M.Tech. (Structural Engineering) [Ankit Gumber] 2018

“Rapid Visual Screening of Buildings”

A DISSERTATION
SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE
OF

MASTER OF TECHNOLOGY
IN
STRUCTURAL ENGINEERING

Submitted by

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CANDIDATE'S DECLARATION

I, Ankit Gumber, Roll No. 2K16/STE/03 Student of M.Tech. (Structural Engineering), hereby declare that the project Dissertation titled " Rapid Visual Screening of Buildings" which is submitted by me/us to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **ANKIT GUMBER**

Date:

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CERTIFICATE

I hereby certify that the Project Dissertation titled " **Rapid Visual Screening of Buildings** " which is submitted by **Ankit Gumber**, Roll No **2K16/STE/03** [Department of Civil Engineering], Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere

Place:Delhi

Date: (SUPERVISOR)

ABSTRACT

The seismic history of India displays a worrisome number of earthquakes and subsequent large scale losses of life and. A few notable examples being the Bhuj Earthquake of 2001, the Indo-Nepal quake of 2015, Kashmir quake of 2005, Great Assam quake of 1897. These events resulted in large scale destruction of life and property and hence call for a risk mitigation and assessment approach. Seismic design however has rapidly evolved over the years but so have the complexities, particularly in design and construction. The structural depreciation is unavoidable in the long run irrespective of the maintenance techniques used. Rapid population increase coupled with a strain on the land for rapid urban development have led to subpar construction quality control being prevalent in the country. Hence the need for a rapid, economical and reliable method of performance evaluation of any structure comes into play and one such viable approach is the Rapid Visual Assessment, called the RVA in short.

By the means of this project, multiple aspects and guidelines for Rapid Visual Assessment (RVA) have been considered. The main guidelines for the process are laid down by FEMA 154 in the USA and no detailed guidelines exist in India. During the course of this project an attempt will be made to model a prototype more suited to the Indian Scenario. A separate sheet that is specified by the Bureau of Indian Standards will be used to screen a number of structures followed by the inferences derived, utility and the suitability of the system thus generated will be discussed in detail.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my project guide *Dr. Alok Verma (Professor, Delhi Technological University)* for giving me the opportunity to work on this topic. It would never be possible for me to complete this project without his precious guidance and his relentless support and encouragement.

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I am also thankful to all the faculty members and my classmates for the support and motivation during this work.

Last but not least, I specially thank all the people who are active in this field. Reference material (pictures, tables and forms) from various national and internal reports and journals are included in this report as per requirement and all these are quoted under the reference section at the last of this report.

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M TECH

STRUCTURAL ENGINEERING

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

There has been a rapid population explosion all over the world over the past decade, especially in the developing nations. This has led to a sudden rise in the level of infrastructure required to support the increased populace, be it commercial, residential or other services like power and transportation. The existing infrastructural facilities face an increased stress level due to this and a rapid rate of construction has been adopted to keep up with the exponentially growing demands.

With the advent of the era of rapid construction techniques quality has become an even more vital and paramount feature of these techniques with more stringent methods being implemented especially for the seismic evaluation and design. However it is seen that there is also an equally large moral grey zone in the industry that consists of improper construction practices, underhanded methods and non-provision of codal requirements. All of these when coupled with substandard material and increased workload on the structure lead to its rapid deterioration, increasing the vulnerability, and as such call for an improved method of evaluation.

Thus, in case of a developing country such as India, we need a rapid, economical and reliable method of risk assessment of a structure from seismic viewpoints and that’s when Rapid Visual Assessment comes in. It is a process developed exclusively along these parameters and has proven its utility in multiple projects all over the world.

However, in case of the Indian subcontinent, this process is still in the stage of infancy and is not widely accepted or used. The major reason behind this would be the differences in the scenario when it comes to India as compared to say USA. A method of overcoming this issue is discussed in this project and that is to alter FEMA 154P scoring system to include factors more pertinent to our Indian scenario. Moreover another drawback of using a manual method can be overcome by creating a program to handle the basic score keeping and calculations, thus reducing the workload on the surveyor. This will not only simplify the process but would also expedite it along with an improved book keeping method.

1.2 OBJECTIVE OF PRESENT STUDY

1. An **in-depth study based approach towards RVA (Rapid Visual Assessment) systems proposed** by various Indian researchers and to incorporate their methodologies into a unified RVA system with modification to existing FEMA scores.

2. **Modifying the factors to be studied for the evaluation of a structure by incorporating factors** more useful to our subcontinent and thus enhancing the scoring system.

3. **Developing a computer aided approach** to the scoring system to expedite and make the project more convenient.

4. Using this methodology to **survey a number of structures** for which data would be gathered and scores generated.

5. Using the said data to **draw useful inferences and to propose future scope** for studies while generating conclusions.

1.3 SCOPE OF PRESENT STUDY

This project will aim at developing a prototype system for Rapid Visual Assessment which can serve as a prerequisite to a more precise model tailor made for the Indian scenario which might prove to be better than the vague methods currently in use.

This would lead to a more economic, quicker and more precise method for seismic evaluation and assessment of structures which would aim to be simpler than the obscure methods prevalent.

With proper development and follow up research along with field studies this could lead to creation of a method which can find its way as an Integrated Assessment Tool which can be further expanded to account for vulnerabilities for a wider spectrum of disasters; not only limited to seismic activities.

The computer based model/program so developed can easily be altered for any changes based on the study or the basic guidelines with an ease of adding or editing current parameters along with a mechanization of the whole process. This could further be used to create a municipal database easily accessed while planning disaster mitigation programmes suited to a particular locality or a niche study.

1.4 BASIC METHODOLOGY

The methodology adopted for this project can be easily subdivided under 5 stages, namely:-

1. Studying a few basic methodologies and procedures normally adopted for the RVA in India.
2. Developing a model more suited for our purpose and refining the weights and factors considered.
3. Developing a program to handle the basic data and generate scores while drawing comparisons with score sheets used under FEMA and IS guidelines.
4. Using the modified method to rate a number of structures via field inspection and studies.
5. Observations, inferences and concluding remarks with a discussion for further scope and developments.

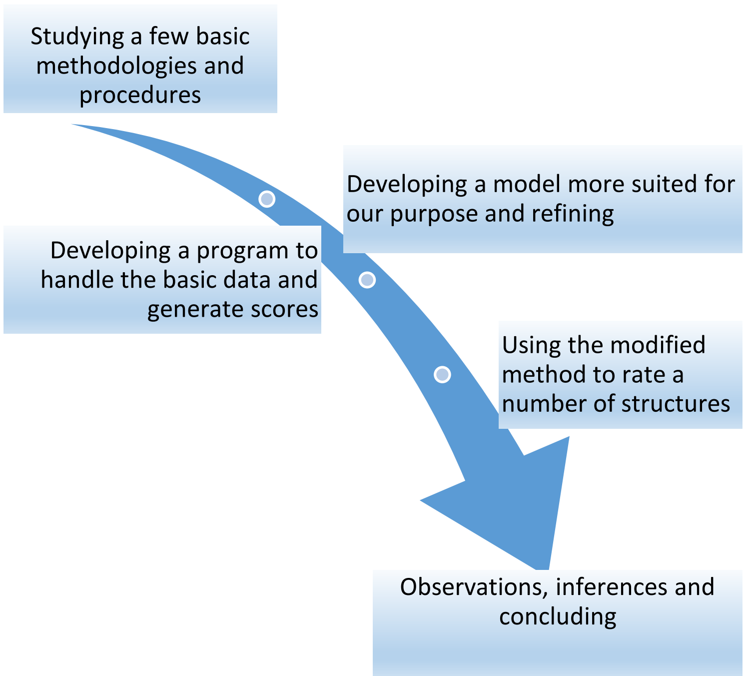


Fig 1.1 Basic RVA Methodology

CHAPTER 2

LITERATURE REVIEW

2.1 BASIC PROCEDURES NECESSITATED

3 levels of risk management techniques need to be used:

1. Level 1- RVS (Rapid Visual Screening) requiring only visual evaluation and limited additional information (Level 1 procedure), a procedure recommended for all buildings.

2. Level 2-SVA (Simplified vulnerability assessment) which requires limited engineering analysis. It is based on information from visual observations and/or structural drawings aided by on-site measurements. It is recommended for buildings housing a large number of people.

3. Level 3- DVA (Detailed vulnerability assessment) which requires detailed computer analysis. It is similar or could be more complex than the design of a new building (procedure). It is required for all important and lifeline structures.

2.2 RVA: BASIC DEFINITION

“Rapid Visual Screening or **Sidewalk Survey** is a procedure of **visual inspection** of a particular building or a group or cluster of buildings of same type so as to identify the presence of basic structural anomalies and environmental damage which that building has faced during the years, recording these observations and thus commenting on the **seismic and overall safety** of the building or group of buildings”

It is to be noted that RVA is only a method for visual assessment and no form of testing procedure can be involved in the process, also it must always be rapid and quick. Thus on the whole it is a process that uses visual inspection techniques and pertinent data for rapid assessment of structures.

2.3 NEED FOR RAPID VISUAL ASSESSMENT

As mentioned previously, RVA methodology comes under the level 1 assessment techniques and is vital in case of high risk zones.

If the building shows a poor score in this preliminary analysis it necessitates the need for further detailed assessments , namely level 2 and level 3 to evaluate the seismic vulnerability.

RVA also provides us a basic tool for the preliminary estimation of the retrofitting techniques and the work involved if the structure is found to have subpar performance characteristics.

For low risk to medium risk structures it gives a reliable and cheap method of analysis without going into detailed work which would potentially increase the cost of investigation. It also helps us identify potential construction or maintenance hazards and apply suitable rectification methods for damage mitigation.

2.4 RESEARCH AND DEVELOPMENT

RVA has been in practice since time immemorial and is not a modern day tool. Since ancient times, those that were involved in the construction of structures were frequently called upon for their advice about the condition or construction of any new building. This, in essence, is the RVA methodology and those technical experts filled in the roles of the screeners.

The modern day variation of this method however is far more sophisticated than those in the old days. It was initially developed by Federal Emergency Management Agency or FEMA in short. It is an agency functioning under the department of homeland security of USA. It came into print in 1988 in the form of FEMA 154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* which was used to instruct both engineers and other trained personnel about the basic procedure and guidelines involved in the process.

Over the next decade there was a rapid rise in the use of RVA procedure among the private as well as government organizations to evaluate structures. The ease of use prompted many countries to develop methodologies of their own.

This was later on followed up by *FEMA 154 2nd edition in 2002*. The basic guidelines and the framework was same as that of the previous edition but there were improved score modifiers based on ground motion criteria as given by FEMA 310 Report, *Handbook for Seismic Evaluation of Building.*

After that **"***Rapid Visual Screening of Buildings for Potential Seismic Hazards" Supporting Documentation* **FEMA 155, Edition 2** was released to further improve the FEMA RVS procedure.It explained how the scores for structure type and modifiers were decided based on Hazus vulnerability analysis.

The latest edition being *FEMA 154 3rd edition published in 2014*, this is also referred to as FEMA P-154. The major enhancements being:

- An optional Level 2 Data Collection Form has been added.
- The number of seismicity regions has been expanded from three to five to increase accuracy of screening in higher seismicity regions. The Third Edition seismicity regions are based on MCER ground motions (rather than the two-thirds of MCE ground motions that were used in the Second Edition).
- Large multi-unit, multi-story wood frame residential and manufactured housing building types have been added.

This is supported by FEMA P-155, which includes the following enhancements:

- Update of the Data Collection Form, and the addition of an optional more detailed page to the form.
- Update of the Basic Scores and Score Modifiers.
- Inclusion of additional building types that are prevalent.
- Inclusion of additional considerations, such as non-structural hazards, existing retrofits, building additions, and adjacency.

Another major development following this was the IRVS, Integrated Rapid Visual Screening process developed under BIPS, Buildings and Infrastructure Protection Series, September 2007 developed by the Department of Homeland Security, USA. This was used to improve the basic RVA method by integrating it with Google Earth with the help of a computer to assess building vulnerability to resist a wider variety of disasters like fires, terrorist attacks, cyclone etc. in addition to the seismic risk.

2.5 FEMA NORMS

2.5.1 OVERVIEW:

The FEMA methodology for Rapid Visual Screening is based on a **structural score method**

In this approach each structure is assigned a *basic score* based on the type of structure. FEMA 154 P classifies 17 basic types of structures and the screener has to identify the structure out of these 17 available types. This provides the screener with the basic score for the structural system.

After this FEMA 154 provides some parameters known as *score modifiers*. These are the additional factors which have an affect on the seismic performance of a structure like stiffness or mass irregularities, soil type, etc. Each factor is provided a score which is used to modify the basic structure score.

The screener records this basic score and the score modifiers by means of visual inspection of the building. This is recorded on the *RVS forms* provided in FEMA 154 P. This is recorded with other details of the structure like photographs, location, occupancy, sketches, structure use etc. The algebraic sum of this basic score and the score modifiers gives the *overall structural score*. If the overall structural score obtained is less than the specified *cut off score,* then the structure is considered unsafe and detailed structural analysis of the building for seismic vulnerability needs to be undertaken. If the score is found higher the structure is considered safe.

The determination of the Cut Off score is the most important part of this methodology. Generally, 2 or 3 is the specified score adopted; it depends on severity, frequency and intensity of earthquakes, but the screener can choose any value according to his experience and on the importance of building. A lower cut off score results in a higher safety criteria and alternatively a higher score results in a greater economy in analysis.

2.5.2 FEMA DOCUMENTS FOR RVA:

1) FEMA P-154:

FEMA P-154 is the basic document that details the procedure for Rapid Visual Assessment of any structure. This is the latest edition that was revised in 2014 which was an improvement over the second edition published in 2002. This is a handbook that outlines the procedure in detail along with the extent of damage any portion of the structure or a structural system is assumed to undergo in the event of any seismic activity. The method is also illustrated in detail by means of a few solved examples.

2) FEMA P-155:

"FEMA P-155 *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation (third edition)* is a companion volume to FEMA 154 report, which documents the technical basis for the RVS procedure described in FEMA 154 *Handbook*, including the method for calculating the Basic Structural Scores and Score Modifiers. The FEMA 155 report (ATC, 2002) also summarizes other information considered during development of this FEMA 154 handbook including the efforts to solicit user feedback and a FEMA 154 Users Workshop held in September 2000."

3) Other FEMA documents related to RVS include-

FEMA 178 *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* [BSSC, 1992])
FEMA 310, *Handbook for Seismic Evaluation of Buildings* (ASCE, 1998)
FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* (ASCE, 2000),
FEMA 273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC, 1997)
FEMA 274 *Commentary on the NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (ATC, 1997b).

2.5.3 RVA PROCEDURE BASIC FLOWCHART: [1]

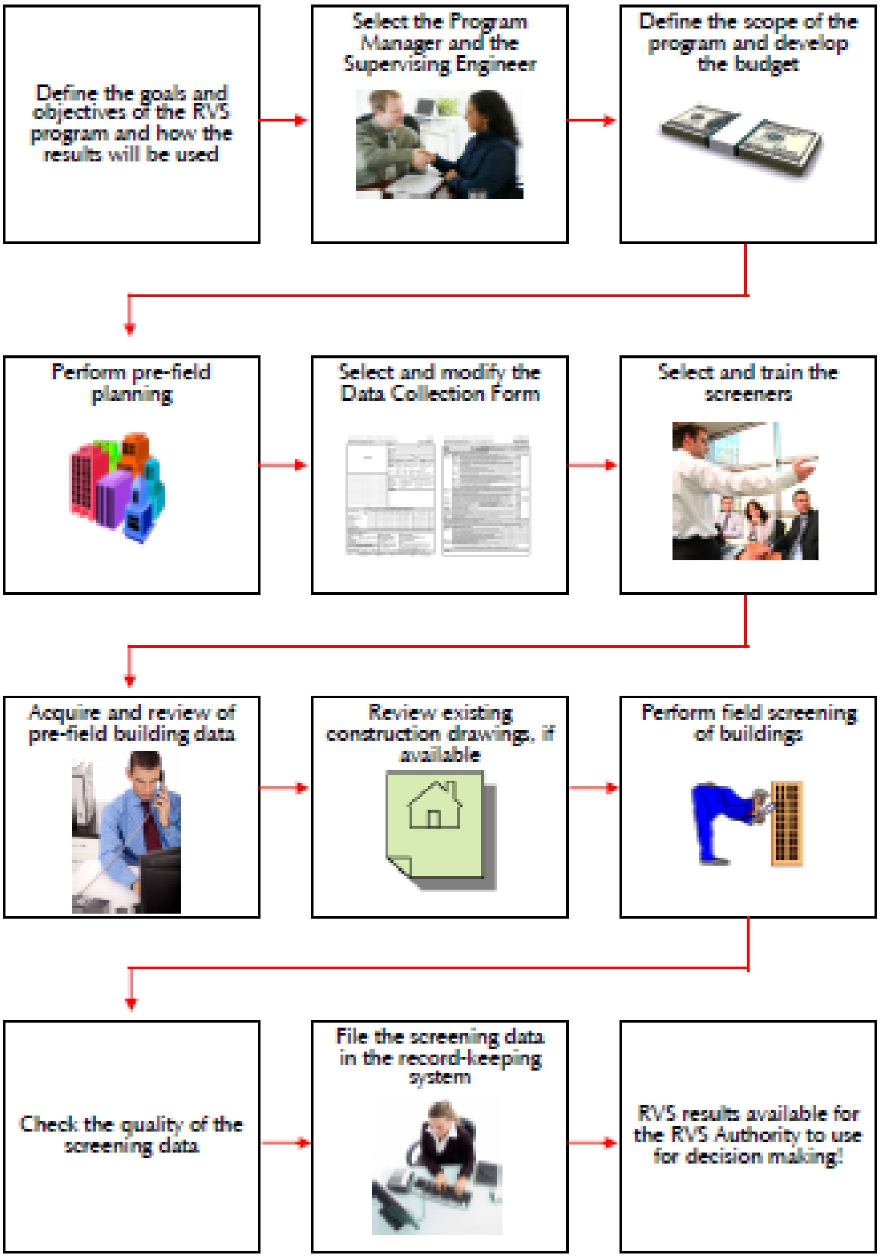


Fig 2.1[1] Steps involved in RVA procedure

The basic process as per this flowchart involves the following steps:

- *Defining the goals and objectives* of the RVS program and how the results will be used
- Selecting the Program Manager and the Supervising Engineer
- *Defining the scope* of the program and develop the budget

- *Performing pre-field planning*, to identify the area to be surveyed, dividing it into a grid pattern and assigning teams to each area, collection of suitable local data about soil types etc.
- Selection and modification of the *Data Collection Form*, to suit the needs of the current survey
- *Selection and training of the screeners*, making them aware of the methods of collecting and reporting data and the proper protocol to be followed.
- Acquisition and review of pre-field building data
- Reviewing existing construction drawings, if available from the local municipal corporation or the builder that performed the construction.
- Performing field screening of buildings.
- *Filing the screening data* in the record-keeping system.
- *Quality check* of the collected data and reviewing it to draw suitable conclusions about the survey quality.

2.5.4 BASIC STRUCTURAL FORMS AND THEIR SCORES [1]

Following are the 17 FEMA Building Types considered in the FEMA P-154 RVS procedure.

1. Light wood frame single- or multiple-family dwellings of one or more stories in height (W1)
2. Light wood frame multi-unit, multi-story residential buildings with plan areas on each floor of greater than 3,000 square feet (W1A)
3. Wood frame commercial and industrial buildings with a floor area larger than 5,000 square feet (W2)
4. Steel moment-resisting frame buildings (S1)
5. Braced steel frame buildings (S2)
6. Light metal buildings (S3)
7. Steel frame buildings with cast-in-place concrete shear walls (S4)
8. Steel frame buildings with unreinforced masonry infill walls (S5)
9. Concrete moment-resisting frame buildings (C1)
10. Concrete shear-wall buildings (C2)
11. Concrete frame buildings with unreinforced masonry infill walls (C3)
12. Tilt-up buildings (PC1)
13. Precast concrete frame buildings (PC2)
14. Reinforced masonry buildings with flexible floor and roof diaphragms (RM1)
15. Reinforced masonry buildings with rigid floor and roof diaphragms (RM2)
16. Unreinforced masonry bearing-wall buildings (URM)
17. Manufactured housing (MH)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 square feet		H = 2.8 M = 5.2 L = 7.4	• Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W2 Light wood frame buildings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	• These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories.

Fig 2.2 [1] FEMA structural types, scores and characteristics

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S1 Steel moment-resisting frame		H = 2.8 M = 3.6 L = 4.6	• Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment- frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns.
S2 Braced steel frame	  Zoom-in of upper photo	H = 3.0 M = 3.6 L = 4.8	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S5 Steel frames with unreinforced masonry infill walls		H = 2.0 M = 3.6 L = 5.0	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
C1 Concrete moment-resisting frames		H = 2.5 M = 3.0 L = 4.4	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	H = 2.6 M = 3.2 L = 4.4	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
C2 Concrete shear wall buildings		H = 2.8 M = 3.6 L = 4.8	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.
C3 Concrete frames with unreinforced masonry infill walls		H =1.6 M = 3.2 L = 4.4	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high-seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC2 Precast concrete frame buildings	 Building under construction  Detail of the precast components  Building nearing completion	H = 2.4 M = 3.2 L = 4.6	• Precast concrete frames are, in essence, post and beam construction in concrete. • Structures often employ concrete or reinforced masonry (brick or block) shear walls. • The performance varies widely and is sometimes poor. • They experience the same types of damage as shear wall buildings (C2). • Poorly designed connections between prefabricated elements can fail. • Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns. • Corrosion of metal connectors between prefabricated elements can occur.

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM1 Reinforced masonry buildings with flexible dia-phragms	  Truss-joists support plywood and light-weight concrete slab  Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or con-crete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately rein-forced and grouted, with suffi-cient diaphragm anchorage. • Poor construction practice can result in ungrouted and unre-inforced walls, which will fail easily.

Fig 2.2 [1] Continued

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM2 Reinforced masonry buildings with rigid dia-phrams		H = 2.8 M = 3.4 L = 4.6	• Walls are either brick or con-crete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately rein-forced and grouted, with suffi-cient diaphragm anchorage. • Poor construction practice can result in ungrouted and unre-inforced walls, which will fail easily.
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architec-tural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usu-ally shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.

Fig 2.2 [1] Continued

2.5.5 DATA COLLECTION FORMS [1]

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

LOW Seismicity

Address: ____

______________________________ **Zip** ______________

Other Identifiers ______________________________________

No. Stories ____________________________ **Year Built** ________

Screener ___________________________ **Date** ________________

Total Floor Area (sq. ft.) ____________________________________

Building Name ____

Use ____

Scale:

PHOTOGRAPH

OCCUPANCY			**SOIL**						**TYPE**	**FALLING HAZARDS**
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ______

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	**W1**	**W2**	**S1 (MRF)**	**S2 (BR)**	**S3 (LM)**	**S4 (RC SW)**	**S5 (URM INF)**	**C1 (MRF)**	**C2 (SW)**	**C3 (URM INF)**	**PC1 (TU)**	**PC2**	**RM1 (FD)**	**RM2 (RD)**	**URM**
Basic Score	**7.4**	**6.0**	**4.6**	**4.8**	**4.6**	**4.8**	**5.0**	**4.4**	**4.8**	**4.4**	**4.4**	**4.6**	**4.8**	**4.6**	**4.6**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-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	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

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

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

MODERATE Seismicity

Address: ______________________________
______________________ **Zip** __________
Other Identifiers ______________________
No. Stories __________________ **Year Built** ______
Screener __________________ **Date** __________
Total Floor Area (sq. ft.) ______________
Building Name ______________________
Use ______________________

Scale:

PHOTOGRAPH

OCCUPANCY			SOIL	TYPE						FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons	A	B	C	D	E	F	☐	☐	☐	☐
Commercial	Historic	Residential	0 – 10 11 – 100	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	Unreinforced Chimneys	Parapets	Cladding	Other: ____
Emer. Services	Industrial	School	101-1000 1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**5.2**	**4.8**	**3.6**	**3.6**	**3.8**	**3.6**	**3.6**	**3.0**	**3.6**	**3.2**	**3.2**	**3.2**	**3.6**	**3.4**	**3.4**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.4	+0.4	N/A	+0.4	+0.4	+0.2	+0.4	+0.2	N/A	+0.4	+0.4	+0.4	-0.4
High Rise (>7 stories)	N/A	N/A	+1.4	+1.4	N/A	+1.4	+0.8	+0.5	+0.8	+0.4	N/A	+0.6	N/A	+0.6	N/A
Vertical Irregularity	-3.5	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	N/A	-1.5	-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	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-0.2	-0.4	-0.4	-0.4	-0.4	-0.2	-1.0	-0.4	-1.0	-0.2	-0.4	-0.4	-0.4	-0.4
Post-Benchmark	+1.6	+1.6	+1.4	+1.4	N/A	+1.2	N/A	+1.2	+1.6	N/A	+1.8	N/A	2.0	+1.8	N/A
Soil Type C	-0.2	-0.8	-0.6	-0.8	-0.6	-0.8	-0.8	-0.6	-0.8	-0.6	-0.6	-0.6	-0.8	-0.6	-0.4
Soil Type D	-0.6	-1.2	-1.0	-1.2	-1.0	-1.2	-1.2	-1.0	-1.2	-1.0	-1.0	-1.2	-1.2	-1.2	-0.8
Soil Type E	-1.2	-1.8	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

FINAL SCORE *S*

COMMENTS

Detailed Evaluation Required

YES NO

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

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

HIGH Seismicity

Address: ____________________

____________________ **Zip** __________

Other Identifiers ____________________

No. Stories ____________________ **Year Built** ________

Screener ____________________ **Date** __________

Total Floor Area (sq. ft.) ____________________

Building Name ____________________

Use ____________________

PHOTOGRAPH

Scale:

OCCUPANCY			SOIL	TYPE						FALLING HAZARDS			
Assembly	Govt	Office	Number of Persons	A	B	C	D	E	F	☐	☐	☐	☐
Commercial	Historic	Residential	0 – 10 11 – 100	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil	Unreinforced Chimneys	Parapets	Cladding	Other: ______
Emer. Services	Industrial	School	101-1000 1000+										

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

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

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

2.5.6 ADDITIONAL FORM DETAILS AND THE SCORE MODIFIERS

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		**Year Seismic Codes Initially Adopted and Enforced***	**Benchmark Year when Codes Improved**
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	_______	_______
W2	Wood frame buildings, > 5000 square feet.	_______	_______
S1	Steel moment-resisting frame	_______	_______
S2	Steel braced frame	_______	_______
S3	Light metal frame	_______	_______
S4	Steel frame with cast-in-place concrete shear walls	_______	_______
S5	Steel frame with unreinforced masonry infill	_______	_______
C1	Concrete moment-resisting frame	_______	_______
C2	Concrete shear wall	_______	_______
C3	Concrete frame with unreinforced masonry infill	_______	_______
PC1	Tilt-up construction	_______	_______
PC2	Precast concrete frame	_______	_______
RM1	Reinforced masonry with flexible floor and roof diaphragms	_______	_______
RM2	Reinforced masonry with rigid diaphragms	_______	_______
URM	Unreinforced masonry bearing-wall buildings	_______	_______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: _______

3. Occupancy Loads

Use	**Square Feet, Per Person**	**Use**	**Square Feet, Per Person**
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

2.5.7 DETERMINING THE STRUCTURAL SCORE AND ADDITIONAL SCORE MODIFIERS

The scoring system in FEMA P-154 follows a probabilistic estimation approach. It is defined as the negative logarithm to the base 10 of the probability of collapse occurring from suspected or designed ground motions, this is taken as maximum considered earthquake or MCE_R. The MCE values considered in edition 2 were modified with a more precise approach by the USGS and the value taken was 2/3 of the MCE characterized in that area. The basic relation as given by FEMA P-155 is

Si = –log10(P[Collapse|MCE_R ground motions])

where Si= Structural Score, MCE = Maximum Considered Earthquake

Earlier in the first edition of FEMA 154 (1984) P was defined as probability of 60% or greater damage which was improved in second edition in 2002 where P was considered as the Probability of Collapse, collapse is more clearly defined in the third edition as; building collapse means that any part of the gravity system experiences dynamic instability leading to the loss of load bearing capacity. The dynamic instability leads to severe structural deformation of a potentially life-threatening nature, especially falling of all or portions of a structure. Partial building collapse means that the dynamic instability occurs only in a portion of the building. The probability of at least partial building collapse refers to the expected value of the chance that partial collapse or collapse will occur, given some specified conditions. The conditions used here are knowledge of building features observed during the screening and occurrence of MCE_R shaking.

Si is a basic score for a class or type of building. Score Modifiers (SMs) need to be added to it that are specific to that system, to get the final Structural Score, S.

i.e**.** ***S*** **= Si +/- SMs**

The final score so obtained is an indicator of the collapse probability of the structure i.e. say for a factor obtained as 2 or 3 the probability of collapse would be taken as as of the order of 0.01 or 0.001 respectively, that is 1 in 100 or 1 in 1000.

The **1st edition FEMA 154(1984)** contained **BSH Scores based on the expert-opinion Damage Probability Matrices (DPMs)** provided in the ATC- 13 report, Earthquake Damage Evaluation Data for California (ATC, 1985). However with the coming of **2nd edition FEMA 154 (2002)** the **basic structural scores** for each structure type and **score modifiers** were decided **based on Hazus Fragility curves and capacity curves** specified in the 1999 SR2 edition of the *HAZUS Technical Manual* (NIBS, 1999). For the ***Third Edition***, the probability of collapse is calculated using a modified version of the **OSHPD HAZUS** methodology (which is itself a modified version of the HAZUS methodology that was used to develop the *Second Edition* scores).

“The **building capacity curve (also known as the push-over curve)** is a plot of a building’s lateral-load resistance as a function of some characteristic lateral displacement. This is derived usually from static push-over analysis that defines the relationship between static equivalent base shear versus a building’s roof displacement. **Standard building fragility curves** in HAZUS99 are used to estimate the probability of being in, or exceeding various damages states of buildings - slight, moderate, extensive, and complete - for a given demand parameter, that is, spectral displacement response.”

The details of how these curves are used to determine BSHs and SMs are specified in HAZUS Technical Manual (NIBS, 1999) and FEMA 155.

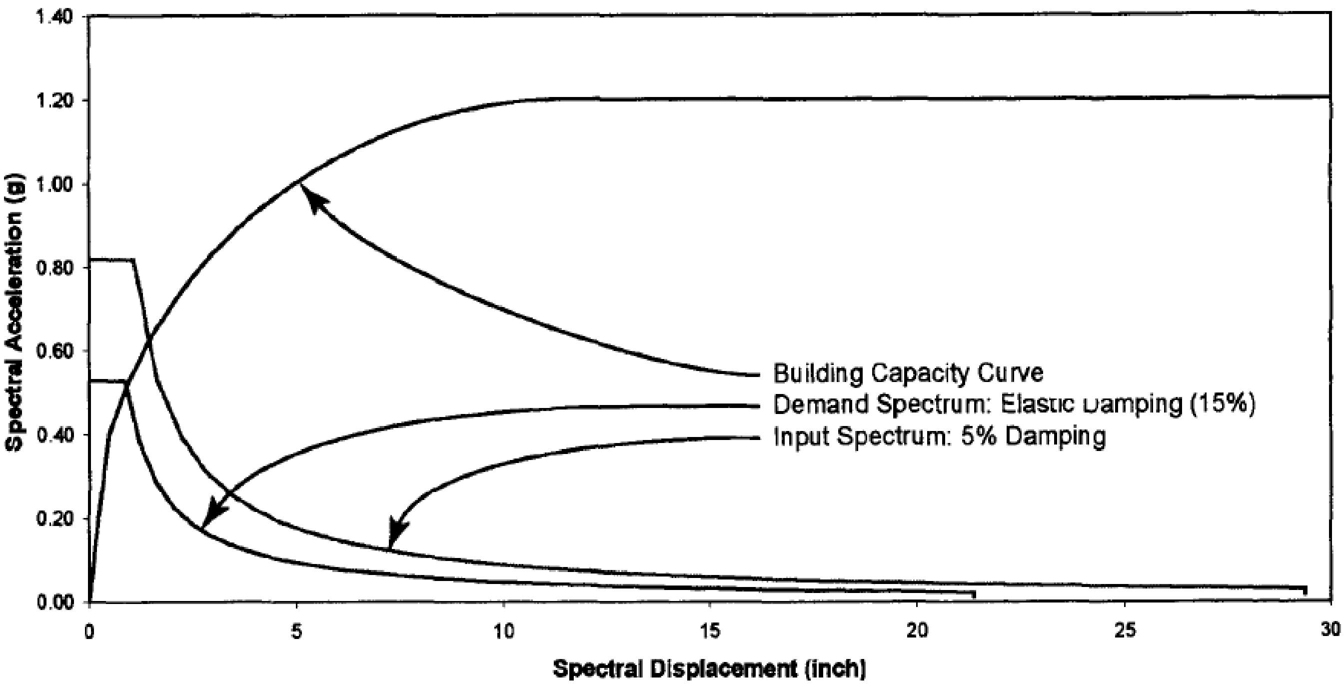


Fig 2.3 Input demand spectrum, demand spectrum with 15% elastic damping, and a typical capacity curve (from NIBS, 1999).

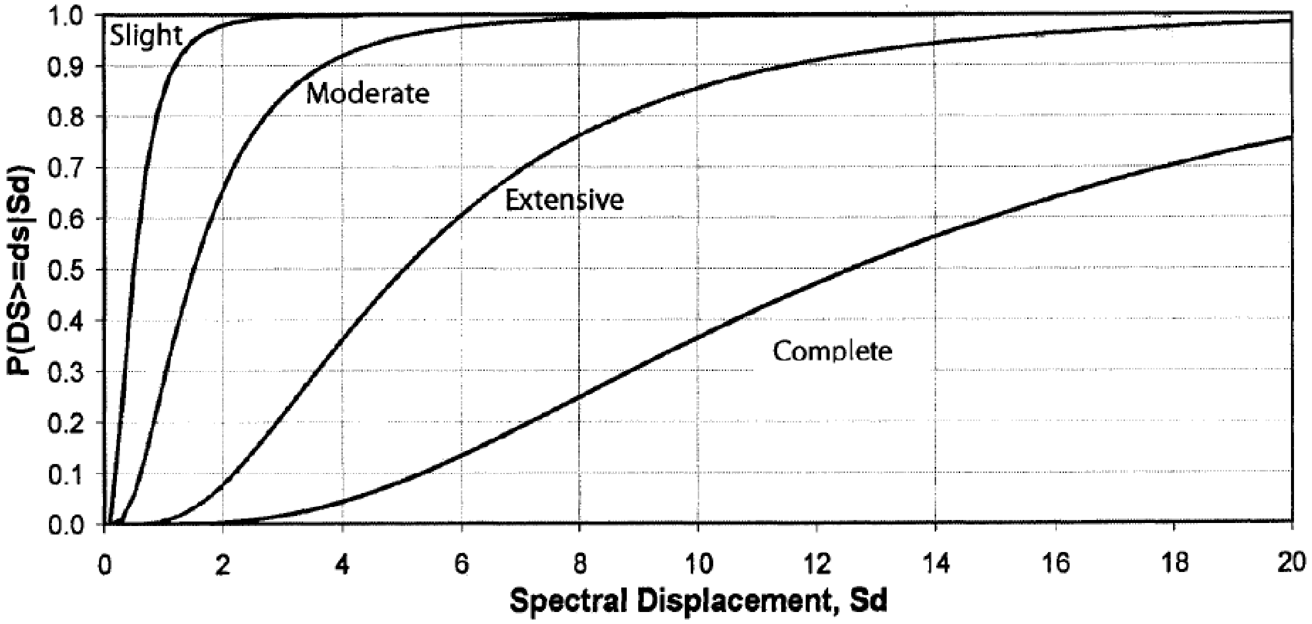


Fig 2.4 Typical HAZUS99 fragility curves (in this case for high-code W1 wood frame-buildings) showing the probability of a damage state being exceeded for a given level of ground shaking (NIBS, 1999).

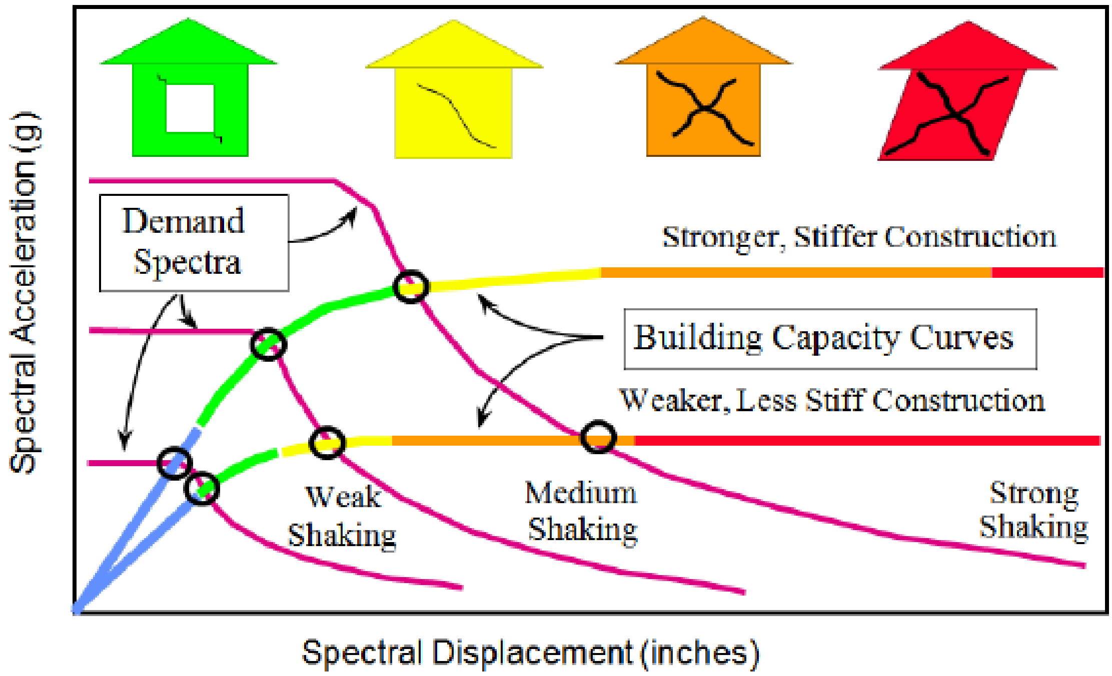


Fig. 2.5 [2] Construction types according to FEMA

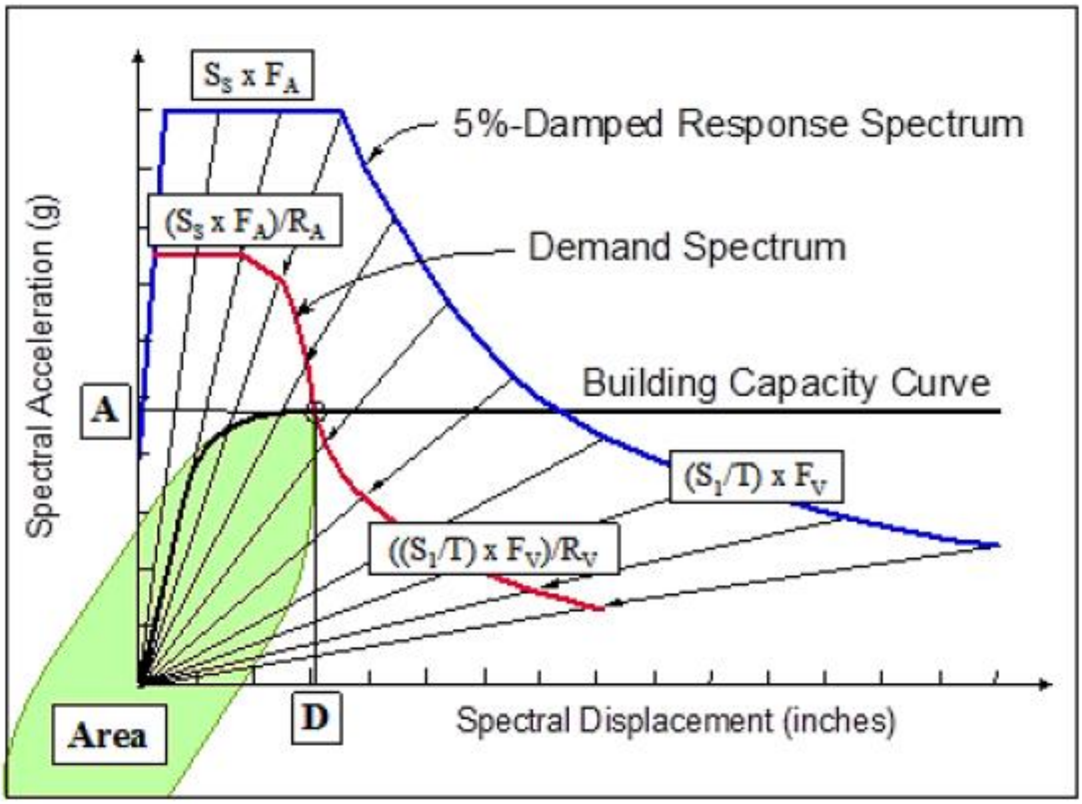


Fig. 2.6 [2] Example calculation of demand spectrum by reduction of 5% damped response spectrum of ground motions

2.5.8 DETERMINING THE CUT OFF SCORE:

"The Rapid Visual Screening (RVS) **Cut off Score** is **decided on the basis of "Costs of Safety" versus "Benefits" analysis.**

The **cost of safety** includes:

• The cost incurred during review and investigation, in detail, of hundreds of buildings to identify some of those that might actually sustain severe structural damage during an earthquake; and

• The cost incurred during rehabilitation of the buildings that are finally determined as being unacceptably weak.

The most significant **benefit** is the life-saving aspect and injury prevention due to reduction in damage for the buildings that will be rehabilitated. This damage reduction not only includes less material damage, but reduces the major disruptions in day to day lives of people and local businesses.

Every community or authority, therefore, has freedom in choosing its own cut-off scores on the basis of the relative importance of cost of safety versus benefits.

National Bureau of Standards (NBC) of U.S. (1980) and SAC (2000) suggest a value of **Cut-off Score *S* as 3 being appropriate for normal day-to-day loads, and about 2, or somewhat less as appropriate for earthquake loadings**.

Unless a community considers by itself the cost / benefit aspect of seismic safety, an estimated *S* value of around 2.0 can be reasonably assumed as a preliminary value for use with RVS to differentiate and determine adequate buildings from potentially inadequate ones. Using a higher cut-off *score* value results in a greater benchmark for safety but consequently increases costs for evaluations and, if needed, rehabilitation; using a lower value of *cut-off score* results in increased seismic risk, lower short-term costs for evaluating and, if needed, rehabilitating of the structures.

Further guidance for cost and societal implications of rehabilitation of vulnerable buildings is available in other FEMA published report series on existing buildings; FEMA-156 and FEMA-157, *Typical Costs for Seismic Rehabilitation of Buildings*, 2nd Edition, Volumes 1 and 2, FEMA-255 and FEMA-256, *Seismic Rehabilitation of Federal Buildings – A Benefit/Cost Model*, Volumes 1 and 2 (VSP, 1994).

2.6 RAPID VISUAL ASSESSMENT (RVA) FOR INDIAN CONDITIONS

2.6.1 OVERVIEW:

The *FEMA methodology* prescribed in FEMA P-154 *isn't exactly ideal for Indian conditions in the raw form*. The reason being the highly diverse Indian scenario where construction practices range from modular steel and Reinforced Cement Concrete structures in urban areas to basic thatch, brick masonry or earthen houses in villages. As such only some but not all structure types as per FEMA P-154 can be found among Indian structures. Moreover, the variation in size, occupancy, and construction practices for these structures has its own influence. The variation in seismicity in India cannot either be overlooked. This necessitates a somewhat different method for RVA in Indian.

With regard to this the contributions and suggestions by *Prof. Ravi Sinha and Prof. Alok Goyal* (IIT Bombay) and *Dr. Anand S. Arya* (Professor Emeritus, Dept. of Eq. Engineering, IIT Roorkee, Chairman, BIS Committee CED 39) are invaluable as they contributed to developing of the basic philosophies of RVS for evaluating Indian Structures (steel frame, RCC, and Masonry) based on the research conducted with reference to seismic code IS 1893:2002. Prof. Sinha and Prof. Goyal using the score system given by FEMA 154 made the use of structural score method to classify various damageability grades as per EMS-98 (European Macro seismic Scale).Later on, the same EMS-98 recommendations were used by Dr. Arya for classification of Indian structures and damageability that any particular structure could undergo. Data collection forms using this, were prepared and suitable procedures proposed. Later on, the same methodology was further incorporated in *IS 13935:2009 "Indian Standard Seismic Evaluation, Repair and Strengthening of Masonry Buildings- Guidelines (First Revision)"*

Rapid Visual Screening (RVS) as specified by IS 13935:2099 is a **“*Logical system*”** rather than being a “structural score system” as per FEMA 154.

In this system there are *6 building types (A to F)* among which some types (C and D) exist commonly among both masonry and RCC or steel frames. + Sign is used to denote more seismic strength (slight) or lower seismic vulnerability. *5 Damageability Grades (G1 to G5)* are specified along with these for masonry and RCC or Steel frames. Using the type of structure and the location in any particular *seismic zone i.e. from zone 2 to zone 5*, the probable damage it can undergo is listed in a table. Moreover, there are also some *other parameters such as URM infill, falling hazards, special hazards, etc. are specified.*

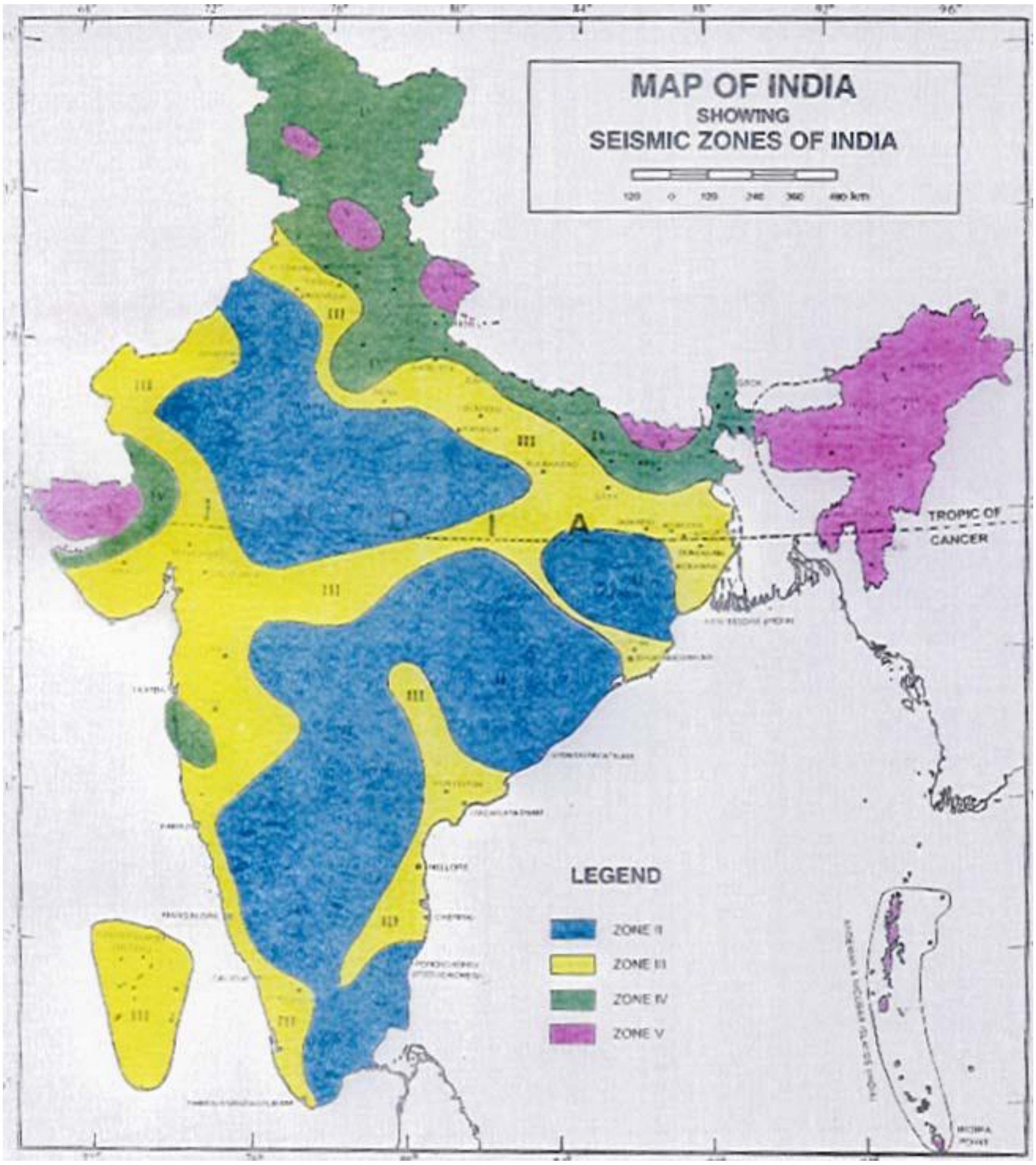
In accordance with these parameters and also the type of structure with the seismic zone the screener can identify the potential damage that the structure could undergo (given by damageability grade G) and possible Remedial measures. All this has been recorded in the *Data Collection Forms; 1 for each seismic zone; a total of 8 forms, (4 being for masonry structures and 4 are for RCC or Steel frames).*

2.6.2 SEISMIC ZONES OF INDIA: [14]

IS 1893:2002 (Part 1) divides India into 4 seismic hazard zones. Their details are as follows:

Zone II - Low seismic hazard with damage of MSK Intensity VI or lower.
Zone III- Moderate seismic hazard with maximum damage of and till MSK Intensity VII.
Zone IV- High seismic hazard with maximum damage of and till MSK Intensity VIII.
Zone V- Very high seismic hazard with maximum damage of MSK Intensity IX or more.

Fig. 2.7: Seismic zones in India (IS: 1893-2002)



2.6.3 STRUCTURE TYPES ACCORDING TO INDIAN CONDITIONS:

We see a variety of construction materials and structural forms being used in urban and semi-urban areas in India. These usually include a variety of locally available materials for example mud, straw, wood and semi-engineered materials i.e. brick and stone masonry and engineering materials like concrete or steel.

The seismic vulnerability of any structure type depends on the building materials and construction method adopted. The vulnerability is generally greatest with use of local materials of the un-engineered types and lowest for engineered materials and practices. The vulnerability class of any building type depends on the average expected seismic response for that structure type.

A building may have its vulnerability class different from basic class defined for that form depending on condition of building, architectural features, earthquake resistance features, height etc. Therefore, it is possible to obtain a damageability range of each building type considering the various factors that are likely to affect its performance. Some variations are therefore defined alphabetically as A, B, B+ etc.

Table 2.1 [6]: Masonry Structure Classes for RVS

Building Type	Description
A	a) Rubble (Field stone) in mud mortar or without mortar usually with sloping wooden roof. b) Uncoursed rubble masonry without adequate 'through stones'. c) Masonry with round stones.
B	Semi-dressed, rubble, brought to courses, **with** *through* stones and long *corner* stones; unreinforced brick walls with country type wooden roofs; unreinforced CC block walls constructed in mud mortar or weak lime mortar.
B+	a) Unreinforced brick masonry in mud mortar with vertical wood posts or horizontal wood elements or seismic band (IS: 13828) b) Unreinforced brick masonry in lime mortar.
C	a) Unreinforced masonry walls built from fully dressed (Ashler) stone masonry or CC block or burnt brick using good cement mortar, either having RC floor/roof or sloping roof having eave level horizontal bracing system or seismic band. b) As at B with horizontal seismic bands (IS: 13828)
C+	Like C(a) type but having horizontal seismic bands at lintel level of doors & windows (IS: 4326)
D	Masonry construction as at C(a) but reinforced with bands & vertical reinforcement, etc (IS: 4326), or *confined* masonry using horizontal & vertical reinforcing of walls.

Table 2.2 [5]: RCC/Steel Frame classification for RVS

Frame Type	Description
C	a) RC Beam Post buildings without ERD or WRD, built in non-engineered way. b) SF without bracings having hinge joints;. c) RCF of ordinary design for gravity loads without ERD or WRD. d) SF of ordinary design without ERD or WRD
C+	a) MR-RCF/MR-SF of ordinary design without ERD or WRD. b) Do, with unreinforced masonry infill. c) Flat slab framed structure. d) Prefabricated framed structure.
D	a) MR-RCF with ordinary ERD without special details as per IS: 13920, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings. b) MR-SF with ordinary ERD without special details as per Plastic Design Hand Book SP:6(6)-1972.
E	a) MR-RCF with high level of ERD as per IS: 1893-2002 & special details as per IS: 13920. b) MR-SF with high level of ERD as per IS: 1893-2002 & special details as per Plastic Design Hand Book, SP:6(6)-1972
E+	a) MR-RCF as at E with well designed infills walls. b) MR-SF as at E with well designed braces
F	a) MR-RCF as at E with well designed & detailed RC shear walls. b) MR-SF as at E with well designed & detailed steel braces & cladding. c) MR-RCF/MR-SF with well designed base isolation.

2.6.4 DAMAGE CLASSIFICATION (AS PER BIS METHOD):

Table 2.3 [6] Classification of Damage to Masonry Buildings

Classification of damage to masonry buildings	
Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	
Structural:	Hair-line cracks in very few walls.
Non-structural:	Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage)	
Structural:	Cracks in many walls, thin cracks in RC* slabs and A.C.* sheets.
Non-structural:	Fall of fairly large pieces of plaster, partial collapse of smoke chimneys on roofs. Damage to parapets, chajjas. Roof tiles disturbed in about 10% of the area. Minor damage in under structure of sloping roofs.
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)	
Structural:	Large and extensive cracks in most walls. Wide spread cracking of columns and piers.
Non-structural:	Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	
Structural:	Serious failure of walls (gaps in walls), inner walls collapse; partial structural failure of roofs and floors.
Grade 5: Destruction (very heavy structural damage)	
	Total or near total collapse of the building.

** RC = Reinforced Concrete; AC = Asbestos Cement*

Table 2.4 [5] Classification of damage to buildings of Reinforced Concrete

Classification of damage to buildings of reinforced concrete
Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage) Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions & infills.
Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage) Cracks in columns & beams of frames & in structural walls. Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall panels.
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition & infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
Grade 5: Destruction (very heavy structural damage) Collapse of ground floor parts (e.g. Wings) of the building.

*The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification. Non-structural damage to infills would be the same as indicated for masonry building in the above table. Structural damage grade in steel & wooden elements still needs to be defined.

2.6.5 DAMAGE CORRELATION AND BUILDING TYPE

Table 2.5 [6]: Structure type and Damageability correlation for Masonry Buildings

MASONRY BUILDINGS	Type of Building	Zone II MSK VI or less	Zone III MSK VII	Zone IV MSK VIII	Zone V MSK IX or More
	A	*Many* of grade 1 *Few* of grade 2 (rest no damage)	*Most* of grade 3 *Few* of grade 4 (rest of grade2or1)	*Most* of grade 4 *Few* of grade 5 (rest of grade 3,2)	*Many* of grade 5 (rest of grade 4&3)
	B and B+	*Many* of grade 1 *Few* of grade 2 (rest no damage)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Most* of grade 3 *Few* of grade 4 (rest of grade 2)	*Many* of grade 4 *Few* of grade 5 (rest of grade 3)
	C and C+	*Few* of grade 1 (rest no damage)	*Many* of grade 1 *Few* of grade 2 (rest of grade 1,0)	*Most* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
	D		*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)

NOTE:

1. **As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.**
2. **Buildings having vertical irregularity may under go severe damage in seismic zones III, IV & V if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.**
3. **Buildings having plan irregularity may under go a damage of one grade higher in zones III, IV & V. The surveyor may recommend re-evaluation.**

Table 2.6 [5]: Structure type and Damageability Correlation for RCC/Steel Frame Buildings

RCF/SF/BUILDING	Type of Building	Zone II MSK VI or less	Zone III MSK VII	Zone IV MSK VIII	Zone V MSK IX or More
	C and C+	*Few* of grade 1 (rest no damage)	*Few* of grade 2 (rest of grade 1,0)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
	D	-	*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)
	E and E+	-	-	-	*Few* of grade 2 (rest of grade 1 or 0)
	F	-	-	-	*Few* of grade 1

NOTE:

1. **As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.**
2. **Buildings having vertical irregularity (see note under table 3) may under go severe damage in seismic zones III, IV & V if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.**
3. **Buildings having plan irregularity may under go a damage of one grade higher in zones III, IV & V. The sur veyor may recommend re-evakuation.**

2.6.6 SPECIAL PARAMETERS FOR DATA COLLECTION FORMS [5],[6],[14]

1) Importance of Building/Structure:

As per IS: 1893-2002, an important factor I is defined for enhancing the seismic strength of buildings & structures, as follows:

***Important buildings**:** Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person.

**Any building having more than 100 Occupants may be treated as Important for purpose of RVS.*

For these important buildings the value of I is specified as 1.5, by which the design seismic force is increased by a factor of 1.5. Now the seismic zone factors for zone II to V are as follows.

Zone II III IV V
Zone Factor 0.10 0.16 0.24 0.36

It is seen that one Unit change in Seismic Zone Intensity increases the Zone Factor 1.5 times. *Hence to deal with the damageability of important buildings in any zone, they should be checked for one Unit higher zone*. The assessment forms are designed accordingly.

2) Special Hazards:

There are some special hazardous conditions to be considered:

I. *Liquefiable condition:* Normal loose sands submerged under high water table are susceptible to liquefaction under moderate to high ground accelerations; building founded on such soils will require special evaluation and treatment.

II. *Land Slide Prone Area:* If the building is situated on a hill slope which is prone to land slide/ land slip or rock-fall under monsoon and/or earthquake, special geological & geotechnical evaluation of the site and treatment of the building will be needed.

III. *Irregular Buildings:*
Irregularities in buildings are defined in *Cl.7.1 of IS: 1893 – 2002* under the following subheads:

i. Plan Irregularities: These are defined in Table 4 of the Code as follows:
a) Torsion Irregularity
b) Re-entrant Corners
c) Diaphragm Discontinuity
d) Out of Plane Offsets
e) Non – Parallel Systems

The Geometric Irregularities in building plans which can be easily identified in Figure 5 These irregularities enhance the overall damage (increased grade of damage e.g. at re-entrant corners). Such a building may be recommended for detailed evaluation.

ii. *Vertical Irregularities:* The following vertical irregularities may be seen in masonry buildings (*see* Fig.5).
a) Mass Irregularity
b) Vertical Geometric Irregularity
c) In-Plane Discontinuity in vertical Elements Resisting Lateral Forces.
If any of these irregularities are noticed, the building should be recommended for detailed evaluation.

3) Falling Hazards:

Falling hazards include chimneys, parapets, cladding etc. Where such hazards are present, particularly in Zones IV & V, recommendations should make reference to these in the survey report as indicated.

4) Type of Foundation Soil:

IS 1893-2002 defines three soil types hard/stiff, medium & soft. No effect of these is seen in the design spectra of short period buildings, T< 0.4 second, covering all masonry buildings, hence the effect may be considered not so significant.

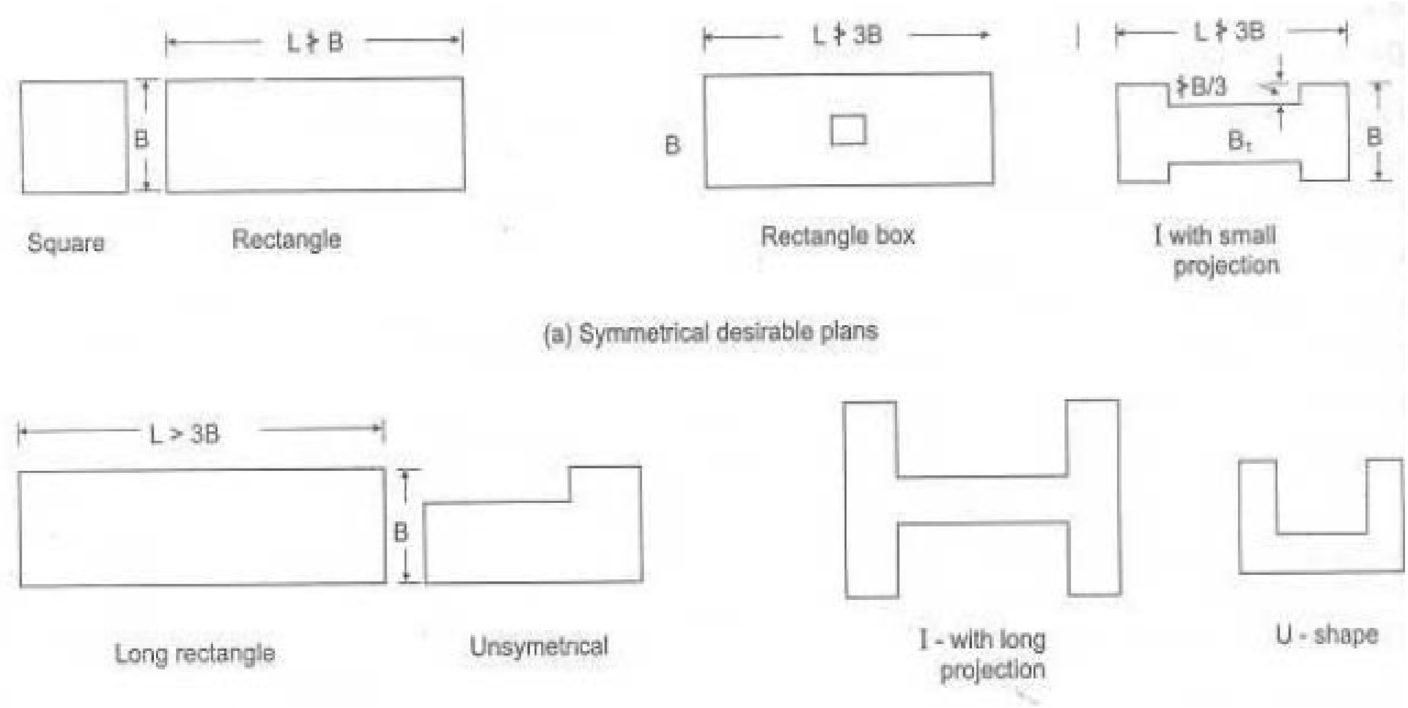
5) Special Observations:

These observations are applicable only for masonry buildings. They specify certain parameters which determine whether the structural components are in correct proportion or not as per IS 4326:1993 “Indian Standard Code of practice for Earthquake Resistant Design and Construction of Buildings” and IS 13828:1993 “Indian Standard Guidelines for Improving Earthquake Resistance of Low Strength Masonry Buildings**”** There absence may call for retrofitting or revaluation.

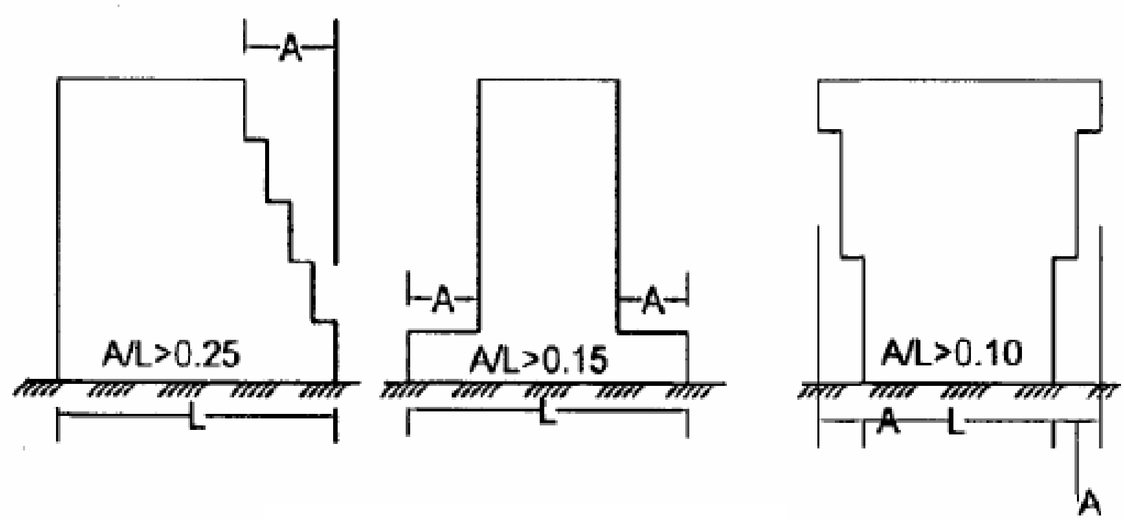
6) URM Infills:

Presence of Unreinforced Masonry (URM) infills also determine whether the structure needs to be further evaluated for seismic vulnerability or not. They are applicable on for RCC and Steel Frame structures

Fig 2.8 [5],[6]: Irregularities in structures (RCC and Masonry)

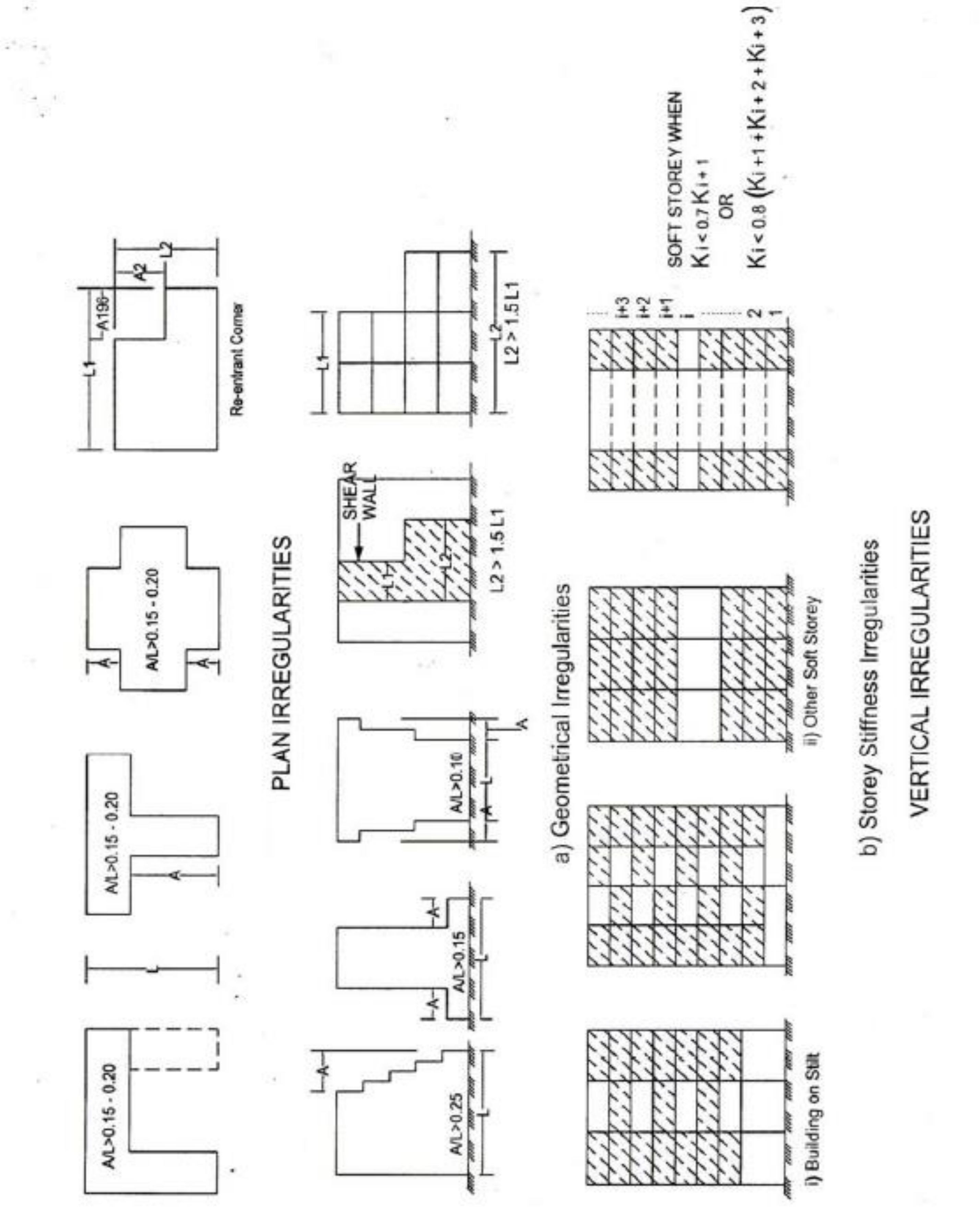


HORIZONTAL IRREGULARITIES



VERTICAL IRREGULARITIES

Fig 2.8 (Continued)



2.6.7 DATA COLLECTION FORMS FOR MASONRY STRUCTURES [6]:

1 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone II Ordinary Building

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name__________
1.2 Use__________
1.3 Address:__________
__________Pin __________
1.4 Other Identifiers__________
1.5 No. of Stories__________ 1.6 Year Built __________
1.7 Total Covered Area; all floors (sq.m) __________
1.8 Ground Coverage (Sq.m):__________
1.9 Soil Type:__________1.10 Foundation Type:__________
1.11 Roof Type:__________ 1.12 Floor Type__________
1.12 Structural Components:
1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐
1.12.2 Thickness of wall:_______ 1.12.3 Slab Thickness:_______
1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐
1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐
1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY

2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person.

**Any building having more than 100 Occupants may be treated as Important.*

2.2 Ordinary buildings:- Other buildings having occupants <100

3.0 SPECIAL HAZARD

3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐
3.2 Land Slide Prone Site Yes ☐ No ☐
3.3 Severe Vertical Irregularity Yes ☐ No ☐
3.4 Severe Plan Irregularity Yes ☐ No ☐

4.0 FALLING HAZARD

4.1 Chimneys ☐
4.2 Parapets ☐
4.3 Cladding ☐
4.4 Others ☐

5.0 SPECIAL OBSERVATION

5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐
5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐
5.3 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐

RECOMMENDED ACTION:-

☐ Ensure adequate maintenance.
☐ If any Special Hazard 3.0 found , re-evaluate for possible retrofitting.
☐ If any of the falling hazard is present, either remove it or strengthen against falling.
☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in Zone II	A	B / B+	C / C+	D
	G2	G2 / G1	G1 / G1	-

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's sign:__________
Name:__________

Executive Engineer's Sign:__________

Date of Survey:__________

2 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone III Ordinary Building

(Also for Zone II Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name____________________

1.2 Use____________________

1.3 Address:____________________

____________ Pin ________

1.4 Other Identifiers____________________

1.5 No. of Stories________ 1.6 Year Built ________

1.7 Total Covered Area; all floors (sq.m) ________

1.8 Ground Coverage (Sq.m):________

1.9 Soil Type:________ 1.10 Foundation Type:________

1.11 Roof Type:________ 1.12 Floor Type________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall:______ 1.12.3 Slab Thickness:______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person.	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐	4.1 Chimneys ☐
**Any building having more than 100 Occupants may be treated as Important.*	3.2 Land Slide Prone Site Yes ☐ No ☐	4.2 Parapets ☐
2.2 Ordinary buildings:- Other buildings having occupants <100	3.3 Severe Vertical Irregularity Yes ☐ No ☐	4.3 Cladding ☐
	3.4 Severe Plan Irregularity Yes ☐ No ☐	4.4 Others ☐

5.0 SPECIAL OBSERVATION

5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐

5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐

5.4 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐

RECOMMENDED ACTION:-

- ☐ Ensure adequate maintenance.
- ☐ Detailed evaluation of B type for need for retrofitting.
- ☐ Detailed evaluation of A types for need for reconstruction or possible retrofitting.
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against falling.
- ☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

Surveyor's Sign :________

Name:________

Executive Engineer's Sign:________

Date of Survey:________

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in Zone III	A	B / B+	C / C+	D
	G4	G3 / G2	G2 / G1	G1

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

3 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone IV Ordinary Building

(Also for Zone III Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name____________________________

1.2 Use__________________________________

1.3 Address:_______________________________

__________________ Pin __________

1.4 Other Identifiers__________________________

1.5 No. of Stories________ 1.6 Year Built _________

1.7 Total Covered Area; all floors (sq.m) ____________

1.8 Ground Coverage (Sq.m):_____________________

1.9 Soil Type:_______1.10 Foundation Type:________

1.11 Roof Type:__________ 1.12 Floor Type_________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall:_____ 1.12.3 Slab Thickness:_____

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings:-*** Other buildings having occupants <100	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐ 3.2 Land Slide Prone Site Yes ☐ No ☐ 3.3 Severe Vertical Irregularity Yes ☐ No ☐ 3.4 Severe Plan Irregularity Yes ☐ No ☐ **5.0 SPECIAL OBSERVATION** 5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐ 5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐ 5.5 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ A or B: evaluate in detail for need of reconstructions or possible retrofitting to achieve type C or D
- ☐ B+, C: evaluate in detail for need for retrofitting
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against falling.
- ☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
Damage- ability in Zone IV	A	B / B+	C / C+	D
	G5	G4 / G3	G3 / G2	G2

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's
Sign :______________
Name:______________

Executive
Engineer's
Sign:______________

Date of Survey:__________

4 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

Seismic Zone V All Buildings

(Also for Zone IV Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name________________________

1.2 Use________________________

1.3 Address:________________________

________________Pin __________

1.4 Other Identifiers________________________

1.5 No. of Stories________ 1.6 Year Built ________

1.7 Total Covered Area; all floors (sq.m) __________

1.8 Ground Coverage (Sq.m):__________

1.9 Soil Type: ________ 1.10 Foundation Type: ________

1.11 Roof Type:________ 1.12 Floor Type________

1.12 Structural Components:

1.12.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐

1.12.2 Thickness of wall:______ 1.12.3 Slab Thickness:______

1.12.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐

1.12.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐

1.12.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

*BB – Burnt Brick, *UCR – Uncoursed Random Rubble
*CCB: Cement Concrete Block

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐ 3.2 Land Slide Prone Site Yes ☐ No ☐ 3.3 Severe Vertical Irregularity Yes ☐ No ☐ 3.4 Severe Plan Irregularity Yes ☐ No ☐ **5.0 SPECIAL OBSERVATION** 5.1 Length of wall between two cross walls are as per IS:4326 or IS:13828. Yes ☐ No ☐ 5.2 Percentage of openings in walls is as per IS:4326 or IS:13828 Yes ☐ No ☐ 5.6 Ratio of height & width of wall is as per IS:4326 or IS:13828 Yes ☐ No ☐	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ A or B, B+ : evaluate in detail for need of reconstructions or possible retrofitting to achieve type C+ or D
- ☐ C: evaluate in detail for need for retrofitting to achieve type C+, D.
- ☐ Wood : evaluate in detail for Retrofitting
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against fall.
- ☐ Special observation if not compliant may lead to more severe damage and will call for retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 Masonry Building			
	A	B / B+	C / C+	D
Damage- ability in Zone V	G5	G5 / G4	G4 / G3	G3

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's
Sign :____________
Name:____________

Executive
Engineer's
Sign:____________

Date of Survey:____________

2.6.8 DATA COLLECTION FORMS FOR RCC/ SF STRUCTURES [5]:

1 Rapid Visual Screening of RC/Steel Buildings for Seismic Hazards

Seismic Zone II Ordinary Building

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name______________________________

1.2 Use__________________________________

1.3 Address:_______________________________

____________________Pin __________

1.4 Other Identifiers____________________________

1.5 No. of Stories__________ **1.6** Year of Const.________

1.7 Storey Ht: 1st ______, 2nd ______, 3rd ______ etc.

1.8 Total Covered Area; all floors (sq.m) ______________

1.9 Ground Coverage (Sq.m):______________________

1.10 Soil Type:________ **1.11** Foundation Type:________

1.12 Depth of Ground water table: __________

1.13 Bldg. Type: Frame ☐ Pre-cast ☐

Frame - Shear Wall ☐ Flat Slab Frame ☐

1.14 Thickness of infill wall: Exterior _____ Interior _____

1.15 Struct. Dwg./Calculations available: Yes / No (If yes,attach)

1.16 Extn. to the original bldg. Yes/ No (If yes pl. indicate)

1.17 Location of Shear walls (if any)

1.18 Special Confining R/F in Beam/Column/joints:

1.19 Stair case: Separated ☐ Connected ☐ Enclosed ☐

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. ***Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	3.1 High Water Table (within 1m) & if sandy soil, then liquefiable site indicated. ☐ Yes ☐ No 3.2 Land Slide Prone Site ☐ Yes ☐ No 3.3 Severe Vertical Irregularity ☐ Yes ☐ No 3.4 Severe Plan Irregularity ☐ Yes ☐ No	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

☐ Ensure adequate maintenance.

☐ If any Special Hazard 3.0 found, re-evaluate for possible retrofitting.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 RC or Steel Frame/ wooden Buildings				5.2 URM Infill
Damage-ability in Zone II	C / C+	D	E,E+	F	
	G1 / G1	-	-	-	G1

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's sign:________________

Name:________________

Executive Engineer's Sign:________________

Date of Survey:____________

2 Rapid Visual Screening of RC/Steel Buildings for Seismic Hazards

Seismic Zone III Ordinary Building

(Also for Zone II Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name__________

1.2 Use__________

1.3 Address:__________

__________Pin __________

1.4 Other Identifiers__________

1.5 No. of Stories__________ **1.6** Year of Const.__________

1.7 Storey Ht.: 1st ______, 2nd ______, 3rd ______ .etc.

1.8 Total Covered Area; all floors (sq.m) __________

1.9 Ground Coverage (Sq.m):__________

1.10 Soil Type:__________ **1.11** Foundation Type:__________

1.12 Depth of Ground water table: __________

1.13 Bldg. Type: Frame ☐ Pre-cast ☐ Frame - Shear Wall ☐ Flat Slab Frame ☐

1.14 Thickness of infill wall: Exterior ______ Interior ______

1.15 Struct. Dwg./Calculations available: Yes / No (If yes,attach)

1.16 Extn. to the original bldg. Yes/ No (If.yes pl. indicate)

1.17 Location of Shear walls (if any)

1.18 Special Confining R/F in Beam/Column/joints:

1.19 Stair case: Separated ☐ Connected ☐ Enclosed ☐

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	**3.1** High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. ☐ Yes ☐ No **3.2** Land Slide Prone Site ☐ Yes ☐ No **3.3** Severe Vertical Irregularity ☐ Yes ☐ No **3.4** Severe Plan Irregularity ☐ Yes ☐ No	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ Ensure adequate maintenance.
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against falling.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 RC or Steel Frame/ wooden Buildings				5.2 URM Infill
Damage- ability in Zone III	C / C+	D	E,E+	F	
	G2 / G1	G1	-	-	G2

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's Sign :__________

Name:__________

Executive Engineer's Sign:__________

Date of Survey:__________

3 Rapid Visual Screening of RC/Steel Buildings for Seismic Hazards

Seismic Zone IV Ordinary Building

(Also for Zone III Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name____________________

1.2 Use____________________

1.3 Address:____________________

________________ Pin __________

1.4 Other Identifiers____________________

1.5 No. of Stories________ **1.6** Year of Const.________

1.7 Storey Ht.: 1st ______, 2nd ______, 3rd ______ .etc.

1.8 Total Covered Area; all floors (sq.m) __________

1.9 Ground Coverage (Sq.m):__________

1.10 Soil Type:________ **1.11** Foundation Type:________

1.12 Depth of Ground water table: ________

1.13 Bldg. Type: Frame ☐ Pre-cast ☐ Frame - Shear Wall ☐ Flat Slab Frame ☐

1.14 Thickness of infill wall: Exterior ______ Interior ______

1.15 Struct. Dwg./Calculations available: Yes / No (If yes,attach)

1.16 Extn. to the original bldg. Yes/ No (If.yes pl. indicate)

1.17 Location of Shear walls (if any)

1.18 Special Confining R/F in Beam/Column/joints:

1.19 Stair case: Separated ☐ Connected ☐ Enclosed ☐

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
*2.1 **Important buildings**:* Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* *2.2 **Ordinary buildings**:-* Other buildings having occupants <100	3.1 High Water Table (within 5m) & if sandy soil, then liquefiable site indicated. ☐ Yes ☐ No 3.2 Land Slide Prone Site ☐ Yes ☐ No 3.3 Severe Vertical Irregularity ☐ Yes ☐ No 3.4 Severe Plan Irregularity ☐ Yes ☐ No	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ C: evaluate in detail for need for retrofitting
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against falling.
- ☐ URM infill : evaluate in detail for need of retrofitting

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 RC or Steel Frame/ wooden Buildings				5.2 URM Infill
Damage-ability in Zone IV	C / C+	D	E,E+	F	
	G3 / G2	G2	-	-	G3

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's
Sign :____________
Name:____________

Executive Engineer's
Sign:____________

Date of Survey:____________

4 Rapid Visual Screening of RC/Steel Buildings for Seismic Hazards

Seismic Zone V All Buildings

(Also for Zone IV Important Building)

Photograph

Sketch Plan with Length & Breadth

1.1 Building Name ______

1.2 Use ______

1.3 Address: ______

______ Pin ______

1.4 Other Identifiers ______

1.5 No. of Stories ______ **1.6** Year of Const. ______

1.7 Storey Ht.: 1st ______, 2nd ______, 3rd ______ .etc.

1.8 Total Covered Area; all floors (sq.m) ______

1.9 Ground Coverage (Sq.m): ______

1.10 Soil Type: ______ **1.11** Foundation Type: ______

1.12 Depth of Ground water table: ______

1.13 Bldg. Type: Frame ☐ Pre-cast ☐ Frame - Shear Wall ☐ Flat Slab Frame ☐

1.14 Thickness of infill wall: Exterior ______ Interior ______

1.15 Struct. Dwg./Calculations available: Yes / No (If yes,attach)

1.16 Extn. to the original bldg. Yes/ No (If.yes pl. indicate)

1.17 Location of Shear walls (if any)

1.18 Special Confining R/F in Beam/Column/joints:

1.19 Stair case: Separated ☐ Connected ☐ Enclosed ☐

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD
2.1 Important buildings: Hospitals, Schools, monumental structures; emergency buildings like telephone exchange, television, radio stations, railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, Important Industrial establishments, VIP residences & Residences of Important Emergency person. **Any building having more than 100 Occupants may be treated as Important.* ***2.2 Ordinary buildings***:- Other buildings having occupants <100	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. ☐ Yes ☐ No 3.2 Land Slide Prone Site ☐ Yes ☐ No 3.3 Severe Vertical Irregularity ☐ Yes ☐ No 3.4 Severe Plan Irregularity ☐ Yes ☐ No	4.1 Chimneys ☐ 4.2 Parapets ☐ 4.3 Cladding ☐ 4.4 Others ☐

RECOMMENDED ACTION:-

- ☐ C: evaluate in detail for need for retrofitting to achieve type E, E+.
- ☐ If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.
- ☐ If any of the falling hazard is present, either remove it or strengthen against fall.
- ☐ URM infill : evaluate for need of reconstruction or possible retrofitting to level D.

5.0 Probable Damageability in Few/Many Buildings

Building Type	5.1 RC or Steel Frame/ wooden Buildings				5.2 URM Infill
Damage-ability in Zone V	C / C+	D	E,E+	F	
	G4 / G3	G3	G2/G1	G1	G4

Note: +sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated.

Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.

Surveyor's Sign :______
Name:______

Executive Engineer's Sign:______

Date of Survey:______

2.7 ANALOGOUS POINTS IN VARIOUS METHODOLOGIES (FEMA P-154 AND BIS METHOD)

2.7.1 STRUCTURE TYPES (ANALOGIES):

Table 2.7: Comparative structure types

S.No.	Structure type	As denoted in FEMA P-154 (Ref. No. 1)	As per Ref. No. 12	As per Ref. No. 5 and Ref. No. 6
1.	Wooden (Light wooden frame with buildings less than 5000 sq. ft.)	W1	Wood	A, B (partially)
2.	Wooden (Light wooden frame with buildings greater than 5000 sq. ft.)	W2		
3.	Moment resistant Steel Frame (FRAME)	S1	S1	*C+,* D, E, E+, F (with varying degree of earthquake resistant design)
4.	Braced steel Frame (BR)	S2	--------------	E+, F (with varying degree of earthquake resistant design)
5.	Light Metal (LM) steel structure	S3	S2	*C
6.	Steel Frame with concrete shear wall (RC SW)	S4	----------------	---------------- (specified in concrete only)
7.	Steel frame with Un reinforced masonry infill wall (URM INF)	S5	----------------	----------------- (specified in concrete only)
8.	Concrete Moment Resisting Frame (MRF)	C1	C1	*C+,* D, E, E+, F (with varying degree of earthquake resistant design)
9.	Concrete Shear Wall Buildings (SW)	C2	C2	F

10.	Concrete frame with Burnt Brick Masonry (URM) Infill Wall (INF)	C3	C3	E+
11.	Tilt Up buildings (TU)	PC1	----------------	---------------
12.	Precast Concrete Frame buildings	PC2	----------------	*C+
13.	Un reinforced or reinforced Masonry Building with Seismic Band + Rigid Diaphragm (BAND+RD)	RM2	URM1	C, C+, D
14.	Unreinforced or Reinforced Masonry building with Seismic Band + Flexible Diaphragm (BAND+ FD)	RM1	URM2	B+
15.	Unreinforced (URM) Burnt Brick or Stone Masonry (Cement mortar)	URM	URM3	B+, C,C+
16.	Unreinforced Masonry (URM) (Lime mortar)		URM4	B

FEMA 154 specifies 15 structure types as shown above out of which 10 structure types have been used in the report of Prof. Sinha and Prof. Goyal (IIT Bombay) (Ref. No.12) for Indian conditions. However the report of BIS Committee (Dr. Anand S. Arya – IIT Roorkee) (Ref. No. 5 and 6) and IS 13935-2009 uses 6 structure types with altogether different symbols (A-F) based on European macro seismic scale (EMS-98) recommendations . Here the prefix symbol * is used to specify concrete and steel and to differentiate between masonry and concrete/steel structures since type C, C+ and D are used to denote both masonry and concrete structures (although this symbol * is not specified in the original literature)

In the above table an analogy or similarity has been shown in the representation of different structure types mentioned in different reports. For the current project work, representations given in Ref. No.12 (which is nearly similar to FEMA 154) are used.

2.7.2 ANALOGY OF SOIL TYPES AND SOIL INFORMATION [1]:

“Soil type information in FEMA is given in FEMA 302 in detail. FEMA 302 classifies six soil types from A to F as-

Soil Type Definitions and Related Parameters
The six soil types, with measurable parameters that define each type, are:
Type A (hard rock): measured shear wave velocity, *vs.* > 5000 ft/sec.
Type B (rock): *vs.* between 2500 and 5000 ft/sec.
Type C (soft rock and very dense soil): *vs.* between 1200 and 2500 ft/sec, or standard blow count *N* > 50, or undrained shear strength *su* > 2000 psf.
Type D (stiff soil): *vs.* between 600 and 1200 ft/sec, or standard blow count *N* between 15 and 50, or undrained shear strength, *su* between 1000 and 2000 psf.
Type E (soft soil): More than 100 feet of soft soil with plasticity index PI > 20, water content w > 40%, and *su* **<** 500 psf; or a soil with *vs.* ≤ 600 ft/sec.
Type F (poor soil): Soils requiring site-specific evaluations:**”**

• Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly-sensitive clays, collapsible weakly-cemented soils.
• Peats or highly organic clays (H > 10 feet of peat or highly organic clay, where H = thickness of soil)
• Very high plasticity clays (H > 25 feet with PI > 75).
• More than 120 ft of soft or medium stiff clays. The parameters *vs***,** *N***,** and *su* are, respectively, the average values (often shown with a bar above) of shear wave velocity, Standard Penetration Test (SPT) blow count and undrained shear strength of the upper 100 feet of soils at the site.

Out of these FEMA 154 makes use of 3 types that is Soil type C, D and E. It specifies that if the soil type is unknown at a particular location, we will assume type E (soft soil). However, for one-story or two-story buildings with a roof height equal to or less than 25 feet, a class D soil type may be assumed when site conditions are not known.

The analogy for soil type in IS Classification and FEMA 154 is-

FEMA 154 soil classification		**IS soil classification**		**soil nature**
Soil type C	----------→	Soil type 1	--------------→	Hard soil
Soil type D	----------→	Soil type 2	-------------→	Medium soil
Soil type E	----------→	Soil type 3	--------------→	Soft soil

CHAPTER 3

DEVELOPMENT OF A NEW AND MODIFIED RVA METHODOLOGY

3.1 OVERVIEW

The RVA method in the Indian condition that has been adopted by BIS (Bureau of Indian Standards) and included in IS 13935:2009 is a very simple and quick method based on logic. This method gives a very detailed and comprehensive classification of structural types which can be commonly found all over India.

But, even though it's a very rapid and simple procedure, it lacks in incorporating the amount of detail and consequently, accuracy that FEMA method provides for RVA. The FEMA method is based on a structural score technique and gives a clear-cut indication of the seismic safety of a building by comparing the calculated structural score with the pre-decided cut off score. It gives a reliable demarcation between seismically safe and unsafe buildings. On the other hand, the BIS method, even though relatively simple and easy, doesn't provide that clear a line demarcating the two. Instead, it provides a logical basis to judge the safety and buildings just lying on the threshold margin between the seismically safe or unsafe structures can easily be misjudged. Thus in the Indian methodology for RVA, the wisdom and experience of the screener plays a pivotal role.

If, on the other hand we try to apply the FEMA methodology for RVA without modification for Indian conditions it shows some areas of limitations. There are certain factors in FEMA methodology that even though are recorded during RVA process, do not actively participate in having a large effect the overall structural score. Some of those are occupancy, age, soft storey presence, condition of building at the time of survey, etc. On the other hand there are some factors which are not yet included by FEMA but play an active role in affecting the overall seismic score of the building. These factors are can be summarised as the characteristic features of the surrounding environment and can have a major influence in countries like India where construction trends are non-uniform and haphazard in nature.

Thus there is a need for a method based on scoring that's similar to FEMA P-154 but can also include some of these other factors that might affect the overall vulnerability of the structure being screened when it comes to seismic forces.

In order to create such a system, during the course of this project, the FEMA P-154 method is adopted directly as a reference base with a handful of structures. To this are added some more modifiers to enhance the suitability and accuracy for the standard method as per Indian conditions. After this a Microsoft Excel program has been created to get a more, accurate, speedy and refined score in accordance with RVA system for Indian conditions.

3.2 FEATURES OF THE NEW MODIFIED RVA SYSTEM

The **factors already mentioned** for RVA procedure specified by FEMA P-154 and by Ref. No. 12 and also by IS 13935-2009 (similar to Ref. No. 5 and 6) that affect the seismic strength of any building being considered are-

1) Structure Type

2) Height of building (low, medium or high)

3) Soil type

4) Code Detailing (noted as Pre code or Post bench-mark by FEMA P-154 and a simple code detail by IS 13935)

5) Plan Irregularity

6) Vertical irregularity

7) Special Hazards like liquefiable soil, land slide prone areas, are also mentioned

In the new RVA prototype method that is being proposed for greater accuracy, the basis would be the structural score system as adopted by FEMA P-154.**The factors mentioned bfore are considered directly in accordance with the handbook guidelines. In addition to these some additional factors** are introduced to modify the determined structural score. A few of these factors have already been touched upon by a few reports but have not been included in the score calculation. For this project they are also assigned some scores as well as a few additional factors are added. All of these together are referred to as **"additional score modifiers".** These factors are:-

8) Last recorded maintenance from the day of construction till the day of screening

9) Condition of building (cracks, presence of vegetation, falling plaster and facades, exposed reinforcement with or without rust, warped members etc.)

10) Occupancy (to determine the importance of building)

11) Falling Hazards (unsupported parapets, chimneys etc.)

12) Bottom Soft storey presence

13) Collateral Damage Probability (It is used to gauge the risk entailed by the surroundings of the building such as a tall tower or a closely spaced structure that can cause pounding etc.)

14) Emergency services availability (proximity to services such as fire stations, hospitals, etc)

15) Ease of Evacuation (Additional emergency exits etc)

Each of the additional score modifiers is assigned a value from 1 to 10 (other than occupancy). This signifies the **degree of dominance or presence (denoted by D)** in the particular structure being screened. The **algebraic nature of D is taken + or –** by considering the effect the parameter has on the safety of the structure (+ refers to an improvement in safety or a reduction in risk and - refers to a decrease in overall safety or an increase in risk).

Since each modifier has a variable extent to which it affects the overall seismic vulnerability, **Sensitivity factor (denoted by W) is applied to every modifier**. The sensitivity factor is analogous to weight factor applied to various readings and is selected according to personal discretion such that the final modifier score (S*W) is restricted in the same range as modifier score obtained by default factors.

The **final score due to every additional modifier in the overall score obtained as a product of D and W**

i.e. <u>ADDITIONAL MODIFIER SCORE</u> = (D) * (W) (+ or – according to nature)

The **Final Score (S)** is to be calculated as mentioned by **FEMA P-154** by **summing up of basic score (factor 1 to 7) and the additional modifier values as obtained from the calculation above (factor 8 to 15)**

As a result of including additional score modifiers the **final cut off values also need to be modified**. The modified cut off is mentioned later on in the report.

3.3 SENSITIVITY/WEIGHTS FOR ADDITIONAL FACTORS TAKEN

Not all the additional modifiers considered have the same amount or intensity of influence or effect. A few of these modifiers such as “soft storey presence” have a large impact on the seismic behaviour of the structure while other ones like “emergency services availability” and “ease of evacuation” have a relatively low effect on the seismic vulnerability. To account for this variability in the extent of influence we need to take every factor with a particular weight instead of a simple algebraic addition and hence W factors have been assigned to every modifier.

The additional modifiers according to order of importance (most important to least important) are mentioned with their Sensitivity/Weightage factors (W) in the following table:

Table 3.1: Weightage factors for additional score modifier parameters

S.No.	Additional Score Modifiers	Nature	Order of Importance	Sensitivity/Weightage Factor (W)
8.	Bottom soft storey presence	-	Most important ↕ Least important	0.1
9.	Occupancy	-		0.001
10.	Condition of building	-		0.05
11.	Maintenance History	-		0.05
12.	Collateral Damage Vulnerability	-		0.025
13.	Falling Hazards	-		0.025
14.	Ease of Evacuation	+		0.01
15.	Emergency Services Availability	+		0.01

3.4 DECIDING THE CUT OFF SCORES

With the inclusion of additional modifiers the final cut off score is also modified. The value of cut of score can be on a safer side by choosing higher presence (i.e. max D) for each additional modifier and adding Σ (+/-DXW) to the original cut off score. Similarly for economy a lower value of D can be chosen. It must be noted while calculating Σ (+/-DXW) for getting the modified cut off score, value of D should be chosen same for all additional modifiers.

In this project work, in order to decide the cut off score, a **medium degree of presence or dominance** has been taken i.e. the **value of D is taken as 5 (for all except for occupancy for which it is taken as 500)** for additional score modifier parameters. Accordingly the final modifier score for each additional modifier parameter is calculated by multiplying 5 or 500 (whichever is applicable) by each additional modifier's weightage factor. Finally summation of all final modifier scores gives the value by which we have to change the cut off score. The calculations are shown by the following table:

Table 3.2: Weightage factors and Final additional Modifier cut off scores

S.No.	Additional Score Modifiers	Degree of Dominance or Presence (D)	Nature of D	Sensitivity/Weightage Factor (W)	Final additional modifier score =[(+/-D) * (W)]
8.	Bottom soft storey presence	5	-	0.1	-0.5
9.	Occupancy	500	-	0.001	-0.5
10.	Condition of building	5	-	0.05	-0.25
11.	Maintenance History	5	-	0.05	-0.25
12.	Collateral Damage Vulnerability	5	-	0.025	-0.125
13.	Falling Hazards	5	-	0.025	-0.125
14.	Ease of Evacuation	5	+	0.01	+0.05
15.	Emergency Services Availability	5	+	0.01	+0.05
FINAL CUT OFF MODIFYING VALUE : Σ[(D) ∗ (W)] = **-1.65**					

Hence we deduct 1.65 (or add -1.65) to each value of Final Structural Score S range (for various damageability grades as specified in report of Prof. Sinha and Prof. Goyal (IIT Bombay)) to get new ranges of S for same Damageability grades and also new value of S required to be used as a check whether the building requires further evaluation or not. The results obtained are shown below:

Table 3.3: Final Cut Off scores and score ranges

ORIGINAL CUT OFF SCORES AND SCORE RANGES	**MODIFIED CUT OFF SCORES AND SCORE RANGES**
DAMAGE PROBABILITY BASED ON FINAL STRUCTURAL SCORE S RANGE	
S<0.3 → Grade 5 (High), Grade 4 (Very High)	S<-1.35 → Grade 5 (High), Grade 4 (Very High)
0.3<S<0.7 → Grade 4 (High), Grade 3 (Very High)	-1.35<S<-0.95 → Grade 4 (High), Grade 3 (Very High)
0.7<S<2 → Grade 3 (High), Grade 2 (Very High)	-0.95<S<0.35 → Grade 3 (High), Grade 2 (Very High)
2<S<3 → Grade 2 (High), Grade 1 (Very High)	0.35<S<1.35 → Grade 2 (High), Grade 1 (Very High)
S>3 → Grade 1 (High)	S>1.35 → Grade 1 (High)
NEED OF FURTHER EVALUATION	
YES if S < 2 (2 is the cut off score)	YES if S <0.35 (2-1.65=0.35 is the cut off score)

3.5 NEW MODIFIED RVS DATA COLLECTION FORMS

Following Data collection forms are developed for different seismic zones/seismicity regions:

MODIFIED DATA COLLECTION FORM FOR RAPID VISUAL SCREENING OF BUILDINGS

(based on FEMA 154 and IIT Bombay report)

(INDIAN STANDARDS SEISMIC ZONE 2 / FEMA (U.S.A.) LOW SEISMICITY ZONE) (FRONT)

BUILDING DETAILS:

Building Name:________________________ Address:____

Pin code:_____________ GPS Coordinates: (latitude)___________ (longitude)____________ Other identifiers:_________________

Year Built:______ No of Stories:__________ Approximate total floor area (sq. ft./ sq. m.):__________ Use:_______________________

Construction drawings available(Yes/No):________ Surveyor's name:____________________ Survey date:_____________________

Additional Comments: ____

	BUILDING TYPE->	Wood	S1(FRAME)	S2(LM)	C1(MRF)	C2(SW)	C3(INF)	URM1(BAND+RD)	URM2(BAND+FD)	URM3	URM4
	BASIC SCORE MODIFIERS:										
1	**Basic structural score**	6.0	4.6	4.6	4.4	4.8	4.4	4.6	4.8	4.6	3.6
2	**Low rise (<4 stories)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	**Mid rise (4-7 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
3	**Vertical irregularity**	-3.0	-2.0	N/A	-1.5	-2.0	-2.0	-1.5	-2.0	-1.5	-1.5
4	**Plan irregularity**	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
5	**Code Detailing**	N/A	+0.4	N/A	+0.6	+0.4	N/A	N/A	N/A	N/A	N/A
6	**Soil type 1/C (Hard soil)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	**Soil type 2/D(*med. soil)**	-0.4	-0.8	-0.4	-0.6	-0.4	-0.4	-0.2	-0.4	-0.4	-0.4
.	**Soil type 3/E (soft soil)**	-0.8	-1.4	-1.0	-1.4	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
7	**Special hazards like liquefiable soil, land slide prone area etc**	-2.0	-2.0	-2.0	-2.0	-2.0	-2.0	-1.6	-1.4	-1.4	-1.4

ADDITIONAL SCORE MODIFIERS: (SAME FOR ALL STRUCTURE TYPES) *med. Denotes medium

ADDITIONAL MODIFIER	DEGREE OF PRESENCE DOMINANCE **(D)**	NATURE (+/-)	WEIGHTAGE/SENSTIVITY FACTOR **(W)**	FINAL SCORE **[= (+/-D) x (W)]**
8. **Bottom soft storey presence**	(GOOD) 0______5______10 (BAD)	---	0.1	________
9. **Occupancy**	(GOOD) 0______500______1000 (BAD)	---	0.001	________
10. **Condition of building**	(GOOD) 0______5______10 (BAD)	---	0.05	________
11. **Maintenance**	(GOOD) 0______5______10 (BAD)	---	0.05	________
12. **Collateral damage Vulnerability**	(GOOD) 0______5______10 (BAD)	---	0.025	________
13. **Falling hazards**	(GOOD) 0______5______10 (BAD)	---	0.025	________
14. **Ease of Evacuation**	(BAD) 0______5______10 (GOOD)	+	0.01	________
15. **Emergency services availability**	(BAD) 0______5______10 (GOOD)	+	0.01	________

FINAL STRUCTURAL SCORE S (S=summation of all modifier values from 1 to 15) **S=**

EXPECTED DAMAGE (Likely building performance)		**FURTHER EVALUATION**
S>-1.35	High probability of **Grade 5** damage, very high probability of **Grade 4** damage	(RECOMMENDED IF S < +0.35)
S€(-1.35,-0.95)	High probability of **Grade 4** damage, very high probability of **Grade 3** damage	
S€(-0.95,+0.35)	High probability of **Grade 3** damage, very high probability of **Grade 2** damage	**YES NO**
S€(+0.35,+1.35)	High probability of **Grade 2** damage, very high probability of **Grade 1** damage	
S>1.35	High probability of **Grade 1** damage	

MODIFIED DATA COLLECTION FORM FOR RAPID VISUAL SCREENING OF BUILDINGS

(based on FEMA 154 and IIT Bombay report)

(INDIAN STANDARDS SEISMIC ZONE 3 / FEMA (U.S.A.) MODERATE SEISMICITY ZONE) (FRONT)

BUILDING DETAILS:

Building Name:________________________ Address:____

Pin code:_____________ GPS Coordinates: (latitude)__________ (longitude)___________ Other Identifiers:________________

Year Built:______ No of Stories:__________ Approximate total floor area (sq. ft./ sq. m.):__________ Use:______________________

Construction drawings available(Yes/No):________ Surveyor's name:____________________ Survey date:_____________________

Additional Comments: ____

____

	BUILDING TYPE->	Wood	S1(FRAME)	S2(LM)	C1(MRF)	C2(SW)	C3(INF)	URM1(BAND+RD)	URM2(BAND+FD)	URM3	URM4
	BASIC SCORE MODIFIERS:										
1	Basic structural score	4.4	3.6	3.8	3.0	3.6	3.2	3.4	3.6	3.0	2.4
2	Low rise (<4 stories)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	Mid rise (4-7 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
3	Vertical Irregularity	-3.0	-2.0	N/A	-2.0	-2.0	-2.0	-2.0	-2.0	-1.5	-1.5
4	Plan Irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
5	Code Detailing	N/A	+1.4	N/A	+1.2	+1.6	+1.2	+2.0	+2.0	N/A	N/A
6	Soil type 1/C (Hard soil)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	Soil type 2/D(*med. soil)	-0.2	-0.6	-0.6	-0.6	-0.8	-0.6	-0.8	-0.8	-0.4	-0.4
.	Soil type 3/E (soft soil)	-0.6	-1.2	-1.0	-1.0	-1.2	-1.0	-1.2	-1.2	-0.8	-0.8
7	Special hazards like liquefiable soil, land slide prone area etc	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6

ADDITIONAL SCORE MODIFIERS: (SAME FOR ALL STRUCTURE TYPES) *med. Denotes

ADDITIONAL MODIFIER	DEGREE OF PRESENCE DOMINANCE (D)	NATURE (+/-)	WEIGHTAGE/SENSTIVITY FACTOR (W)	FINAL SCORE [= (+/-D) x (W)]
8. Bottom soft storey presence	(GOOD) 0_____5_____10 (BAD)	---	0.1	________
9. Occupancy	(GOOD) 0_____500_____1000 (BAD)	---	0.001	________
10. Condition of building	(GOOD) 0_____5_____10 (BAD)	---	0.05	________
11. Maintenance	(GOOD) 0_____5_____10 (BAD)	---	0.05	________
12. Collateral damage Vulnerability	(GOOD) 0_____5_____10 (BAD)	---	0.025	________
13. Falling hazards	(GOOD) 0_____5_____10 (BAD)	---	0.025	________
14. Ease of Evacuation	(BAD) 0_____5_____10 (GOOD)	+	0.01	________
15. Emergency services availability	(BAD) 0_____5_____10 (GOOD)	+	0.01	________

FINAL STRUCTURAL SCORE S (S=summation of all modifier values from 1 to 15) **S=**

EXPECTED DAMAGE (Likely building performance)		**FURTHER EVALUATION**
S>-1.35	High probability of **Grade 5** damage, very high probability of **Grade 4** damage	(RECOMMENDED IF S < +0.35)
SЄ(-1.35,-0.95)	High probability of **Grade 4** damage, very high probability of **Grade 3** damage	
SЄ(-0.95,+0.35)	High probability of **Grade 3** damage, very high probability of **Grade 2** damage	**YES NO**
SЄ(+0.35,+1.35)	High probability of **Grade 2** damage, very high probability of **Grade 1** damage	
S>1.35	High probability of **Grade 1** damage	

MODIFIED DATA COLLECTION FORM FOR RAPID VISUAL SCREENING OF BUILDINGS

(based on FEMA 154 and IIT Bombay report)

(INDIAN STANDARDS SEISMIC ZONE 4 AND 5 / FEMA (U.S.A.) HIGH SEISMICITY ZONE) (FRONT)

BUILDING DETAILS:

Building Name:________________________ Address:____

Pin code:____________ GPS Coordinates: (latitude)__________ (longitude)___________ Other identifiers:________________

Year Built:______ No of Stories:__________ Approximate total floor area (sq. ft./ sq. m.):__________ Use:______________________

Construction drawings available(Yes/No):________ Surveyor's name:____________________ Survey date:____________________

Additional Comments: ____

____

	BUILDING TYPE->	Wood	S1(FRAME)	S2(LM)	C1(MRF)	C2(SW)	C3(INF)	URM1(BAND+RD)	URM2(BAND+FD)	URM3	URM4
	BASIC SCORE MODIFIERS:										
1	**Basic structural score**	3.8	2.8	3.2	2.5	2.8	2.6	2.8	2.8	1.8	1.4
2	**Low rise (<4 stories)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	**Mid rise (4-7 stories)**	N/A	+0.2	N/A	+0.4	+0.4	+0.2	+0.4	+0.4	-0.2	-0.4
.	**High rise (>7 stories)**	N/A	+0.6	N/A	+0.6	+0.8	+0.3	N/A	N/A	N/A	N/A
3	**Vertical Irregularity**	-2.0	-1.0	N/A	-1.5	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
4	**Plan Irregularity**	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
5	**Code Detailing**	N/A	+0.4	N/A	+0.2	+1.4	+0.2	N/A	N/A	N/A	N/A
6	**Soil type 1/C (Hard soil)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
.	**Soil type 2/D(*med. soil)**	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
.	**Soil type 3/E (soft soil)**	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6
7	**Special hazards like liquefiable soil, land slide prone area etc**	-0.8	-1.2	-1.0	-1.2	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8

ADDITIONAL SCORE MODIFIERS: (SAME FOR ALL STRUCTURE TYPES) *med. Denotes medium

ADDITIONAL MODIFIER	DEGREE OF PRESENCE DOMINANCE (D)	NATURE (+/-)	WEIGHTAGE/SENSTIVITY FACTOR (W)	FINAL SCORE [= (+/-D) x (W)]
8. **Bottom soft storey presence**	(GOOD) 0______5______10 (BAD)	---	0.1	__________
9. **Occupancy**	(GOOD) 0______500______1000 (BAD)	---	0.001	__________
10. **Condition of building**	(GOOD) 0______5______10 (BAD)	---	0.05	__________
11. **Maintenance**	(GOOD) 0______5______10 (BAD)	---	0.05	__________
12. **Collateral damage Vulnerability**	(GOOD) 0______5______10 (BAD)	---	0.025	__________
13. **Falling hazards**	(GOOD) 0______5______10 (BAD)	---	0.025	__________
14. **Ease of Evacuation**	(BAD) 0______5______10 (GOOD)	+	0.01	__________
15. **Emergency services availability**	(BAD) 0______5______10 (GOOD)	+	0.01	__________

FINAL STRUCTURAL SCORE S (S=summation of all modifier values from 1 to 15) **S=**

EXPECTED DAMAGE (Likely building performance)	**FURTHER EVALUATION**
S>-1.35 High probability of **Grade 5** damage, very high probability of **Grade 4** damage **SЄ(-1.35,-0.95)** High probability of **Grade 4** damage, very high probability of **Grade 3** damage **SЄ(-0.95,+0.35)** High probability of **Grade 3** damage, very high probability of **Grade 2** damage **SЄ(+0.35,+1.35)** High probability of **Grade 2** damage, very high probability of **Grade 1** damage **S>1.35** High probability of **Grade 1** damage	(RECOMMENDED IF S < +0.35) **YES NO**

(BACK)

SKETHCHES OF LAYOUT (PLAN AND ELEVATION)	
PLAN	ELEVATION
PHOTOGRAPHS	

CHAPTER 4

SALIENT FEATURES OF MS EXCEL PROGRAM DEVELOPED (RVS)

4.1 OVERVIEW

In accordance with RVS methodologies mentioned by IS 13935:2009 and by FEMA P-154 (3rd edition) 2 MS Excel Spreadsheets have been created separately. The first Excel program is based on the RVS method mentioned by IS 13935:2009 and hence provides results in accordance with this. (This program is used mainly for comparative purposes later on). The second Excel program is based on the new modified RVS system as explained previously. This one however is also set to provide results in accordance with FEMA guidelines and gives a comparative analysis result and provides results side by side with both methods.

The need for manual entering of data has been completely eradicated as the sheet is programmed to accept binary inputs only i.e. 1 or 0 to generate a true or false logic statement. This provides a speedier approach. Moreover, there is no need to carry operation manual along by the screener while conducting the survey as the first page in the sheet is dedicated to theory and basic instructions regarding the working and operating procedures of the RVS software. This leads to an even shorter execution time as the surveyor can accomplish the task on a handheld tablet or a sufficiently advanced smartphone or PDA. The program, also, automatically saves the data in the spreadsheet itself which can be easily read and retrieved later on.

The programs is designed on the basis of a *user friendly* GUI. Every tab of import is colour coded along with comments and instructions entered at suitable locations. These are aimed towards user comfort and ease of operations. The results generated are in simple English text or numerical values which are easy to understand as compared to the archaic manual forms. The logical operators in the formula are simple statements formed along basic functions such as IF clause, ELSE, nested IF ELSE, AND, OR, and text based output operators which are easy to comprehend and alter as per need. The results also include a generated comment based on the structural score obtained by the building, extent of possible damage, need for evaluation or basic performance.

4.2 MS EXCEL PROGRAM IN ACCORDANCE WITH BIS (BEUREAU OF INDIAN STANDARDS)

This excel program is based on the BIS committee reports and IS code IS 13935:2009

The Excel program includes **5 worksheets**

Sheet 1: This sheet is an instruction manual for the screener to follow while conducting the RVS. It also contains the basic references and alphanumeric codes used to refer to various types of structures, namely, RCC, masonry or steel and the estimated damage which the structure could undergo during seismic activity. The sheet also lists the various abbreviations used throughout the excel spreadsheet and the basic gauging criteria.

Sheet 2- Sheet5: These sheets are created specifically for the zones as per IS 1893:2002 (zone 2, 3, 4, and 5). The sheets are have colour coded segments in the form of green and red cells. The green cells are used to Input general data such as basic details, structure type, special hazards, codal provisions etc. The red cells display the alphanumeric output comments.

To begin the survey the screener is advised to carefully read the first sheet and select the requisite seismic zone from among the bottom tabs. This should be followed by the basic data entry in the green cells. The data entered such should be entered carefully. This data can include alphanumeric values and is purely for record keeping purposes only. The rest of the cells take an binary data form where 0 indicates the absence of the parameter being entered while 1 signifies the presence of the same in the structure. The first sheet may be used as a reference guide in filling up this data.

After the completion of the data entry process, the program will analyse the inputs and display the outputs in the red zone of the sheet. The output is of alphanumeric form and represents the damageability grade of the structure under scrutiny and the recommendations for the same. The specific values are present in a tabular form in sheet number 1 and hence must be referred to from there.

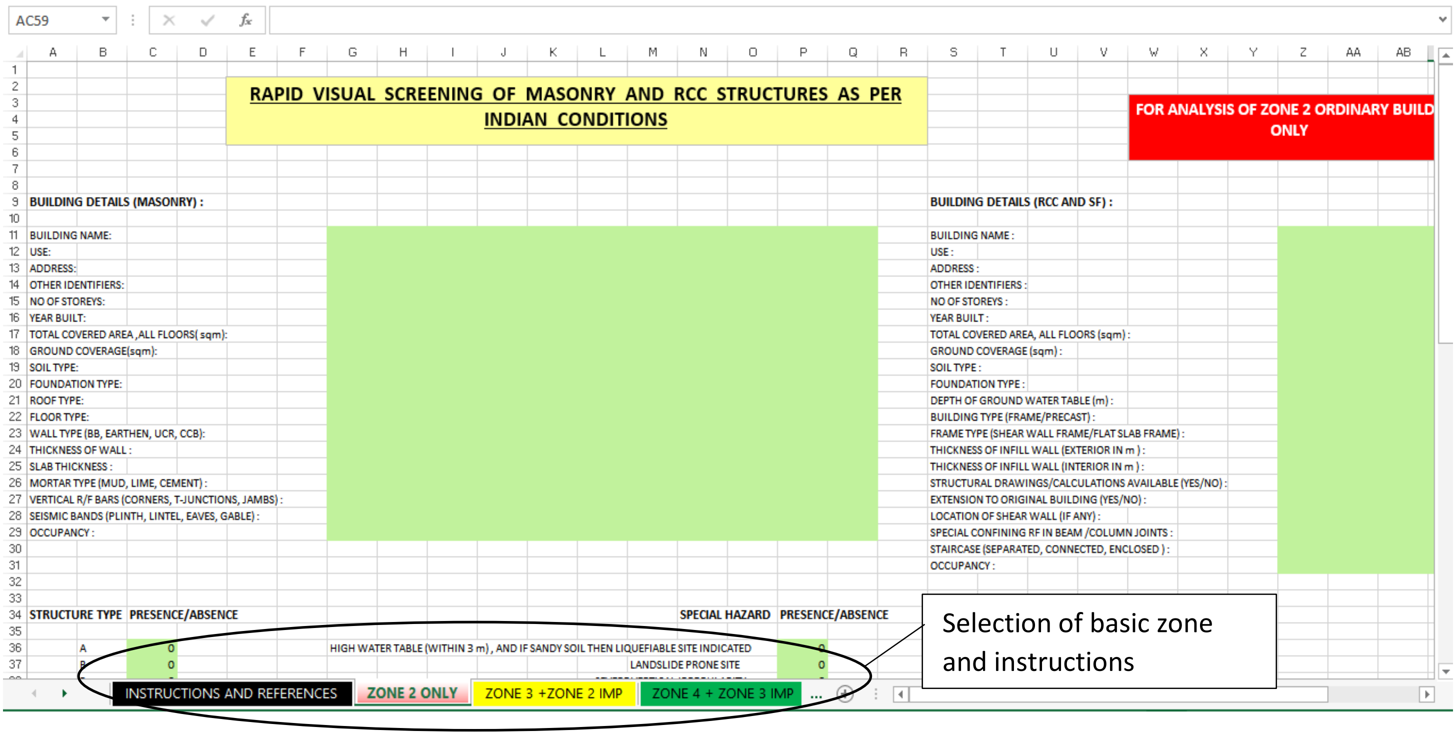
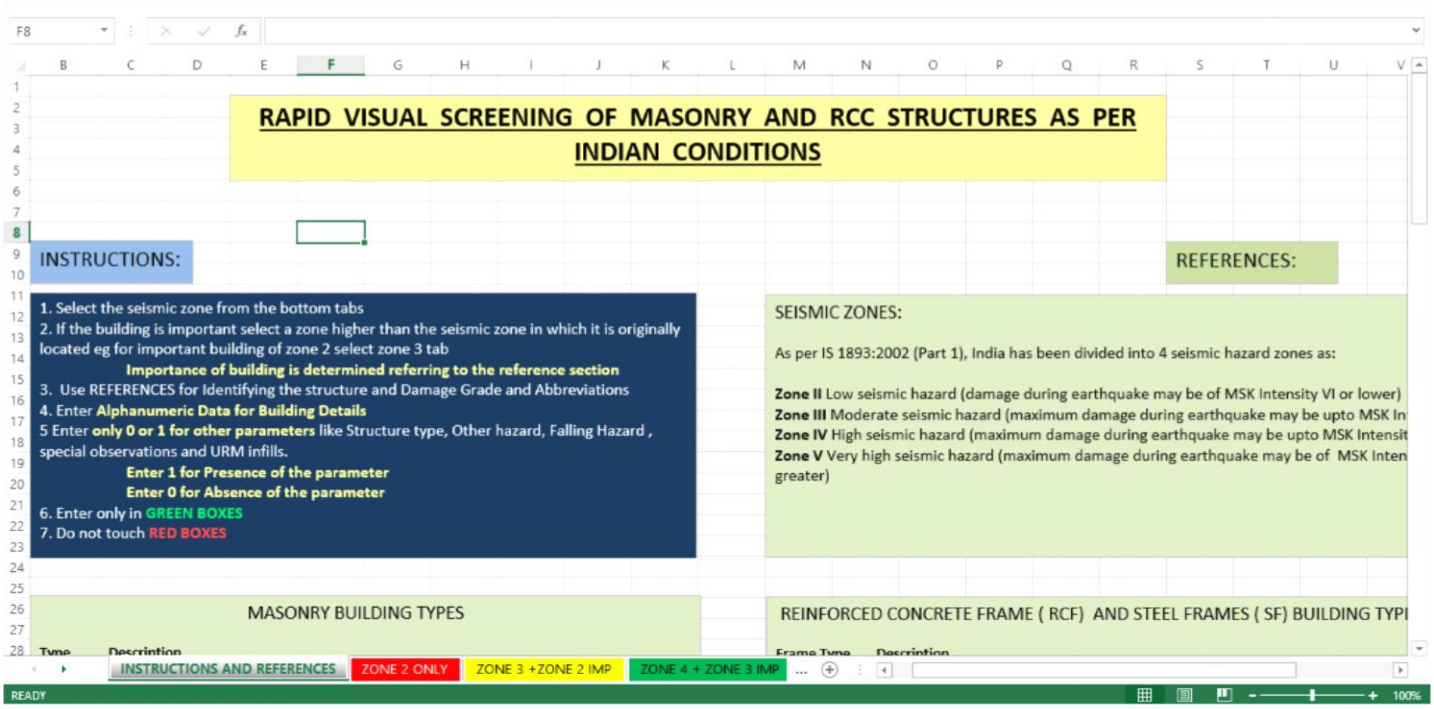
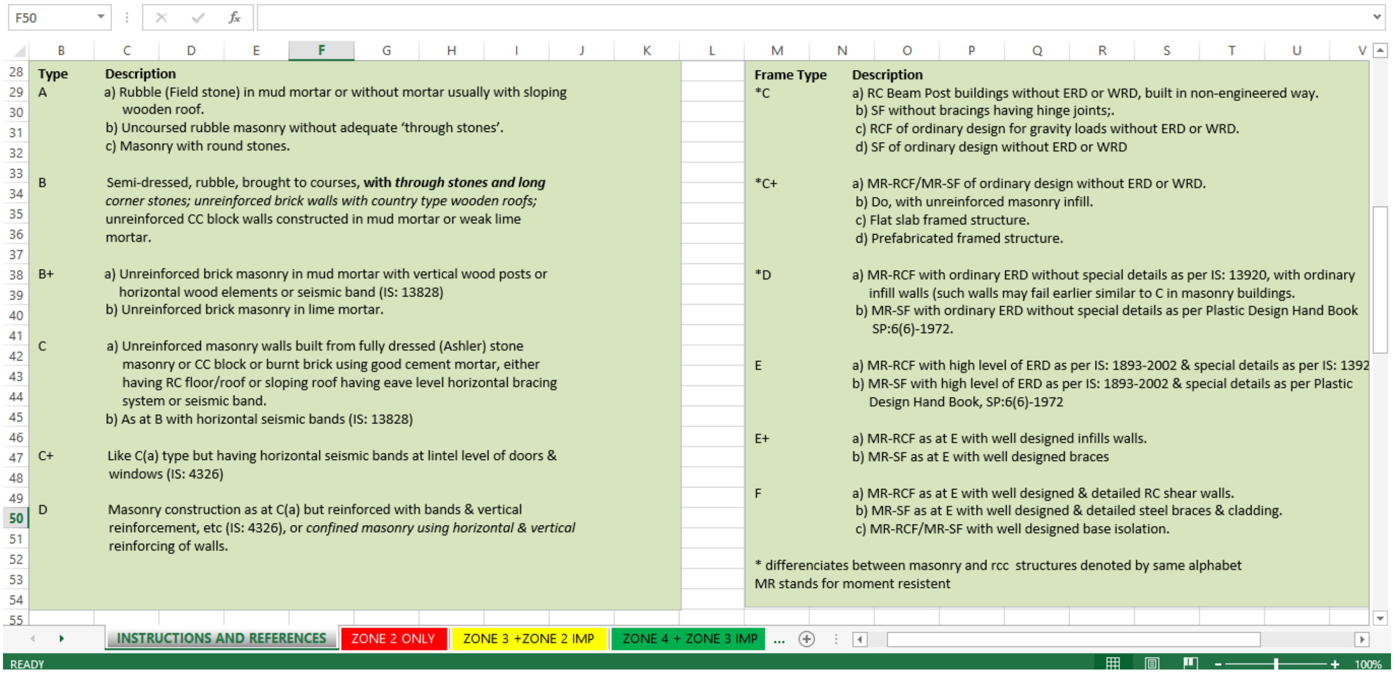


Fig. 4.1: MS Excel program screenshots (RVA)



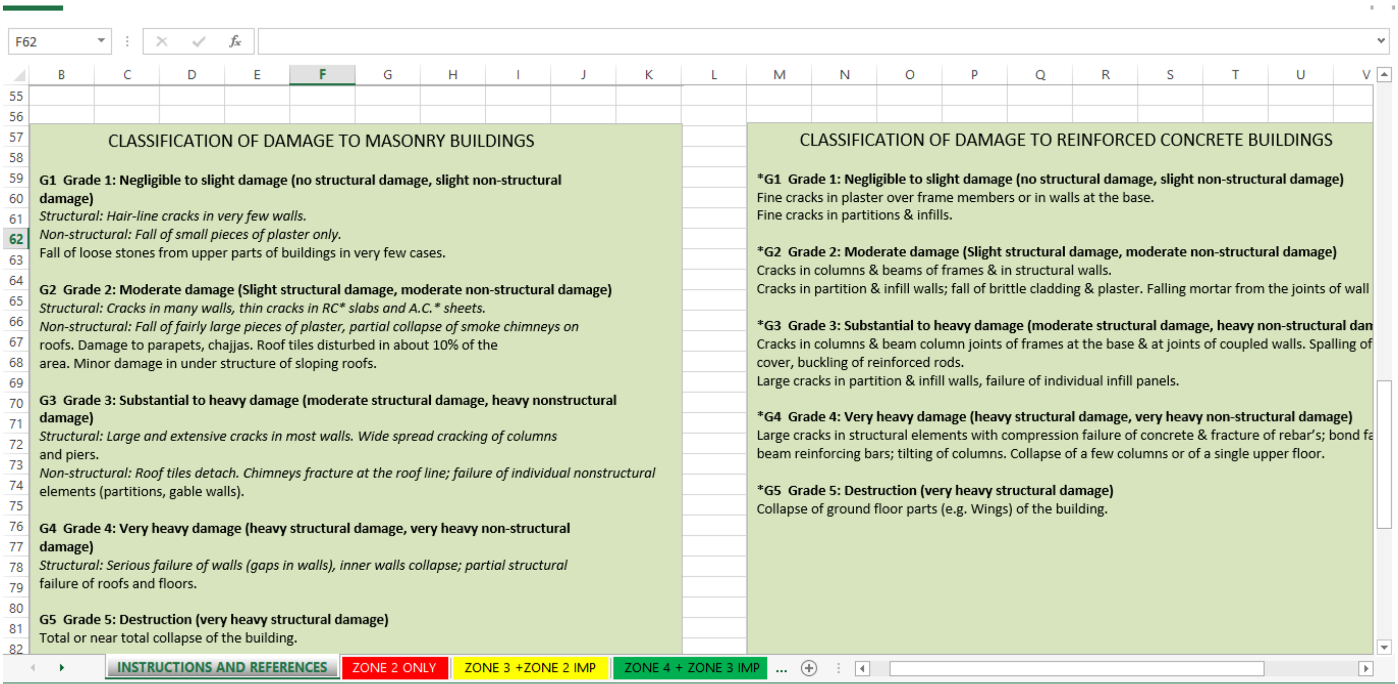


Type	Description
A	a) Rubble (Field stone) in mud mortar or without mortar usually with sloping wooden roof. b) Uncoursed rubble masonry without adequate 'through stones'. c) Masonry with round stones.
B	Semi-dressed, rubble, brought to courses, **with *through stones and long*** *corner stones; unreinforced brick walls with country type wooden roofs;* unreinforced CC block walls constructed in mud mortar or weak lime mortar.
B+	a) Unreinforced brick masonry in mud mortar with vertical wood posts or horizontal wood elements or seismic band (IS: 13828) b) Unreinforced brick masonry in lime mortar.
C	a) Unreinforced masonry walls built from fully dressed (Ashler) stone masonry or CC block or burnt brick using good cement mortar, either having RC floor/roof or sloping roof having eave level horizontal bracing system or seismic band. b) As at B with horizontal seismic bands (IS: 13828)
C+	Like C(a) type but having horizontal seismic bands at lintel level of doors & windows (IS: 4326)
D	Masonry construction as at C(a) but reinforced with bands & vertical reinforcement, etc (IS: 4326), or *confined masonry using horizontal & vertical* reinforcing of walls.

Frame Type	Description
*C	a) RC Beam Post buildings without ERD or WRD, built in non-engineered way. b) SF without bracings having hinge joints;. c) RCF of ordinary design for gravity loads without ERD or WRD. d) SF of ordinary design without ERD or WRD
*C+	a) MR-RCF/MR-SF of ordinary design without ERD or WRD. b) Do, with unreinforced masonry infill. c) Flat slab framed structure. d) Prefabricated framed structure.
*D	a) MR-RCF with ordinary ERD without special details as per IS: 13920, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings. b) MR-SF with ordinary ERD without special details as per Plastic Design Hand Book SP:6(6)-1972.
E	a) MR-RCF with high level of ERD as per IS: 1893-2002 & special details as per IS: 1392 b) MR-SF with high level of ERD as per IS: 1893-2002 & special details as per Plastic Design Hand Book, SP:6(6)-1972
E+	a) MR-RCF as at E with well designed infills walls. b) MR-SF as at E with well designed braces
F	a) MR-RCF as at E with well designed & detailed RC shear walls. b) MR-SF as at E with well designed & detailed steel braces & cladding. c) MR-RCF/MR-SF with well designed base isolation.

* differenciates between masonry and rcc structures denoted by same alphabet
MR stands for moment resistent

Fig. 4.2: Reference section MS Excel Program



CLASSIFICATION OF DAMAGE TO MASONRY BUILDINGS

G1 Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)
Structural: Hair-line cracks in very few walls.
Non-structural: Fall of small pieces of plaster only.
Fall of loose stones from upper parts of buildings in very few cases.

G2 Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage)
Structural: Cracks in many walls, thin cracks in RC slabs and A.C.* sheets.*
Non-structural: Fall of fairly large pieces of plaster, partial collapse of smoke chimneys on roofs. Damage to parapets, chajjas. Roof tiles disturbed in about 10% of the area. Minor damage in under structure of sloping roofs.

G3 Grade 3: Substantial to heavy damage (moderate structural damage, heavy nonstructural damage)
Structural: Large and extensive cracks in most walls. Wide spread cracking of columns and piers.
Non-structural: Roof tiles detach. Chimneys fracture at the roof line; failure of individual nonstructural elements (partitions, gable walls).

G4 Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)
Structural: Serious failure of walls (gaps in walls), inner walls collapse; partial structural failure of roofs and floors.

G5 Grade 5: Destruction (very heavy structural damage)
Total or near total collapse of the building.

CLASSIFICATION OF DAMAGE TO REINFORCED CONCRETE BUILDINGS

***G1 Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)**
Fine cracks in plaster over frame members or in walls at the base.
Fine cracks in partitions & infills.

***G2 Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage)**
Cracks in columns & beams of frames & in structural walls.
Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall

***G3 Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural dan**
Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of cover, buckling of reinforced rods.
Large cracks in partition & infill walls, failure of individual infill panels.

***G4 Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)**
Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond fa beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.

***G5 Grade 5: Destruction (very heavy structural damage)**
Collapse of ground floor parts (e.g. Wings) of the building.

Fig. 4.2 (Continued)

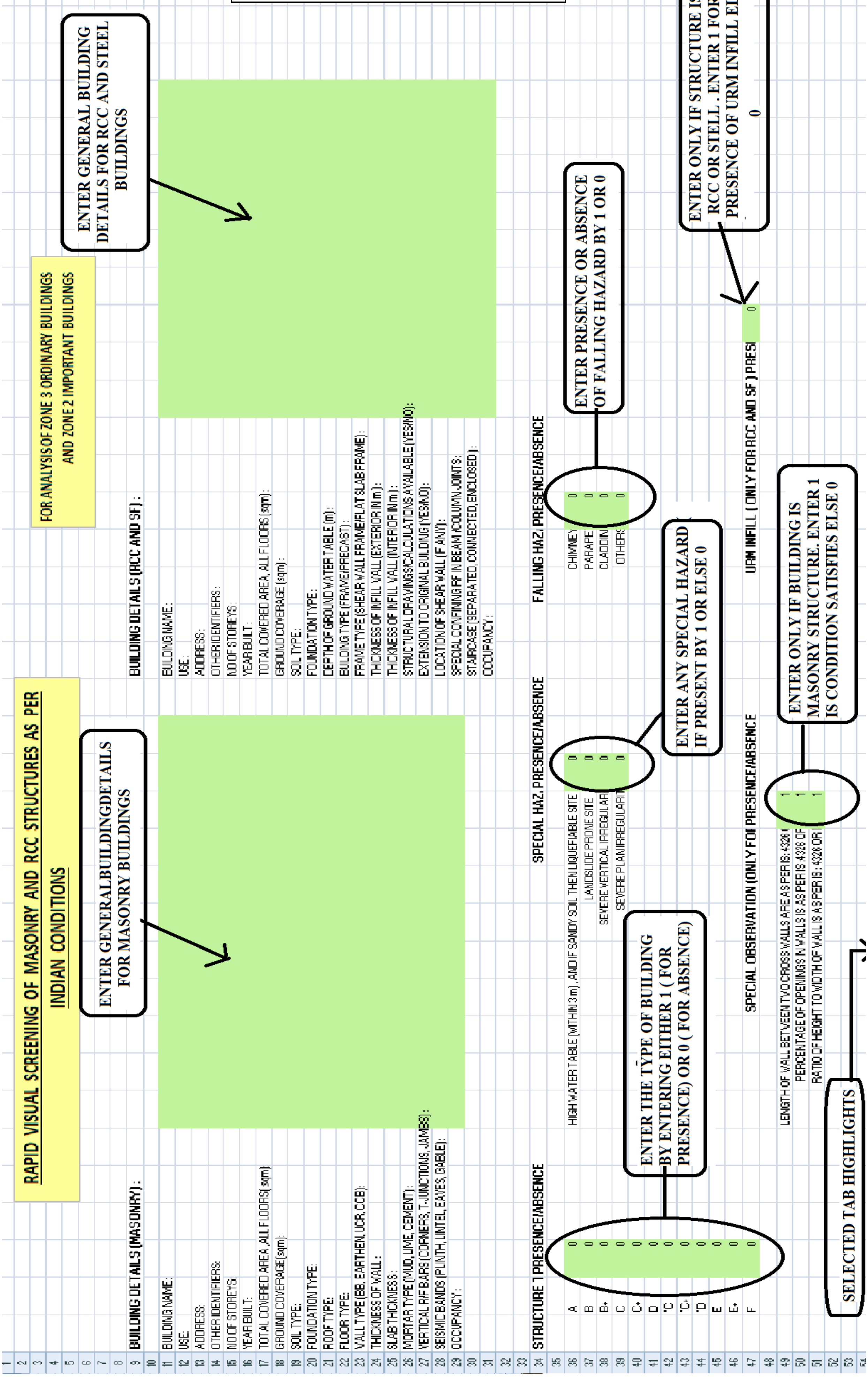
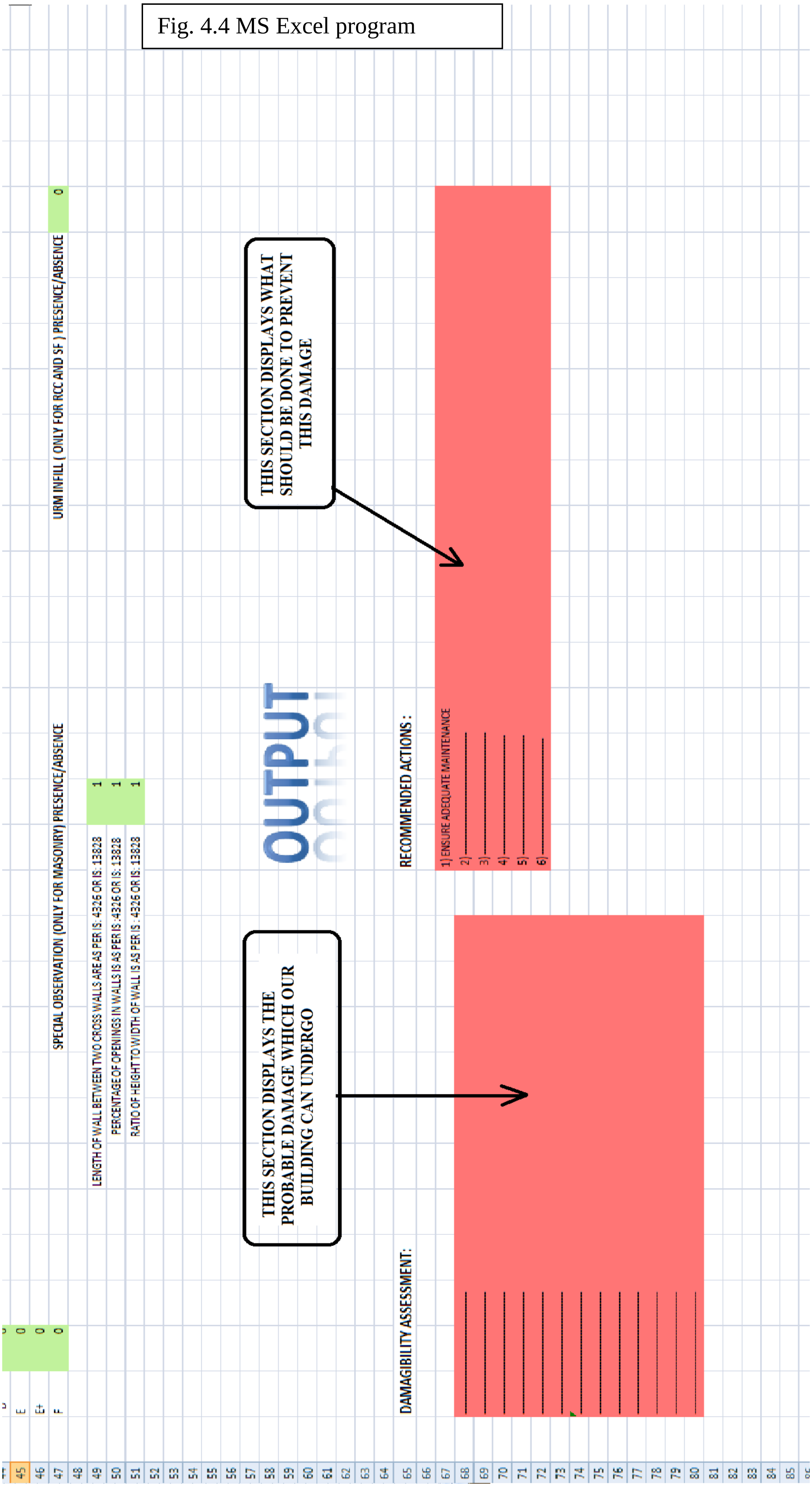


Fig. 4.3 MS Excel program inputs

Fig. 4.4 MS Excel program



4.3 MODIFIED MS EXCEL SHEET FOR RVS SYSTEM (BASED ON FEMA METHODOLOGY)

The Excel program consists of **4 worksheets**

Sheet 1: This sheet includes the instructions for the screener to follow while using RVS with the aid of this program. It contains the references as well as the abbreviations used for various structural forms and the type of damageability for every form This sheet is to be used as a reference while conducting the procedure.

In the addition to the reference material and instructions this sheet also contains links to various documents which can be studied by the screener if he/she wishes to acquire in-depth knowledge of the scoring system and the additional modifiers being used.

Sheet 2-4: These are sheets specific to the four seismic zones of India (Zone 2-5) . Seismic zone 4 and 5 are considered collectively under the high seismicity zone that is specified in FEMA manuals. The sheets are colour coded with green being for basic input cells. These include data like building details, basic score modifiers and presence of additional modifiers and their degree of effect. Yellow and pink cells represent the output cells that show data such as score modifiers and the final scores.

The first step to be taken by the screener is a careful study of the basic instructions as laid down in sheet 1 and then select the suitable tab for the seismic zone. The input data in the green boxes should be entered carefully with a unique building number being used every time. The data to be entered can be alphanumeric and the building details are needed just for accurate book keeping. These will have no impact on the score. However, the data to be entered in the scoring portion must be of numeric form only as explained in the instruction sheet.

Basic score modifiers require data to be entered in binary form only i.e. 0 or 1 with 0 denoting the absence of the recorded factor and 1 being the presence.

The data entry cells for additional score modifiers must be filled with numerical values ranging from 0 to 10 (except for occupancy). This multiplied by their weight factor will show the score modifier value for that particular feature under consideration.

Once the data entry step is complete the program will automatically calculate and display the scores, modifiers and the values according to FEMA and the modified system. The output includes score, damageability values and the assessment/evaluation needed.

The final step of the method is to hit the next building tab present on the sheet which will reset the input cells and hence allow input of a new data value and continuation of the survey.

Fig. 4.5: MS Excel screenshots of modified RVS system

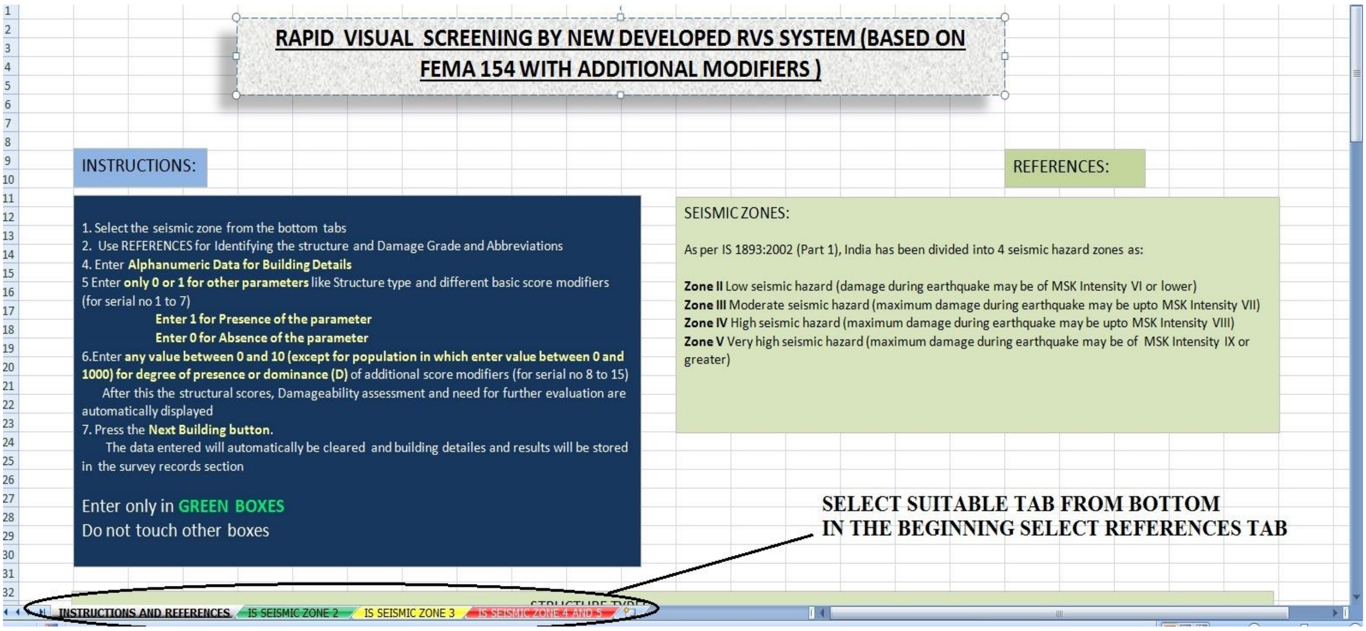
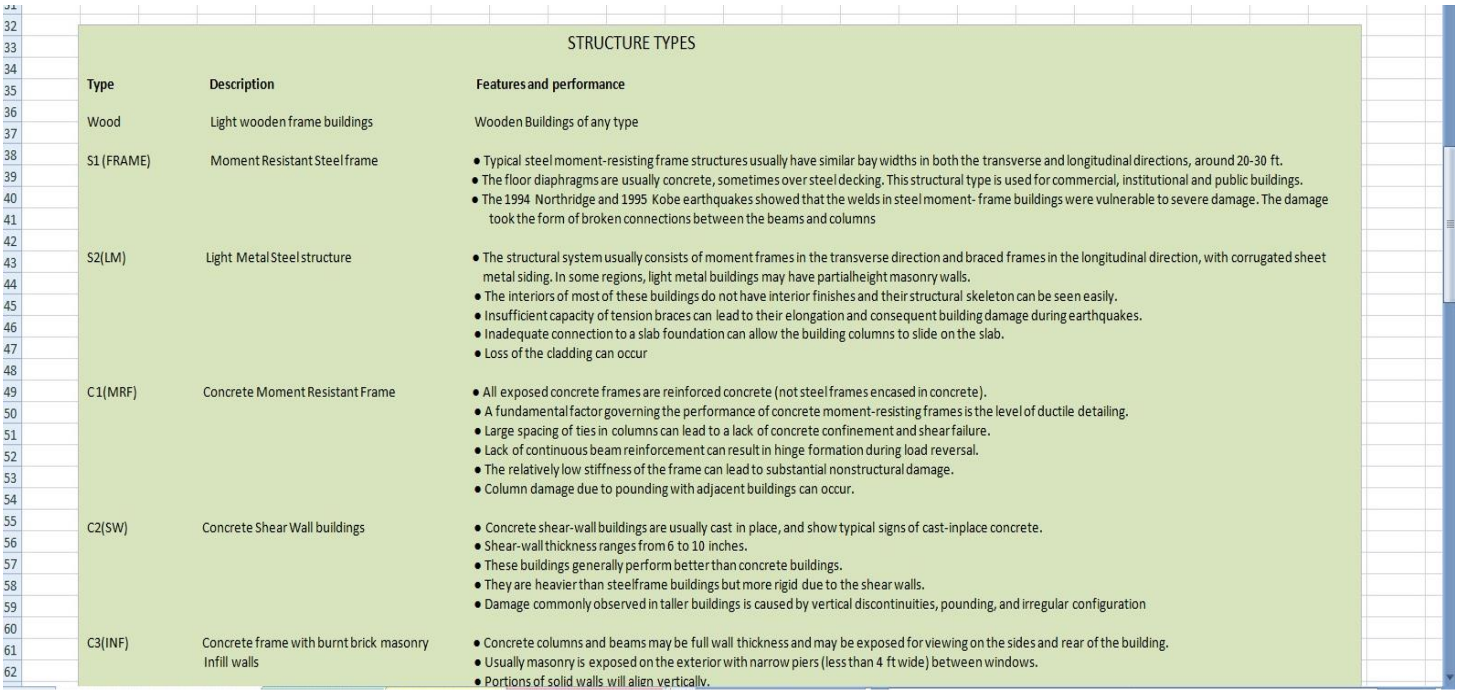


Fig. 4.6: Reference section in MS excel for modified RVS System



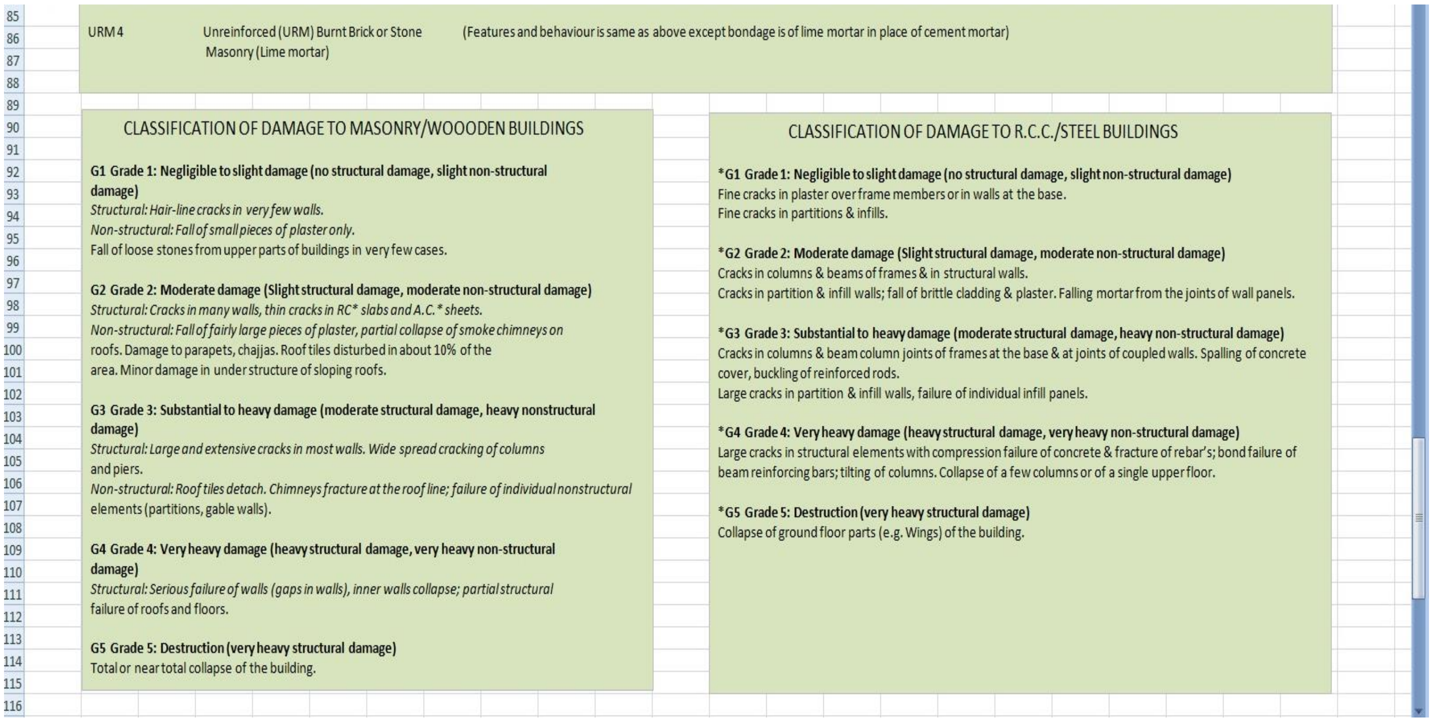


Fig. 4.7: Important document links in Excel sheet (modified RVS system)

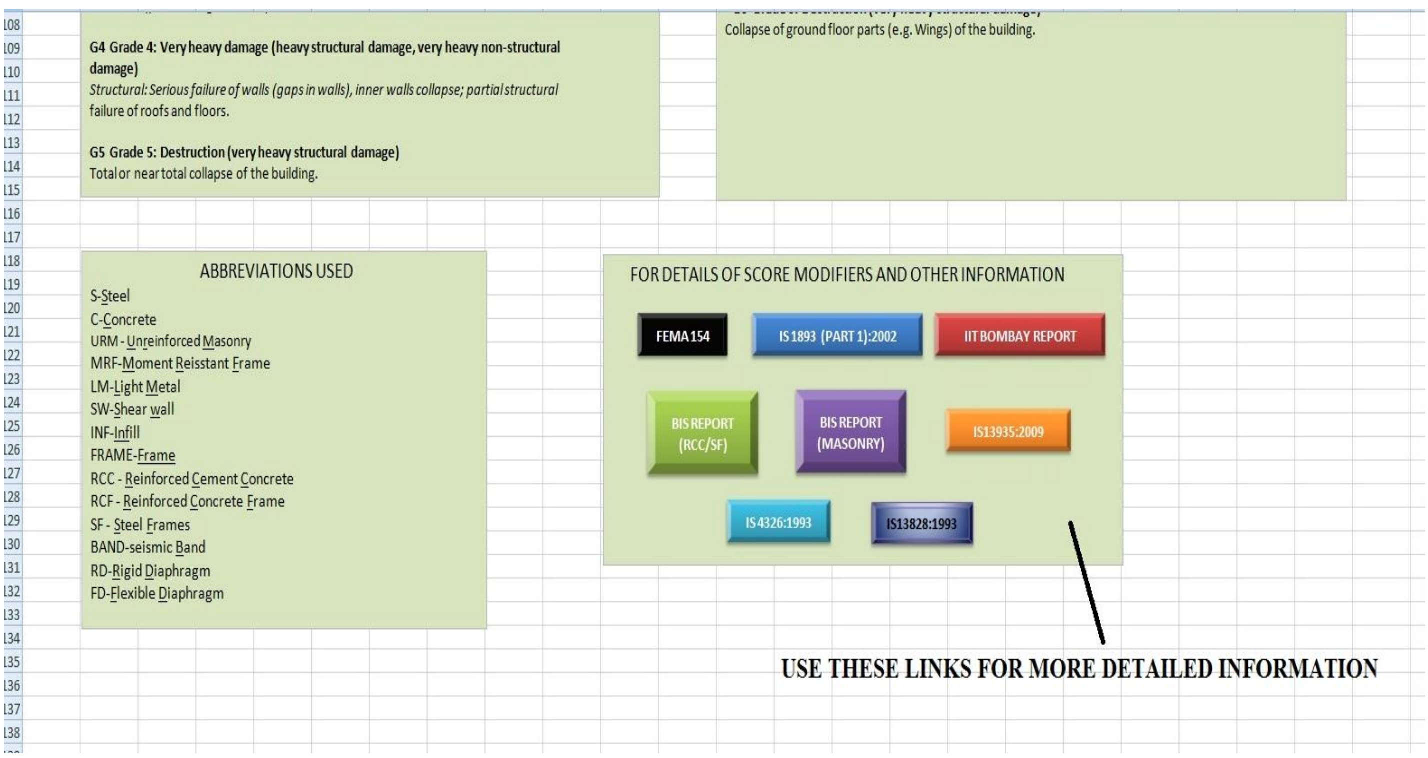
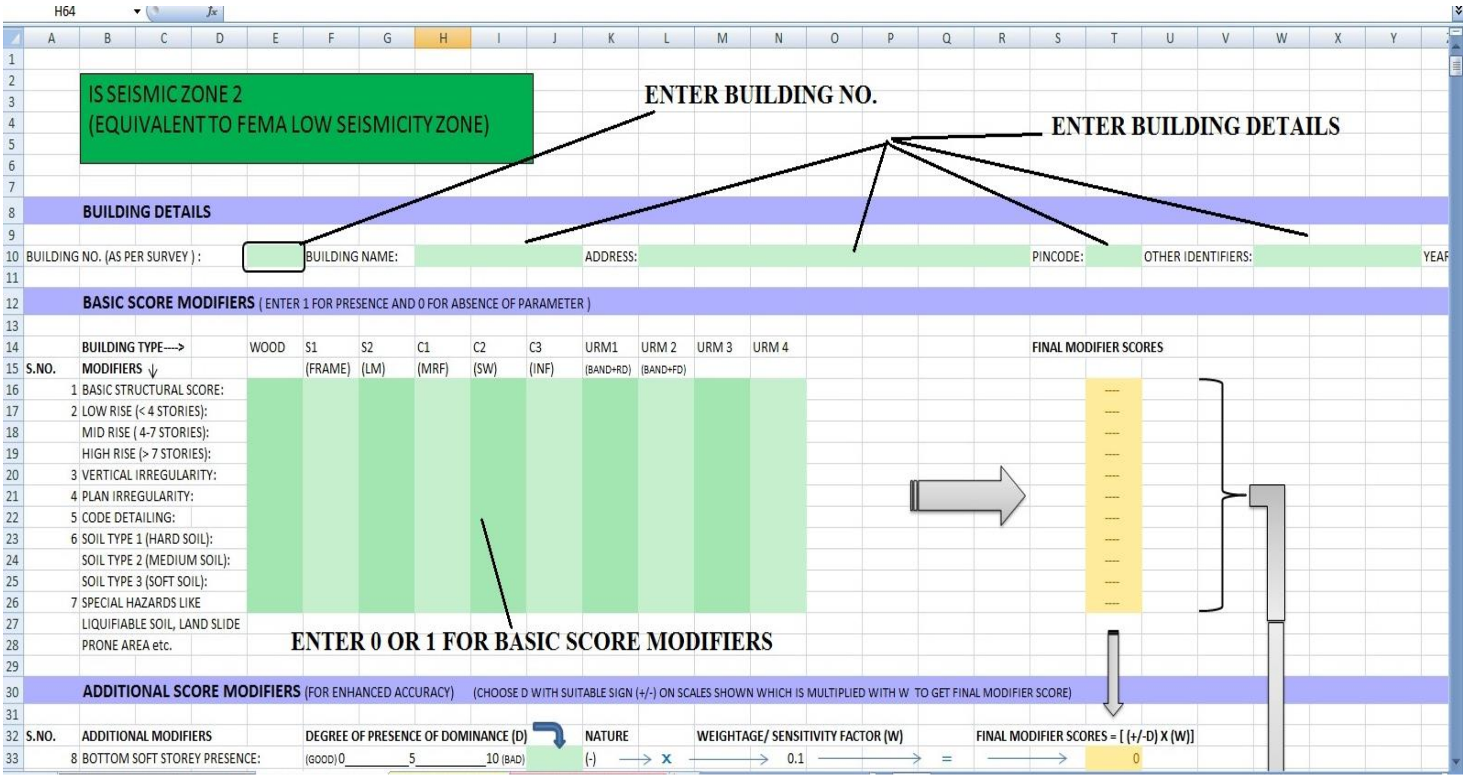


Fig. 4.8: Input section (MS Excel) of modified RVS system



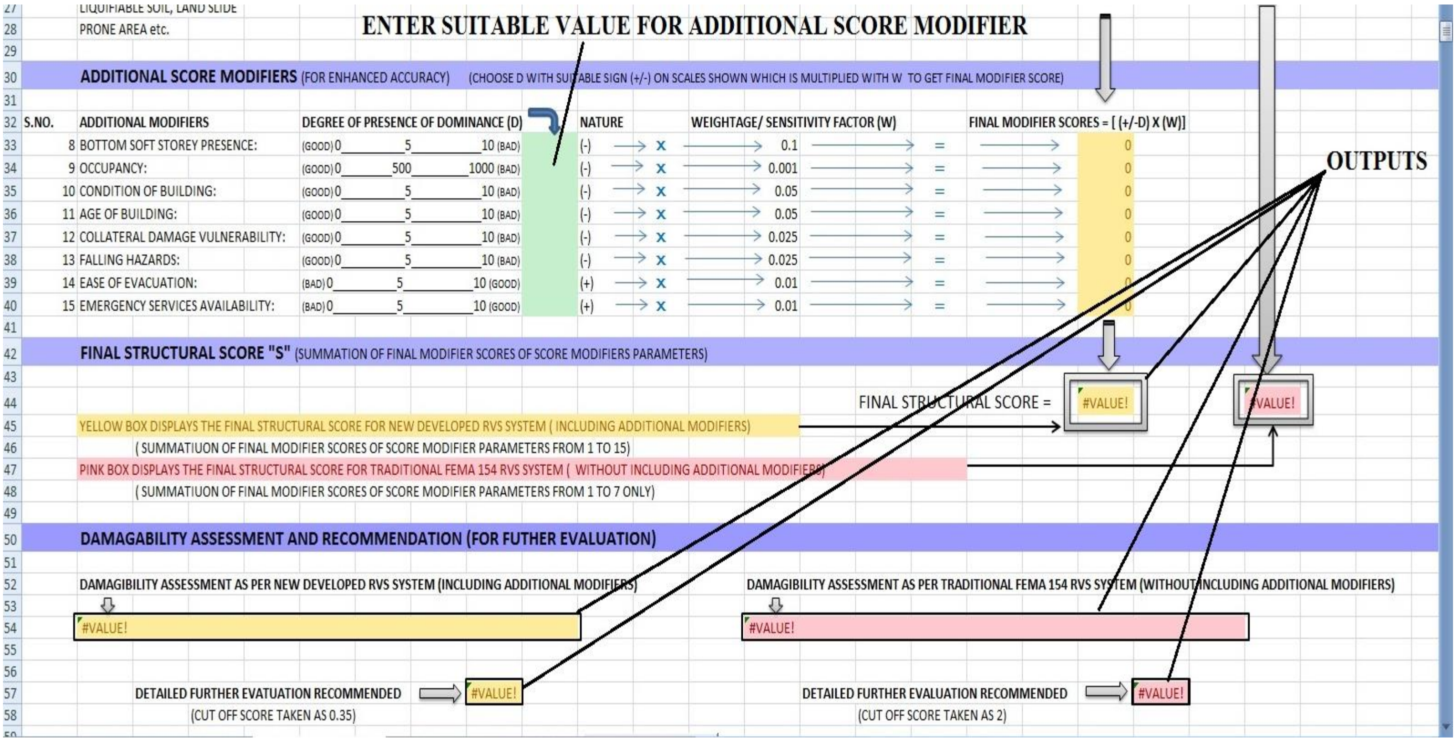
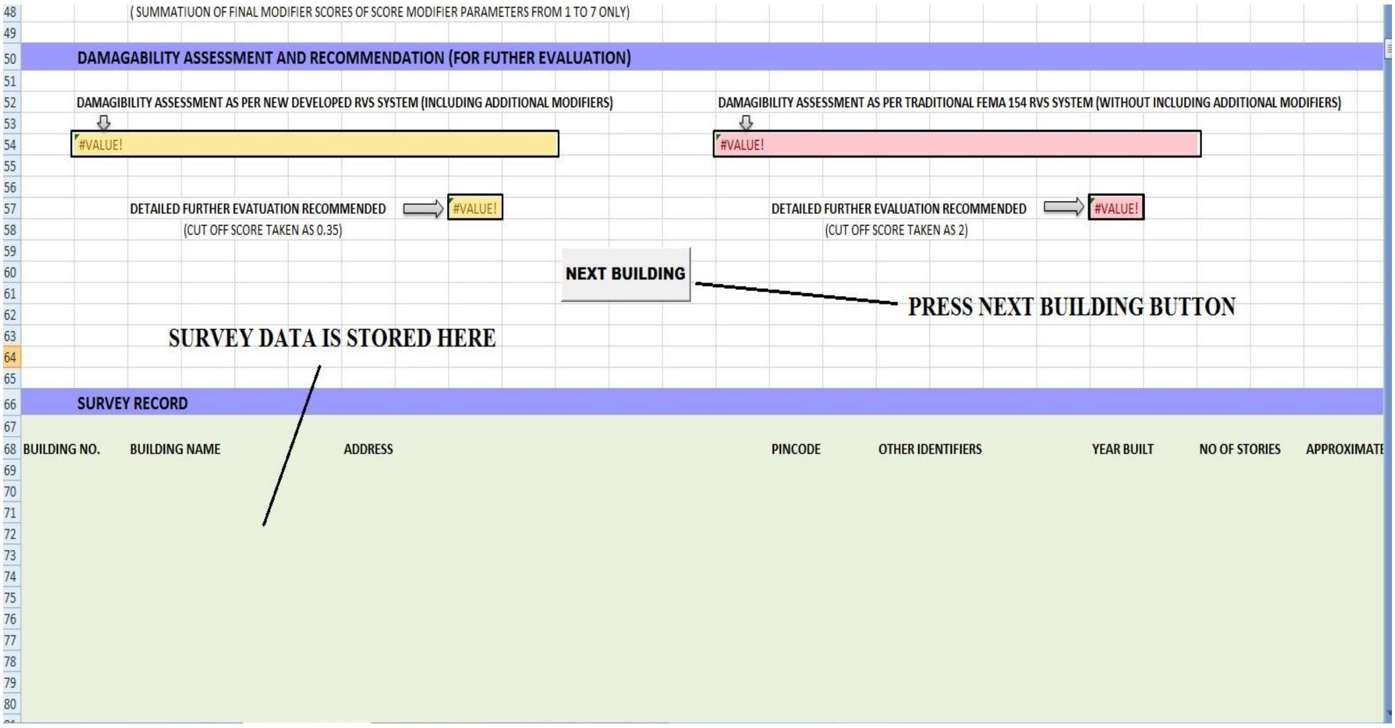


Fig. 4.9: Program outputs, results section (MS Excel) of modified RVS system



CHAPTER 5

SURVEY AND STUDY

5.1 OVERVIEW

In order to determine the viability of the method developed and to derive scores according to the process formulated above, Rapid Visual Screening of a number of structures was carried out in the city of Ludhiana, Punjab. The buildings selected provide a representative sample of vulnerable localities in the area including old town sections as well as commercial buildings.

The above mentioned structures were also scored by the traditional FEMA guidelines to provide a comparative sample data to draw inferences from. Since most of the structures surveyed were of masonry type the method specified by BIS was also used and a comparison between the three methods was made.

Photographs for each structure are attached along with their index number in the report. A representative photograph for the general construction form is otherwise mentioned for the areas where singular construction forms were prevalent such as in government colonies. In certain structures photography or entry was prohibited to the general public and hence the surveyor has used his own discretion to score those buildings.

5.2 SOIL TYPE

The nature and type of soil along with the liquefaction risk has been compiled from various regional reports as well as government databases. In certain cases direct consultation from the engineer in charge of the area has been carried out. Detailed soil investigation techniques are not permitted in RVS since it is a level 0 investigation technique.

South-western Punjab is mainly dominated by calcareous soil which includes desert soil and sierozem soil. The pH value in this zone ranges from 7.8 to 8.5 and also have grey and red desert soil, calsisol soil, regosol soil and alluvial soil. The soil of central Punjab ranges from sandy loam to clayey with pH value from 7.8 to 8.5 making alkalinity and salinity problematic for this place. The alluvial soil of this zone can be widely described as arid and brown soil or tropical arid brown soil. The soil in Eastern Punjab is loamy to clayey. Ludhiana falls in central Punjab.

Liquefaction risk is most commonly associated with loose sands submerged under a high water table resulting in liquefaction under seismic forces. Since the soil in Ludhiana is basically alluvium which has a very low liquefaction risk the relevant parameter was taken as 0 in the report for every zone. This is further supported by the site engineer for certain structures as well as a lack of investigative techniques permitted

.

5.3 SURVEY OBSERVATIONS

5.3.1 STRUCTURAL SURVEY OBSERVATIONS MADE:

Table 5.1: Survey data for structure 1

BUILDING NUMBER	1
	
BUILDING NAME	Railway Quarters
ADDRESS	222, Railway Colony 10
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	9
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	5
FALLING HAZARDS:	5
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.2: Survey data for structure 2

BUILDING NUMBER	2
	
BUILDING NAME	Railway Quarters
ADDRESS	236, Railway Colony 10
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	30
CONDITION OF BUILDING:	5
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	2
FALLING HAZARDS:	4
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.3: Survey data for structure 3

BUILDING NUMBER	3
	
BUILDING NAME	Railway Quarters
ADDRESS	220, Railway Colony 10
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	5
FALLING HAZARDS:	4
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.4: Survey data for structure 4

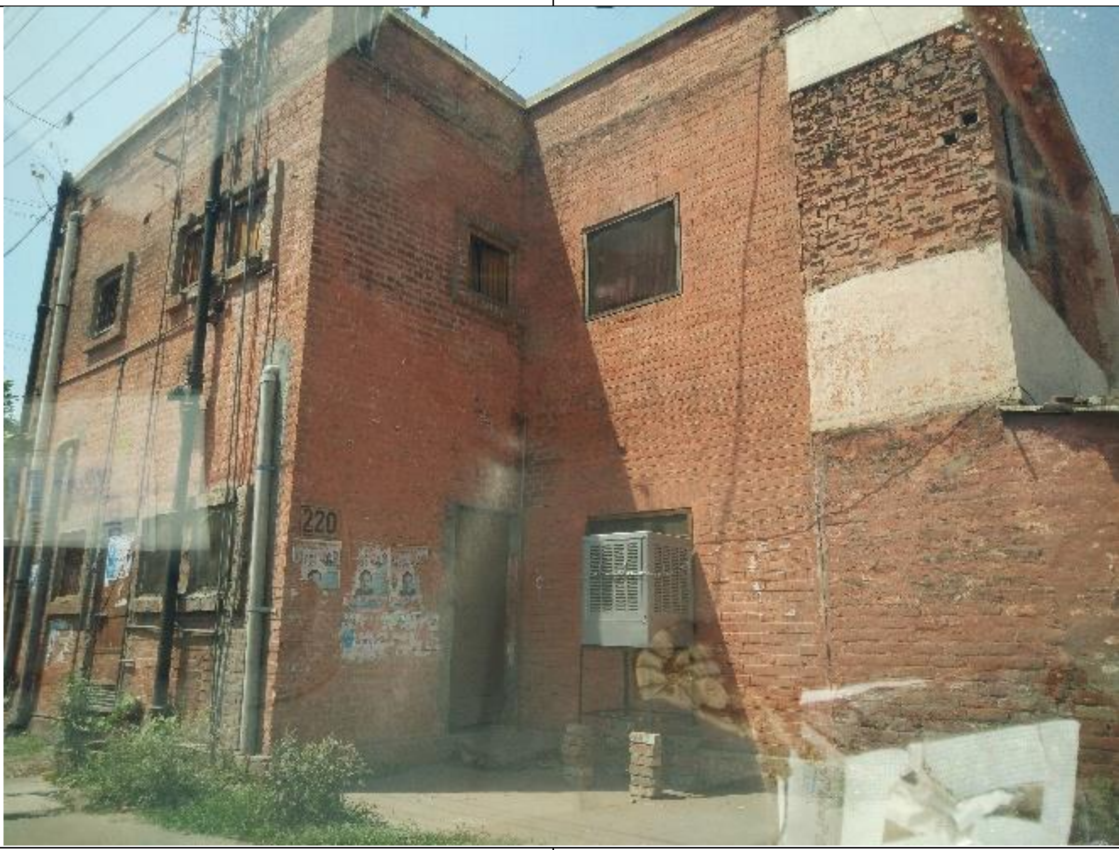
BUILDING NUMBER	4
	
BUILDING NAME	Railway Quarters
ADDRESS	230, Railway Colony 10
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	5
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	5
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.5: Survey data for structure 5

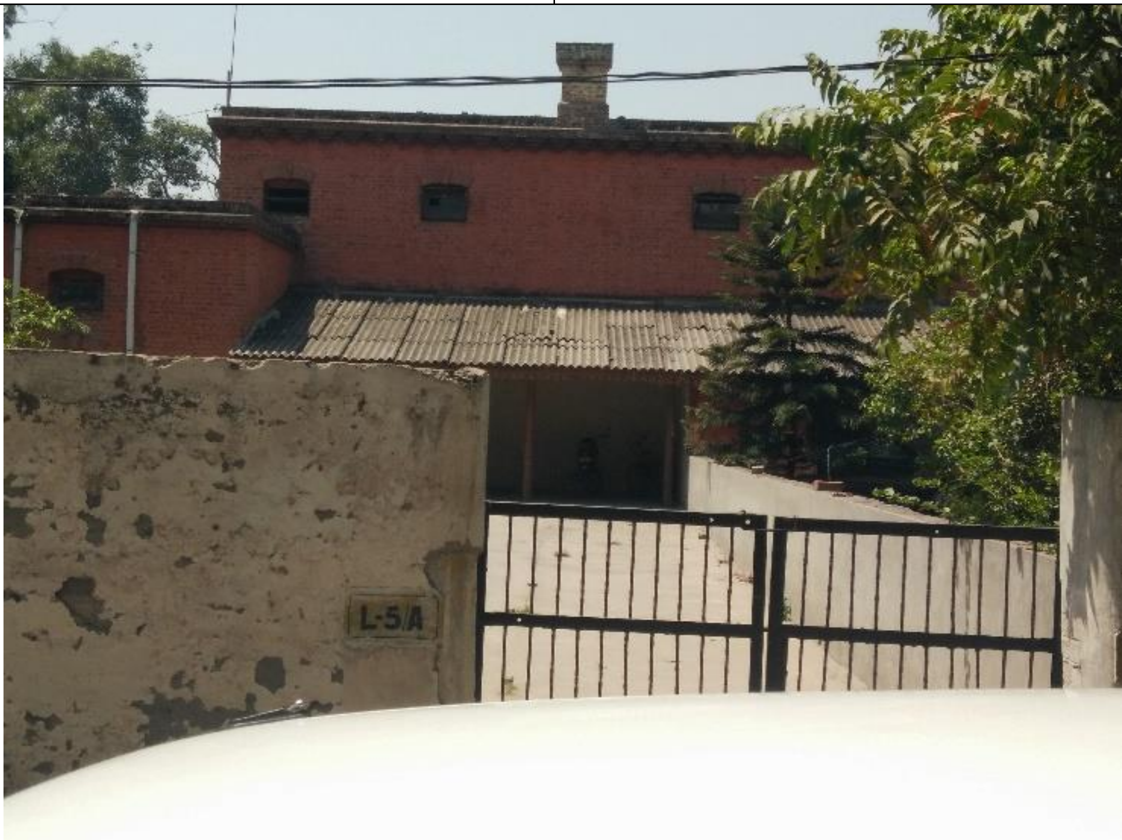
BUILDING NUMBER	5
	
BUILDING NAME	Railway Bungalow
ADDRESS	L-5/A, Railway Colony 9
NO. OF STORIES	1
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	9
CONDITION OF BUILDING:	3
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	0
FALLING HAZARDS:	1
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.6: Survey data for structure 6

BUILDING NUMBER	6
	
BUILDING NAME	Railway Quarters
ADDRESS	362, Railway Colony 9
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	5
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	2
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.7: Survey data for structure 7

BUILDING NUMBER	7
	
BUILDING NAME	Railway Quarters
ADDRESS	285, Railway Colony 7
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	15
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	3
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.8: Survey data for structure 8

BUILDING NUMBER	8
	
BUILDING NAME	Railway Quarters
ADDRESS	284, Railway Colony 7
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	15
CONDITION OF BUILDING:	5
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	3
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.9: Survey data for structure 9

BUILDING NUMBER	9
	
BUILDING NAME	Railway Quarters
ADDRESS	336, Railway Colony 7
NO. OF STORIES	3
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	30
CONDITION OF BUILDING:	6
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	5
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.10: Survey data for structure 10

BUILDING NUMBER	10
	
BUILDING NAME	Railway Quarters
ADDRESS	361, Railway Colony 7
NO. OF STORIES	3
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	30
CONDITION OF BUILDING:	6
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	3
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.11: Survey data for structure 11

BUILDING NUMBER	11
	
BUILDING NAME	Railway Quarters
ADDRESS	283, Railway Colony 7
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	7
MAINTENANCE RECORD:	3
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	5
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.12: Survey data for structure 12

BUILDING NUMBER	12
	
BUILDING NAME	Railway Quarters
ADDRESS	270, Railway Colony 8
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	15
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	5
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.13: Survey data for structure 13

BUILDING NUMBER	13
	
BUILDING NAME	Railway Quarters
ADDRESS	269, Railway Colony 8
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	15
CONDITION OF BUILDING:	10
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	4
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.14: Survey data for structure 14

BUILDING NUMBER	14

BUILDING NAME	EPFO
ADDRESS	Employee Provident Fund Organization, Shyam Nagar
NO. OF STORIES	5
USE	Government
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	100
CONDITION OF BUILDING:	2
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	4
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.15: Survey data for structure 15

BUILDING NUMBER	15
	
BUILDING NAME	Railway Quarters
ADDRESS	394, Railway Colony 5
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	4
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.16: Survey data for structure 16

BUILDING NUMBER	16
	
BUILDING NAME	Railway Quarters
ADDRESS	406-C,Railway Colony 5
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	4
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.17: Survey data for structure 17

BUILDING NUMBER	17
	
BUILDING NAME	Railway Quarters
ADDRESS	8,Railway Colony 1
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	6
FALLING HAZARDS:	4
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.18: Survey data for structure 18

BUILDING NUMBER	18
	
BUILDING NAME	Railway Quarters
ADDRESS	9, Railway Colony 1
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	6
FALLING HAZARDS:	6
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.19: Survey data for structure 19

BUILDING NUMBER	19
	
BUILDING NAME	Railway Quarters
ADDRESS	11, Railway Colony 1
NO. OF STORIES	
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	6
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.20: Survey data for structure 20

BUILDING NUMBER	20
	
BUILDING NAME	Railway Quarters
ADDRESS	12, Railway Colony 1
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	6
EASE OF EVACUATION:	3
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.21: Survey data for structure 21

BUILDING NUMBER	21
	
BUILDING NAME	Railway Quarters
ADDRESS	13, Railway Colony 1
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	8
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	6
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.22: Survey data for structure 22

BUILDING NUMBER	22
	
BUILDING NAME	Surya Commercial Centre
ADDRESS	Surya Commercial Centre, Ferozepur Road, near PAU
NO. OF STORIES	6
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C1
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	125
CONDITION OF BUILDING:	3
MAINTENANCE RECORD:	3
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	4
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.23: Survey data for structure 23

BUILDING NUMBER	23

BUILDING NAME	Hotel Mahal
ADDRESS	Hotel Mahal, Ferozepur Road, Inder Nagar
NO. OF STORIES	7
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C2
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	300
CONDITION OF BUILDING:	3
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	5
FALLING HAZARDS:	5
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.24: Survey data for structure 24

BUILDING NUMBER	24

BUILDING NAME	Grand Walk Mall
ADDRESS	Grand Walk Mall, Ferozepur Road, Aggar Nagar
NO. OF STORIES	6
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C2
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	300
CONDITION OF BUILDING:	3
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	5
FALLING HAZARDS:	3
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.25: Survey data for structure 25

BUILDING NUMBER	25
	
BUILDING NAME	Waves Mall
ADDRESS	Waves Mall, Ferozepur Road
NO. OF STORIES	7
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C2
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	5
OCCUPANCY:	250
CONDITION OF BUILDING:	1
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	5
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.26: Survey data for structure 26

BUILDING NUMBER	26
	
BUILDING NAME	PNB
ADDRESS	PNB, Rajguru Nagar, Ludhiana
NO. OF STORIES	4
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C1
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	150
CONDITION OF BUILDING:	2
MAINTENANCE RECORD:	5
COLLATERAL DAMAGE VULNERABILITY:	6
FALLING HAZARDS:	3
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.27: Survey data for structure 27

BUILDING NUMBER	27

BUILDING NAME	MBD Neopolis
ADDRESS	MBD Neopolis, ferozepur road, Housing Board colony
NO. OF STORIES	6
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	300
CONDITION OF BUILDING:	2
MAINTENANCE RECORD:	2
COLLATERAL DAMAGE VULNERABILITY:	6
FALLING HAZARDS:	6
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	3

Table 5.28: Survey data for structure 28

BUILDING NUMBER	28
	
BUILDING NAME	Dainik Bhaskar Office
ADDRESS	Dainik Bhaskar Office, near MBD Neopolis, Ferozepur Road
NO. OF STORIES	6
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	C3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	5
OCCUPANCY:	45
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	10
COLLATERAL DAMAGE VULNERABILITY:	1
FALLING HAZARDS:	2
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.29: Survey data for structure 29

BUILDING NUMBER	29
	
BUILDING NAME	AXEN Construction Office
ADDRESS	AXEN Construction Office, near Ludhiana Station
NO. OF STORIES	2
USE	Government
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	30
CONDITION OF BUILDING:	1
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	2
FALLING HAZARDS:	0
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.30: Survey data for structure 30

BUILDING NUMBER	30

BUILDING NAME	Silver Arc Mall
ADDRESS	Silver Arc mall, Gurdev Nagar, Ludhiana
NO. OF STORIES	6
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C2
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	300
CONDITION OF BUILDING:	1
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	2
FALLING HAZARDS:	2
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.31: Survey data for structure 31

BUILDING NUMBER	31
	
BUILDING NAME	Pavilion Mall
ADDRESS	Pavilion Mall, Fountain Chowk, Ludhiana
NO. OF STORIES	7
USE	Commercial
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	Yes
STRUCTURE TYPE	C2(SW)
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	400
CONDITION OF BUILDING:	1
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	2
EASE OF EVACUATION:	5
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.32: Survey data for structure 32

BUILDING NUMBER	32
	
BUILDING NAME	Railway Bungalow
ADDRESS	L-36/A, Civil Lines, College Road, Ludhiana
NO. OF STORIES	1
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	8
CONDITION OF BUILDING:	3
MAINTENANCE RECORD:	0
COLLATERAL DAMAGE VULNERABILITY:	3
FALLING HAZARDS:	3
EASE OF EVACUATION:	7
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.33: Survey data for structure 33

BUILDING NUMBER	33
	
BUILDING NAME	Railway Bungalow
ADDRESS	L-36/B, Civil Lines, Ludhiana
NO. OF STORIES	1
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM4
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	0
CONDITION OF BUILDING:	9
MAINTENANCE RECORD:	10
COLLATERAL DAMAGE VULNERABILITY:	5
FALLING HAZARDS:	4
EASE OF EVACUATION:	6
EMERGENCY SERVICES AVAILABILITY:	4

Table 5.34: Survey data for structure 34

BUILDING NUMBER	34
	
BUILDING NAME	Railway Quarter
ADDRESS	Railway Colony 13
NO. OF STORIES	2
USE	Residential
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	URM3
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	0
OCCUPANCY:	20
CONDITION OF BUILDING:	4
MAINTENANCE RECORD:	3
COLLATERAL DAMAGE VULNERABILITY:	4
FALLING HAZARDS:	2
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	5

Table 5.35: Survey data for structure 35

BUILDING NUMBER	35
	
BUILDING NAME	Full Stop Grocery Market
ADDRESS	Full Stop, College Road, Rose Enclave, Ludhiana
NO. OF STORIES	2
USE	Res+Comm.
CONSTRUCTION DRAWINGS	No
IMPORTANCE OF BUILDING	No
STRUCTURE TYPE	C3(INF)
ADDITIONAL SCORE MODIFIERS	
BOTTOM SOFT STOREY PRESENCE:	5
OCCUPANCY:	40
CONDITION OF BUILDING:	1
MAINTENANCE RECORD:	1
COLLATERAL DAMAGE VULNERABILITY:	2
FALLING HAZARDS:	2
EASE OF EVACUATION:	4
EMERGENCY SERVICES AVAILABILITY:	4

5.3.2 EXCEL SHEET INPUTS:

Table 5.36: Survey inputs

BASIC PARAMETERS							
BUILDING NUMBER	1	2	3	4	5	6	7
BUILDING NAME	Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Railway Bungalow	Railway Quarters	Railway Quarters
ADDRESS	222, railway colony 10	236, Railway Colon	220, Railway Colon	230, Railway Colo	L-5/A, Railway Col	362, Railway Colo	285, Railway Colon
NO. OF STORIES	2	2	2	2	1	2	2
USE	Residential	Residential	Residential	Residential	Residential	Residential	Residential
CONSTRUCTION DRAWINGS	No	No	No	No	No	No	No
IMPORTANCE OF BUILDING	No	No	No	No	No	No	No
Basic Score Modifiers							
STRUCTURE TYPE	URM3	URM4	URM4	URM4	URM4	URM4	URM4
LOW RISE (< 4 STORIES):	1	1	1	1	1	1	1
MID RISE (4-7 STORIES):	0	0	0	0	0	0	0
HIGH RISE (> 7 STORIES):	0	0	0	0	0	0	0
VERTICAL IRREGULARITY:	0	0	0	0	0	0	0
PLAN IRREGULARITY:	0	1	0	1	0	0	0
CODE DETAILING:	0	0	0	0	0	0	0
SOIL TYPE 1 (HARD SOIL):	0	0	0	0	0	0	0
SOIL TYPE 2 (MEDIUM SOIL):	0	0	0	0	0	0	0
SOIL TYPE 3 (SOFT SOIL):	1	1	1	1	1	1	1
SPECIAL HAZARDS LIKE	0	0	0	0	0	0	0
LIQUIFIABLE SOIL, LAND SLIDE							
PRONE AREA etc.							
ADDITIONAL SCORE MODIFIERS							
BOTTOM SOFT STOREY PRESENCE:	0	0	0	0	0	0	0
OCCUPANCY:	20	30	20	20	9	20	15
CONDITION OF BUILDING:	9	5	4	5	3	5	4
MAINTENANCE RECORD:	2	2	1	1	0	2	2
COLLATERAL DAMAGE VULNERABILITY:	5	2	5	4	0	3	3
FALLING HAZARDS:	5	4	4	5	1	2	3
EASE OF EVACUATION:	4	3	6	6	5	4	4
EMERGENCY SERVICES AVAILABILITY:	4	3	4	4	4	3	4

Table 5.36 (continued)

8	9	10	11	12	13	14	15
Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	EPFO	Railway Quarters
284, Railway Colo	336, Railway Colon	361, Railway Colc	283, Railway Colc	270, Railway Colo	269, Railway Colon	Employee Provident I	394, Railway Colon
2	3	3	2	2	2	5	2
Residential	Residential	Residential	Residential	Residential	Residential	Government	Residential
No	No	No	No	No	No	No	No
No	No	No	No	No	No	Yes	No
URM4	URM4	URM4	URM4	URM4	URM4	C3	URM4
1	1	1	1	1	1	0	1
0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0
0	1	0	1	1	1	1	0
0	0	0	1	1	1	0	0
0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0
1	1	1	1	1	1	0	1
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
15	30	30	20	15	15	100	20
5	6	6	7	8	10	2	4
2	1	1	3	0	0	1	1
3	3	3	4	4	3	3	3
3	5	3	5	5	4	4	4
4	4	3	4	4	4	4	3
4	3	3	3	3	3	3	3

Table 5.36 (continued)

16	17	18	19	20	21	22	23	24
Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Railway Quarters	Surya Commercial Centre	Hotel Mahal	Grand Walk Mall
406-C,Railway Colo	8,Railway Colony 1	9, Railway Colony 1	11, Railway Colony	12, Railway Colon	13, Railway Colon	Surya Commercial Centre	Hotel Mahal, F	Grand Walk Mall, F
2	2	2		2	2	6	7	6
Residential	Residential	Residential	Residential	Residential	Residential	Commercial	Commercial	Commercial
No	No	No	No	No	No	No	No	No
No	No	No	No	No	No	Yes	Yes	Yes
URM4	URM4	URM4	URM4	URM4	URM4	C1	C2	C2
1	1	1	1	1	1	0	0	0
0	0	0	0	0	0	1	1	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1
1	1	1	1	1	1	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
20	20	20	20	20	20	125	300	300
4	8	8	8	8	8	3	3	3
1	1	2	1	1	1	3	2	2
3	6	6	4	4	4	4	5	5
4	4	6	6	6	6	4	5	3
3	3	6	3	3	4	4	4	6
4	3	4	4	4	4	4	4	5

Table 5.36 (continued)

25	26	27	28	29	30	31
Waves Mall	PNB	MBD Neopolis	Dainik Bhaskar Office	AXEN Construction Office	Silver Arc Mall	Pavilion Mall
Waves Mall, Fero	PNB, Rajguru Nagar,	MBD Neopolis, fer	Dainik Bhaskar Office,	AXEN Construction Office,	Silver Arc mall,	Pavilion Mall, F
7	4	6	6	2	6	7
Commercial	Commercial	Commercial	Commercial	Government	Commercial	Commercial
No	No	No	No	No	No	No
Yes	Yes	Yes	No	Yes	Yes	Yes
C2	C1	C3	C3	C3	C2	C2(SW)
0	0	0	0	1	0	1
1	1	1	1	0	1	0
0	0	0	0	0	0	0
1	1	1	1	0	0	1
0	1	1	1	0	0	1
1	1	1	1	1	1	1
0	0	0	0	0	0	0
1	1	1	0	0	1	1
0	0	0	1	1	0	0
0	0	0	0	0	0	0
5	0	0	5	0	0	0
250	150	300	45	30	300	400
1	2	2	4	1	1	1
1	5	2	10	0	0	0
3	6	6	1	2	2	3
5	3	6	2	0	2	2
6	5	5	4	5	5	5
4	3	3	5	5	4	5

Table 5.36 (continued)

32	33	34	35
Railway Bungalow	Railway Bungalow	Railway Quarter	Full Stop Grocery Market
L-36/A, Civil Lines,	L-36/B, Civil Lines,	Railway Colony 1	Full Stop, College Road, Rose Enclave, Ludhiana
1	1	2	2
Residential	Residential	Residential	Res+Comm.
No	No	No	No
No	No	No	No
URM4	URM4	URM3	C3(INF)
1	1	1	1
0	0	0	0
0	0	0	0
0	0	0	1
0	0	0	0
0	0	1	1
0	0	0	0
0	0	0	0
1	1	1	1
0	0	0	0
0	0	0	5
8	0	20	40
3	9	4	1
0	10	3	1
3	5	4	2
3	4	2	2
7	6	4	4
5	4	5	4

CHAPTER 6

RESULTS, COMPARISONS, AND CONCLUSIONS

6.1 SURVEY RESULTS

Table 6.1: Survey Results

BUILDING NO.	DAMAGEABILITY GRADE			STRUCTURAL SCORES			NEED FOR FURTHER EVALUATION		
	RVS AS PER IS	NEW DEVELOPED RVS	RVS AS PER FEMA 154	RVS AS PER IS	NEW DEVELOPED RVS	RVS AS PER FEMA 154	RVS AS PER IS	NEW DEVELOPED RVS	RVS AS PER FEMA 154
1	G3	G2,G1	G3,G2	N/A	0.46	1.2	YES	NO	YES
2	G3	G3,G2	G4,G3	N/A	-0.17	0.3	YES	YES	YES
3	G3	G2,G1	G3,G2	N/A	0.405	0.8	YES	NO	YES
4	G3	G3,G2	G4,G3	N/A	-0.145	0.3	YES	YES	YES
5	G3	G2,G1	G2,G3	N/A	0.706	0.8	YES	NO	YES
6	G3	G2,G1	G2,G3	N/A	0.375	0.8	YES	NO	YES
7	G3	G2,G1	G2,G3	N/A	0.415	0.8	YES	NO	YES
8	G3	G2,G1	G2,G3	N/A	0.365	0.8	YES	NO	YES
9	G3	G2,G3	G5,G4	N/A	-0.71	-0.2	YES	YES	YES
10	G3	G2,G3	G3,G2	N/A	0.32	0.8	YES	YES	YES
11	G3	G5,G4	G5,G4	N/A	-1.375	-0.7	YES	YES	YES
12	G3	G4.G3	G5,G4	N/A	-1.27	-0.7	YES	YES	YES
13	G3	G4.G3	G5,G4	N/A	-1.32	-0.7	YES	YES	YES
14	G3	G2,G1	G3,G2	N/A	1.245	1.6	YES	NO	YES
15	G3	G2,G1	G3,G2	N/A	0.415	0.8	YES	NO	YES
16	G3	G2,G1	G3,G2	N/A	0.425	0.8	YES	NO	YES
17	G3	G2,G3	G3,G2	N/A	0.14	0.8	YES	YES	YES
18	G3	G2,G3	G3,G2	N/A	0.08	0.8	YES	YES	YES
19	G3	G2,G3	G3,G2	N/A	0.15	0.8	YES	YES	YES
20	G3	G2,G3	G3,G2	N/A	0.15	0.8	YES	YES	YES
21	G3	G2,G3	G3,G2	N/A	0.16	0.8	YES	YES	YES
22	G3	G2,G1	G3,G2	N/A	0.655	1.2	YES	NO	YES
23	G1	G1	G1	N/A	2.48	3.2	NO	NO	NO
24	G1	G1	G1	N/A	3.56	4.2	NO	NO	NO
25	G1	G1	G1	N/A	2.25	3.2	NO	NO	NO
26	G3	G2,G3	G2,G3	N/A	0.055	0.7	YES	YES	YES
27	G1	G1	G2,G1	N/A	1.8	2.7	NO	NO	NO
28	no damage	G2,G3	G2,G3	N/A	-0.13	1.1	YES	YES	YES
29	G3	G1	G2,G1	N/A	2.37	2.4	NO	NO	NO
30	G1	G1	G1	N/A	3.84	4.2	NO	NO	NO
31	G1	G1	G1	N/A	2.625	3.1	NO	NO	NO
32	G3	G2,G1	G2,G3	N/A	0.612	0.8	YES	NO	YES
33	G3	G2,G3	G2,G3	N/A	-0.275	0.8	YES	YES	YES
34	G3	G2,G1	G2,G3	N/A	0.77	1.2	YES	NO	YES
35	G2	G2,G1	G2,G3	N/A	0.74	1.4	YES	NO	YES

Where:

→ Shows difference in need for evaluation by FEMA and Modified RVS system

→ Shows Difference in need for evaluation by IS code method and Modified RVS method

→ Shows Major Difference in Damageability grades between any two systems being highlighted

→ Corresponds to minimum score by any given method

→ Corresponds to maximum score by any given method

6.2 OBSERVATIONS

- **DAMAGEABILITY GRADE:**

1. Of the 35 structures that were surveyed in this project
1 structure i.e. 28 is observed to have no damage according to **IS method** of RVS while 6 Structures are found to have negligible damage scale of G1: 23, 24, 25, 27, 30, 31.

   7 Structures were found to have negligible damage, damage grade G1 in accordance with the new **developed RVS** methodology namely 23, 24, 25, 27, 29, 30, 31

   5 Structures were found to have negligible damage, damage grade G1 in accordance with traditional **FEMA methodology** namely 23, 24, 25, 30, 31

2. For the structures with negligible damage scales in the standard BIS method we see a range of damageability grades in the other two methods varying from grade G1 to grade G3.

3. There is only 1 structure, 9 for which we see a large variation in damageability grades between the FEMA method and the Developed RVS method. FEMA method denotes it as G4, G5 whereas the developed method denotes it as G2, G3. The rest of the structure grades do not vary too widely with a maximum of +/- 1 Grade with the average being the same.

4. This overall variation can be summarised as follows. For the older URM structures the estimates made by FEMA and BIS almost coincide with BIS value being a bit conservative and equal to the higher damageability grade given by FEMA. In those structures we see that our developed method lags behind a bit and estimates a slightly lower grade owing to the variation that is included due to the presence of additional modifiers and certain ones of those end up giving a higher estimate of grade. For the more modern constructions the estimates made by the developed system and FEMA can be taken as almost the same values. In those structures the BIS method was found to give similar results to FEMA estimates, most probably due to them being high grades of construction.

5. This experiment was limited to 35 structures only and a larger sample pool might be necessary to draw any certain conclusions.

- **STRUCTURAL SCORE:**

1. The final structural score by FEMA method results in the same values for a large number of structures, example being structure 15-21 which have the same basic features and result in the same score of 0.8. This occurs because FEMA works on binary logic i.e. the presence of a factor or not and has a fixed value for each case.

2. However, the final score in case of the modified RVS method has a larger variation since it takes into account various score modifiers which occur on a spectrum rather than simple binary logic. For example, the condition of the structure.

3. This helps us see the variation among similarly scored structures which would have otherwise been grouped together and improves the quality of the results obtained and is a distinct advantage over the standard Quantitative FEMA system.

4. The highest score obtained by the RVS method was 3.84 for structure 30. The same structure when analysed by FEMA method gave a score of 4.2. This discrepancy occurred due to factors such as falling hazards, ease of evacuation, occupancy classes etc which combine to give a better picture of the real risk that the structure entails. FEMA method gave it a higher score due to the recent construction along with proper and symmetric design.

5. Likewise the lowest score in FEMA method is -0.7 which has a corresponding score of -1.375 in RVS system for structure 11. This clearly shows the difference in the classical method and the new developed method since we have been able to incorporate the real condition of the structure. This structure had multiple structural cracks, loose lintels, exposed reinforcement, unauthorized extensions etc which cannot be account for in the FEMA method.

6. This, however does not give any concrete conclusions about the applicability of the method in field. However even if the damageability grades of the structures obtained are comparable the modified method provides a qualitative improvement to the simple FEMA method. It successfully points out certain weaknesses such as evacuation measures or ease with which emergency services can reach a location , falling hazards etc to name a few so the relevant authorities know which things have a dominant effect in the risk assessment.

- **FURTHER EVALUATION**

1. Of the survey sample containing 35 structures the need for further evaluation as prescribed by various methods is as follows,
28 structures need further evaluation according to **BIS** method
15 structures need further evaluation according to **modified RVS** method
28 structures need further evaluation according to **FEMA** method

2. Thus it can be seen that the BIS method gives more weightage to higher level analysis than the modified RVS system for vulnerability assessment of seismic risk.

3. Out of the surveyed 35 structures we see 13 instances where the modified RVS system and the BIS system differ in their suggestions for further evaluation of structures. In all these structures BIS suggests further analysis whereas RVS system denies the need. The possible reason being that the additional score modifiers have imparted a highly positive impact on the total score and hence this method considers that there is no need for further evaluation.

4. Of these 13 instances, all of them agree with the standard FEMA suggestions for further evaluation. The possible reason being the age and construction of the structures coupled with the high seismic zone suggests that further evaluation is necessary for the continued safety of these structures.

5. To summarize the inferences, the BIS method is more prone to suggesting re-evaluation since it gauges its necessity based on the presence or absence of a handful of features only such as asymmetry or irregularities. The modified RVS system and the FEMA system on the other hand are more conservative when making those estimates. These two tend to disagree only in the cases where the positive modifiers have a high impact on the total score such as in case of well-maintained but old structures or with structures having a low degree of occupancy. In case of newer constructions the results are in agreement with FEMA method.

6.3 CONCLUSIONS

- In the project consisting of RVS of 35 structures in various localities of Ludhiana 7 structures came in the category of no damage, namely 23,24,25,27,29,30,31.

- Modified RVS method shows that 15 structures, i.e. 43 % of the total sample require further evaluation. The same as per BIS and FEMA methods is 27, i.e. 77% of the total sample.

- Some results are supported by both FEMA and BIS methods. For example Structure 30 was found to be the strongest in terms of both damageability estimates, G1 and final score, 3.84 whereas structure 11 was found to be the weakest in the same, G4, G5 and -1.375.

- The BIS method was found to give damageability estimates of a higher degree out of all 3 methods. The modified RVS method usually gave estimates close to or slightly lower than those by FEMA standards. This could be due to the positive modifier scores influencing the proposed damageability grades such as in case of old and well maintained structures. Thus it can be stated that the modified system gives a more qualitative result than the other two methods.

- A further variation in structures which obtained the same FEMA scores shows a more detailed estimate of their seismic vulnerabilities. This improves our results since otherwise they would have been impossible to differentiate.

- Thus the modified RVS system provides a better method for older structural forms as compared to FEMA method since it provides a more accurate picture of their current condition.

- Considering the availability of computers and other electronic gadgets RVS procedure may be efficiently and economically applied for condition assessment of structures on a large scale.

- RVS procedure may be applied in difficult situations such as in post-earthquake surveys for condition assessment of structures for the sake of award of compensation.

6.4 FUTURE SCOPE

- Firstly, the additional modifier factors and weights can be further improved to improve the accuracy of the system. Along with this further research can be conducted by using test buildings to obtain practical data and checking if it was consistent with the data obtained during RVS or not.

- Secondly, a more mechanized approach involving neural networks or fuzzy logic or any such spectrum based logic function could be utilized to further improve the results of RVS. Along with this suitable devices with built in optical analysis software can be used to more accurately gauge any structure with only a handful of input parameters requires. This will thus eliminate the human subjective errors.

- Thirdly, more research can be carried out to develop a scoring method that is entirely separate from the FEMA method as is used in this project.

- Fourthly, a slight amount of testing apparatus could be used during the course of the survey for better assessment of the structure since not all damages can be visually inspected.

ANNEXURE A – PHOTOGRAPHS

Structure 1- 222, colony 10

Structure 2- 236, colony 10

Structure 3- 220, colony 10

Structure 4- 230, colony 10

Structure 5- L-5A, colony 9

Structure 6- 362, colony 9

Structure 7- 285, colony 7

Structure 8- 284, colony 7

Structure 9- 336, colony 7

Structure 10- 361, colony 7

Structure 11- 283, colony 8

Structure 12- 270, colony 8

Structure 13- 269, colony 8

Structure 15- 394, colony 5

Structure 14- EPFO

Structure 14- EPFO

Structure 16- 406 C, Colony 5

Structure 17- 8, Colony 1

 Structure 18- 9, Colony 1	 Structure 19- 11, Colony 1
 Structure 20- 12, Colony 1	 Structure 21- 13, Colony 1
 Structure 22- Surya Commercial Centre	 Structure 23- Hotel Mahal

Structure 24- Grand walk mall

Structure 25- Waves Mall

Structure 26- PNB

Structure 27- MBD Neopolis

Structure 28- Dainik Bhaskar Office

Structure 29- AXEN C office

Structure 30- Silver Arc Mall

Structure 31- Pavilion Mall

Structure 32- L 36/A

Structure 33- L 36/B

Structure 34- Railway Quarter, colony 13

Structure 35- Full Stop Grocery Store

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