Seismic Vulnerability Assessment of Buildings for Seismic Retrofitting Strategies: Rapid Visual Screening Method

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Abstract

The objective of this study is to provide the assessment of the seismic vulnerability of R.C.C. and Load bearing structures by the Rapid Visual Screening Method. As Rapid Visual Screening is a preliminary stage to conducting a Simplified Vulnerability Assessment of the building. The rapid visual screening procedure requires only a visual evaluation and a few additional details. These procedures are recommended for all buildings. Rapid Visual Screening score has been evaluated for the various building which suggests further assessment for Seismic Vulnerability.

India is expected to be the most populous country in the world by 2025. India has a huge volume of building stocks at present, and most of them are significantly vulnerable to earthquake hazards. In order to overcome this issue, firstly it is required to conduct the seismic vulnerability assessment at a massive scale of building stocks and buildings with a high probability of damage further evaluated with the simplified vulnerability assessment method procedures. After a detailed evaluation, it recommends a suitable retrofitting strategy. In this paper, we have studied various parameters of the Rapid Visual Screening method and the procedure to conduct it.

Keywords: *Seismic vulnerability, Existing Building, Simplified Vulnerability Assessment, Method, Rapid Visual Screening, Detailed vulnerability assessment.*

1. Introduction

The building profile for various structure types created on the basis of the first procedure (rapid visual screening) will be suitable for identifying buildings to which the simplified vulnerability assessment procedure should be applied. The simplified vulnerability assessment procedure will provide a more reliable assessment of the building's seismic vulnerability and will serve as the foundation for determining the need for a more complex vulnerability assessment. Except for critical structures, where detailed vulnerability assessment is always required, the rapid visual screening will be appropriate for all buildings.

An easier and approximate procedure for vulnerability assessment (Level Zero procedure) can also be established; however, this is not recommended due to the non-technical and highly empirical nature of the Level Zero assessment procedure, which will make the gradual transition to higher level procedures untenable. The use of Level Zero procedures in a national earthquake disaster risk management framework for city areas may also send an incorrect message about the problem's complexity, making later migration to technically rigorous procedures difficult.

A method for rapid visual screening (RVS) was first proposed in the United States in 1988, and it was revised in 2002 to incorporate the most recent technological developments and lessons learned from earthquake disasters in the 1990s. This RVS procedure, which was originally developed for typical structures in the United States, has been widely used in many other countries after appropriate modifications. The most important aspect of this procedure is that it allows a trained surveyor to assess vulnerability based on a walk-around of the building. The evaluation procedure and system are GIS-compatible, and the collected building information can be used for a variety of other planning and mitigation purposes.

1) Rapid Visual Screening:

The rapid visual screening method is considered to be implemented without carrying out any structural calculations. The procedure utilizes a scoring system that needs the evaluator to

1. Recognize the key structural lateral load-resisting system
2. Identify building attributes that modify the seismic performance expected for this lateral load-resisting system. The survey, data collection and decision-making process typically occurs at the building site and is projected to take about 40 minutes for each building.

2) Scope of Rapid Visual Screening

1. The screening is performed using a numerical seismic hazard and vulnerability score. The scores are based on the expected ground shaking levels in the region, as well as the city's or region's seismic design and building practices.
2. The scores are consistent with advanced assessment methods and use probability concepts. The RVS procedure can be used with advanced risk analysis and can be integrated with a GIS-based city planning database.
3. The methodology also enables quick and easy reassessment of risk in previously surveyed structures based on the availability of new knowledge that may become available in the future due to scientific or technological advancements. The RVS methodology can be implemented in both rural and urban areas. However, the variation in construction practice is more easily quantifiable for urban areas and the reliability of the RVS results for rural areas may be very low.
4. It is, therefore, preferable to use the RVS methodology with caution for non-standard (or non-government) constructions in rural areas. The RVS methodology is also not intended for non-building structures.
5. The use of detailed evaluation methods is recommended for important structures such as bridges and lifeline facilities. Even in urban areas, some non-engineered buildings are well-known for their low seismic vulnerability and do not require RVS to estimate their vulnerability. These structures are also not covered by the RVS procedure.

3) Uses of Rapid Visual Screening Score:

The results of rapid visual screening can be used for a variety of applications as part of a city's or region's earthquake disaster framework. The following are the primary applications of this procedure:

1. Establish whether a certain building needs to be evaluated further to determine its seismic susceptibility.
2. To examine a city's or community's seismic restoration needs (or an organization's).
3. Develop a plan for managing earthquake risk in a city or neighbourhood.
4. To plan to build safety inspections following an earthquake.

5. To generate seismic vulnerability data for individual buildings for purposes such as regional rating, redevelopment prioritization, and so on.
6. When additional studies are not possible, categorize simplified retrofitting requirements for a given structure (to collapse prevention level).
7. Raise public awareness of buildings' seismic risk among city people.

4) Seismicity in India

As per IS 1893:2002 (Part 1), India has been divided into 4 seismic zones (Figure 1). The details of different seismic zones are given below:

a) Zone II	Low seismic hazard (up to MSK intensity VI)
b) Zone III	Moderate seismic hazard (up to MSK intensity VII)
c) Zone IV	High seismic hazard (up to MSK intensity VIII)
d) Zone V	Very high seismic hazard (up to MSK intensity IX or greater)

Table 1: Seismicity as per Zone (II-V)

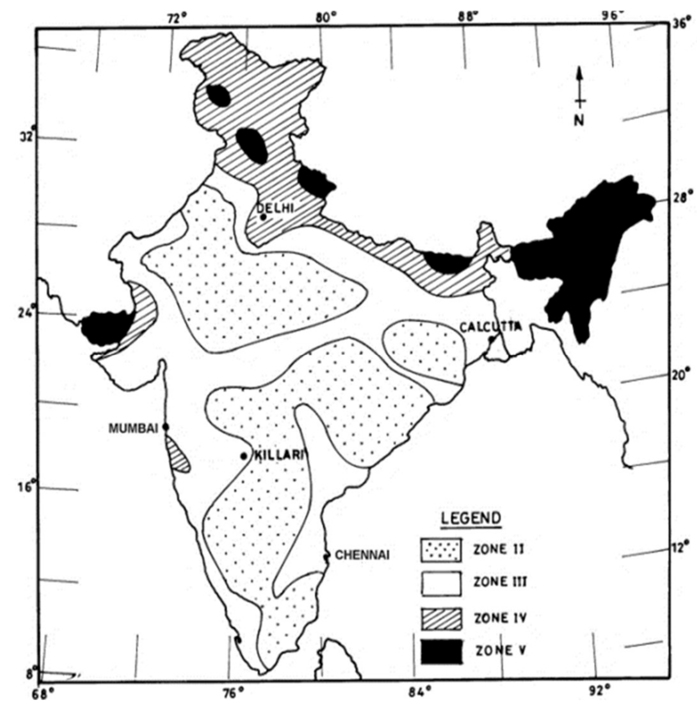

Figure 1: Seismic Zone Map of India

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Table 2, Expected damage level as a function of RVS score.

The RVS score can be used to estimate the likely damage, which is shown below. However, it should be noted that the actual damage will be determined by a number of factors not addressed by the RVS procedure. As a result, this table should only be used to determine the need for a simplified vulnerability assessment of the buildings. These findings can also be used to determine the need for building retrofitting in cases where a more comprehensive vulnerability assessment is not possible.

RVS Score	Damage Potential
S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

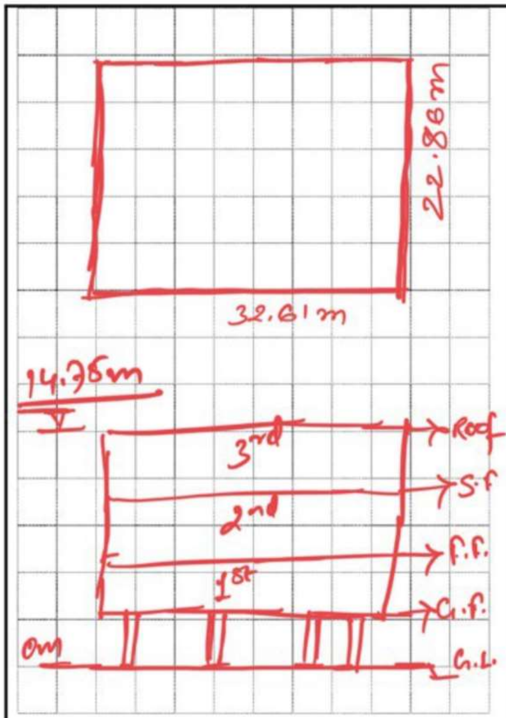
Table 2: RVS Score Class

2. Methodology

Illustration of samples for RVS using Federal Emergency Management Agency (FEMA) FORM [11]:

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zone III)**



Plan and Elevation Scale:

Address: Shri Ram Parisar, NH 43, Manendragarh
Distt. Korriya, (C.G.) Pin 497442
Other Identifiers
GPS Coordinates (if available)
No. Stories (G+3) Year Built 2018
Surveyor Prabhu Agrawal Date 10/05/2022
Total Floor Area (sq. ft./sq. m) 2236.39 m2
Building Name Shri Ram Parisar
Use Residential
Current Visual Condition: Excellent ☐/ Good ☑/ Damaged ☐/ Distressed ☐
Building on Stilts / Open Ground Floor: Yes ☑ / No ☐
Construction Drawings Available: Yes ☑ / No ☐

OCCUPANCY					SOIL TYPE (IS 1893:2002)			FALLING HAZARDS			
Assembly	Govt.	Office	Max. Number of Persons		Type I	Type II	Type III	☐	☑	☐	☐
Commercial	Historic	Residential	0 – 10	11 – 100	Hard Soil	Medium Soil	Soft Soil	Chimneys	Parapets	Cladding	Other:
Emer.Service	Industrial	School	101 – 1000	1000+							

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**4.4**	**3.6**	**3.8**	**3.0**	**3.6**	**3.2**	**3.4**	**3.6**	**3.0**	**2.4**
Mid Rise (4 to 7 stories)	N/A	+0.4	N/A	+0.2	+0.4	+0.2	+0.4	+0.4	-0.4	-0.4
High Rise (>7 stories)	N/A	+0.8	N/A	+0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquifiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, *S* 2.1

Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended

YES **NO**

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

FRAME = Steel Frame
INF = Burnt Brick Masonry Infill Wall
MRF = Moment-Resisting Frame
FD = Flexible Diaphragm
SW = Shear Wall
LM = Light Metal
BAND = Seismic Band
URM4 = Unreinforced masonry (lime mortar)
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
RD = Rigid diaphragm

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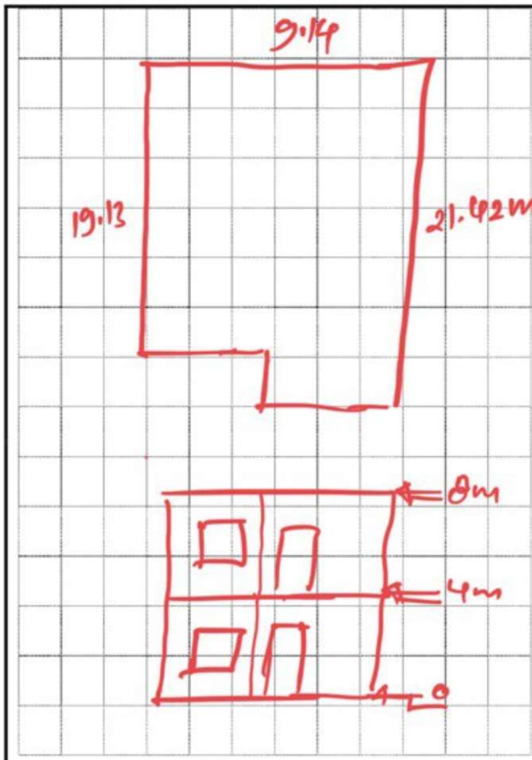
Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zone III)**



Plan and Elevation Scale:

Address: Near LIC, Gram Chainpur Distt. Koriya (C.G.) Pin 497442
Other Identifiers
GPS Coordinates (if available)
No. Stories G+1 Year Built 2020
Surveyor Prabhu Agrawal Date 10/05/2022
Total Floor Area (sq. ft./sq. m) 370.53 m2
Building Name Manoj Majhi
Use Residential
Current Visual Condition: Excellent ☑ / Good ☐ / Damaged ☐ / Distressed ☐
Building on Stilts / Open Ground Floor: Yes ☐ / No ☑
Construction Drawings Available: Yes ☑ / No ☐

OCCUPANCY				SOIL TYPE (IS 1893:2002)			FALLING HAZARDS			
Assembly Commercial Emer.Service	Govt. Historic Industrial	Office Residential School	Max. Number of Persons 0 – 10 11 – 100 101 – 1000 1000+	**Type I** Hard Soil	**Type II** Medium Soil	**Type III** Soft Soil	☐ Chimneys	☐ Parapets	☑ Cladding	☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**4.4**	**3.6**	**3.8**	**3.0**	**3.6**	**3.2**	**3.4**	**3.6**	**3.0**	**2.4**
Mid Rise (4 to 7 stories)	N/A	+0.4	N/A	+0.2	+0.4	+0.2	+0.4	+0.4	-0.4	-0.4
High Rise (>7 stories)	N/A	+0.8	N/A	+0.5	+0.8	+0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
Soil Type II	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
Soil Type III	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
Liquifiable Soil	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE, *S* 1.7

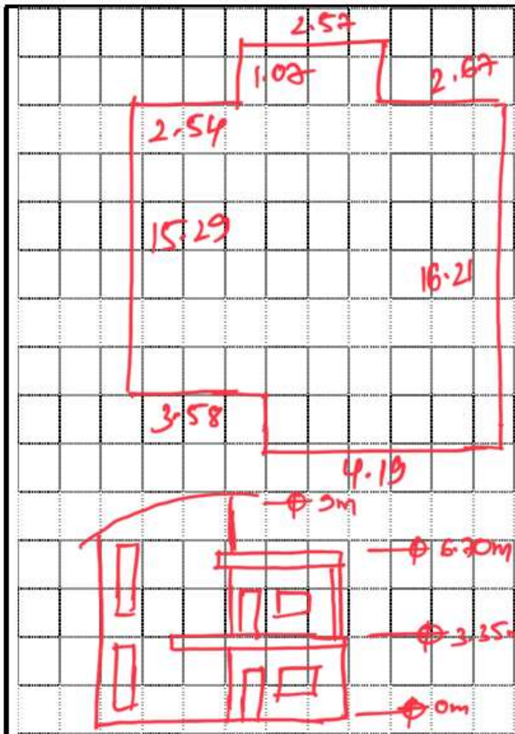
Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage	**Further Evaluation Recommended**
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage	
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage	**YES** ✓ **NO**
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage	
S > 3.0	Probability of Grade 1 damage	

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
FRAME = Steel Frame
INF = Burnt Brick Masonry Infill Wall
MRF = Moment-Resisting Frame
FD = Flexible Diaphragm
SW = Shear Wall
LM = Light Metal
BAND = Seismic Band
URM4 = Unreinforced masonry (lime mortar)
URM3 = Unreinforced burnt brick or stone masonry (cem mortar)
RD = Rigid diaphragm

Rapid Visual Screening of Buildings for Potential Seismic Vulnerability

FEMA-154/ATC-21 Based Data Collection Form **(Seismic Zone II)**



Plan and Elevation Scale:

Address: H.NO. 42, INDU IMAGICA
VIL. CHATONA, BILASPUR Pin 493442

Other Identifiers

GPS Coordinates (if available)

No. Stories 2 Year Built 2020

Surveyor Prabhu Agrawal Date 14/06/2022

Total Floor Area (sq. ft./sq. m) 250.83 m²

Building Name MOHIT CHAWLA

Use RESIDENTIAL

Current Visual Condition: Excellent ☐ / Good ☑ / Damaged ☐ / Distressed ☐

Building on Stilts / Open Ground Floor: Yes ☐ / No ☑

Construction Drawings Available: Yes ☑ / No ☐

OCCUPANCY				SOIL TYPE (IS 1893:2002)			FALLING HAZARDS			
Assembly Commercial Emer.Service	Govt. Historic Industrial	Office Residential School	Max. Number of Persons 0 – 10 11 – 100 101 – 1000 1000+	Type I Hard Soil	Type II Medium Soil	Type III Soft Soil	☐ Chimneys	☐ Parapets	☑ Cladding	☐ Other

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	Wood	S1 (FRAME)	S2 (LM)	C1 (MRF)	C2 (SW)	C3 (INF)	URM1 (BAND+RD)	URM2 (BAND+FD)	URM3	URM4
Basic Score	**6.0**	**4.6**	**4.6**	**4.4**	**4.8**	**4.4**	**4.6**	**4.8**	**4.6**	**3.6**
Mid Rise (4 to 7 stories)	N/A	+0.2	N/A	+0.4	-0.2	-0.4	-0.2	-0.4	-0.6	-0.6
High Rise (>7 stories)	N/A	+1.0	N/A	+1.0	0.0	-0.4	N/A	N/A	N/A	N/A
Vertical Irregularity	-3.0	-2.0	N/A	-1.5	-2.0	-2.0	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Code Detailing	N/A	+0.4	N/A	+0.6	+0.4	N/A	N/A	N/A	N/A	N/A
Soil Type II	-0.4	-0.8	-0.4	-0.6	-0.4	-0.4	-0.2	-0.4	-0.4	-0.4
Soil Type III	-0.8	-1.4	-1.0	-1.4	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Liquifiable Soil	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-1.6	-1.4	-1.4	-1.4

FINAL SCORE, S $4.4 + 0.4 - 1.5 - 1.4 = 1.9 \Rightarrow \boxed{S = 1.9}$

Result Interpretation (*Likely building performance*)

S < 0.3	High probability of Grade 5 damage; Very high probability of Grade 4 damage
0.3 < S < 0.7	High probability of Grade 4 damage; Very high probability of Grade 3 damage
0.7 < S < 2.0	High probability of Grade 3 damage; Very high probability of Grade 2 damage
2.0 < S < 3.0	High probability of Grade 2 damage; Very high probability of Grade 1 damage
S > 3.0	Probability of Grade 1 damage

Further Evaluation Recommended

YES ✓ **NO**

* = Estimated, subjective, or unreliable data
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BAND = Seismic Band
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3. Conclusion

1) Seismic Vulnerability Assessment by RVS, which is the first stage for SVA has been done on 15 buildings and it is found, that 12 out of 15 buildings are to be found Vulnerable to Seismic Hazard.
2) As of 3 buildings that have scored 0.3 are Highly Probable to Grade 3 damage, 5 Buildings that have scored above 2.0 High Probability of Grade 2 Damage and 4 Buildings that have scored above 3.0 High Probability of Grade 1 Damage.
3) It is recommended that the building found to be vulnerable or have scored low, must be further evaluated in the Level 2 and Level 3 assessment procedures i.e., SVA & DVA.

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