## **DISSERTATION**

## On

## "Condition Assessment of Buildings using Rapid Visual Screening Procedure"

Submitted by-

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Under the guidance of-

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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 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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#### 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-

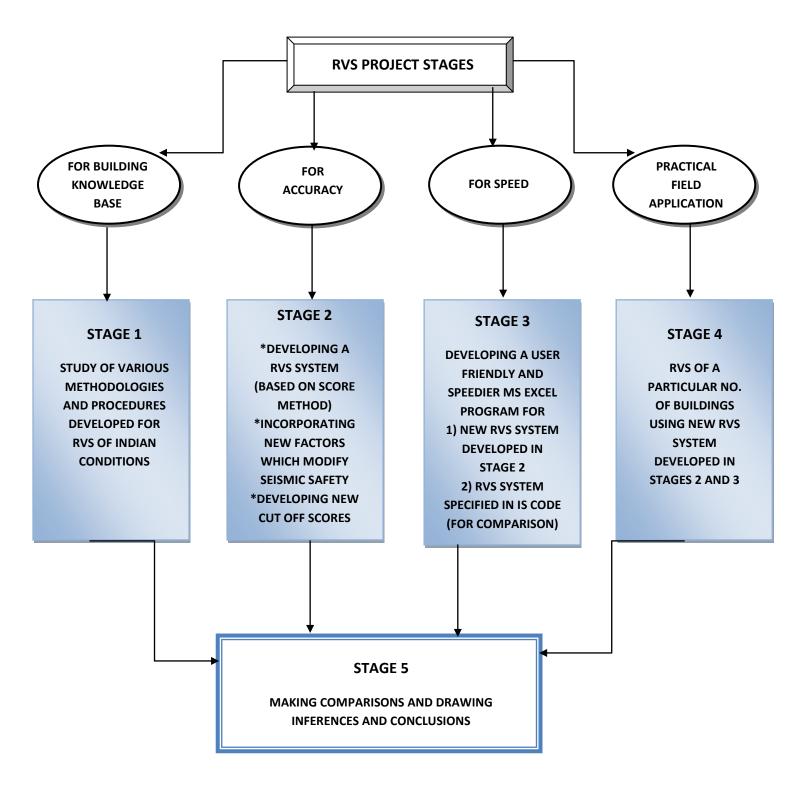


Figure 1: Flowchart for RVS methodology

## **<u>2 LITERATURE REVIEW</u>**

### 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  $2^{nd}$  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 <u>score modifiers</u>. 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 <u>RVS forms</u> 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 <u>overall structural score</u>. If this overall structural score is less than the <u>cut off score</u>, 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  $2^{nd}$  edition published in 2002 which an improvement over  $1^{st}$  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]

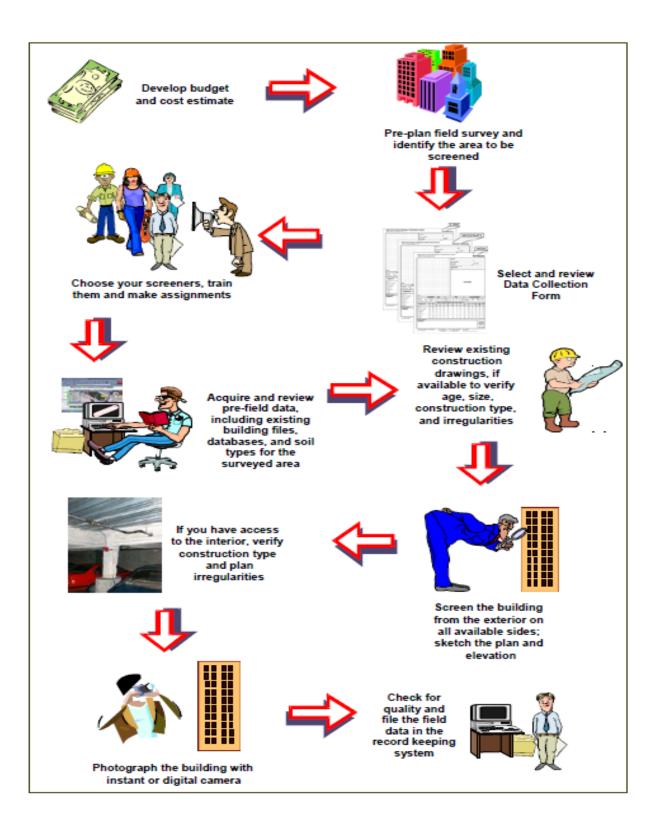


Figure 2\*[1]: A flow chart showing the steps involved In RVS implementation sequence

# The general sequence of RVS procedure \*[1] (taken from FEMA 154) is depicted in Figure 1. 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  $2^{nd}$  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	Dia ta ang l	Basic Structural	Characteristics and Derfer
W1 Light wood frame resi- dential and commercial buildings equal to or smaller than 5,000 square feet	Photograph	Hazard Score H = 2.8 M = 5.2 L = 7.4	<ul> <li>Characteristics and Performance</li> <li>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).</li> <li>Most common exterior finish materials are wood siding, metal siding, or stucco.</li> <li>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.</li> <li>Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage.</li> <li>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.</li> </ul>
W2 Light wood frame build- ings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	<ul> <li>These are large apartment buildings, commercial build- ings or industrial structures usually of one to three stories, and, rarely, as tall as six sto- ries.</li> </ul>

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
S1 Steel moment- resisting frame		H = 2.8 M = 3.6 L = 4.6	<ul> <li>Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft.</li> <li>The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings.</li> <li>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.</li> </ul>
S2 Braced steel frame	<image/> <image/>	H = 3.0 M = 3.6 L = 4.8	<ul> <li>These buildings are braced with diagonal members, which usually cannot be detected from the building exterior.</li> <li>Braced frames are sometimes used for long and narrow buildings because of their stiffness.</li> <li>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.</li> <li>In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.</li> </ul>

 $Figure \ 3 \ *[1]:$  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	<ul> <li>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.</li> <li>The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily.</li> <li>Insufficient capacity of tension braces can lead to their elongation and consequent building earthquakes.</li> </ul>
			<ul> <li>Inadequate connection to a slab foundation can allow the building columns to slide on the slab.</li> <li>Loss of the cladding can occur.</li> </ul>
S4 Steel frames with cast-in- place con- crete shear walls		H = 2.8 M = 3.6 L = 4.8	<ul> <li>Lateral loads are resisted by shear walls, which usually sur- round elevator cores and stair- wells, and are covered by finish materials.</li> <li>An interior investigation will permit a wall thickness check. More than six inches in thick- ness usually indicates a con- crete wall.</li> <li>Shear cracking and distress can occur around openings in concrete shear walls during</li> </ul>
			<ul> <li>Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.</li> </ul>

Figure 3\*[1] (continued)

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

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

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

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

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
PC2 Precast con- crete frame buildings	<image/>	H = 2.4 M = 3.2 L = 4.6	<ul> <li>Precast concrete frames are, in essence, post and beam construction in concrete.</li> <li>Structures often employ con- crete or reinforced masonry (brick or block) shear walls.</li> <li>The performance varies widely and is sometimes poor.</li> <li>They experience the same types of damage as shear wall buildings (C2).</li> <li>Poorly designed connections between prefabricated ele- ments can fail.</li> <li>Loss of vertical support can occur due to inadequate bear- ing area and insufficient con- nection between floor elements and columns.</li> <li>Corrosion of metal connectors between prefabricated ele- ments can occur.</li> </ul>

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

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
RM1 Reinforced masonry buildings with flexible dia- phragms	<image/> <image/> <image/> <image/>	H = 2.8 M = 3.6 L = 4.8	<ul> <li>Walls are either brick or concrete block.</li> <li>Wall thickness is usually 8 inches to 12 inches.</li> <li>Interior inspection is required to determine if diaphragms are flexible or rigid.</li> <li>The most common floor and roof systems are wood, light steel, or precast concrete.</li> <li>These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage.</li> <li>Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.</li> </ul>

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

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	<ul> <li>Walls are either brick or concrete block.</li> <li>Wall thickness is usually 8 inches to 12 inches.</li> <li>Interior inspection is required to determine if diaphragms are flexible or rigid.</li> <li>The most common floor and roof systems are wood, light steel, or precast concrete.</li> <li>These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage.</li> <li>Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.</li> </ul>
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	<ul> <li>These buildings often used weak lime mortar to bond the masonry units together.</li> <li>Arches are often an architec- tural characteristic of older brick bearing wall buildings.</li> <li>Other methods of spanning are also used, including steel and stone lintels.</li> <li>Unreinforced masonry usu- ally shows header bricks in the wall surface.</li> <li>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.</li> </ul>

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

### 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

										Address	:							
															Zip			
										Other Id	entifier	s						
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Assembly		ovt	Offic			er of Pe		A	B	С	D	E F Soft Po				Ľ		
Commercial Emer. Service		istoric idustrial		idential ool	0 - 10	11 · 00 100	– 100 )0+	Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soil So		einforced mneys	Parapets	Clac	lding	Other:
					B		CORF	MODI	FIFR	S AND	FINΔI	SCORE		,,.				
BUILDING	G TYPI	E	W1	W2	S1	S2	S3	, 1110 D1 S4		\$5	C1	C2	C3	PC1	PC2	RM1	RM2	URM
					(MRF)	(BR)	(LM)	(RC S	W)	(URM INF)	(MRF)	(SW)	(URM INF)	(TU)		(FD)	(RD)	
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			N/A	N/A	+0.2	+0.4	N/A		2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7	stories	5)	N/A	N/A	+1.0	+1.0	N/A N/A	+1.0		+1.2	+1.0	0.0	-0.4 -2.0	N/A	-0.2	N/A	0.0	N/A
Vertical Irregul Plan Irregularit	anty		-4.0 -0.8	-3.0 -0.8	-2.0 -0.8	-2.0 -0.8	-0.8	-2.0 -0.8		-2.0 -0.8	-1.5 -0.8	-2.0 -0.8	-2.0 -0.8	-0.8	-1.5 -0.8	-2.0 -0.8	-1.5 -0.8	-1.5 -0.8
Pre-Code	.y		N/A	N/A	N/A	N/A	-0.0 N/A	N/A		N/A	N/A	N/A	-0.0 N/A	N/A	-0.0 N/A	N/A	N/A	N/A
Post-Benchma	ark		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	 1	-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	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4
FINAL SC	ORE,	S																
COMMENT	rs																Eval	ailed uation juired

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

#### Rapid Visual Screening of Buildings for Potential Seismic Hazards

#### FEMA-154 Data Collection Form

## **MODERATE Seismicity**

			I		1				Address	:							
									Other Ide	entifier							
									No. Stori	ies				Y	ear Bui	ilt	
									Screene	r				_ Date _			
												PHC	TOGRAP	н			
Scale:	l																
	0	CCUP	ANCY	sc	)					YPE			FΔ			DS.	
Assembly	Govt	Office			er of Pe	rsons	Α	В		D	E F	-				1	
Commercial	Historic	Resid	lential	0 – 10	11	– 100	Hard	Avg	. Dense	Stiff	Soft Poo	or Un	L reinforced	Parapets	Clad	_ ding	Other:
Emer. Services	Industrial	Scho	ol	101-100	0 10	00+	Rock	Roc	k Soil	Soil	Soil So		himneys	-	_		
				B	ASIC				RS, AND								
BUILDING T	YPE	W1	W2	S1 (MRF)	<b>S2</b> (BR)	S3 (LM)	<b>S4</b> (RC S)		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		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 sto		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 Irregularit Plan Irregularity	ty	-3.5 -0.5	-3.0 -0.5	-2.0 -0.5	-2.0 -0.5	N/A -0.5	-2.0 -0.5		-2.0 -0.5	-2.0 -0.5	-2.0 -0.5	-2.0 -0.5	N/A -0.5	-1.5 -0.5	-2.0 -0.5	-1.5 -0.5	-1.5 -0.5
Pre-Code		-0.5	-0.5	-0.5 -0.4	-0.5 -0.4	-0.5	-0.5		-0.5	-0.5 -1.0	-0.5	-0.5	-0.5	-0.5 -0.4	-0.5 -0.4	-0.5 -0.4	-0.5 -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	6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6
FINAL SCOR	RES																
COMMENTS																Evalı Req	ailed uation uired
															I	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

#### Rapid Visual Screening of Buildings for Potential Seismic Hazards

#### FEMA-154 Data Collection Form

# HIGH Seismicity

							Address	:						
												)(		
							Other Ide	entifier						
							No. Stori	ies			Y	'ear Bui	ilt	
											DЦ			
										PHOTOGRA	РП			
Scale:		•••••		<b>.</b>										
0	CCUPA	NCY	SC				Т	YPE		F	ALLING H	1AZAR	DS	
Assembly Govt	Office			er of Per	rsons	A B		D	EF			<u>л ш п</u>	7	
Commercial Historic	Reside	ential	0 – 10	11 -	- 100	Hard Av	g. Dense		Soft Poor	Unreinforced	Parapets	Clad	ding	Other:
Emer. Services Industrial	Schoo		101-100	0 100	)0+	Rock Ro	ck Soil	Soil	Soil Soil	Chimneys	-	-		
			BA	SIC S	CORE,	MODIFIER			SCUDE S					
BUILDING TYPE	W1	W2	04	00					300KL, 3					
		¥¥2	S1 (MRF)	<b>S2</b> (BR)	S3 (LM)	<b>S4</b> (RC SW)	S5 (URM INF)	C1 (MRF)	C2	C3 PC1 RM INF) (TU)	PC2	<b>RM1</b> (FD)	<b>RM2</b> (RD)	URM
Basic Score	4.4	3.8				S4	S5	C1	C2		PC2 2.4			URM 1.8
Basic Score Mid Rise (4 to 7 stories)			(MRF)	(BR)	(LM)	<b>S4</b> (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW) (U 2.8	RM INF) (TU)		(FD)	(RD)	
Mid Rise (4 to 7 stories) High Rise (> 7 stories)	<b>4.4</b> N/A N/A	<b>3.8</b> N/A N/A	(MRF) 2.8 +0.2 +0.6	(BR) <b>3.0</b> +0.4 +0.8	(LM) 3.2 N/A N/A	<b>S4</b> (RC SW) <b>2.8</b> +0.4 +0.8	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8	C1 (MRF) 2.5 +0.4 +0.6	C2 (SW) (U 2.8 +0.4 +0.8	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A	2.4	(FD) 2.8	(RD) 2.8 +0.4 +0.6	<b>1.8</b> 0.0 N/A
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity	<b>4.4</b> N/A N/A -2.5	<b>3.8</b> N/A N/A -2.0	(MRF) 2.8 +0.2 +0.6 -1.0	(BR) <b>3.0</b> +0.4 +0.8 -1.5	(LM) 3.2 N/A N/A N/A	<b>S4</b> (RC SW) <b>2.8</b> +0.4 +0.8 -1.0	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0	C1 (MRF) 2.5 +0.4 +0.6 -1.5	C2 (sw) (U 2.8 +0.4 +0.8 -1.0	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A	<b>2.4</b> +0.2 +0.4 -1.0	(FD) 2.8 +0.4 N/A -1.0	(RD) 2.8 +0.4 +0.6 -1.0	<b>1.8</b> 0.0 N/A -1.0
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity	<b>4.4</b> N/A N/A -2.5 -0.5	<b>3.8</b> N/A N/A -2.0 -0.5	(MRF) <b>2.8</b> +0.2 +0.6 -1.0 -0.5	(BR) +0.4 +0.8 -1.5 -0.5	(LM) 3.2 N/A N/A N/A -0.5	<b>S4</b> (RC SW) <b>2.8</b> +0.4 +0.8 -1.0 -0.5	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5	<b>2.4</b> +0.2 +0.4 -1.0 -0.5	(FD) 2.8 +0.4 N/A -1.0 -0.5	(RD) 2.8 +0.4 +0.6 -1.0 -0.5	<b>1.8</b> 0.0 N/A -1.0 -0.5
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code	<b>4.4</b> N/A N/A -2.5 -0.5 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0	(MRF) <b>2.8</b> +0.2 +0.6 -1.0 -0.5 -1.0	(BR) +0.4 +0.8 -1.5 -0.5 -0.8	(LM) 3.2 N/A N/A -0.5 -0.6	<b>S4</b> (RC SW) <b>2.8</b> +0.4 +0.8 -1.0 -0.5 -0.8	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8	<b>2.4</b> +0.2 +0.4 -1.0 -0.5 -0.8	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0	(RD) <b>2.8</b> +0.4 +0.6 -1.0 -0.5 -0.8	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4	(LM) 3.2 N/A N/A -0.5 -0.6 N/A	<b>S4</b> (RC SW) <b>2.8</b> +0.4 +0.8 -1.0 -0.5 -0.8 +1.6	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4	<b>2.4</b> +0.2 +0.4 -1.0 -0.5 -0.8 N/A	(FD) 2.8 +0.4 N/A -1.0 -0.5 -1.0 +2.8	(RD) <b>2.8</b> +0.4 +0.6 -1.0 -0.5 -0.8 +2.6	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark Soil Type C	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4 -0.4	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4 -0.4	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4 -0.4	(LM) 3.2 N/A N/A -0.5 -0.6 N/A -0.4	S4 (RC SW) 2.8 +0.4 +0.8 -1.0 -0.5 -0.8 +1.6 -0.4	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A -0.4	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4 -0.4	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4 -0.4	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4           -0.4         -0.4	2.4 +0.2 +0.4 -1.0 -0.5 -0.8 N/A -0.4	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0 +2.8 -0.4	(RD) <b>2.8</b> +0.4 +0.6 -1.0 -0.5 -0.8 +2.6 -0.4	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A -0.4
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark Soil Type C Soil Type D	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4 0.0 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4 -0.4 -0.8	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4 -0.4 -0.6	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4 -0.4 -0.6	(LM) 3.2 N/A N/A -0.5 -0.6 N/A -0.4 -0.6	S4 (RC SW) 2.8 +0.4 +0.8 -1.0 -0.5 -0.8 +1.6 -0.4 -0.6	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A -0.4 -0.4 -0.4	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4 -0.4 -0.6	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4 -0.4 -0.6	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4           -0.4         -0.4           -0.4         -0.6	2.4 +0.2 +0.4 -1.0 -0.5 -0.8 N/A -0.4 -0.6	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0 +2.8 -0.4 -0.6	(RD) 2.8 +0.4 +0.6 -1.0 -0.5 -0.8 +2.6 -0.4 -0.6	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A -0.4 -0.6
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark Soil Type C Soil Type D Soil Type E	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4 -0.4	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4 -0.4	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4 -0.4	(LM) 3.2 N/A N/A -0.5 -0.6 N/A -0.4	S4 (RC SW) 2.8 +0.4 +0.8 -1.0 -0.5 -0.8 +1.6 -0.4	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A -0.4	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4 -0.4	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4 -0.4 -0.6	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4           -0.4         -0.4	2.4 +0.2 +0.4 -1.0 -0.5 -0.8 N/A -0.4	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0 +2.8 -0.4	(RD) <b>2.8</b> +0.4 +0.6 -1.0 -0.5 -0.8 +2.6 -0.4	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A -0.4
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark Soil Type C Soil Type D Soil Type E <b>FINAL SCORE, S</b>	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4 0.0 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4 -0.4 -0.8	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4 -0.4 -0.6	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4 -0.4 -0.6	(LM) 3.2 N/A N/A -0.5 -0.6 N/A -0.4 -0.6	S4 (RC SW) 2.8 +0.4 +0.8 -1.0 -0.5 -0.8 +1.6 -0.4 -0.6	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A -0.4 -0.4 -0.4	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4 -0.4 -0.6	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4 -0.4 -0.6	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4           -0.4         -0.4           -0.4         -0.6	2.4 +0.2 +0.4 -1.0 -0.5 -0.8 N/A -0.4 -0.6	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0 +2.8 -0.4 -0.6	(RD) 2.8 +0.4 +0.6 -1.0 -0.5 -0.8 +2.6 -0.4 -0.6	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A -0.4 -0.6
Mid Rise (4 to 7 stories) High Rise (> 7 stories) Vertical Irregularity Plan irregularity Pre-Code Post-Benchmark Soil Type C Soil Type D Soil Type E	<b>4.4</b> N/A -2.5 -0.5 0.0 +2.4 0.0 0.0	<b>3.8</b> N/A -2.0 -0.5 -1.0 +2.4 -0.4 -0.8	(MRF) 2.8 +0.2 +0.6 -1.0 -0.5 -1.0 +1.4 -0.4 -0.6	(BR) <b>3.0</b> +0.4 +0.8 -1.5 -0.5 -0.8 +1.4 -0.4 -0.6	(LM) 3.2 N/A N/A -0.5 -0.6 N/A -0.4 -0.6	S4 (RC SW) 2.8 +0.4 +0.8 -1.0 -0.5 -0.8 +1.6 -0.4 -0.6	<b>S5</b> (URM INF) <b>2.0</b> +0.4 +0.8 -1.0 -0.5 -0.2 N/A -0.4 -0.4 -0.4	C1 (MRF) 2.5 +0.4 +0.6 -1.5 -0.5 -1.2 +1.4 -0.4 -0.6	C2 (sw) (U 2.8 +0.4 +0.8 -1.0 -0.5 -1.0 +2.4 -0.4 -0.6	RM INF)         (TU)           1.6         2.6           +0.2         N/A           +0.3         N/A           -1.0         N/A           -0.5         -0.5           -0.2         -0.8           N/A         +2.4           -0.4         -0.4           -0.4         -0.6	2.4 +0.2 +0.4 -1.0 -0.5 -0.8 N/A -0.4 -0.6	(FD) <b>2.8</b> +0.4 N/A -1.0 -0.5 -1.0 +2.8 -0.4 -0.6	(RD) 2.8 +0.4 +0.6 -1.0 -0.5 -0.8 +2.6 -0.4 -0.6 -0.6 Def Eval	<b>1.8</b> 0.0 N/A -1.0 -0.5 -0.2 N/A -0.4 -0.6

\* = 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

#### 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)

	lodel Building Types and Critical Code Adoption nd Enforcement Dates	Year Seismic Codes Initially Adopted	Benchmark Year when
<u>Struc</u>	tural Types	and Enforced*	Codes Improved
W1	Light wood frame, residential or commercial, $\leq$ 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 a	pplicable in regions of low seismicity		

#### 2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted:

3. Occupancy Loads								
Use	<u>Square Feet, Per Person</u>	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 Det	finitions							
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 <i>Handbook</i> for additional information).							
Soil Type C:	Soft rock or very dense soil; S-wa undrained shear strength > 2000		ft/s; blow count > 50; or					
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1 1000 – 2000 psf.	200 ft/s; blow count: 15 –	50; or undrained shear strength:					
Soil Type E:	Soft soil; S-wave velocity < 600 ft/ water content > 40%, and undrain							

# 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 1<sup>st</sup> edition of FEMA 154 (1984) defined P as probability of 60% or more damage but it was later improved in 2<sup>nd</sup> 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 1<sup>st</sup> 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 2<sup>nd</sup> 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.

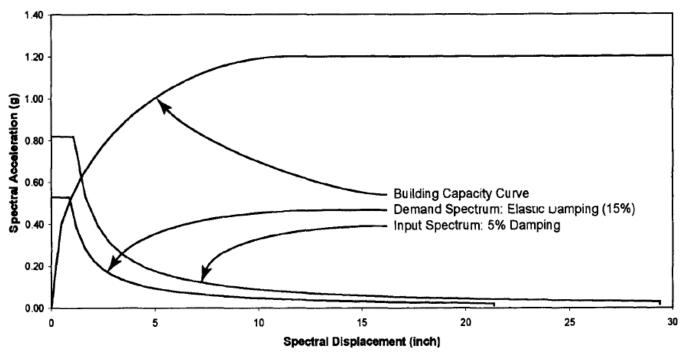
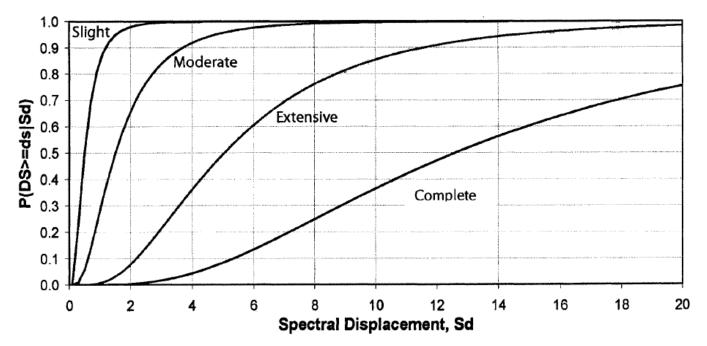


Figure 4\*[2]

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





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]

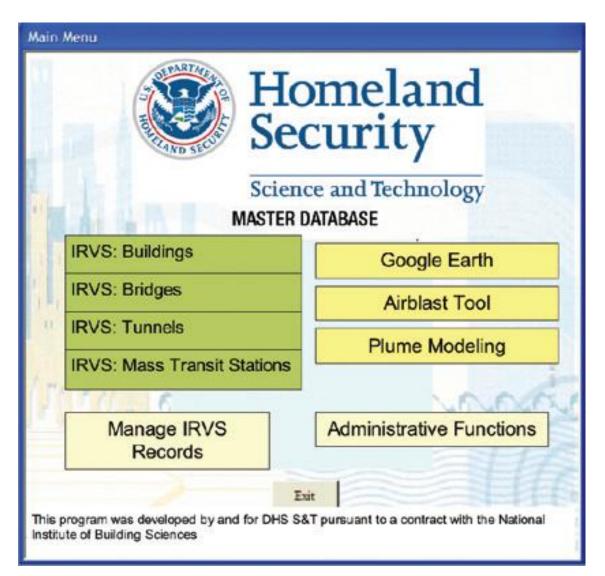


Figure 6 \*[7]: Glimpse of IRVS Database Software

#### 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). 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

# 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.* 

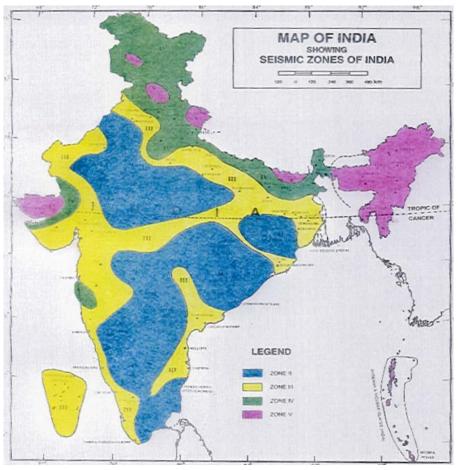


Figure 7 \*[6]: Seismic zones in India as per IS: 1893-2002

#### 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	<ul> <li>Rubble (Field stone) in mud mortar or without mortar usually with sloping wooden roof.</li> </ul>
	<ul> <li>b) Uncoursed rubble masonry without adequate 'through stones'.</li> <li>c) Masonry with round stones.</li> </ul>
В	Semi-dressed, rubble, brought to courses, <b>with</b> <i>through</i> stones and long <i>corner</i> stones; unreinforced brick walls with country type wooden roofs; unreinforced CC block walls constructed in mud mortar or weak lime mortar.
B+	<ul><li>a) Unreinforced brick masonry in mud mortar with vertical wood posts or horizontal wood elements or seismic band (IS: 13828)</li><li>b) Unreinforced brick masonry in lime mortar.</li></ul>
С	<ul> <li>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.</li> <li>b) As at B with horizontal seismic bands (IS: 13828)</li> </ul>
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 <i>confined</i> masonry using horizontal & vertical reinforcing of walls.

### Table 1\*[6] : Classification of Masonry Structures for RVS

Frame	Description
Туре	
С	a) RC Beam Post buildings without ERD or WRD, built in non-engineered way.
	<li>b) SF without bracings having hinge joints;.</li>
	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: Neglig damage)	gible to slight damage (no structural damage, slight non-structural							
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: Mode	rate 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: Subst structural dam	antial to heavy damage (moderate structural damage, heavy non- age)							
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: Destru	uction (very heavy structural damage)							
	Total or near total collapse of the building.							

\* RC = Reinforced Concrete; AC = Asbestos Cement

### 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:

M A S	Type of Building	Zone II MSK VI or less	Zone III MSK VII	Zone IV MSK VIII	Zone V MSK IX or More
O N R Y B	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)
U I D I N	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)
G S	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)

Table 5 \*[6]: Structure type and Damageability correlation for Masonry Buildings

#### NOTE:

- 1. As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.
- 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

-

. .

R	Type of	Zone II	Zone III	Zone IV	Zone V
С	Building	MSK VI or less	MSK VII	MSK VIII	MSK IX or
F					More
/	С	Few of grade 1	Few of grade 2	Many of grade 2	Many of grade 3
s	and	(rest no damage)	(rest of grade 1,0)	Few of grade 3	Few of grade 4
F	C+			(rest of grade 1)	(rest of grade 2)
/	D		Few of grade 1	Few of grade 2	Many of grade 2
В		-			Few of grade 3
U					(rest of grade 1)
I	Е				Few of grade 2
L	and	-	-	-	(rest of grade 1 or
D	E+				0)
I					
Ν	F	_	-	-	Few of grade 1
G					6

#### NOTE:

- 1. As per MSK scale, few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.
- 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. <u>Hence to deal with the damageability of important buildings in any zone, they should be</u> <u>checked for one Unit higher zone</u>. 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:

<u>i. Plan Irregularities</u>: 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.

<u>ii. Vertical Irregularities</u>: 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:

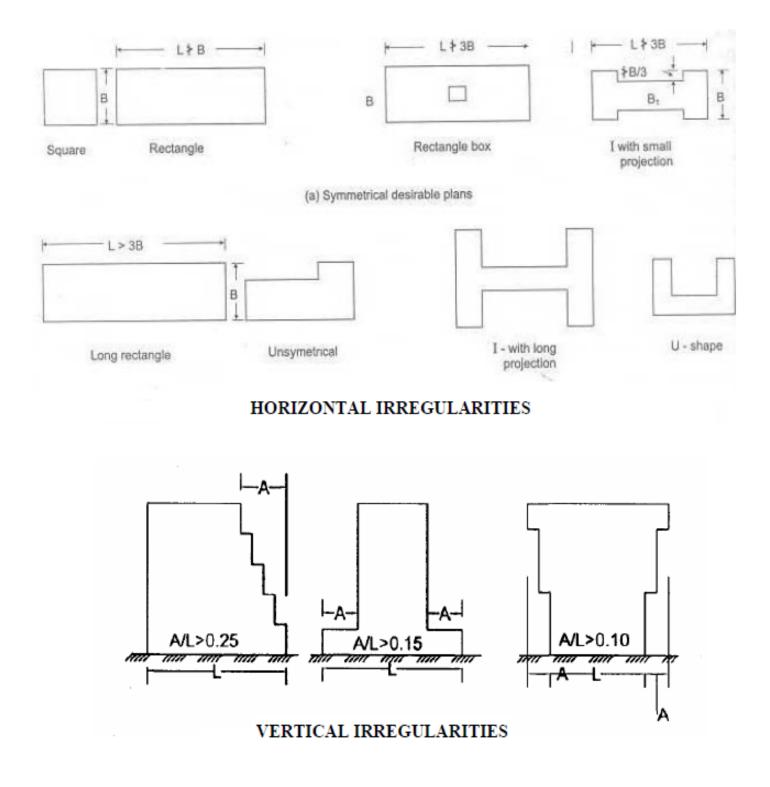
IS 1893-2002 defines three soil types hard/stiff, medium & soft. No effect of these is seen in the design spectra of short period buildings, T < 0.4 second, covering all masonry buildings, hence the effect may be considered not so significant.

#### 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)

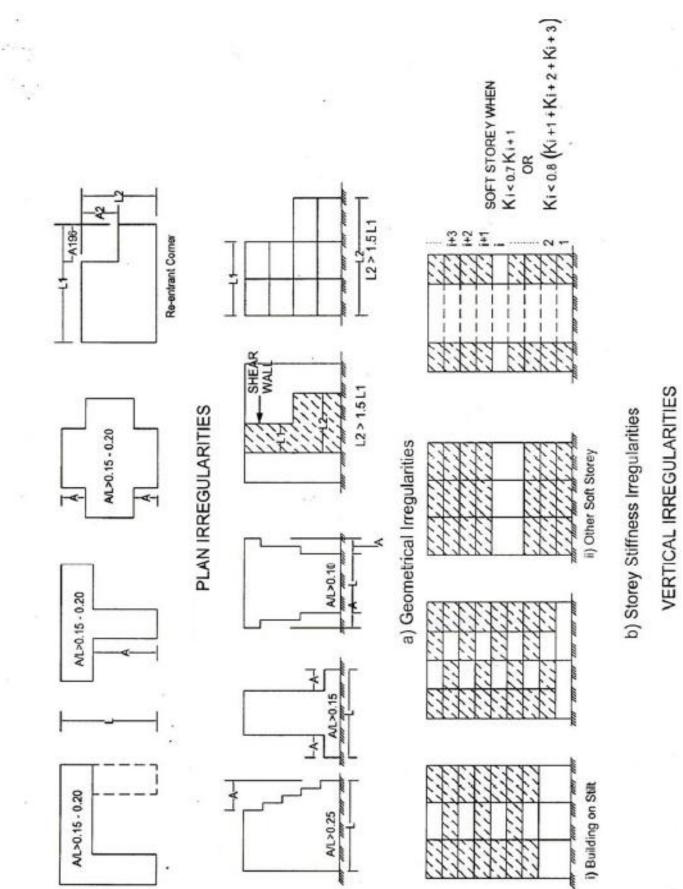


Fig 8 (Continued)

## 2.6.7 DATA COLLECTION FORMS FOR MASONRY **STRUCTURES**\*[6]:

# **1** Rapid Visual Screening of Masonry Buildings for Seismic Hazards

### 1.1 Building Name\_\_\_\_\_ 1.2 Use 1.3 Address: Pin 1.4 Other Identifiers 1.5 No. of Stories \_\_\_\_\_ 1.6 Year Built \_\_\_\_\_ Photograph 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

#### Sketch Plan with Length & Breadth

2.1 Important       buildings:         3.1 High Water Table (within 3m) & if sandy soil, Hospitals, Schools, monumental structures; emergency buildings       3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes       No       4.1 Chimneys       If any Special Hazard 3 , re-evaluate for possible retrofitting.         1 ke       telephone       exchange,       3.2 Land Slide Prome Site       Yes       No       4.2 Parapets       If any of the falling h	2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD	RECOMMENDED ACTION:-
stations, fire stations, large 3.3 Severe Vertical Irregularity Yes No 4.4 Cladding present, either remov community halls like cinemas, assembly halls and subway stations, power stations, Important Inducting extensions, Important	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	antal       3.1 High Water Table (within 3m) & if sandy soil, antal         ings       then liquefiable site indicated. Yes       No         ings       3.2 Land Slide Prone Site       Yes       No         ings       3.3 Severe Vertical Irregularity       Yes       No         ings       3.4 Severe Plan Irregularity       Yes       No         ings       3.4 Severe Plan Irregularity       Yes       No         viratt       5.0 SPECIAL OBSERVATION         of       5.1 Length of wall between two cross walls and         is:13828.       Yes       No         is:2 Percentage of openings in walls is as per IS:432         Yes       No       15.3 Ratio of height & width of wall is as per IS:433	4.1 Chimneys   4.2 Parapets   4.3 Cladding   4.4 Others   N re as per IS:4326 or 26 or IS:13828	<ul> <li>If any of the falling hazard is present, either remove it or strengthen against falling.</li> <li>Special observation if not compliant may lead to more severe damage and will call for</li> </ul>

#### 5.0 Probable Damageability in Few/Many Buildings

Building Type		5.1 M		Surveyor				
Damage- ability in	Α	B / B+		sign:				
Zone II	G2	G2 / G1	G1 / G1	-		Name:		
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.								

#### Seismic Zone II Ordinary Building

Surveyor's
sign:
Name:
-
Executive
-

# 2 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

### Seismic Zone III Ordinary Building

### (Also for Zone II Important Building)

										1.1 Building Name
	-	-	$\vdash$					$\rightarrow$		1.2 Use
	-	-	$\vdash$					$\rightarrow$		1.3 Address:
		$\vdash$	$\vdash$					$\rightarrow$		
										1.4 Other Identifiers
										1.5 No. of Stories 1.6 Year Built
	_		Pl	ioto	graj	oh				1.7 Total Covered Area; all floors (sq.m)
	<u> </u>	-	$\vdash$						_	1.8 Ground Coverage (Sq.m):
		-	$\vdash$					$\rightarrow$		1.9 Soil Type:1.10 Foundation Type:
								$\rightarrow$		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:
		<u> </u>						_		1.12.4 Mortar Type: Mud Lime Cement
	<u> </u>	<u> </u>						$\rightarrow$		1.12.5 Vert. R/F bars: Corners T-junctions Jambs
		-	$\vdash$					$\rightarrow$		1.12.6 Seismic bands: Plinth Lintel Eaves Gable
								$\rightarrow$		
										*BB – Burnt Brick, *UCR – Uncoursed Random Rubble *CCB: Cement Concrete Block

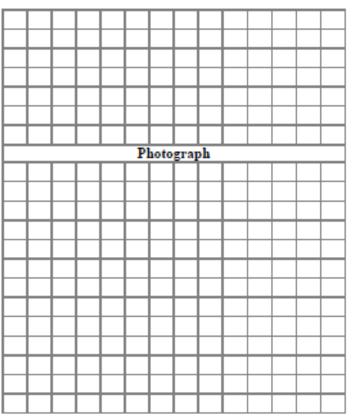
#### Sketch Plan with Length & Breadth

2.0 OCCUPA	NCY	3.0 SPE	CIAL HAZARD		LLING RD	RECOMMENDED ACTION:-
2.1 Important Hospitals, Schools, s structures; emergency like telephone television, radio statis stations, fire stati community halls like assembly halls an	monumental y buildings exchange, i ons, railway ons, large e cinemas, d subway	<ul> <li>3.1 High Water Table then liquefiable sit</li> <li>3.2 Land Slide Prone</li> <li>3.3 Severe Vertical 1</li> <li>3.4 Severe Plan Irreg</li> </ul>	e indicated. Yes Site Yes irregularity Yes	<ul> <li>Ensure adequate maintenance.</li> <li>Detailed evaluation of B type for need for retrofitting.</li> <li>Detailed evaluation of A types for need for reconstruction on possible retrofitting.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible</li> </ul>		
stations, power station Industrial establishm residences & Resi Important Emergency, *Any building har than 100 Occupan treated as Importan 2.2 Ordinary buildi buildings having occup	sents, VIP idences of person. ving more ts may be t. ngs:- Other	5.1 Length of wal IS:13828. Y 5.2 Percentage of op Y 5.4 Ratio of height	'es □ No □ enings in walls is a 'es □ No □	ERVATION ss walls are as per s per IS:4326 or IS:13 as per IS:4326 or IS:13	\$28	<ul> <li>revention/retrofitting.</li> <li>If any of the falling hazard is present, either remove it or strengthen against falling.</li> <li>Special observation if not compliant may lead to more severe damage and will call for retrofitting.</li> </ul>
5.0 Probable I Building Type	)amageabi	Surveyor's Sign :				
Damage- ability in	A	B / B+	nry Building C / C+	D		Name:
Zone III						Executive

	Zone III	64	G3 / G2	G2 / G1	GI		Executive
ł	Note: +sign indica					5	Engineer's
	stated. Also avera	Sign:					
	grade point than	Date of Survey:					
I						.	Date of Survey.

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

# 3 Rapid Visual Screening of Masonry Buildings for Seismic Hazards



#### 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 I Jambs
1.12.6 Seismic bands: Plinth 🗌 Lintel 🗆 Eaves 🔲 Gable 🗌
*BB - Burnt Brick, *UCR - Uncoursed Random Rubble *CCB: Cement Concrete Block

Seismic Zone IV Ordinary Building

(Also for Zone III Important Building)

2.0 OCCUPANCY	3.0 SPECIAL HAZARD	4.0 FALLING HAZARD	RECOMMENDED ACTION:-
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 5.0 Probable Damagea	3.1 High Water Table (within 3m) & if sandy soil, then liquefiable site indicated. Yes       No         3.2 Land Slide Prone Site       Yes       No         3.3 Severe Vertical Irregularity       Yes       No         3.4 Severe Plan Irregularity       Yes       No         5.0 SPECIAL OBSERVATION         5.1 Length       of wall between two cross walls ar         IS:13828.       Yes       No         5.2 Percentage of openings in walls is as per IS:432         Yes       No         5.5 Ratio of height & width of wall is as per IS:432         Yes       No         Stillity in Few/Many Buildings	we as per IS:4326 or 6 or IS:13828	<ul> <li>A or B: evaluate in detail for he reconstructions or possible retrot to achieve type C or D</li> <li>B+, C: evaluate in detail for need f retrofitting</li> <li>If any Special Hazard 3.0 found evaluate for poprevention/retrofitting.</li> <li>If any of the falling hazard is preither remove it or strengthen as falling.</li> <li>Special observation if not com may lead to more severe damage will call for retrofitting.</li> </ul>
			Commence 1 a

#### 5.0 Probable Damageability in Few/Many Buildings

						Surveyor's
Building Type		5.1 Mas	onry Building			Sign :
Damage- ability in	A	B / B+	C / C+	D		Name:
Zone IV						rvame.
	G5	G4 / G3	G3 / G2	G2		Executive
Note: +sign indica			mewhat lower dami ype in the area may			Engineer's
			-	be lower by on	*	Sign:
grade point than th	e probabi	le damageability in	ndicated.			
Surveyor will identi	fy the Bui	lding Type; encircle	e it, also the correspo	nding damage ;	grade.	Date of Survey:_

Special observation if not compliant may lead to more severe damage and will call for retrofitting.

A or B: evaluate in detail for need of reconstructions or possible retrofitting

B+, C: evaluate in detail for need for

If any Special Hazard 3.0 found , re-

If any of the falling hazard is present, either remove it or strengthen against

possible

# 4 Rapid Visual Screening of Masonry Buildings for Seismic Hazards

#### Seismic Zone V All Buildings

# (Also for Zone IV Important Building)

												1.1 Building Name			
												1.2 Use			
												1.3 Address:			
				$\vdash$						-		Pin			
												1.4 Other Identifiers			
												1.5 No. of Stories1.6 Year Built			
_				Pl	hoto	graj	ph					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			
				$\vdash$								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			
	$\vdash$			$\vdash$								1.12.5 Vert. R/F bars: Corners T-junctions Jambs			
				$\square$								1.12.6 Seismic bands: Plinth 🗌 Lintel 🗆 Eaves 🗔 Gable 🗌			
												*BB – Burnt Brick, *UCR – Uncoursed Random Rubble *CCB: Cement Concrete Block			
Sketch Plan with Length & Breadth							gth é	t Br	ead	th		COD. CEMERI CORCIERE DIOLA			
											4.0 FALLING RECOMMENDED ACTION:-				

#### 5.0 Probable Damageability in Few/Many Buildings

5.0110040101	Jamagea	omity in Fewis	any Dunung	3		Surveyor's						
Building Type		5.1 May	sonry Building			Sign :						
Damage- ability in	A	B / B+	C / C+	D	]	Name:						
Zone V	G5	G5 / G4	G4 / G3	G3		Executive						
stated. Also avera	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 t	the probable	e damageability in	ndicated.			Date of Survey:						
Surveyor will iden	Surveyor will identify the Building Type; encircle it, also the corresponding damage grade.											

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

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

															0000	110 200	ie 11 Orainary Building		
														1.1	Building Nam				
														1.2	Use				
														1					
															_		Pin		
							<u> </u>						_	1.4	Other Identifi	ers			
							<u> </u>			-			_	1.5	No. of Stories		1.6 Year of Const.		
					PI	hoto							-	1.7	Storey Ht: 1 <sup>st</sup>		, 2 <sup>nd</sup> , 3 <sup>nd</sup> etc.		
							gra							1			floors (sq.m)		
														1.9	Ground Cover	rage (Sq.m	):		
														1			1.11 Foundation Type:		
														1			table:		
														1.1	3 Bldg. Type:		Frame Pre-cast		
													_		2 /1		hear Wall 🗌 Flat Slab Frame		
			<u> </u>				<u> </u>	<u> </u>		<u> </u>			_	11	4 Thickness of		: Exterior Interior		
			-				-			-			_	1			ns available: Yes / No (If yes,attach)		
							-						-	1	-		lg. Yes/ No ( If.yes pl. indicate)		
														1	7 Location of				
														1			in Beam/Column/joints:		
														1	-	-	Connected Enclosed		
		Ske	tch	Plan	ı wit	th L	engt	h &	Bre	adtl	h				9 Stati Case. 5	eparateu L			
															4.0 FALLIN	G	<b></b>		
		2.	0 0	CCUI	PAN	CY			3.	.0 SI	PECL	AL H	AZAI	D	HAZARD		RECOMMENDED ACTION:-		
2.	t h	прот	tant	bui	lding	\$1	Hosp	itals,	3.1	High	Water	Table	(withir	ılm)			Ensure adequate maintenance.		
Sc	hools,	mon	umen	tal st	ructu	res; e	merg	ency					n lique	uefiable 4.1 Chimneys , re-evaluate for possible					
	ildings lio sta								5		dicated				4.4 Cillung)		retrofitting.		
lar	ge co	mmun	ity ha	alls lik	e cin	emas,	asser	nbly			res		No		4.2 Darapata		p		
	lls an portar								3.2			Prone S			4.2 Parapets				
	idence										Yes		No						
	nergen						•						regular	ity	4.3 Cladding				
	iny b									_									
1	сира		-						3.4			ı İrregi	-		4.4 Others				
	2.2 Ordinary buildings:- Other buildings Yes N aaving occupants <100										res		No						
5.	0 Pı	roba	ıble	Da	mag	geab	oility	y in	Few	/ <b>M</b>	any	Bui	lding	s					
]	Build	ing				5.1	RC	or St	eel I	ган	ie/ w	oode	n Bui	lding	s	5.2			
$\vdash$	Typ		+		1.0				P				The second		F	URM	Surveyor's sign:		
	Dama abilit	y in	$\vdash$	C	/ C-		+		D		-+	1	¢, <b>E</b> +	-+	F	Infill	Name:		
	Zone		1		/ G				-		_		• .		-	G1	Executive		
1.2.5			n indicates higher strength hence somewhat lower damage											and a stand set					

Seismic Zone II Ordinary Building

Date of Survey:\_

Occupants may	oe treatea as Impor	tani. 5.4 severe	Plan megularity	4.4 Others		
2.2 Ordinary having occupants	<i>buildings:</i> - Other bu s ≤100	uldings Y	es 🗌 No	4.4 Otters		
5.0 Probab	le Damageabil	ity in Few/Ma	ny Buildings			
Building Type	5.1 R	C or Steel Frame	e/ wooden Buildin	igs	5.2 URM	Surveyor's
Damage-	C / C+	D	E,E+	F	Infill	sign:
ability in Zone II	G1 / G1	-	-	-	G1	Name:
Note: +sign ii	ndicates higher str	ength hence some	what lower damag	ze expected as		Executive
stated. Also a	iverage damage in	one building type	in the area may b	e lower by on	8	Engineer's
grade point t	han the probable d	amageability indi	icated.			Sign:

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

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

#### 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<sup>st</sup>\_\_\_\_\_, 2<sup>nd</sup>\_\_\_\_\_, 3<sup>nd</sup>\_\_\_\_\_.etc. Photograph 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: Frame Pre-cast 1.13 Bldg. Type: 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

#### Sketch Plan with Length & Breadth

2.1 Important Schools, monumer buildings like telep radio stations, rail large community h halls and subway Important Industr residences & R Emergency person. *Any building I Occupants may building I Occupants may building I 2.2 Ordinary building occupants <	CCUPANCY buildings: Hosp ital structures; emery phone exchange, telev way stations, fire sta alls like cinemas, asse stations, power sta ial establishments, lesidences of Imp having more than a treated as Importa ildings:- Other buil 100 Damageabilit	itals, ency     3.1 High Wa       & if sandy     & if sandy       ision,     isie indica       inons,     Pes       inons,     3.2 Land Sliv       VIP     Yes       ortant     3.3 Severe V       100     Yes       nt.     3.4 Severe F       dings     Yes	le Prone Site le Prone Site le No Vertical Irregularity le No Plan Irregularity le No	1	\$	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.
Building Type			/ wooden Buildin	-	5.2 URM	Surveyor's
Damage- ability in Zone III	C / C+	D	E,E+	F	Infill	Sign : Name:
	G2 / G1	Gl	-	-	G2	
stated. Also ave grade point tha	icates higher stren rage damage in or in the probable da entify the Building	e building type ii nageability indic	n the area may be vated.	lower by one	,	Executive Engineer's Sign: Date of Survey:

# Seismic Zone III Ordinary Building

(Also for Zone II Important Building)

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

_															
														1.1	Building Name
														1.2	2 Use
															3 Address:
															Pin
														14	4 Other Identifiers
														1	
														1.5	5 No. of Stories1.6 Year of Const
┝	_				Pl	ioto	grap	oh						1.7	7 Storey Ht.: 1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>nd</sup> etc.
F							-							1.8	3 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
														1.1	13 Blog. Type: Frame Pre-cast
┝	-		$\vdash$						_				$\vdash$		Frame - Shear Wall 🗌 Flat Slab Frame 🗌
┝									_		_			1.1	14 Thickness of infill wall: Exterior Interior
F														1.1	15 Struct. Dwg/Calculations available: Yes / No (If yes,attach)
														1.1	16 Extn. to the original bldg. Yes/ No (If yes pl. indicate)
														1.1	7 Location of Shear walls (if any)
														1.1	18 Special Confining R/F in Beam/Column/joints:
														1	19 Stair case: Separated Connected Enclosed
	_	SI	cetcl	ı Pla	n w	ith I	Leng	th 8	e Br	ead	th			1.1	star case, separated Connected C Enclosed
t		 					-	-							40 FALLING
		2	0 0	CCU	PAN	CY			3.	.0 SP	ECL	AL F	LAZAR	Ð	4.0 FALLING RECOMMENDED ACTION:- HAZARD

### Seismic Zone IV Ordinary Building (Also for Zone III Important Building)

C: evaluate in detail for need for

□ If any Special Hazard 3.0 found ,

□ If any of the falling hazard is

URM infill : evaluate in detail for

present, either remove it or

for

possible

retrofitting

re-evaluate

prevention/retrofitting.

strengthen against falling.

need of retrofitting

#### 5.0 Probable Damageability in Few/Many Buildings

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

\*Any building having more than 100

2.2 Ordinary buildings:- Other buildings

Occupants may be treated as Important.

Emergency person.

having occupants <100

Building	5.1	RC or Steel Fram	e/ wooden Buildir	igs	5.2	Surveyor's
Type					URM	Sign :
Damage-	C / C+	D	E,E+	F	Infill	Name:
ability in						Ivame.
Zone IV	G3 / G2	G2	-	-	G3	Executive
Note: +sign i	ndicates higher	strength hence some	ewhat lower dama	ge expected as		Engineer's
stated. Also a	average damage	in one building typ	e in the area may	be lower by one	8	Sign:
grade point ti	han the probabl	e damageability indi	icated.			.51gii
Surveyor will	identify the Buil	rade.	Date of Survey:			

No

No 

3.1 High Water Table (within 5m)

□ Yes □ No

Yes No 3.3 Severe Vertical Irregularity

3.4 Severe Plan Irregularity

Π

3.2 Land Slide Prone Site

site indicated.

□ <sup>Yes</sup>

□ <sup>Yes</sup>

& if sandy soil, then liquefiable

4.1 Chimneys

4.2 Parapets

4.3 Cladding

 $\square$ 

4.4 Others



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

Г

### Seismic Zone V All Buildings

# (Also for Zone IV Important Building)

													1	.1 Building Nat	me			
													1	.2 Use				
	_		$\square$													Pin		
			$\vdash$									$\square$	1	.4 Other Identif	iers			
	+		$\vdash$									$\vdash$				1.6 Year of Const.		
				Ph	oto	graj						Ч		1.7 Storey Ht.: 1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>nd</sup> etc.				
					1010	21.01								1.8 Total Covered Area; all floors (sq.m)				
					_			_				$\vdash$	- I			n):		
			$\square$										- I			1.11 Foundation Type:		
																r table:		
														13 Bldg. Type		Frame Pre-cast		
	$\vdash$															Shear Wall 🗌 Flat Slab Frame 🗌		
	+													14 Thickness o		ll: Exterior Interior		
																ions available: Yes / No (If yes,attach)		
	+		$\vdash$		_			_		-		$\vdash$		-		ldg. Yes/No (If.yes pl. indicate)		
	+		$\vdash$		_			_				Н		.17 Location of	-			
	+		$\vdash$		_		$\vdash$	_				$\vdash$				in Beam/Column/joints:		
	1		$\vdash$					_				$\vdash$	- I	-	-	-		
	Sketch Plan with Length & Breadth														Connectea 🗆 Enclosea 🗆			
	<b>DP</b>	CICI	гга	п wi		лещу	cui o	c Di	cau									
	51	etti	I FIA	n wi		Jeng	çui o	C DI	cau					4.0 FALLI	NG	RECOMMENDED ACTION:-		
	2.	0 00	CUP	ANO	Y		_	3.	.0 SF	ECI		LAZA		HAZARD	NG	C: evaluate in detail for need for		
	2. Impor	0 OC	CCUP buil	ANC	<b>Y</b> 5:	Hospi	itals,	3. 3.11	.0 SE High V	PECI Water	Table	(with	n 3m	HAZARD		C: evaluate in detail for need for retrofitting to achieve type E, E+.		
School buildin	2. Imports, mor gs like	0 OC	CCUP buil tal str hone e	ANC ding nuctur	CY s: i es; e nge, t	Hospi mergy televis	itals, ency sion,	3. 3.11 8	.0 SE High V	PECI Water ndy s	Table oil, the		n 3m	HAZARD		<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/</li> </ul>		
School buildin radio large o	2. Imports, mor gs like stations, ommun	0 OK tant tumen telep , raily ity ha	CCUP built tal str hone e vay str dls like	ANC ding tuctur exchar ations e cine	CY s: e nge, f s, fire emas,	Hospi energy televis stati asser	itals, ancy sion, ions, nbly	3. 3.11 8 5	0 SH High V t if sa ite ind	PECI Water ndy se licates	Table oil, the	e (withi en liqu	n 3m	HAZARD 4.1 Chimney:	<sup>1</sup>	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> </ul>		
School buildin radio large o halls Import	2. Impor s, mor gs like stations, ommun and su ant Ir	0 OC tant tumen telep , raily ity ha bway adustri	CCUP buil tal str hone e vay sta ills like station ial es	ANC ding tuctur exchar ations e cine ns, p stablis	CY s: es; e nge, t s, fire emas, xower shimer	Hospi mergy televis stati asser stati	itals, ency sion, ons, nbly ions, VIP	3. 3.11 8 5	0 SH High V t if sa ite ind Land S	PECI Water ndy so licated (es Slide 1	Table oil, the d. Prone	e (withi en liqu No Site	n 3m	HAZARD	<sup>1</sup>	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is present, either remove it or</li> </ul>		
School buildin radio large o halls Import resider	2. Imports, mor stations, onmour and su ant In ces &	0 OC tant umen telep , raily ity ha bway adustri k R	CCUP buil tal str hone e vay sta ills like station ial es	ANC ding tuctur exchar ations e cine ns, p stablis	CY s: es; e nge, t s, fire emas, xower shimer	Hospi mergy televis stati asser stati	itals, ency sion, ons, nbly ions, VIP	3. 3.11 8 5 3.21	0 SH High V t if sa ite ind Land S	PECI Water ndy se licated Tes Slide I Yes	Table oil, the d. Prone	e (withi en liqu No Site No	n 3m efiabl	HAZARD e 4.1 Chimney: 4.2 Parapets	<sup>1</sup>	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is</li> </ul>		
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School buildir radio large o halls Import resider Emerg *Any Occup	2. Import s, mort gs like stations, onnum and su ant In ces & ency pe buildi cants m	0 OC tant tumen telep traily bway adustri k R rson. ing h ay be	CCUP build tal str hone e way stat dls like station ial es esidence arving a treate	ANC dings nuctur exchar ations e cine ns, p stablis ces mor ed as	CY s: c nge, t s, fire emas, sower shmer of re ti Imp	Hospi mergy televis stati asser stati nts, Impoi han bortan	itals, ency sion, ions, nbly ions, VIP rtant 100 u.	3. 3.11 8 3.21 3.3 3.4	0 SH High V t if sa ite ind Land Sever Sever Sever Sever	PECI Water ndy si licated licated licated licated licated Ves re Ver les re Plan	Table oil, the d. Prone tical li n Irreg	e (withi en liqu No Site No rregula No gularity	n 3m efiabl	HAZARD e 4.1 Chimney: 4.2 Parapets 4.3 Cladding		<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is present, either remove it or strengthen against fall.</li> <li>URM infill : evaluate for need of</li> </ul>		
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School buildin radio : large o halls : Import resider Emerg *Any Occup 2.2 O having 5.0 I Buil	2. Imports, mori gs like stations, onumum and suit and suit and suit buildi buildi rainar occupa Proba	0 OX tant telep , railw boway adustri k R rson. k R rson. ing h aqu bu y bu y bu	CCUP built tal str hone e way str ills like station ial es esidence aving treate ilding: 00	ANC dingu uctur exchat ations e cine ns, p stablis ces moto ed as s:- C	CY s: c es; e anas, ower shmer of re ti Imp Other	Hospi mergy televis e stati assen stati nts, Impor han build	tals, ency sion, ons, nbly ons, VIP rtant 100 ut ings 7 in	3.11 8 3.21 3.3 3.4 Few	0 SH High I to if sa Land ( Sever Sever Sever	PECI Water ndy su licater (es Slide ! Yes ve Ver (es ve Plan (es any	Table oil, the d. Prone tical li d. n Irreg	e (withi an liqu No Site No rregula No gularity No	n 3m efiabl rity gs	HAZARD 4.1 Chimney: 4.2 Parapets 4.3 Cladding 4.4 Others	5.2	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is present, either remove it or strengthen against fall.</li> <li>URM infill : evaluate for need of reconstruction or possible retrofitting to level D.</li> <li>Surveyor's</li> </ul>		
School buildin radio : large o halls : Import resider Emerg *Any Occup 2.2 O having 5.0 I Buil	2. Imports, mori gs like stations, ounnum and sui and sui and sui and sui buildi buildi rainar occupa Proba dding ype	0 OX tant telep , railw boway adustri k R rson. k R rson. ing h aqu bu y bu y bu	CCUP built tal str hone e way str ills like station ial ess essidence arving treating 00 Dan	ANC ding: uctur exchau ations e cine ns, p stablis ces moi ed as s:- C nag	CY s: c es; e nge, f s, fire emas, of re ti Imp Other eab	Hospi mergy televis e stati assen stati nts, Impor han build	tals, ency sion, ons, nbly ons, VIP rtant 100 ut ings 7 in	3.11 8 3.21 3.3 3.4 Few sel F	0 SH High I to if sa Land ( Sever Sever Sever	PECI Water ndy si licated Tes Slide I Yes te Ver Tes te Plan Tes any e/ wo	Table oil, the d. Prone tical In tical In Bui	e (withi an liqu No Site No rregula No galarity No	n 3m efiabl rity gs	HAZARD 4.1 Chimney: 4.2 Parapets 4.3 Cladding 4.4 Others	5.2 URM	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is present, either remove it or strengthen against fall.</li> <li>URM infill : evaluate for need of reconstruction or possible retrofitting to level D.</li> <li>Surveyor's Sign :</li> </ul>		
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School buildin radio : large o halls : Import resider Emerg *.4ny Occup 2.2 O having 5.0 I Buil T; Dat abil Zo Note: state	2. Imports, mori gs like stations, outnum and suit and suit and suit buildi buildi buildi rations r	0 OC tant telepiner, raily telepiner, raily telepiner, raily telepiner, raily toway to toway to to to to to to to to to to to to to t	CCUP built tal str hone e way sta ills like station ial es esidence aving treate ilding: 00 Dan C / G4 icates rage	PANC ding: wetur exchautions e cine ins, p stabilis ces motion ed as s:- 0 nag ( C+ ( C3 hig) dam	CY s: es; e es; e fire es; e fire emas, fire of re ti Imp Other eab 5.1 1 her s age ; her s	Hospi mergy televis stati assen stati its, Impoi han orian build ility RC o	tals, ency sion, oons, vIP ttant 100 ut. ings 7 in 1 or Stee D Grant gth has built built or built	3.11 8 3.21 3.3 3.4 Few sel F	0 SF High V k if sa Land : Sever Sever Sever Y Sever Y rame	PECI Water ndy so licates Tes Slide I Yes e Ver Tes e Plan Tes e Plan Tes e Plan Tes e Ver Tes e Ver Tes e Ver Tes e Ver Suide I Slide I Yes e Ver Tes e Ver e Ver e Ver e Ver tes e Ver tes e Ver e e tes e Ver e e e Ver e e e Ver e e e e e e e e e e e e e e e e e e		e (withi en liqu No Site No megula No ularity No Idin n Bui	n 3m efiabl rity gs Idin	HAZARD 4.1 Chimney: 4.2 Parapets 4.3 Cladding 4.4 Others g <sup>3</sup> F G1 re expected as	5.2 URM Infill G4	<ul> <li>C: evaluate in detail for need for retrofitting to achieve type E, E+.</li> <li>If any Special Hazard 3.0 found , re-evaluate for possible prevention/ retrofitting.</li> <li>If any of the falling hazard is present, either remove it or strengthen against fall.</li> <li>URM infill : evaluate for need of reconstruction or possible retrofitting to level D.</li> <li>Surveyor's Sign :</li></ul>		

# 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		А, В
2.	Wooden (Light wooden frame with buildings greater than 5000 sq. ft.)	W2	Wood	(partially)
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	В

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  $vs. \le 600$  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 classi	ification	IS soil classifica	tion	soil nature				
Soil type C	→	Soil type 1	→	Hard soil				
Soil type D soil	→	Soil type 2	→	Medium				
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	-	$\land$	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  $\Sigma$  (+/-DXW) to the original cut off score. Similarly for economy a lower value of D can be chosen. It must be noted while calculating  $\Sigma$  (+/-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:

S.No.	Additional Score	Degree of	Nature of	Sensitivity/Weightage	Final additional
	Modifiers	Presence or	D	Factor (W)	modifier score
		Dominance			=[(+/-D) X (W)]
		(D)			
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
FINAI	L CUT OFF MODIFY	ING VALUE (S	ummation of	f final additional modifie	r scores)
					= -1.65

Table 9: Weightage factors and Final additional Modifier cut off scores

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	MODIFIED CUT OFF SCORES AND SCORE
SCORE RANGES	RANGES
DAMAGE PROBABILITY BASED ON FINA	AL STRUCTURAL SCORE S RANGE
$S < 0.3 \rightarrow$ Grade 5 (High) Grade 4 (Very	S<-1.35 → Grade 5 (High), Grade 4 (Very High)
High)	S (1.55 ) Grade 5 (Tingh), Grade ( ( ) Gry Tingh)
$0.3 < S < 0.7 \rightarrow$ Grade 4 (High), Grade 3 (Very	-1.35 <s<-0.95 <math="">\rightarrow Grade 4 (High), Grade 3 (Very</s<-0.95>
High)	High)
$0.7 < S < 2 \rightarrow Grade 3$ (High), Grade 2 (Very	-0.95 <s<0.35 (high),="" (very<="" 2="" 3="" grade="" td="" →=""></s<0.35>
High)	High)
	(ingli)
$2 < S < 3 \rightarrow$ Grade 2 (High), Grade 1 (Very	0.35 <s<1.35 (high),="" (very<="" 1="" 2="" grade="" td="" →=""></s<1.35>
High)	High)
$S>3 \rightarrow$ Grade 1 (High)	$S>1.35 \rightarrow$ Grade 1 (High)
NEED OF FURTHER EVALUATION	
YES if $S < 2$	YES if S <0.35
	115 11 5 <0.55
(2 is the cut off score)	(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: Basic structural score 4.6 4.6 6.0 4.6 4.4 4.8 4.4 4.6 4.8 3.6 1 Low rise (<4 stories) N/A N/A N/A N/A N/A N/A N/A N/A 2 N/A N/A Mid rise (4-7 stories) N/A +0.2N/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 Plan Irregularity -0.8 -0.8 -0.8 -0.8 -0.8 -0.8 4 -0.8 -0.8 -0.8 -0.8 N/A 5 **Code Detailing** N/A +0.4+0.6 +0.4 N/A N/A N/A N/A N/A Soil type 1/C (Hard soil) N/A N/A N/A 6 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 -2.0 -2.0 -2.0 -2.0 -2.0 -2.0 -1.6 -1.4 -1.4 -1.4 liquefiable soil, land slide prone area etc ADDITIONAL SCORE MODIFIERS: (SAME FOR ALL STRUCTURE TYPES) \*med. Denotes medium ADDITIONAL DEGREE OF PRESENCE NATURE WEIGHTAGE/SENSTIVITY FINAL SCORE MODIFIER DOMINANCE (D) (+/-) FACTOR (W) $[= (+/-D) \times (W)]$ 8. Bottom soft storey presence (GOOD) 0\_\_\_\_\_5\_\_\_\_ 0.1 10 (BAD) ----500\_\_\_\_\_ 1000 (BAD) 9. Occupancy 0.001 (GOOD) 0 ----0.05 10. Condition of building (GOOD) 0 \_5\_\_\_\_10 (BAD) ----11. Age of building (GOOD) 0\_\_\_\_ 0.05 5 10 (BAD) 12. Collateral damage Vulnerability 0.025 (GOOD) 0 5 10 (BAD) 13. Falling hazards 0.025 (GOOD) 0 5 10 (BAD) 14. Ease of Evacuation (BAD) 0 10 (GOOD) 0.01 5 15. Emergency services availability 0.01 (BAD) 0 5 10 (GOOD) S= FINAL STRUCTURAL SCORE S (S=summation of all modifier values from 1 to 15) FURTHER EVALUATION EXPECTED DAMAGE (Likely building performance) S>-1.35 High probability of Grade 5 damage, very high probability of Grade 4 damage (RECOMMENDED IF S < +0.35) SE(-1.35,-0.95) High probability of Grade 4 damage, very high probability of Grade 3 damage YES NO SE(-0.95,+0.35) High probability of Grade 3 damage, very high probability of Grade 2 damage SE(+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)

(FRONT)

#### (INDIAN STANDARDS <u>SEISMIC ZONE 3</u> / FEMA (U.S.A.) <u>MODERATE SEISMICITY ZONE</u>)

BU	ILDING DETAILS:											
Bu	ilding Name:			Addr	ess:							
	code:		S Coordinate	s: (latitud	le)	(lo	ngitude)		Othe	r identifiers:		
				Approxim	ate total f	loor area	(sq. ft./	sq. m.):		Use:		
BL	ILDING TYPE->	Wood	S1(FRAME)	S2(LM)	C1(MRF)	C2(SW)	C3(INF)	URM1(BA	ND+RD)	URM2(BAND+F	D) URM3	URM4
BA	SIC SCORE MODIFIE	RS:										
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	N/A	N/A
6	Soil type 1/C (Hard so			N/A	N/A	N/A	N/A	N/A		N/A	N/A	N/A
•	Soil type 2/D(*med.	1		-0.6	-0.6	-0.8				-0.8	-0.4	-0.4
	Soil type 3/E (soft so			-1.0	-1.0			-		-1.2	-0.8	-0.8
7	Special hazards like	-1.2	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6		-1.6	-1.6	-1.6
	liquefiable soil, land											
	slide prone area etc											
		of Stories:										
A	DDITIONAL SCORE N	IODIFIE	RS: (SAME F	OR ALL ST	RUCTURE T	YPES)		*med	d. Denotes	3		
AI	DDITIONAL SCORE N		ERS: (SAME F	OR ALL ST	RUCTURE T	YPES)		*mec	d. Denotes	; 		
AI	DDITIONAL SCORE M	IODIFIE	RS: (SAME F	OR ALL ST	RUCTURE T	TYPES)	↓	*mec	d. Denotes	; •	↓   ↓	<b>↓</b>
		10DIFIE	RS: (SAME F	¥	¥	¥	↓ ↓	•		+	↓ ↓ ↓	<b>•</b>
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AD M0 8. 9. 10 11	DITIONAL DDIFIER Bottom soft storey pr Occupancy Condition of building Age of building Collateral damage Vi	esence	(GOOI (GOO (GOOI (GOOI (GOOI	DEGREE ( DOMINA D) 0 D) 0 D) 0 D) 0 D) 0 D) 0	DF PRESEN NCE (D) 5 5 5 5	ICE 10 (E 1000 ( 10 (B 10 (B 10 (E	BAD) (BAD) BAD) BAD) BAD)	NATURE (+/-)	WEIGHTA FACTOR ( 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	GE/SENSTIVITY (W) 1 .001 .05 0.05 0.05 0.025		
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#### MODIFIED DATA COLLECTION FORM FOR RAPID VISUAL SCREENING OF BUILDINGS

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

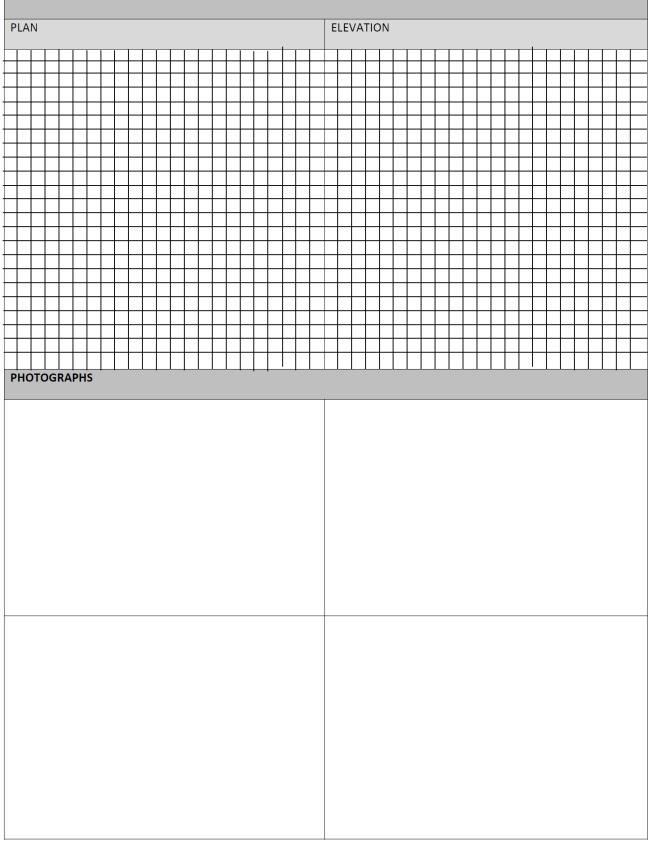
(INDIAN STANDARDS SEISMIC ZONE 4 AND 5 / FEMA (U.S.A.) HIGH SEISMICITY ZONE)

(FRONT)

BU	ILDING DETAILS:											
Bu	ilding Name:			Addr	ess:							
Pir	code:	GPS	S Coordinate	s: (latitud	le)	(lo	ngitude)		Othe	er identifiers:		
Yea	ar Built: No of S	Stories:	/	Approxim	nate total f	loor area	(sq. ft./	sq. m.):		Use:		
Co	nstruction drawings av	ailable(`	Yes/No):	S	urveyor's	name:			Surv	ey date:		
Ad	ditional Comments:											
BL	ILDING TYPE->	Wood	S1(FRAMF)	\$2(LM)	C1(MRE)	C2(SW)	C3(INF)	URM1(	BAND+RD)	URM2(BAND+F		URM4
		moou	51(110 (1112)	52(211)	01(1111)	02(011)			5, 110 - 110 -			
BA	SIC SCORE MODIFIE	RS:										
1	Basic structural score		2.8	3.2	2.5	2.8	2.6	2.		2.8	1.8	1.4
2	Low rise (<4 stories)	N/A	N/A	N/A	N/A	N/A	N/A	N/		N/A	N/A	N/A
·	Mid rise (4-7 stories)		+0.2	N/A	+0.4	+0.4	+0.2	+0.		+0.4	-0.2	-0.4
•	High rise (>7 stories)		+0.6	N/A	+0.6	+0.8	+0.3		/A	N/A	N/A	N/A
3	Vertical Irregularity	-2.0	-1.0	N/A	-1.5	-1.0	-1.0		.0	-1.0	-1.0	-1.0
4 5	Plan Irregularity Code Detailing	-0.5 N/A	-0.5 +0.4	-0.5 N/A	-0.5 +0.2	-0.5 +1.4	-0.5 +0.2		).5 /A	-0.5 N/A	-0.5 N/A	-0.5 N/A
6	Soil type 1/C (Hard so			N/A	+0.2 N/A	+1.4 N/A	+0.2 N/A		/A /A	N/A N/A	N/A N/A	N/A
	Soil type 2/D(*med.			-0.4	-0.4	-0.4	-0.4		).4	-0.4	-0.4	-0.4
•	Soil type 3/E (soft soi	1		-0.6	-0.6	-0.6	-0.4		).6	-0.6	-0.6	-0.6
7	Special hazards like	-0.8	-1.2	-1.0	-1.2	-0.8	-0.8		).6	-0.6	-0.8	-0.8
Ĺ	liquefiable soil, land	0.0		1.0		0.0	0.0			0.0	0.0	0.0
	slide prone area etc											
A	DDITIONAL SCORE M	ODIFIE	RS: (SAME F	OR ALL ST	RUCTURF T	YPES)		*	med. Denot	es medium		ł
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	DITIONAL			DEGREE	OF PRESEN	ICE		NATURE		AGE/SENSTIVITY	FINAL SC	
	DIFIER			DOMINA				(+/-)	FACTOR	-	[= (+/-D)	
	Bottom soft storey pro	esence			• • •	10 (BAD)				.1	1-(., 0)	~ (•• /]
	Occupancy				500					.001		
	Condition of building	z			5					0.05		
	Age of building				5					0.05		
	Collateral damage Vu	ulnerabi			5					0.025		
13	Falling hazards				5				0	0.025		
14	Ease of Evacuation				5			+	(	0.01		
15	Emergency services a	availabil	lity (BAI	0 (0	5	10 (0	GOOD)	+		0.01		
FI	AL STRUCTURAL SC	ORE S (	(S=summation	of all mod	difier values	from 1 to	15)			S=		l l
EX	PECTED DAMAGE (Li	kely bui	ilding perforr	mance)					FUR	THER EVALUATION	DN	
<b>C</b> ~	1.35 High pro	hahilite	of Grade E	20020	any high -	robabilite	of	0 1 dam-			S < 10.3E)	
	(-1.35,-0.95) High prot		of <b>Grade 5</b> d	-						COMMENDED IF	3 < +0.35)	
30	(-0.95,+0.35) High prot (-0.95,+0.35) High prot			-		-			-	YES	NO	
SE		Jubility (		annage, vi	ery mgn pi	Socomery	Janadi		<b>ь~</b>			
				amage, v			of Grad	e 1 dama	age			
SE	<b>(+0.35,+1.35)</b> High prol	bability					of <b>Grad</b>	<b>e 1</b> dama	age			

(ВАСК)

#### SKETHCHES OF LAYOUT (PLAN AND ELEVATION)



# 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 (2<sup>nd</sup> 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.

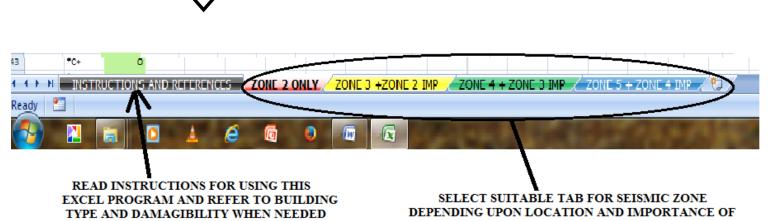
To begin with the screener has to carefully read the instructions and select suitable seismic zone from the bottom tabs. He has to then enter data in the green boxes. Care should be taken to enter this data. Data which has to be entered for buildings details can be of alphanumeric in nature and is for 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.

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USE: ADDRESS:														USE : ADDRESS :														
OTHER IDENTIFIERS:														ADDRESS : OTHER IDE	melene .													
NO OF STOREYS:														NO OF STOP														
YEAR BUILT:														YEAR BUILT														
TOTAL COVERED AREA ,ALL FLOORS( sqm):														TOTAL COV		A, ALL FLOO	DRS (sqm) :											
GROUND COVERAGE(sqm):														GROUND C		(sqm):												
SOIL TYPE:														SOIL TYPE:														
FOUNDATION TYPE:														FOUNDATIO														
ROOF TYPE:														DEPTH OF C														
FLOOR TYPE: WALL TYPE (BB, EARTHEN, UCR, CCB):														BUILDING T FRAME TYP					-1.									
THICKNESS OF WALL :														THICKNESS														
SLAB THICKNESS :														THICKNESS														
MORTAR TYPE (MUD, LIME, CEMENT) :														STRUCTUR/					E (YES/NO)									
VERTICAL R/F BARS (CORNERS, T-JUNCTION	6, JAMBS) :													EXTENSION	TO ORIG	INAL BUILD	ING (YES/N	0):										
SEISMIC BANDS (PLINTH, LINTEL, EAVES, GA	BLE):													LOCATION														
OCCUPANCY:														SPECIAL CO														
														STAIRCASE OCCUPANO		ED, CONNE	CTED, ENCI	LOSED ):										
														OCCUPANC	0.5													
STRUCTURE TYPE PRESENCE/ABSENC									SPECIAL	HAZARD	PRESEN	CE/ABSEN	CE		F	ALLING H	AZARDS	PRESEN	CE/ABSEN	CE								
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#### Figure 9: Screenshots of MS Excel Program for RVS



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

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	Page Layout	1		•		CLASSIFICATION OF DAMAGE TO MASONRY BUILDINGS	G1. Grade 1: Negligible to slight damage (no structural damage, slight non-structura) damage)	Structural: Hair-line cracks in very few walls. Non-structural: Foll of small aleces 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: Crocks in many walls, thin crocks in RC+ slabs and A.C + sheets. Non-structural: Eall of Britiu James closes of slatter - partial collance of smoke chimaeus on	riori successus, en ej janij orge prezes oj proster, por concestor of success roofs. Damage to parapeta Chajjas Koto files di Aturbed in about 10% of the sasa Mont damas in under structura of choice roofs		63 Grade 3: Substantial to heavy damage (moderate structural damage, heavy nonstructural damage)	uameser Structural: Large and extensive cracks in most walls. Wide spread cracking of columns and store	unspiret. Non-structural: Roof tiles detach. Chimneys fracture at the roof line; failure of individual nonstructural Admonstructural:	elements (particions, gable walls).	64 Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage.	aamage) Structurai: Serious foilure of walls (gaps in walls), inner wolls collapse; portial structural failure of roofs and floors.	65 Grade 5: Destruction (very heavy structural damage)		ABBRE	RCC - Reinforced Cement Concrete	RCF - Reinforced Concrete Buildings SF - Steel Frames	istent	UCR- Uncoursed Random Rubble CCB- Cement Concrete Block	INSTRUCTIONS AND REFERENCES ZONE 2 ONEV ZONE 3 +ZONE 2 IMP		
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Figure 10 (Continued)

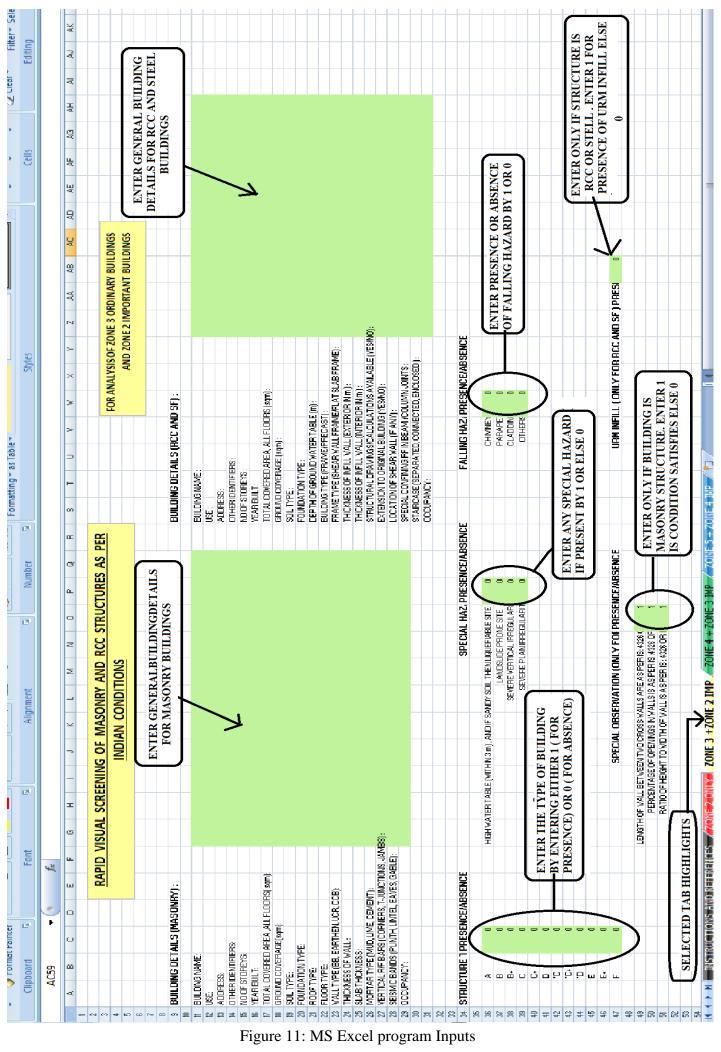


Figure 11: MS Excel program Inputs

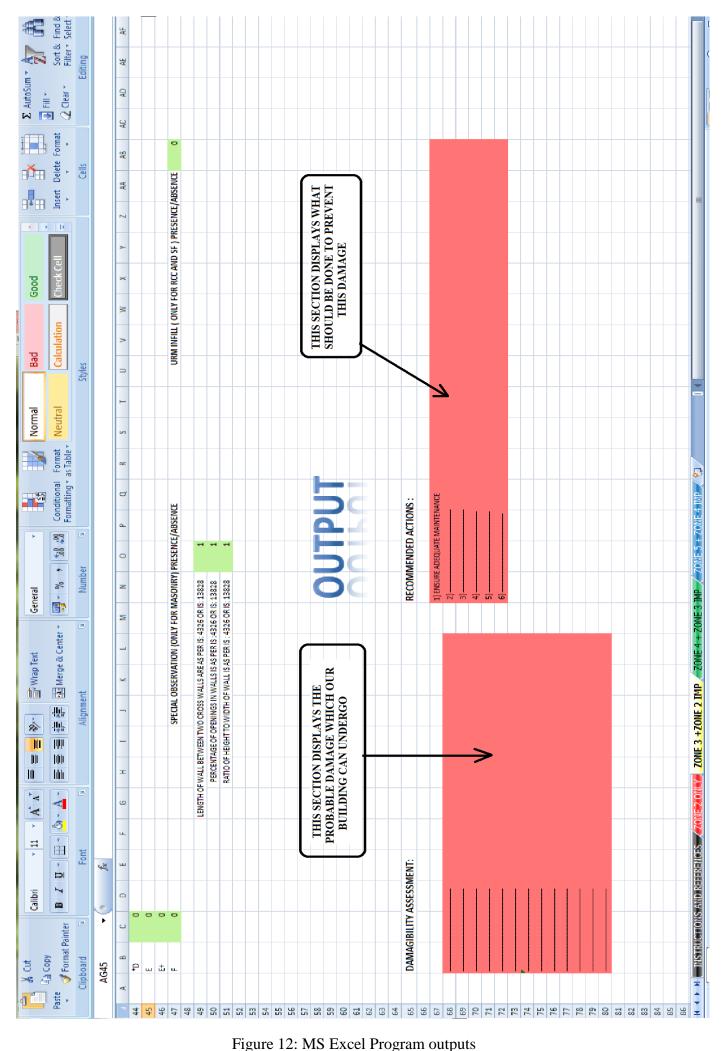


Figure 12: MS Excel Program outputs

# 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.

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

A	В	С	D	E	F	G	Н	1	J	K	L	М	N	0	Р	Q	R	S	T	U	V	W	Х
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2 3	-								STRU	CTURE T	VPES											n n	
1									51110	crone r	11 25												
5	Туре		Descripti	ion			F	eatures and	l performa	nce													
5																							
7	Wood		Light wo	oden frar	ne building	IS	W	looden Buil	dings of an	y type													
3	S1 (FRAME)		Moment	tRocistan	t Steel fran	no		Typical stee	Imoment	rocistingfi	rame stru	turocusua	ly have sim	ilar hay wir	Iths in both	the trans	orso and l	ongitudina	directions	around 20	1-30 ft		
	STURNE		Women	encolocum	toteen an	inc.		The floor di															
)							•	The 1994 N	orthridge a	nd 1995 Ko	be earth	uakes sho	wed that th	e welds in s	teelmome	nt- frame	buildings v	vere vulne	rable to sev	ere damag	ge. The dam	nage	
								took the fo	orm of brol	(en connec	tions betw	veen the b	eams and c	olumns									
_	(111)		Light Mart	talStaalst	tructure			The structu	rol cueto	ucually car	winte of m	omont from	ac in the t		iraction	d brace of f	omocir 4	o longitud	in al dira eti-	n with se	rugata d - b	ant	
	S2(LM)		Light Met	laisteers	tructure			metal siding									amesin u	ie iongitud	inai directio	on, with coi	rugated sr	leet	
								The interio									can be see	en easily.					
							•	Insufficient	capacity o	f tension b	races can	lead to the	r elongatio	n and cons	equent bui	ding dama			es.				
								Inadequate			foundatio	n can allow	the buildin	g columns	to slide on	the slab.							
							•	Loss of the	cladding c	an occur													
	C1(MRF)		Concrete	Moment	Resistant F	rame		All exposed	concrete	rames are	reinforce	d concrete i	not steel f	amesenca	sed in conc	ete).							
	()							A fundame									elofductil	e detailing.					
-								Large spaci															
								Lack of con								rsal.							
								The relative Column da							al damage.								
								column ua	nage uue i	o poundin	gwithauj	scent build	ings can ou	ur.									
	C2(SW)		Concrete S	Shear Wa	ll buildings			Concrete s	hear-wall b	uildings ar	e usually c	ast in place	, and show	typical sign	ns of cast-ir	place con	rete.						
								Shear-wall															
								These build															
								They are he Damage co								unding on	d irrogular	configurat	tion				
								Damage CO	initionity of	serveulin	aner bullu	ings is caus	eaby vert	cardiscont	nuices, po	maing, an	unregular	comgulat	LION				
	C3(INF)		Concrete f	frame wit	h burnt bri	ck masonry	•	Concrete co	olumns and	l beams ma	ay be full v	all thickne	ss and may	be expose	d for viewi	ng on the s	ides and re	ear of the b	ouilding.				
			Infill walls	5				Usually ma				r with narro	w piers (le	s than 4 ft	wide) betv	veen wind	ows.						
	INSTRUCTIONS A	ND REE	ERENCES	IS SEIS	NC ZONE 2		MIC ZONE	Portions of	solid walls	will align v	ertically.	_		141					-				
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# Figure 14: MS excel program Reference section for new developed RVS System

-	B C D E F G H I J K URM4 Unreinforced (URM) Burnt Brick or Stone (Features and behaviour is same as Masonry (Lime mortar)		PQRSIUVWX
	CLASSIFICATION OF DAMAGE TO MASONRY/WOOODEN BUILDINGS		CLASSIFICATION OF DAMAGE TO R.C.C./STEEL BUILDINGS
	G1 Grade 1: Negligible to slight damage (no structural damage, slight non-structural		*G1 Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)
	damage)		Fine cracks in plaster overframe members or in walls at the base.
	Structural: Hair-line cracks in very few walls.		Fine cracks in partitions & infills.
	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)
			Cracks in columns & beams of frames & in structural walls.
	G2 Grade 2: Moderate damage (Slight structural damage, moderate non-structural damage)		Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall panels.
	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		*G3 Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)
	area. Minor damage in under structure of sloping roofs.		Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete
	area. Winter damage in dirder structure of stopping roots.		cover, buckling of reinforced rods. Large cracks in partition & infill walls, failure of individual infill panels.
	G3 Grade 3: Substantial to heavy damage (moderate structural damage, heavy nonstructural		Large cracks in partition & innii wais, failure of individual innii partes.
	damage)		*G4 Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)
	Structural: Large and extensive cracks in most walls. Wide spread cracking of columns		Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond failure of
	and piers.		beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
	Non-structural: Roof tiles detach. Chimneys fracture at the roof line; failure of individual nonstructural		
	elements (partitions, gable walls).		*G5 Grade 5: Destruction (very heavy structural damage)
			Collapse of ground floor parts (e.g. Wings) of the building.
	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.		
	STRUCTIONS AND REFERENCES, IS SEISMIC ZONE 2 / IS SEISMIC ZONE 3 / IS SEISMIC ZONE 4 AND 5	2/	
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Figure 15: Links to important documents in Excel program for new developed RVS system

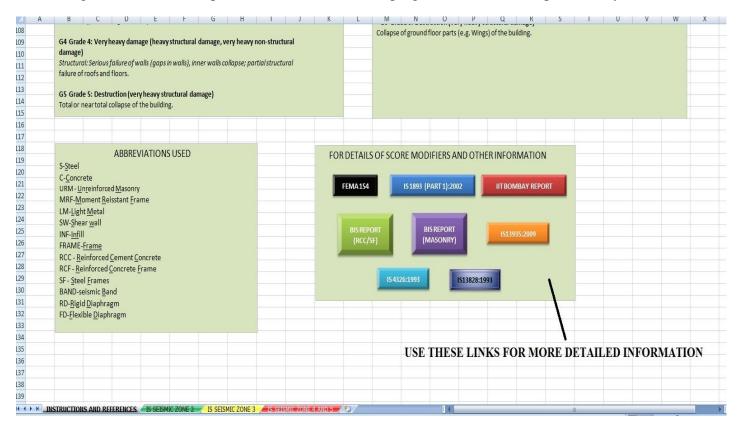
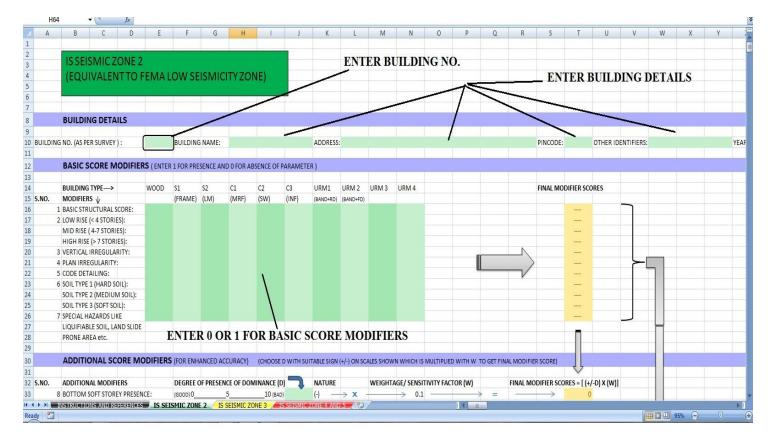


Figure 16: MS Excel program input section for new developed RVS system



	LIQUIFIABLE SOIL, LAND SLIDE												100			H		
	PRONE AREA etc.		ENTER	SUITABI	LEVA	<b>ALU</b>	E FOF	<b>ADDIT</b>	IONAL	L SCORI	E MO	DIFIER						
						1												
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					- 1													
S.NO.	ADDITIONAL MODIFIERS	DEGREE O	OF PRESENCE OF D	DOMINANCE (D)	7/	NATUR	E	WEIGHTAGE	E/ SENSITIVIT	TY FACTOR (W)		FINAL MODIF	IER SCORES = [	(+/-D) X (W)]	1.			
	8 BOTTOM SOFT STOREY PRESENCE:	(GOOD) 0	55	10 (BAD)	1	(-) -	-> x		→ 0.1 -		-> =		$\rightarrow$	0				
	9 OCCUPANCY:	(GOOD) 0	500	1000 (BAD)	1	(-) -	→ x	- 3	> 0.001 -		-> =		$\rightarrow$	0			OUT	PU
	10 CONDITION OF BUILDING:	(GOOD) 0	5	10 (BAD)		(-) -	→ x	- 3	> 0.05 -		→ =	-	$\rightarrow$	0			1	
	11 AGE OF BUILDING:	(GOOD) 0	5	10 (BAD)		(-) -	→ x		> 0.05 ─		> =	3	$\rightarrow$	0			1	
	12 COLLATERAL DAMAGE VULNERAB	ILITY: (GOOD) 0	5	10 (BAD)		(-)	$\rightarrow x$	- 3	> 0.025 —		> =		$\rightarrow$	0	/	11		
	13 FALLING HAZARDS:	(GOOD) 0	5	10 (BAD)		(-)	→ x	+ ;	→ 0.025 -		> =		$\rightarrow$	0	/	$\Lambda \Pi$		
	14 EASE OF EVACUATION:	(BAD) 0	5	10 (GOOD)		(+)	$\rightarrow x$	-	→ 0.01 -		> =	8	$\rightarrow$	2/		11		
	15 EMERGENCY SERVICES AVAILABILI	TY: (BAD) 0	5	10 (GOOD)		(+)	$\rightarrow x$	-	→ 0.01 -		> =	-	$\rightarrow //$	0	/	11		
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										FINΔI	STRUCT	LIPAL SCORE	=			AVALUET	1	
	VELLOW BOY DISPLAYS THE FINAL	STRUCTURAL SCOR	RE FOR NEW DEVE		TEM / INCI	HDING				FINAL	STRUCT	URAL SCORE	= #VALU	E!		VALUE!		
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Figure 17: MS Excel program output and result section for new developed RVS system

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49																							
50	DAMA	GABILITY	ASSESS	MENT AND	RECOMMEN	DATION	(FOR FUT	THER EV	ALUATIO	N)					ń.	tit.							
51																							
52	DAMAGI	BILITY ASSE	SSMENT AS	PER NEW DI	EVELOPED RVS S	STEM (INCL	UDING ADD	DITIONAL	AODIFIERS)			DAMAGI	BILITY ASSE	SSMENT A	S PER TRA	DITIONAL	FEMA 154 R	VS SYSTEM	A (WITHOU	T INCLUDI	NG ADDITI	DNAL MOD	IFIERS)
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55																							
56																							
57		DETAILED	FURTHER E	VATUATION	RECOMMENDED	$\square$	#VALUE!						DETAILED	FURTHER	EVALUATI	ON RECON	IMENDED	$\square$	#VALUE!				
58			(CUT OFF S	CORE TAKEN	AS 0.35)									(CUT OFF	SCORE TAK	EN AS 2)							
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60									NEXT	BUILDI	NG												
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# **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**

	Α	В	С	D	E	F	G	Н	1	J	K	L	М	Ν	0	Р	Q	R
1	BUILDING	6 NO	>		1		2		3		4			5		6		
2	PARAME	TERS																
3	BUILDING	NAME			Ramadhin I	Market	Shashvat's	home	DNK		Z Square	apartment		Arif Cham	ber 1	Sahara	group of buil	dings
4	ADDRESS				Baaboogan	j, Lucknow	Hasanganj,	Lucknow	Hasangan	, Lucknow	Daliganj, l	ucknow		Kapoortha	ala, Lko	Kapoor	thala, Iko	
5	NO OF STO	ORIES			2		3		5		3			4+1		10-12 o	n avg	
6	YEAR BUIL	Т			2001		1950 (reno	vated 2007	2010		2008			DNK		DNK		
7	USE				commerci	al	residentia	d	residentia	d	residentia	l+commer	cial	commerci	al+ office	comme	rcial+office	
			WINGS AV		no		no		no		no			no		no		
9	IMPORTAN	NCE OF BU	ILDING (BA	SED ON OCCUPANCY AND USE)	imp		not imp.		not imp.		not imp.			imp		imp		
10		BASIC SCO	DRE MODIF	IERS		NOTE- 0 A	ND 1 INDIO	ATE ABSE	NCE AND P	RESENCE C	OF THE PAR	AMETER RE	SPECTIVE	LY THEY DO	NOT IND	ICATE SC	ORE	
11	STRUCTUR	E TYPE (BA	SED ON FE	MA 154 )	C1(MRF)		URM4		C3(INF)		C1(MRF)			C1(MRF)		C3(INF)	+C2(SW)=tak	e C2(SW)
12	LOW RISE	( < 4 STORI	ES)		1		1		0		1			0		0		
13	MEDIUM R	RISE ( 4-7 S	TORIES)		0		0		1		0			1		0	Since several	
	HIGH RISE				0		0		0		0			0		1	structure typ	
15	VERTICAL	IRREGULA	RITY		0		0		0		0			0		0	present, we	
	PLAN IRRE				0		1		0		0			1			the one who	se
	CODE DET/				1		N/A		1		1			DNK		DNK	effect is dom	inant
			PE C (HARE		0		0		0		0			0			(shown by pl	
			PE D (MEDI		1		1		0		1			0		-	Here we sele	ct type
20	SOIL TYPE	3/ SOIL TY	PE E (SOFT	SOIL)	0		0		1		0			1		1	C2 (SW)	
21	LIQUIFIAB	LE SOIL			0		0		0		0			0		0		
22	STRUCTUR	E TYPE (BA	ASED ON IS	CLASSIFICATION)	*C+		B+		*C+		*C+			*D		E		
23		ADDITION	IAL SCORE I	MODIFIERS (FOR INCREASED AC	CURACY)				NOTE- TH	E VALUES F	PROVIDED	NDICATE D	EGREE OF	PRESENCE	OR DOMI	NANCE (	D) ON A SCAL	E OF 1-10
24	BOTTOM S	OFT STOR	EY PRESEN	CE	-2		-1		-7.5		-8			-10		-2.5		
25	OCCUPAN	CY			-150		-10		-50		-100			-1000		>-1000		
26	CONDITIO	N OF BUIL	DING		-2		-2.5		-2		-2			-6		-4		
27	AGE OF BU	JILDING			-2.5		-5		-1		-5			-6		-5		
28	COLLATER	AL DAMAG	E VULNER	ABILITY	-1		-7.5		-7.5		-6			-6		-2		
29	FALLING H	AZARDS			-5		-7.5		-2		-7.5			-7.5		-2.5		
30	EASE OF E	VACUATIO	N		2.5		2		5		6			8		7.5		
31	EMERGEN	CY SERVIC	ES AVAILAB	BILITY	5		7.5		7.5		7.5			7.5		7.5		

🔺 A B C	D	S	Т	U	V	W	Х	Y	Z	AA	AB	AC	AD	AE	AF
1 BUILDING NO>	7			8		9			10			11		12	
2 PARAMETERS															
3 BUILDING NAME	K	aramat m	narket	Ambika Ar	cade	Masi's hor	ne		Sahar	a Shopping Ce	ntre	Lekhraj Kł	najana	High court	colony
4 ADDRESS	N	lishatgan	j,Lko	IT Crossing	g, Lko	Vibhav Kha	nd, Gomtina	agar, Iko	Indira	anagar, Lko		Indiranag	ar, Lko	Kaisarbagh	, Lko
5 NO OF STORIES	2-	-3 on avg		3+1		2			5+1			6+1		3	
6 YEAR BUILT	19	985		1995		2003			DNK			1985		1960	
7 USE	co	ommerci	al	commerci	al	residentia	I		comn	nercial+office		Commerc	ial+office	Residentia	l i
8 CONSTRUCTION DRAWINGS AVAILABLE	n	0		no		no			no			no		no	
9 IMPORTANCE OF BUILDING (BASED ON C	CCUPANCY AND USE) in	mp		imp		not imp.			imp			imp		imp	
10 BASIC SCORE MODIFIERS															
11 STRUCTURE TYPE (BASED ON FEMA 154)	U	JRM3		URM3		URM3			C1(MF	RF)+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	Since several		1		0	
14 HIGH RISE ( > 7 STORIES)	0			0		0			0	structure type	esare	0		0	
15 VERTICAL IRREGULARITY	1			0		0			1	present, we		0		0	
16 PLAN IRREGULARITY	1			1		0			0	the one whos		0		0	
17 CODE DETAILING PRESENT	N	I/A		N/A		N/A			DNK	effect is domi	nant	N/A		N/A	
18 SOIL TYPE 1 / SOIL TYPE C (HARD SOIL)	0			0		0			0	(shown by pla		0		0	
19 SOIL TYPE 2/ SOIL TYPE D (MEDIUM SOIL)	1			0		1			0	Here we sele	ct type	0		1	
20 SOIL TYPE 3/ SOIL TYPE E (SOFT SOIL)	0			1		0			1	C2 (SW)		1		0	
1 LIQUIFIABLE SOIL	0			0		0			0			0		0	
22 STRUCTURE TYPE (BASED ON IS CLASSIFIC	CATION) C	:		С		С			E+			D		В	
ADDITIONAL SCORE MODIFIER	S ( FOR INCREASED ACC	URACY)													
24 BOTTOM SOFT STOREY PRESENCE	-4	4		-2.5		-1			-2			-7		-2.5	
25 OCCUPANCY	>	-1000		-150		-8			>-100	00		>-1000		-150	
26 CONDITION OF BUILDING	-8	8		-6		-9			-5			-7		-6	
27 AGE OF BUILDING	-6	6		-4		-3			-4			-6		-7.5	
28 COLLATERAL DAMAGE VULNERABILITY	-5	5		-5		-4			-2			-6		-1	
29 FALLING HAZARDS	-9	9		-9		-4			-6			-6		-5	
80 EASE OF EVACUATION	2			7.5		5			7.5			7		5	
1 EMERGENCY SERVICES AVAILABILITY	7.	.5		7.5		8			7.5			6		4	

Table 11: RVS survey observations

	А	В	С	D	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1	BUILDING	3 NO	->		13			14		15			16			17		18	
2	PARAME	TERS																	
3	BUILDING	NAME			Ravi's hom	ne		Kendriya	Bhawan	DNK			Conventio	onal Centre	e	Halwasia	market	LIC office	
4	ADDRESS				Hydel colo	ony , Aliganj,	, Lko	Aliganj,	ko	Chandral	k colony, /	Aliganj,lko	Shalimar	road, Chov	vk, Lko	Hazratgar	ij, Lko	Hazratgan	j, Lko
5	NO OF STO	ORIES			3			14		3+1			4			5		1st-5 2nd-	7+1
6	YEAR BUIL	.T			DNK			1995		2005			2003			1948		DNK	
7	USE				residentia	l .		Office (G	iov.)	commme	rcial		commerc	ial		commerc	ial +resi.	office	
8	CONSTRU	CTION DR	AWINGS AV	AILABLE	no			no		no			no			no		no	
9	IMPORTA	NCE OF BL	JILDING (BA	SED ON OCCUPANCY AND USE)	not imp.			imp		not imp.			imp			imp		imp	
10		BASIC SC	ORE MODIF	IERS													]		
11	STRUCTUR	RE TYPE (B	ASED ON FE	MA 154 )	URM 3			C1(MRF)+	C2(SW)=C2	URM 4			C1(MRF)			URM 3		URM3	
12	LOW RISE	( < 4 STOP	RIES)		1			0	1	0			0			0		0	
13	MEDIUM R	RISE ( 4-7 9	STORIES)		0			0 Since	several	1			1			1		1	
14	HIGH RISE	( > 7 STO	RIES)		0			1 struc	ture	0			0			0		0	
15	VERTICAL	IRREGULA	RITY		1			1 type	s are	1			1			1		DNK	
16	PLAN IRRE	GULARIT	(		1				ent, we	1			1			1		DNK	
17	CODE DET	AILING PF	RESENT		N/A			1	t the one	N/A			1			N/A		N/A	
18	SOIL TYPE	1/SOILT	YPE C (HARI	D SOIL)	0			0	se effect minant.	0			0			0		0	
19	SOIL TYPE	2/ SOIL T	PE D (MEDI	UM SOIL)	1			0 Here		0			0			0		0	
20	SOIL TYPE	3/ SOIL T	PE E (SOFT	SOIL)	0			1	ttype C2	1			1			1		1	
21	LIQUIFIAB	LE SOIL			0			0	ctype ez	0			0			0		0	
22	STRUCTUR	RE TYPE (B	ASED ON IS	CLASSIFICATION)	C+			F		С			E			С		C+	
23		ADDITIO	NAL SCORE	MODIFIERS (FOR INCREASED AG	CURACY)														
24	BOTTOM S	SOFT STO	REY PRESEN	CE	-1			-7.5		-2			-2			-7.5		-5	
25	OCCUPAN	ICY			-25			-900		-50			>-1000			-600		-500	
26	CONDITIO	N OF BUI	LDING		-7			-4		-3			-2			-7.5		-5	
27	AGE OF BL	JILDING			-5			-3		-2			-2.5			-8		DNK	
28	COLLATER	AL DAMA	GE VULNER	ABILITY	-1			-1		-1			-1			-5		-6	
29	FALLING H	AZARDS			-6			-7		-7			-7.5			-7.5		-5	
30	EASE OF E	VACUATIO	DN		7.5			7.5		2			7.5			2		4	
31	EMERGEN	CY SERVIC	ES AVAILAE	BILITY	5			5		5			7.5			8		7.5	

🖌 A B C	D	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI
1 BUILDING NO>		19		20		21		22			23			24	
2 PARAMETERS															
3 BUILDING NAME		Shri Ram	Tower	Bhopal ho	use	Durgama	tower	Indrap	orastha Apartm	ents	Annapurr	ia apartmer	nts	Cross Roa	d Plaza
4 ADDRESS		Hazratgan	j, Lko	Lalbagh, L	ko	Lalbagh, L	ko	IT Coll	ege crossing,L	ko	Opposite	police line	s, Lko	Badshahn	agar 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		commerc	al	commerci	ial+resi.	commerci	al+office	reside	ntial		residentia	al		commerci	al
8 CONSTRUCTION DRAWINGS A	VAILABLE	no		no		no		no			no			no	
9 IMPORTANCE OF BUILDING (B	ASED ON OCCUPANCY AND USE)	imp		imp		not imp.		imp			imp			not imp.	
10 BASIC SCORE MOD	FIERS														
11 STRUCTURE TYPE (BASED ON F	EMA 154 )	URM 3		URM3		URM3		C1(MR	F)+C2(SW)= take	C2(SW)	C1(MRF)+ 9	light 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	Since several		0			1	
14 HIGH RISE ( > 7 STORIES)		0		0		0		1	structure type:	are	1			0	
15 VERTICAL IRREGULARITY		1		1		1		0	present, we se		0			1	
16 PLAN IRREGULARITY		0		1		1			the one whose		1			0	
17 CODE DETAILING PRESENT		N/A		N/A		N/A			effect is		0			N/A	
18 SOIL TYPE 1 / SOIL TYPE C (HA		0		0		0			dominant(sho		0			0	
19 SOIL TYPE 2/ SOIL TYPE D (MEI		0		1		0		· ·	plan). Here we		0			0	
20 SOIL TYPE 3/ SOIL TYPE E (SOF	r soil)	1		0		1		1	select type C2	SW)	1			1	
21 LIQUIFIABLE SOIL		0		0		0		0			0			0	
22 STRUCTURE TYPE (BASED ON I	S CLASSIFICATION)	D		С		С		F			E			C+	
23 ADDITIONAL SCOR	MODIFIERS (FOR INCREASED A	CURACY)													
24 BOTTOM SOFT STOREY PRESE	NCE	-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 VULNE	RABILITY	-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 AVAILA	BILITY	8		6		5		8			7.5			6.5	

Table 11 (Continued)

	Α	В	С	D	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU	BV	BW	/ BX	BY
1 <b>B</b>	UILDING	NO	>		25		26				27			28				29		
2 P	ARAMET	TERS																		
3 B	JILDING N	NAME			Shalimar El	dee Plaza	West e	nd Mall and v	vave multi	plex	Fun Republ	ic mall and	multiplex	<b>River sid</b>	e mall and I	Inox multip	olex	City m	all and SRS m	ultiplex
4 A	DDRESS				Indiranaga	r ,Lko	Gomtin	agar, Lko			Gomtinag	ar, Lko		Gomtina	gar, Lko			Gomti	nagar, Luckno	w
5 N	O OF STO	ORIES			6		3+1				5+2			3+1				5+1		
6 YE	AR BUILT	Г			2010		2005				2005			2010				2013		
7 U	SE				commerci	al	comme	rcial			commerci	al		commer	cial			comm	ercial	
8 C	DNSTRUC	CTION DRA	AWINGS AV	/AILABLE	no		no				no			no				no		
9 IN	IPORTAN	ICE OF BU	ILDING (BA	ASED ON OCCUPANCY AND USE)	imp		imp				imp			imp				imp		
10		BASIC SCO	ORE MODIF	FIERS																
11 ST	RUCTUR	UCTURE TYPE (BASED ON FEMA 154 )		EMA 154 )	C1(MRF)		C1(MRF	+C2(SW)+C3(II	NF)+URM2(B	AND+FD)	C1(MRF)+	C2 (SW)+C	3(INF)	C1(MRF)	+C2(SW)=ta	akeC1(MRF	)	C1(MR	RF)+C2(SW)+C	3(INF)
12 LC	OW RISE (	<4 STOR	IES)		0		0		¥		0	/		0				0		
13 M	EDIUM RI	ISE ( 4-7 S	TORIES)		1			i <mark>nce</mark> several st			1 /			1	nce severals	tructure		1	Since several	
14 H	IGH RISE (	( > 7 STOR	RIES)		0			resent , we se			0 /			0	pes are pres			0	structure type	sare
		RREGULA			0			ffect is domina			1/				lect the one			0	present, we s	
		GULARITY			0			y plan layout). /pe C1 (MRF) k			1			0 ef	fect is domi	nant		0 t	the one whose	e
		AILING PR			1			rge and prese			<b>1</b>			1 (s	nown by pla	n layout).			effect is domir	
_			YPE C (HARI		0		0 st	ructure types	is scattered	lin .	0				ere we selec	t type <b>C1</b>			shown by pla	
_			PE D (MEDI		0			ature. The stru			0			0 <b>(</b> N	IRF)			· ·	ayout).Here v	
20 SC	OIL TYPE 3	3/ SOIL TY	PE E (SOFT	SOIL)	1			asically compri	ses of RC p	anels of	1			1				1 5	select type C3	
21 LI	QUIFIABL	LE SOIL			0		0 5	everal shapes.			0			0				0		
22 ST	RUCTUR	E TYPE (BA	ASED ON IS	CLASSIFICATION)	E		E+				E+			E+				E+		
23		ADDITION	NAL SCORE	MODIFIERS (FOR INCREASED AG	CURACY)															
24 B	OTTOM S	OFT STOR	EY PRESEN	CE	-2		-2				-2			-2				-2		
25 O	CCUPANO	СҮ			-150		-400				-600			-150				-300		
26 C	DNDITION	N OF BUIL	DING		-2.5		-2.5				-2			-2				-1		
27 A	GE OF BU	ILDING			-1		-2				-4			-2				-1		
28 C	OLLATERA	AL DAMAG	GE VULNER	ABILITY	-1		-1				-1			-2.5				-2		
29 F/	ALLING H	AZARDS			-8		-7.5				-7.5			-5				-2		
30 E/	ASE OF EV	ACUATIO	DN .		4		8				7			8				6		
31 E	MERGENC	CY SERVIC	ES AVAILA	BILITY	7		7.5				6			6				4		

	А	В	С	D	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	СК	CL	CM
1	BUILDING	3 NO	>		30		31		32		33				34			
2	PARAME	TERS																
3	BUILDING	NAME			DNK		KM Apartr	ments	DNK		Lal Bahad	ur Shastri E	Bhawan (KO	GMC)	Naveen em	ergency and	l trauma cent	tre (KGMC)
4	ADDRESS				Daliganj, L	.ko	Daliganj, l	ko	Daliganj,L	ko	Near Hath	ni park, Lko			KGMC, Lk	0		
5	NO OF ST	ORIES			4		4+1		4		4+1				4 stories u	upper stori	es beingno	w built
6	YEAR BUIL	.T			1950		2011		2005		DNK				DNK			
-	USE				residentia	d .	residentia	d	Storage +	esi.	Emergen	y Services	(Hospital)		Emergend	y services	(Hospital)	
8	CONSTRU	CTION DRA	WINGS AV	AILABLE	no		no		no		no				no			
9	IMPORTA	NCE OF BU	ILDING (BA	SED ON OCCUPANCY AND USE)	not imp.		imp		not imp.		imp				imp			
10		BASIC SCO	DRE MODIF	IERS														
11	STRUCTUR	RE TYPE (BA	SED ON FE	MA 154 )	URM4		C3(INF)		URM3		C3(INF)				C3(INF)			
12	LOW RISE	( < 4 STORI	ES)		0		0		0		0				0			
13	MEDIUM R	RISE ( 4-7 S	TORIES)		1		1		1		1				1			
14	HIGH RISE	( > 7 STOR	IES)		0		0		0		0				0			
_	VERTICAL		RITY		0		0		1		0				1			
_	PLAN IRRE				0		1		1		1				1			
	CODE DET				0		1		N/A		DNK				DNK			
			PE C (HARE		0		0		0		0				0			
			PE D (MEDI		0		0		0		0				0			
			PE E (SOFT	SOIL)	1		1		1		1				1			
21	LIQUIFIAB	SLE SOIL			0		0		0		0				0			
22	STRUCTUR	RE TYPE (BA	SED ON IS	CLASSIFICATION)	B+		*D		С		*D	1			*D	1	10	
23		ADDITION	IAL SCORE I	MODIFIERS (FOR INCREASED AC	CURACY)													
24	BOTTOM	SOFT STOR	EY PRESENC	E	-7.5		-7.5		-9		-6				-2.5			
25	OCCUPAN	ICY			-80		-150		-25		-700				-700			
26	CONDITIC	ON OF BUIL	DING		-7.5		-4		-6		-4				-4			
27	AGE OF BU	UILDING			-8		-2		-4		-5				-5			
_			SE VULNERA	ABILITY	-7.5		-2.5		-6		-3				-2			
	FALLING H				-8		-6		-7.5		-8				-3.5			
	EASE OF E				2.5		6		2.5		7.5				7.5			
31	EMERGEN	CY SERVICE	ES AVAILAB	ILITY	5		5		5		7.5				8			

Table 11(Continued)

A B C	D	C	N CO	СР	CQ	CR	CS	СТ	CU	CV	CW	СХ	СҮ	CZ
1 BUILDING NO>		35			36				37		38		39	
2 PARAMETERS														
3 BUILDING NAME		New	Dental Block (KG	GMC)	Minar ma	rriage hall a	and guest l	nouse	Kusumdee	p complex	Aarohi tra	de centre	Ahmad co	mplex
4 ADDRESS		KGMO	C, Lko		Takseen g	ganj chaura	ha, Thakur	ganj, Iko	Chowk, L	ko	Chowk, Lk	0	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		Emer	gency Services(H	Hospital)	Resident	al + Comm	ercial		Resident	ial+ Comm	. Commerc	ial	Commerci	al+Resi.
8 CONSTRUCTION DRAWINGS AV	AILABLE	no			no				no		no		no	
9 IMPORTANCE OF BUILDING (BAS	ED ON OCCUPANCY AND USE)	imp			imp				imp		imp		not imp.	
10 BASIC SCORE MODIFI	ERS													
11 STRUCTURE TYPE (BASED ON FER	MA 154)	C3(IN	F)+C2(SW)=take	C3(INF)	URM3				C3(INF)		C3(INF)		URM3	
12 LOW RISE ( < 4 STORIES)		0			0				0		0		0	
13 MEDIUM RISE ( 4-7 STORIES)		1	Since several		1				0		1		1	
14 HIGH RISE ( > 7 STORIES)		0	structure types	are	0				1		0		0	
15 VERTICAL IRREGULARITY		1	present, we sel		1				0		0		1	
16 PLAN IRREGULARITY		1	the one whose		1				1		1		DNK	
17 CODE DETAILING PRESENT		1	effect is domina	ant	N/A				0		0		DNK	
18 SOIL TYPE 1 / SOIL TYPE C (HARD		0	(shown by plan		0				0		0		0	
19 SOIL TYPE 2/ SOIL TYPE D (MEDIU	JM SOIL)	0	layout).Here we		1				0		0		0	
20 SOIL TYPE 3/ SOIL TYPE E (SOFT S	OIL)	1	select type C3 (	NF)	0				1		1		1	
21 LIQUIFIABLE SOIL		0			0				0		0		0	
22 STRUCTURE TYPE (BASED ON IS C	CLASSIFICATION)	*D			C+				E		*D		С	
23 ADDITIONAL SCORE N	ODIFIERS (FOR INCREASED AC	CURA	CY)											
24 BOTTOM SOFT STOREY PRESENCE	E	-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 VULNERA	BILITY	-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 AVAILAB	LITY	7.5			5				6		5		3	

A B	С	D	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM
1 BUILDING NO>			40					41		42				43	
2 PARAMETERS															
3 BUILDING NAME			Charbagh r	ailway stat	ion complex	with compo	nents	KSM Towe	ers	Hamid	Estate Buidin	g		Agarwal A	shram
4 ADDRESS			Charbagh,	Lko				Alambagh	, Lko	La Tou	che road, Lko			La Touche	road, Lko
5 NO OF STORIES			1 in gener	al, somwh	ere 2			3+1		2				4	
6 YEAR BUILT			1923					2010		1933				1950	
7 USE			Assembly	( infrstruc	tural use)			Commerci	al+Office	Comm	ercial+Reside	ntial		Commerc	ial+Resi.
8 CONSTRUCTION DRAW	INGS AV	AILABLE	no					no		no				no	
9 IMPORTANCE OF BUILD	ING (BAS	SED ON OCCUPANCY AND USE)	imp					not imp.		not im	р.			not imp.	
10 BASIC SCORE	E MODIFI	ERS													
11 STRUCTURE TYPE (BASE	D ON FE	MA 154)	URM 3 ( fo	r building	)_S2(LM) ( f	or platfor	n area)	URM 3		URM 3	type (but reir	nforced wi	h girders)	URM 3 (No	ot sure)
12 LOW RISE ( < 4 STORIES	)		1					0		1		$\checkmark$		0	
13 MEDIUM RISE ( 4-7 STO	RIES)		0	We perfo	*			1		0	Since the bui	lding lacks		1	
14 HIGH RISE ( > 7 STORIES	5)		0	calculatio				0		0	reinforcent (	mettalic ba	rs as	0	
15 VERTICAL IRREGULARIT	γ		1		ly for each			1		1	used in RB co		·	1	
16 PLAN IRREGULARITY			1	structure	type i.e			1		1	of masonry it			1	
17 CODE DETAILING PRESE	NT		N/A	URM 3 ar				N/A		0	3 category . b			0	
18 SOIL TYPE 1 / SOIL TYPE	C (HARD	SOIL)	0		average of			0		0	on columns a effect of stift			0	
19 SOIL TYPE 2/ SOIL TYPE	D (MEDIU	JM SOIL)	1	final stru	ctural			1		1	bands.Heno			0	
20 SOIL TYPE 3/ SOIL TYPE	E (SOFT S	GOIL)	0	scores				0		0	for URM 1 (B			1	
21 LIQUIFIABLE SOIL			0					0		0 L		,		0	
22 STRUCTURE TYPE (BASE	D ON IS C	CLASSIFICATION)	D and *D					C+		D				С	
23 ADDITIONAL	SCORE N	NODIFIERS (FOR INCREASED AC	CURACY)												
24 BOTTOM SOFT STOREY	PRESENC	E	-1					-6.5		-5				-7	
25 OCCUPANCY			>-1000					-100		-50				-40	
26 CONDITION OF BUILDIN	NG		-2					-3		-7				-5	
27 AGE OF BUILDING			-7.5					-2.5		-7.5				-6	
28 COLLATERAL DAMAGE	VULNERA	BILITY	-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	AVAILABI	ILITY	9					8		3				4	

Table 11(Continued)

	А	В	С	D	DN	DO	DP	DQ	DR	DS	DT	DU	DV	DW	DX	DY	DZ	EA	EB	EC
1	BUILDING	3 NO	->		44				45				46				47			
2	PARAMET	TERS																		
3	BUILDING	NAME			DNK				Munna Lal	Bhawan			Sheetal	Sahu Dhara	mshala		Aditya Bh	awan		
4	ADDRESS			La Touche road, Lko			Gurudwar	Gurudwara road, Naka Hindola, Lko			Naka Hindola Chauraha, Lko				Aminabad, Lko					
5	NO OF STO	ORIES			3				3				4				2			
-	YEAR BUIL	T			1930				1927				1960				1915			
_	USE				Comme	ercial+Reside	ential+Scho	ol	residentia	l			resident	ial			Commerc	ial +Reside	ential	
_			AWINGS AV		no				no				no				no			
9		1		ASED ON OCCUPANCY AND USE)	not imp	).	W.	1	not imp.			1	not imp.			1	not imp.	1		
10		BASIC SC	ORE MODI	IERS																
_			ASED ON F	EMA 154 )	URM 3	type (but rei	inforced wi	h girders)						/pe (but rei	nforced wi	h girders)	URM 3 typ	e (but reir	nforced wit	n girders)
_	LOW RISE				1		¥		1				0		¥		1	/		
_	MEDIUM R					Since the bui			0				-	nce the buil inforcent (r			0 /			
	HIGH RISE				-	reinforcent ( used in RB co			0				·	sed in RB cor			0 /			
	VERTICAL				-	of masonry it			1				1	f masonry it			1/			
	PLAN IRRE					3 category . I			1				0 3	category . b			1			
	CODE DET			D 40011)	0	on columns a	nd ceiling p	provide	0					n columns ai			0			
_			YPE C (HAR			effect of stif			0 1					ffect of stiff			0			
			YPE D (MED	,	-	bands . Henc			-				- 0	ands . Hence			1			
_			YPE E (SOFT	SUIL)	-	for URM 1 (B	AND+RD) i	sused	0					or URM 1 (B/	AND+RD) IS	used	0			
_	LIQUIFIAB				0 -				0				0				0			
		1		CLASSIFICATION)	D			1	C			1	D		1	1	D			
23		1		MODIFIERS (FOR INCREASED AG	-	<u>()</u>							_							
			REY PRESEN	CE	-5				-4				-5				-5			
_	OCCUPAN				-20				-20				-25				-100			
	CONDITIO		LDING		-7.5				-6.5				-6				-6			
_	AGE OF BU				-8				-7				-6				-7.5			
			GE VULNER	ABILITY	-4 -7				-6 -6				-3				-2.5 -7			
_	FALLING H EASE OF E				-/				-0 3				-6 4				-7			
_			UN CES AVAILAI	עדו ווס	4 5				3 5				4 5				3.5			
21	CIVIERGEIN	CT SERVIC	LES AVAILA	DILIT	J				J				J				1			

	А	В	С	D	ED	EE	EF	EG	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ
1	BUILDING	3 NO>	>		48		49				50		51					
2	PARAME	TERS																
3	BUILDING	NAME			Indira Mar	rket	Wahab	Mansion			(Neighbour	s' house)	Kamta Ap	artments				
4	ADDRESS				Aminabad	l, Lko	Amina	bad, Lko			Daliganj, l	ko	Daliganj,	Lko				
5	NO OF STO	ORIES			5+1		2				3		4					
6	YEAR BUIL	T			1985		1960				2007		2005					
-	USE				Commerci	ial+Resi.	Comm	ercial+Resi.			Residenti	al	Residenti	al				
		CTION DRA			no		no	no			no		no					
9	IMPORTA	NCE OF BUI	ILDING (BA	SED ON OCCUPANCY AND USE)	imp	1	not im	р.	1		not imp.		not imp.					
10		BASIC SCO	ORE MODIF	IERS														
11	STRUCTUR	RE TYPE (BA	SED ON FE	MA 154 )	URM3		URM 3	type (but rein	forced wil	n girders)	URM3		C1(MRF)					
12	LOW RISE	( < 4 STORI	ES)		0		1		V		1		0					
13	MEDIUM P	RISE ( 4-7 ST	TORIES)		1			Since the buil	ding lacks		0		1					
		( > 7 STORI			0			reinforcent (r			0		0					
_		IRREGULAF	RITY		1		1	used in RB cor			0		0					
		GULARITY			1			of masonry it			1		0					
		AILING PRE			N/A		0	3 category . b on columns ar			N/A		1					
		1/SOIL TY			0		0	effect of stiff			0		0					
		2/ SOIL TYP			0		1	bands.Hence			1		0					
		3/ SOIL TYP	PE E (SOFT	SOIL)	1			for URM 1 (B			0		1					
_	LIQUIFIAB				0		0 L				0		0					
22	STRUCTUR	RE TYPE (BA	SED ON IS	CLASSIFICATION)	С		D				C		*C+	10000				
23		ADDITION	AL SCORE I	MODIFIERS (FOR INCREASED AC	CURACY)													
24	BOTTOM S	SOFT STORE	EY PRESENC	CE	-6.5		-5.5				-4		-7					
25	OCCUPAN	ICY			-120		-60				-6		-70					
26	CONDITIO	N OF BUILD	DING		-8		-6				-4		-6					
27	AGE OF BL	JILDING			-6		-6.5				-6		-5					
28	COLLATER	AL DAMAG	E VULNER	ABILITY	-7		-6				-8		-7.5					
29	FALLING H	AZARDS			-7.5		-7				-6		-5					
		VACUATIO			5		2.5				2.5		2.5					
31	EMERGEN	CY SERVICE	ES AVAILAB	ILITY	4		6				2.5		2.5					

Table 11(Continued)

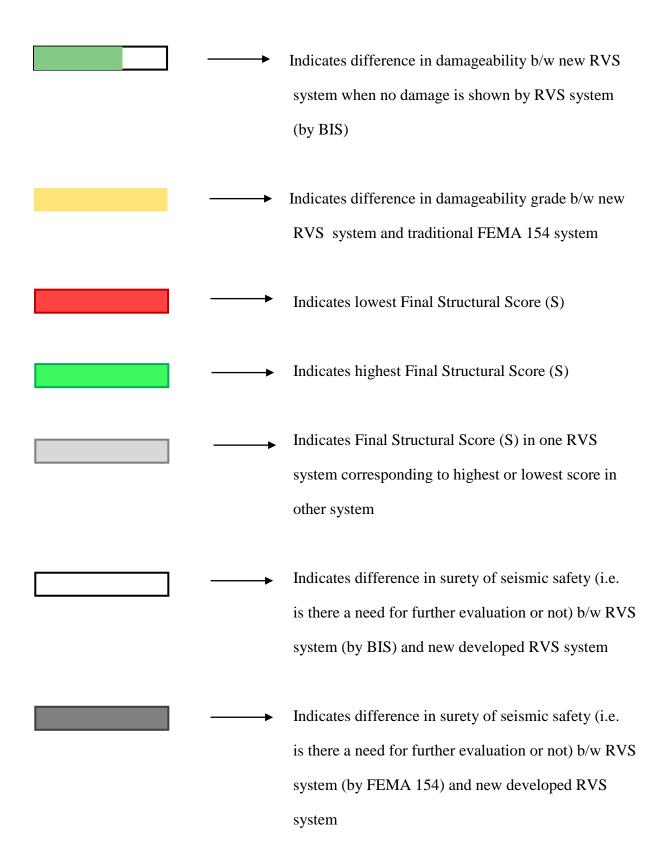
# **6. RESULTS, COMPARISONS AND CONCLUSIONS**

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

	A B	C D	E	F	G H		J	K L	М	N
BL	JILDING	DAMAGIBILITY	GRADE		STRUCTURA	AL SCORES		NEED FOR I	URTHER EVALUAT	ION
NC	<u>).</u>									
		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
	1	G2	G1	G1	N/A	2.95	3.6	YES	NO	NO
	2	G2	G1,G2	G2,G3	N/A	0.735		YES	NO	YES
	3	G1,G2 (infill areas)		G1	N/A	2.5375		NO	NO	NO
	4	G1	G1	G1	N/A	2.1475		NO	NO	NO
	5	G2	G3,G4	G2,G3	N/A	-1.0825		YES	YES	YES
	6	no damage	G1	G1	N/A	1.5375		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		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
	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			YES	YES
	31	G2 (infill areas)	G1	G1	N/A	1.7975		YES	NO	NO
	32	G2	G4,G5	G4,G5	N/A	-1.8875		YES	YES	YES
	33	G2 (infill areas)	G2,G3	G2,G3	N/A	0.025		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		YES	YES	YES
	36	G2	G4,G5	G4,G5	N/A	-1.43		YES	YES	YES
	37	G3 (infill areas)	G1,G2	G1,G2	N/A	1.1125		YES	NO	NO
	38	G2,G3 (infill areas)		G2,G3	N/A	0.5625		YES	NO	YES
_	39	G2	G3,G4	G3,G4	N/A	-1.305			YES	YES
	40	G2	G1,G2,G3,G4	G1,G2,G3,G4	N/A	[(-1.0075)+(1.0925)]/2=0.0425		YES	(YES & NO)> YES	(YES & NO)> YES
	41	G1	G2,G3	G4,G5	N/A	-0.945		YES		YES
	42	G1	G4,G5	G4,G5	N/A	-1.42				YES
	43	G2	G4,G5	G4,G5	N/A	-1.78		YES	YES	YES
	44	G1	G4,G5	G4,G5	N/A	-1.38				YES
	45	G2	G2,G3	G3,G4	N/A	-0.715				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			YES	YES
	50	G2	G1,G2	G1,G2	N/A	0.894		YES	NO	NO
	51	G1	G1	G1	N/A	1.8175		NO	NO	NO

#### Table 12: RVS survey results

The Legend used in this result table is-



# 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 2<sup>nd</sup> 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 3<sup>rd</sup> 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  $2^{nd}$  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 9<sup>th</sup> 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.

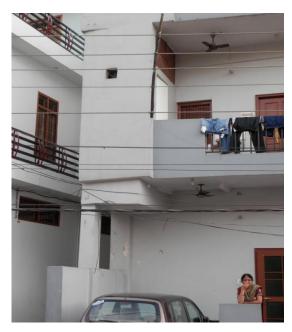
Research work could also be performed for the improvement of Basic structural score values and basic score modifier values by using some new methodology other than HAZUS fragility and capacity curves\*[2] which have till now been used to calculate these values.

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 4** 









#### **BUILDING SET NO 6**















#### **BUILDING NO 9**



#### **BUILDING NO 10**















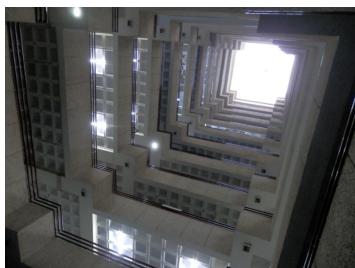


























**BUILDING NO 17** 



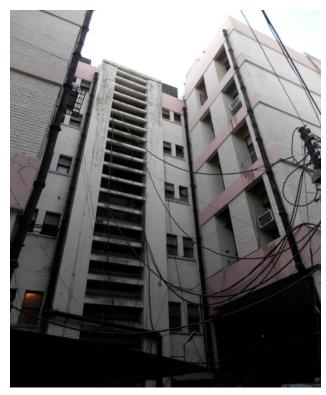




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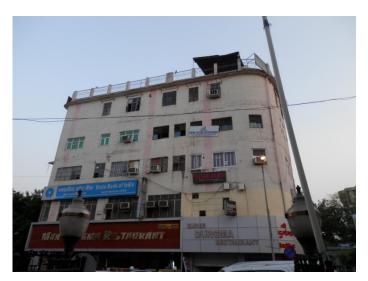


**BUILDING NO 19** 











#### **BUILDING SET NO 22**































#### **BUILDING NO 28**





107







**BUILDING NO 30** 



#### **BUILDING NO 31**





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## **BUILDING NO 33**



























**BUILDING NO 38** 











































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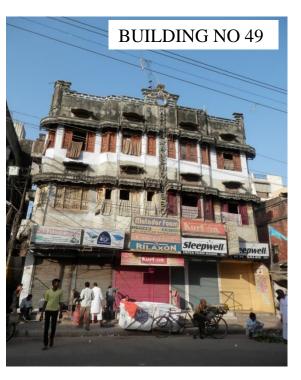










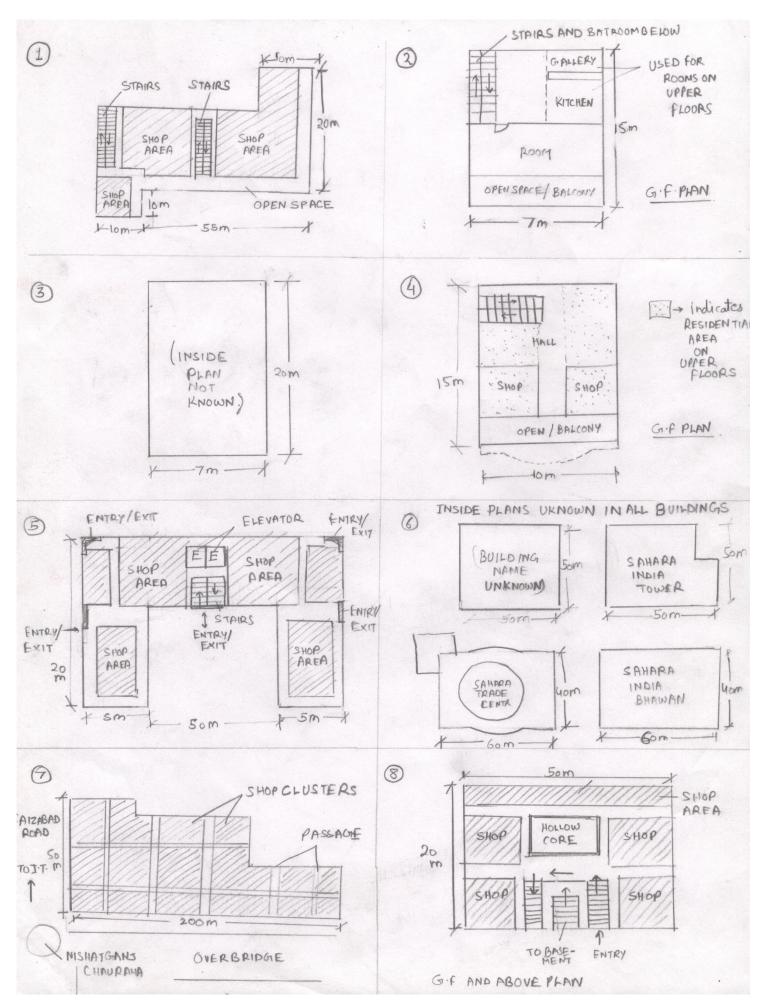


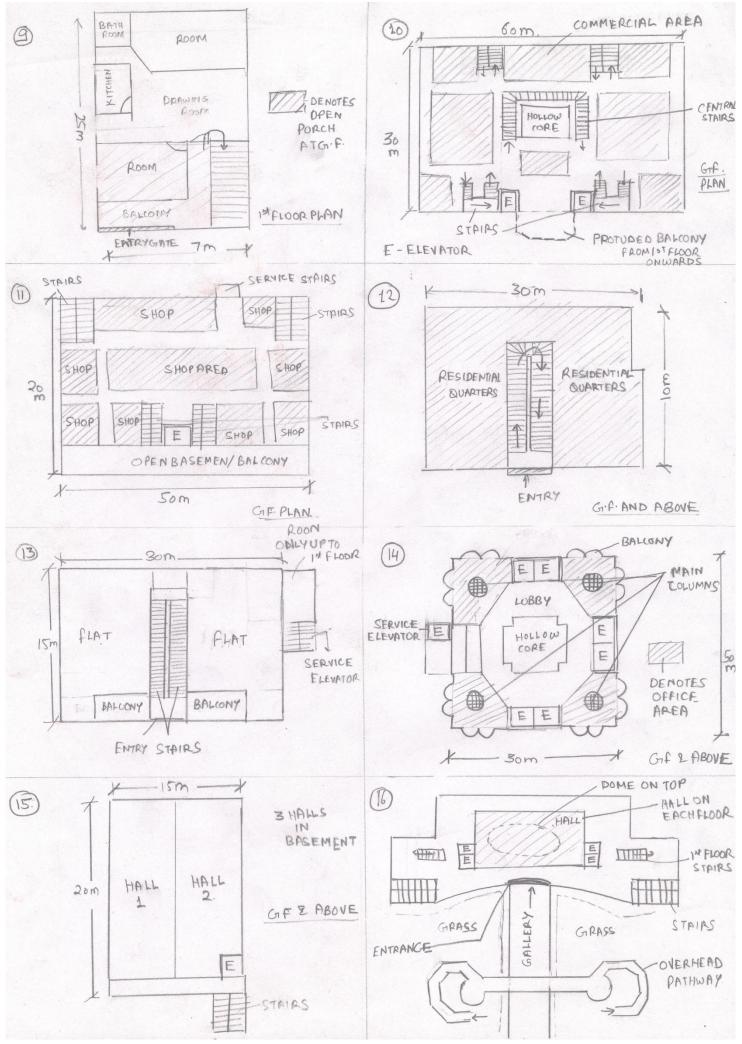


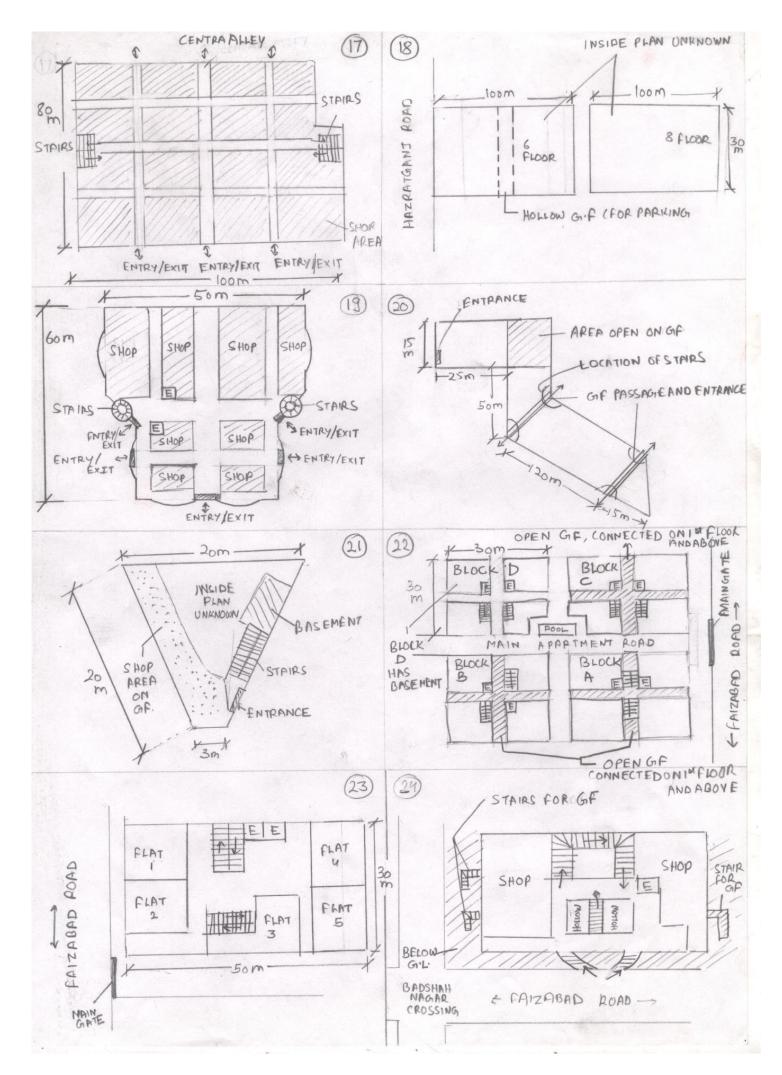


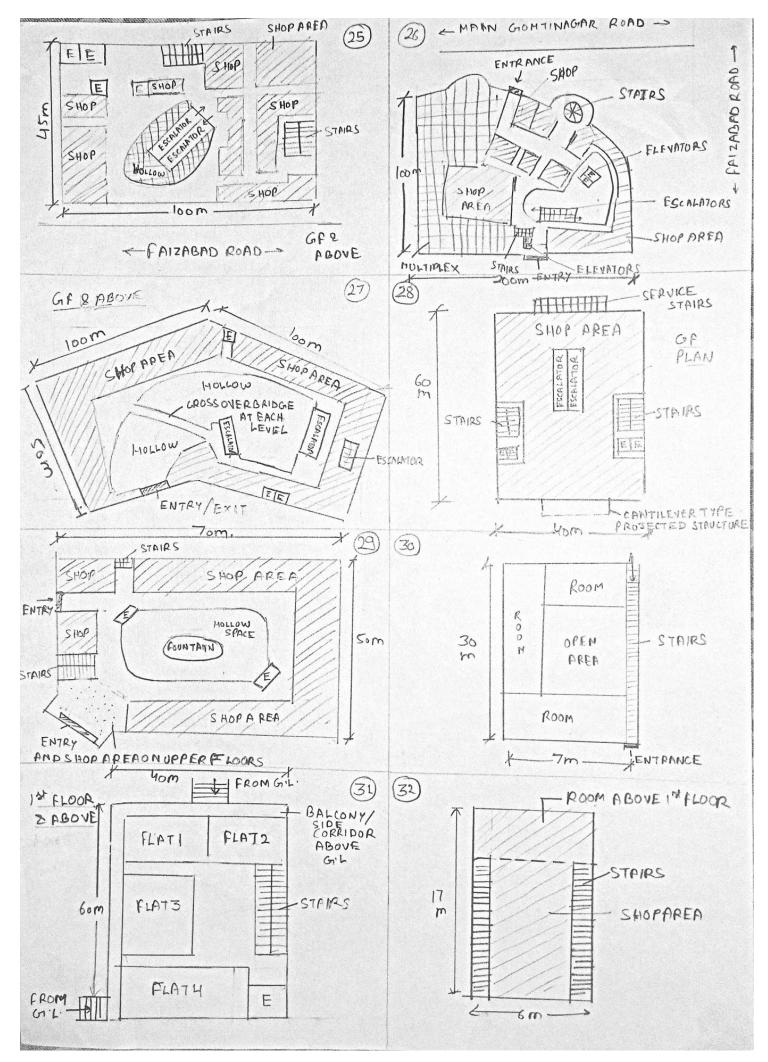


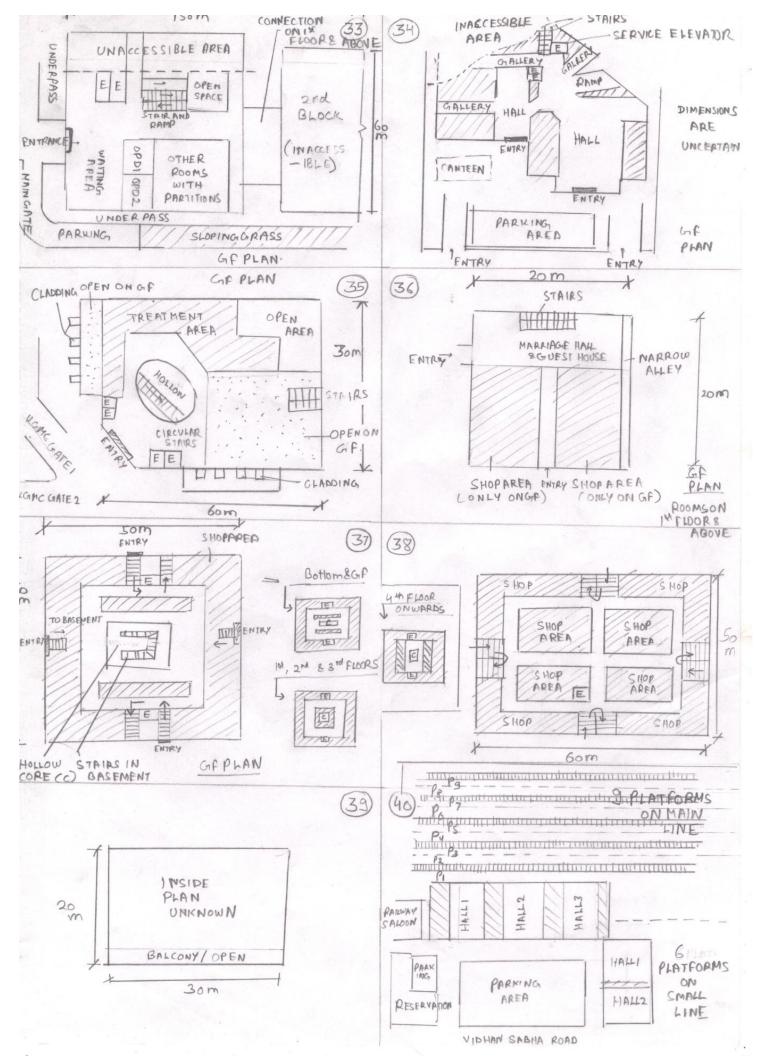
## **ANNEXURE B (LAYOUT AND PLAN SKETCHES)**

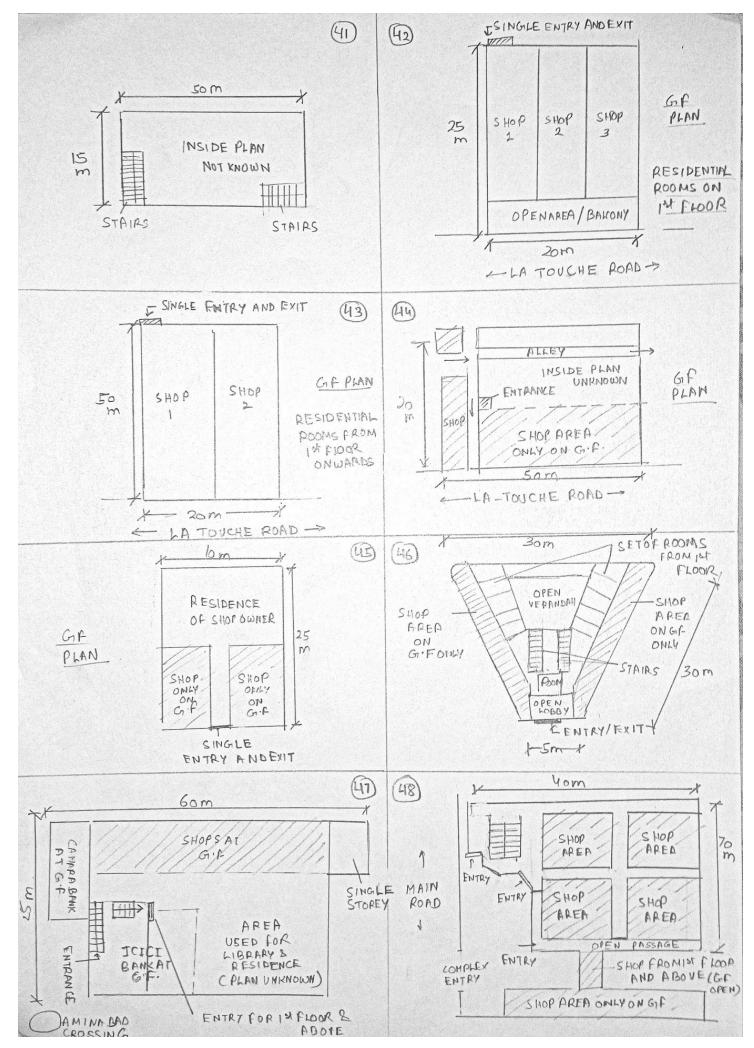


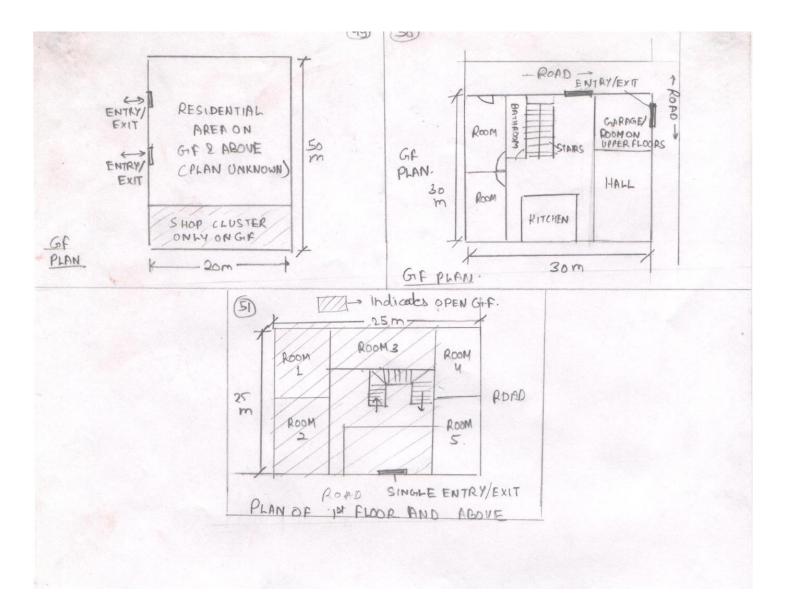












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