DISSERTATION

On

"Condition Assessment of Buildings using Rapid Visual Screening Procedure"

Submitted by-

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2K12/STR/20

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CERTIFICATE

This is to certify that the report entitled "CONDITION ASSESSMENT OF BUILDINGS USING RAPID VISUAL SCREENING PROCEDURE" is being submitted by me, which is a bonafide record of my own work under the guidance and supervision of my project guide Mr. Alok Verma, in the partial fulfilment of requirement for the award of the degree of Master of Technology (M.Tech.) in Structural Engineering, Department of Civil Engineering, Delhi Technological University (D.T.U.), Delhi.

The matter embodied in the project has not been submitted for the award of any other degree.

Siddharth Singh

2K12/STR/20

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

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I would like to express my sincere gratitude to my project guide *Mr. Alok Verma (Associate 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.

I would also like to present my sincere regards to my Head of Civil Engineering Department *Dr. A.K. Trivedi* , for his support and encouragement throughout the programme.

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

ABSTRACT

With the occurrence of a number of earthquakes in the past and chances of many more in the future, seismic risk assessment has become a key factor in the seismic risk mitigation and management. Seismic design for structures has evolved with the passage of time and so has the complexities in design and construction. But Seismic design has its own limitations. Every type of structure deteriorates with time and becomes seismically vulnerable. Seismic vulnerability also depends a lot on the quality of construction and use of the structure. Also with the rapid rate of construction fulfilling the need of exploding population in developing countries like India, the number of buildings is increasing exponentially with small regard to seismic safety. Therefore a very rapid, reliable and economic method is required to roughly judge the seismic safety of buildings and Rapid Visual Screening of building structures appropriately serves the purpose.

In the present work, various aspects of Rapid Visual Screening (R.V.S.) are considered. Rapid visual screening practices in US as per FEMA 154 and those in India are studied and an overview of the topic is developed. Later on efforts are made to devise a new more accurate and quicker RVS system for Indian conditions. This new modified system of RVS is proposed and explained in sufficient detail. Separate MS excel programs are developed for this new developed system and for RVS system specified by Bureau of Indian Standards (BIS) and using them screening of a certain number of buildings is carried out in the city of Lucknow (U.P.). Then finally the outcomes and results are stated, comparisons are made and utility and suitability of new developed RVS system is explained.

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1. INTRODUCTION

1.1 GENERAL

With the exploding population of the world, especially in the developing countries, the need for buildings for residential, commercial and other purposes is exponentially increasing. This has put pressure on the existing infrastructure of these countries which has resulted in an accelerated rate of building construction.

With the mass construction of the buildings, it is a prerequisite to take special care of seismic safety at the design stage itself. But in countries like India, where negligence and corruption has engulfed every phase of life, one can easily expect that the construction norms as specified by the government and other agencies would not be properly followed. Also the below grade quality of construction material, prolonged faulty use of the building structure and deteriorating practices, all contribute to the seismic vulnerability of the building.

Also it must be noted that in every practice associated with construction, economy plays a vital role. Hence its role in seismic risk assessment of buildings also cannot be overlooked.

Thus in this Indian scenario one needs a very rapid, reliable and economically sound process for risk assessment of buildings for seismic safety. Rapid Visual Screening methodology has been developed for solving this purpose and has proved to be quite useful.

But the RVS procedure for Indian conditions is still in its oversimplified preliminary stage and needs to be revived. One possibility is to incorporate the score system as in FEMA 154 with some modifications which would probably make this process more accurate and reliable. Moreover, we should also aim at enhancing the speed of the process by using computer technology. The possibilities in this field are endless and we must strive to explore them.

1.2 OBJECTIVE OF PRESENT STUDY

1. Detailed study of various Rapid Visual Screening (RVS) methodologies proposed by various Indian researchers and **building a common RVS procedure incorporating the features of all these researches which uses a score system** (since score system is a more accurate classifier of seismic safety of a building than a logical system as in IS13935)

2**. Further enhancing the accuracy of the above developed system by incorporating some new factors** in the score system which affects the overall seismic safety of a building.

3**. Developing MS Excel Programs to make this system more and speedier and user friendly**.

4. With this enhanced and speedy system **performing RVS of a particular no of building structures (say 50-70 structures).**

5. Making **comparisons** of the results obtained and **drawing suitable inferences and conclusions.**

1.3 SCOPE OF PRESENT STUDY

The expected result of this project would be a prototype system to a more developed, accurate and quick RVS methodology for Indian conditions which may be better than the current RVS methodology and a suitable computer platform or program to execute the RVS process.

Thus it would facilitate checking the seismic vulnerability of buildings in India with a higher degree of precision and accuracy and that too in a smaller time and in a simple manner.

With proper developments and improvements, the RVS system under this project could possibly serve as a base for a totally new Integrated Rapid Visual Screening System in India as currently exists in US and few other countries. This system not only checks seismic vulnerability but also for vulnerability against other natural and manmade disasters.

1.4 METHODOLOGY

The methodology for the project can easily explained by the following flowchart-

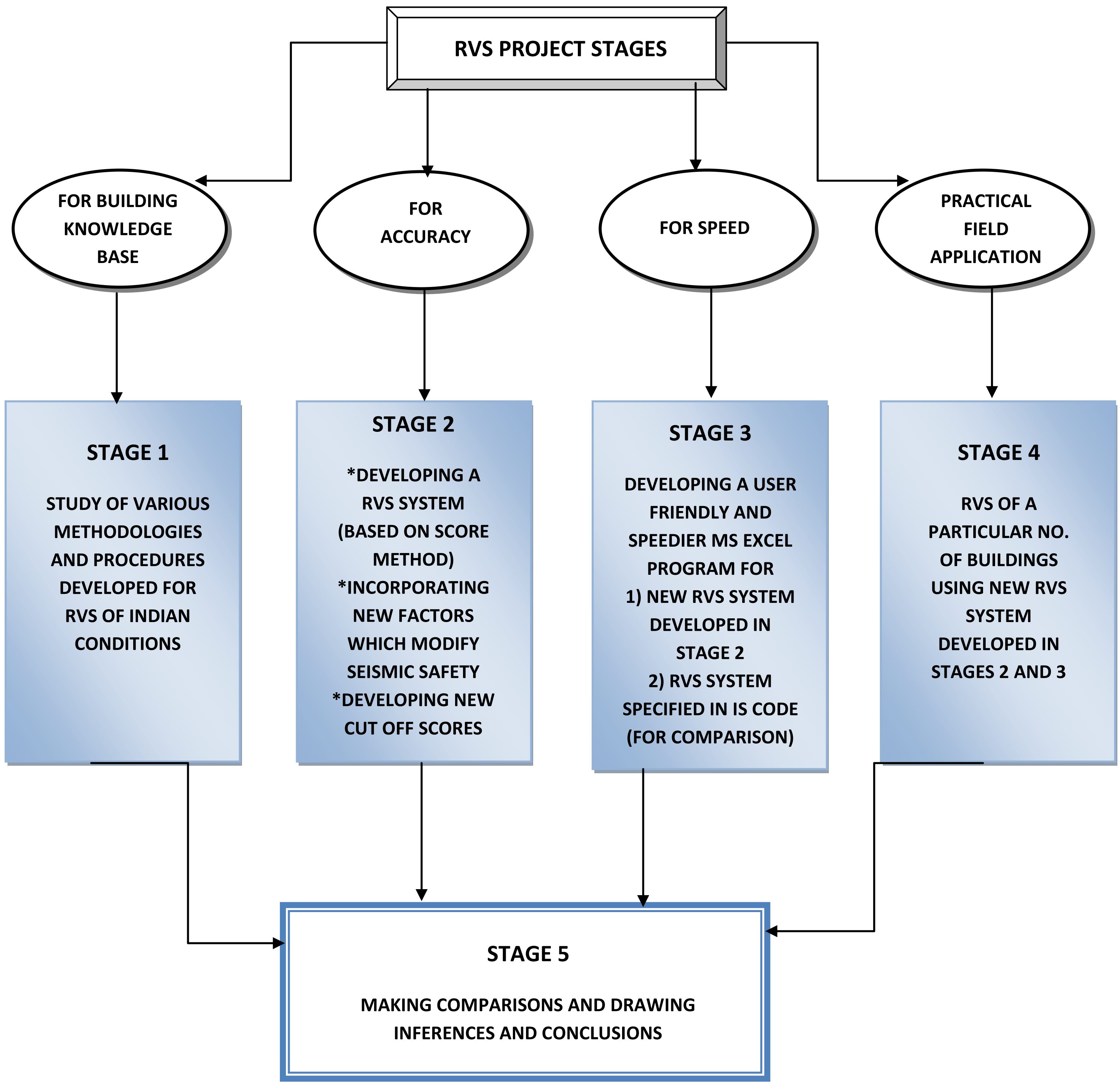


Figure 1: Flowchart for RVS methodology

2 LITERATURE REVIEW

2.1 RAPID VISUAL SCREENING (RVS) 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 must be noted that Rapid Visual Screening is only a visual screening procedure and no testing of any nature can be carried out for determination of risk assessment of buildings, moreover the screening process must be rapid and quick in nature. Thus rapid visual screening is quick risk assessment process which uses visual inspection of buildings and recording of data.

2.2 NEED FOR RAPID VISUAL SCREENING

Rapid Visual Screening is the first basic fundamental step in risk assessment of buildings and its need cannot be overlooked

Rapid Visual Screening is needed to identify if a particular building requires **further evaluation for assessment** of its seismic vulnerability.
It is needed to assess the **seismic damageability (structural vulnerability)** of the building and seismic rehabilitation needs.
It is needed to **identify simplified retrofitting requirements** for the building (to collapse prevention level) where further evaluations are not considered necessary or not found feasible.

Thus RVS procedure can be implemented relatively quickly and inexpensively to develop a list of potentially hazardous buildings **without the high cost of a detailed seismic analysis of individual buildings** and also to suggest suitable measures for damage mitigation of a building or a group.

2.3 RESEARCH AND DEVELOPMENT

Rapid Visual Screening (RVS) is not a new methodology. It has been in use since ancient times when ancient civilizations used the advice of people with expertise in construction for the renovation and repair of existing structures based on visual inspection by these so called screeners of those days.

The modern day RVS procedure was originally developed by the FEMA (Federal Emergency Management Agency) of the United States Department of Homeland Security. It originated in**1988** with the publication of the **FEMA 154 Report**, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* written for a broad audience ranging from engineers and building officials to appropriately trained non-professionals

During the decade following publication of the first edition of the FEMA 154 *Handbook*, the rapid visual screening (RVS) procedure was used by private-sector organizations and government agencies to evaluate buildings in various countries of the world.

Later on after a decade a revised **2nd edition** of **FEMA 154** Report *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* was published in **2002**. The revised RVS procedure retained the same framework and approach of the original procedure, but incorporated a revised scoring system compatible with the ground motion criteria in the 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 **Integrated Rapid Visual Screening Process (I-RVS)** was developed under **BIPS (Buildings and Infrastructure Protection Series)** 04 / September **2007** by the U.S. Dept. of Homeland Security. It was an improvement over RVS process by integrating RVS with Google earth by means of computer software and assessing the building capabilities to resist various other disasters like cyclone, terrorist attack etc in addition to earthquake.

Meanwhile in other parts of the world, researchers contributed in further enriching the basic FEMA methodology for RVS by modifying the FEMA process for **location Specific factors and requirements**. In this regard contributions of *Yumei Wang and Kenneth A. Goettel (*Enhanced Rapid Visual Screening (E-RVS) method for Prioritization of Seismic Retrofits in Oregon) and that of *G. Achs and C. Adams* (Rapid-Visual-Screening Methodology for the Seismic Vulnerability Assessment of Historic Brick-Masonry Buildings in Vienna) are notable.

In India also researchers like *Prof. Ravi Sinha and Prof. Alok Goyal* (Department of Civil Engineering , IIT Bombay) and *Dr. Anand S. Arya*, (Professor Emeritus, Dept. of Eq. Engineering, IIT Roorkee) contributed to development of **RVS process as per Indian Conditions**

In **IS 13935:2009** *"Indian Standard* Seismic Evaluation, Repair and Strengthening of Masonry Buildings-Guidelines *(First Revision)"* RVS was incorporated in Annex A (Clause 7)

2.4 RAPID VISUAL SCREENING AS PER FEMA NORMS

2.4.1 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 classifies 15 types of structures and one has to identify the building being screened with these 15 available types. Thus the screener can get the basic score of the building being screened.

After that FEMA 154 specifies some parameters called *score modifiers*. These are in fact the factors which affect the seismic performance of the structure like irregularities, soil type etc. Each factor is assigned a score which modifies the basic structural score hence called score modifier.

The observer or screener records the basic score and suitable score modifiers by visual inspection of the structure. This record is made on the pre available *RVS forms* provided in FEMA 154 along with other details of structure like location, photographs, sketches, occupancy, structure use etc. The algebraic sum of basic score and score modifiers gives the *overall structural score*. If this overall structural score is less than the *cut off score*, than the structure is unsafe and it is proposed to carry out detailed analysis of structure for seismic vulnerability, otherwise structure is safe.

Determining the Cut Off score is the most important part of this methodology. Generally a cut off score of 2 or 3 is adopted depending on severity and frequency of earthquakes, but the observer is free to choose any value depending upon the importance of building. Lower is the value of cut off score, higher is the safety criteria and higher the score the better is the economy criteria.

Thus in this way comparing the overall score of the structure obtained from the RVS form and the cut off score the screener can draw the conclusion whether the structure is safe or not and suitable measure for retrofitting and repair could be suggested

2.4.2 FEMA DOCUMENTS FOR RVS:

1) FEMA 154:

The FEMA 154 is the basic document which specifies the complete procedure for rapid visual screening. Its latest edition is the 2nd edition published in 2002 which an improvement over 1st edition. This handbook specifies RVS procedure in detail along with type of structures and damageability which each type or different structural components can undergo during an earthquake. It also provides RVS forms and specifies some example cases so as to clarify how to screen buildings as per this handbook. Thus FEMA 154 is complete guide for RVS.

2) FEMA 155:

"FEAM 155 *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation (second 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."*[1]

3) Other FEMA documents*[1] 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).

2.4.3 RVS PROCEDURE OUTLINE*[1]

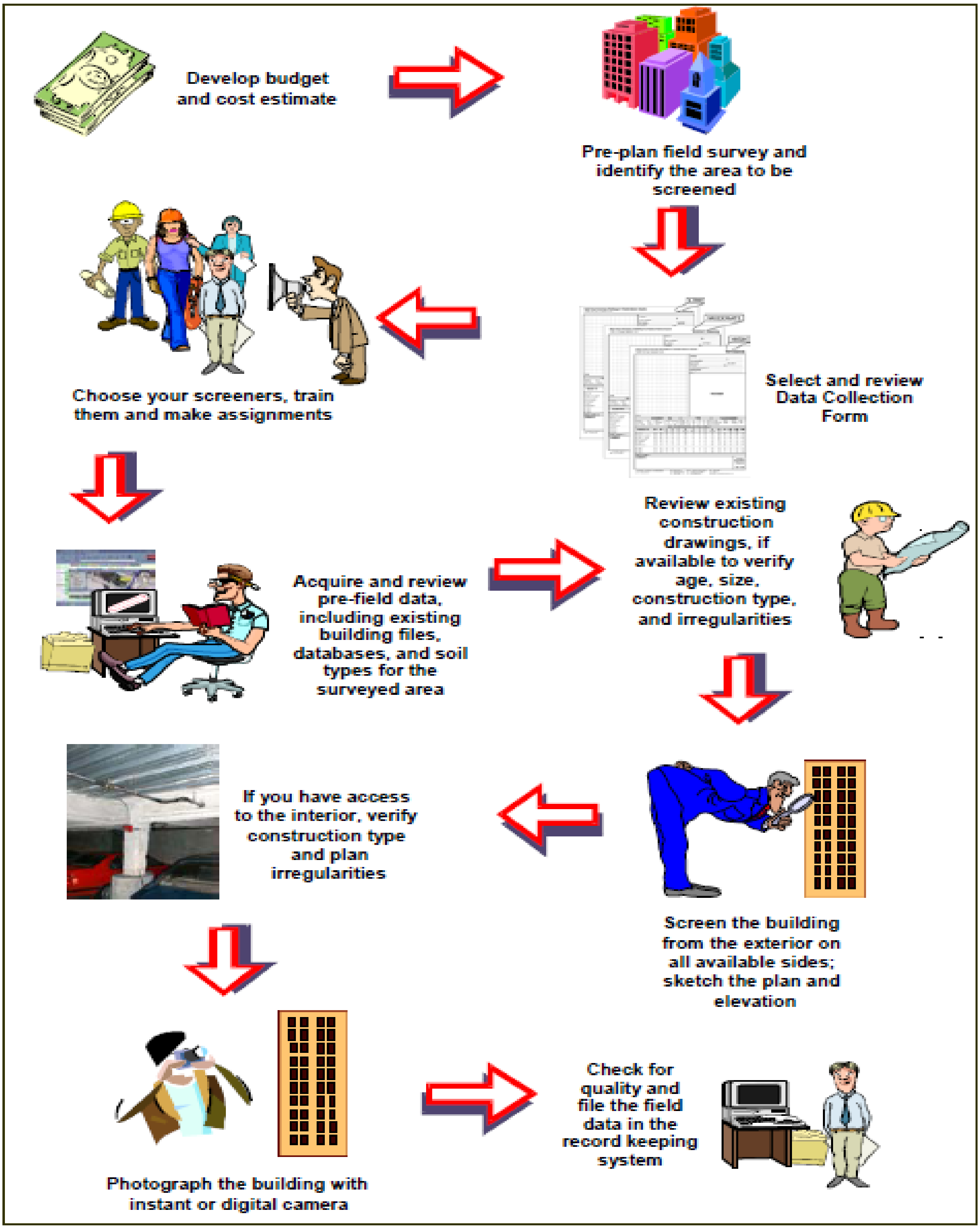


Figure 2*[1]: A flow chart showing the steps involved In RVS implementation sequence

The general sequence of RVS procedure *[1] (taken from FEMA 154) is depicted in Figure1. The implementation sequence includes:

• *Budget development and cost estimation*, recognizing the expected extent of the screening and further use of the gathered data

• *Pre-field planning*, including selection of the area to be surveyed, identification of building types to be screened, selection and development of a record-keeping system, and compilation and development of maps that document local seismic hazard information

• Selection and review of the *Data Collection Form*

• Selection and *training of screening personnel*

• *Acquisition and review of pre-field data*; including review of existing building files and databases to document information identifying buildings to be screened (e.g., address, lot number, number of stories, design date) and identifying soil types for the survey area;

• Review of *existing building plans*, if available

• *Field screening of individual buildings*, which consists of:

1. Verifying and updating building identification information,
2. Walking around the building and sketching a plan and elevation view on the Data Collection Form,
3. Determining occupancy (that is, the building use and number of occupants),
4. Determining soil type, if not identified during the pre-planning process,
5. Identifying potential non-structural falling hazards,
6. Identifying the seismic-lateral-load resisting system (entering the building, if possible, to facilitate this process) and circling the Basic Structural Hazard Score on the Data Collection Form,
7. Identifying and circling the appropriate seismic performance attribute Score Modifiers (e.g., number of stories, design date, and soil type) on the Data Collection Form,
8. *Determining the Final Score, S* (by adjusting the Basic Structural Hazard Score with the Score Modifiers identified in Step 7)
9. Photographing the building

• Checking the quality and filing the screening data in the record-keeping system, or database

• Selection of Suitable *Cut off Score*

• *Drawing Conclusions* regarding safety of building

2.4.4 BASIC STRUCTURE TYPES AND THEIR BEHAVIOUR*[1]

Following are the fifteen building types used in the RVS procedure as per 2nd edition FEMA 154(2002). Alpha-numeric reference codes used on the Data Collection Form are shown in parentheses.

1. Light wood-frame residential and commercial buildings smaller than or equal to 5,000 square feet (W1)
2. Light wood-frame buildings larger than 5,000 square feet (W2)
3. Steel moment-resisting frame buildings (S1)
4. Braced steel frame buildings (S2)
5. Light metal buildings (S3)
6. Steel frame buildings with cast-in-place concrete shear walls (S4)
7. Steel frame buildings with unreinforced masonry infill walls (S5)
8. Concrete moment-resisting frame buildings (C1)
9. Concrete shear-wall buildings (C2)
10. Concrete frame buildings with unreinforced masonry infill walls (C3)
11. Tilt-up buildings (PC1)
12. Precast concrete frame buildings (PC2)
13. Reinforced masonry buildings with flexible floor and roof diaphragms (RM1)
14. Reinforced masonry buildings with rigid floor and roof diaphragms (RM2)
15. Unreinforced masonry bearing-wall buildings (URM)

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.

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.

Figure 3 *[1]: **Building Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes**

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S3 Light metal building		H = 3.2 M = 3.8 L = 4.6	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial-height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.
S4 Steel frames with cast-in-place concrete shear walls		H = 2.8 M = 3.6 L = 4.8	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. More than six inches in thickness usually indicates a concrete wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.

Figure 3*[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.

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).

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.

Figure 3 *[1]: **Building Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes**

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.

Figure 3 *[1]: **Building Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes**

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM1 Reinforced masonry buildings with flexible diaphragms	  Truss-joists support plywood and lightweight concrete slab  Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or concrete 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 reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.

Figure 3*[1]: **Building Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes**

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.

Figure 3 *[1]: **Building Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes**

2.4.5 DATA COLLECTION FORMS *[1] (AS PER FEMA 154(2002))

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 ______________________

PHOTOGRAPH

Scale:

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

Scale:

Address: ______________________________

______________________ **Zip** __________

Other Identifiers ______________________

No. Stories ______________ **Year Built** ________

Screener ______________ **Date** ____________

Total Floor Area (sq. ft.) ______________________

Building Name ______________________

Use ______________________

PHOTOGRAPH

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

(TYPE applies to the soil classes A–F.)

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

Scale:

Address: ______________________________

______________________ **Zip** __________

Other Identifiers ______________________

No. Stories ______________ **Year Built** ________

Screener ______________ **Date** ________

Total Floor Area (sq. ft.) ______________

Building Name ______________________

Use ______________________

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	**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

2.4.6 FORM DETAILS AND SCORE MODIFIERS (FEMA 154 (2002))

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.

2.4.7 DETERMINATION OF BASIC STRUCTURAL SCORE AND SCORE MODIFIER VALUES

The basic structural score in FEMA 154 methodology is defined as the negative of the logarithm (base 10) of the probability of collapse of the building, given the ground motion corresponding to the maximum considered earthquake (MCE). This can be written as follows

BSH = -log10 [P (collapse at given MCE)]

where BSH=Basic Structural Score and MCE = Maximum Considered Earthquake

Earlier the 1st edition of FEMA 154 (1984) defined P as probability of 60% or more damage but it was later improved in 2nd edition FEMA 154 (2002) which defined P as Probability of Collapse

The BSH is a generic score for a type or class of building, and is modified for a specific building by Score Modifiers (SMs) specific to that building, to arrive at a final Structural Score, S.

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

The Final Structural Score S is an indicative of final Probability of collapse of a building .e.g. If S of a building is 2 it means the probability of collapse of a building is 1 in 10^2 i.e. 1 in 100.

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)

"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."*[2]

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

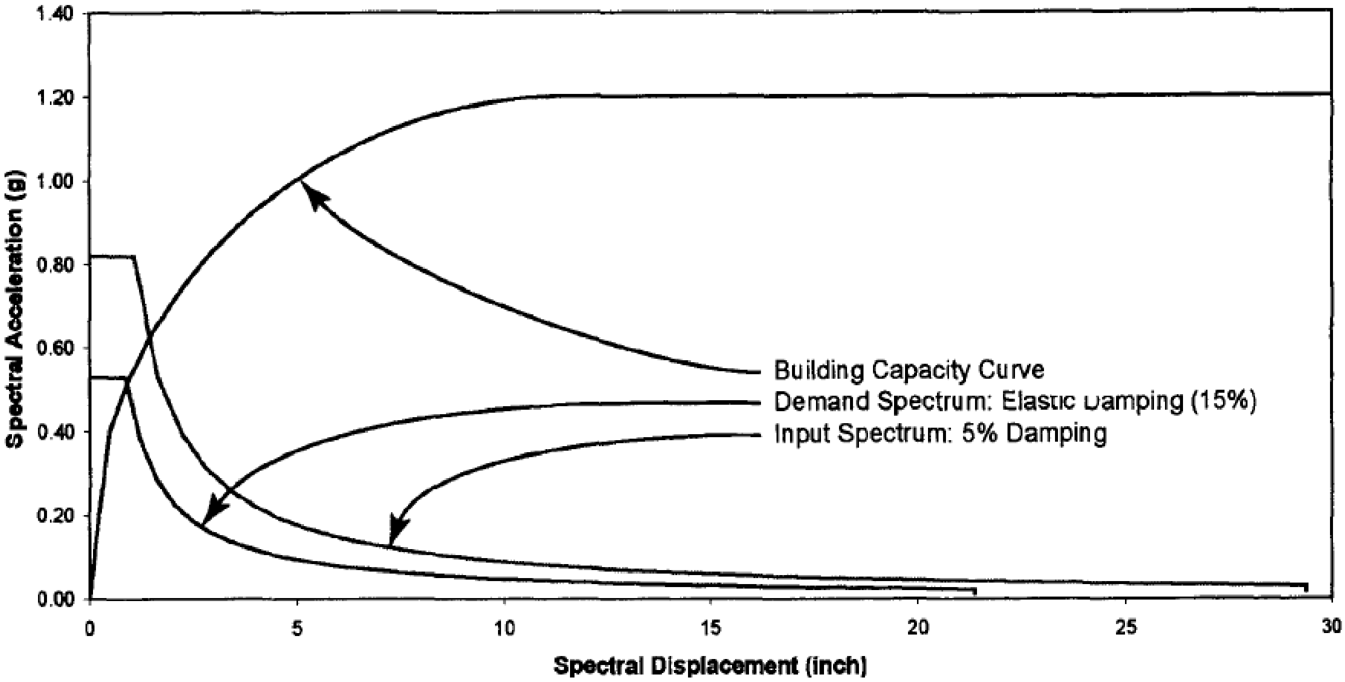


Figure 4*[2]

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

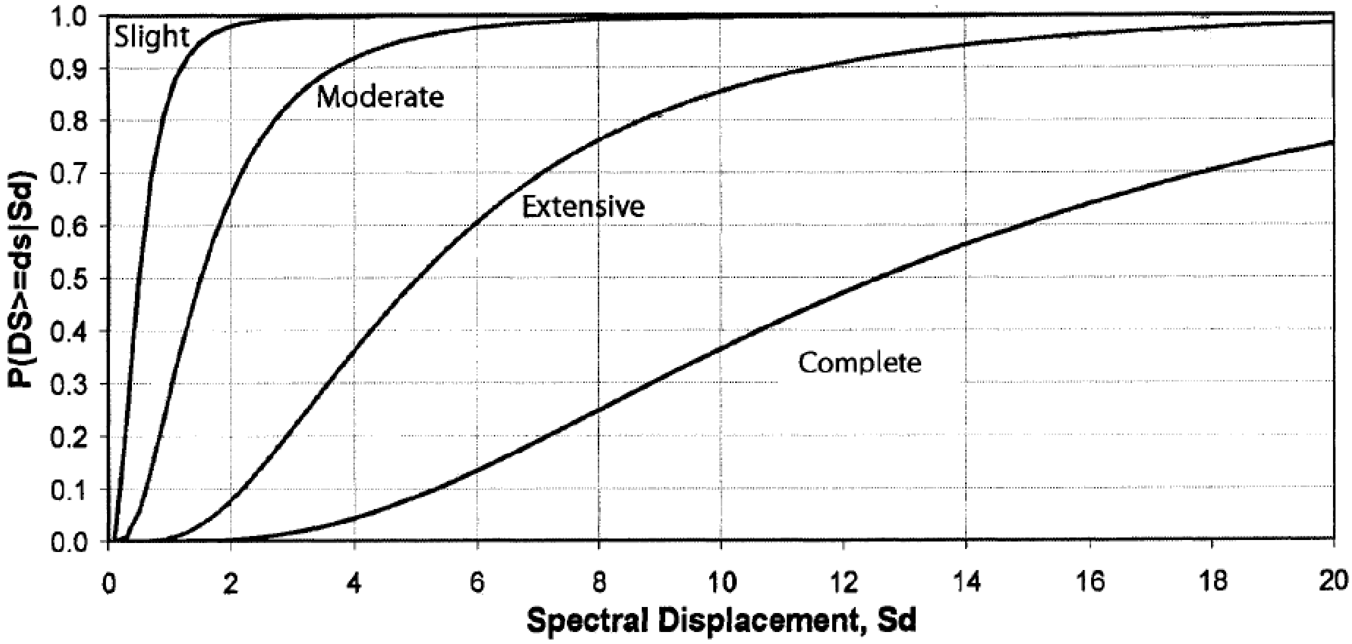


Figure 5*[2]

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).

2.4.8 DETERMINING THE CUT OFF SCORE:

“The Rapid Visual Screening (RVS) **structural Cut off Score (Cut off S)** is **decided on the basis of relative importance of “Costs of Safety” v/s “Benefits” ”***[1]

The **costs of safety** include:

- The costs of reviewing and investigating in detail hundreds or thousands of buildings in order to identify some fraction of those that would actually sustain major damage in an earthquake; and
- The costs associated with rehabilitating those buildings finally determined to be unacceptably weak.

The most compelling **benefit** is the saving of lives and prevention of injuries due to reduced damage in those buildings that are rehabilitated. This reduced damage includes not only less material damage, but fewer major disruptions to daily lives and businesses.

Every community or authority is free to choose its cut off score depending upon to which factor it gives more importance, Cost of safety or Benefits.

As per *National Bureau of Standards (NBC) of U.S. (1980) and SAC (2000)* , value of **Cut off Score *S* of about 3 is appropriate for day to- day loadings, and a value of about 2, or somewhat less, is appropriate for infrequent, but possible, earthquake loadings**.

Unless a community itself considers the cost and benefit aspects of seismic safety, an *S* value of about 2.0 is a reasonable preliminary value to use within the context of RVS to differentiate adequate buildings from those potentially inadequate and thus requiring detailed review. Use of a higher cut-off *S* value implies greater desired safety but increased community-wide costs for evaluations and rehabilitation; use of a lower value of *S* equates to increased seismic risk and lower short-term community-wide costs for evaluations and rehabilitation (prior to an earthquake).

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

2.5 INTEGRATED RAPID VISUAL SCREENING (IRVS)

2.5.1 OVERVIEW:

The U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate's Infrastructure Protection and Disaster Management Division (IDD) has developed an *integrated rapid visual screening (IRVS)* procedure for assessing the risk to a building from natural and human-caused hazards that have the potential to cause catastrophic losses (fatalities, injuries, damage, and business interruption).

This procedure is an *enhanced version of FEMA 455, Handbook for Rapid Visual Screening of Buildings to Evaluate Terrorism Risk*, and includes improvements to the methodology, updates to the catalogue of building characteristics, and updates to the forms that incorporate natural hazards, building types, and critical functions.

IRVS is a simple and quick procedure for obtaining a preliminary risk assessment rating. Risk is determined by evaluating key building characteristics for consequences, threats, and vulnerabilities. The screening process can be conducted by one or two screeners and completed in a few hours. The procedure is intended to be used to identify the level of risk for a single building, to identify the relative risk among buildings in a community or region, and to be used as a prioritization tool for further risk management activities. Information from the visual inspection can be used to support higher level assessments and mitigation options by experts.

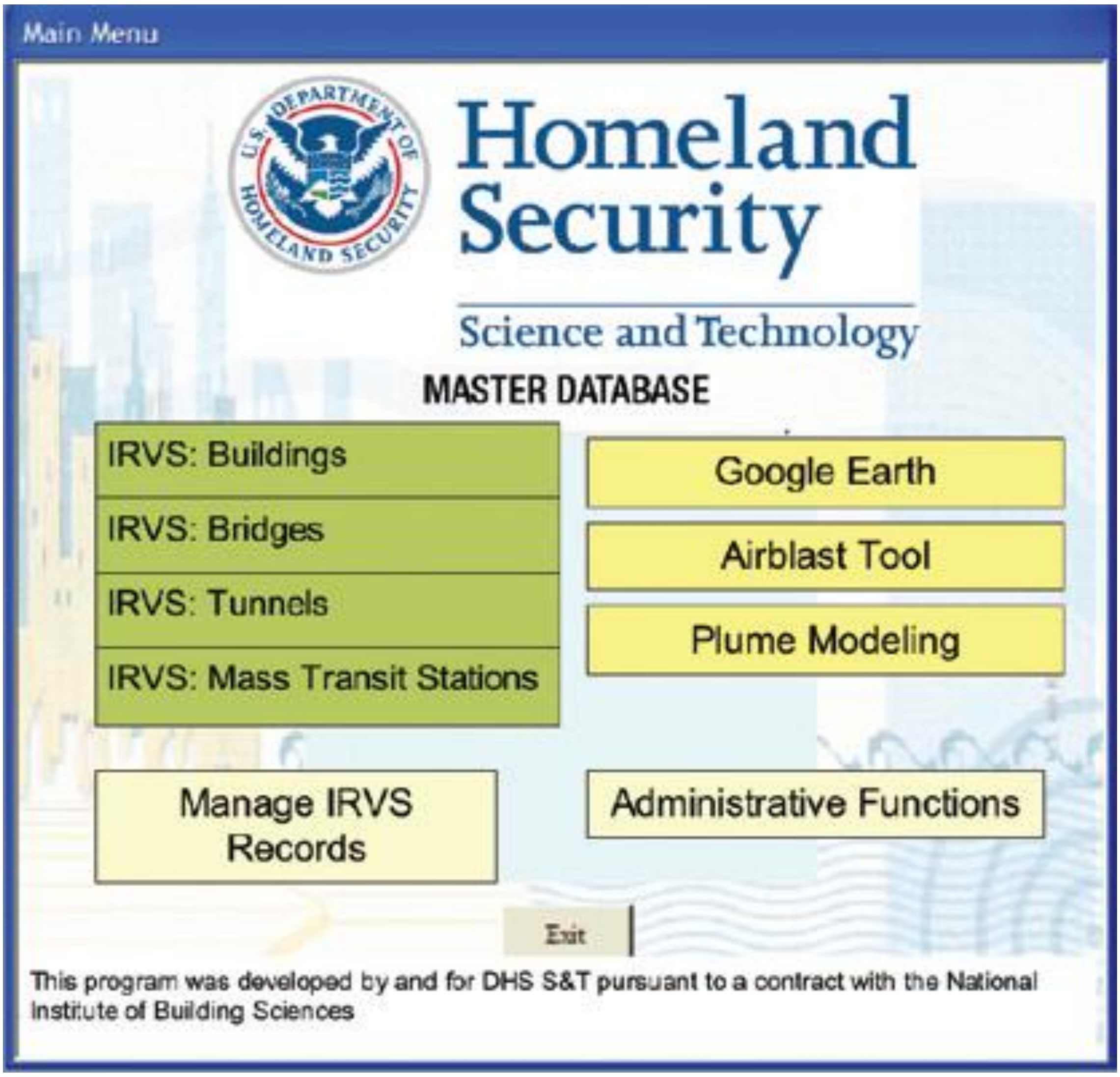
IRVS uses an ***enhanced computer software package*** that integrates itself with *Google earth and local emergency services* database to allow for quick screening and quickest possible hazard recovery

2.5.2 IRVS DATABASE SOFTWARE*[7]:

IRVS Database software is a computer software package available on FEMA website that uses RVS observations and suggests suitable measures itself. It also integrates itself with Google Earth and emergency management systems for accurate position determination of the structure being screened and hence facilitates adequate measures in case of occurrence of an emergency.

"With the improvements to the IRVS database software, the IRVS methodology is now completely digital. The software facilitates data collection and functions as a data management tool. Assessors can use the software on a PC tablet or laptop to systematically collect, store, and report screening data. The software can be used during all phases of the IRVS procedure (pre-field, field, and post-field)"*[7]

Figure 6 *[7]: Glimpse of IRVS Database Software



Capabilities of IRVS Database Software*[7]:

Digital catalogue and forms
Field data collection and storage
Automatic risk scoring
Printable reports
Interaction with Hazus-MH
Google Earth application
Fast running air blast tool
Chemical, biological, and radiological (CBR) plume modeling
Resiliency model
Cost-effectiveness tool

Audience for IRVS Database Software*[7]:

Engineers, architects, and other design professionals
City, county, and State officials
Emergency managers
Law enforcement agencies
Lenders
Insurers
Building owners/operators
Facility managers
Security consultants

IRVS Tools Timetable*[7]:

FY2010 IRVS Tool 2.0 for Buildings
IRVS Tool for Mass Transit Stations
IRVS Tool for Tunnels
IRVS Database Software

FY2011 IRVS Tool for Bridges

2.6 RAPID VISUAL SCREENING (RVS) FOR INDIAN CONDITIONS

2.6.1 OVERVIEW:

The *FEMA methodology* of rapid visual screening is *not exactly suitable for Indian conditions in its original form*. The reason behind this is that India is diversified country with construction practices ranging from highly urban construction comprising of modular steel and RCC structures to basic mud or earthen structures in villages. Hence only some not all structure types mentioned in FEMA 154 can be associated with Indian structures. Moreover the difference in size and occupancy and construction practices used to build these structures also has their own influence. The seismicity variation in India cannot be also overlooked. Thus we need a somewhat different methodology for RVS as per Indian conditions.

In this regard the contributions of *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 worth mentioning who contributed to development of basic philosophy of RVS for Indian Structures (RCC, steel frame and Masonry) through their research on the basis of norms of new seismic code of India IS 1893:2002. Prof. Sinha and Prof. Goyal used score system of FEMA 154 to and made the use of final structural score S to classify various damageability grades derived from European Macro seismic Scale (EMS-98). Later, based on same European Macro seismic Scale (EMS-98) recommendations, classification of Indian structures and damageability that particular structure could undergo was done by Dr. Arya. Data collection forms were prepared and suitable procedure was proposed. Later on the same methodology was incorporated in *IS 13935:2009 "Indian Standard Seismic Evaluation, Repair and Strengthening of Masonry Buildings- Guidelines (First Revision)"*

Rapid Visual Screening (RVS) for Indian conditions as specified in IS 13935:2099 is based on a **"*Logical system*"** rather than a "structural score system" as in FEMA 154.

In this system *6 building types are mentioned (A to F)* in which some types (C and D) are common for both masonry and RCC/steel frame structures. + Sign is used to specify slightly more seismic strength or lower seismic vulnerability. *Five Damageability Grades (G1 to G5)* are also specified separately for masonry and RCC/Steel frame structures. Based on the type of structure and its location in a particular *seismic zone (zone 2 to zone 5)*, the damage which it can undergo is specified in the form of a table. Moreover some *other parameters like falling hazards, special hazards, URM infills and Special observations are specified.*

Based on these parameters and the type of structure and seismic zone the observer or screener can identify the damage which the structure can undergo (in terms of damageability grade G) and Remedial measures that could be done for its prevention. All this is recorded in

Data Collection Forms (separate form for each seismic zone (4 zones) ; total 8 forms, 4 for masonry structures and 4 for RCC/Steel frame Structures)

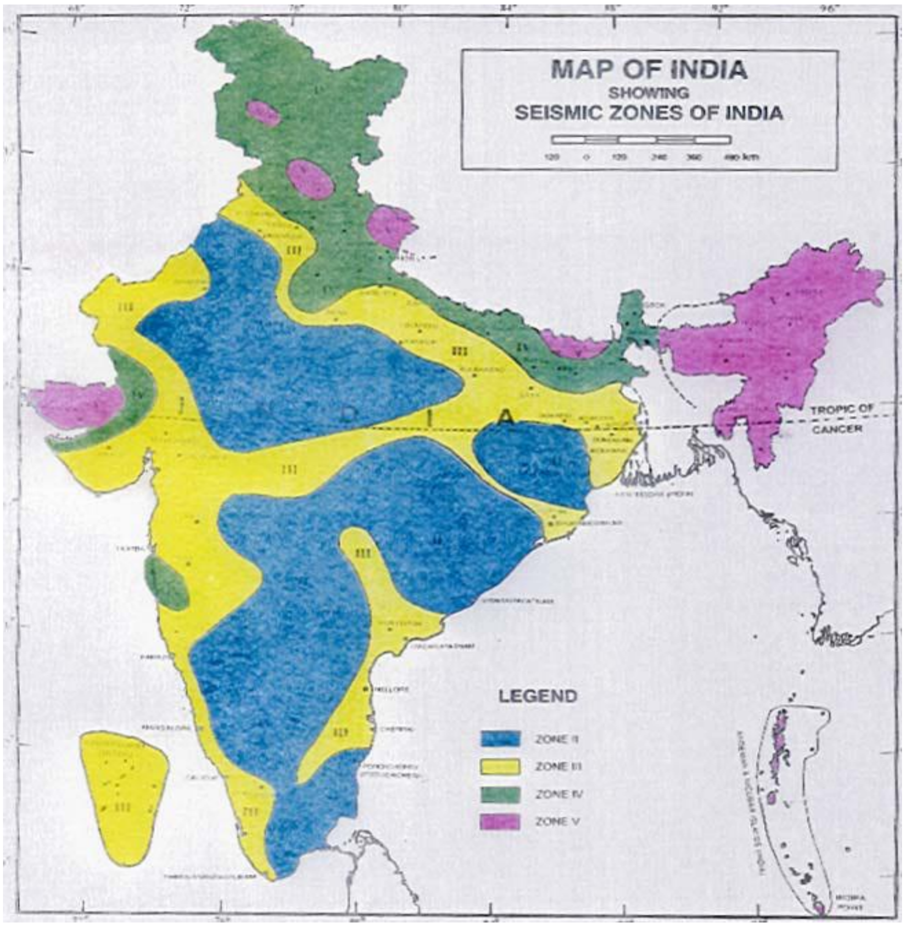
2.6.2 SEISMIC ZONES IN INDIA*[14]:

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

Zone II Low seismic hazard (damage during earthquake may be of MSK Intensity VI or lower)
Zone III Moderate seismic hazard (maximum damage during earthquake may be up to MSK Intensity VII)
Zone IV High seismic hazard (maximum damage during earthquake may be up to MSK Intensity VIII)
Zone V Very high seismic hazard (maximum damage during earthquake may be of MSK Intensity IX or greater)

When a particular damage Intensity occurs, different building types experience different levels of damage depending on their inherent characteristics. *For carrying out the Rapid Visual Screening, all four hazard zones have been considered.*

Figure 7 *[6]: Seismic zones in India as per IS: 1893-2002



2.6.3 STRUCTURE TYPES FOR RVS AS PER INDIAN CONDITIONS:

Variety of construction types and building materials are used in urban and rural areas of India. These include local materials such as mud, straw and wood, semi-engineered materials such as burnt brick and stone masonry and engineered materials such as concrete and steel.

The seismic vulnerability of the different building types depends on the choice of building materials and construction technology adopted. The building vulnerability is generally highest with the use of local materials without engineering inputs and lowest with the use of engineered materials and skills. The basic vulnerability class of a building type is based on the average expected seismic performance for that building type.

All buildings have been divided into 6 types; type A to type F based on the European Macro seismic Scale (EMS-98) recommendations. The buildings in type A have the highest seismic vulnerability while the buildings in type F have the lowest seismic vulnerability.

A building of a given type, however, may have its vulnerability different from the basic class defined for that type depending on the condition of the building, presence of earthquake resistance features, architectural features, number of storeys etc. It is therefore possible to have a damageability range for each building type considering the different factors affecting its likely performance. Some variations in building type are therefore defined as A, B, B+ etc.

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 1*[6] : Classification of Masonry Structures 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.

Table 2 *[5]: Classification of RCC/Steel Frame Structures for RVS

2.6.4 DAMAGE CLASSIFICATION AS PER INDIAN CONDITIONS:

Table 3 *[6]

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 4 *[5]

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 BUILDING TYPE AND DAMAGE CORRELATION AS PER INDIAN CONDITIONS:

Table 5 *[6]: Structure type and Damageability correlation for 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
MASONRY BUILDINGS	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 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 IN RVS 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.

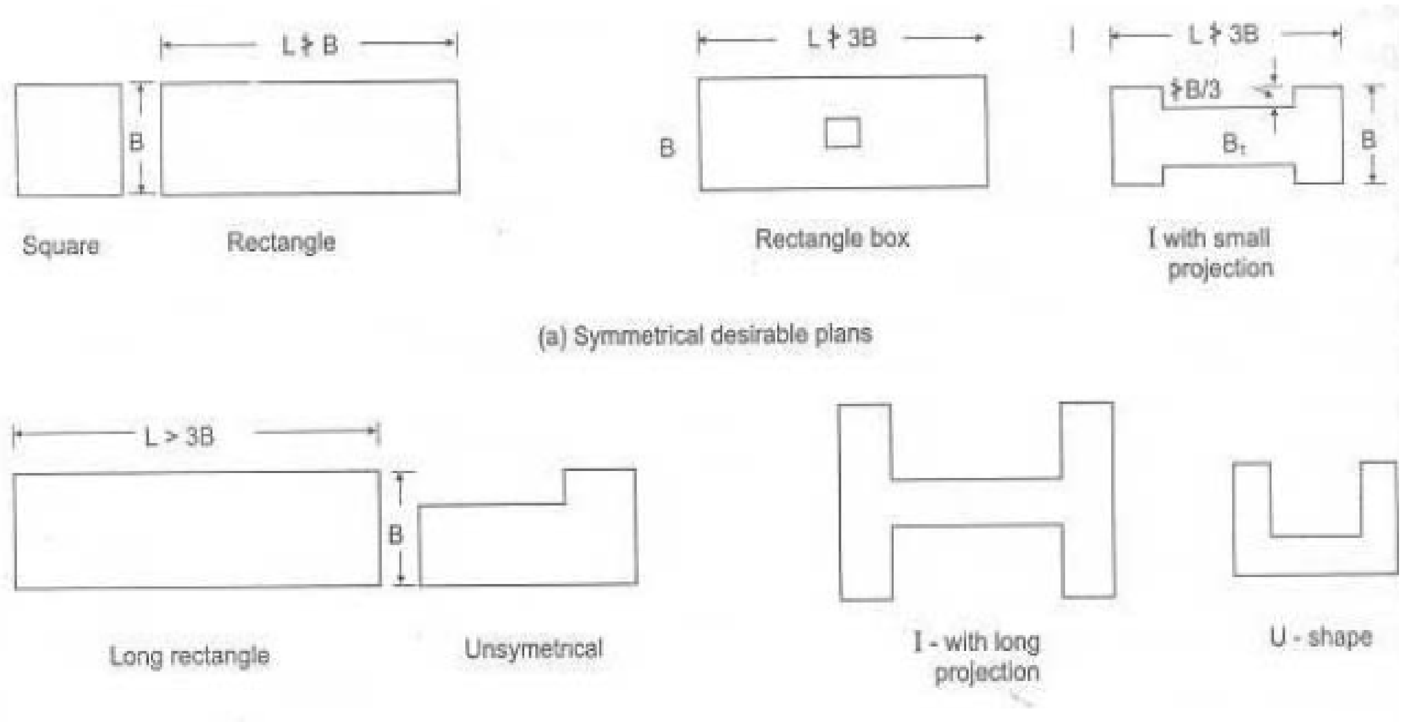
5) Special Observations:

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.

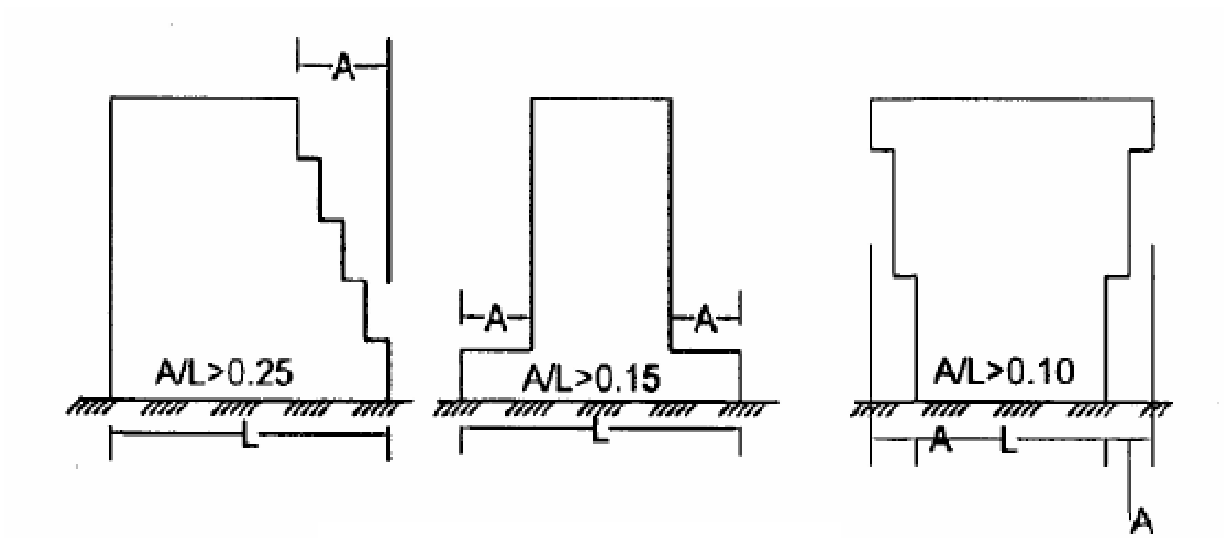
6) URM Infills:

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 8 *[5] *[6]: Various Irregularities in structures (masonry and RCC/SF)

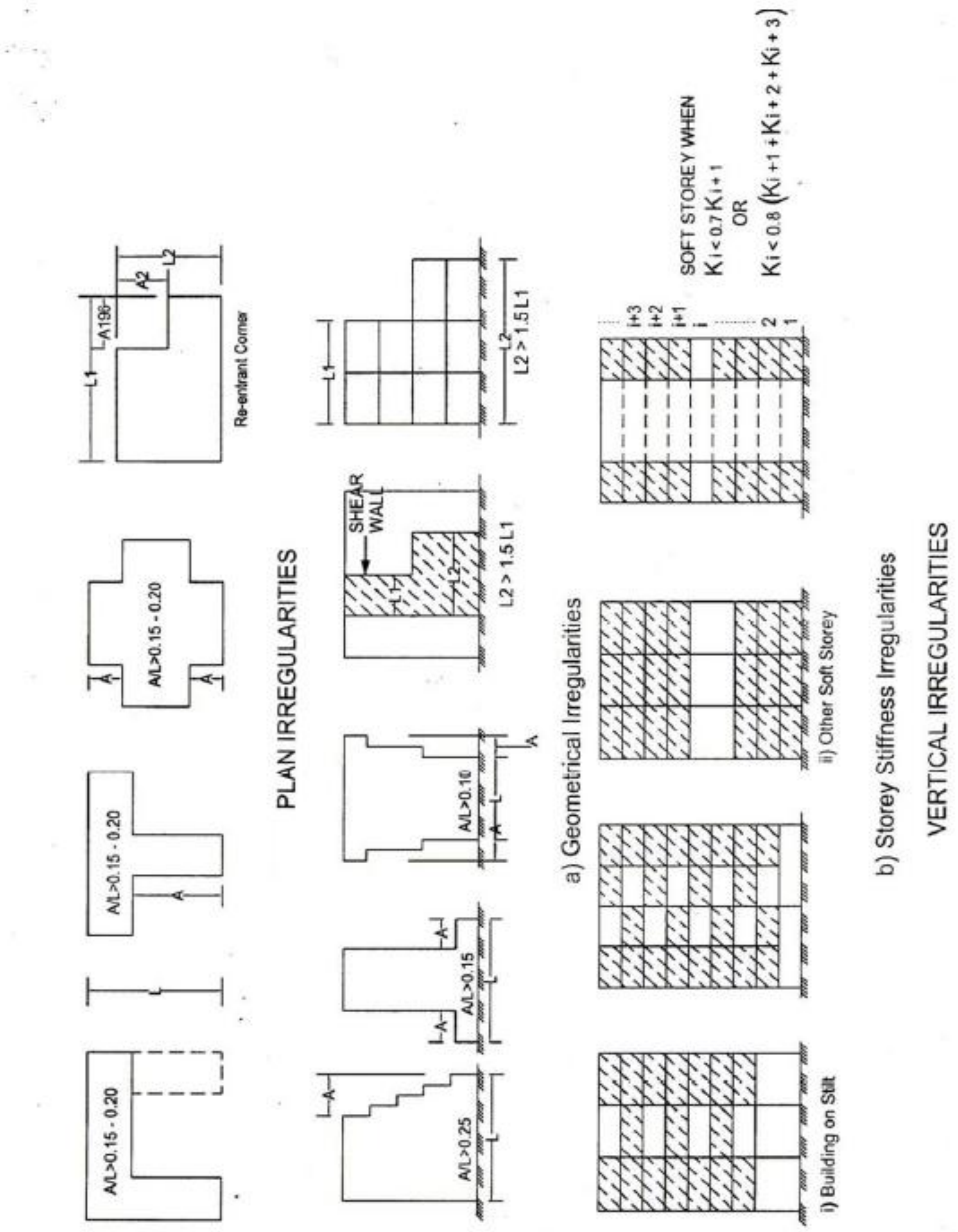


HORIZONTAL IRREGULARITIES



VERTICAL IRREGULARITIES

Fig 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	A	B / B+	C / C+	D
Zone II	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

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 ☐

5.4 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.

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.

Surveyor's Sign : ____________

Name: ____________

Executive Engineer's Sign: ____________

Date of Survey: ____________

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.	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 ☐
**Any building having more than 100 Occupants may be treated as Important.* *2.2 Ordinary buildings:-* Other buildings having occupants <100	**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 ☐	

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.	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 ☐
**Any building having more than 100 Occupants may be treated as Important.* *2.2 Ordinary buildings*:- Other buildings having occupants <100	**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 ☐	

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			
Damage- ability in Zone V	A	B / B+	C / C+	D
	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.: 1^{st} _____, 2^{nd} ______, 3^{rd}_______ .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.: 1^{st} ______, 2^{nd} ______, 3^{rd} ______ .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 POINTS OF ANALOGY IN VARIOUS METHADOLOGIES (FEMA 154 AND INDIAN RVS METHODOLOGIES SPECIFIED IN IS CODE AND DIFFERENT REPORTS)

2.7.1 ANALOGY OF STRUCTURE TYPES:

S.No.	Structure type	As denoted in FEMA 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

Table 7:Analogy of structure types

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*[1]
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:**”*[1]**

• 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

3. DEVELOPMENT OF NEW MODIFIED RVS METHODOLOGY

3.1 OVERVIEW

The RVS procedure for Indian conditions as adopted by BIS and mentioned in IS 13935:2009 is a no doubt a very simple and quick procedure based on logic. It gives a very comprehensive and detailed classification of structure types which are very commonly found in India.

But although it is a very quick and simple procedure, it somewhat lacks in incorporating the level of details and accuracy of FEMA process for RVS. The FEMA methodology is based on structural score method and gives a clear indication of whether a building is seismically safe or not by comparing the structural score and cut off score. It gives a clear line of demarcation between safe and unsafe buildings. While on the other hand, the Indian methodology, although relatively simple and easy to apply, does not give a clear line of demarcation, instead it gives logical basis of judging safety and buildings just lying on the boundary line of seismically safe and unsafe structure can easily be misjudged. Thus in Indian methodology for RVS, a lot lies on the wisdom of the screener or the observer.

On the other hand the FEMA methodology for RVS when used for Indian conditions has its own areas of limitations. There certain factors in FEMA methodology that although recorded during RVS process, but they do not actively participate in affecting the overall structural score. Examples are occupancy, condition of building, age, soft storey presence etc. There are some other factors also which are not yet mentioned in FEMA and play a dominant role in affecting the overall seismic safety of the building. These factors are characteristic features of building's surrounding environment and play a very dominant role in a country like India where construction might be highly diversified and unplanned.

Thus we need a RVS system that uses a scoring method just like FEMA 154 but at the same time also incorporates sufficient no of factors that might be affecting overall seismic vulnerability of the structure being screened.

In order to achieve such a system, in the present project work, the FEMA 154 methodology is adopted in its original form with limited no of structures (10 in place of 15 structures as taken in report of Prof. Sinha and Prof. Goyal (IIT Bombay)*[12]. Some additional modifiers are also added in order to enhance the accuracy and suitability of the system as per Indian conditions. Later on an MS Excel program has been developed in order to get a more refined, accurate and speedy score based RVS system for Indian conditions.

3.2 FEATURES OF NEW DEVELOPED RVS SYSTREM

The **factors that are already mentioned** in RVS procedures specified in FEMA 154 and in Ref. No. 12 and also in IS 13935-2009 (Which is similar to Ref. No. 5 and Ref. No. 6) that contribute to enhancing or lowering of seismic strength of a particular building are-

1) Structure Type

2) Height of building (low medium or high rise depending upon no of storeys)

3) Soil type

4) Code Detailing (Pre code and Post benchmark as per FEMA 154 and simple code detailing as per other Indian reports and IS 13935)

5) Plan Irregularity

6) Vertical irregularity

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

In the new system for RVS that is being developed for <u>more accuracy</u>, the structural score system is adopted. **Above mentioned 7 factors are taken as such. In addition some new factors** are introduced which modify the structural score. Some of these factors were already mentioned in previous reports but not included in calculating scores. Now these are also assigned some specific scores along with some totally new factors. Together clubbed they are termed as **<u>"additional score modifiers"</u>.** They are-

8) Age of Building at the time of screening

9) Condition of building (Presence of vegetation, cracks, fallen plaster, exposed reinforcement, deflected members etc.)

10) Occupancy (decides the importance of building)

11) Falling Hazards (Chimneys, parapets etc.)

12) Bottom Soft storey presence (Stilt Building)

13) Collateral Damage Vulnerability (It signifies whether the surrounding environment of the building being screened can pose a threat e.g. a tall tower in close proximity to the building)

14) Emergency services availability (nearness to a fire station and hospital)

15) Ease of Evacuation (Presence of wider staircase, no of exits)

Each of these additional modifiers is given a value on a scale of 1 to 10 (except occupancy) to signify their **degree of presence or dominance (denoted by D)** in a particular structure. The **nature of D is + or –** depending upon whether a particular additional modifier contributes to seismic safety (+ increases the final structural score) or reduces the seismic safety (- reduces the final structural score).

Since every additional modifier affects the seismic vulnerability to different degree, hence a **Sensitivity/weightage factor (denoted by W) is given to each additional modifier**. The sensitivity/weightage factor is chosen wisely so that the final modifiers score (SXW) lies in the same range as modifier score of default factors.

The **final modifier score that each additional modifier contributes to the overall score is the product of D and W**

i.e. ADDITIONAL MODIFIER SCORE (for additional modifier) **= (+/-D) X (W)**

The **Final Structural Score (S)** is given by the **summation of basic score modifier values (from 1 to 7) and additional score modifier values as calculated above (from 8 to 15)**

With the inclusion of additional modifiers the **final cut off score is also modified**. The details are mentioned further in the report.

3.3 ORDER OF IMPORTANCE OF ADDITIONAL MODIFIERS (SENSTIVITY/WEIGHTAGE FACTORS)

Not all additional modifiers mentioned before have the same degree of influence or effect. Some additional modifiers like "soft storey presence" highly dominate the seismic behaviour of the building while other additional modifiers like "ease of evacuation" and "emergency services availability" affect the overall seismic vulnerability to a very small degree. This is the reason why Sensitivity/weightage factors (W) have been assigned to each additional modifier.

The additional modifiers in there order of importance (starting from most important to least important) along with their Sensitivity/Weightage factors (W) are expressed in the following table:

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

Table 8: Weightage factors for additional score modifier parameters

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 9: Weightage factors and Final additional Modifier cut off scores

S.No.	Additional Score Modifiers	Degree of Presence or Dominance (D)	Nature of D	Sensitivity/Weightage Factor (W)	Final additional modifier score =[(+/-D) X (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.	Age of Building	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 (Summation of final additional modifier scores) = **-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:

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)

Table 10: Final Cut Off scores and score ranges

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 Ref. No. 12)

(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. **Age of building**	(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	**YES NO**
S€(-0.95,+0.35)	High probability of **Grade 3** damage, very high probability of **Grade 2** damage	
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 Ref. No. 12)

(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. **Age of building**	(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)

S>-1.35 High probability of **Grade 5** damage, very high probability of **Grade 4** damage

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

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

FURTHER EVALUATION

(RECOMMENDED IF S < +0.35)

YES NO

MODIFIED DATA COLLECTION FORM FOR RAPID VISUAL SCREENING OF BUILDINGS

(Based on FEMA 154 and Ref. No. 12)

(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. **Age of building**	(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	**YES NO**
S∈(-0.95,+0.35)	High probability of **Grade 3** damage, very high probability of **Grade 2** damage	
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	

(BACK)

SKETHCHES OF LAYOUT (PLAN AND ELEVATION)	
PLAN	ELEVATION
PHOTOGRAPHS	

4. DEVELOPMENT OF MS EXCEL PROGRAMS FOR RAPID VISUAL SCREENING (RVS)

4.1 OVERVIEW

Based on the RVS methodologies as mentioned in IS 13935:2009 (taken from Ref. No. 5 and Ref. No. 6) and as mentioned in FEMA 154 (2nd edition) and Ref. No. 12, 2 separate MS Excel Programs have been prepared. One Excel program is completely based on the RVS procedure mentioned in IS code and is used for performing RVS and recording results accordingly (This program is later used to attain results which can be used for comparison purposes), while the other Excel program is based on new modified RVS system developed (as explained in the previous articles) but at the same time also performs RVS as per traditional FEMA 154 procedure and gives results for both approaches.

These programs facilitate the process of RVS as the screener now does not have manually fill the RVS data collection form. He simply has to enter 0 and 1 for some parameters and the program itself gives desired outputs Moreover the screener does not have refer to the theory of RVS because all the necessary references and instructions are attached with the program itself. Thus it *saves a lot of time* and *screening of the building can be done in a very short time by means of a handled tablet or laptop only*. Moreover, The RVS survey data and RVS results are also recorded for each building type for further reference

The programs are designed to be as *user friendly* as possible. The colour demarcations and instructions in simple language in these 2 MS Excel programs are aimed to provide better accessibility so that they are simple to understand and execute. These programs directly *display structural scores in numerical values and the other outputs in English language*. They are designed on *simple Logical basis using logical operators like IF, ELSE, AND, OR and some other functions.* They combine various structural types under the same sheet and gives *suitable outputs in terms of structural scores, expected damage, measures which should be undertaken to avoid damage and need for further evaluation*

Thus these programs help in **enhancing the speed** of new modified and developed RVS system as well previously defined RVS System by BIS.

4.2 MS EXCEL PRGRAM FOR RVS SYSTEM AS SPECIFIED BY BIS (BEUREAU OF INDIAN STANDARDS)

The source documents which have been used for developing this Excel program are the BIS committee reports*[5] and[6] and IS13935:2009*[3]

The Excel program consists of **5 worksheets**

Sheet 1 contains the *instructions* which the screener has to follow while conducting RVS using this program. It also contains the necessary *references* for different structure types (masonry, RCC and steel) and also the different types of damageability which each of these structures can undergo during an earthquake. This sheet also contains the necessary abbreviations used throughout the Excel spreadsheets and importance criteria of the building.

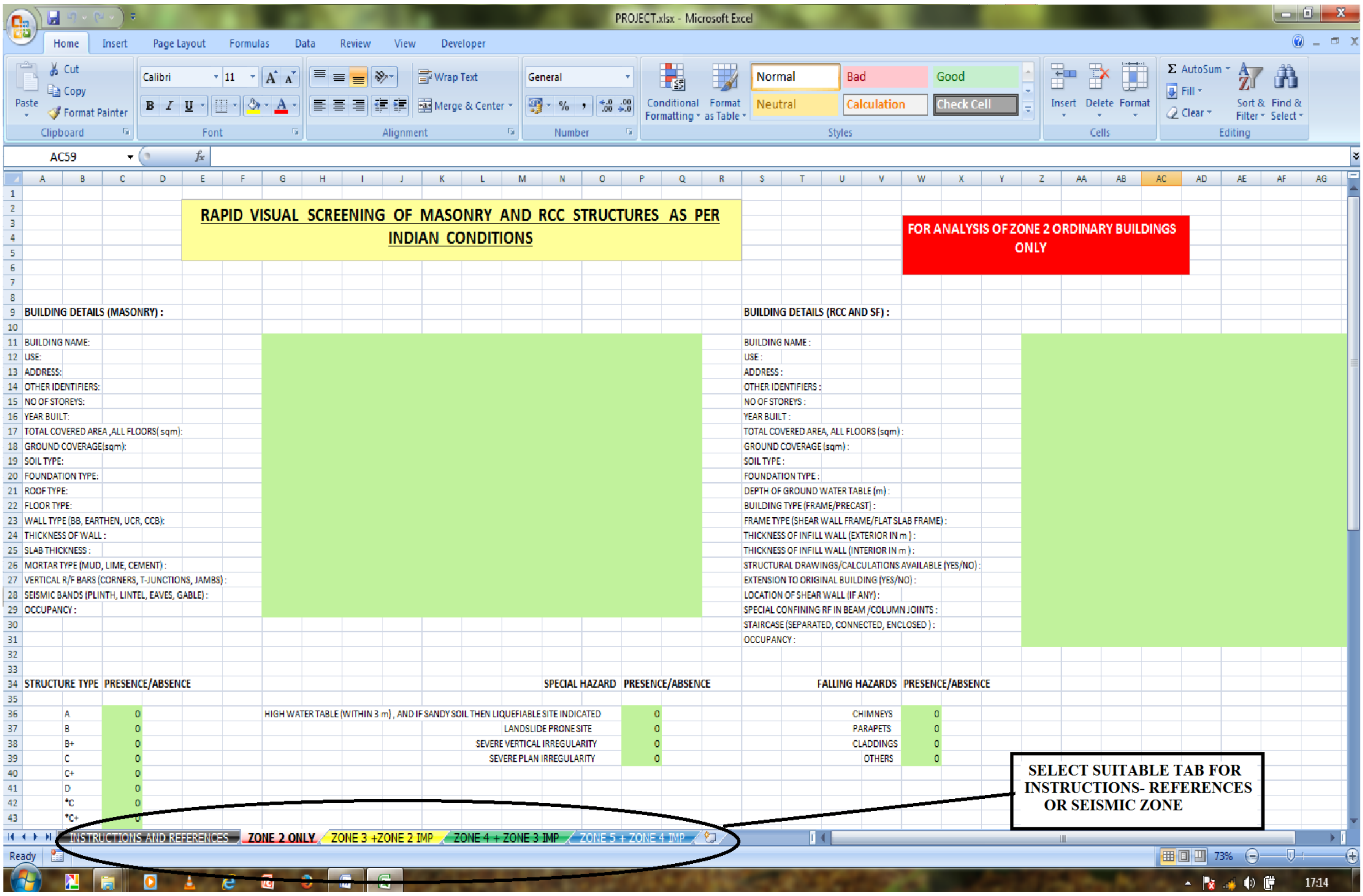
Sheet 2- Sheet5 are for the *four seismic zones of India* (zone 2, zone 3, zone 4 and zone 5). Each of the four sheets contains several green boxes or cells and some red boxes. The green boxes accept Input data like type of general building details, type of structure, special hazards, falling hazards, codal provisions and URM infills. The red boxes or cells display the output.

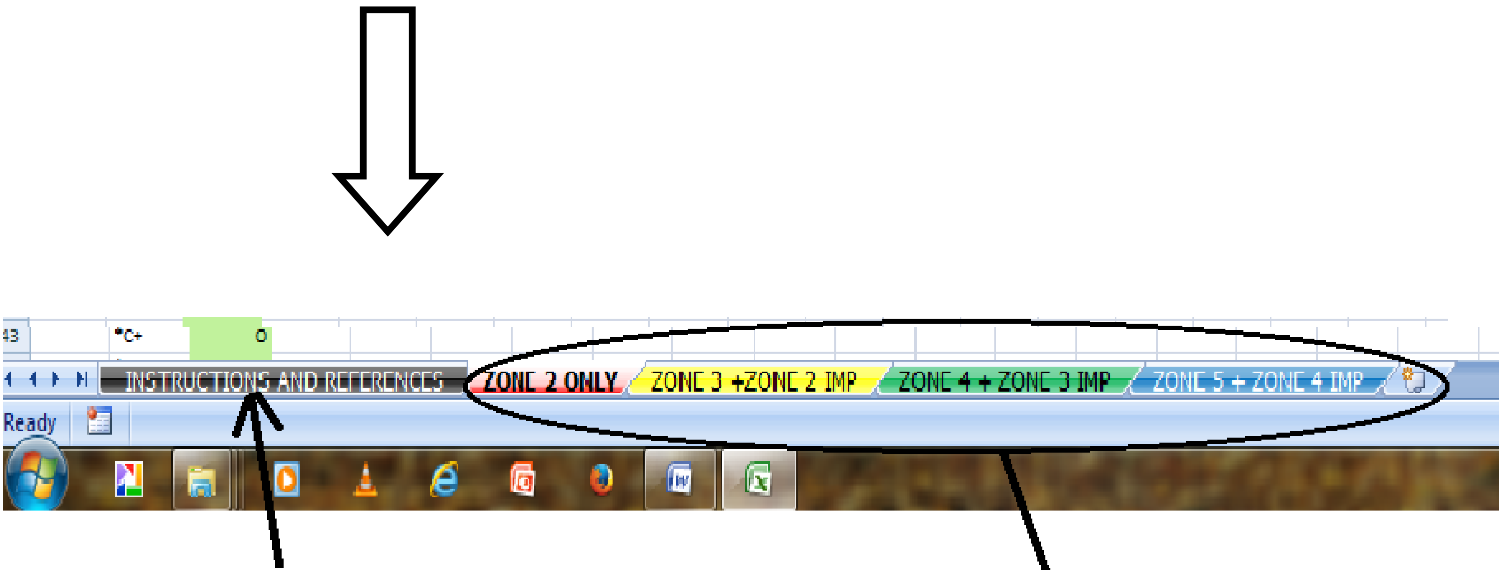
To begin with the screener has to carefully read the instructions and select suitable seismic zone from the bottom tabs. He has to then enter data in the green boxes. Care should be taken to enter this data. Data which has to be entered for buildings details can be of alphanumeric in nature and is for record sake only, while the data that has to be entered in all the other green boxes must be specifically in the form of 0 and 1. 0 indicates that the particular parameter for which it is entered is absent while 1 denotes the presence of the parameter. While entering the structure type the user can refer to the references provided in the 1^{st} sheet.

Once all the data has been entered by the user/screener, the Excel program will automatically display the output under the output section (in red boxes/cells). The output is displayed as the expected damageability grade in the screened structure and recommended measures to avoid that damage. To refer the details of the expected damage the screener can again go back to the reference section (Sheet 1)

Thus in this way within a short time the screener can screen the building for seismic vulnerability and recommended actions are suggested by the program.

Figure 9: Screenshots of MS Excel Program for RVS





READ INSTRUCTIONS FOR USING THIS EXCEL PROGRAM AND REFER TO BUILDING TYPE AND DAMAGIBILITY WHEN NEEDED

SELECT SUITABLE TAB FOR SEISMIC ZONE DEPENDING UPON LOCATION AND IMPORTANCE OF THE BUILDING BEING SCREENED

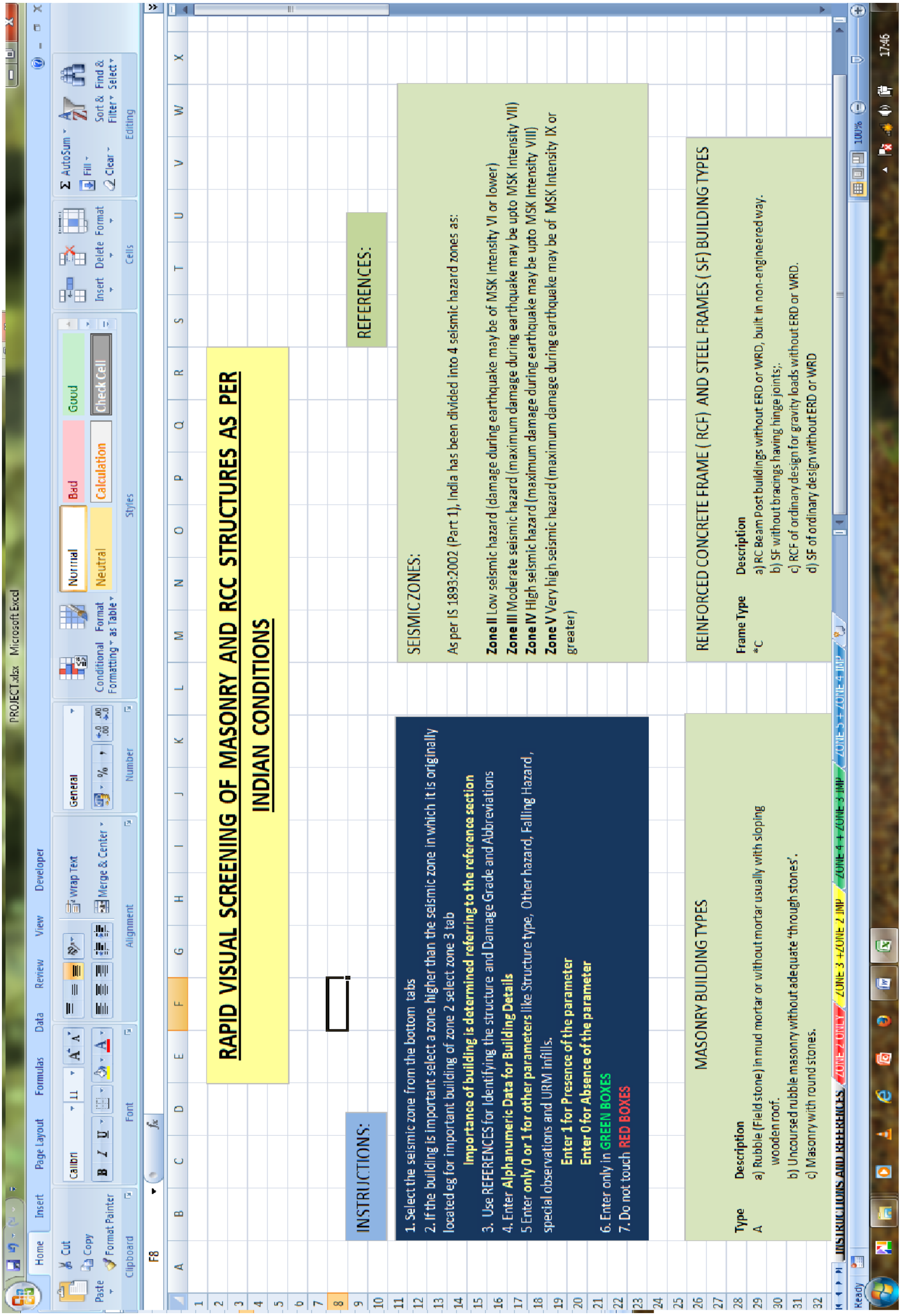


Figure 10: MS excel Program Reference Section (Sheet 1)

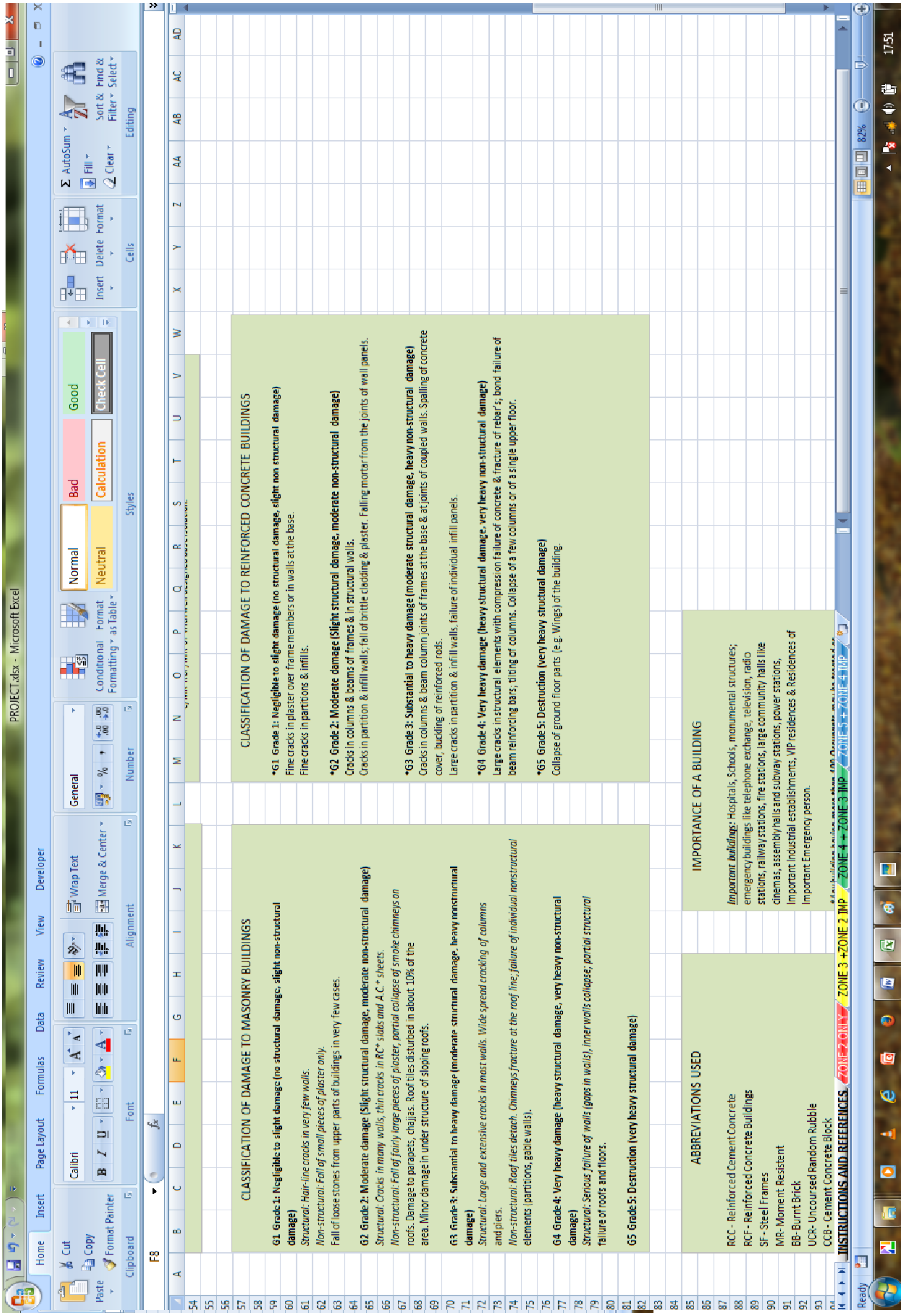


Figure 10 (Continued)

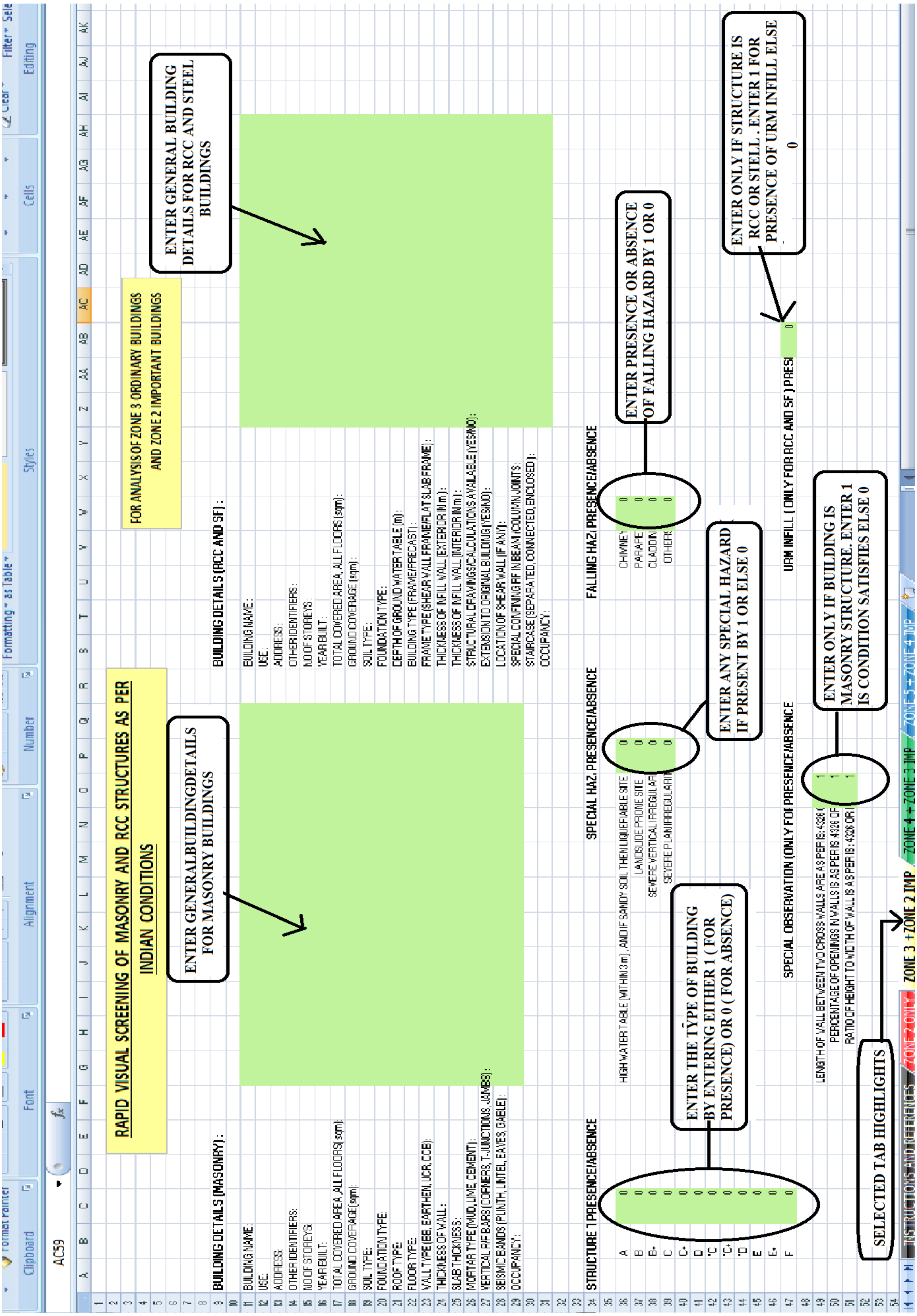


Figure 11: MS Excel program Inputs

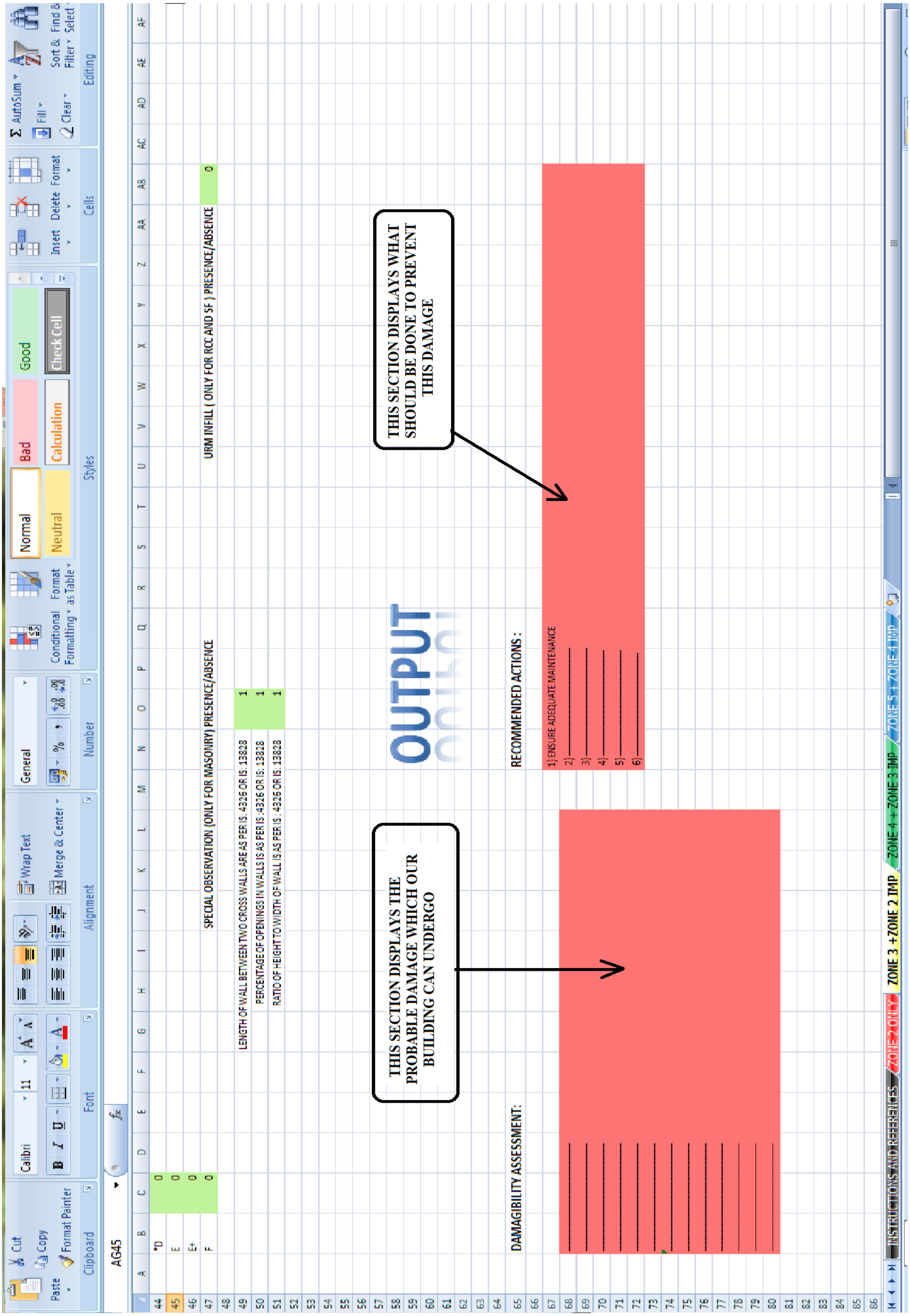


Figure 12: MS Excel Program outputs

4.3 MS EXCEL PROGRAM FOR NEW MODIFIED RVS SYSTEM (BASED ON FEMA 154 METHODOLOGY)

The source documents which have been used for developing this Excel program are FEMA 154*[1] and Ref. No. 12

The Excel program consists of **4 worksheets**

Sheet 1 contains the *instructions* which the screener has to follow while conducting RVS using this program. It also contains the necessary *references* for different structure types and also the different types of damageability which each of these structures can undergo during an earthquake. This sheet also contains the necessary abbreviations used throughout the Excel spreadsheets and importance criteria of the building.

Moreover, in addition to above, this sheet contains to links to important documents (FEMA documents, IS codes and reports) which may be referred by the screener if he/she is required to aquire additional knowledge about score modifiers and other RVS parameters while screening.

Sheet 2, Sheet 3 and Sheet 4 are for the *four seismic zones of India* (zone 2, zone 3 and zone 4 & 5). The seismic zones 4 and 5 are clubbed together because collectively represent high seismicity zone specified by FEMA. Each of the three sheets contains several green boxes or cells and various other coloured boxes. Only the green boxes accept Input data like type of general building details, presence or absence of basic score modifiers and degree of presence or dominance of additional score modifiers. The yellow and pink boxes display the score modifier values, final structural scores and other outputs.

To begin with the screener has to carefully read the instructions and select suitable seismic zone from the bottom tabs. He has to then enter data in the green boxes. Care should be taken to enter this data. The Building no that is being screened must be entered carefully. Data which has to be entered for buildings details can be of alphanumeric in nature and is for record sake only, while the data that has to be entered in all the other green boxes must be of numeric nature.

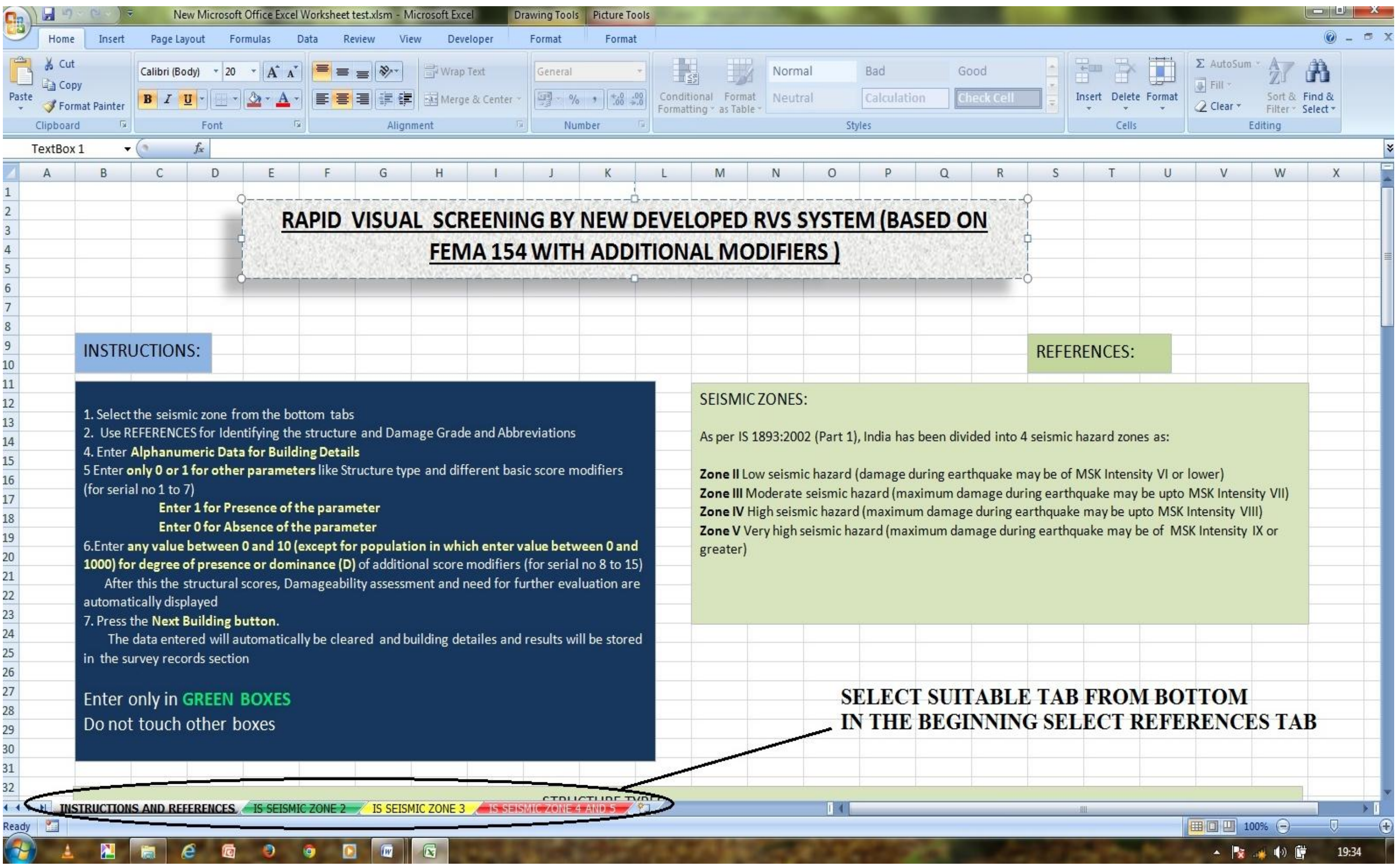
The data entered for basic score modifiers must be either 0 or 1. 0 indicates that the particular parameter for which it is entered is absent while 1 denotes the presence of the parameter.

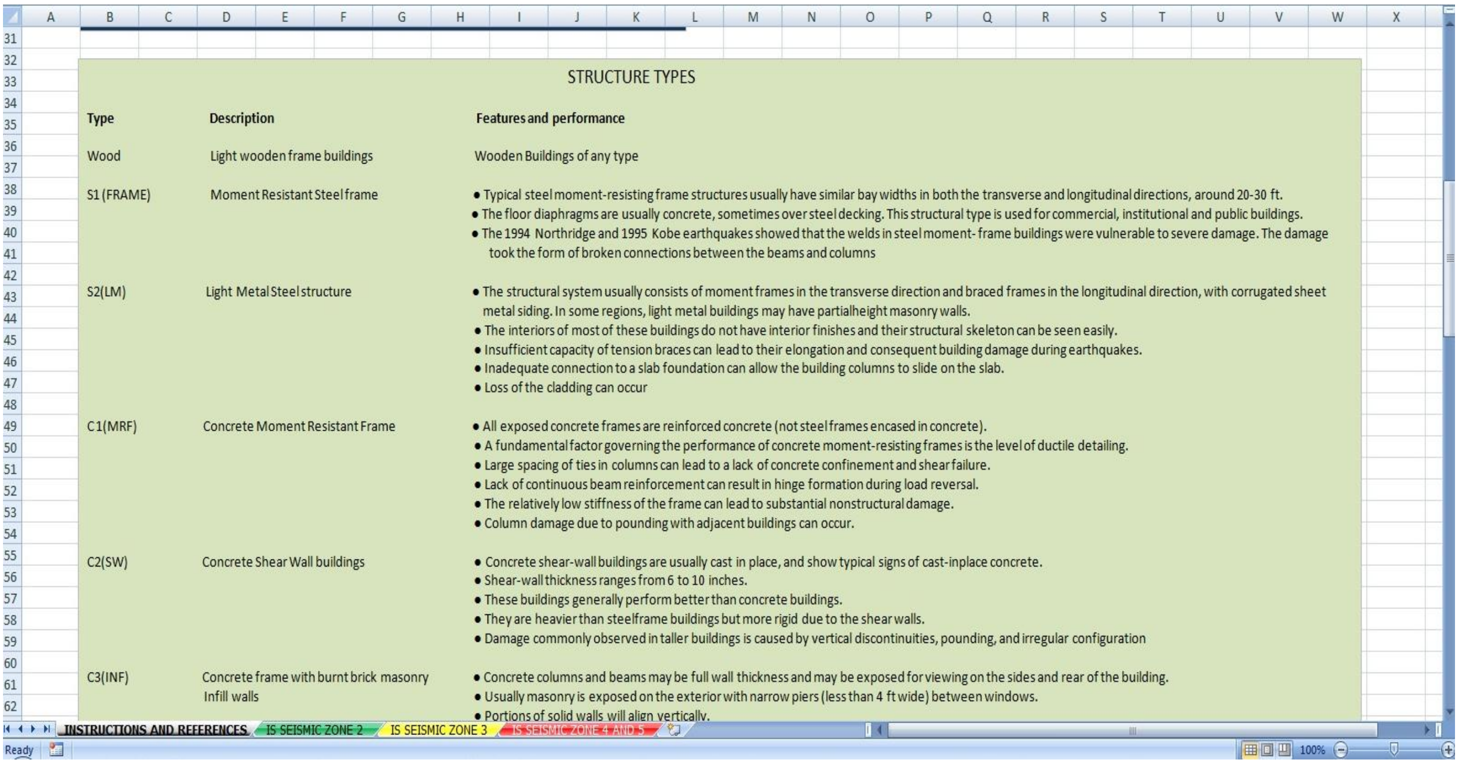
On the other hand, the data entered for Additional score modifiers must be between 0 and 10 (except for population for which it must be between 0 and 1000). This data represents the degree of presence or dominance of a particular additional modifier.

Once all the data has been entered by the user/screener, the Excel program will automatically display the structural scores and other outputs, both for new modified RVS system and for traditional FEMA 154 systems separately. This gives a very good scope of comparison. The output is expressed as Final structural score, expected damageability and requirement for need of further evaluation.

Now the screener has to press the “NEXT BUILDING” button. As soon as it is done the building details together with different outputs are automatically recorded in the survey records section and all the inputs are automatically cleared. Thus the sheet is again ready for screening of a new building.

Figure 13: Screenshots of MS Excel program for new modified RVS system

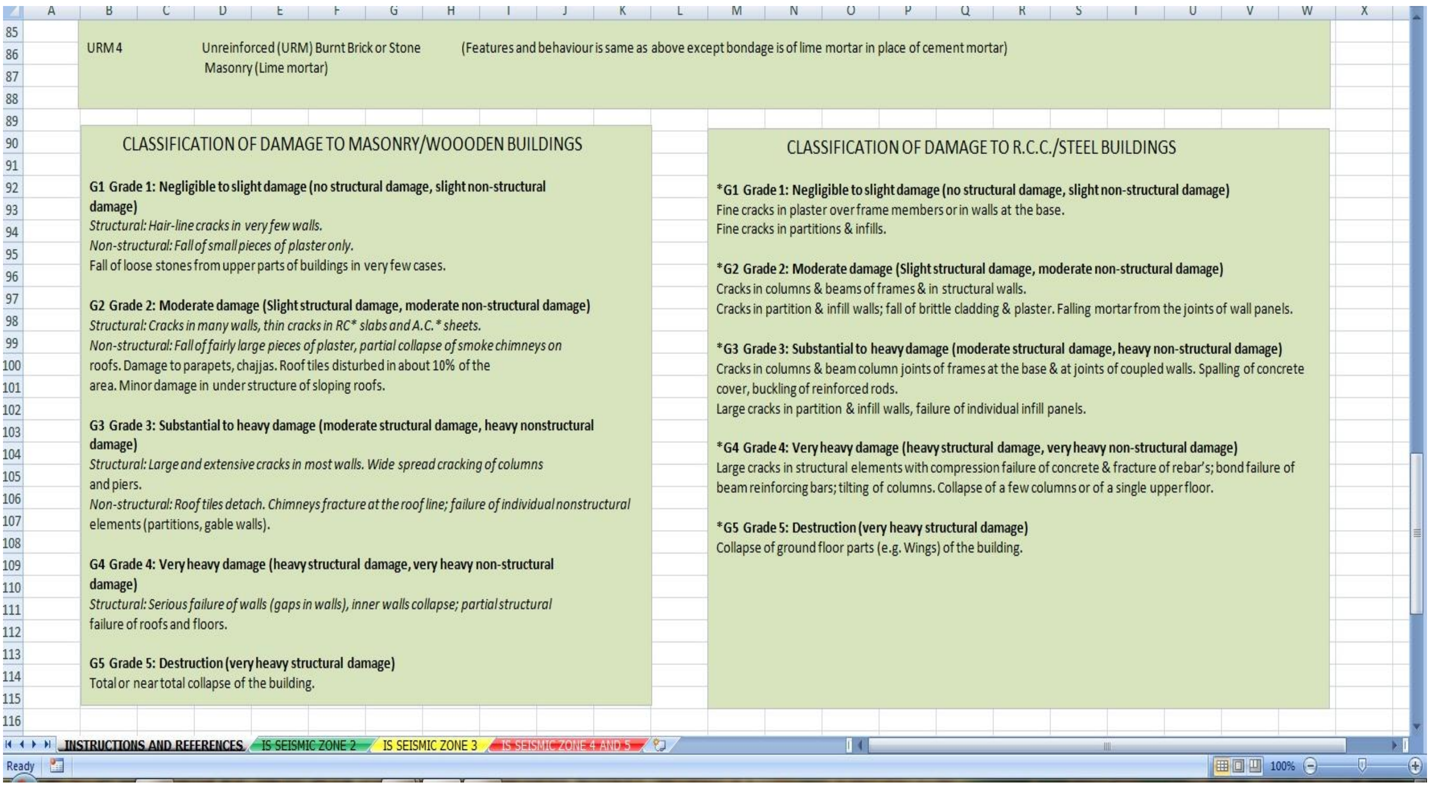




STRUCTURE TYPES

Type	Description	Features and performance
Wood	Light wooden frame buildings	Wooden Buildings of any type
S1 (FRAME)	Moment Resistant Steel frame	• 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(LM)	Light Metal Steel structure	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet metal siding. In some regions, light metal buildings may have partial height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur
C1(MRF)	Concrete Moment Resistant Frame	• 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.
C2(SW)	Concrete Shear Wall buildings	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-inplace concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete buildings. • They are heavier than steelframe 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(INF)	Concrete frame with burnt brick masonry Infill walls	• 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.

Figure 14: MS excel program Reference section for new developed RVS System



URM 4	Unreinforced (URM) Burnt Brick or Stone Masonry (Lime mortar)	(Features and behaviour is same as above except bondage is of lime mortar in place of cement mortar)

CLASSIFICATION OF DAMAGE TO MASONRY/WOOODEN 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 R.C.C./STEEL 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 panels.

***G3 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.

***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 failure of 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.

Figure 15: Links to important documents in Excel program for new developed RVS system

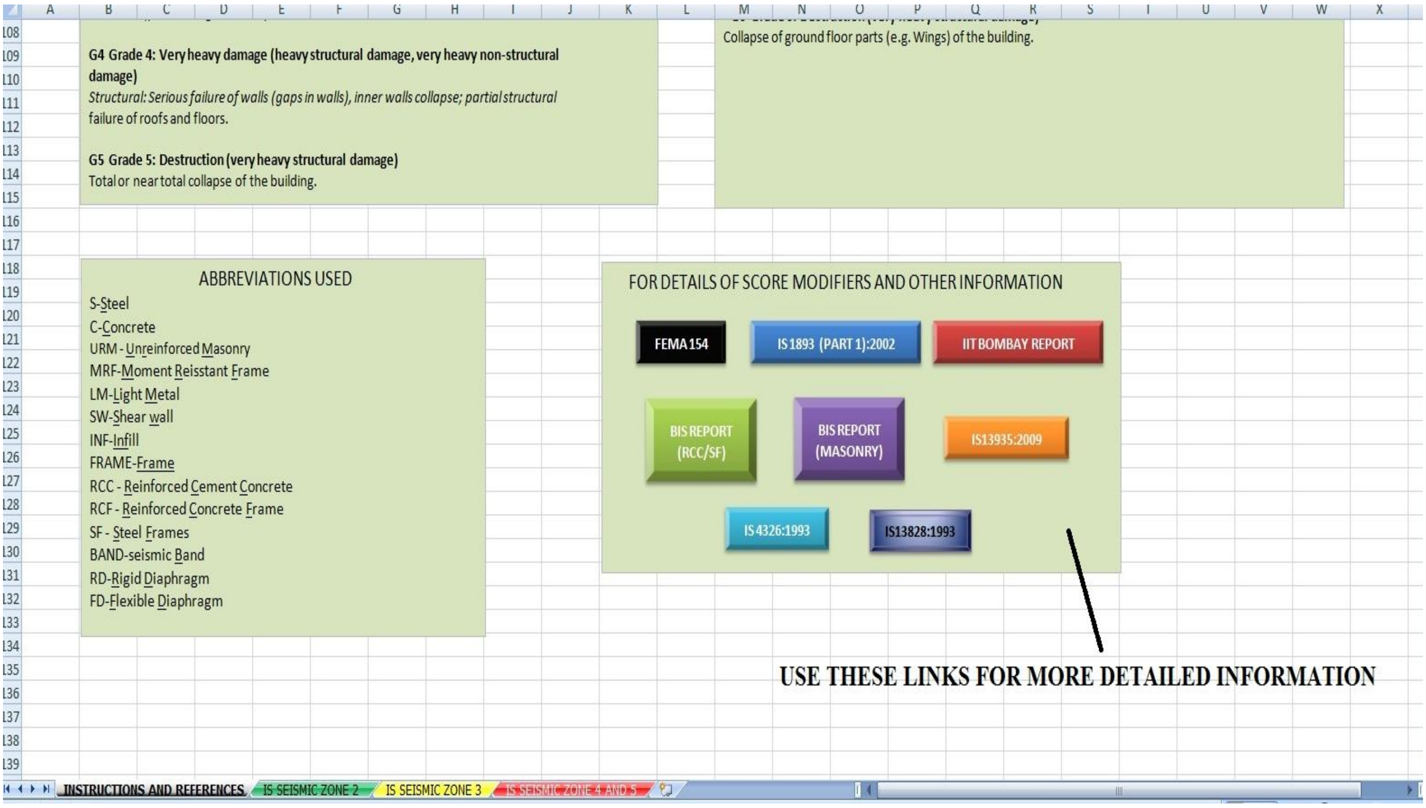
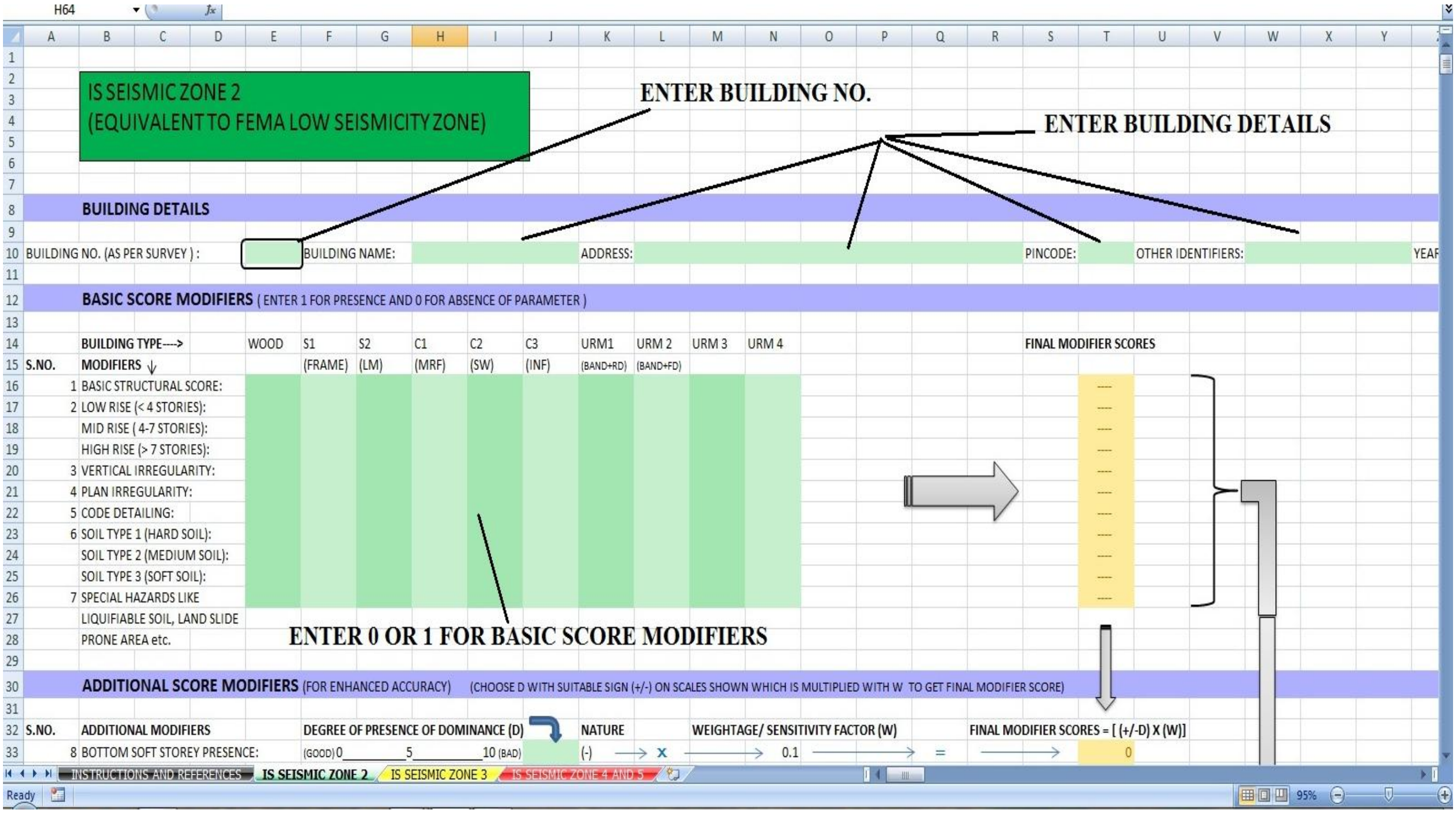


Figure 16: MS Excel program input section for new developed RVS system



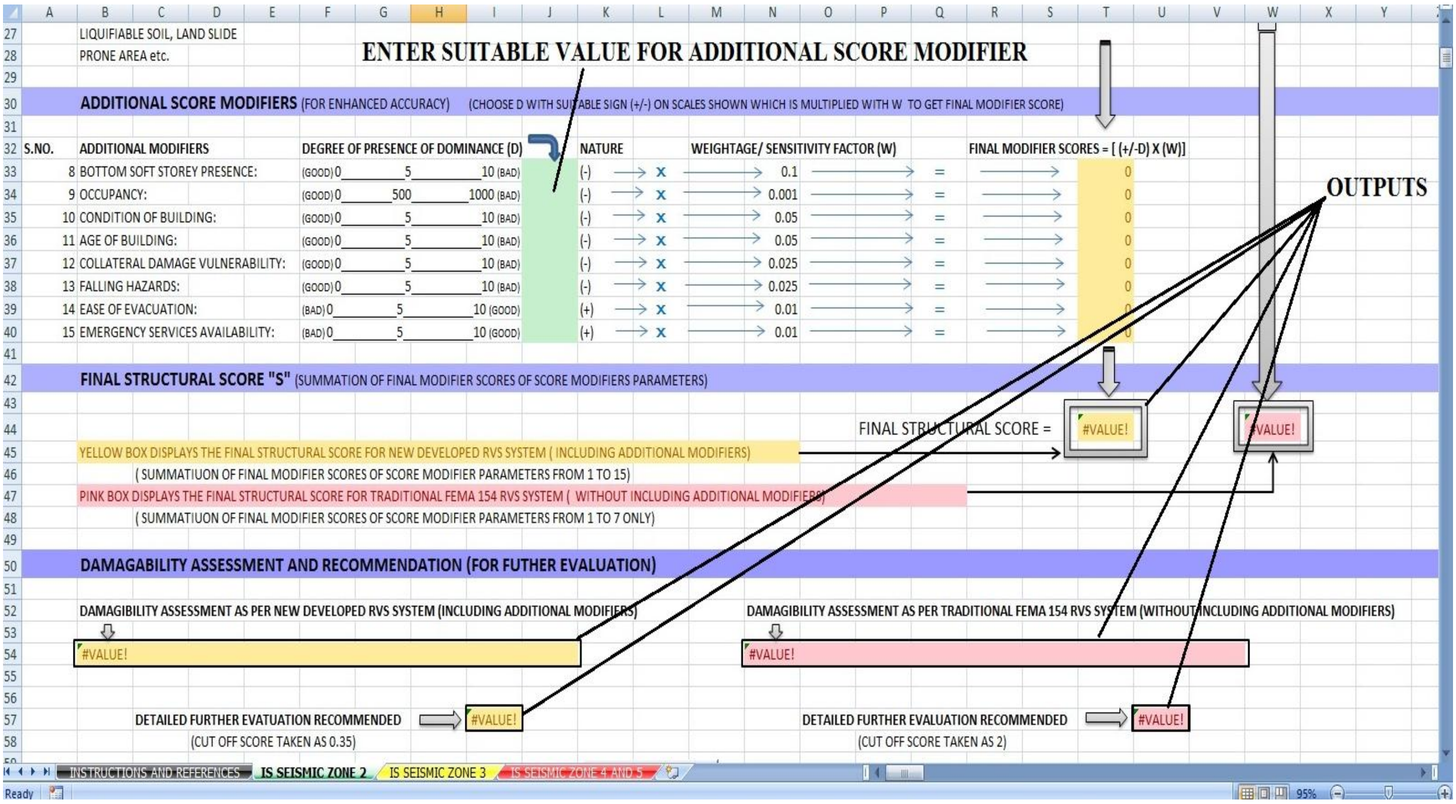
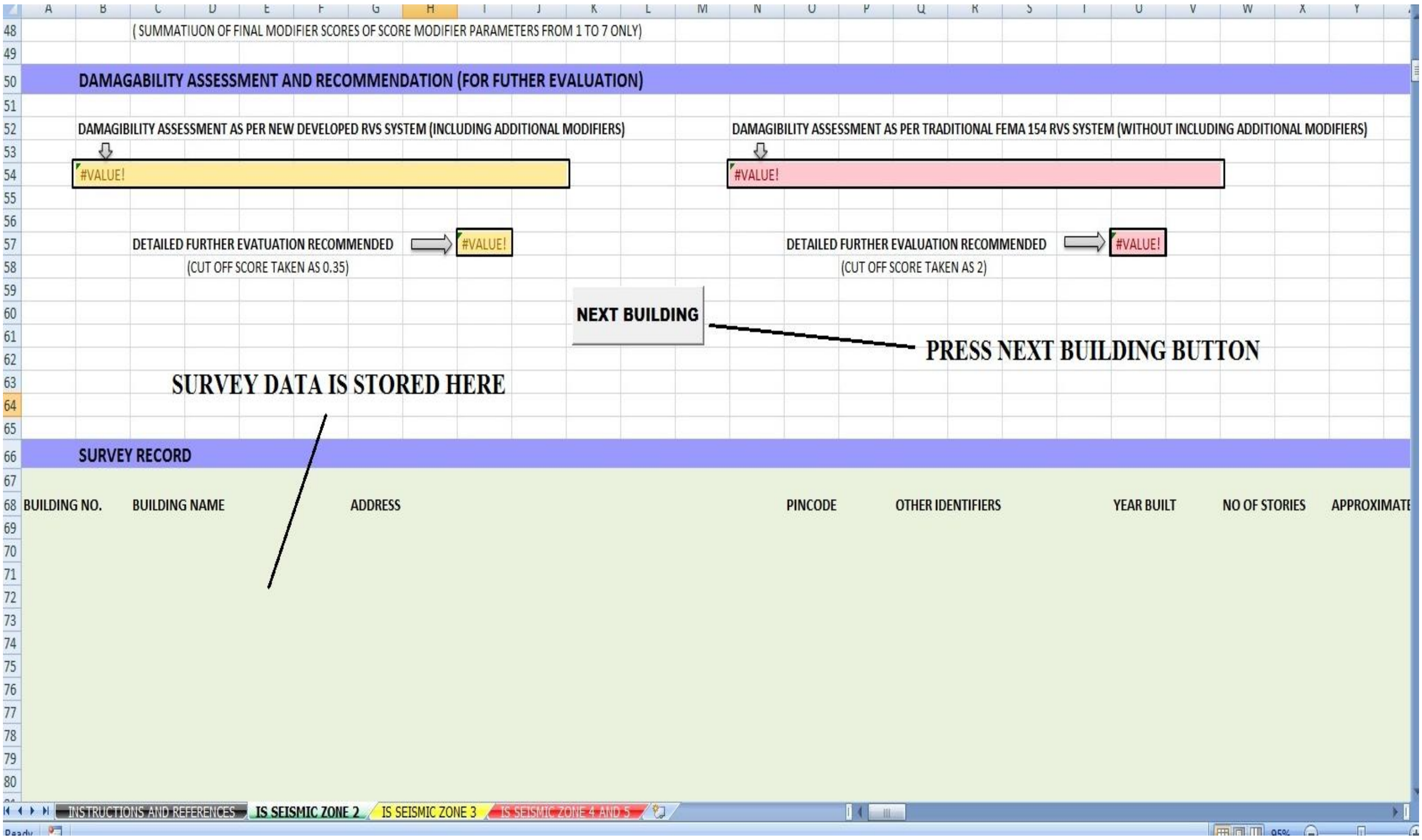


Figure 17: MS Excel program output and result section for new developed RVS system



5. FIELD STUDY AND SURVEY

5.1 OVERVIEW

In order to check the practical applicability of the new modified RVS system developed as explained in previous articles, Rapid Visual Screening (RVS) of a selected no of building structures was carried out in the city of Lucknow(Uttar Pradesh). About 51 building structures were screened to check their seismic vulnerability.

At the same time, RVS of these buildings was also performed using traditional FEMA 154 methodology (without the effect of additional modifiers) and also by RVS methodology mentioned in BIS reports and is13935:2009. This was done so that RVS results of all three methodologies could be compared and suitable meaningful inferences could be drawn.

The Following areas in Lucknow were surveyed during the screening process which mostly represent the major inhabited areas of Lucknow-

1 Daliganj

2 IT College area, Nishatganj and Mahanagar

3 Aliganj

4 Indiranagar and Gomtinagar

4 Old Lucknow (Chowk, Wazirganj ,Aminabad)

5 Hazratganj

6 Charbagh and Alambagh

Separate photographs for each building were taken and recorded. Layout sketches (Plan and elevation) were also made. In certain structures entry was prohibited, so the screener was unable to take the record of internal structure and plan. All these observations along with regular observations for RVS parameters are represented in the sections that follow.

5.2 INFORMATION ABOUT SOIL TYPE

The nature of soil type and liquefiable conditions were decided based on the information obtained from different reports. On site soil investigation was not performed since in RVS, being a level 0 investigation method, no kind of experimentation and detailed investigation is permitted.

Since Lucknow lies in centre of U.P. which is a part of the Indo Gangetic plains, the soil type in Lucknow is mainly alluvium with small traces of clay and gravel. Therefore, the soil type in Lucknow was assumed to be type E/ type 3 in most of the cases. For low rise structures it was assumed as type D (since FEMA 154 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).

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. As per a report*[17], the northern, western and central parts of Lucknow fall under very slightly critical to critical for liquefaction while southern parts shows low to very low critical area. But since the site specific data was unavailable and soil type in Lucknow is mostly alluvium is which has a very low liquefaction potential. Therefore, in this project work, we have considered Lucknow a liquefaction free area and thus used this parameter as “absent” (0) everywhere.

5.3 RVS OBSERVATIONS

	BUILDING NO------>	1	2	3	4	5	6
2	PARAMETERS						
3	BUILDING NAME	Ramadhin Market	Shashvat's home	DNK	Z Square apartment	Arif Chamber 1	Sahara group of buildings
4	ADDRESS	Baabooganj, Lucknow	Hasanganj, Lucknow	Hasanganj, Lucknow	Daliganj, Lucknow	Kapoorthala, Lko	Kapoorthala, lko
5	NO OF STORIES	2	3	5	3	4+1	10-12 on avg
6	YEAR BUILT	2001	1950 (renovated 2007)	2010	2008	DNK	DNK
7	USE	commercial	residential	residential	residential+commercial	commercial+ office	commercial+office
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	not imp.	not imp.	not imp.	imp	imp
10	BASIC SCORE MODIFIERS	NOTE- 0 AND 1 INDICATE ABSENCE AND PRESENCE OF THE PARAMETER RESPECTIVELY THEY DO NOT INDICATE SCORE					
11	STRUCTURE TYPE (BASED ON FEMA 154)	C1(MRF)	URM4	C3(INF)	C1(MRF)	C1(MRF)	C3(INF)+C2(SW)=take C2(SW)
12	LOW RISE (< 4 STORIES)	1	1	0	1	0	0
13	MEDIUM RISE (4-7 STORIES)	0	0	1	0	1	0
14	HIGH RISE (> 7 STORIES)	0	0	0	0	0	1
15	VERTICAL IRREGULARITY	0	0	0	0	0	0
16	PLAN IRREGULARITY	0	1	0	0	1	0
17	CODE DETAILING PRESENT	1	N/A	1	1	DNK	DNK
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1	1	0	1	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0	0	1	0	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	*C+	B+	*C+	*C+	*D	E
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)			NOTE- THE VALUES PROVIDED INDICATE DEGREE OF PRESENCE OR DOMINANCE (D) ON A SCALE OF 1-10 (			
24	BOTTOM SOFT STOREY PRESENCE	-2	-1	-7.5	-8	-10	-2.5
25	OCCUPANCY	-150	-10	-50	-100	-1000	> -1000
26	CONDITION OF BUILDING	-2	-2.5	-2	-2	-6	-4
27	AGE OF BUILDING	-2.5	-5	-1	-5	-6	-5
28	COLLATERAL DAMAGE VULNERABILITY	-1	-7.5	-7.5	-6	-6	-2
29	FALLING HAZARDS	-5	-7.5	-2	-7.5	-7.5	-2.5
30	EASE OF EVACUATION	2.5	2	5	6	8	7.5
31	EMERGENCY SERVICES AVAILABILITY	5	7.5	7.5	7.5	7.5	7.5

Since several structure types are present, we select the one whose effect is dominant (shown by plan) Here we select type **C2 (SW)**

	BUILDING NO------>	7	8	9	10	11	12
2	PARAMETERS						
3	BUILDING NAME	Karamat market	Ambika Arcade	Masi's home	Sahara Shopping Centre	Lekhraj Khajana	High court colony
4	ADDRESS	Nishatganj,Lko	IT Crossing, Lko	Vibhav Khand, Gomtinagar, lko	Indiranagar, Lko	Indiranagar, Lko	Kaisarbagh, Lko
5	NO OF STORIES	2-3 on avg	3+1	2	5+1	6+1	3
6	YEAR BUILT	1985	1995	2003	DNK	1985	1960
7	USE	commercial	commercial	residential	commercial+office	Commercial+office	Residential
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	imp	not imp.	imp	imp	imp
10	BASIC SCORE MODIFIERS						
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM3	URM3	URM3	C1(MRF)+C2(SW)= take C2(SW)	URM3	URM 4
12	LOW RISE (< 4 STORIES)	1	0	1	0	0	1
13	MEDIUM RISE (4-7 STORIES)	0	1	0	1	1	0
14	HIGH RISE (> 7 STORIES)	0	0	0	0	0	0
15	VERTICAL IRREGULARITY	1	0	0	1	0	0
16	PLAN IRREGULARITY	1	1	0	0	0	0
17	CODE DETAILING PRESENT	N/A	N/A	N/A	DNK	N/A	N/A
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1	0	1	0	0	1
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0	1	0	1	1	0
21	LIQUIFIABLE SOIL	0	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	C	C	C	E+	D	B
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)						
24	BOTTOM SOFT STOREY PRESENCE	-4	-2.5	-1	-2	-7	-2.5
25	OCCUPANCY	> -1000	-150	-8	> -1000	> -1000	-150
26	CONDITION OF BUILDING	-8	-6	-9	-5	-7	-6
27	AGE OF BUILDING	-6	-4	-3	-4	-6	-7.5
28	COLLATERAL DAMAGE VULNERABILITY	-5	-5	-4	-2	-6	-1
29	FALLING HAZARDS	-9	-9	-4	-6	-6	-5
30	EASE OF EVACUATION	2	7.5	5	7.5	7	5
31	EMERGENCY SERVICES AVAILABILITY	7.5	7.5	8	7.5	6	4

Since several structure types are present, we select the one whose effect is dominant (shown by plan) Here we select type **C2 (SW)**

Table 11: RVS survey observations

	A–D	AG	AJ	AL	AO	AR	AT
1	**BUILDING NO------>**	13	14	15	16	17	18
2	**PARAMETERS**						
3	BUILDING NAME	Ravi's home	Kendriya Bhawan	DNK	Conventional Centre	Halwasia market	LIC office
4	ADDRESS	Hydel colony , Aliganj, Lko	Aliganj, Lko	Chandralok colony, Aliganj,lko	Shalimar road, Chowk, Lko	Hazratganj, Lko	Hazratganj, Lko
5	NO OF STORIES	3	14	3+1	4	5	1st-5 2nd-7+1
6	YEAR BUILT	DNK	1995	2005	2003	1948	DNK
7	USE	residential	Office (Gov.)	commmercial	commercial	commercial +resi.	office
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	not imp.	imp	not imp.	imp	imp	imp
10	**BASIC SCORE MODIFIERS**						
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM 3	C1(MRF)+C2(SW)=C2	URM 4	C1(MRF)	URM 3	URM3
12	LOW RISE (< 4 STORIES)	1	0	0	0	0	0
13	MEDIUM RISE (4-7 STORIES)	0	0	1	1	1	1
14	HIGH RISE (> 7 STORIES)	0	1	0	0	0	0
15	VERTICAL IRREGULARITY	1	1	1	1	1	DNK
16	PLAN IRREGULARITY	1	1	1	1	1	DNK
17	CODE DETAILING PRESENT	N/A	1	N/A	1	N/A	N/A
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1	0	0	0	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0	1	1	1	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	C+	F	C	E	C	C+
23	**ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)**						
24	BOTTOM SOFT STOREY PRESENCE	-1	-7.5	-2	-2	-7.5	-5
25	OCCUPANCY	-25	-900	-50	> -1000	-600	-500
26	CONDITION OF BUILDING	-7	-4	-3	-2	-7.5	-5
27	AGE OF BUILDING	-5	-3	-2	-2.5	-8	DNK
28	COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1	-1	-5	-6
29	FALLING HAZARDS	-6	-7	-7	-7.5	-7.5	-5
30	EASE OF EVACUATION	7.5	7.5	2	7.5	2	4
31	EMERGENCY SERVICES AVAILABILITY	5	5	5	7.5	8	7.5

Since several structure types are present , we select the one whose effect is dominant. Here we select type **C2**

	A–D	AV	AX	AZ	BB	BE	BH
1	**BUILDING NO------>**	19	20	21	22	23	24
2	**PARAMETERS**						
3	BUILDING NAME	Shri Ram Tower	Bhopal house	Durgama tower	Indraprastha Apartments	Annapurna apartments	Cross Road Plaza
4	ADDRESS	Hazratganj, Lko	Lalbagh, Lko	Lalbagh, Lko	IT College crossing,Lko	Opposite police lines, Lko	Badshahnagar Lko
5	NO OF STORIES	6+1	3	5+1	A-7+1 B-11 C-8+1 D-8 avg 10	8	3+1
6	YEAR BUILT	1985	1960	1970	2008	1995	2003
7	USE	commercial	commercial+resi.	commercial+office	residential	residential	commercial
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	imp	not imp.	imp	imp	not imp.
10	**BASIC SCORE MODIFIERS**						
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM 3	URM3	URM3	C1(MRF)+C2(SW)= take C2(SW)	C1(MRF)+ slight C3(INF)=C1(MRF)	URM3
12	LOW RISE (< 4 STORIES)	0	1	0	0	0	0
13	MEDIUM RISE (4-7 STORIES)	1	0	1	0	0	1
14	HIGH RISE (> 7 STORIES)	0	0	0	1	1	0
15	VERTICAL IRREGULARITY	1	1	1	0	0	1
16	PLAN IRREGULARITY	0	1	1	1	1	0
17	CODE DETAILING PRESENT	N/A	N/A	N/A	1	0	N/A
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	0	1	0	0	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	1	0	1	1	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	D	C	C	F	E	C+
23	**ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)**						
24	BOTTOM SOFT STOREY PRESENCE	-2	-7.5	-7	-7	-6	-1.5
25	OCCUPANCY	-500	-700	-100	-700	-180	-100
26	CONDITION OF BUILDING	-4	-7	-6	-2	-3	-6.5
27	AGE OF BUILDING	-4	-8	-6	-2	-4	-3
28	COLLATERAL DAMAGE VULNERABILITY	-2.5	-2.5	-1	-4	-2	-2
29	FALLING HAZARDS	-2.5	-7.5	-6	-7.5	-7.5	-7.5
30	EASE OF EVACUATION	4	4	1	4	7	5
31	EMERGENCY SERVICES AVAILABILITY	8	6	5	8	7.5	6.5

Since several structure types are present , we select the one whose effect is dominant(shown by plan). Here we select type **C2 (SW)**

Table 11 (Continued)

	A–D	BJ	BL	BP	BS	BW
1	**BUILDING NO------>**	25	26	27	28	29
2	**PARAMETERS**					
3	BUILDING NAME	Shalimar Eldee Plaza	West end Mall and wave multiplex	Fun Republic mall and multiplex	River side mall and Inox multiplex	City mall and SRS multiplex
4	ADDRESS	Indiranagar ,Lko	Gomtinagar, Lko	Gomtinagar, Lko	Gomtinagar, Lko	Gomtinagar, Lucknow
5	NO OF STORIES	6	3+1	5+2	3+1	5+1
6	YEAR BUILT	2010	2005	2005	2010	2013
7	USE	commercial	commercial	commercial	commercial	commercial
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	imp	imp	imp	imp
10	**BASIC SCORE MODIFIERS**					
11	STRUCTURE TYPE (BASED ON FEMA 154)	C1(MRF)	C1(MRF)+C2(SW)+C3(INF)+URM2(BAND+FD)	C1(MRF)+C2 (SW)+C3(INF)	C1(MRF)+C2(SW)= takeC1(MRF)	C1(MRF)+C2(SW)+C3(INF)
12	LOW RISE (< 4 STORIES)	0	0	0	0	0
13	MEDIUM RISE (4-7 STORIES)	1	1	1	1	1
14	HIGH RISE (> 7 STORIES)	0	0	0	0	0
15	VERTICAL IRREGULARITY	0	0	1	0	0
16	PLAN IRREGULARITY	0	1	1	0	0
17	CODE DETAILING PRESENT	1	1	1	1	1
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	0	0	0	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	1	1	1	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	E	E+	E+	E+	E+
23	**ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)**					
24	BOTTOM SOFT STOREY PRESENCE	-2	-2	-2	-2	-2
25	OCCUPANCY	-150	-400	-600	-150	-300
26	CONDITION OF BUILDING	-2.5	-2.5	-2	-2	-1
27	AGE OF BUILDING	-1	-2	-4	-2	-1
28	COLLATERAL DAMAGE VULNERABILITY	-1	-1	-1	-2.5	-2
29	FALLING HAZARDS	-8	-7.5	-7.5	-5	-2
30	EASE OF EVACUATION	4	8	7	8	6
31	EMERGENCY SERVICES AVAILABILITY	7	7.5	6	6	4

Note (building 26): **Since** several structure types are present , we select the one whose effect is dominant (which is shown by plan layout). Here we select type **C1 (MRF)** because area is large and presence of other structure types is scattered in nature. The structure here basically comprises of RC panels of several shapes.

Note (building 28): Since several structure types are present , we select the one whose effect is dominant (shown by plan layout). Here we select type **C1 (MRF)**

Note (building 29): Since several structure types are present , we select the one whose effect is dominant (shown by plan layout).Here we select type **C3 (INF)**

	A–D	BZ	CB	CD	CF	CJ
1	**BUILDING NO------>**	30	31	32	33	34
2	**PARAMETERS**					
3	BUILDING NAME	DNK	KM Apartments	DNK	Lal Bahadur Shastri Bhawan (KGMC)	Naveen emergency and trauma centre (KGMC)
4	ADDRESS	Daliganj, Lko	Daliganj, lko	Daliganj,Lko	Near Hathi park, Lko	KGMC , Lko
5	NO OF STORIES	4	4+1	4	4+1	4 stories upper stories beingnow built
6	YEAR BUILT	1950	2011	2005	DNK	DNK
7	USE	residential	residential	Storage +resi.	Emergency Services(Hospital)	Emergency services(Hospital)
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	not imp.	imp	not imp.	imp	imp
10	**BASIC SCORE MODIFIERS**					
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM4	C3(INF)	URM3	C3(INF)	C3(INF)
12	LOW RISE (< 4 STORIES)	0	0	0	0	0
13	MEDIUM RISE (4-7 STORIES)	1	1	1	1	1
14	HIGH RISE (> 7 STORIES)	0	0	0	0	0
15	VERTICAL IRREGULARITY	0	0	1	0	1
16	PLAN IRREGULARITY	0	1	1	1	1
17	CODE DETAILING PRESENT	0	1	N/A	DNK	DNK
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	0	0	0	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	1	1	1	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	B+	*D	C	*D	*D
23	**ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)**					
24	BOTTOM SOFT STOREY PRESENCE	-7.5	-7.5	-9	-6	-2.5
25	OCCUPANCY	-80	-150	-25	-700	-700
26	CONDITION OF BUILDING	-7.5	-4	-6	-4	-4
27	AGE OF BUILDING	-8	-2	-4	-5	-5
28	COLLATERAL DAMAGE VULNERABILITY	-7.5	-2.5	-6	-3	-2
29	FALLING HAZARDS	-8	-6	-7.5	-8	-3.5
30	EASE OF EVACUATION	2.5	6	2.5	7.5	7.5
31	EMERGENCY SERVICES AVAILABILITY	5	5	5	7.5	8

Table 11(Continued)

	A–D	CN	CQ	CU	CW	CY
1	**BUILDING NO------>**	35	36	37	38	39
2	**PARAMETERS**					
3	BUILDING NAME	New Dental Block (KGMC)	Minar marriage hall and guest house	Kusumdeep complex	Aarohi trade centre	Ahmad complex
4	ADDRESS	KGMC, Lko	Takseen ganj chauraha, Thakurganj, lko	Chowk, Lko	Chowk, Lko	Aminabad, Lko
5	NO OF STORIES	6+1	3+1	7+1	4+1	5
6	YEAR BUILT	2013	DNK	1985	1985	2004
7	USE	Emergency Services(Hospital)	Residential + Commercial	Residential+ Comm.	Commercial	Commercial+Resi.
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	imp	imp	imp	not imp.
10	BASIC SCORE MODIFIERS					
11	STRUCTURE TYPE (BASED ON FEMA 154)	C3(INF)+C2(SW)=takeC3(INF)	URM3	C3(INF)	C3(INF)	URM3
12	LOW RISE (< 4 STORIES)	0	0	0	0	0
13	MEDIUM RISE (4-7 STORIES)	1	1	0	1	1
14	HIGH RISE (> 7 STORIES)	0	0	1	0	0
15	VERTICAL IRREGULARITY	1	1	0	0	1
16	PLAN IRREGULARITY	1	1	1	1	DNK
17	CODE DETAILING PRESENT	1	N/A	0	0	DNK
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	0	1	0	0	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	1	0	1	1	1
21	LIQUIFIABLE SOIL	0	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	*D	C+	E	*D	C
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)					
24	BOTTOM SOFT STOREY PRESENCE	-7.5	-7	-2	-5	-7.5
25	OCCUPANCY	-300	-150	-110	-100	-80
26	CONDITION OF BUILDING	-2	-6	-6	-7	-6
27	AGE OF BUILDING	-1	-5	-6	-6	-4
28	COLLATERAL DAMAGE VULNERABILITY	-2	-4	-2.5	-2.5	-6
29	FALLING HAZARDS	-7	-8	-6	-6	-7
30	EASE OF EVACUATION	7.5	2	7.5	7.5	2
31	EMERGENCY SERVICES AVAILABILITY	7.5	5	6	5	3

Since several structure types are present, we select the one whose effect is dominant (shown by plan layout).Here we select type **C3 (INF)**

	A–D	DA	DF	DH	DL
1	**BUILDING NO------>**	40	41	42	43
2	**PARAMETERS**				
3	BUILDING NAME	Charbagh railway station complex with components	KSM Towers	Hamid Estate Buiding	Agarwal Ashram
4	ADDRESS	Charbagh, Lko	Alambagh , Lko	La Touche road, Lko	La Touche road, Lko
5	NO OF STORIES	1 in general, somwhere 2	3+1	2	4
6	YEAR BUILT	1923	2010	1933	1950
7	USE	Assembly (infrstructural use)	Commercial+Office	Commercial+Residential	Commercial+Resi.
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	not imp.	not imp.	not imp.
10	BASIC SCORE MODIFIERS				
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM 3 (for building) S2(LM) (for platform area)	URM 3	URM 3 type (but reinforced wih girders)	URM 3 (Not sure)
12	LOW RISE (< 4 STORIES)	1	0	1	0
13	MEDIUM RISE (4-7 STORIES)	0	1	0	1
14	HIGH RISE (> 7 STORIES)	0	0	0	0
15	VERTICAL IRREGULARITY	1	1	1	1
16	PLAN IRREGULARITY	1	1	1	1
17	CODE DETAILING PRESENT	N/A	N/A	0	0
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1	1	1	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0	0	0	1
21	LIQUIFIABLE SOIL	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	D and *D	C+	D	C
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)				
24	BOTTOM SOFT STOREY PRESENCE	-1	-6.5	-5	-7
25	OCCUPANCY	>-1000	-100	-50	-40
26	CONDITION OF BUILDING	-2	-3	-7	-5
27	AGE OF BUILDING	-7.5	-2.5	-7.5	-6
28	COLLATERAL DAMAGE VULNERABILITY	-1	-2	-6	-6
29	FALLING HAZARDS	-7.5	-7	-6	-8
30	EASE OF EVACUATION	9	2.5	2.5	2
31	EMERGENCY SERVICES AVAILABILITY	9	8	3	4

We perform score calculation separately for each structure type i.e **URM 3 and S2** and **take the average of final structural scores**

Since the building lacks reinforcent (mettalic bars as used in RB construction) and is of masonry it is placed in URM 3 category . but metallic girders on columns and ceiling provide effect of stiffing effect seismic bands . Hence the score system for **URM 1 (BAND+RD)** is used

Table 11(Continued)

Row	Parameter			
1	**BUILDING NO------>**	44	45	46	47
2	**PARAMETERS**				
3	BUILDING NAME	DNK	Munna Lal Bhawan	Sheetal Sahu Dharamshala	Aditya Bhawan
4	ADDRESS	La Touche road, Lko	Gurudwara road, Naka Hindola, Lko	Naka Hindola Chauraha, Lko	Aminabad, Lko
5	NO OF STORIES	3	3	4	2
6	YEAR BUILT	1930	1927	1960	1915
7	USE	Commercial+Residential+School	residential	residential	Commercial +Residential
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	not imp.	not imp.	not imp.	not imp.
10	BASIC SCORE MODIFIERS				
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM 3 type (but reinforced wih girders)	URM 3	URM 3 type (but reinforced wih girders)	URM 3 type (but reinforced wih girders)
12	LOW RISE (< 4 STORIES)	1	1	0	1
13	MEDIUM RISE (4-7 STORIES)	0	0	1	0
14	HIGH RISE (> 7 STORIES)	0	0	0	0
15	VERTICAL IRREGULARITY	1	1	1	1
16	PLAN IRREGULARITY	1	1	0	1
17	CODE DETAILING PRESENT	0	0	0	0
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1	1	0	1
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0	0	1	0
21	LIQUIFIABLE SOIL	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	D	C	D	D
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)				
24	BOTTOM SOFT STOREY PRESENCE	-5	-4	-5	-5
25	OCCUPANCY	-20	-20	-25	-100
26	CONDITION OF BUILDING	-7.5	-6.5	-6	-6
27	AGE OF BUILDING	-8	-7	-6	-7.5
28	COLLATERAL DAMAGE VULNERABILITY	-4	-6	-3	-2.5
29	FALLING HAZARDS	-7	-6	-6	-7
30	EASE OF EVACUATION	4	3	4	3.5
31	EMERGENCY SERVICES AVAILABILITY	5	5	5	7

Since the building lacks reinforcent (mettalic bars as used in RB construction) and is of masonry it is placed in URM 3 category . but metallic girders on columns and ceiling provide effect of stiffing effect seismic bands . Hence the score system for **URM 1 (BAND+RD)** is used

Since the building lacks reinforcent (mettalic bars as used in RB construction) and is of masonry it is placed in URM 3 category . but metallic girders on columns and ceiling provide effect of stiffing effect seismic bands . Hence the score system for **URM 1 (BAND+RD)** is used

Row	Parameter				
1	**BUILDING NO------>**	48	49	50	51
2	**PARAMETERS**				
3	BUILDING NAME	Indira Market	Wahab Mansion	(Neighbours' house)	Kamta Apartments
4	ADDRESS	Aminabad, Lko	Aminabad, Lko	Daliganj, Lko	Daliganj, Lko
5	NO OF STORIES	5+1	2	3	4
6	YEAR BUILT	1985	1960	2007	2005
7	USE	Commercial+Resi.	Commercial+Resi.	Residential	Residential
8	CONSTRUCTION DRAWINGS AVAILABLE	no	no	no	no
9	IMPORTANCE OF BUILDING (BASED ON OCCUPANCY AND USE)	imp	not imp.	not imp.	not imp.
10	BASIC SCORE MODIFIERS				
11	STRUCTURE TYPE (BASED ON FEMA 154)	URM3	URM 3 type (but reinforced wih girders)	URM3	C1(MRF)
12	LOW RISE (< 4 STORIES)	0	1	1	0
13	MEDIUM RISE (4-7 STORIES)	1	0	0	1
14	HIGH RISE (> 7 STORIES)	0	0	0	0
15	VERTICAL IRREGULARITY	1	1	0	0
16	PLAN IRREGULARITY	1	DNK	1	0
17	CODE DETAILING PRESENT	N/A	0	N/A	1
18	SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0	0	0	0
19	SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	0	1	1	0
20	SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	1	0	0	1
21	LIQUIFIABLE SOIL	0	0	0	0
22	STRUCTURE TYPE (BASED ON IS CLASSIFICATION)	C	D	C	*C+
23	ADDITIONAL SCORE MODIFIERS (FOR INCREASED ACCURACY)				
24	BOTTOM SOFT STOREY PRESENCE	-6.5	-5.5	-4	-7
25	OCCUPANCY	-120	-60	-6	-70
26	CONDITION OF BUILDING	-8	-6	-4	-6
27	AGE OF BUILDING	-6	-6.5	-6	-5
28	COLLATERAL DAMAGE VULNERABILITY	-7	-6	-8	-7.5
29	FALLING HAZARDS	-7.5	-7	-6	-5
30	EASE OF EVACUATION	5	2.5	2.5	2.5
31	EMERGENCY SERVICES AVAILABILITY	4	6	2.5	2.5

Since the building lacks reinforcent (mettalic bars as used in RB construction) and is of masonry it is placed in URM 3 category . but metallic girders on columns and ceiling provide effect of stiffing effect seismic bands . Hence the score system for **URM 1 (BAND+RD)** is used

Table 11(Continued)

6. RESULTS, COMPARISONS AND CONCLUSIONS

6.1 RVS RESULTS FOR ALL THREE METHODOLOGIES (BIS METHODOLOGY, NEW DEVELOPED RVS SYSTEM AND TRADITIONAL FEMA 154 METHODOLOGY)

Table 12: RVS survey results

BUILDING NO.	DAMAGIBILITY 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	G2	G1	G1	N/A	2.95	3.6	YES	NO	NO
2	G2	G1,G2	G2,G3	N/A	0.735	1.5	YES	NO	YES
3	G1,G2 (infill areas)	G1	G1	N/A	2.5375	3.6	NO	NO	NO
4	G1	G1	G1	N/A	2.1475	3.6	NO	NO	NO
5	G2	G3,G4	G2,G3	N/A	-1.0825	1.7	YES	YES	YES
6	no damage	G1	G1	N/A	1.5375	3.2	NO	NO	NO
7	G3	G4,G5	G3,G4	N/A	-1.755	0.6	YES	YES	YES
8	G3	G2,G3	G2,G3	N/A	0.2	1.3	YES	YES	YES
9	G2	G1	G1,G2	N/A	1.822	2.6	NO	NO	NO
10	no damage	G2,G3	G2,G3	N/A	-0.9	0.8	YES	YES	YES
11	G2	G2,G3	G2,G3	N/A	-0.72	1.8	NO	YES	YES
12	G4	G1,G2	G1,G2	N/A	0.865	2	YES	NO	NO
13	G1	G2,G3	G3,G4	N/A	-0.175	0.6	YES	YES	YES
14	no damage	G2,G3	G1,G2	N/A	0.225	2.3	YES	YES	NO
15	G2	G4,G5	G4,G5	N/A	-1.43	-0.8	YES	YES	YES
16	no damage	G2,G3	G2,G3	N/A	-0.5875	0.9	YES	YES	YES
17	G3	G4,G5	G4,G5	N/A	-2.5375	-0.2	YES	YES	YES
18	G2	G2,G3	G2,G3	N/A	0.14	1.8	YES	YES	YES
19	G2	G2,G3	G3,G4	N/A	-0.805	0.3	YES	YES	YES
20	G3	G4,G5	G3,G4	N/A	-1.75	0.6	YES	YES	YES
21	G2	G4,G5	G4,G5	N/A	-1.715	-0.2	YES	YES	YES
22	no damage	G1	G1	N/A	2.5325	4.3	YES	NO	NO
23	no damage	G1,G2	G1,G2	N/A	0.7775	2	YES	NO	NO
24	G1	G2,G3	G3,G4	N/A	-0.5475	0.3	YES	YES	YES
25	no damage	G1	G1	N/A	2.76	3.4	NO	NO	NO
26	no damage	G1	G1,G2	N/A	2.0175	2.9	YES	NO	NO
27	no damage	G2,G3	G2,G3	N/A	-0.2825	0.9	YES	YES	YES
28	no damage	G1	G1	N/A	2.8025	3.4	YES	NO	NO
29	G2 (infill areas)	G1	G1	N/A	3	3.6	YES	NO	NO
30	G2	G2,G3	G2,G3	N/A	-0.7175	1.2	YES	YES	YES
31	G2 (infill areas)	G1	G1	N/A	1.7975	3.1	YES	NO	NO
32	G2	G4,G5	G4,G5	N/A	-1.8875	-0.2	YES	YES	YES
33	G2 (infill areas)	G2,G3	G2,G3	N/A	0.025	1.9	YES	YES	YES
34	G2 (infill areas)	G4,G5	G4,G5	N/A	-1.4825	-0.1	YES	YES	YES
35	G2 (infill areas)	G2,G3	G2,G3	N/A	-0.175	1.1	YES	YES	YES
36	G2	G4,G5	G4,G5	N/A	-1.43	0.2	YES	YES	YES
37	G3 (infill areas)	G1,G2	G1,G2	N/A	1.1125	2.1	YES	NO	NO
38	G2,G3 (infill areas)	G1,G2	G2,G3	N/A	0.5625	1.9	YES	NO	YES
39	G2	G3,G4	G3,G4	N/A	-1.305	0.3	YES	YES	YES
40	G2	G1,G2,G3,G4	G1,G2,G3,G4	N/A	[(-1.0075)+(1.0925)]/2=0.0425	[0.6+2.7]/2=1.65	YES	(YES & NO)--> YES	(YES & NO)--> YES
41	G1	G2,G3	G4,G5	N/A	-0.945	0.2	YES	YES	YES
42	G1	G4,G5	G4,G5	N/A	-1.42	0.1	YES	YES	YES
43	G2	G4,G5	G4,G5	N/A	-1.78	-0.2	YES	YES	YES
44	G1	G4,G5	G4,G5	N/A	-1.38	0.1	YES	YES	YES
45	G2	G2,G3	G3,G4	N/A	-0.715	0.6	YES	YES	YES
46	G1	G2,G3	G3,G4	N/A	-0.66	0.6	YES	YES	YES
47	G1	G3,G4	G4,G5	N/A	-1.3075	0.1	YES	YES	YES
48	G3	G4,G5	G4,G5	N/A	-1.9425	-0.2	YES	YES	YES
49	G1	G2,G3	G3,G4	N/A	-0.875	0.6	YES	YES	YES
50	G2	G1,G2	G1,G2	N/A	0.894	2.1	YES	NO	NO
51	G1	G1	G1	N/A	1.8175	3.4	NO	NO	NO

The **Legend used** in this result table is-

→ Indicates difference in damageability b/w new RVS system when no damage is shown by RVS system (by BIS)

→ Indicates difference in damageability grade b/w new RVS system and traditional FEMA 154 system

→ Indicates lowest Final Structural Score (S)

→ Indicates highest Final Structural Score (S)

→ Indicates Final Structural Score (S) in one RVS system corresponding to highest or lowest score in other system

→ Indicates difference in surety of seismic safety (i.e. is there a need for further evaluation or not) b/w RVS system (by BIS) and new developed RVS system

→ Indicates difference in surety of seismic safety (i.e. is there a need for further evaluation or not) b/w RVS system (by FEMA 154) and new developed RVS system

6.2 COMMENTS ON DAMAGEABILITY ASSESSMENT

- Out of 51 building structures that were surveyed in this project work-

  10 buildings (about 20%) (Building no 6, 10, 14, 16, 22, 23, 25, 26, 27 and 28) were found to have no expected damage as per the RVS methodology specified by BIS (Bureau of Indian Standards).

  12 buildings (About 24%) (Building no 1, 3, 4, 6, 9, 22, 25, 26, 28, 29, 31 and 51) were found to have expected damageability of Grade G1 (which is equivalent to no damage) as per the new developed and modified RVS system.

  10 buildings (about 20%) (Building no 1, 3, 4, 6, 22, 25, 28, 29, 31 and 51) were found to have expected damageability of Grade G1 (which is equivalent to no damage) as per traditional FEMA 154 RVS methodology.

- For the 10 buildings that were found to have no expected damage by RVS system (BIS), the other 2 methodologies (new developed RVS system and FEMA 154 system) suggest expected damageability grade from G1 to G3 in those buildings.

- There are about 10 buildings (Building no 2, 5, 7, 9, 13, 14, 19, 20, 24 and 26) in which the traditional FEMA 154 RVS methodology and new developed RVS system differ in terms of expected damageability grade.

- Out of these 10 buildings, there are 4 buildings (Building no 5, 7, 14 and 20) in which the new developed RVS system gives a slightly higher expected damageability grade as compared to traditional FEMA 154 RVS system. In the remaining 6 buildings (building no 2, 9, 13, 19, 24 and 26) the traditional FEMA 154 RVS system gives a higher expected damageability grade.

- Thus we may conclude that the RVS system as specified by BIS, on whole gives a slightly lower expected damageability grade as compared to new developed RVS system which in turn gives slightly lower expected damageability grade as compared to conventional FEMA 154 RVS methodology. The obvious reason for this is the inclusion of additional modifiers in the new developed modified RVS system which sort of bridges the gap between FEMA 154 RVS methodology and RVS methodology specified by BIS

  (Although it must be noted that the above conclusion is a representative of 51 structures only and might be subjected to a change if large no of structures (say 1000-2000) are surveyed)

6.3 COMMENTS ON FINAL STRUCTURAL SCORE

- Out of the 51 building structures that were surveyed, it has been found that several buildings have same final structural score (S) in traditional FEMA 154 RVS methodology. For example, Building no. 1, 3, 4 and 29 have the same score of 3.6; building no. 25, 28 and 51 have the same score of 3.4 and many such cases are present. This is because traditional FEMA 154 RVS system gives a value of score modifier depending on if the modifier is present or absent. It does take into consideration the degree of presence. Hence many buildings end up having the same final structural score S.

- On the other hand in the new developed modified RVS system, no two buildings have the same final structural score. This is because of the variable degree of presence of additional modifiers in new developed RVS system.

- Thus the new developed modified RVS system provides a scope of comparison of seismic vulnerability of these buildings which have the same final structural score calculated by FEMA 154 system and would be impossible to compare otherwise.

- Highest final structural score as per new developed RVS system is 3 (S=3 for building no 29). The corresponding structural score for the same building in traditional FEMA 154 RVS methodology is 3.6 which is 2nd highest as per that system.
  The probable reason is that building no 29 has characteristics like it was recently constructed, it is simple in architecture and plan, it is good in condition, it has sufficient no exits and is situated in and isolated environment with very low collateral damage vulnerability. The effect of all these characteristics is included in RVS score calculation by the means of additional modifiers which has in this case increased the final structural score as per new developed RVS system and made it the highest. Since these additional modifiers are absent in traditional FEMA 154 RVS system, hence the final structural score was not so high.

- Owing to the similar nature of reasons, the highest final structural score in traditional FEMA 154 system is 4.3 (S=4.3 for building no. 22) and the corresponding score in new developed RVS system for the same building is 2.5325 which is 3rd highest in that system.

- Similarly, the lowest final structural score as per new developed RVS system is -2.5375 (S= -2.5375 for building no 17). The corresponding structural score for the same building in traditional FEMA 154 RVS methodology is -0.2 which is 2nd lowest as per that system.

- Similarly, the lowest score in FEMA 154 methodology is -0.8 (S=-0.8 for building no 15) and the corresponding score in new developed RVS methodology for same building is -1.43 which is 9th lowest in the same methodology
  .

- Although it cannot be stated that the new developed RVS system gives a lower or a higher final structural score S as compared to conventional FEMA 154 RVS system, but it can be concluded that this new developed system is more accurate owing to the differences in highest and lowest scores when compared to FEMA 154 scores for same buildings.

6.4 COMMENTS ON NEED FOR FURTHER EVALUATION

- Out of 51 building structures that were surveyed, the following no. of structures require further evaluation-

  44 buildings (about 86%) (By RVS system specified by BIS)
  33 buildings (about 65%) (By new developed RVS system)
  34 buildings (about 65%) (By traditional FEMA 154 RVS system)

- Thus it can be stated that RVS methodology as specified by BIS gives more weightage to higher level analysis (level 1 or higher analysis RVS being level 0 analysis) for seismic vulnerability assessment as compared to the other 2 methodologies (traditional FEMA 154 RVS procedure and new developed RVS method)

- Out of the surveyed 51 buildings, there are 13 buildings (Building no. 1, 2, 11, 12, 22, 23, 26, 28, 29, 31, 37, 38 and 50) which differ in the regard of output (between RVS as per BIS and new developed RVS system) on whether there is a need for further evaluation or not. In all these 13 buildings the RVS methodology specified in BIS proposes the requirement for further evaluation except for building no 11 in which this methodology rejects the need for further evaluation but new developed RVS system proposes it.

  The probable reason for this is that building no 11 has very high degree of presence of negative (-) additional modifier parameters like occupancy, age of building, condition of building, collateral damage vulnerability etc. which reduce the score.

- Out of 51 buildings surveyed, there are only 3 buildings (Building no. 2, 14 and 38) which differ on whether there is need for further evaluation or not between new developed RVS system and traditional FEMA 154 RVS system. The reason for these differences are again the extreme values of degree of presence of either negative (-) or positive (+) additional modifier parameters in new developed RVS system.

- Thus in totality it can be stated that RVS methodology specified by BIS is more inclined towards proposing further evaluation. It proposes further evaluation even if a single property (like unsymmetricity, falling hazard etc) is present. On the other hand the other two RVS methodologies (new developed RVS and RVS as per FEMA 154) do not propose further evaluation to that degree. These two methodologies give nearly the same output in this regard and differ only occasionally (3 times in this project survey) when additional score modifier parameters are present in highly dominant state (i.e. the value of degree of presence or dominance 'D' of these parameters are either very high or very low). Thus additional score modifiers in new developed RVS system do not have significant effect on deciding whether there is need for further evaluation or not.

6.5 FINAL RESULTS AND CONCLUSIONS

1) In the project survey (RVS) in the city of Lucknow(U.P.), out of 51 buildings that were surveyed, about 20 to 24% buildings (10-12 buildings) were found to expect no damage.

2) Rapid Visual Screening (RVS) as per method specified by BIS concluded that 80% of total structures surveyed needed further evaluation, while RVS as per method specified in FEMA154 and new developed method concluded that only 65% buildings needed further evaluation.

3) Building no 22 and 29 were found to be the safest or strongest with regard to seismic vulnerability. Building no 15 and 17 were found to be the weakest.

4) RVS system as specified by BIS was found to give a slightly lower expected damageability grade as compared to new developed RVS system which in turn was found to give slightly lower expected damageability grade as compared to conventional FEMA 154 RVS methodology because of the inclusion of additional modifiers in the new developed modified RVS system. Thus new developed RVS system **bridges the gap between BIS RVS system and FEMA 154.**

5) The new developed modified RVS system **provides a scope of comparison of seismic vulnerability** of the buildings which have the same final structural score calculated by FEMA 154 system and would be impossible to compare otherwise.

6) The new developed RVS system is **more accurate** owing to the differences in highest and lowest scores when compared to FEMA 154 scores for same buildings.

6.6 FUTURE SCOPE OF STUDY:

The additional score modifiers in new developed RVS system were not found to have significant effect on deciding whether there is need for further evaluation or not. Thus new developed RVS system is not so effective in this regard. This can be overcome with the inclusion of some different score modifiers in place of these additional modifiers (which have a greater degree of effect to seismic safety) and changing the values of additional parameters' weightage factors (W). Thus further study could be carried out in this direction.

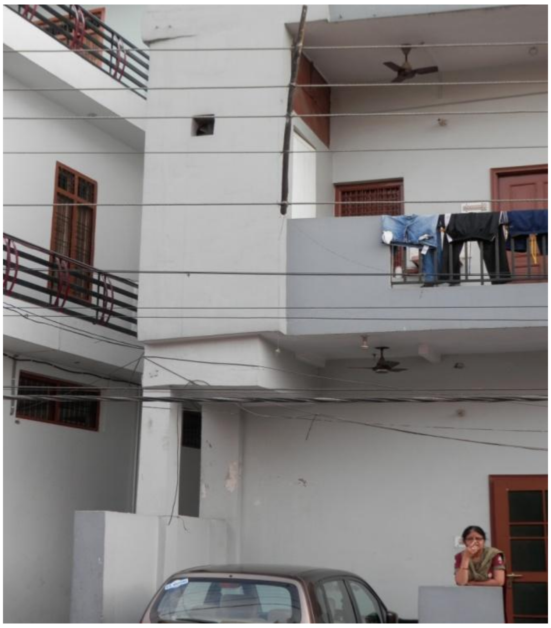
Research work could also be performed for the improvement of Basic structural score values and basic score modifier values by using some new methodology other than HAZUS fragility and capacity curves*[2] which have till now been used to calculate these values.

For further enhancing the speed of overall RVS Procedure significantly, Mathematical and computer techniques like "Fuzzy Logic" and "Neural networks" could be used*[18]*[19]*[20]*[21]. With the help of these, the computer systems could be trained to identify buildings and give required results for assessing the seismic safety of buildings with limited number of Rapid Visual Screening inputs available and also in a very short time compared to conventional Rapid Visual Screening process.

ANNEXURE A (PHOTOGRAPHS)

BUILDING NO 1

BUILDING NO 2



BUILDING NO 3

BUILDING NO 4

BUILDING NO 5

BUILDING SET NO 6

BUILDING NO 7

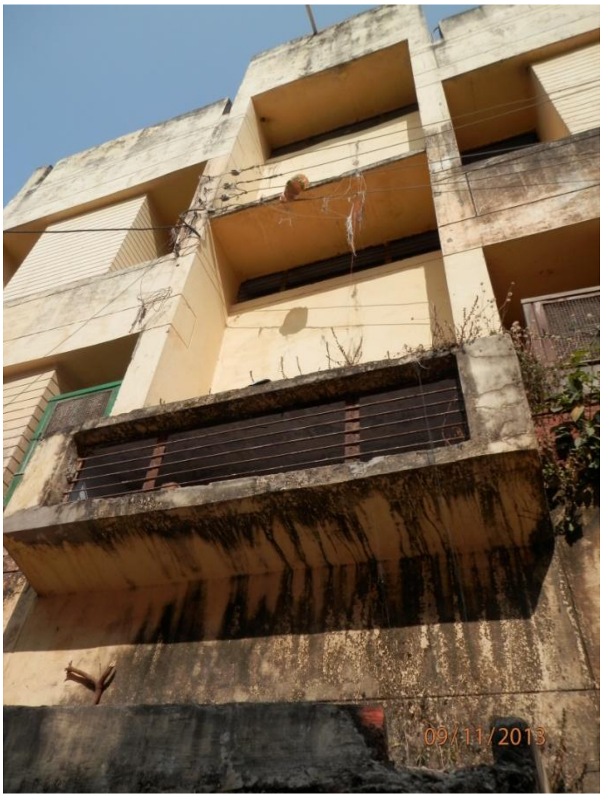
BUILDING NO 8

BUILDING NO 9

BUILDING NO 10

BUILDING NO 11

BUILDING NO 12



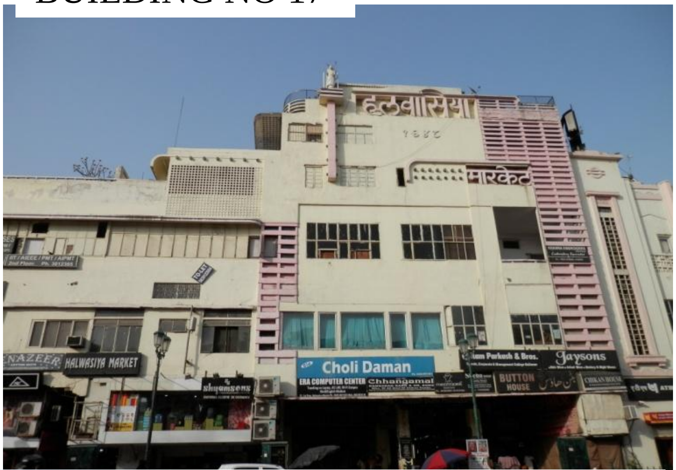
BUILDING NO 13

BUILDING NO 14

BUILDING NO 15

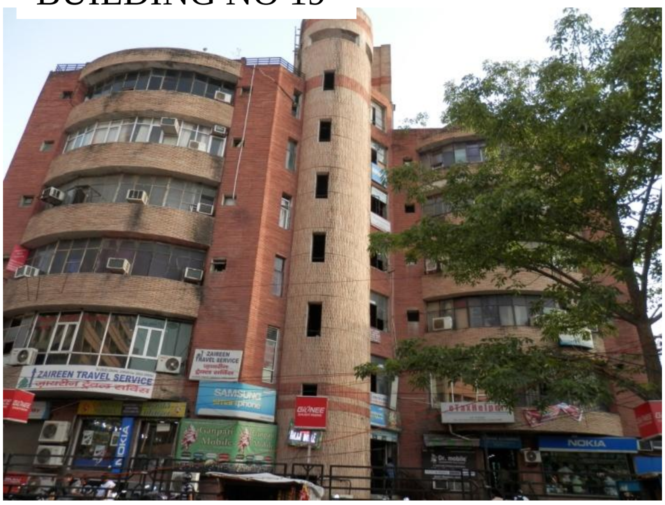
BUILDING NO 16

BUILDING NO 17



BUILDING NO 18

BUILDING NO 19



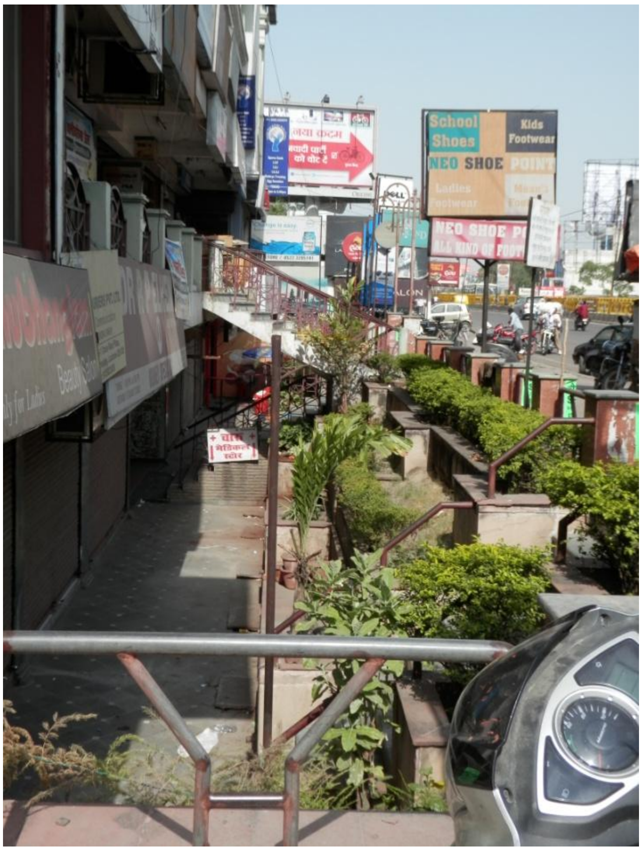
BUILDING NO 20

BUILDING NO 21

BUILDING SET NO 22

BUILDING NO 23

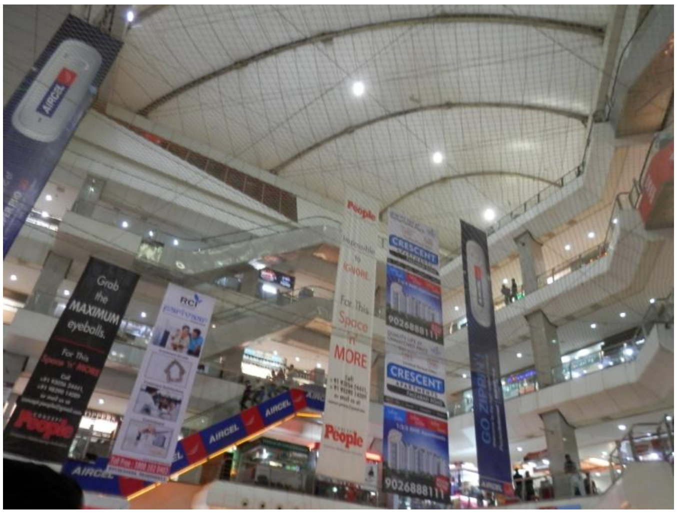
BUILDING NO 24



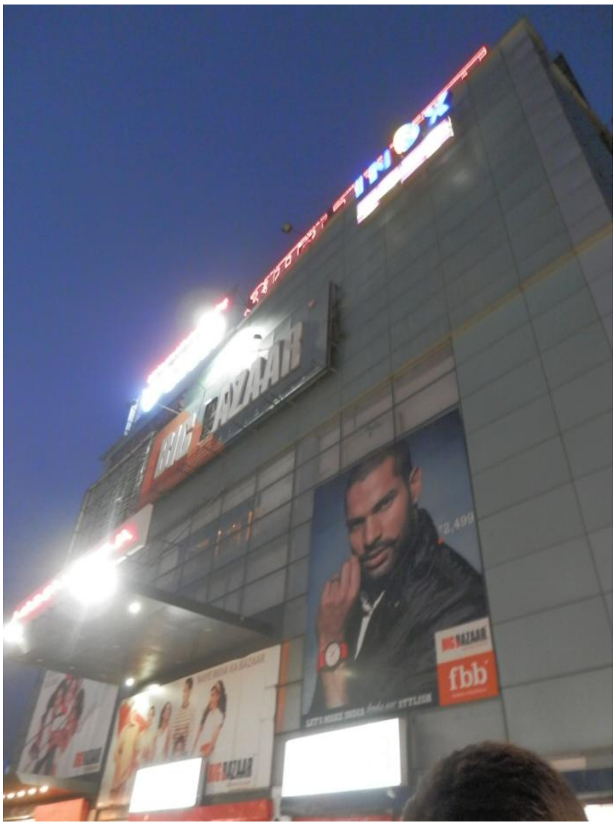
BUILDING NO 25

BUILDING NO 26

BUILDING NO 27



BUILDING NO 28



BUILDING NO 29

BUILDING NO 30

BUILDING NO 31

BUILDING NO 32

BUILDING NO 33

BUILDING NO 34

BUILDING NO 35

BUILDING NO 36

BUILDING NO 37

BUILDING NO 38

BUILDING NO 39

BUILDING NO 40

BUILDING NO 41

BUILDING NO 42

BUILDING NO 43

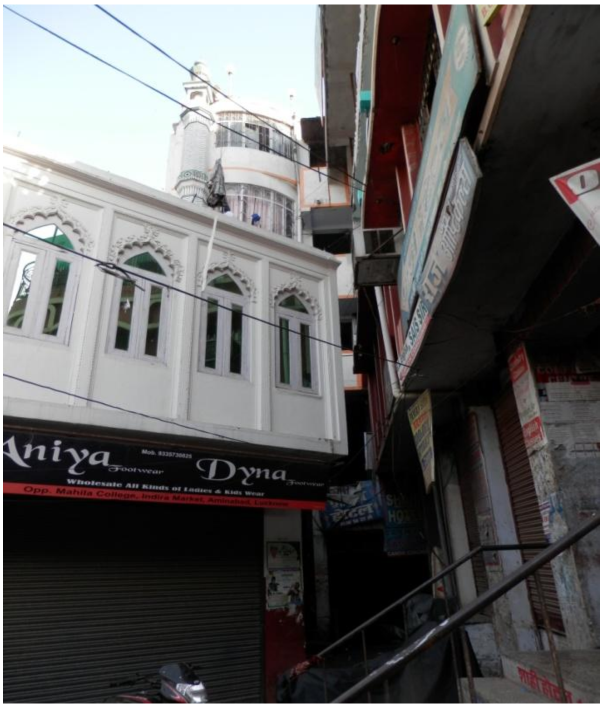
BUILDING NO 44

BUILDING NO 45

BUILDING NO 46

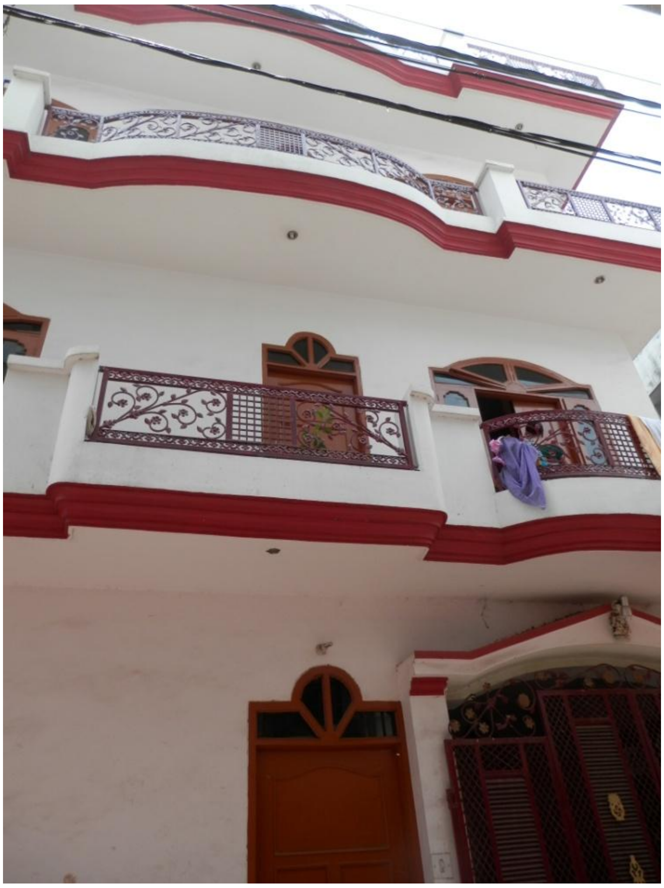
BUILDING NO 47

BUILDING NO 48



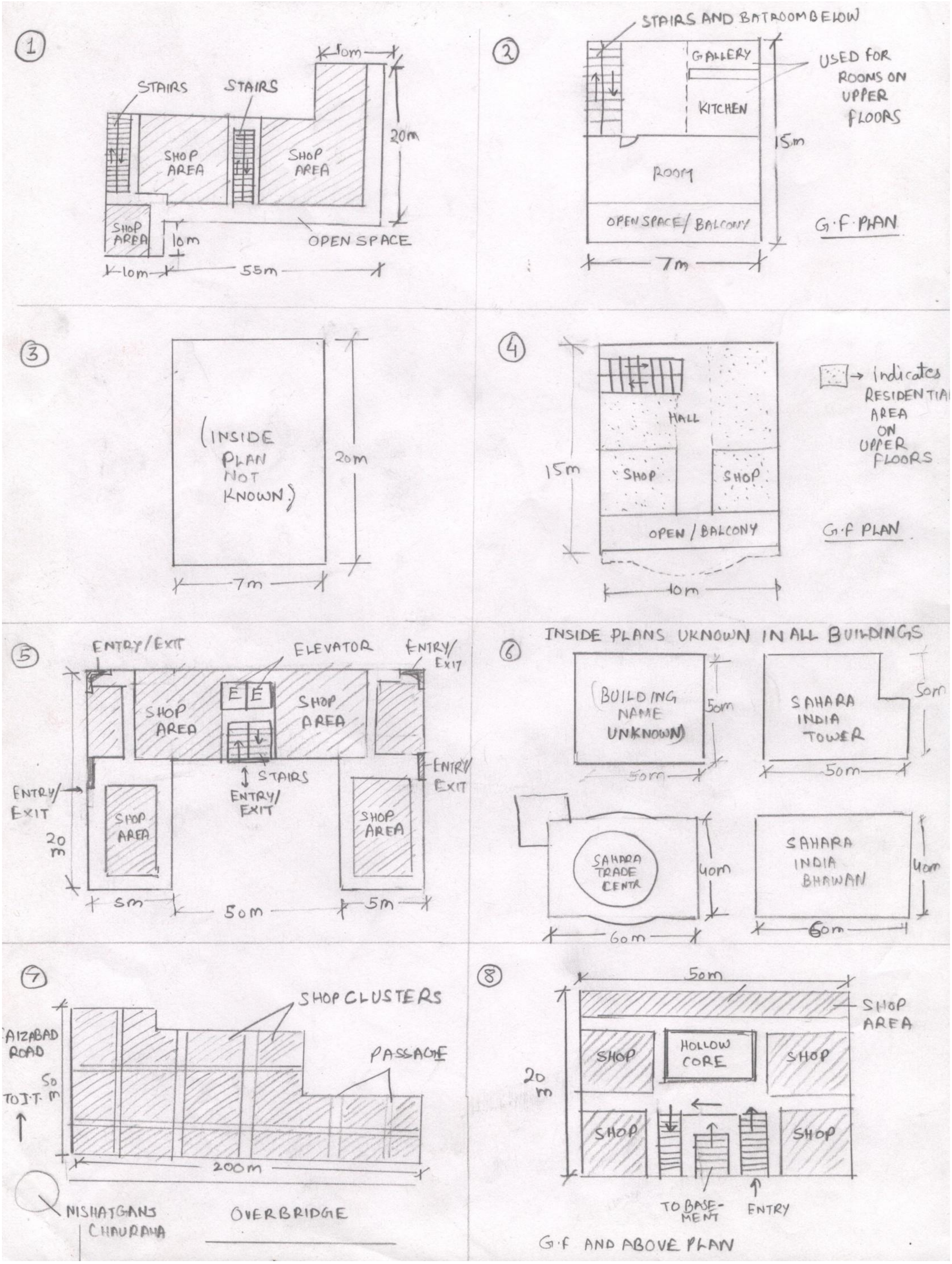
BUILDING NO 49

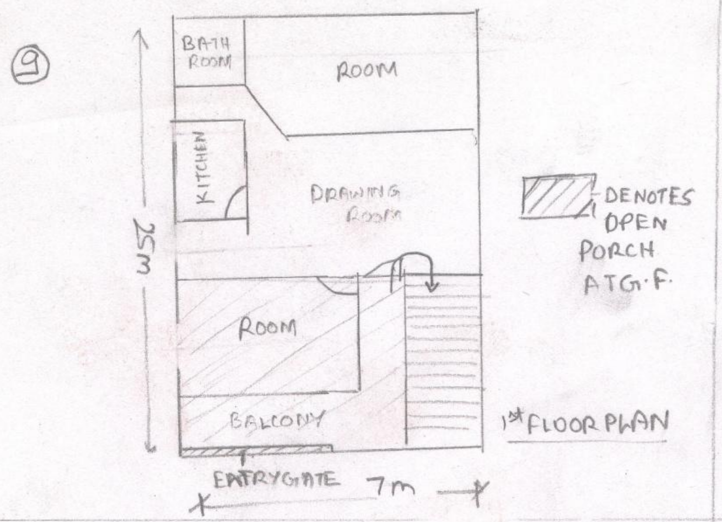
BUILDING NO 50

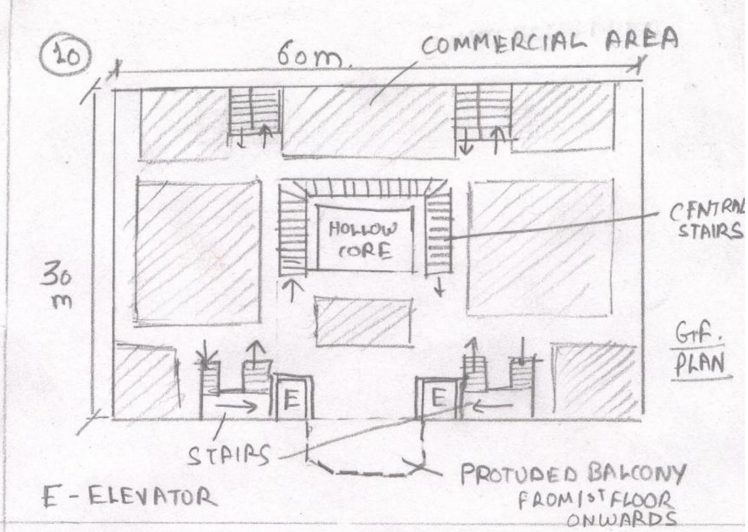


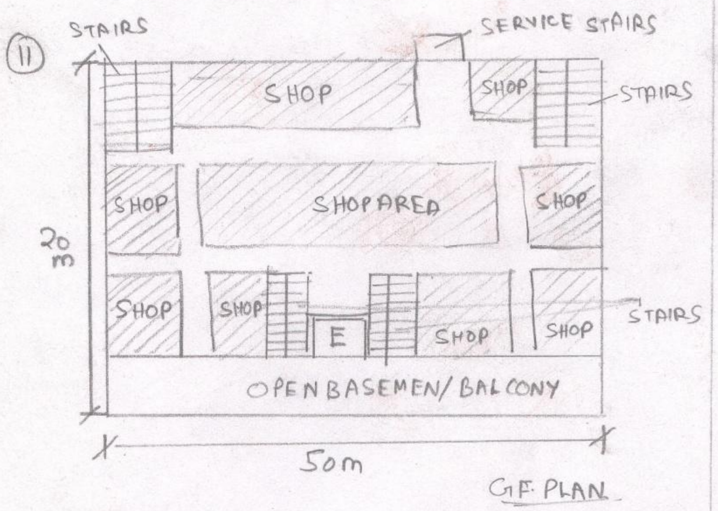
BUILDING NO 51

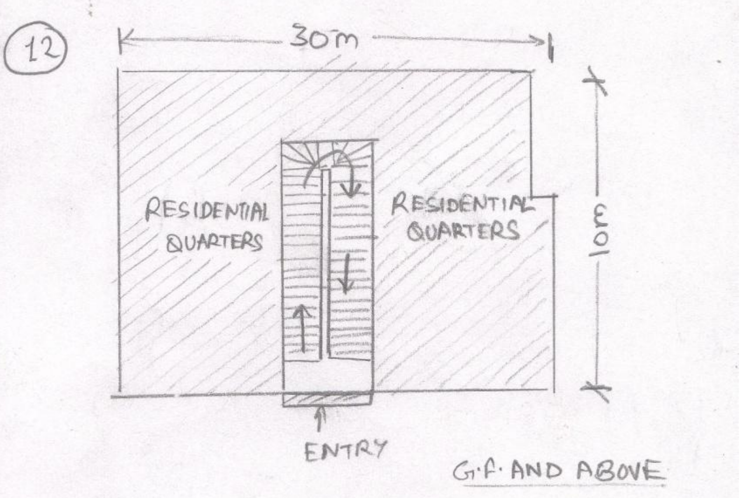
ANNEXURE B (LAYOUT AND PLAN SKETCHES)

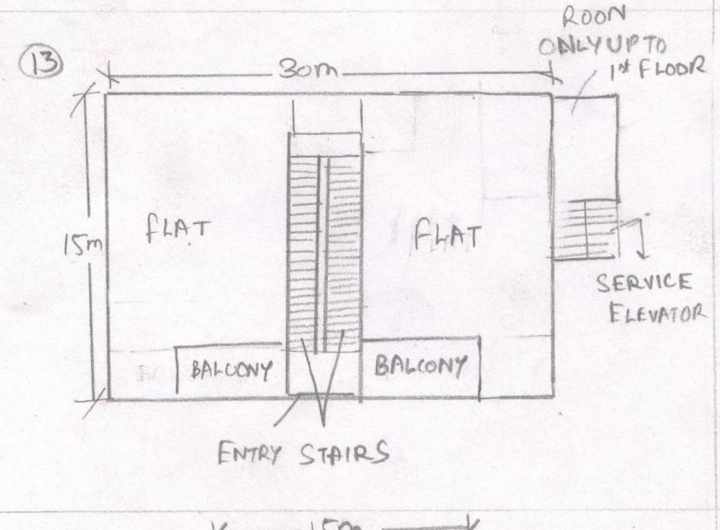


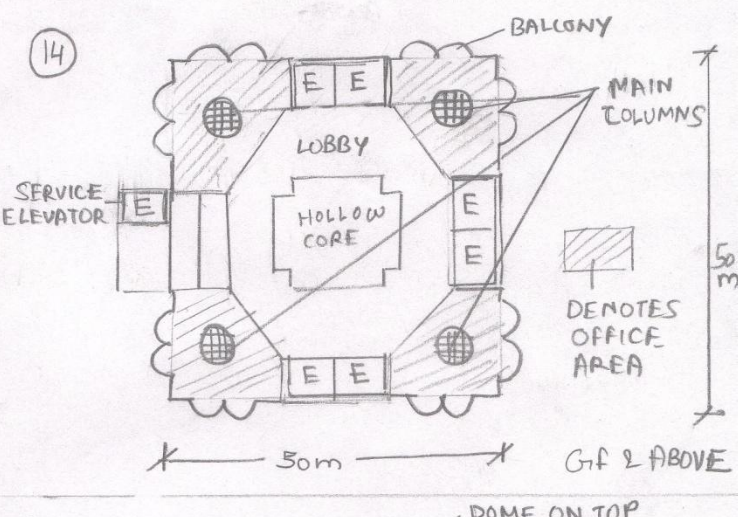

9
BATH ROOM
ROOM
KITCHEN
DRAWING ROOM
ROOM
BALCONY
ENTRYGATE
7m
35m
DENOTES OPEN PORCH AT G.F.
1st FLOOR PLAN

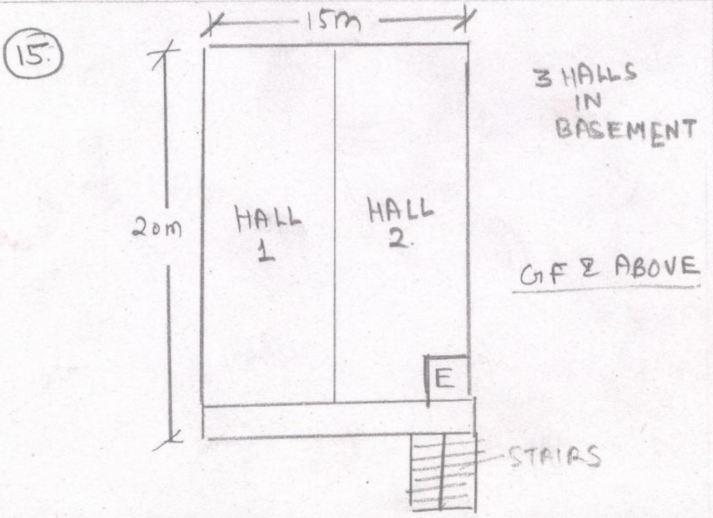

10
60m.
COMMERCIAL AREA
CENTRAL STAIRS
HOLLOW CORE
30 m
E
E
G.F. PLAN
STAIRS
PROTUDED BALCONY FROM 1st FLOOR ONWARDS
E - ELEVATOR

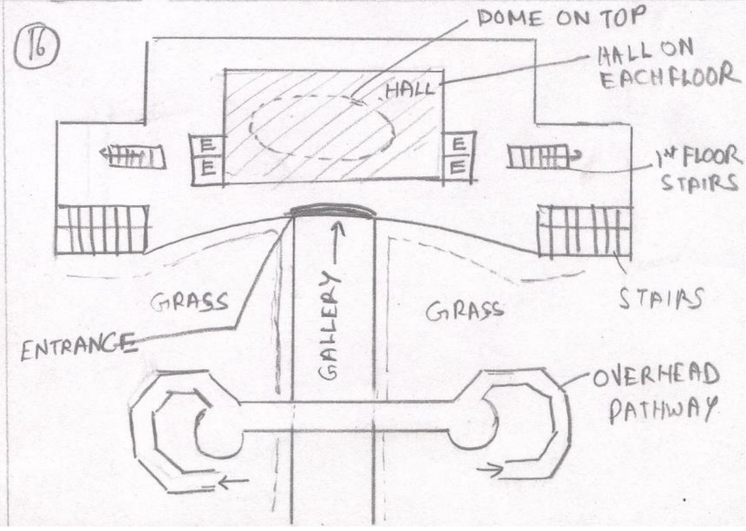

11
STAIRS
SERVICE STAIRS
SHOP
SHOP
STAIRS
SHOP
SHOP AREA
SHOP
20 m
SHOP
SHOP
E
SHOP
SHOP
STAIRS
OPEN BASEMEN/BALCONY
50m
G.F. PLAN

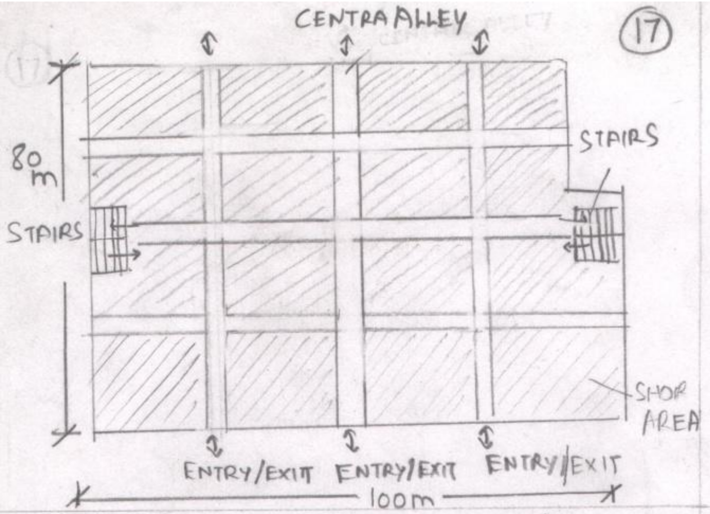

12
30m
RESIDENTIAL QUARTERS
RESIDENTIAL QUARTERS
10m
ENTRY
G.F. AND ABOVE

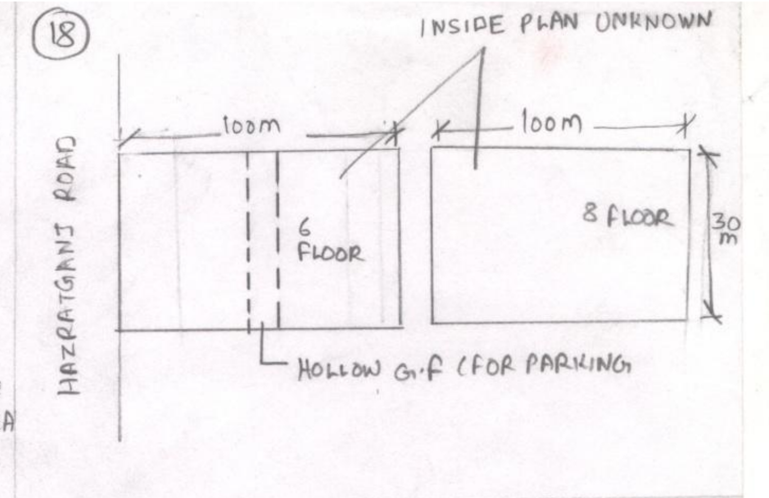

13
30m
ROON ONLY UP TO 1st FLOOR
15m
FLAT
FLAT
SERVICE ELEVATOR
BALCONY
BALCONY
ENTRY STAIRS

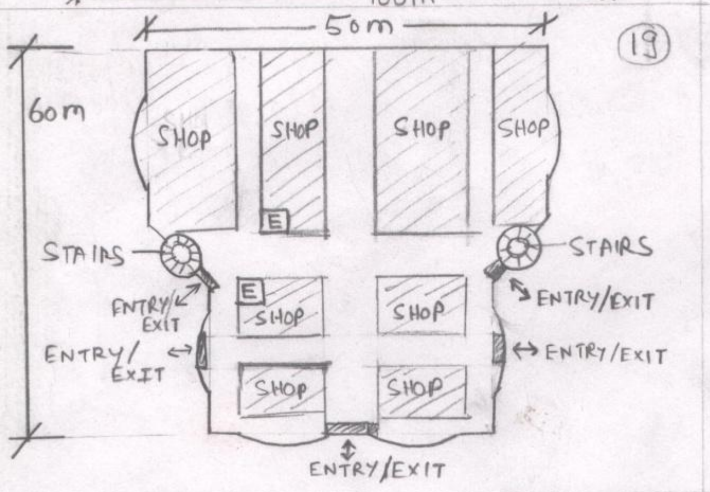

14
BALCONY
E E
MAIN COLUMNS
LOBBY
SERVICE ELEVATOR
E
HOLLOW CORE
E
E
50 m
DENOTES OFFICE AREA
E E
30m
Gf & ABOVE

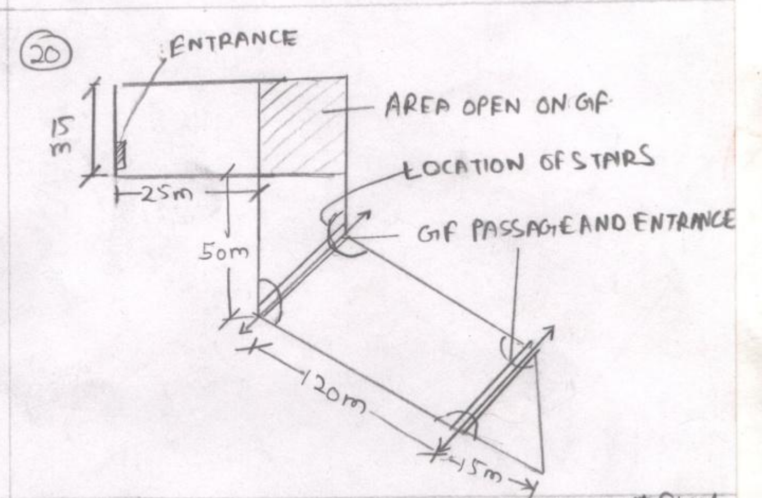

15.
15m
3 HALLS IN BASEMENT
20m
HALL 1
HALL 2
GF & ABOVE
E
STAIRS

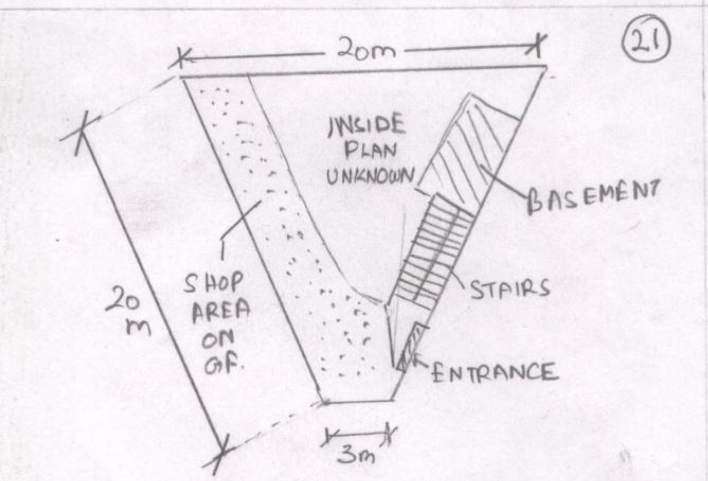

16
DOME ON TOP
HALL ON EACH FLOOR
HALL
E
E
E
E
1st FLOOR STAIRS
STAIRS
GRASS
GALLERY
GRASS
ENTRANCE
OVERHEAD PATHWAY

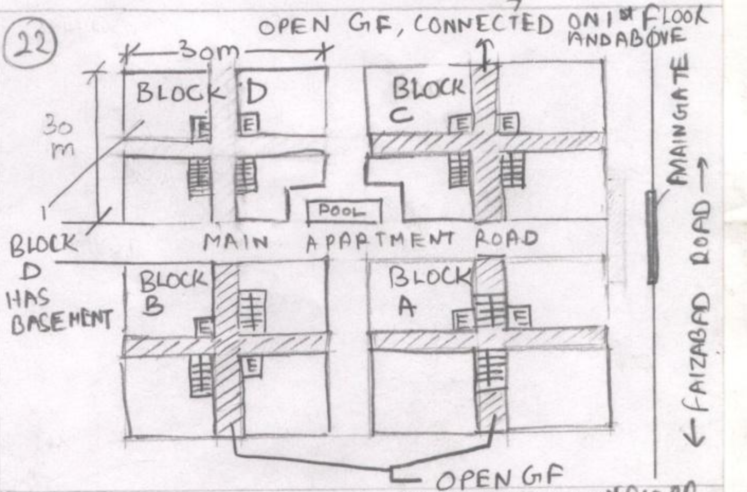

17
CENTRA ALLEY
80 m
STAIRS
STAIRS
SHOP AREA
ENTRY/EXIT ENTRY/EXIT ENTRY/EXIT
100m

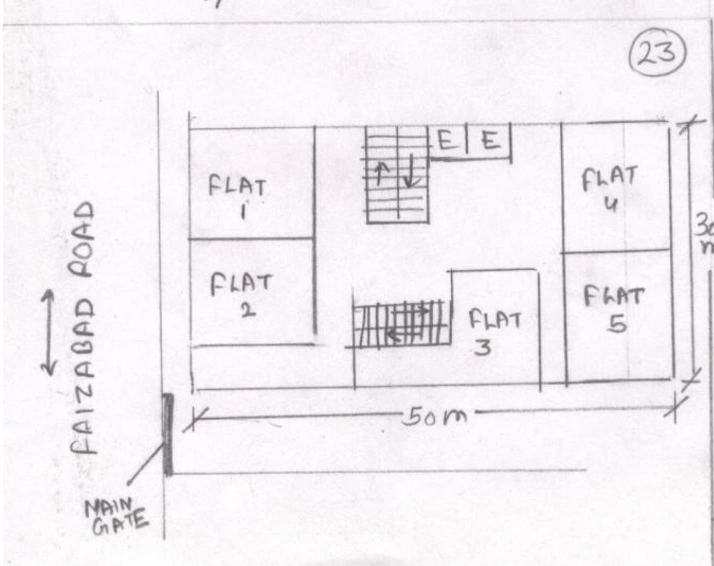

18
INSIDE PLAN UNKNOWN
HAZRATGANJ ROAD
100m
100m
6 FLOOR
8 FLOOR
30 m
HOLLOW G.F (FOR PARKING

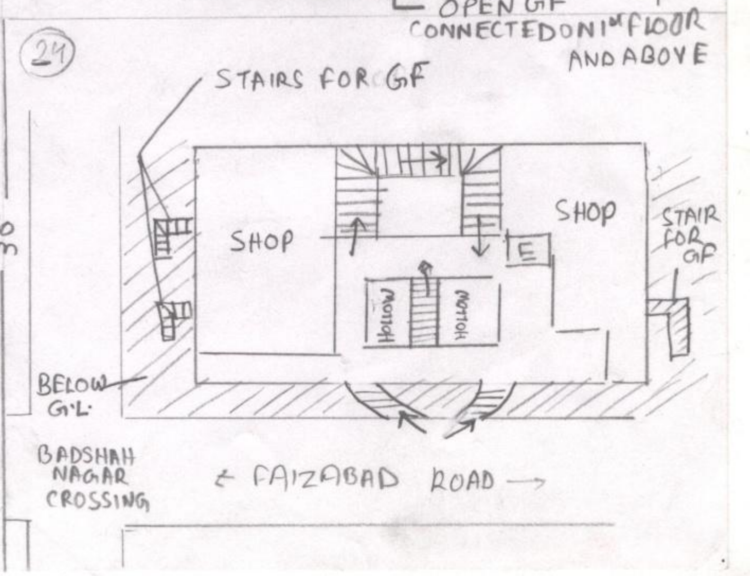

19
50m
60m
SHOP
SHOP
SHOP
SHOP
E
STAIRS
STAIRS
E
SHOP
SHOP
ENTRY/ EXIT
ENTRY/EXIT
ENTRY/ EXIT
ENTRY/EXIT
SHOP
SHOP
ENTRY/EXIT

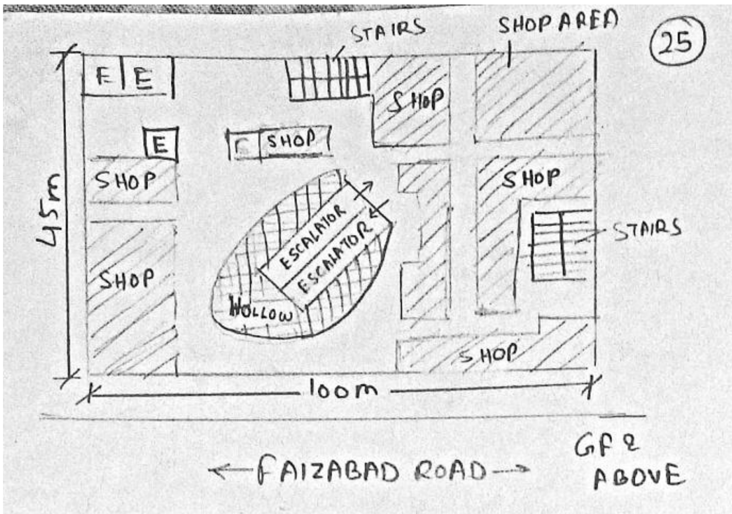

20
ENTRANCE
15 m
AREA OPEN ON G/F
25m
LOCATION OF STAIRS
50m
G/F PASSAGE AND ENTRANCE
120m
15m

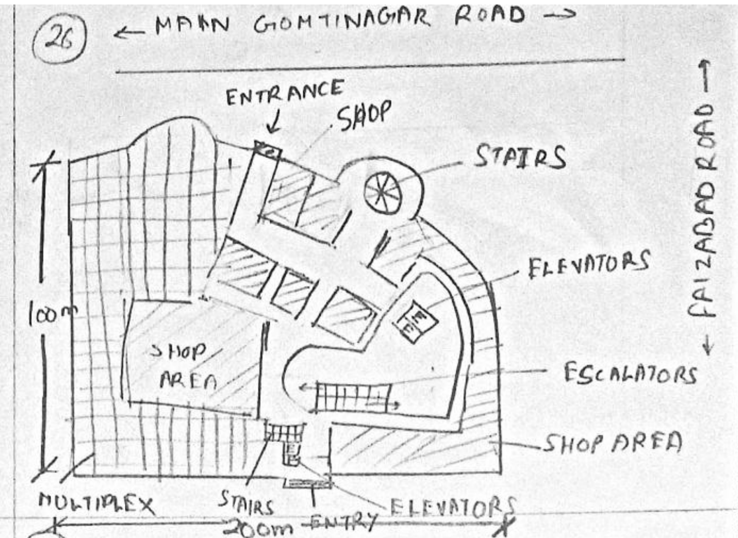

21
20m
INSIDE PLAN UNKNOWN
BASEMENT
STAIRS
SHOP AREA ON G/F.
20 m
ENTRANCE
3m

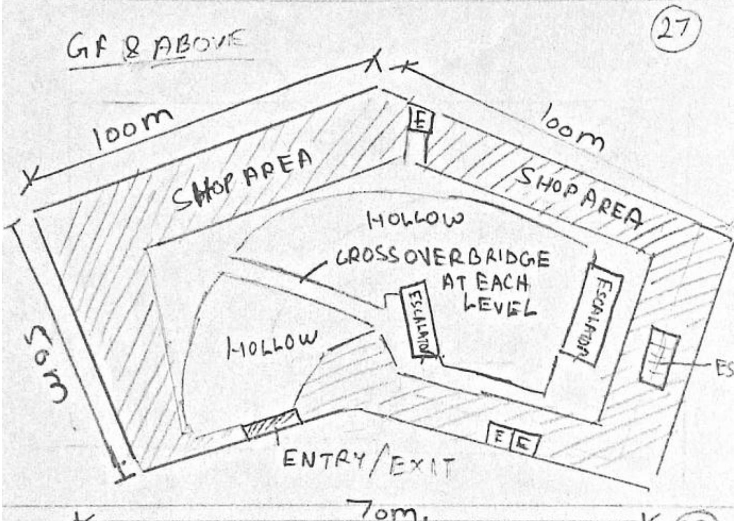

22
OPEN G/F, CONNECTED ON 1st FLOOR AND ABOVE
30m
BLOCK D
BLOCK C
30 m
E E
E E
POOL
MAIN APPARTMENT ROAD
BLOCK D HAS BASEMENT
BLOCK B
BLOCK A
E
E E
E
MAIN GATE
FAIZABAD ROAD
OPEN G/F CONNECTED ON 1st FLOOR AND ABOVE

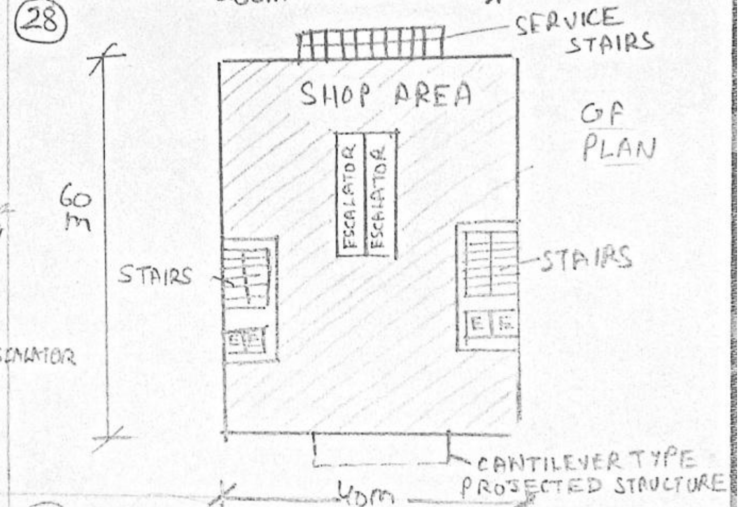

23
E E
FLAT 1
FLAT 4
FLAT 2
FLAT 3
FLAT 5
30 m
FAIZABAD ROAD
50m
MAIN GATE

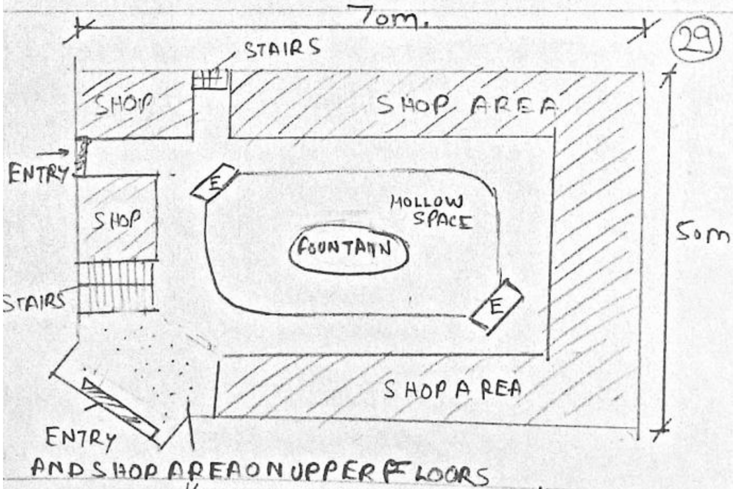

24
STAIRS FOR G/F
SHOP
SHOP
STAIR FOR G/F
E
HOLLOW
HOLLOW
BELOW G.L.
BADSHAH NAGAR CROSSING
FAIZABAD ROAD

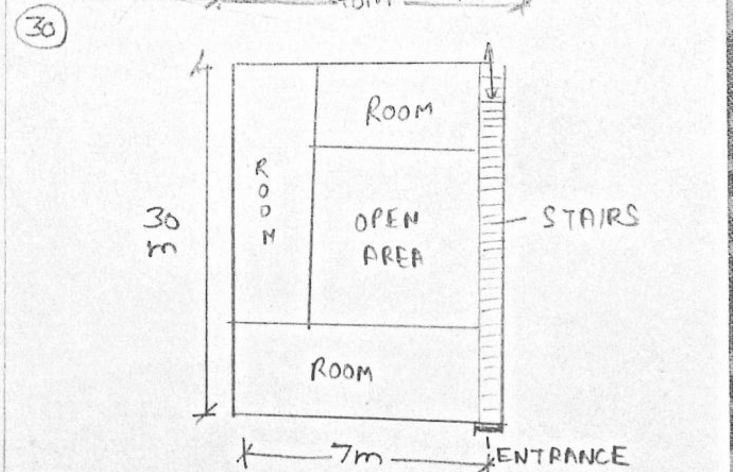

25
STAIRS
SHOP AREA
E E
E
SHOP
SHOP
SHOP
SHOP
SHOP
SHOP
ESCALATOR
ESCALATOR
HOLLOW
STAIRS
45m
100m
← FAIZABAD ROAD →
GF & ABOVE

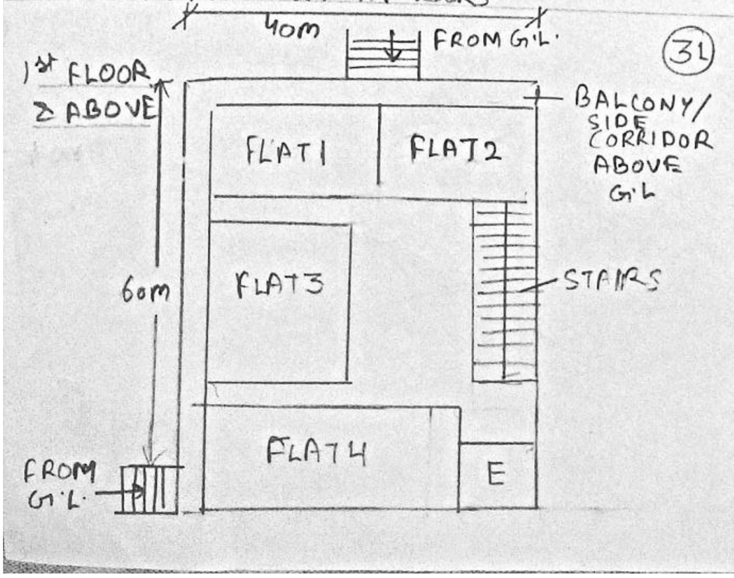

26
← MAIN GOMTINAGAR ROAD →
ENTRANCE
SHOP
STAIRS
FAIZABAD ROAD
ELEVATORS
100m
SHOP AREA
ESCALATORS
SHOP AREA
MULTIPLEX
STAIRS
ENTRY
ELEVATORS
200m

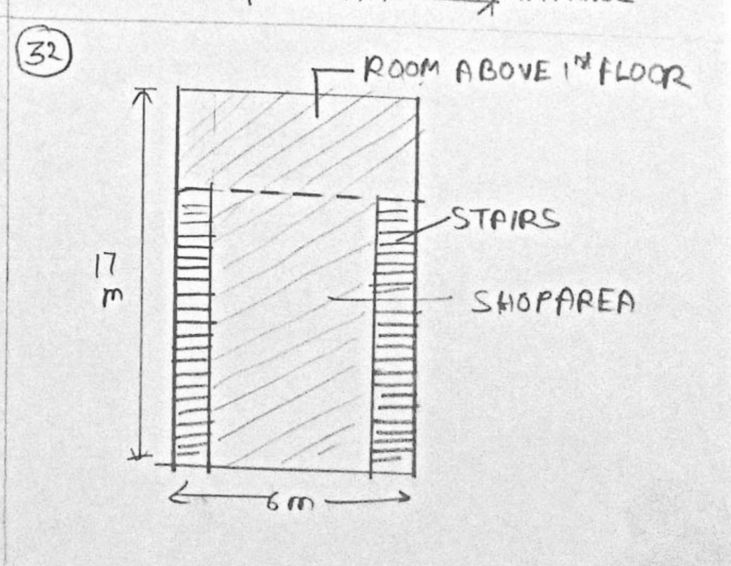

27
GF & ABOVE
100m
100m
E
SHOP AREA
SHOP AREA
HOLLOW
CROSSOVERBRIDGE AT EACH LEVEL
ESCALATOR
ESCALATOR
HOLLOW
ESCALATOR
50m
E E
ENTRY/EXIT

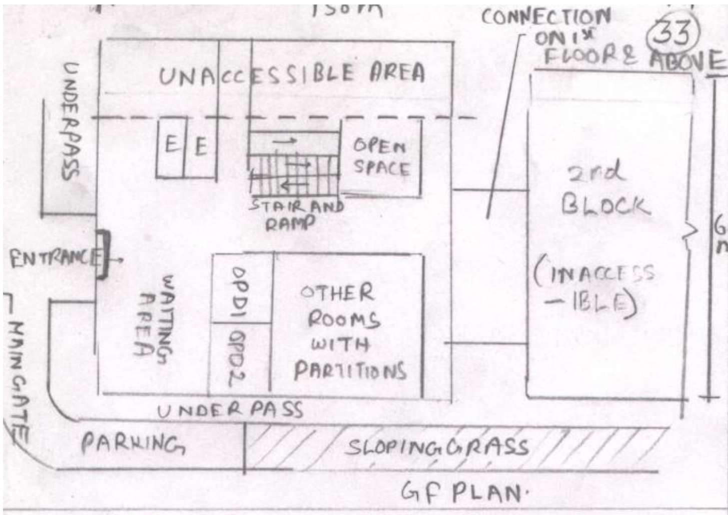

28
SERVICE STAIRS
SHOP AREA
GF PLAN
60 m
ESCALATOR
ESCALATOR
STAIRS
STAIRS
E E
CANTILEVER TYPE PROJECTED STRUCTURE
40m

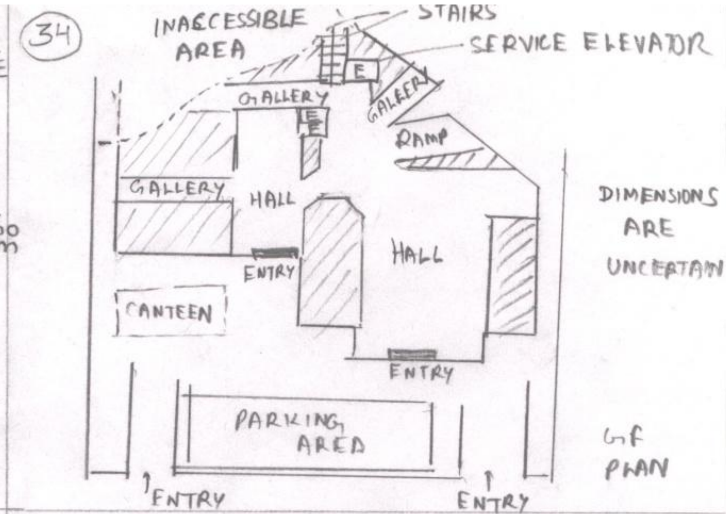

70m.
29
STAIRS
SHOP
SHOP AREA
ENTRY
E
HOLLOW SPACE
SHOP
FOUNTAIN
50m
STAIRS
E
SHOP AREA
ENTRY
AND SHOP AREA ON UPPER FLOORS

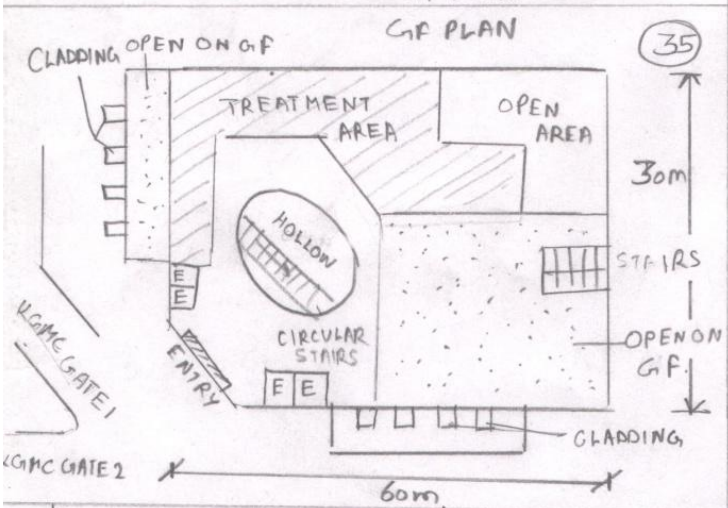

30
ROOM
ROOM
30 m
OPEN AREA
STAIRS
ROOM
7m
ENTRANCE

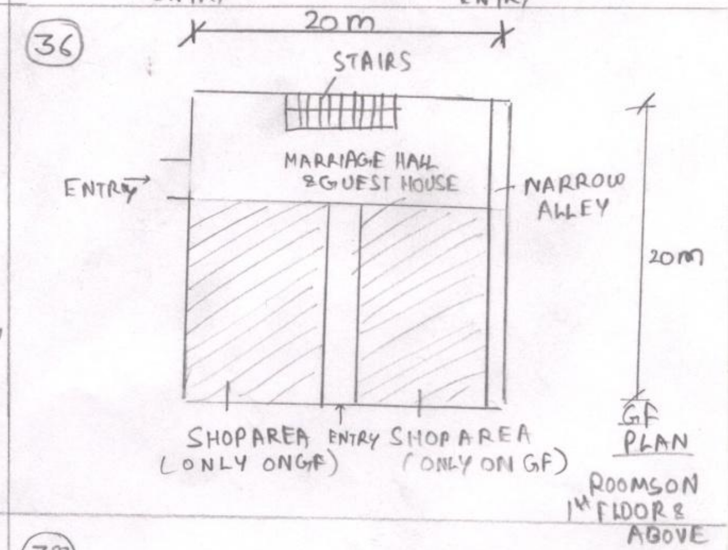

40m
FROM G.L.
31
1st FLOOR & ABOVE
BALCONY/ SIDE CORRIDOR ABOVE G.L
FLAT1
FLAT2
FLAT3
STAIRS
60m
FLAT4
E
FROM G.L.

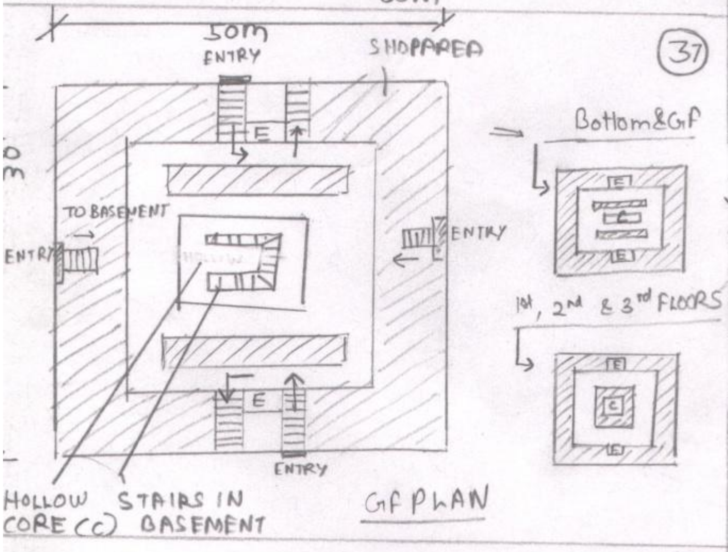

32
ROOM ABOVE 1st FLOOR
STAIRS
17 m
SHOPAREA
6m

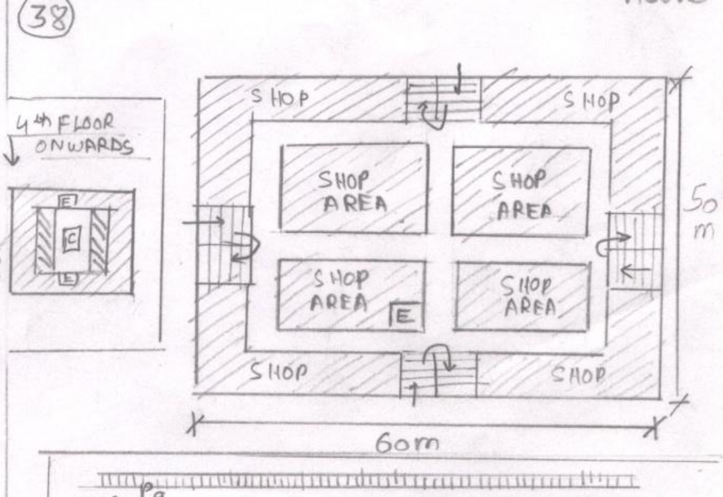

33
UNACCESSIBLE AREA
UNDERPASS
CONNECTION ON 1st FLOOR & ABOVE
E E
OPEN SPACE
STAIR AND RAMP
2nd BLOCK (INACCESS -IBLE)
60 m
ENTRANCE
MAIN GATE
WAITING AREA
OPD1 OPD2
OTHER ROOMS WITH PARTITIONS
UNDER PASS
PARKING
SLOPING GRASS
GF PLAN

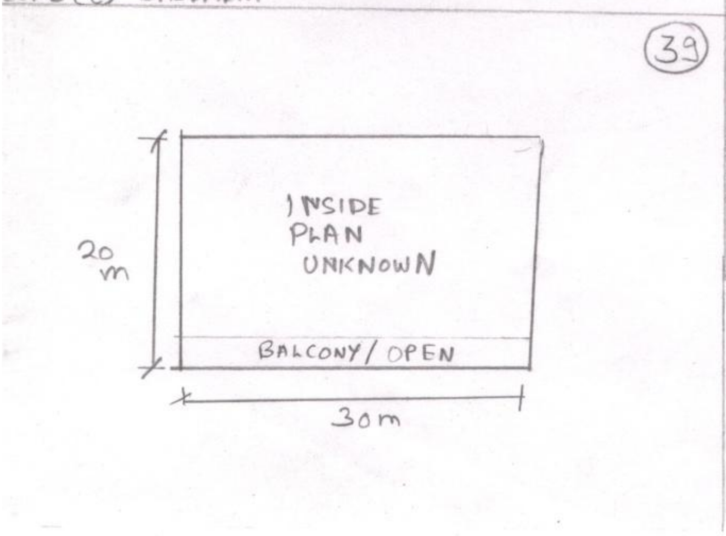

34
INACCESSIBLE AREA
STAIRS
SERVICE ELEVATOR
GALLERY
GALLERY
RAMP
GALLERY
HALL
HALL
ENTRY
CANTEEN
ENTRY
DIMENSIONS ARE UNCERTAIN
PARKING AREA
ENTRY
ENTRY
GF PLAN

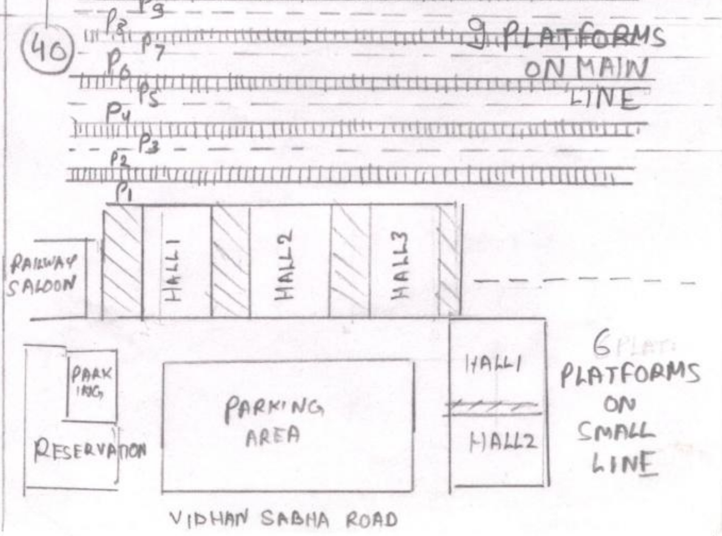

GF PLAN
35
CLADDING
OPEN ON GF
TREATMENT AREA
OPEN AREA
30m
HOLLOW
STAIRS
CIRCULAR STAIRS
ENTRY
KGMC GATE 1
OPEN ON GF.
E E
CLADDING
KGMC GATE 2
60m


36
20m
STAIRS
ENTRY
MARRIAGE HALL & GUEST HOUSE
NARROW ALLEY
20m
SHOP AREA (ONLY ON GF)
ENTRY
SHOP AREA (ONLY ON GF)
GF PLAN
ROOMS ON 1st FLOOR & ABOVE

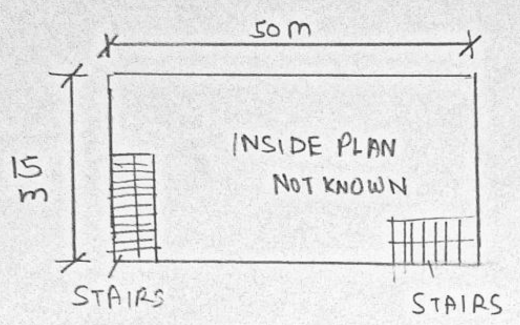

37
50m
ENTRY
SHOP AREA
30 m
TO BASEMENT
ENTRY
ENTRY
HOLLOW
E
E
ENTRY
Bottom & GF
4th FLOOR ONWARDS
1st, 2nd & 3rd FLOORS
HOLLOW CORE (C)
STAIRS IN BASEMENT
GF PLAN


38
SHOP
SHOP
SHOP AREA
SHOP AREA
SHOP AREA
SHOP AREA
E
SHOP
SHOP
50 m
60m

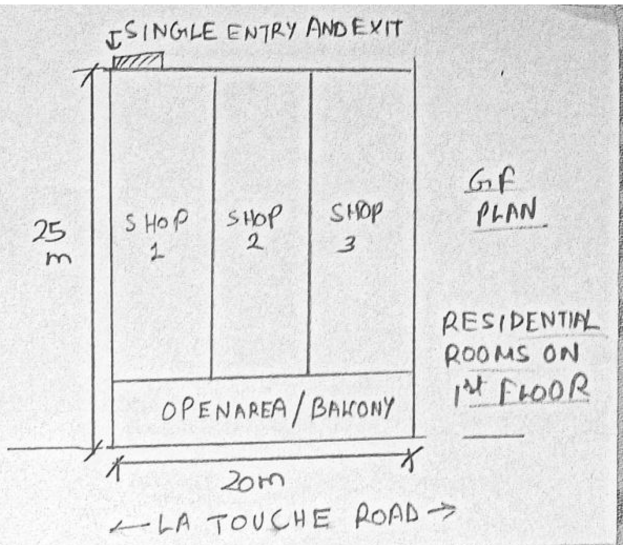

39
INSIDE PLAN UNKNOWN
BALCONY / OPEN
20 m
30m


40
P9
P8
P7
P6
P5
P4
P3
P2
P1
9 PLATFORMS ON MAIN LINE
RAILWAY SALOON
HALL1
HALL2
HALL3
PARKING
RESERVATION
PARKING AREA
HALL1
HALL2
6 PLATFORMS ON SMALL LINE
VIDHAN SABHA ROAD

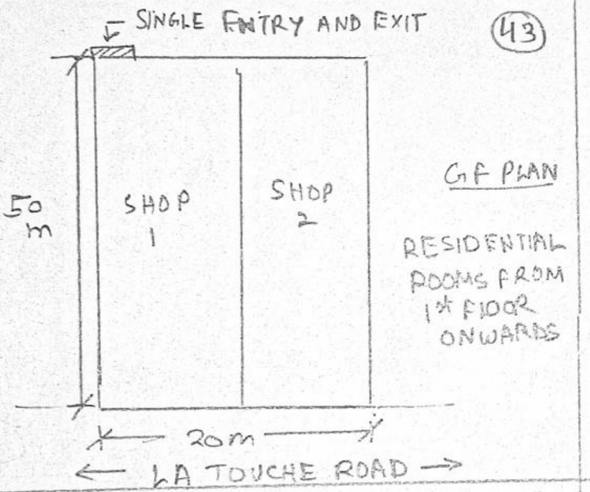
(41)



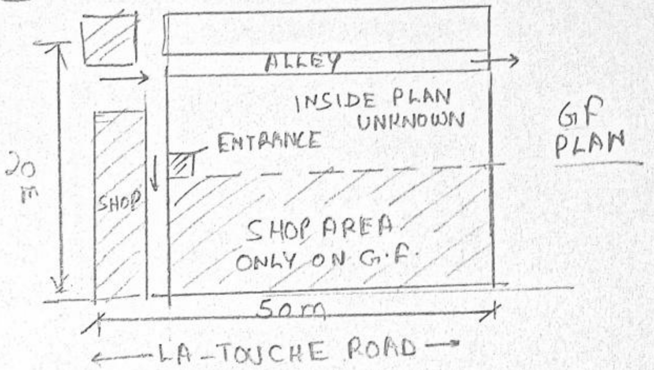
(42)



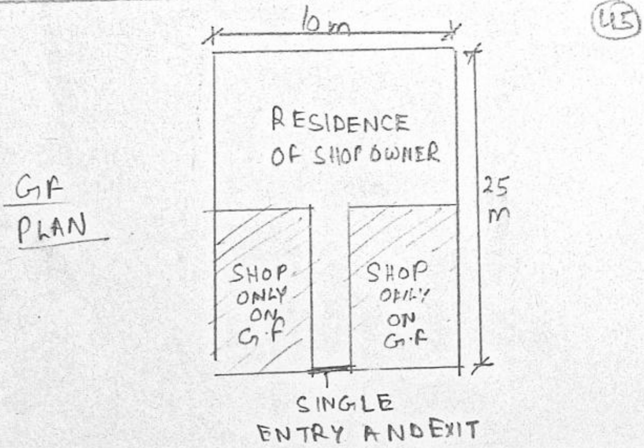
(43)



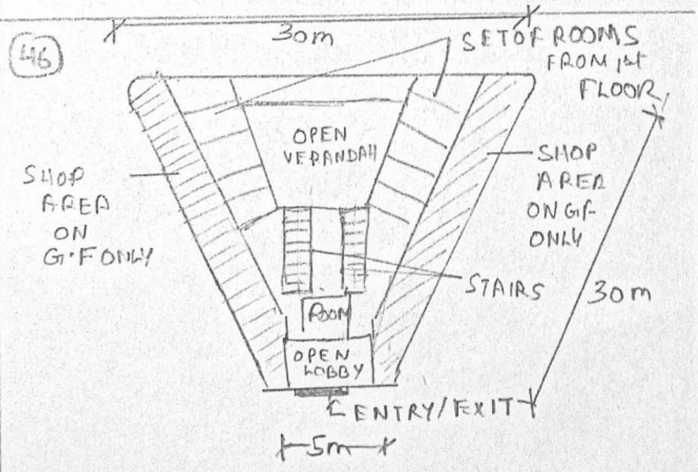
(44)



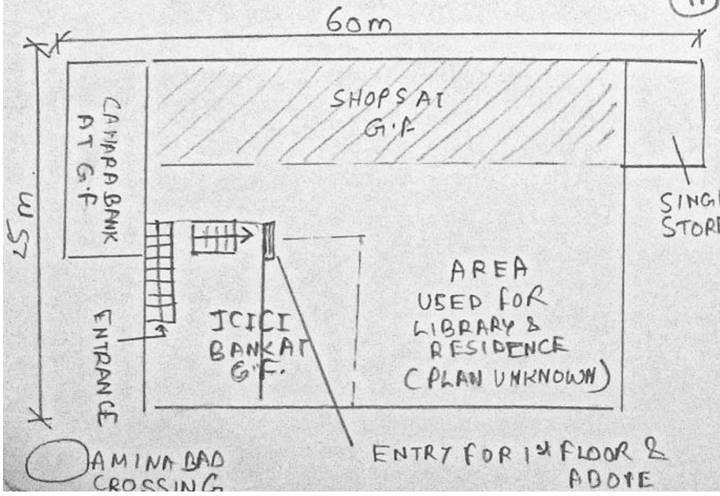
(45)



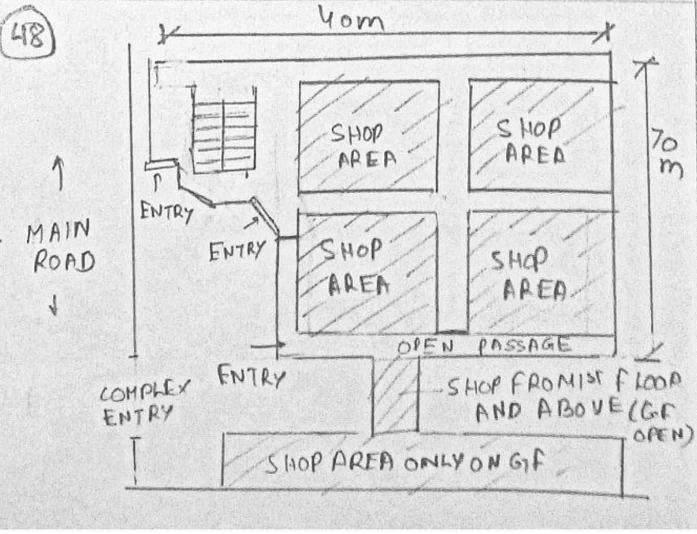
(46)

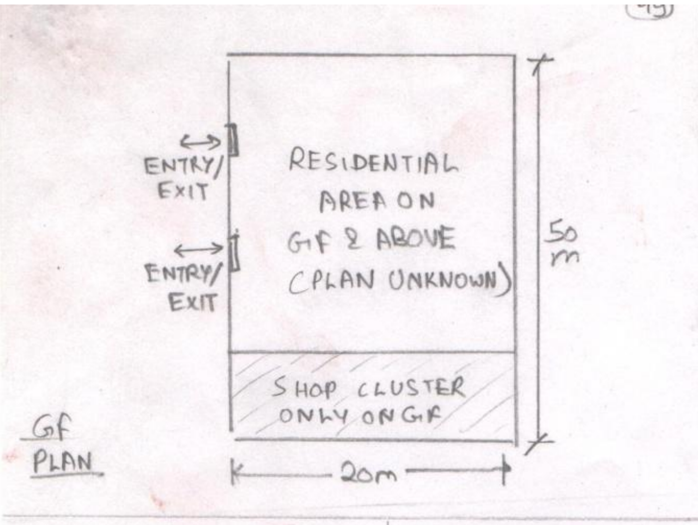


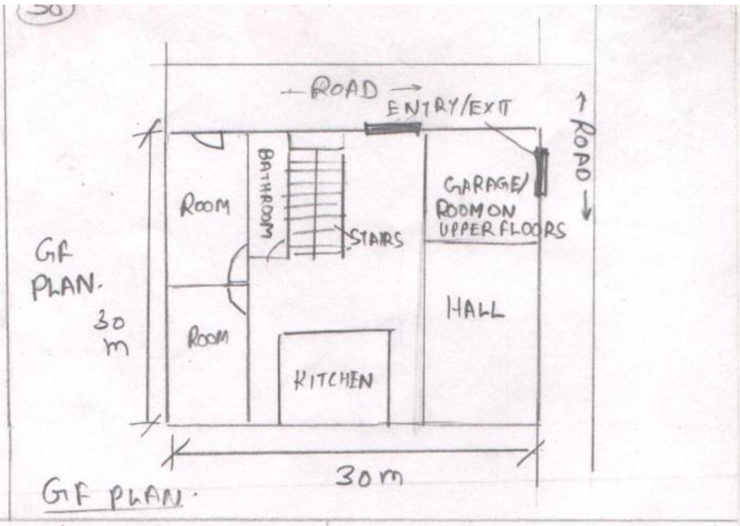
(47)

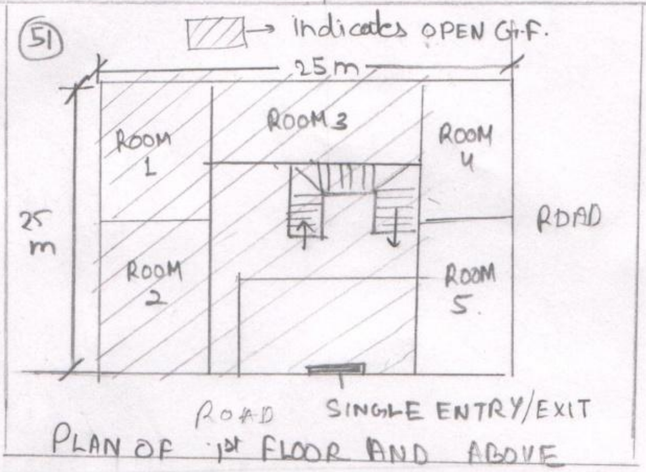


(48)




ENTRY/ EXIT
ENTRY/ EXIT
RESIDENTIAL AREA ON GF & ABOVE (PLAN UNKNOWN)
50 m
SHOP CLUSTER ONLY ON GF
GF PLAN
20m


ROAD
ENTRY/EXIT
ROAD
ROOM
BATHROOM
STAIRS
GARAGE/ ROOM ON UPPER FLOORS
GF PLAN.
30 m
ROOM
HALL
KITCHEN
30m
GF PLAN.


51
Indicates OPEN G.F.
25m
ROOM 1
ROOM 3
ROOM 4
25 m
ROAD
ROOM 2
ROOM 5.
ROAD
SINGLE ENTRY/EXIT
PLAN OF 1st FLOOR AND ABOVE

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Department of Civil Engineering, NITK Surathkal

[5] *Dr. Anand S. Arya,* **"Rapid Viual Screening Of RCC Buildings"**
(Professor Emeritus, Dept. of Eq. Engineering, IIT Roorkee)
Chairman, BIS Committee CED 39
National Seismic Advisor (EVR)
Ministry of Home Affairs

[6] *Dr. Anand S. Arya,* **"Rapid Viual Screening Of Masonry Buildings"**
Professor Emeritus, Dept. of Eq. Engineering, IIT Roorkee)
Chairman, BIS Committee CED 39
National Seismic Advisor (EVR)
Ministry of Home Affairs

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1Oregon Department of Geology and Mineral Industries, 800 NE Oregon St., Suite 965, Portland, Oregon 97232 2 Goettel and Associates Inc., 1732 Arena Drive, Davis, California, 95616.

[11] "Concept of risk and vulnerability studies; Different methods; Different level of risk assessment"
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[13] *G. Achs*1 and C. Adams*2* **"A Rapid-Visual-Screening Methodology for the Seismic Vulnerability Assessment of Historic Brick-Masonry Buildings in Vienna"**
1 *VCE Holding GmbH,Austria*
2 *University of Innsbruck, Department of Civil Engineering Sciences, Austria*

[14] IS 1893 (Part 1) : 2002 **" *Indian Standard* CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES Part 1 General provisions and buildings (Fifth Revision)"**

[**15**] IS 4326:1993 **"Indian Standard Code of practice for Earthquake Resistant Design and Construction of Buildings"**

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[19]*Juang, C.H. and Elton, D.J. (1986)*, **"Fuzzy logic for estimation of earthquake intensity based on building damage records",** ***Civil Engineering and Environmental System"***,

[20]*Jang, J-S. (1993)*, *"* **ANFIS: Adaptive network-based fuzzy inference system",** ***IEEE Transactions on Systems, Man and Cybernetics****"*

[21]*Kartalopoulos, S. (1995*), **"Understanding neural networks and fuzzy logic: Basic concepts and applications"**
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