 12 kN/m^2 based on a study of existing RC buildings located in Bangladesh (Islam 2019). Therefore, in this method, the average unit weight per floor area, w, is set as 11kN/m^2.

2.4.3 Basic Assumptions for Modification Factors

Modification parameters includes, building's irregularities due to vertical irregularity and horizontal irregularity, deterioration and buildings' age.

2.4.3.1 Modification factor for vertical irregularity (F_{IV})

Modification factors for vertical irregularity are shown in Table 2.1. (See commentary 4-1)

Table 2.1 Modification factors for vertical irregularity (F_{IV})

Items	Regular	Nearly Regular	Irregular
Criteria	No opening at ground floor	Small opening at ground floor and setback (See Figure 2.6 a-b)	Soft story or open ground floor (See Figure 2.6 c)
F_{IV}	1.0	0.8	0.6

2.4.3.2 Modification factor for horizontal irregularity (F_{IH})

The modification factors for different horizontal irregularity factors are shown in Table 2.2. For more clarification, the criteria for plan irregularity are shown in Figure 2-7 in commentary 4-2.

Table 2.2 Modification factor for horizontal irregularity (F_{IH})

Items	Regular	Nearly Regular	Irregular
Shape	Regular shape	L, T or U shaped plan.	L, T or U shaped plan
The projection area, "a" (as shown in shaded part)*	≤ 10 % of floor area	≤ 30% of floor area	> 30% of floor area
F_{IH}	1	0.9	0.8

*Projection area indicates shaded part in the Figure 11(a), 11(b) and 11(c)

[Commentary 4]

Buildings Irregularities

Many seismic evaluation guidelines in different countries such as American Standard (ASCE/SEI 7-10), Japanese seismic evaluation standard (JBDPA), New Zealand standard 2004 (NZS 1170.5), describe the irregularities of buildings into two categories. These are vertical and horizontal irregularities. Moreover, those seismic evaluation guidelines propose different approaches to consider these influencing parameters during seismic capacity evaluation.

Past earthquake damage investigation helps to quantify the irregularities of existing RC buildings. However, the existing rapid visual screening method proposed several factors for seismic influencing parameters based on study of past earthquake damage databases, engineering justification and also individual perceptions.

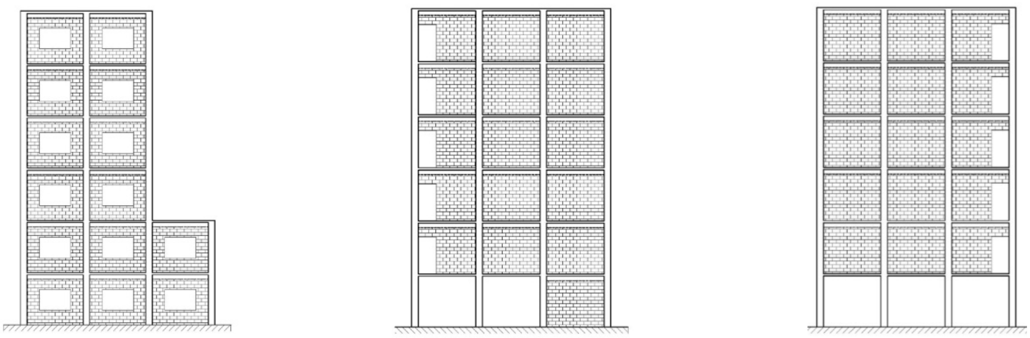
Japan Building Disaster Prevention Association (JBDPA) (2001) proposed standard for seismic capacity evaluation which does not cover masonry infilled RC buildings. In this method, JBDPA (2001) manual is extended to be used for the masonry infilled RC structures for modifying the Visual Rating Index, according to the horizontal and vertical irregularity. Therefore, the proposed method assumes modification factors following Japanese seismic evaluation standard during estimation of Visual Rating index. The following sections describe seismic capacity reduction factors due to vertical and horizontal irregularities:

(4-1) Vertical irregularity factor (F_{IV})

It is generally accepted that the vertical irregularity significantly influences the seismic performance of RC buildings more than that of horizontal irregularity. Many researchers reported different types of the vertical irregularities such as story stiffness distribution along the height, the inconsistency between adjacent floor, ground floor parking, soft story etc. Usually, opening and soft story due to ground floor parking and commercial usage which are commonly found in most of RC buildings in developing countries. Many buildings were severely damaged due to this types of irregularities as shown in Figure 2.5 in Nepal Earthquake 2015 (datacenterhub.org).

Figure 2.5 Examples of buildings subjected to soft-story collapse during the 2015 Nepal earthquake (datacenterhub.org)

It is necessary to quantify the aforementioned vertical irregularities for taking into account in seismic evaluation procedure. However, it is not easy to investigate all types of vertical irregularities by visual inspection within a very short time. Hence, this method considers full and partial opening at ground floor, setback etc. which can be visually observed during a building survey and inspection. Therefore, this method classifies the vertical irregularities into three categories for easy understanding such as regular, nearly regular, irregular as shown in Figure 2.6.



(a) Setbacks (b) Some panels without infill at ground floor (c) soft or open story

Figure 2.6: Elevation view of some typical RC frame having vertical irregularities

A vertical irregularity factor *(F_{IV})* has been imposed in this method to quantify the vertical irregularity of existing buildings. In this context, many researchers and seismic evaluation code proposed values for quantification of these types of irregularity in seismic evaluation procedure (JBDPA 2001; Sucuoglu et al. 2007; Ozcebe et al. 2004, Al-Nimry et al. 2015). This method assumes modification factors which are based on Japanese seismic evaluation procedure.

The reduction factors for different vertical irregularity criteria are shown in Table 2.1 (JBDPA 2001) described as follows:

(a) ***Regular:*** The building has been considered as regular if there are no significant vertical irregularities. In this case, the value has been considered as unity.

(b) ***Nearly Regular***: Partial opening at ground floor as well as setback are sometimes present in existing RC buildings (See Figure 2.6 (a) & (b)) which are also responsible for reduction of seismic capacity during earthquake.

(c) ***Irregular:*** Opening at ground floor due to car parking is very common for mid-rise RC building in developing countries (See Figure 2.6 c).

Many guidelines and researchers propose values for reduction factors for open ground floor or soft story effect. However, Al-Nimry et al (2015) proposed reduction factors for soft story structures 0.85 and 0.75 for mid-rise and low-rise buildings respectively. It indicates about 15% to 25 % of reduction of actual seismic capacity. Similar observations also have been found by other researchers such as Sucuoglu and Yazgan (2003), Gulkan and Yakut (1994), Magliulo et al. (2002) based on engineering judgement and field observations of actual earthquake damages. It has been concluded that the earthquake response magnifies about 13.5 % to 20% due to soft story compared with regular buildings. Furthermore, JBDPA (2001) propose reduction factor for soft story about 0.9 and eccentric soft story is of 0.8 for both first level and second level evaluation. As the proposed method is based on visual inspection within short time, this method assumes vertical irregularity factors is of 0.6 as a conservative for preliminary investigation as shown in Table 2.1. In case of partial opening or set back, a reduction factors are of 0.8 chosen as shown in Table 2.1.

Table 2.1 Factors for vertical irregularity (F_{IV})

Items	Regular	Nearly Regular	Irregular
Criteria	Regular	Small opening at ground floor and setback (See Figure 2.6 a-b)	Soft story or open ground floor (See Figure 2.6 c)
$\boldsymbol{F_{IV}}$	1.0	0.8	0.6

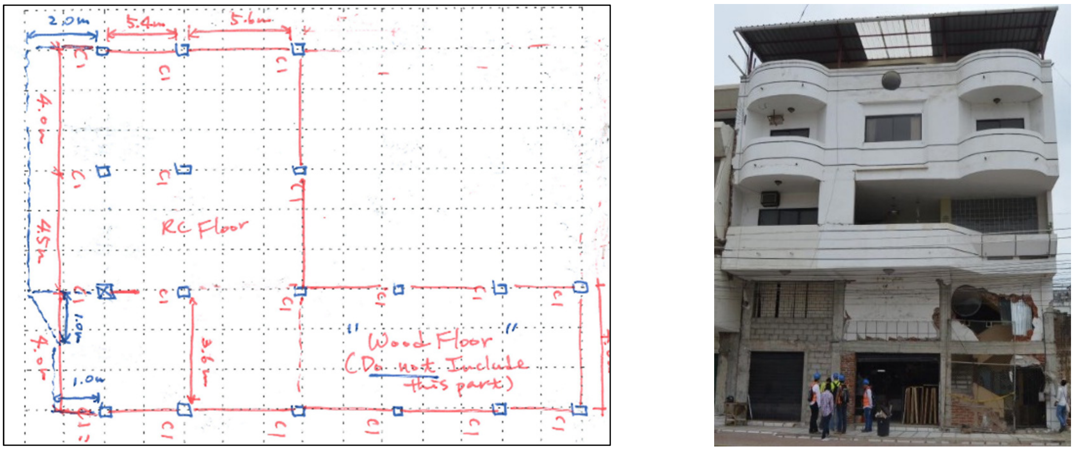
(4-2) Horizontal irregularity factor (F_{IH})

Buildings also suffer diverse of seismic damages due to different types of structural configurations in plan such as L, T, and U shape of building. Sometimes, severe damage occurs due to high aspect ratio of floor plan (here aspect ratio means the ratio of building's length between longitudinal and transverse direction). Those types of buildings have been reported as severely damaged during past earthquakes based on past earthquake damaged database. Figure 2.7 shows RC buildings with irregular shape suffered severe damage in the 2016 Ecuador and the 2015 Nepal earthquakes. Figure 2.7(a) shows the building has an L shaped floor plan. Since the perpendicular part is narrower than the main part of the building, the center of mass is changed during the earthquake due to torsional effect. The torsional effects during earthquake which turned into severe damage. Figure 2.7 (b) showing a building with large aspect ratio has been severely affected during Nepal earthquake. The investigated building is three storied and seismic capacities is not much lower to be severely damaged. However, the building has been reported severely damaged due to plan irregularity with aspect ratio even though high seismic capacity.

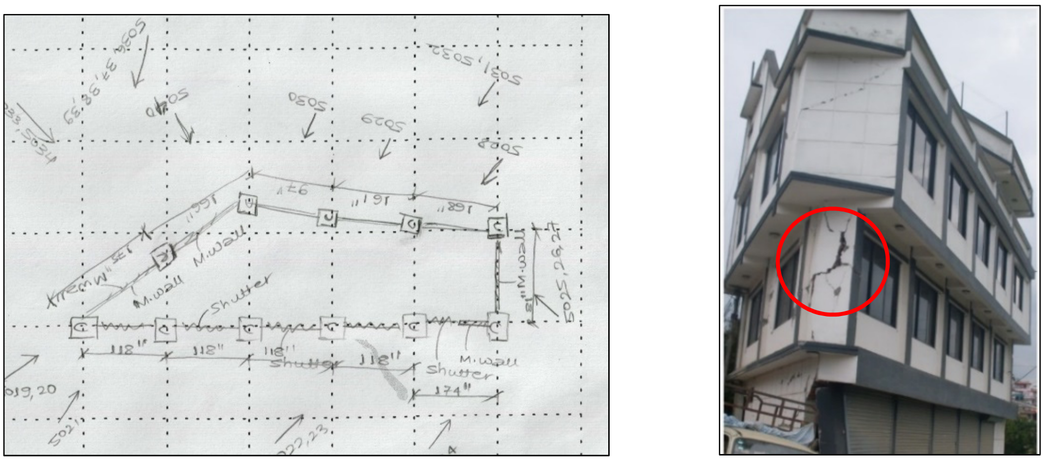
The horizontal irregularity including different shape of buildings floor plan (such as L, T, U shaped floor plan), aspect ratio, re-entrant corner, extended floor plan etc. which are commonly observed in existing RC buildings. Since the propose method is based on visual inspection with limited time, all types of horizontal regularities cannot be considered during visual investigation. Hence, buildings shape and aspect ratio is considered and those parameters can be easily inspected during field survey.

Many researchers worked to understand the behavior of RC buildings with plan irregularity. Many of seismic design codes propose some guidelines to avoid torsional effects during earthquake. In addition, these guidelines are sometimes strict about selection of building shape in high seismicity region whenever designing new buildings. However, in seismic evaluation of existing RC buildings, it is necessary to quantify and consider a reduction factor associated with horizontal irregularities.

Most of researchers consider the horizontal irregularity factor as a qualitative approach. Some of them are trying to quantify the horizontal irregularity factors for seismic capacity evaluation. Al-Nimry et al. (2015) propose a reduction factors for horizontal irregularity of 0.95 and 0.9 for low-rise and mid-rise buildings respectively based on different types of shape of buildings. However, JBDPA (2001) proposes guidelines for different criteria of plan irregularity and a reduction factor for modifying the seismic capacity. The values have been considered as 1, 0.9, and 0.8 for regular, nearly regular, and irregular, respectively.



(a) Building with L shaped floor plan



(b) Floor plan with large aspect ratio

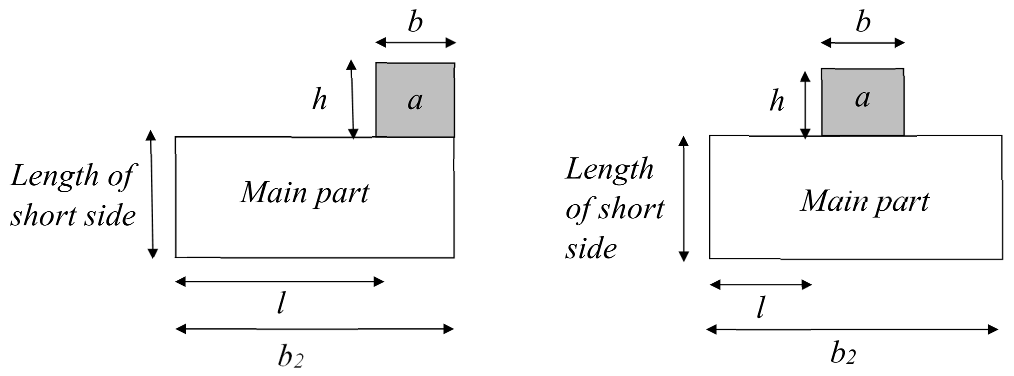
Figure 2.7 Damage due to horizontal irregularity of RC buildings in Nepal and Ecuador Earthquake

The factors are considered depending on different possible shaped building plan (i.e. L, T or U shaped). All types of horizontal irregularity are not easy to investigate during visual inspection. Therefore, only building configurations considering different possible shaped building plan (i.e. L, T or U shaped) is considered in this method. JBDPA classified into three categories according to floor plan. The basic criteria for each parameter is described in JBDPA manual (2001), and the brief descriptions of plan regularity are shown in Figure 2.8. The following considerations are taken for plan irregularity:

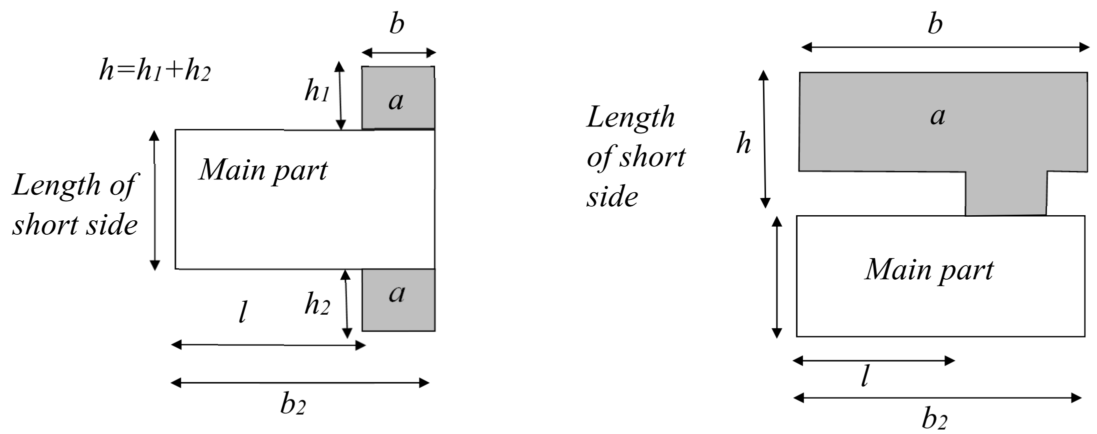
(i) ***Regular:*** Structural balance is good, and the area of a projection part (*a*) is not more than 10% of the floor area.

(ii) ***Nearly Regular***: Structural balance is worse than regular, or the area of a projection part (*a*) is not more than 30% of the floor area with L, T or U shaped plan.

(iii) ***Irregular:*** Structural balance is worse than nearly regular, or the area of a projection part (*a*) is larger than 30% of the floor area with L, T or U shaped plan.



(a) L shaped floor plan (b) T shaped floor plan



(c) T shaped floor plan (d) U shaped floor plan

Figure 2.8 Criteria for plan irregularity

Table 2.1 shows reduction factors for different horizontal irregularity factors based on Japanese seismic evaluation standard (JBDPA 2001).

Table 2.1 Factors for horizontal irregularity (F_{IH})

Items	Regular	Nearly Regular	Irregular
Shape	Regular	L, T or U shaped plan.	L, T or U shaped plan
The projection area "a"	≤ 10 % of floor area	≤ 30% of floor area	> 30% of floor area
F_{IH}	1.0	0.9	0.8

2.4.3.3 Modification factor for deterioration of concrete (F_D)

Table 2.3 shows the values of reduction coefficient due to presence of visible crack in the buildings according to JBDPA 2001.

Table 2.3 Deterioration Factor (F_d)

Item	None	Minor	Severe
Criteria	No deterioration	Some cracks in structural element or minor spalling	Major Spalling in concrete and major crack
F_d	1.0	0.9	0.8

2.4.3.4 Modification factor for year of construction (F_Y)

In VR method modified values as shown in Table 2.4 has been considered upon construction practices, design criteria and enforcement of Building Code in Bangladesh.

Table 2.4 Year of construction factor (F_y)

Item	New	Middle	Old
Criteria	After 2006	1993-2006	Before 1993
F_y	1.0	0.95	0.9

[Commentary 5]

Reduction Factors Related to Deterioration and Buildings Age

Generally, seismic capacity of existing building is reduced due to deterioration caused by poor maintenance, quality of existing buildings and building's age. The proposed Visual Rating Index also considers those reduction parameters.

(5-1) Deterioration factor (F_d)

Deterioration of concrete in structural elements strongly affects the actual state of seismic capacity of the building. Theoretically, presences of cracks as well as spalling in concrete are responsible for the degradation of seismic capacity. This also refers a building can be attributed to weak material and poor workmanship. Furthermore, the correlation between the building quality and damage state has been observed based on study of past earthquake damage database (Sucuoglu et al. 2007).

Figure 2.9 shows typical cracks in existing RC structures which can be easily identified by visual inspection.

(a) Spalling of concrete and rebar rust

(b) Crack through RC column

Figure 2.9 Deterioration of concrete

Figure 2.10 shows typical cracks in existing RC structures which can be easily identified by visual inspection. However, this types of cracks are not suggested to consider during visual inspection.

c) crack in masonry infill

d) plaster deterioration

Figure 2.10 Deterioration of concrete and masonry infill not need to consider

Table 2.3 shows the values of reduction coefficient due to presence of visible crack in the buildings according to JBDPA 2001.

Table 2.3 Deterioration Factor (F_d)

Item	None	Minor	Severe
Criteria	No deterioration	Some cracks in structural element or minor spalling	Major Spalling in concrete and major crack
F_d	1.0	0.9	0.8

(5-2) Building's year of construction factor (F_y)

Building year of construction refers to the age of building which reflects the quality of construction as well as the design procedure adopted for a particular building. Generally, an old(er?) building cannot be expected to have a good performance during earthquakes due to old construction practices ignoring seismic detailing employed in the recent building codes. For example, in Japan, poor seismic performance has been observed in older buildings, in the 1995 Kobe earthquake, especially to those constructed before adopting new seismic design code 1981. Hence, those buildings were severely damaged due to this devastating earthquake (Ohba et al. 2000). Therefore, the building age affects its overall seismic performance. Based on experiences of past earthquakes, JBDPA (2001) proposed a capacity reduction factor in the seismic evaluation manual for building year of construction or aging. In VR method modified values as shown in Table 2.4 has been considered upon construction practices, design criteria and enforcement of Building Code in Bangladesh.

Table 2.4 Year of construction factor (F_y)

Item	New	Middle	Old
Criteria	After 2006	1993-2006	Before 1993
F_y	1.0	0.95	0.9

The aforementioned assumed values for each parameter in Equation (4) could be adjusted for each country based on suitable characteristics of buildings and materials strength properties in that region.

CHAPTER 3
Application of Visual Rating Method

3.1 General

This chapter contains the instructions of application of Visual Rating method and procedure of completing the VR survey data sheet during field investigation.

3.2 Data Collection Survey Datasheet

Completion of survey data sheet is one of the major tasks for application of Visual Rating method. This method considers a rapid inspection of buildings over a short period of time. The survey datasheet is attached below with detailed instructions for each element of the sheet.

Visual Rating (VR) Survey Sheet

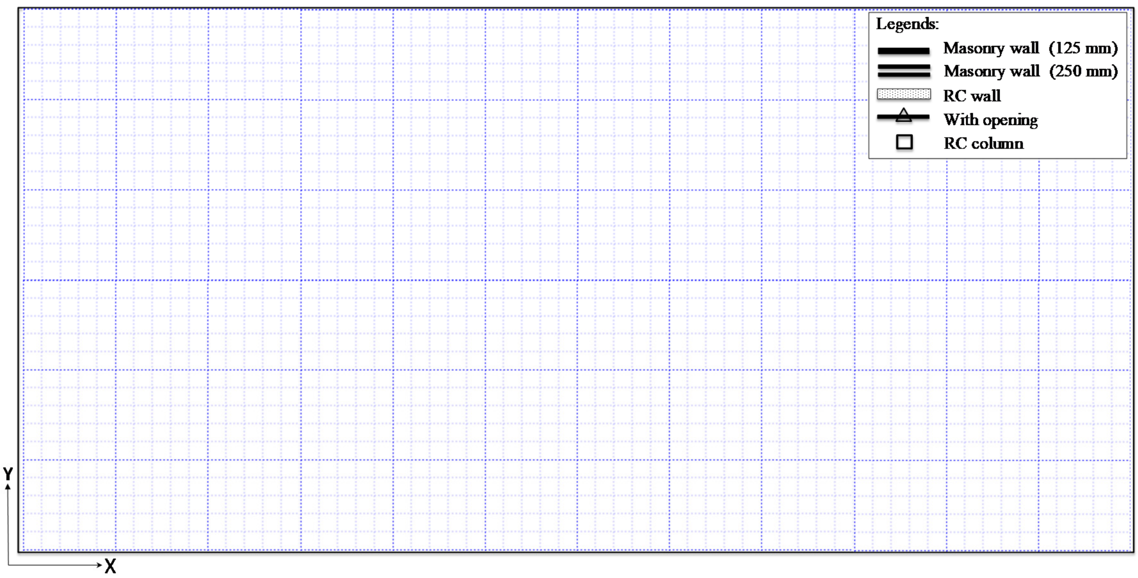
General Information							
Building ID:							
Address:				Zip code		Date:	(day/month/year)
Occupancy Categories:		Construction Year		Latitude: Longitude:		Time:	

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_s), (mm)	The size of equivalent square floor area carried by a single column				
4	RC wall ratio	Shear wall ratio, R_{sw}: $= \frac{No\ of\ RC\ shear\ wall\ in\ x\ or\ y\ dir.}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X- direction:		Y-direction:	
5	Masonry infill ratio	Masonry infill Ratio, R_{inf} $= \frac{No\ of\ infill\ panel\ in\ x\ or\ y\ dir.}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X-direction:		Y-direction:	
6	Vertical irregularity (F_{IV})	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_{IH})	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_{VR} score :		Comments
		Buildings category :		

3.3 Parameters of VR Survey Data Sheet

The surveyor should complete the sketch of the building showing the location of columns, masonry infill and RC walls. Necessary dimension can be written as per requirements. Qualitative sketches of front and side elevation are suggested to draw. This shall be done by visually observing the building and noting its number of stories and shape. Several snaps/photographs of the building indicating floor, front elevation, and side elevations shall be taken by the surveyors during survey. During completion of the VR Sheet, double writing/overwriting should be avoided in order to away from confusion. If any special case appears, the surveyor shall mention it on the right side of the sheet on the column named “Note”.

In the following sections, each parameter of the survey data sheet is discussed with consideration as follows:

3.3.1 Number of Stories (n)

The number of stories is directily related to the total building weight. Surveyor shall input the total story number at present. If there is a different story number observed in a building or setback in the same building; surveyor shall take the maximum story number excluding the “Chilekotha”. However, surveyors have to mark the part and story number in the rough sketch of VR Survey Sheet accordingly.

3.3.2 Average column size (b_c)

In this method, the cross-sectional area of column is simplified by using representative column size (b_c) instead of measuring all columns area of a building. The average size of columns (b_c) represents a dimension of a single column which reflects dimensions of all columns of an investigated building. This proposed method requires the inspectors to enter the building and investigate columns by visual inspection.

The average column size (b_c) shall be chosen based on following procedure:

1. First of all, surveyors shall investigate corner, exterior column, and interior columns. Based on dimension of these three columns, average column size (b_c) can be estimated using the Eq. (3.1).

$$b_c = \sqrt{\frac{a_1+a_2+a_3}{3}} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (3.1)$$

a_1, a_2 and a_3= Cross-sectional area of corner column, exterior column and interior column. Figure 3.1 illustrates the columns to be investigated.

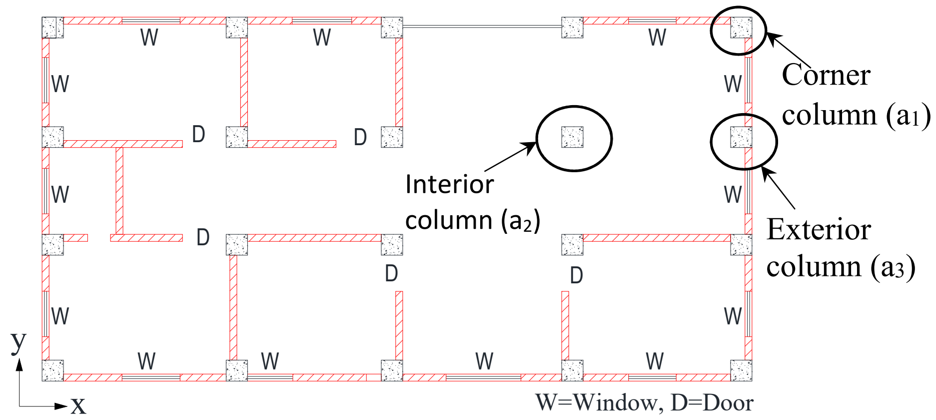


Figure 3.1 Schematic floor plan of a building for option 1

2. If it is not easy to find dimension of corner column and exterior column. In this case, surveyor shall consider representative column size (b_c) based on investigating three interior columns and consider Eq. (3.1). mentioned above. An example has been shown in Figure 3.2.

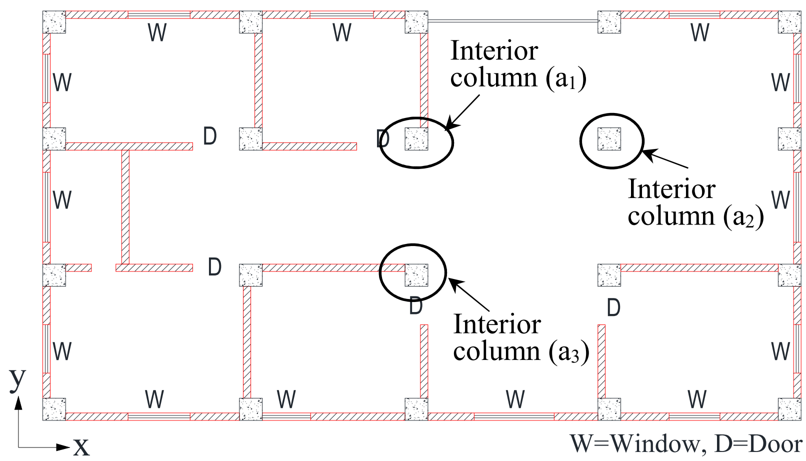


Figure 3.2 Schematic floor plan of a building for option 2

It has been suggested to surveyors exclude due to plaster and tiles:

1. Surveyors 50 mm plaster width shall be excluded while computing the average column size (b_c).
2. In case of tiles work, thickness of tiles should be taken of 75 mm. The tile thickness should be deducted from column dimension

3.3.3 Average Span Length (l_s)

The average span length, l_s is considered as the size of equivalent square sized floor area, the load of which will be carried by the representative column. Average span length is related with total floor area. It not easy to measure the floor area by visual inspection within a short time. Because it requires as-built drawing preparation if architectural drawings are not available, this takes longer time for building survey. In order to determine average span length, surveyor shall follow the following ways.

1. If it is possible to measure length (L) and width (B) of the buildings as shown in Figure 3.3.

$$l_s = \sqrt{\frac{L.B}{n_c}} \quad \text{……………………………………………………………. (3.2)}$$

Where, L=Length of building

B= Width of building

n_c= Total number of columns in a story

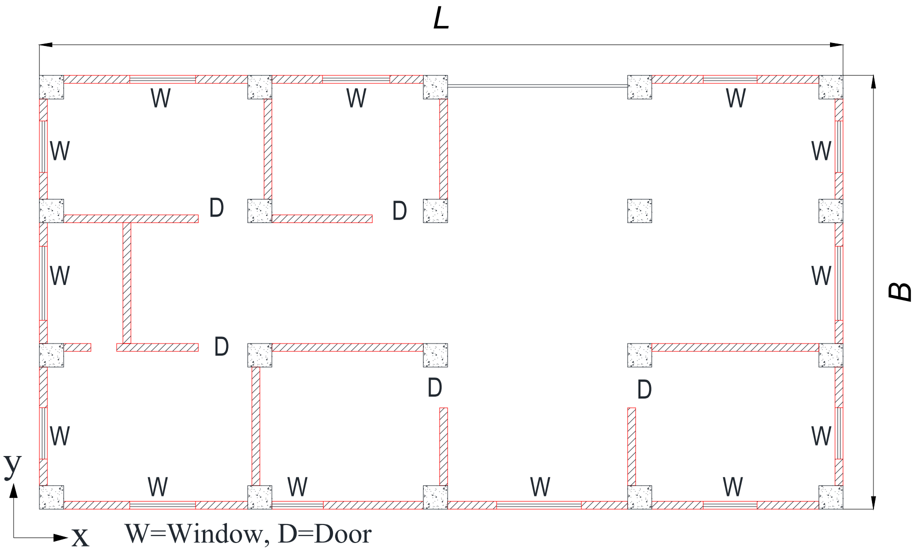


Figure 3.3 Schematic floor plan of a building for option 1.

2. If it is not possible to measure the whole area of existing buildings, Surveyor should measure at least three tributary areas as shown in Figure 3.4 such as A_1, A_2 and A_3 for corner column, exterior column and interior column respectively. The average span length will be calculated using the following equation;

$$l_s = \sqrt{\frac{A_1+A_2+A_3}{3}} \quad \text{…………………………………………………………(3.3)}$$

Where, A_1=Tributary area of Corner column

A_2= Tributary area of exterior column

A_3= Tributary area of interior column

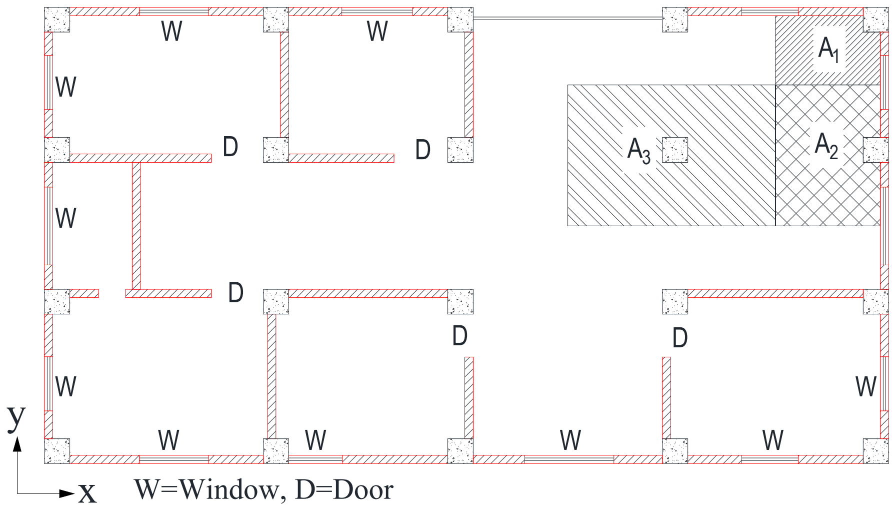


Figure 3.4 Schematic floor plan of a building for option 2

3. If it is not possible to measure tributary area mentioned above, surveyor is suggested to measure length of two or three spans in both direction and average span length is calculated using the Equation Figure 3.5 shows an example of inspection procedure of average span length (l_s) of a surveyed building.

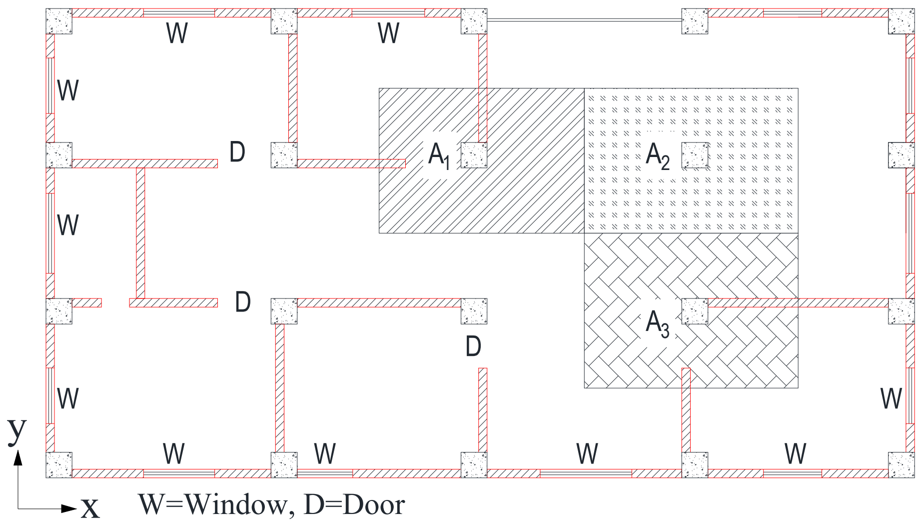


Figure 3.5 Schematic floor plan of a building for option 3

3.3.4 Masonry Infill Ratio (R_{inf})

This section explains the simplified procedure of calculating masonry infill ratio using simple parameters depending on visual inspection. Generally, two types of masonry infill are commonly found in existing RC buildings: masonry infill without opening and with opening due to door, window, and high window. Sometimes, partial masonry infills with corridor are also found in existing buildings. It is not easy to measure length and width of each masonry infill either solid or with opening by visual inspection within a short time. On the contrary, it is easy to count the number of masonry infill panels in each direction by visual inspection instead of measuring dimension of each masonry infill. Thus, the sectional area of masonry infills can be easily estimated using the number of infill panels, average span length (l_s) and thickness of masonry infill (t_{inf}) in each direction. Hence, the masonry infill area ratio can be simplified by using masonry infill ratio (R_{inf}), thickness of masonry infill (t_{inf}) and average span length (l_s) as shown in Eq. (3.4).

$$I_{\text{inf}} = \frac{A_{\text{inf}}}{A_f} \approx \frac{t_{\text{inf}}}{l_s}.R_{\text{inf}} \tag{3.4}$$

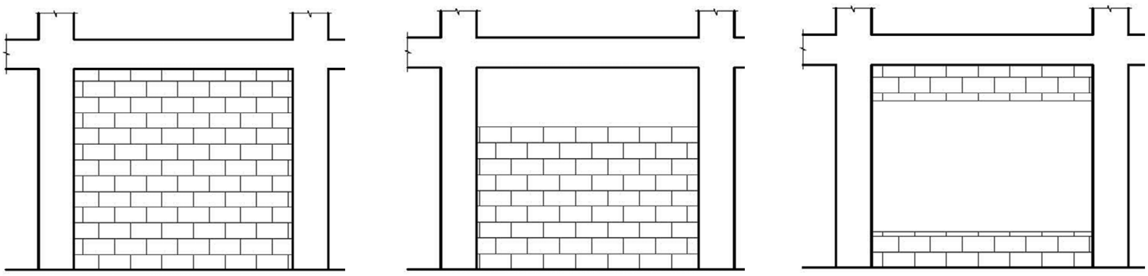
where, R_{inf} is the masonry infill ratio which indicates the quantity of masonry infill expressed as the ratio of the total number of solid masonry panel in a direction to the total number of spans for that direction.

Therefore, the masonry infill ratio (R_{inf}) is simplified as expressed by Eq. (3.5).

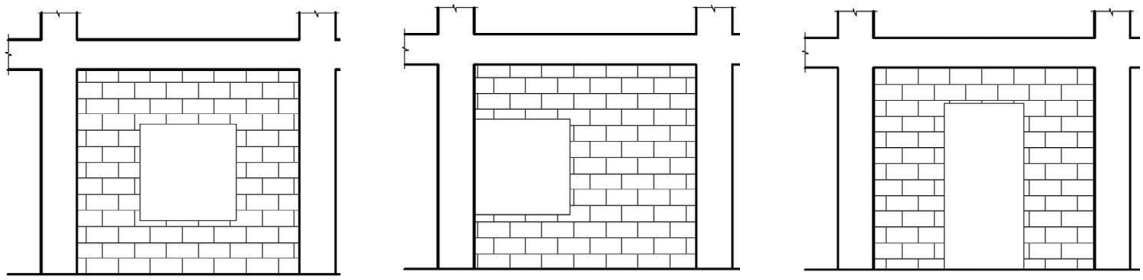
$$R_{inf} = \frac{Number\ of\ masonry\ panels\ in\ a\ direction}{Total\ number\ of\ spans\ in\ a\ direction} \tag{3.5}$$

Since the proposed method considers visual inspection, the surveyor is suggested to count the number of solid masonry infills and of spans for both directions in the inspection. Afterward, the masonry infill ratio, R_{inf} shall be calculated for both orthogonal directions. Finally, the minimum value of R_{inf} is used for conservative evaluation.

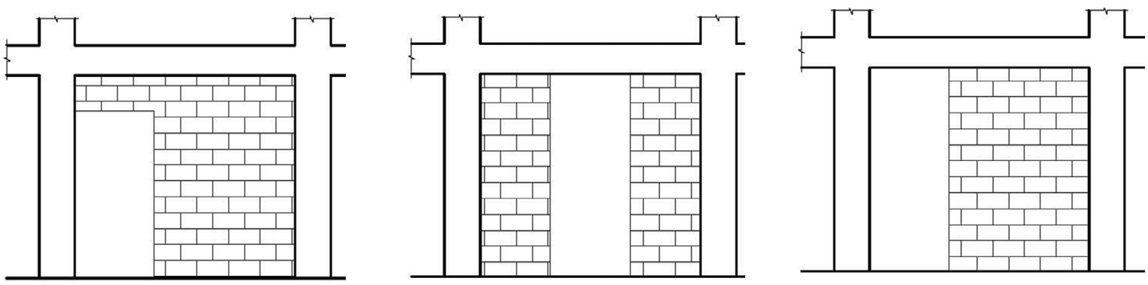
Note: Since the proposed method is based on visual inspection with limited time, it should be noted that the partial infill or infill with opening due to door, and window is not considered in this method. Therefore, only solid masonry infills are considered to estimate the masonry wall area for the conservative side. Figure 3.4 shows an example of different types of opening. In addition, the solid infill outside the RC frame shall not be shall not be considered. Masonry infill enclosed by RC frame wall (Fig. 3.2a) shall be considered.



(a) Solid infill (to be considered in *Rinf*) (b) Infill with high window (c) Infill with cont. window



(d) Infill with central window (e) Infill with side window (f) Infill with door (central)



(g) Infill with door (side) (h) wing wall (i) wing wall

Figure 3.4: Masonry infill with different types of opening

A typical floor plan is shown in Figure 3.5 as an example of calculation procedure of simplified masonry infill wall ratio (R_{inf}). As described in the previous sections, masonry infills with opening are not considered in this method. Therefore, the numbers of solid masonry infill panels are 2 (marked by square) in X direction and 3 (marked by circle) in Y direction as shown in Figure 3.3. On the other hand, the total numbers of spans are obtained as 16 (4 spans x 4 frames) and 15 (3 span x 5 frames) in X and Y direction, respectively. Therefore, R_{inf} are found

2/16 and 3/15 in X and Y direction, respectively. Here, the minimum R_{inf} value 2/16 is considered for capacity prediction.

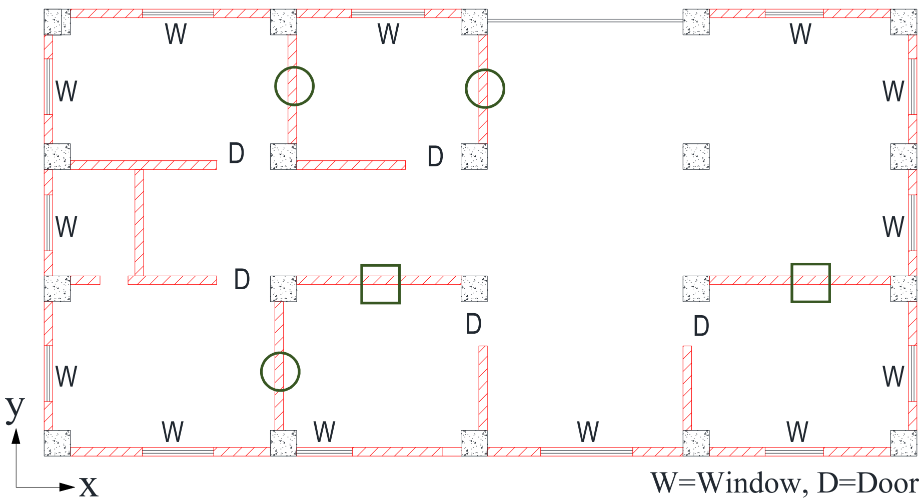


Figure 3.5: Typical floor plan showing location of masonry infill

3.3.5 Concrete Wall Ratio (R_{CW})

The concrete wall area ratio (I_{CW}) has been simplified by using a similar way of masonry infill area ratio (I_{inf}) as discussed in the previous section. Therefore, the concrete wall area ratio (I_{cw}) is simplified with the concrete wall thickness (t_{cw}) and the average span length (l_s) as shown in Eq. (3.6).

$$I_{cw} = \frac{A_{cw}}{A_f} \approx \frac{t_{cw}}{l_s}.R_{cw} \tag{3.6}$$

where, concrete wall ratio (R_{cw}) indicates the quantity of concrete wall expressed as the ratio of the total number of solid concrete wall panels in a direction to the total number of spans for that direction as shown in Eq. (3.7).

$$R_{cw} = \frac{Numberof\ concrete\ walls\ in\ a\ direction}{Total\ number\ of\ spans\ in\ a\ direction} \tag{3.7}$$

Concrete walls with opening due to door and window are not considered in this method as a conservative approach. R_{cw} shall be calculated for both orthogonal directions and the minimum value is considered.

3.3.6 Modification Factor

3.3.6.1 Vertical Irregularity Factor (F_{IV})

This factor aims to check the balance of story stiffness distribution along the height, the inconsistency between adjacent floor, ground floor parking, soft story etc. Detailed information is described in article 2.6.1 and 2.6.1.1 of Chapter 02.

3.3.6.2 Horizontal Irregularity Factor (F_{IH})

Sometimes a high aspect ratio of floor plan (here aspect ratio means the ratio of building's length between longitudinal to transverse direction) might exist in a building, and this type of building has been reported to experience severe damage during past earthquakes based on past earthquake damaged database. Detailed information has been described in article 2.6.1.1 and 2.6.1.2 of Chapter 2.

3.3.6.3 Deterioration Factor (F_d)

Deterioration of a building has an impact on its structural performance. So it is important to identify if there is any type of deterioration and judge the significance of such damage. Detailed information has been described in article 2.6.2.1 and 2.6.2.2 of Chapter 02.

3.3.6.4 Building's year of construction Factor (F_y)

Building construction year i.e., building age reflects the quality of construction, concrete strength as well as the design procedure adopted for a particular building. Therefore, building age affects its overall seismic capacity. The approximate age of a building can also indicate the possible structure type. The ability to identify the age of a building by considering its architectural style and construction materials requires an extensive knowledge of architectural history and past construction practice. In case of phased construction, starting time of first phase shall be taken into consideration. Detailed information has been described in article 2.6.2.1 and 2.6.2.2 of Chapter 02.

3.3.7 Sketch of Floor Plan

A preliminary sketch of the floor plan has to be drawn at the bottom of the VR survey sheet. However, it does not have to be a properly scaled drawing. The main purpose of this rough sketch is to have a preliminary idea about the floor plan, frames/framing system and location of solid masonry walls. Later this sketch will be used to calculate R_{inf}. The surveyor must sketch the plan as clear as possible for future reference. It is suggested to draw the front and side elevation of the building to understand the story number and vertical irregularities. It should be emphasized that several photographs should be taken to reassess the obtained data and for further verification.

3.4 Inspection Procedure

VR is basically intended for rapid screening of large number of building stocks. So, detailed inspections are not required. However, if a surveyor thinks it necessary, detailed inspections may be carried out with use of proper instruments. Simple measuring instruments like steel tape, scale, laser meter, rebar detector etc. shall be used to determine the parameters. The surveyor should try his best to get the closest values of the parameters.

VR Index Calculation requires only the inspection of the ground floor and first floor. Parameters like column size, span length, Masonry Infill Ratio shall be obtained only from the ground floor. The reason behind this is that the ground floor is typically the most vulnerable against seismic incidents. However, to understand the frame system, possibility of soft story, and other vertical/horizontal irregularity or any other technical reasons necessary to fill up VR survey form, surveyors may also need to survey other floors.

Two engineers have been considered for building survey. The surveyors should take necessary actions to ensure entry at all essential locations for survey of the building. For this reason, they might ensure the schedule 2 to 3 days before the inspection. If the surveyors cannot take some parameters due to any restriction, they will note other data such as photos for indication of survey parameters, but not complete the survey. Irrational assumptions without confirmation are not encouraged.

The surveyors should be capable of understanding the whole picture of the ground floor as well as the frame system. If there is possibility for serious pounding effect, the surveyors might include it somewhere in the survey sheet.

3.5 Guidelines for Filling up the Survey Data Sheet

In this section, the procedure for filling up the survey datasheet will be discussed step by step.

Step 1: General Information:

a) Surveyors will input survey date, surveyed building's name and its address at the top of survey data sheet as shown in Table 3.1.
b) Surveyors will write their names in the place of Name of the Investigator located at the bottom of the sheet as shown in Table 3.2.
c) If possible, surveyors will collect structural/architectural drawings of the building.

Table 3.1 General information of survey datasheet

Visual Rating (VR) Survey Sheet			
Building ID: XXX		Date: xx/yy/zz	
Building Name: YYYY		Time: 0:00	
Address: ZZZ	Zip: 000- 000000	Latitude: ---------	Longitude: --------
Occupancy Categories: Residential	Construction Year: -------		

Table 3.2 Investigator's Name in survey datasheet

Name of the Investigator:	

IVR score:		Comments:
Buildings category:		

Step 2: Number of Stories

Surveyors will count the story number from outside of the building. They will also write the category of the building i.e. in which purpose the building is currently used like residential/official/educational/institutional etc.

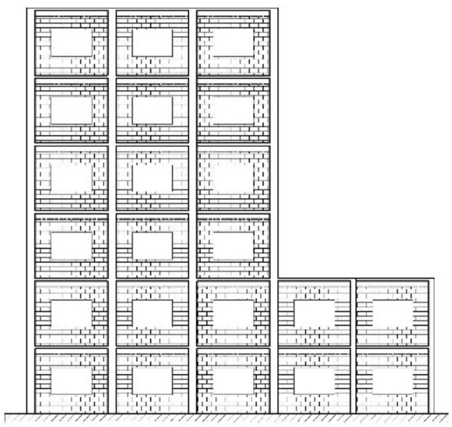


Figure 3.6 Front View of the Building Showing Number of Stories

Here, the illustration in Figure 3.6 shows the front view of the building. There is difference in number of stories in the same building. In this case, the largest number should be used for survey and a note shall be kept for this story difference with a rough sketch.

Table 3.3 Building category, number of story and other information in survey datasheet.

No.	Items	Selection Criteria	Categories of Data	Note
1	Number of Stories (n)	Put Story number	06 (Six)	Part of building is 2 (Two) Storied

Step 3: Drawing Rough Sketch of the Building

Surveyors will draw a rough sketch of the building. In this sketch, surveyors are suggested to draw the location of columns, solid infill masonry walls and concrete wall. Masonry walls with openings are not included in the calculation of VR index. Therefore, surveyors may neglect them. But in this case, they should mention if the ground floor is open or not to avoid any misunderstanding. In the rough sketch, the surveyors may also include column size, span length for later judgment. But the rough sketch shall be as neat as possible to get the useful information for VR method as shown in Figure 3.5.

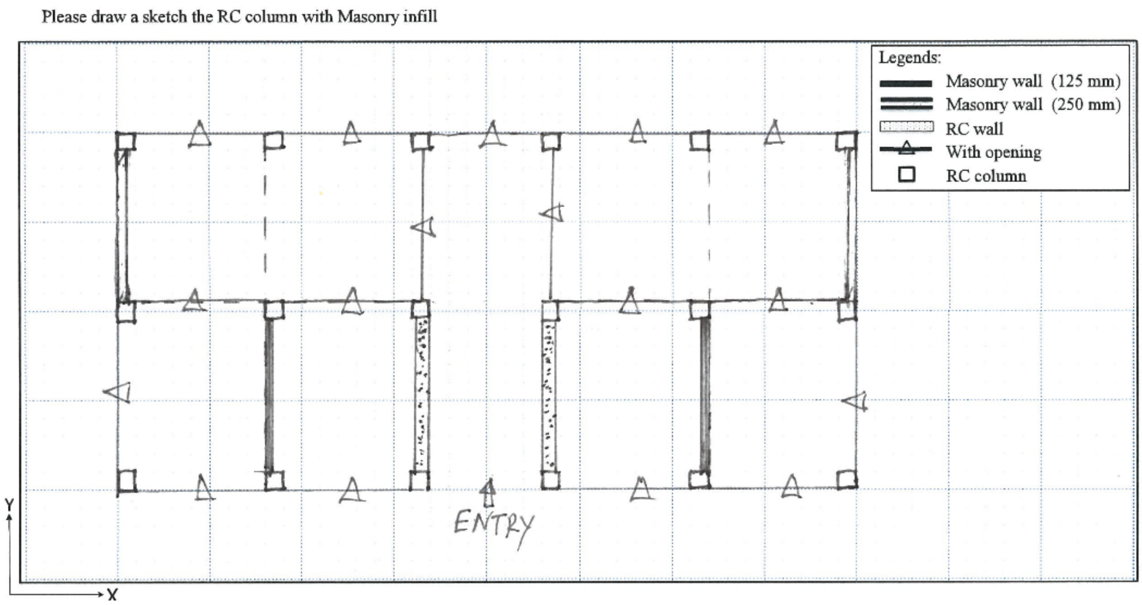


Figure 3.7: Rough sketch of the building showing Column layout and masonry walls with/without opening

Step 4: Average column size

For selecting average column size, surveyors shall follow section 3.3.2. According to the section 3.3.2, surveyor shall follow option one, if corner and exterior column can be measured.

Otherwise, surveyor can measure interior column and follow the second option.

An example has been given below with Figure 3.8. For this building, it is possible to measure dimension of corner (A1), exterior column (A2) and interior column (A3). Therefore, average column size has been found calculated using Equation……. The calculation procedure has been given as follows:

Corner column, C1 =300 mm X 300 mm

Exterior column, C2= 300 mm X 375 mm

Interior column, C3=375 mm X 400 mm,

Hence, the average column size = 350 mm (After excluding mortar thickness)

Surveyor shall fill the dimension in the No.2 item in the survey data sheet accordingly as shown in Table 3.2.

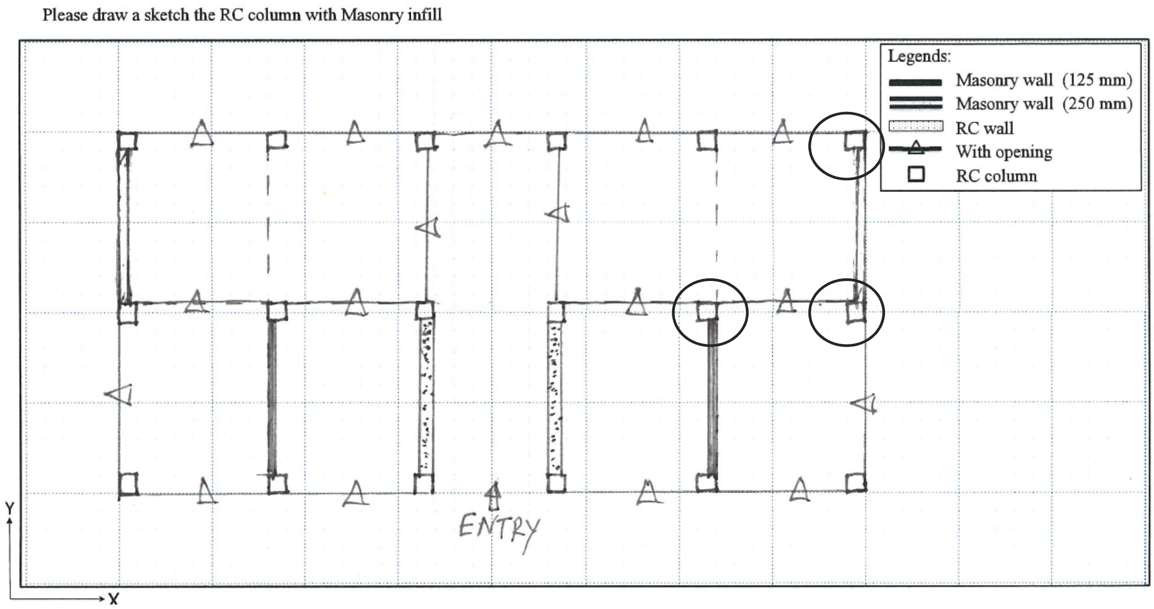


Figure 3.8: Selecting three columns from column layout of the building for Average Column Size

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Table 3.4 Average Column Size (b_c) in survey datasheet

No	Items	Selection Criteria	Categories of Data	Note
2	Average column size, (b_c), (mm)	Please exclude: (i) 50 mm for plaster, (ii) 75 mm for tiles work.	350	

Step 5: Average Span Length

For selecting average span length, surveyors shall follow section 3.3.3. First of all, it is preferable to go first option. If surveyor can measure total buildings length and width, then surveyor can go thorough first option for calculating average span length of the building. Otherwise, surveyor can follow option 2 and option 3.

Figure 3.9 has been shown calculation procedure for the surveyed building. In this buildings, it is possible to measure total building length in both directions. The average span length can be estimated using the Equation……..

The calculation procedure has been given as follows:

Where, L=Length of building=20700 mm

B= Width of building=9800 mm

$n_{span.L}$= *Number of spans in long direction=7*

$n_{span.B}$= *Number of spans in short direction=3*

Average span length, l_s= $\sqrt{\frac{20700\ x\ 9800}{7x\ 3}}$ =3111 mm

Assume, 3000mm for conservative estimation.

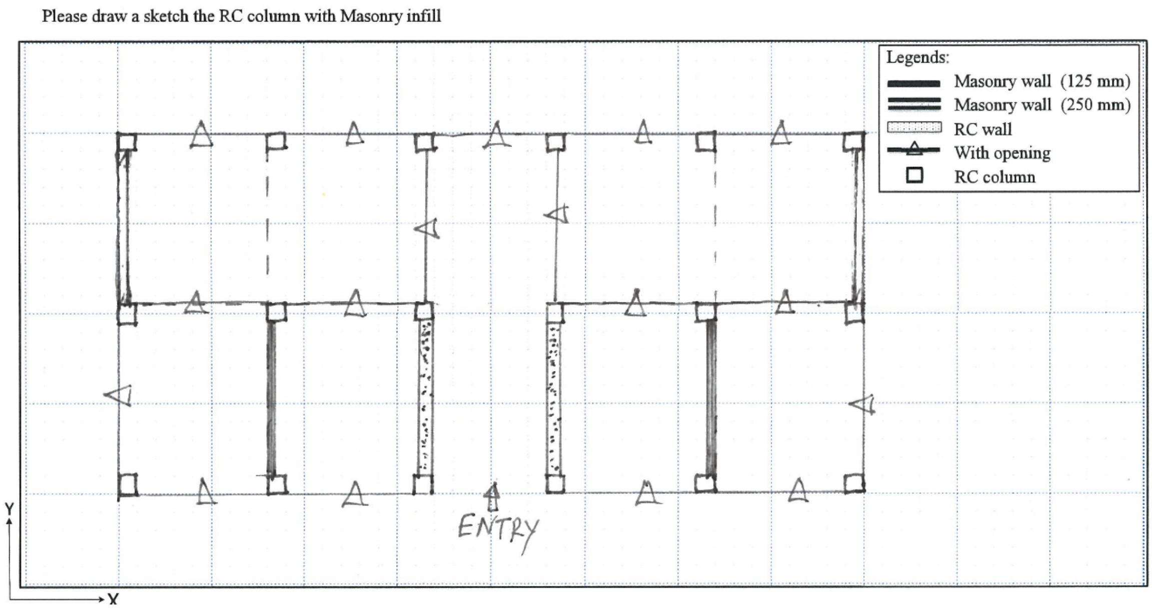


Figure 3.9: Selecting average span from column layout of the building

Table 3.5 Average span length in survey data sheet

No	Items	Selection Criteria	Categories of Data	Note
3	Average span length (l_s), (mm)	The size of equivalent square floor area carried by a single column	3000	

Step 6: Masonry Infill Ratio

For calculating masonry infill ratio, R_{inf}, number of masonry infill wall in the frame in each direction shall be counted and divided by the total number of spans of that respective direction.

It should be noted that infill panels connecting adjacent frames shall only be counted. Walls with opening like doors and windows shall not be included.

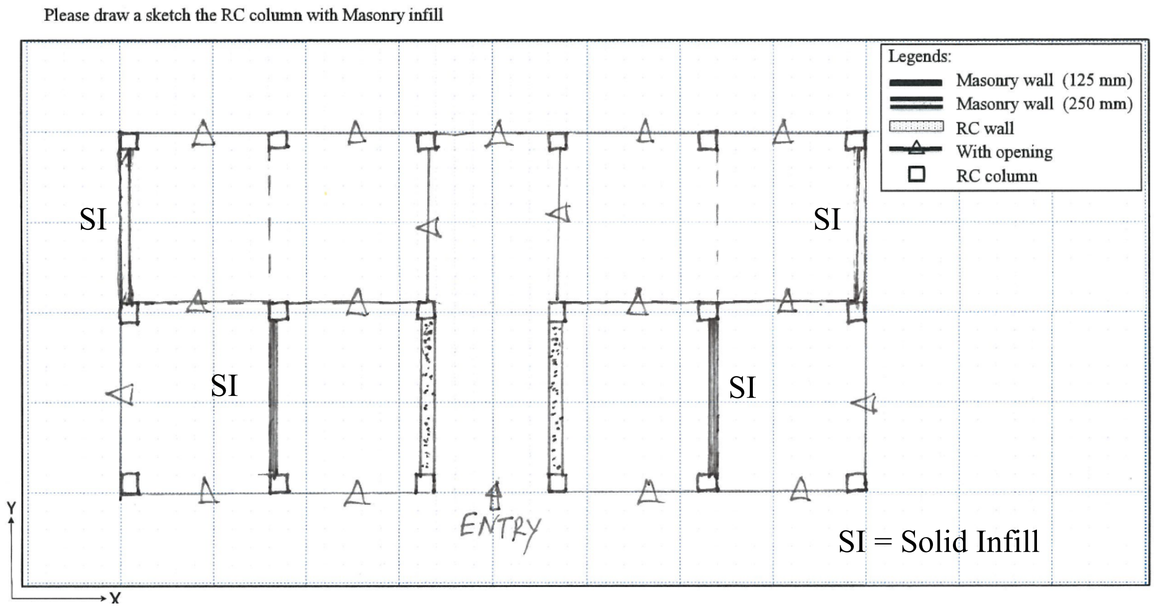


Figure 3.10: Sketch showing number of Infill walls with or without openings

For example, in Figure 3.10, the total number of spans in X direction is 15 (5 spans x 3 frames). But there are no solid infill walls in X direction. So the masonry infill ratio in X direction will be $\frac{0}{15}$. Similarly, the total number of spans in Y direction is 12 (2 spans x 6 frames). The number of 125 mm solid infill is 2 and that of 250 mm solid infill is 2. So, the total number of solid infill masonry walls is 6 (2*2+2 = 6), counting 250 mm solid infill twice. So the masonry infill ratio in y direction will be $\frac{6}{12}$ excluding the wall with opening. The following shows how to complete this part of survey datasheet.

Table 3.6 Masonry Infill Ratio in survey data sheet

No	Items	Selection Criteria	Categories of Data		Note
4	Masonry Infill Ratio, R_{inf}	Masonry Wall Ratio, R_{inf}= $\frac{Number\ of\ infill\ panels\ in\ X\ or\ Y\ dir.}{total\ number\ of\ spans\ in\ X\ or\ Y dir.}$	X-Direction: $\frac{0}{15}$	Y-Direction: $\frac{6}{12}$	

Step 7: Concrete Wall Ratio (R_{CW})

Likewise, the masonry infill ratio, for calculating concrete wall ratio, R_{CW}, the number of concrete walls in the frame in each direction shall be counted and divided by the total number of spans of that respective direction. It should be noted that the concrete wall connecting adjacent frames shall only be counted. Walls with opening like doors and windows shall not be included.

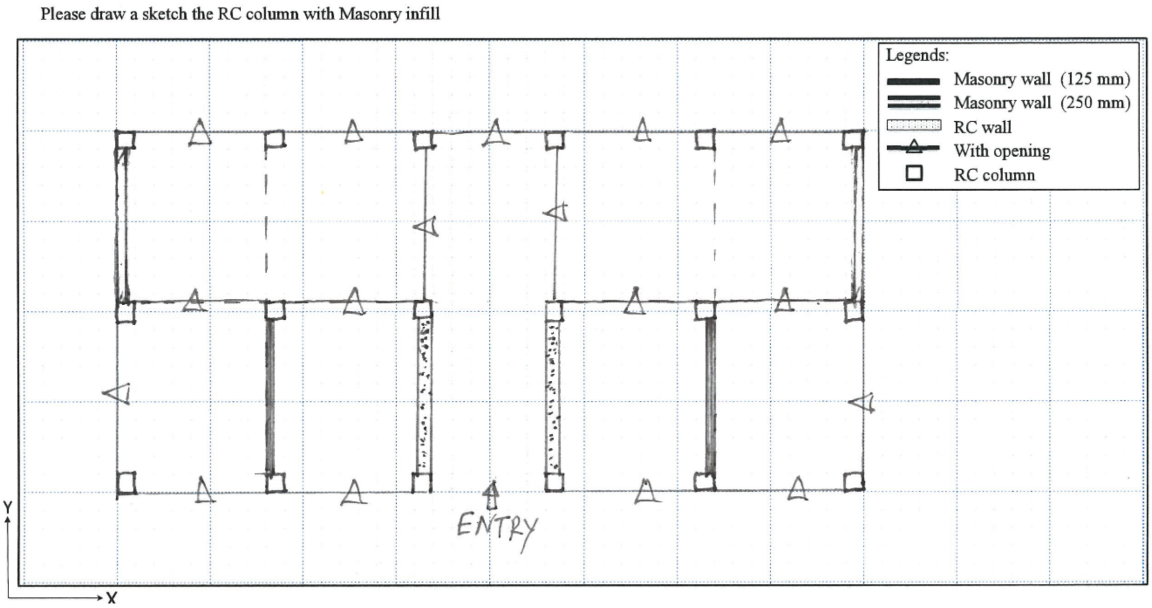


Figure 3.11: Sketch showing number of concrete walls with or without openings

In this Figure 3.9, the number of shear wall in X-direction is 0 (zero) and that of spans is 15. Again the number of shear wall in Y-direction is 2 (Two) and the number of spans is 12.

R_{CW} (X-dir.) = 0/15

R_{CW} (Y-dir.) = 2/12

Following shows how to complete this part of survey datasheet.

Table.3.7 Concrete wall ratio in survey data sheet

No	Items	Selection Criteria	Categories of Data		Note
5	Concrete wall ratio, R_{cw}	Concrete Wall Ratio, R_{CW}= $\frac{Number\ \ of\ Concrete\ walls\ in\ Xor\ Y\ di}{total\ number\ of\ spans\ in\ X\ or\ Y\ dir.}$	X-Direction: $\frac{0}{15}$	Y-Direction: $\frac{2}{12}$	

Step 8: Vertical Irregularity

Surveyors shall follow section 2.6.1.1 in chapter 2 to determine if there is any vertical irregularity in the building. If the surveyors cannot determine the vertical irregularity on their own, they shall draw a rough sketch of the building showing necessary elevations of the building so that a higher supervising authority can judge the building frame system. From the front view of the building in Figure 3.4, the building has a setback and it is one kind of irregularity. In the survey datasheet, reduction factors for vertical irregularity are mentioned for various cases at section 3.4. Surveyor should tick or encircle the case which most fits the building. For the case in Figure 3.4, the data sheet shall be like following:

Table 3.8 Vertical irregularity in survey datasheet

No	Items	Selection Criteria	Categories of Data			Note
6	Vertical irregularity, F_{IV}	Regular = No irregularity Nearly Regular= Small opening at ground floor Irregular= Ground Floor Open/ Parking	Regular (1)	Nearly Regular (0.8)	Irregular (0.6)	Keep Note if there is any confusion (Along with sketch)

Step 9: Horizontal Irregularity

Surveyor shall follow section 2.6.1.2 in chapter 2 to determine if there is any horizontal irregularity in the building. If the surveyors cannot determine horizontal irregularity on their own, they shall draw a rough sketch of the building showing necessary plan and projection of the building so that a higher supervising authority can judge the building frame system. The example building plan shown in Figure.3.5 represents a regular shape of a building. In the survey datasheet reduction factor for horizontal irregularity are mentioned for various cases. For this building, surveyors shall encircle “Regular” for item no.7.

Table 3.9 Horizontal irregularity in survey datasheet

No	Items	Selection Criteria	Categories			Note
7	Horizontal irregularity, F_{IH}	Regular = No irregularity Nearly Regular= Small projection exists with irregular shape Irregular= Large projection exists with irregular shape	Regular (1.0)	Nearly Regular (0.9)	Irregular (0.8)	Keep Note if there is any confusion (Along with sketch)

Step 10: Deterioration and Year of Construction

Judgment of deterioration is sometimes very crucial. It takes extensive knowledge and vast experiences to understand whether the deterioration is considered structural or non-structural.

Surveyors may identify several common types of deterioration as mentioned in section 2.6.2. If it is difficult to take decision about reduction factor for deterioration, surveyors shall take photos of damaged location for better understanding of their supervising authority.

Similarly, for year of construction surveyors shall look up for the drawing and construction time. If the drawing is not available, the surveyors may take information from the owner. If that is also not possible, they shall take as many pictures as possible for understanding the architectural pattern and construction practice and notify their supervising authority. However, a precise year of construction is not a must as the range is given in the datasheet.

In the survey datasheet, item number 8 and item number 9 represent the factors deterioration F_D and Year of Construction F_Y. For a new building with some minor cracks on structural element such as beam or column, the survey datasheet shall be as following:

Table 3.10 Deterioration of concrete, F_d and Year of Construction, F_y

No	Items	Selection Criteria	Categories			Note
8	Deterioration of Concrete, F_D	None= No deterioration Minor= Some crack in structural element or minor spalling Severe=Major spalling of concrete and major Crack	None (1.0)	Minor (0.9)	Severe (0.8)	Keep Note if there is any confusion (Along with photos)
9	Year of Construction, F_Y	New= After 2006 Middle= 1993~2006 Old=Before 1993	New (1.0)	Middle (0.95)	Old (0.9)	Keep Note if there is any confusion (Along with photos)

Final output of the VR sheet shall be as follows:

Visual Rating (VR) Survey Sheet

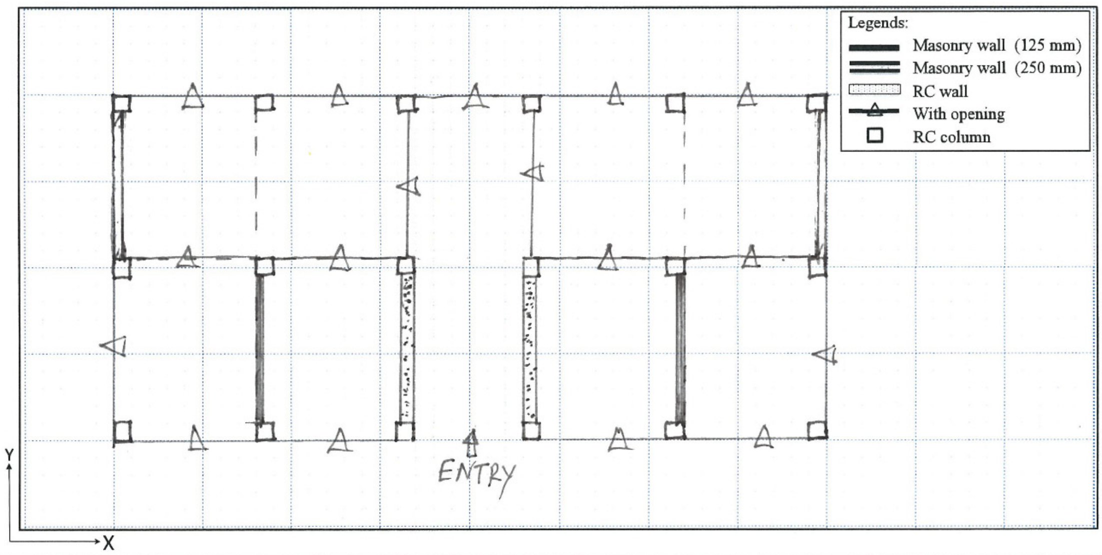
General Information							
Building ID:	XXXXXXX						
Address:	XXXXX			Zip code	XXX-XXX	Date:	XX / YY / ZZ (day/month/year)
Occupancy Categories:	XX XX	Construction Year	XXXX	Latitude: / Longitude:	X° Y' / X° Y'	Time:	XX : XX

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	6 (Six)			
2	Average column size (b_c), (mm)	Please exclude: (i) 50 mm for plaster, (ii) 75 mm for tiles work.	350			
3	Average span length (l_s), (mm)	The size of equivalent square floor area carried by a single column	3000			
4	RC wall ratio	Shear wall ratio, R_{sw}: $= \frac{No\ of\ RC\ shear\ wall\ in\ x\ or\ y\ dir.}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X- direction: $\frac{0}{15}$	Y-direction: $\frac{2}{12}$		
5	Masonry infill ratio	Masonry infill Ratio, R_{inf}: $= \frac{No\ of\ infill\ panel\ in\ x\ or\ y\ dir.}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X-direction: $\frac{0}{15}$	Y-direction: $\frac{6}{12}$		
6	Vertical irregularity (F_{IV})	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_{IH})	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 structrual 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:	XXX	I_{VR} score :		Comments
		Buildings category :		

3.6 Calculation of VR Index

The Visual Rating Index (I_{VR}) is calculated by Equation (5) of Chapter 2.

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

The notation of each items in equation are as follows:

τ_c= The average shear strength of column = 1.0 MPa

τ_{sw} =The average shear strength of shear wall = 1.0 MPa

τ_{inf}=the average shear strength masonry infill = 0.2 MPa

n= Number of story = 6 (Six)

w=Unit weight of buildings = 11 kNm^{-2}

t_{inf}= Thickness of masonry infill = 125mm (Count twice if 250 mm)

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

Visual Rating Parameters:

b_c=Average column size = 350 mm (Average of the encircled Range)

l_s=Average span length = 3000 mm (Calculated average span length)

R_{inf} =Masonry infill ratio, = 0/15, 6/12 (Consider the minimum value, 0/15)

R_{inf} =Concrete wall ratio, = 0/15, 2/12 (Consider the minimum value, 0/15)

The reduction factors are as follows:

F_{IV}=The modification factors for vertical irregularity = 0.8

F_{IH}= The modification factors for horizontal irregularity = 1.0

F_D = The modification factors deterioration of concrete and year of construction = 0.9

F_Y = The modification factors for year of construction = 1.0

I_{VR}=$\frac{1000}{6x11}\left[1x\left(\frac{350^2}{3000^2}\right) + 0.2x\frac{250}{3833.33}x\frac{0}{15} + 1\left(\frac{250}{3833.33}x\frac{0}{15}\right)\right] \times 0.8x1x0.9x1$=***0.15***

CHAPTER 4

Judgment criteria of Visual Rating index for priority setting

4.1 General

In general, judgment criteria are used to understand the seismic performance level of an existing building subjected to an earthquake. The buildings are to be categorized into vulnerable or not vulnerable based on Visual Rating index. The judgment criteria of Visual Rating method are in this chapter is to categorize the vulnerable buildings into less to most vulnerable buildings and these buildings are to be considered for further detailed seismic evaluation. This chapter presents the proposal of judgment criteria and boundary for each category according to Visual Rating index (I_{VR}).

4.2 Judgement criteria of Visual Rating method

In this manual, the buildings are to be classified into 5 categories. Buildings are to be divided into 5 categories such as (A, B, C, D and E) as follows:

Table 4.1 Proposed boundaries for Visual Rating method

Range	Categories	**Priority of detailed evaluation**
$0.25 \leq I_{VR}$	A	Least
$0.20 \leq I_{VR} < 0.25$	B	Less
$0.15 \leq I_{VR} < 0.20$	C	Moderate
$0.10 \leq I_{VR} < 0.15$	D	High
$I_{VR} < 0.10$	E	Highest

Commentary 4-1

4.1 Introduction

Bangladesh is now adopting Japanese seismic evaluation standard (JBDPA standard) in CNCRP standard for detailed seismic evaluation of existing RC buildings. The CNCRP standard proposes judgement criteria of detailed seismic evaluation, seismic demand index (I_{SO}), ranging from 0.28 to 0.36 based on seismic demand and seismicity in Bangladesh National Buildings Code (2015) [BNBC, 2015]. In this manual, the judgement criteria of VR method are set based on seismic demand index (I_{SO}) of detailed seismic evaluation. However, due to lack of past earthquake database in Bangladesh, seismic demand index (I_{SO}) proposed by CNCRP standard [CNCRP, 2015] verified in previous study [Islam, MS, 2019] before using in VR method. Based on the study, buildings are classified into 5 groups namely A, B, C, D and E according to proposed the judgement criteria as shown in Table 4.2. In the criteria, the buildings have lower seismic capacity (i.e. I_{S2} less than 0.40) are considered as vulnerable buildings and E are the most vulnerable buildings. In this manual, judgment criteria of VR method are proposed using the categorization according to seismic index (I_{S2}), and an obtained correlation between seismic index (I_{S2}) and Visual Rating index (I_{VR}) from previous study [Islam, MS, 2019].

Table 4.2 Judgement criteria according to seismic index (I_{S2}) [Islam, MS, 2019]

Seismic index (I_{S2})	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

4.2 Boundaries for judgement criteria

Since the proposed VR method is a preliminary evaluation by visual inspection and the main target is to screen all of vulnerable buildings, it is acceptable if not vulnerable buildings are to be identified as the vulnerable buildings (such as in categories C to E). However, the number of not vulnerable buildings within these categories (such as in categories C to E) should be as few as possible. For this instance, a correlation between cumulative distribution of buildings (in percentage) for each range of seismic index (I_{S2}) and Visual Rating index (I_{VR}) is developed in the previous study [Islam, MS, 2019] as shown in Figure 4.1.

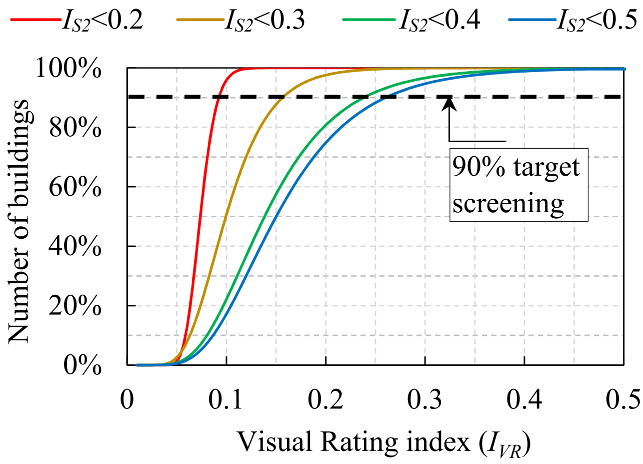


Fig. 4.1 Cumulative percentage of buildings according to Visual Rating index (I_{VR})

According to the Figure 4.1, this manual proposes the boundaries of judgement criteria of VR method considering the target number of buildings (in percentages) in each category are to be screened. Considering the target screening 90% in each category as shown in Figure 4.1, boundaries of I_{VR} are set as mentioned in Table 4.3. It has been observed that there are still some variations in each range ranges of I_{VR} and the difference of range $0.24 \leq I_{VR} < 0.26$ is narrow comparing with other ranges. The reason behind is that the number of buildings investigated within these range are few. It is noted that increasing the number of building might change the range of these boundaries.

Table 4.3 Boundaries according to different target number of buildings

Number of buildings (percentages) identified in each categories	90%
Visual Rating Index (I_{VR}) ranges	$0.26 \leq I_{VR}$ $0.24 \leq I_{VR} < 0.26$ $0.16 \leq I_{VR} < 0.24$ $0.09 \leq I_{VR} < 0.16$ $I_{VR} < 0.09$

Based on above discussion and considering simplification of each range, boundaries of judgement criteria of VR method is proposed as shown in Table 4.4. From the criteria, the buildings with I_{VR} is less than 0.10, located at E category, are the most vulnerable buildings and detailed evaluation is highly recommended.

Table 4.4 Proposed boundaries for Visual Rating method

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

The buildings with Visual Rating Index (I_{VR}) less than 0.25, are classified as C, D and E and those buildings are regarded as the seismically vulnerable and might be collapse during earthquake. Besides, the existing buildings consisting of much lower Visual Rating index (I_{VR}) (such as $I_{VR}<0.10$) are classified into E category, have been categorized as the most vulnerable buildings and those buildings are to be considered as higher priority for detail seismic evaluation comparing with other classes. On the other hand, the buildings with higher I_{VR} (I_{VR} is larger than 0.25) indicating that those buildings might not be severely damaged during earthquake. Detail evaluation is not urgently required for those buildings with higher VR index.

It should be noted that the proposed judgment criteria have been set for Dhaka seismicity. Further, investigation is needed for application to other seismic area. In addition, in order to increase effectiveness and accuracy of the proposed judgment criteria, further buildings survey and investigation of seismic capacity is required.

SUPPLEMENTS

Example building-01

Name of the building: Rehabilitation center for drug addicts

Address: Tejgaon, Dhaka.

I. **Pictorial Preview:**

	
5-Storied building used for hospital purpose	Double height column in front of the building
	
Interior column with no solid wall	Out of frame interior wall with openings

II. Completed VR Survey Datasheet:

Visual Rating (VR) Survey Sheet

Name of Building: Rehabilitatio centre for Drug Addicts Date: 13.07.2019

Address: Tejgaon, Dhaka.

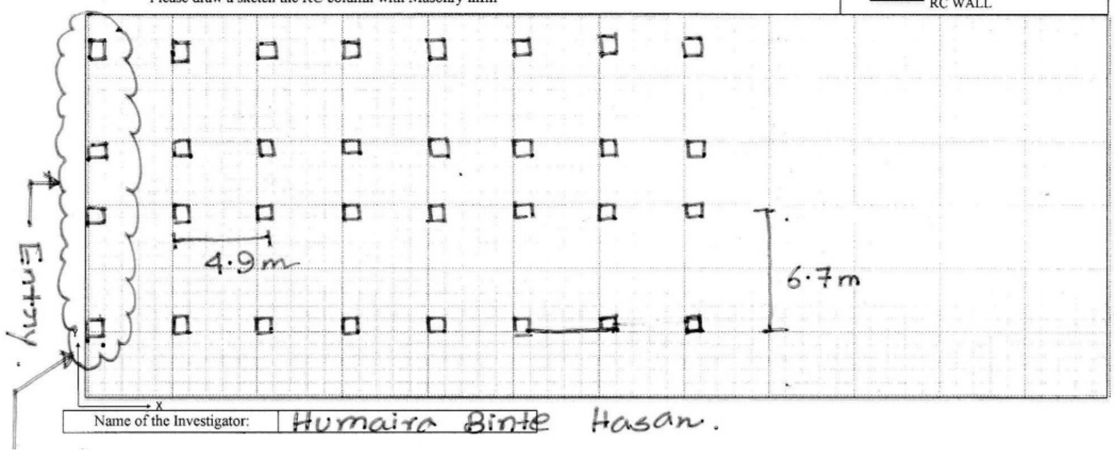
Please read carefully the selection criteria and put circle [○] in the appropriate items

No	Items	Selection Criteria	Categories								Please specify, If the value is found	Note
1	No of story (n)	Put story number	05 (Five) Hospital									
2	Representative column size (b_c), (mm)	Please exclude the mortar/plaster thickness 50 mm	250 mm ~ 350 mm	350 mm ~ 450 mm	450 mm ~ 550 mm	550 mm ~ 650 mm	650 mm ~ 750 mm	750mm ~ 850 mm	850mm ~ 950 mm	950mm ~ larger	500 mm	
3	Average span length (l_s), (m)	The size of equivalent square floor area carried by a single column	2.50 m ~ 3.50 m	3.50 m ~ 4.50 m	4.50 m ~ 5.50 m	5.50 m ~ 6.50 m	6.50 m ~ 7.50 m	7.50 m ~ 8.50 m	8.50 m ~ 9.50 m	6.50 m ~ larger	mm	
4	Masonry infill ratio	Masonry infill Ratio, R_{inf}: $= \frac{\textit{No of infill panel in x or y dir.}}{\textit{Total no of span in x or y dir.}}$	X-direction: $\frac{1}{28}$				Y-direction: $\frac{1}{24}$					
5	Concrete wall ratio	Concrete wall Ratio, R_{cw}: $= \frac{\textit{No of Concrete wall in x or y dir.}}{\textit{Total no of span in x or y dir.}}$	X-direction: $\frac{0}{28}$				Y-direction: $\frac{0}{24}$					
6	Vertical irregularity, F_{IV}	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_{IH}	Regular= No irregularity Nearly Regular= Small projection exists with irregular shape Irregular= large projection with irregular shape	Regular (1)			Nearly regular (0.8)			Irregular (0.6)			
8	Deterioration of concrete, F_D	None= No deterioration Minor= Some crack in structrual element Severe= Spalling of concrete and major Crack	None (1)			Minor (0.9)			Severe (0.8)			
9	Year of construction (F_y)	New= less than 15 years Middle=15~30 years Old= More than 30 years	New (1)			Middle (0.95)			Old (0.9)			

*numeral in parenthesis indicates corresponding weightage

Legends:
M.WALL W/OPENING
M.SOLID INFILL WALL
RC WALL

Please draw a sketch the RC column with Masonry infill



Name of the Investigator: Humaira Binte Hasan.

III. Calculation of Visual Rating index

The Visual Rating index (I_{VR}) is calculated by Equation (5) of Chapter 2.

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

The notation of each items in equation are as follows:

τ_c= The average shear strength of column = 1.0 MPa

τ_{sw} =The average shear strength of shear walls = 1.0 MPa

τ_{inf}=the average shear strength masonry infill = 0.20 MPa

n= Number of story = 5 (Five)

w=Unit weight of buildings = 11 kNm^{-2}

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

t_{cw}= Thickness of concrete wall= No Concrete wall

Visual Rating parameters:

b_c=Average column size = 500 mm

l_s=Average span length = 5000 mm

R_{inf} =Masonry infill ratio, = 1/28, 1/24 (Consider the minimum value, 1/28)

R_{inf} =Concrete wall ratio, =0 (Considering minimum direction)

The reduction factors are as follows:

F_{IV}=The modification factors for vertical irregularity = 1.0

F_{IH}= The modification factors for horizontal irregularity = 1.0

F_D = The modification factors deterioration of concrete = 1.0

F_Y = The modification factors for year of construction = 0.95

$I_{VR} = \frac{1000}{5x11}\left[1\left(\frac{500^2}{5000^2}\right) + 0.2\left(\frac{125}{5000}x\frac{1}{28}\right) + 1x0\right]1x1x1x0.95 = 0.185$

*According to Judgement criteria, the building will be classified into '**C**'*

Example Building-02

Name of the Building: BG Press Staff Quarter (Quarter Number-Q)

Address: Tejgaon, Dhaka.

I. Pictorial Preview:

	
a. 5 Storied Residential Building	**b. In Frame Interior Wall with Openings**
	
c. Exterior Wall with Opening in Front of the Building	**d. One Solid Exterior Wall in the Outside Frame of the Building**

II. Completed VR Survey Datasheet:

Visual Rating (VR) Survey Sheet

Name of Building: BG Press Staff Quarter (Q) Date: 13.07. 2019

Address: Tejgaon, Dhaka.

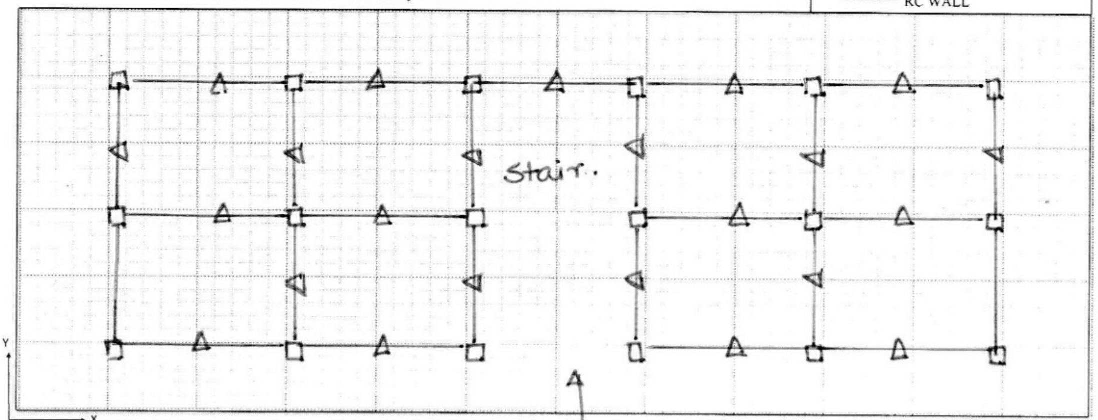
Please read carefully the selection criteria and put circle [○] in the appropriate items

No	Items	Selection Criteria	Categories								Please specify, If the value is found	Note
1	No of story (n)	Put story number	Residential.								05	
2	Representative column size (b_c), (mm)	Please exclude the mortar/plaster thickness 50 mm	250 mm ~ 350 mm	350 mm ~ 450 mm	450 mm ~ 550 mm	550 mm ~ 650 mm	650 mm ~ 750 mm	750mm ~ 850 mm	850mm ~ 950 mm	950mm ~ larger	250 X300 mm	
3	Average span length (l_x), (m)	The size of equivalent square floor area carried by a single column	2.50 m ~ 3.50 m	3.50 m ~ 4.50 m	4.50 m ~ 5.50 m	5.50 m ~ 6.50 m	6.50 m ~ 7.50 m	7.50 m ~ 8.50 m	8.50 m ~ 9.50 m	6.50 m ~ larger	mm	
4	Masonry infill ratio	Masonry infill Ratio, R_{inf}: $= \frac{No\ of\ infill\ panel\ in\ x\ or\ y\ dir.}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X-direction: $\frac{0}{15}$				Y-direction: $\frac{2}{12}$					
5	Concrete wall ratio	Concrete wall Ratio, R_{cw}: $= \frac{No\ of\ Concrete\ wall\ in\ x\ or\ y\ dir}{Total\ no\ of\ span\ in\ x\ or\ y\ dir.}$	X-direction: $\frac{0}{15}$				Y-direction: $\frac{0}{12}$					
6	Vertical irregularity, F_{IV}	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_{IH}	Regular= No irregularity Nearly Regular= Small projection exists with irregular shape Irregular= large projection with irregular shape	Regular (1)			Nearly regular (0.8)			Irregular (0.6)			
8	Deterioration of concrete, F_D	None= No deterioration Minor= Some crack in structrual element Severe= Spalling of concrete and major Crack	None (1)			Minor (0.9)			Severe (0.8)			
9	Year of construction (F_y)	New= less than 15 years Middle=15~30 years Old= More than 30 years	New (1)			Middle (0.95)			Old (0.9)			

*numeral in parenthesis indicates corresponding weightage

Legends:
- M WALL W/OPENING
- M SOLID INFILL WALL
- RC WALL

Please draw a sketch the RC column with Masonry infill



Name of the Investigator: Humaira Binte Hasan

Entry

III. Calculation of VR Index

The Visual Rating Index (I_{VR}) is calculated by Equation (5) of Chapter 2.

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

The notation of each items in equation are as follows:

τ_c= The average shear strength of column = 1.0 MPa

τ_{cw} =The average shear strength of shear walls = 1.0 MPa

τ_{inf}=the average shear strength masonry infill = 0.2 Mpa

n= Number of story = 5 (Five)

w=Unit weight of buildings = 11 kNm^{-2}

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

t_{cw}= Thickness of concrete wall= No concrete wall

Visual Rating Parameters:

b_c=Average column size = 300mm

l_s=Average span length = 3000 mm

R_{inf} =Masonry infill ratio, = 0/15, 2/12 (Consider the minimum value, 0/15)

R_{inf} =Concrete wall ratio, = 0 (due to no concrete wall)

The reduction factors are as follows:

F_{IV}=The modification factors for vertical irregularity = 1.0

F_{IH}= The modification factors for horizontal irregularity = 1.0

F_D = The modification factors deterioration of concrete = 1.0

F_Y = The modification factors for year of construction = 0.95

$I_{VR} = \frac{1000}{5x11}\left[1\left(\frac{300}{3000^2}^2\right) + 0.2\left(\frac{125}{3000}x0\right) + 1x0\right]1x1x1x0.95 = 0.172$

According to Judgement criteria, the building will be classified into 'C'

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