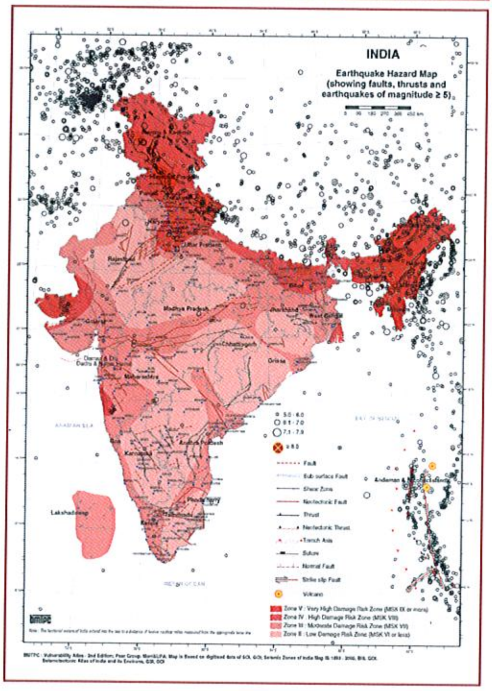
Guidelines

Rapid Visual Screening (RVS) of Buildings of Masonry and Reinforced Concrete as prevalent in India



Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
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Prepared by Dr. Anand S.Arya, Professor Emeritus, IIT Roorkee

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Building Materials & Technology Promotion Council,
Ministry of Housing & Urban Poverty Alleviation, Government of India,
Core-5A, 1st Floor, India Habitat Centre, Lodhi Road, New Delhi - 110003
Phone: +91-11-24636705, 24638096, Fax: +91-11-24642849
E-Mail: bmtpc@del2.vsnl.net.in; info@bmtpc.org
Website: www.bmtpc.org

Foreword

Four great earthquakes of magnitude 8.0 and above in different parts of the country and in recent times earthquakes of different magnitudes [Uttarakhashi (1991), Killari (1993), Jabalpur (1997), Chamoli (1999), Bhuj (2001) and Jammu & Kashmir (2005)] at regular interval have resulted in large number of deaths and huge property losses. These devastating earthquakes have exposed the vulnerability of our housing stock in earthquake prone regions of the country. A comprehensive earthquake disaster risk management is, therefore, necessary to mitigate the effects of earthquake.

Earthquake do not kill people, it is the collapse of buildings which kills people. Unfortunately both load bearing and Reinforced concrete framed structures, which collapsed during these earthquakes, have been found to be deficient from earthquake safety point of view. While newer buildings may be found vulnerable due to poor design and construction; the older buildings, designed and constructed based on provision of prevalent codes at that time may also be found deficient vis-à-vis more stringent provisions of latest earthquake resistant buildings codes.

For earthquake mitigation, it is not only necessary to build earthquake safe structures but also ensure safety of existing buildings. For this assessment of existing buildings is necessary. Detailed seismic vulnerability analysis is an expensive procedure and in case of RCC framed structures is also technically complex, which may not be necessary for all buildings. A simpler procedure, therefore, is called for which can help in rapid evaluation of the vulnerability profile of a building. The Rapid Visual Survey (RVS) is used for this purpose, so as to prioritize the buildings for more complex and expensive evaluation.

Rapid Visual Screening of Buildings for potential seismic hazards, originated in 1988 with the publication of FEMA 154 Report, Rapid Visual Screening of Buildings for Potential Seismic Hazards A Hand Book. In India, Prof. A.S. Arya, in his capacity as National Seismic Advisor developed a procedure of Rapid Visual Screening of building types prevalent in India. The procedure is also now incorporated in Indian Standard IS 13935:2009, Seismic Evaluation, Repair and strengthening of Masonry Buildings Guidelines.

As a part of our drive to propagate disaster resistant construction practises and mitigation measures, this publication written by Prof. A.S. Arya has been brought out by BMTPC. This gives the glimpse of earthquake hazard scenario with building typologies prevalent in the country and the detailed procedure of RVS developed by Prof. Arya. The publication also gives in brief, the procedure adopted in FEMA 154 report for information.

BMTPC places on record with gratitude, its deep appreciation for the untiring and inspiring efforts of Prof. A.S. Arya in the area of earthquake hazard mitigation and providing a tool to Disaster Management Authorities to develop a better Disaster Management Plan for the future in the form of these guidelines.

Dr. Shailesh Kr. Agrawal
Executive Director
BMTPC

Preface

Vulnerability can be defined as the degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given magnitude or intensity. Earthquake vulnerability is thus a function of the potential losses from earthquakes- death and injury to people, damage to various man made structures: buildings, bridges, etc. The damages and losses also depend on the mitigation and preparedness measure adopted before the occurrence of a damaging earthquake. They reflect the uncared for weakness in the built environment. Also, the ability of the community to cope with the hazard's damaging impact and to absorb the losses after an earthquake event, and also to recover from the damages. Vulnerable conditions preceding the earthquake event contribute to its disastrous impact and create an emergency situation usually continuing long after the earthquake had struck.

According to the Census of housing 2011 India has 304,882,448 housing units consisting of wall materials varying from mud/unburnt brick, wood, stone, burnt brick and concrete besides biomass materials like grass, thatch, bamboo, etc. It has been seen that older residential and commercial buildings constructed of unreinforced masonry have inadequate resistant to seismic forces. The Kutcha buildings consisting of mud/unburnt bricks are highly vulnerable to earthquake shaking and more so under wet rainy season. Even Pucca construction, if not properly designed and constructed with adequate reinforcement, will also be vulnerable to earthquake shaking. Even reinforced concrete modern buildings of poor design and constructions can be seriously damaged as seen in the Bhuj earthquake in the city of Ahmedabad.

It has been seen that under varying intensities of the earthquake from magnitude 5.5 to 8.7 buildings have been damaged under five categories of damage from G1 (minor damage) to G5 (total collapse). The number of buildings which are variously damaged may be Few or Many or Most depending on the building types and the impacting seismic intensity.

It is tragic that with a glorious tradition of earthquake engineering in world class academic centers the Earthquake Code is still not mandatory and buildings are constructed annually without any seismic resistance. Since, the number of earthquake unsafe buildings is too huge, concerted action can only be taken for seismic retrofitting of selected critical and important buildings. To evaluate the need of retrofitting a building can quickly be assessed by using the RVS procedure developed originally by Prof. A.S. Arya in 2003 while working as National Seismic Advisor to MHA, Govt. of India. Now for masonry structures, it is a part of Indian Standard IS 13935:2009 Seismic Evaluation, Repair and Strengthening of Masonry Buildings – Guidelines. It can be carried out quickly without resorting to the time consuming analytical methods or detailed testing procedures, that is the usefulness of RVS procedures applicable to a masonry building or a reinforced concrete frame building.

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Prof. A.S. Arya

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1. Introduction

1.1 Need for Seismic Evaluation

An existing building may not comply with requirements of the earthquake building codes for various reasons, such as the following:

i) The buildings may not have been designed initially to resist earthquake loads, as it may have been constructed before such a *code* was adopted, or even if adopted it may not have been mandatory.

ii) Even if the building was initially built to the *earthquake code* provisions, the seismic resistance requirements may have been revised upwards in the later revisions of the *code*. For example, the basic *earthquake code* in India namely Indian Standard Criteria for Earthquake Resistant Design of structures was first published in 1962. Since then it has been revised in the years 1966, 1970, 1975, 1984 and the latest revision in 2002. Comparing the requirements of Earthquake Resistant Design in 1962 with those in 2002, it is seen that the design forces have almost doubled in the year 2002 as compared with 1962. Therefore, buildings designed as per 1962 version of the *code* will need seismic strength evaluation to check if the building needs retrofitting to come to the level of 2002 version of the *code*.

iii) The use of building may have changed requiring higher level of safety. For example a residential building might have been converted to a building for storage of goods critical to safety or for commercial use or for a school or medical clinic. For the various building uses, the design criteria in the *code* are different, the school or hospital buildings to be designed for 50% higher forces as compared with residential buildings.

iv) The condition of the building may have deteriorated over the years in the absence of proper maintenance, which may require refurbishing and retrofitting of the building for continuous use over the remaining years of the building life.

1.2 Work done in California USA

Rapid visual screening of buildings for potential seismic hazards, originated in 1988 with the publication of the FEMA 154 Report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook.*

It was written for a broad audience ranging from engineers and building officials to appropriately trained non-professionals. The *Handbook* provided a "sidewalk survey" approach that enabled users to classify surveyed buildings into two categories: those acceptable as to *risk to life safety* or those that may be *seismically hazardous* and should be evaluated in more detail by a design professional experienced in seismic design.

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 more than 70,000 buildings nationwide. This widespread application provided important information about the purposes for which the document was used, the ease-of-use of the document, and perspectives on the accuracy of the scoring system upon which the procedure was based. Concurrent with the widespread use of the document, damaging earthquakes occurred in California and elsewhere, and extensive research and development efforts were carried out under the National Earthquake Hazards Reduction Program (NEHRP). These efforts yielded important new data on the performance of buildings in earthquakes, and on the expected distribution, severity, and occurrence of earthquake-induced ground shaking.

1.3 Work done by Arya in India

While working as National Seismic Advisor in the Ministry of Home Affairs, Govt of India, Prof. Arya developed a procedure of Rapid Visual Screening of Building types prevalent in India. In view of the fact that the buildings covered under FEMA 154 were almost entirely of different construction technology commonly used in California, USA, the use of the FEMA 154 was not found suitable to Indian buildings. The guidelines on the subject of RVS of Indian buildings was prepared during 2005-2006 and its use was tried in Tamil Nadu where the seismic zone was upgraded from zone II to zone III which created some scare in Chennai. The methodology was found very suitable since it applied to the various building types seen in Chennai.

1.4 Main Steps in Seismic Evaluation of an Existing Building

There are a few steps involved in the evaluation of the seismic resistance of an existing building.
First, A quick assessment may be carried out by the procedure called Rapid Visual Screening (RVS). This procedure involves a rapid visual inspection and information gathering about the buildings, from the municipal building department records where available and/or the owner of the building and the maintenance personnel to identify the vulnerable elements in the buildings.

When a building is identified as vulnerable, the next step will be to have detailed evaluation by acquiring relevant data so as to carry out the detailed assessment of the deficiencies which would need treatment by retrofitting.

1.5 Objective of the Guideline

The objective of this guideline is to formulate the procedure to carry out the Rapid Visual Screening of large number of various buildings in all the regions of India by which an initial appraisal could be obtained about the collapse potential or the damageability grades to which they may be subjected under the Seismic Intensity occurrence postulated in the Seismic Zone they are situated in. This information will help in developing damage potential of such various community buildings in future earthquake occurrences so that the states may prepare suitable disaster management plans accordingly.

1.6 Scope of the Guideline

The guideline basically covers buildings constructed using various masonry materials and reinforced concrete frame buildings. It starts with the need for seismic evaluation of existing buildings and the purpose of RVS to be done in the Indian context. The main factors entering into the seismic evaluation of existing buildings are the building type, the seismic intensity zone in which the building is situated and the vulnerability (damagebility) of the building when impacted by the postulated seismic intensity. Therefore, the topics included are seismic hazard intensity zones in India, the building typologies prevalent in India and the grades of damagebility under various intensity occurrences. Based on these factors the RVS procedure developed by Arya is fully described and the RVS data forms to be used by the assessors (screeners) are developed. For implementation of the RVS procedure, an appropriate sequence of the operations is suggested.

Quick reference guides are also described in very brief which the assessors could carry with them for use in the field. Finally, a template is developed for collection of building data for general use.

The procedure of RVS developed by FEMA, which has been used extensively for the building types prevalent in California, USA, is given in an Appendix for ready information.

2. Outline of the RVS Procedure

2.1 Purpose of RVS

The RVS procedure has been formulated to assess, *inventorise*, and to *rank* buildings that may be potentially hazardous under Maximum Considered Earthquake (MCE) as postulated in the seismic zoning in India at the site of the building. The RVS procedure is designed to be implemented without performing structural analysis calculations. It utilizes a procedure that requires the Assessor to (1) identify the primary structural lateral-load-resisting system of the building; and (2) identify building attributes that will modify the seismic performance expected of this lateral-load-resisting system as per the MSK Intensity, which is the basic criteria for determining the macro zones in the country.

2.2 Data Collection Forms for RVS

The inspection, data collection, and decision-making process will occur mostly at the building site with access to its exterior as well as the interior. Results are recorded on one of RVS Forms (Data Collection Forms), prepared separately according to the seismicity of the region being surveyed. The 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. Some times buildings may be reviewed from the sidewalk without the benefit of building entry, structural drawings, or structural calculations. But the reliability and confidence in building attribute determination are increased, however, if the structural framing system can be verified during interior inspection, or on the basis of a review of construction documents. The RVS procedure may be applicable throughout the country only for all conventional building types. But it may not be applicable to bridges, large towers, and other non-building structures.

2.3 RVS Result

If a building receives a *high safety score as in FEMA 154* or indicative of *minimum structural damage Grade,* the building is considered to have adequate seismic resistance. If a building receives a *lower safety score,* or high damageability Grade, it is recommended to be retrofitted, or to be evaluated by a professional engineer having experience or training in seismic design.

On the basis of a detailed inspection, engineering analysis, and other detailed procedures, a final determination of the seismic adequacy and need for retrofitting can be finalized. If the RVS authority decides that a low safety score or high damageability grade will automatically require that further study be performed by a professional engineer, then some *acceptable level* of qualification to be held by the Assessor performing the screening job, will be necessary.

2.4 Use of RVS Result

RVS projects may have a wide range of goals. Such as general level of seismic safety of majority of building types under residential use, specific safety levels of important buildings used for schools and hospitals or some critical selected buildings. Accordingly they may have constraints on budget, completion date and accuracy, which must be considered by the RVS authority as it selects qualification requirements of the screening personnel. Under most circumstances, a well planned and thorough RVS project will require qualified *engineers* to perform the inspections. In any case, the program should be overseen by a design professional knowledgeable in seismic design for quality assurance purposes.

2.5 List of References

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8. IS 1905: 1987, "Code of Practice for Structural Use of Unreinforced Masonry", Bureau of Indian Standards.
9. IS 4326: 1993, "Earthquake Resistant Design and Construction of Buildings - Code of Practice", Bureau of Indian Standards.
10. Model Town and Country Planning Legislation, Zoning Regulations, Development Control, Building Regulation/Byelaws for Natural Hazards Zones of India (2004), Ministry of Home Affairs, Government of India.
11. Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings (Draft version, 2006) Bureau of Indian Standards.

3. Seismic Hazard Intensities in India

3.1 MSK 1964 Intensities used in India (IS:1893- Part I: 2002)

The intensities scale have 12 steps describing the experiences and damages in buildings observed in the past earthquakes varying from very minor influences to major disaster effects. These are broadly describe in Table 3.2.

3.2 European Macro Seismic Scale (EMS 1998)

This scale also follows closely the MSK intensities scale in 12 steps. There are minor differences in the quantities descriptions between EMS and MSK. EMS also a described in table 3.2 side by side MSK intensities for ease of understanding and comparison.

3.3 Seismic Hazard Intensities in Arya method for RVS

Arya method uses MSK intensities for preparing RVS form. An equivalence with FEMA 154 hazard intensities is studied below:

FEMA 154 specifies the following criteria for adoption of seismic hazard intensities namely **High** hazard, **Moderate** hazard and **Low** hazard. The value of acceleration determined from acceleration response spectra are used as criterion. The spectral value is obtained for two fundamental time periods of 0.2 sec and 1.0 sec. If 2/3 of the 0.2 sec acceleration spectrum for a site is 0.5g more and 1.0 sec spectrum value is 0.2g or more, the area will be classified as **High** hazard intensity area.

If 2/3 of the spectral value for 0.2 sec period lies between 0.5g and 0.167g the area will be classified as **Moderate** hazard area but if the 2/3 value of 0.2 sec and 1.0 sec spectra values lie below 0.167g, and 0.067g respectively, it will be treated as **Low** hazard area.

The spectral Acceleration curves adopted in IS:1893-2002 are shown in Fig. 3.1 for Peak Ground Acceleration of 1.0g. Using these curves with Peak Ground Acceleration values specified for the zones, namely 0.36g in Zone V (MSK IX), 0.24g in Zone IV (MSK VIII), 0.16g in Zone III (MSK VII), and 0.1g in Zone II (MSK VI or less) the value of 2/3 acceleration are obtained as given in Table 3.1, along with FEMA criterion.

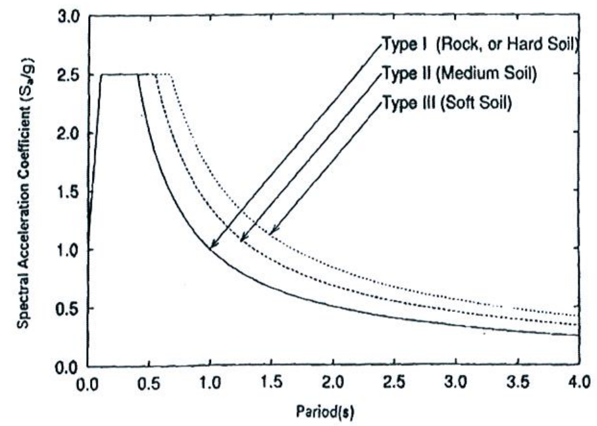


Fig. 3.1 Response Spectra for Rock and Soil Sites for 5 percent Damping

Table 3.1 Definition of MSK Intensities in Arya's RVS relative to FEMA 154

Zone	Intensity	PGA	2/3 SA for T= 0.20 sec Hard Soil	2/3 SA for T=1.0 sec Hard Soil	Hazard Intensity Zone
Zone V	MSK IX	0.36g	≥ 0.60 g	≥ 0.24 g	Very High
	FEMA 154		*≥ 0.50g*	*≥ 0.20g*	*High*
Zone II	MSK VIII	0.24 g	≥ 0.40g to 0.6 g	≥ 0.16 g to 0.24 g	High
	FEMA 154		*0.167g to 0.5 g*	*≥ 0.067g to 0.20 g*	*Moderate*
Zone III	MSK VII	0.16 g	≥ 0.27g to 0.4 g	≥ 0.11 g to 0.16 g	Moderate
	FEMA 154		*<0.167g*	*<0.067g*	*Low*
Zone II	MSK VI	0.10 g	≥ 0.169g to 0.27 g	≥ 0.06g to 0.11 g	*Low*

Comparing the values of FEMA 154 criteria with the spectral Acceleration result of IS: 1893-2002 (the India Standard Design Criteria), shown in the Table 3.1, where only values for Hard Soil are compared since FEMA 154 has Score Modifiers for softer soils, it may be concluded that for all purposes, MSK IX, VIII,VII and II may be considered as **Very High, High, Moderate** and **Low** hazard intensities for RVS procedure.

3.4 Hazard Intensities for various States and UTs in India

Four seismic zones are specified in the seismic zoning map of India shown in Fig.3.2 namely Seismic Zone V, IV, III and II based on MSK Intensities **'IX and more'**, MSK **VIII**, MSK **VII** and MSK **'VI or lower'** respectively. As stated earlier Seismic Zone V may be taken as Very high hazard intensity, Zone IV be considered as **high** hazard intensity and Zone III may be considered as **Moderate** hazard intensity area for purposes of carrying out RVS survey of various buildings.

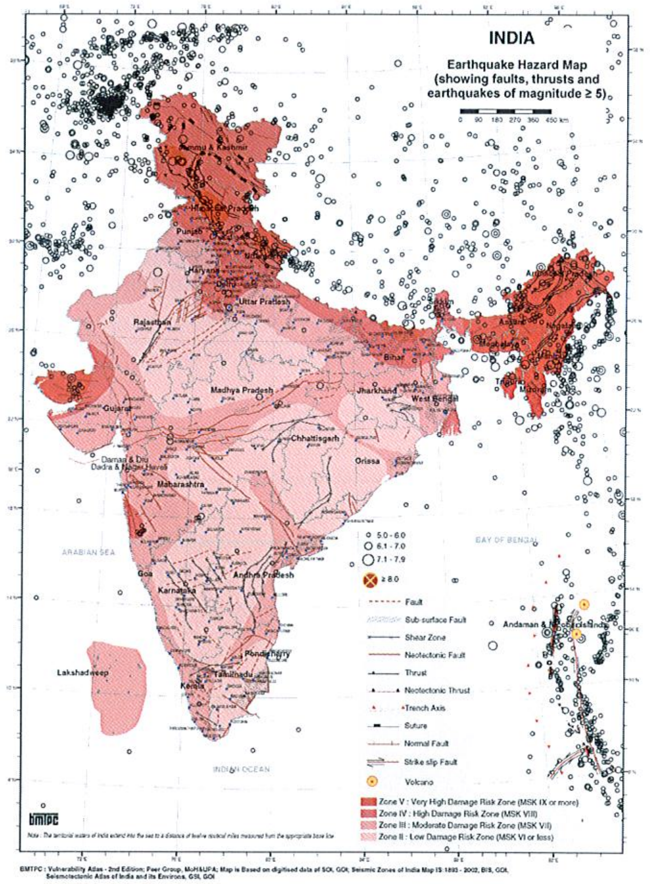


Fig. 3.2 Seismic Zone Map of India

3.5 Seismic Hazards considered in RVS forms

Four levels of seismic hazard intensities are considered in Vulnerability Atlas of India (1997 and 2006) corresponding to the four seismic zones as given below:-

(i) **Very High** seismic hazard Zone V (maximum damage during earthquake may be under MSK Intensity IX or greater).

(ii) **High** seismic hazard Zone IV (maximum damage during earthquake may be as per MSK Intensity VIII).

(iii) **Moderate** seismic hazard Zone III(maximum damage during earthquake may correspond to MSK Intensity VII).

(iv) **Low** seismic hazard Zone II(corresponding to MSK Intensity VI or lower) is considered negligible, hence not used for developing RVS Form.

When a particular hazard Intensity occurs, different building types experience different levels of damage depending on their inherent characteristics.

Table 3.2 Intensity Scales

Arrangement of the scale: **The effects of an earthquake occurrence on habitat as observed are co-related with the intensity scale under the following subdivision:**

(a) Effects on humans; (b) Effects on objects and on nature; (c) Effects on buildings

The effects are described in EMS and MSK Intensity Scales using three quantitative terms: Few, Many and Most; three building types A.B and C in MSK scale and six buildings vulnerability classes A, B, C, D, E and F in EMS scale. Both the scales use five grades of damage Grade 1, Grade 2, Grade 3, Grade 4 and Grade 5. All these terms are explained in Chapter 5 and 6.

EMS SCALE	MSK SCALE
I. Not Felt a. Not felt, even under the most favorable circumstances. b. No effect. c. No damage.	**I. Not Noticeable** a. The intensity of the vibration is below the limits of sensibility; the tremor is detected and recorded by seismograph only. b. None. c. No damage.
II. Scarcely Felt a. The tremor is felt only at isolated instances (<1%) of individuals at rest and in especially receptive position indoors. b. No effect. c. No damage.	**II. Scarcely noticeable (very slight)** a. Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings. b. No effect. c. No damage.
III. Weak a. The earthquake is felt indoors by a **few**. People at rest feel a swaying or light trembling. b. Hanging objects swing slightly. c. No damage.	**III. Weak, partially observed only** a. The earthquake is felt indoors by a **few** people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. b. Attentive observers notice a slight swinging of hanging objects, somewhat more heavily on upper floors. c. No damage.

EMS SCALE	MSK SCALE
IV. Largely observed a. The earthquake is felt indoors by many and felt outdoors only by very **few**. A **few** people are awakened. The level of vibration is not frightening. The vibration is moderate. Observers feel a slight trembling or swaying of the building, room or bed, chair etc. b. Chine, glasses, windows and doors rattle. Hanging objects swing. Light furniture shakes visibly in a **few** cases. Woodwork creaks in a **few** cases. c. No damage.	**IV. Largely observed** a. The earthquake is felt indoors by many people, outdoors by **few**. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. b. Windows, doors and dishes rattle. Furniture begins to shake. Hanging objects swing slightly. Liquid in open vessels are slightly disturbed. In standing motor cars the shock is noticeable. c. Floors and walls crack.
V. Strong a. The earthquake is felt indoors by most, outdoors by **few**. A **few** people are frightened and run outdoors. Many sleeping people awake. Observers feel a strong shaking or rocking of the whole building, room or furniture. b. Hanging objects swing considerably. China and glasses clatter together. Small top-heavy and/or precariously supported objects may be shifted or fall down. Doors and windows swing open or shut. In a **few** cases window panes break. Liquids oscillate and may spill from well-filled containers. Animals indoors may become uneasy. c. Damage of grade 1 to a **few** buildings of vulnerability class A and B.	**V. Awakening** a. The earthquake is felt indoors by all, outdoors by many. Many people awake. A **few** run outdoors. Animals become uneasy. b. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects overturn or shift. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to heavy objects falling inside the buildings. Sometimes changes in flow of springs. c. Slight damages in buildings of type A are possible.
VI. Slightly damaging a. Felt by most indoors and by many outdoors. A **few** persons lose their balance. Many people are frightened and run outdoors. b. Small objects of ordinary stability may fall and furniture may be shifted. In **few** instances dishes and glassware may break. Farm animals (even outdoors) may be frightened. c. Damage of grade 1 is sustained by **many** buildings of vulnerability class A and B; a **few** of class A and B suffer damage of grade2; a **few** of class C suffer damage of grade 1.	**VI. Frightening** a. Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A **few** persons loose their balance. Domestic animals run out of their stalls. b. In **few** instances, dishes and glassware may break, and books fall down. Heavy furniture may possibly move and small steeple bells may ring. In **few** cases, cracks up to widths of 1 cm possible in wet ground; in mountains occasional landslips; change in flow of springs and in level of well water are observed. c. Damage of Grade 1 is sustained in **single** buildings of type B and in **many** of Type A. Damage in **few** buildings of Type A is of Grade 2.
VII. Damaging a. Most people are frightened and try to run outdoors. Many find it difficult to stand, especially on upper floors. b. Furniture is shifted and top-heavy furniture may be overturned. Objects fall from shelves in large numbers. Water splashes from containers, tanks and pools. **c.** **Many** buildings of vulnerability class A suffer damage of grade 3 ; a **few** of grade 4. **Many** buildings of vulnerability class B suffer damage of grade 2; a **few** of grade 3. A **few** buildings of vulnerability class C sustain damage of grade 2. A **few** buildings of vulnerability class D sustain damage of grade 1.	**VII. Damage of buildings** a. Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring. b. Waves are formed on water, and is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. Sometimes dry springs have their flow resorted and existing springs stop flowing. In isolated instances parts of sand and gravelly banks slip off. In single instances, landslides of roadway on steep slopes; crack in roads; seams of pipelines damaged; cracks in stone walls. **c.** **Most** buildings of Type A suffer damage of Grade 3, **few** of Grade 4. In **many** buildings of Type B damage is of Grade 2. In **many** buildings of Type C damage of Grade 1 is caused.

EMS SCALE	MSK SCALE
VIII. Heavily damaging a. Many people find it difficult to stand, even outdoors. b. Furniture may be overturned. Objects like TV sets, typewriters etc. fall to the ground. Tombstones may occasionally be displaced, twisted or overturned. Waves may be seen on very soft ground. **c.** **Many** buildings of vulnerability class A suffer damage of grade 4; a **few** of grade 5. **Many** buildings of vulnerability class B suffer damage of grade 3; a **few** of grade 4. **Many** buildings of vulnerability class C suffer damage of grade2; a **few** of grade 3. A **few** buildings of vulnerability class D sustain damage of grade 2.	**VIII. Destruction of buildings** a. Fright and panic; also persons driving motor cars are disturbed. b. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part. Small landslips in hollows and banked roads on steep slopes; cracks in ground upto widths of several centimeters. Water in lakes become turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, change in flow and level of water is observed. **c.** **Most** buildings of Type A suffer damage of Grade 4. **Most** buildings of Type B suffer damage of Grade 3. **Most** buildings of Type C suffer damage of Grade2, and **few** of Grade 3. Occasional breaking of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.
IX. Destructive a. General panic. People may be forcibly thrown to the ground. b. Many monuments and columns fall or are twisted. Waves are seen on soft ground. **c.** **Many** buildings of vulnerability class A sustain damage of grade 5. **Many** buildings of vulnerability class B suffer damage of grade4; a **few** of grade 5. **Many** buildings of vulnerability class C suffer damage of grade 3; a **few** of grade 4. **Many** buildings of vulnerability class D suffer damage of grade 2; a **few** of grade 3. A **few** buildings of vulnerability class E sustain damage of grade 2.	**IX. General damage of buildings** a. General panic; considerable damage to furniture. Animals run to and fro in confusion, and cry. b. On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm on slopes and river banks more than 10 cm. Further more,, a large number of slight cracks in ground; falls of rock, ,many land slides and earth flows; large waves in water. Dry wells renew their flow and existing wells dry up. Considerable damage to reservoirs; underground pipes partly broken. In individuals cases, railway lines are bent and roadway damaged. **c.** **Many** buildings of Type A suffer damage of Grade 5. **Many** buildings of Type B show a damage of Grade 4 and a **few** old Grade 5. **Many** buildings of Type C suffer damage of Grade 3, and a **few** of Grade 4. Monuments and columns fall.
X. Very destructive c. **Many** buildings of vulnerability class A sustain damage of grade 5. **Many** buildings of vulnerability class B sustain damage of grade 5. **Many** buildings of vulnerability class C suffer damage of grade 4; a **few** of grade 5. **Many** buildings of vulnerability class D suffer damage of grade 3; a **few** of grade 4. **Many** buildings of vulnerability class E suffer damage of grade 2; a **few** of grade 3. A **few** buildings of vulnerability class F suffer damage of grade2.	**X. General destruction of buildings** b. Critical damage to dykes and dams. Severe damage to bridges. Railway lines are bent slightly. Underground pipes are bent or broken. Road paving and asphalt show waves. In ground, cracks up to widths of several centimeters, sometimes up to 1 m. Parallel to water courses occur broad fissures. Loose ground slides from steeps slopes. From river banks and steep coasts, considerable landslides are possible. In coastal areas, displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers, etc, thrown on land. New lakes occur. **c.** **Most** of type A have destruction of Grade 5. **Many** buildings of type B show damage of Grade 5. **Many** buildings of Type C suffer damage of Grade 4, and a **few** of Grade 5.

EMS SCALE	MSK SCALE
XI. Devastating c. **Most** buildings of vulnerability class B sustain damage of grade 5. **Most** buildings of vulnerability class C suffer damage of grade4; **many** of grade 5. **Many** buildings of vulnerability class D suffer damage of grade4; **few** of grade 5. **Many** buildings of vulnerability class E suffer damage of grade3; **few** of grade 4. **Many** buildings of vulnerability class F suffer damage of grade2; **few** of grade 3.	**XII. Destruction** b. Severe damage to bridges, water dams and railway lines. Highways become useless. Underground pipes destroyed. Ground considerably distorted by broad cracks and fissures, as well as movement in horizontal and vertical directions. Numerous landslips and falls of rocks. The intensity of the earthquake requires to be investigated specifically. c. Severe damage even to well built buildings.
XIII. Completely devastating c. All buildings of vulnerability class A, B and practically *all of vulnerability class C are destroyed.* ***Most*** *buildings of vulnerability class D, E and F are destroyed.* *The earthquake* effects have reached the maximum conceivable effects.	**XIV. Landscope changes** b. The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falling of rock and slumping of river banks over wide areas, lakes are dammed; waterfalls appear and rivers are deflected. The intensity of the earthquake requires to be investigated specially. c. Practically **all** structures above and below ground are greatly damaged or destroyed.

4. Building Typologies in India

4.1 Building Types in India

The building typologies used in various types of buildings in India are listed in Census of Housing (2011) by wall material and roof material as shown in Tables 4.1 and 4.2 here.

Table 4.1 – H-3B : Census (2011) Houses by Predominant Material of Wall

Area Name		INDIA
Total No. of Census Houses		**04,882,448**
MATERIAL OF WALL		
1.	Grass/Thatch/Bamboo etc.	28,947,594
2.	Plastic/Polythene	1,097,831
3.	Mud/Unburnt brick	66,449,827
4.	Wood	2,781,271
5.	Stone not packed with mortar	10,441,142
6.	Stone packed with mortar	33,041,790
7.	G.I./Metal/Asbestos sheets	2,331,869
8.	Burnt brick	146,545,805
9.	Concrete	10,983,679
10.	Any other material	2,261,640
Derived categories of houses from above house types:		
Category A =	Building in field stone, rural structures, unburnt brick houses, clay houses(3+5)	76,890,969
Category B =	Ordinary brick building: buildings of the large block & Prefabricated type, half-timbered structures, building in natural hewn stone(6+8)	179,587,595
Category C =	Reinforced buildings, well built wooden structures(9+4)	13,764,950
Category X =	Other materials not covered in A.B.C. These are generally light (1+2+4+10)	34,638,934

Table 4.2 – H-3A : Census (2011) Houses by Predominant Material of Roof (Excluding locked/vacant houses)

Area Name		INDIA
Total No. of Census Houses		**04,882,448**
MATERIAL OF ROOF		
1.	Grass/Thatch/Bamboo etc.	46,987,669
2.	Plastic/Polythene	2,073,373
3.	Hand Made Tiles	40,276,749
4.	Machine made Tiles	26,425,060
5.	Burnt brick	20,254,881
6.	Stone/Slate	26,981,694
7.	G.I./Metal/Asbestos sheets	50,336,403
8.	Concrete	90,243,883
9.	Any other material	1,302,736
Derived categories of houses form above house types:		
Category R1 =	Light Weight Pitched (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials) (1+2+7+9)	100,700,181
Category R2 =	Heavy Weight Pitched (tiles, Slate) (3+4+6)	93,683,503
Category R3=	Flat Roof Rigid (Brick, Stone, Concrete) or Flexible (joisted with flexible coverings) (5+8)	110,498,764

4.2 Building Typologies Classification

Considering that there will be varying typologies based on technologies in rural and urban areas, somewhat similar to residential building technologies, a detailed list of building types is prepared here out of which the assessors of RVS should be able to identify those used therein.

The nomenclature used for various buildings as used in Arya's method namely, A, A+, B2, C+ and D for masonry buildings and C to F for reinforced concrete and steel framed buildings and were identified for each building as given in the last column of Table 4.3 to 4.6. The nomenclatures A to D and C to F are in order of decreasing seismic vulnerability (damagebility) have been adopted with reference vulnerability classes identified in EMS Intensity Scale given in Chapter 3 and further explained in Chapter 5.

Table 4.3 Building Typologies - Clay, Stone and Wood buildings

S.No.	Wall Material	Description of construction	Roof Type	Floor if any	Designation in Arya's RVS
1	**Clay (Cl1)**	Walls constructed on ground or shallow foundation	Pitched & Flexible	Flat & Flexible	A
			Flat & Flexible		
			Flat & rigid		
2	**Adobe & Unburnt brick(Cl2)**	Walls constructed on ground or shallow foundation	Pitched & Flexible	Flat & Flexible	A+
			Flat & Flexible		
3	**Stone (ST1)**	Random Rubble, dry construction or with mud mortar	Pitched & Flexible	Flat & Flexible	A+
			Flat & Flexible		
4	**Stone (ST2)**	As above with horizontal wooden dovels	Pitched & Flexible	Flat & Flexible	B
			Flat & Flexible		
			Flat & Rigid		
5	**Stone (ST3)**	Dressed stone laid in good lime mortar/ cement mortar	Pitched & Flexible	Flat & Rigid	B+
			Flat & Rigid		
6	**Stone (ST4)**	As ST2 with horizontal wood runners used as bands or RC bands	Pitched & Flexible	Flat & Rigid	C
			Flat & Rigid		
7	**Wood (WD1)**	Wattle & daub	Pitched & Flexible	-	B
8	**Wood (WD2)**	Assam Type Stud wall with Ikra wall panels	Pitched & Flexible	Flat & Flexible	D
9	**Wood (WD3)**	Wood frame with brick nogging (Dhajji Diwari)	Pitched & Flexible	Flat & Flexible	C+
10	**Wood (WD4)**	wood stud wall with wood or metal siding	Pitched & Flexible	Flat & Flexible	D

Notes:

1. **Pitched & Flexible:** Sloping roofs with tiles, slates or shingle corrugated iron. Corrugated galvanised iron sheets or asbestos cement sheets or thatch, grass, leaves, bamboo etc.
2. **Pitched & Rigid :** Reinforced Cement Concrete sloping slabs
3. **Flat & Flexible :** Wooden logs or joists with reeds & bushes covered with earth/wooden joist with bricks & stone slabs
4. **Flat & Rigid :** Reinforced brick concrete slab /Reinforced Cement Concrete slab / Jack Arch Floor/ roof

Table 4.4 Building Typologies - Burnt Brick & Cement Concrete Block buildings

S.No.	Wall Material	Description of construction	Roof Type	Floor if any	Designation in Arya's RVS
1	**Burnt brick (BB1)**	Burnt brick walls in mud mortar	Pitched & Flexible	Flat & Flexible	B
			Flat & Flexible	Flat & Rigid	
			Flat & Rigid		
2	**Burnt brick (BB2)**	Burnt brick walls in ordinary lime mortar	Pitched & Flexible	Flat & Rigid	B+
			Flat & Flexible		
			Flat & Rigid		
3	**Burnt brick (BB3)**	Burnt brick walls in good cement mortar	Pitched & Flexible	Flat & Rigid	C
			Flat & Rigid		
4	**Burnt brick (BB4)**	Similar to BB3 with RC Seismic Bands	Pitched & Flexible	Flat & Rigid	C+
			Pitched & Rigid		
			Flat & Rigid		
5	**Burnt brick (BB5)**	Similar to BB3 but with seismic bands & vertical reinforcements at corners and jambs of openings or confined masonry	Pitched & Rigid	Flat & Rigid	D
			Flat & Rigid		
	Burnt brick (BB6)	Reinforced masonry walls	Pitched & Rigid	Flat & Rigid	D+
			Flat & Rigid		
6	**Cement Concrete block (CC1) (Solid/ hollow)**	CC blocks with cement mortar	Pitched & Flexible	Flat & Rigid	C
			Pitched & Rigid		
			Flat & Rigid		
7	**CC block (CC2) (Solid/hollow)**	As CC1 but with seismic bands	Pitched & Flexible	Flat & Rigid	C+
			Pitched & Rigid		
			Flat & Rigid		
8	**CC block (CC3) (Solid/hollow)**	As CC2 with vertical steel at corners	Pitched & Flexible	Flat & Rigid	D
			Pitched & Rigid		
			Flat & Rigid		

Notes:

1. **Pitched & Flexible:** Sloping roofs with tiles, slates or shingle corrugated iron. Corrugated galvanised iron sheets or asbestos cement sheets or thatch, grass, leaves, bamboo etc.
2. **Pitched & Rigid :** Reinforced Cement Concrete sloping slabs
3. **Flat & Flexible :** Wooden logs or joists with reeds & bushes covered with earth/wooden joist with bricks & stone slabs
4. **Flat & Rigid :** Reinforced brick concrete slab /Reinforced Cement Concrete slab / Jack Arch Floor/ roof

Table 4.5 Building Typologies - Reinforced Concrete Frame buildings

S.No.	Wall Material	Description of construction	Roof Type	Floor if any	Designation in Arya's RVS
1	**Reinforced Concrete (RC1)**	Non-engineered beam post construction with unreinforced brick infill walls	Flat & Rigid	Flat & Rigid	C
2	**Reinforced Concrete (RC2)**	Prefabricated reinforced concrete building	Flat & Rigid	Flat & Rigid	C+
3	**Reinforced Concrete (RC3)**	Moment Resistant Reinforced Concrete frame of ordinary design with unreinforced masonry infill	Flat & Rigid	Flat & Rigid	C+
4	**Reinforced Concrete (RC4)**	Moment resistant RC frame with ordinary earthquake resistant design without ductility details with unreinforced masonry infill	Flat & Rigid	Flat & Rigid	D
5	**Reinforced Concrete (RC5)**	Moment resistant RC frame with earthquake resistant design and special ductility details with unreinforced masonry infill	Flat & Rigid	Flat & Rigid	E
6	**Reinforced Concrete (RC6)**	Same as RC5 but with well designed infill walls	Flat & Rigid	Flat & Rigid	E+
7	**Reinforced Concrete (RC7)**	Moment resistant RC frame with earthquake resistant design with special ductility details and shear walls	Flat & Rigid	Flat & Rigid	F

Notes:

1. **Pitched & Flexible:** Sloping roofs with tiles, slates or shingle corrugated iron. Corrugated galvanised iron sheets or asbestos cement sheets or thatch, grass, leaves, bamboo etc.
2. **Pitched & Rigid :** Reinforced Cement Concrete sloping slabs
3. **Flat & Flexible :** Wooden logs or joists with reeds & bushes covered with earth/wooden joist with bricks & stone slabs
4. **Flat & Rigid :** Reinforced brick concrete slab /Reinforced Cement Concrete slab / Jack Arch Floor/ roof

Table 4.6 Building Typologies - Steel Frame buildings

S.No.	Wall Material	Description of construction	Roof Type	Floor if any	Desig. in Arya's RVS
1	**Steel Frame (SF1)**	Steel frame without bracings having hinged joints	Pitched & Flexible	Flat & Flexible	C
2	**Steel Frame (SF2)**	Steel frame of ordinary design with unreinforced masonry infill	Pitched & Flexible Flat & Flexible Flat & Rigid	Flat & Flexible Flat & Rigid	C+
3	**Steel Frame (SF3)**	Moment resistant steel frame without bracings & without plastic design details	Flat & Rigid	Flat & Rigid	C+
4	**Steel Frame (SF4)**	Moment resistant steel frame with ordinary ERD without special details	Flat & Rigid	Flat & Rigid	D
5	**Steel Frame (SF5)**	Ordinary steel frame with braces	Flat & Rigid	Flat & Rigid	E
6	**Steel Frame (SF6)**	Moment resistant steel frame with high level earthquake resistant design and special plastic design details/steel braces	Flat & Rigid	Flat & Rigid	E+
7	**Steel Frame (SF7)**	Steel frames with cast in place shear walls with ductile design	Flat & Rigid	Flat & Rigid	F

Notes:

1. **Pitched & Flexible:** Sloping roofs with tiles, slates or shingle corrugated iron. Corrugated galvanised iron sheets or asbestos cement sheets or thatch, grass, leaves, bamboo etc.
2. **Pitched & Rigid :** Reinforced Cement Concrete sloping slabs
3. **Flat & Flexible :** Wooden logs or joists with reeds & bushes covered with earth/wooden joist with bricks & stone slabs
4. **Flat & Rigid :** Reinforced brick concrete slab /Reinforced Cement Concrete slab / Jack Arch Floor/ roof

4.3 Wooden Structure

Wooden buildings are given relatively brief treatment above since they are not so often encountered India except the more seismically active parts in North Eastern States and western Himalayas. The flexibility of wooden construction gives them a high resistance to damage, though this can vary considerably as function of construction details and durability. Loose joints or rotten wood can make a wooden house quite vulnerable to collapse, it was notable in the case of Iran earthquake of Manjil Roudbar where the wooden houses called zigali construction collapse totally due to inadequate nailed joints between main vertical and horizontal members also in the Kobe earthquake of 1995 that traditional wooden houses in parts of the city performed very badly on account of poor condition. This was a very good example of how vulnerability depends on something quite other than type or building construction material.

The structure system providing lateral resistance should be considered carefully. If the beam and columns are connected by nailed plates (of gypsum and other brittle materials like AC sheets) or if these connections are weak, the structure will fail if connections fail. This type of timber structure is typically represented by vulnerability class C, and should be distinguished from timber frame structures which are resistant against lateral loads caused by earthquake shaking. The ductility of wooden structures depend on the ductility of the connections.

Some improvements should be made in the future to the way in which wooden structures are handled by the scale. These should include making some subdivision of wooden structures into different groups, and addressing in details the stages of damage to wooden buildings which are not described in the definitions of damage grades in the scale in the way that they are for masonry and RC structures.

4.4 Two traditional earthquake Resistant Building Types used in India

4.4.1 Dhajji Dewari Houses in the Western Himalayas

The term dhajji dewari is thought to be derived from a Persian word meaning "patchwork quilt wall" and is a traditional building type found in the western Himalayas. It is a straightforward construction technology that can be easily built using local materials; timber and masonry infill with mud mortar. Typical image is shown in Figure 4.1.

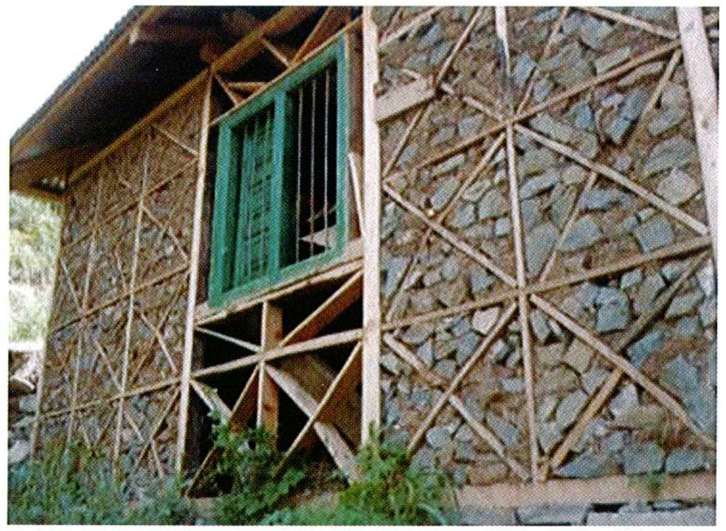


Fig. 4.1 Typical dhajji dewari buildings from Kashmir

buildings may have been much more vulnerable than would normally have been the case on account of damage (perhaps not very visible) caused by the main shock. This should be taken into consideration when assessing vulnerability.

5.2 Definition of terms Few, Many and Most in Intensity Scales

(a) *MSK Intensity Scale:*

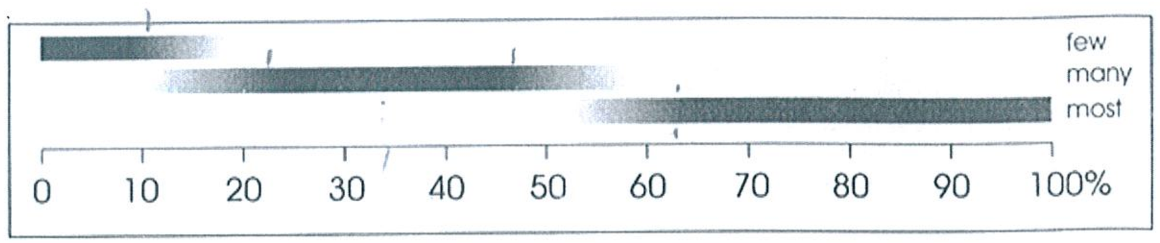
The following quantities are indicated for the terms:

Single, Few	About 5 percent
Many	About 50 percent
Most	About 75 percent

(b) *EMS Intensity Scale:*

The use of quantitative terms (few, many, most) provides an important statistical element in the scale. It is necessary to confine this statistical element to broad terms, since any attempt to present the scale as a series of graphs showing exact percentages would be impossible to apply in practice and would destroy the robustness of the scale. But defining these terms numerically is not very easy. If **few**, **many** and **most** are defined as three contiguous ranges of percentages (e.g. 0-20%, 20-60%, 60-100%), the undesirable effect occurs that a small percentage increase in some observation may in one case cross a threshold value and put the intensity up by one degree, whereas in another case the same increase will not cross a threshold and so not have the same effect. Broadly overlapping definitions (0-35%), 16-65%, 50-100%) cause problems of ambiguity for an observed value (e.g. 25%) in the overlap, and widely separated definitions. For example (0-20%, 40-60%, 80-100%) cause similar problems where a value may be undefined. A compromise solution has been found for this version of the EMS scale, using narrowly overlapping definitions (see fig 5.1), but no solution is ideal. The objective here has been to try and maximize the robustness of the scale, and the definitions of quantity presented here should be used with this in mind. This has been presented, very deliberately, in graphical format to emphasize the way these numerical categories are blurred rather than sharply defined.

In such a case as a precisely determined quantity falls into an overlapping area, the user should consider the implications of classing it as one category or the other, in terms of which would be more consistent with any other data available for the same place.



Few 0-10% Many 20-47% Most 64-100%
Blurred overlap 10-20% Blurred overlap 47-64%

Fig 5.1 Definition of Quantity (EMS)

5.3 Damageability grades of buildings of Masonry and RCC

Five grades of damageability from G1 to G5 are specified in MSK and European Macro Intensity Scales as described in Tables 5.1 and 5.2 for Masonry and RCC buildings respectively.

Table 5.1: Grades of Damageability of Masonry Buildings

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

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

Table 5.2: Grades of Damageability of RCC Buildings

Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	
Structural:	Nil
Non-Structural:	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)	
Structural:	Cracks in columns & beams of frames & in structural walls.
Non-Structural:	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)	
Structural:	Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods.
Non-Structural:	Large cracks in partition & infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	
Structural:	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.
Non-Structural:	Failure of loosely filled partition and infill wall panels.
Grade 5: Destruction (very heavy structural damage)	
Structural:	Collapse of ground floor parts (e.g. Wings) of the building.
Non-Structural:	Total destruction of non-structural building components.

* *The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification (shown in bold print in above Table 5.2). Non-structural damage to infills would be the same as indicated for masonry infills in the above table 5.2. Structural damage grade in steel & wooden elements still needs to be defined.*

5.4 Examples of Grades of Damage of Masonry Buildings

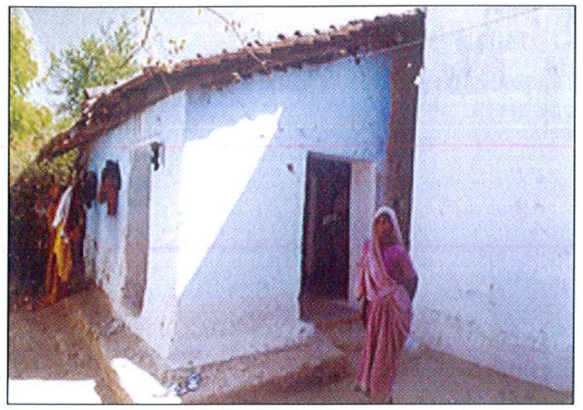


Fig 5.1 G1 Cracks (a) Fine diagonal cracks in Brick Wall House with Tile Roof

Fig 5.1 G1 Cracks (b) Raking Shear Fine Cracks in Brick Pier

Fig. 5.2 G2 Cracks
(a) Diagonal wide cracks in gable wall

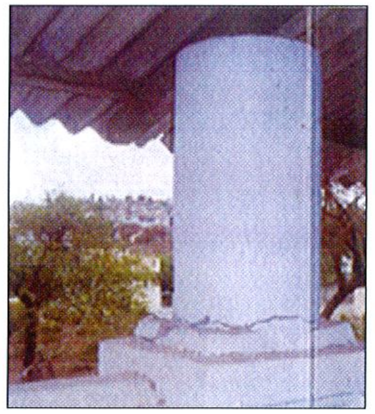


Fig. 5.2 G2 Cracks
(b) Column Base Shear Crack

Fig. 5.2 G2 Cracks
(c) Large Plaster Spalling

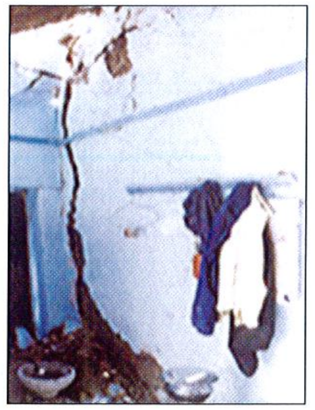


Fig. 5.3 G3 damage
(a) Corner Deep & Wide Crack

Fig. 5.3 G3 damage
(b) Disturbed Tiles on Bricks House

Fig. 5.4 G4 damage Partial Collapse

Fig. 5.5 G5 damage Total Collapse

5.5 Illustrations of Grades of Damage of RCC Buildings

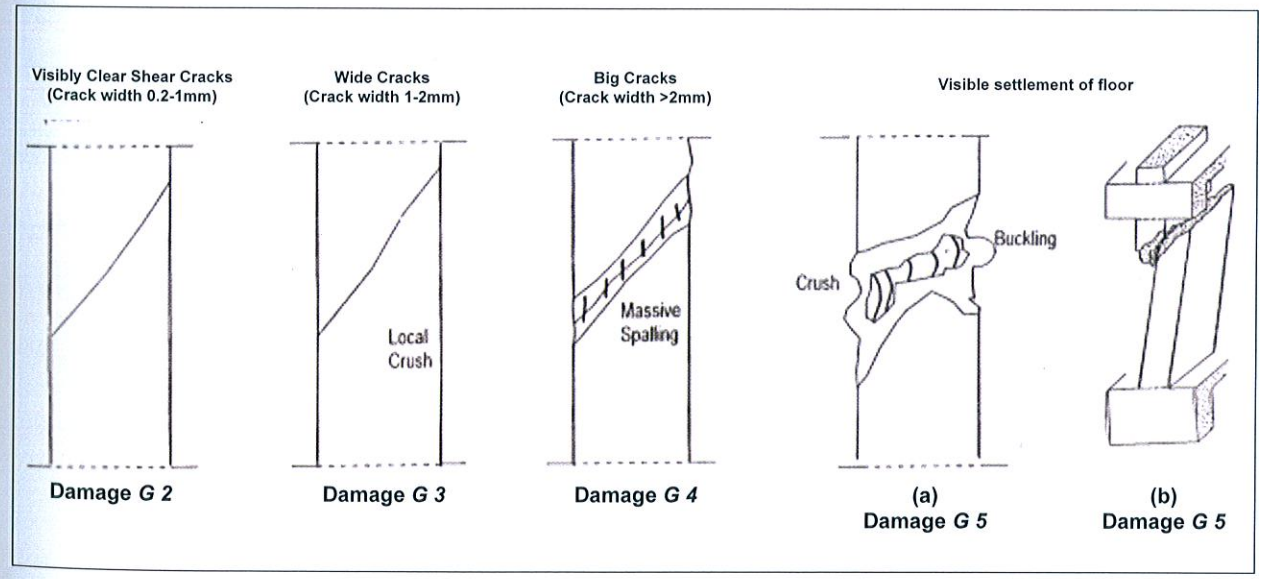


Fig. 5.6 Grades of Damage in RC Columns

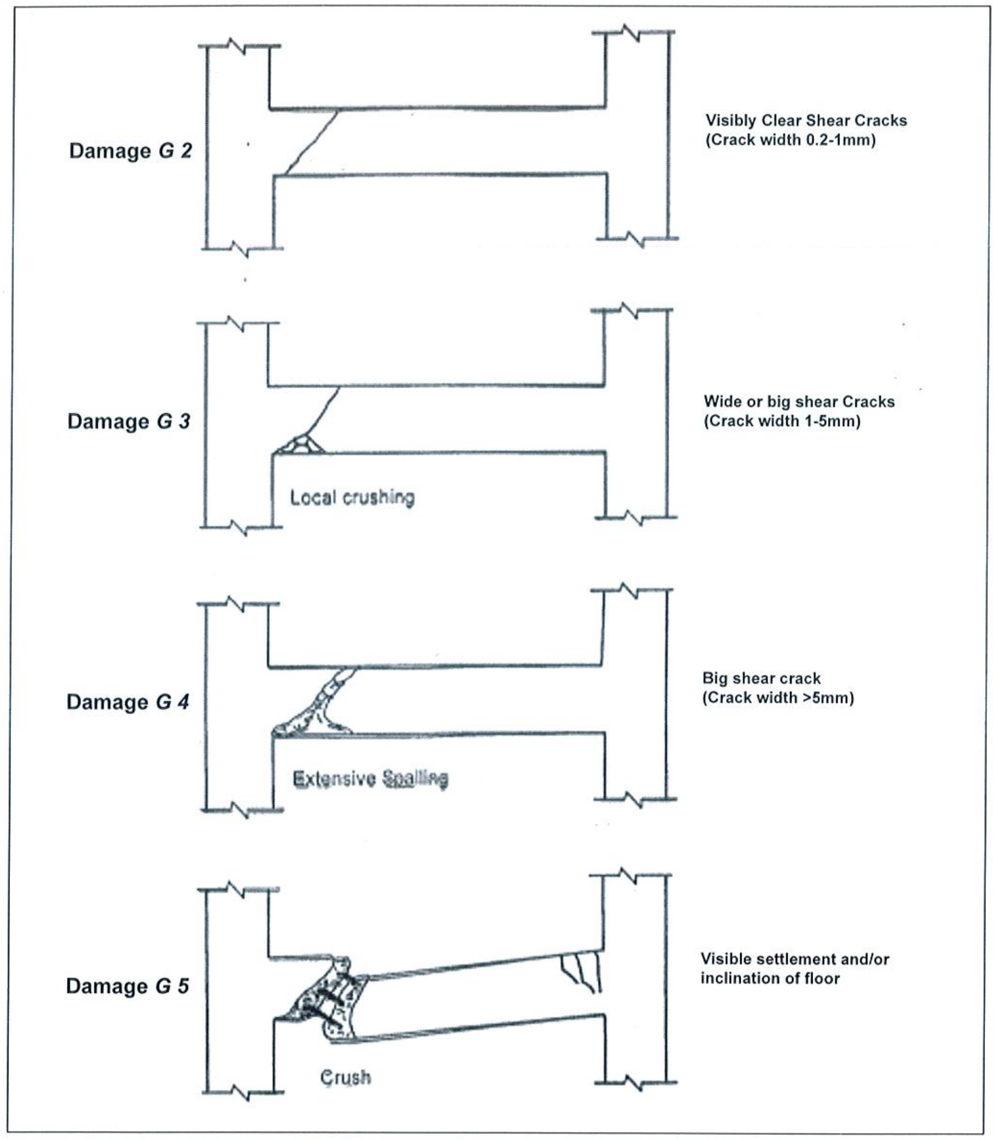


Fig. 5.7 Grades of Damage in RC Beams

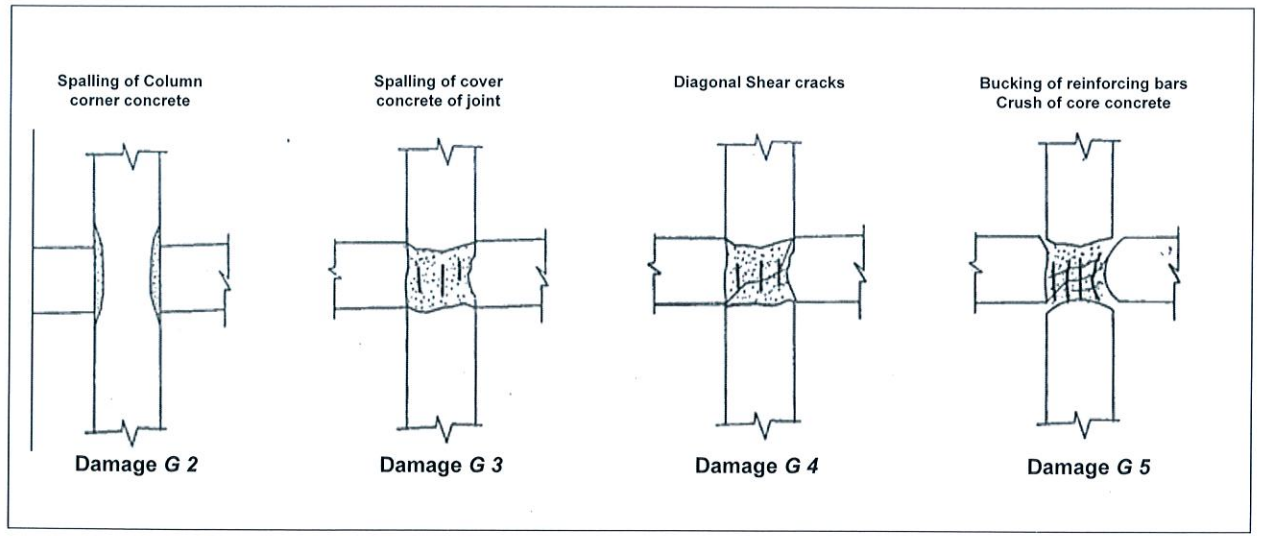


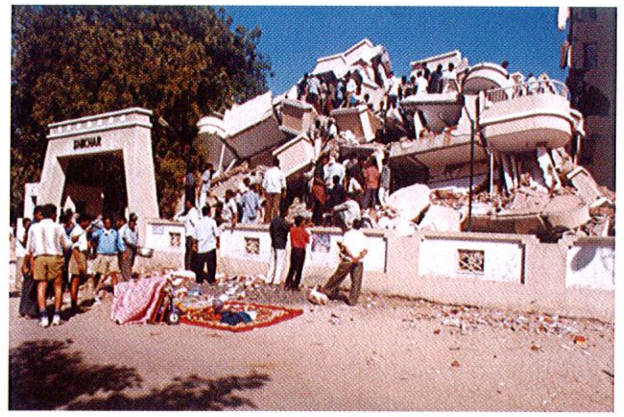
Fig. 5.8 Grades of Damage in RC Beam-Column Joints

Fig. 5.9 G4 Damage of RC Short Column

Fig. 5.10 G5 Damage of RC Column

Fig. 5.11 G5 Damage of Beam Column Joint

Fig. 5.12 Total Damage G5 of RC Frame Building



6. Seismic Vulnerability

6.1 Vulnerability

Vulnerability can be defined as the degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given magnitude or intensity, which is usually expressed on a scale from 0 (no damage) to 10 (total loss).

Earthquake vulnerability is thus a function of the potential losses from earthquakes- death and injury to people, damage to various man made structures: buildings, bridges, etc. The damages and losses also depend on the mitigation and preparedness measure adopted the occurrence of a damaging earthquake. They reflect the uncared for weakness in the built environment of a village, town or city. Also, the limitations in the community which affect its ability to cope with the hazard's damaging impact and to absorb the losses after an earthquake event, and also to recover from the damages. Vulnerable conditions preceding the earthquake event contribute to its disastrous impact and create an emergency situation usually continuing long after the earthquake had struck.

6.2 Vulnerable Elements in the Physical Environment

The likelihood of an earthquake disaster increases when the community's built environment (i.e. buildings and lifeline systems- or community infrastructure) is comprised of the following vulnerable elements.

- Older residential and commercial buildings and infrastructure constructed of unreinforced masonry or any other construction materials having inadequate resistance to lateral forces of ground shaking, or if they were not built to seismic codes and standards on built to those standard that are now considered to be outdated and inadequate.
- Older non-engineered residential and commercial buildings that have no lateral resistance and are also vulnerable to fire following an earthquake.
- New buildings and infrastructure that have not been sited, designed and constructed with adequate reinforcement as per earthquake building codes and regulations.
- Buildings and lifeline systems sited in close proximity to an active fault system, or on poor soils that either enhance ground shaking or fall through permanent displacements (e.g., liquefaction and landslides), or in low-lying or coastal areas subject to tsunami flood waves.
- Modern buildings of poor design and construction (examples are buildings that were damaged seriously even in low intensity of shaking in Ahmedabad and Bhuj in the January 2001 earthquake).
- Schools and other buildings that have been to low construction standards.
- Communication and control centers that are concentrated in one area and not built to seismic standards.
- Hospital buildings and facilities that are insufficient for large number of casualties and injuries.
- Bridges, overhead crossings and viaducts that have not been built to withstand shaking forces of earthquakes and are likely to collapse or be rendered unusable by ground shaking.
- Electrical, gas and water supply lines that are likely to be knocked out of service by ground failure (i.e., liquefaction, lateral spreads, and landslides).

6.3 Prevalence of Non-Engineered Constructions

It is estimated for most of the towns and cities of India, that non-engineered construction accounts for more than half, and in some case more than even 90% of all building stock. The volume of such non-engineered buildings is, unfortunately growing, especially in the periphery of cities. It is to be understood that about 75% of fatalities attributed to earthquakes in the last 50 years were caused by the collapse of masonry buildings or even RC buildings that were not adequately designed for earthquake resistance, were built with inadequate materials, or were poorly constructed.

There are large human settlements located in earthquake/prone areas in India. Most of these settlements have a significant proportion of old and unsafe buildings that are of poor quality of design and construction. Aging and lack of maintenance are other factors of the deterioration of the material quality.

Erosion of the traditional wisdom in building construction is also responsible for the increased vulnerability of traditional building types.

- Extensive use of timber bands running over the walls.
- Use of wooden pins to provide integrity between structural members of the building for restricting relative displacement,
- Very strict selection of quality materials,
- Adequate thickness of the walls
- High level of craftsmanship

6.4 Inadequate Control in the Building Construction

While the building code is mandatory in China and Japan, and they have developed the required institutional capacity at the municipal levels, in India, the **seismic building code** is yet a recommended practice, and the municipal organizations do not have the human resources capacity for the strict implementation of the seismic code for building construction.

It is tragic that India with a glorious tradition of earthquake engineering in world class academic centers, the earthquake code is not mandatory and millions of buildings are constructed annually without any seismic resistance.

6.5 Factors Affecting Seismic Vulnerability of Buildings

IS: 4326 : 1993, lays down general principles to be observed in the construction of earthquake resistant buildings. The factors considered are the following:

i. *Lightness of the building components* as far as possible consistent with structural safety and the functional requirements.

ii. *Continuity of construction* between the parts of the buildings so that the buildings acts as an integral unit to resist the earthquake force which may impacting the buildings in any direction. The principles should apply to all additions and alterations carried out after the initial constructions of the building.

iii. *Projecting and suspended parts* of the building are recommended to be avoided as far as possible and if avoiding is not practical, then these should be properly reinforced and firmly connected with the building structure.

iv. *Building configuration* has to be made as regular and symmetrical as possible in plan as well as elevation so that torsion and stress concentration during earthquake is minimized if not totally avoided. This principle applies to both mass and rigidity of the various components of the building.

v. *Strength in various directions*, the building structure should have adequate strength against earthquake effects in the longitudinal as well as transverse directions.

vi. *Ductility* in the building components as well as their connections needs to be achieved by appropriate details.

vii. *Damage to non-structural parts* has to be avoided by suitable design of the non-structural parts and their connection with the main structure of the building.

viii. *Fire safety* of building structure needs to be ensured since there will be chances of fire occurrence during a severe earthquake due to kitchen fire or electrical short-circuiting.

ix. *Separation of adjoining buildings* with proper gap must be achieved to avoid mutual impact during earthquake vibrations which may damage either or both of the adjoining buildings or blocks of the same building.

x. *Foundations* of buildings will have to be planned and designed after due soil investigations to avoid displacement or tilting of the foundations on soft soils or liquefaction of sandy soils submerged under high water table.

xi. *Roofs and floors* should not preferably be constructed using terrace of ordinary bricks or prefabricated concrete elements supported on steel, timber or RC joists, since during earthquake shaking the supporting joists may be moved apart and the prefabricated elements may fall down. If adopted the roof or floor will have to be contained in RC bands preventing the separation of the joists.

xii. *Jack Arches of masonry* resting on steel joists will have to be prevented from spreading by use of steel ties in all spans so as to ensure integral diaphragm action.

xiii. *Staircases* are frequently cause of distress in view of their diagonal strut action during earthquake vibrations leading to their own damage or damage to the supporting building structure. Appropriate construction details will have to be adopted as advised in the standard, IS: 4326.

The above important guidelines provided in the Code where followed in construction will give a safe earthquake resistant construction. But in the case, the above guidelines are not followed, the building will be unsafe and will have a vulnerability of the same grade as any other non-engineered building constructed in the usual manner. Besides the above points for achieving earthquake safe construction, there are other points which may result into higher damageability of the building.

i. *Quality of material and workmanship* during construction. What will constitute good and bad construction during a building survey may generally be of subjective nature. It is certain that use of good quality materials and good construction techniques will result in a building which will be much better able to withstand earthquake shaking than the building having use of poor materials as well as workmanship. In masonry construction, the quality and strength of mortar is of particular importance. Poor workmanship in stone construction will be the one where the through stones will not be used in the walls.

ii. *State of maintenance*, a building which is well maintained will perform with the expected strength and a building which has been allowed to decay may be much weaker, hence more vulnerable. A particular case is that of a building already damaged in an earlier shock but not properly restored. Such buildings can behave very poorly even under a weak earthquake shock and may suffer large amount of damage including collapse. One should note that a building may appear to be in good condition if repaired aesthetically by nice plaster and paint. Such a building will only be safe if structurally restored after the earlier damage.

iii. *Position of building* in the cluster, if it is at the end of a row of many buildings, it gets worst affected during an earthquake.

iv. *Seismically retrofitted buildings* behave much better during a severe earthquake with reduced vulnerability.

v. *Earthquake resistance design (ERD)* could be of three qualities; (a) Low with minimum level of ERD (b) Medium with of moderate level of ERD and (c) High with high level of ERD. Accordingly the vulnerability of the building will be higher with level low and lowest with level High.

6.6 Vulnerability classes specified in EMS (European Macro Seismic Scale)

The vulnerability classes suggested in EMS are shown in table 6.1 wherein the solid circle indicates the most likely vulnerability class of the building type stated. The solid line variation to the right side shows the better performance of the building class with reduced vulnerability and the dotted line variation to the left side shows the poorer performance of the building class with increased vulnerability. The same type of variation has been adopted by Arya while changing the nomenclature of the buildings as A to A+, B to B+ etc. where in A and B etc., coincide with the solid circle of EMS.

Table 6.1 Vulnerability as per EMS

	Type of Structure	Vulnerability Class					
		A	B	C	D	E	F
MASONRY	Rubble stone, fieldstone	O					
	Adobe (earth brick)	O	—|				
	Simple stone	|…	O				
	Massive stone		|—	O	…|		
	Unreinforced, with manufactured Stone units	|…	O	…|			
	Unreinforced, with RC floors		|—	O	…|		
	Reinforced or confined			|…	O	—|	
REINFORCED CONCRETE (RC)	Frame without earthquake-resistant design (ERD)	|…	…—	O	…|		
	Frame with moderate level of ERD		|…	…—	O	—|	
	Frame with high level of ERD			|…	…—	O	—|
	Walls without ERD		|…	O	—|		
	Walls with moderate level of ERD			|…	O	—|	
	Walls with high level of ERD				|…	O	—|
STEEL	Steel structures			|…	…—	O	…|
WOOD	Timber structures		|…	…—	O	…|	

O Most likely vulnerability class; —| probable higher class;

|..... Range of lesser class, exceptional cases

The masonry types of structures are to be read as, e.g., simple stone masonry, whereas the reinforced concrete (RC) structure types are to be read as, e.g., RC frame or RC wall.

F and damageability grades **G1** to **G5** as described here above. Some special cases included therein are explained below:

7.6.1 Identifying the Lateral, Load resisting System

A frame structure (for example, those given in Table 7.2) is made up of beams and columns throughout the entire structure, resisting both vertical and lateral loads. A bearing wall structure (for example, those given in Table 7.1) uses vertical-load-bearing walls, which are more or less solid, to resist the vertical and lateral loads. When a building has large openings on all sides, it is probably a frame structure as opposed to a bearing wall structure. A common characteristic of a frame structure is the rectangular grid pattern of the facade, indicating the location of the columns and beams behind the finish material. This is particularly revealing when windows occupy the entire opening in the frame, and no infill wall is used. A newer multistory commercial building should be assumed to be a frame structure, even though there may exist interior shear walls carrying the lateral loads (this would be a frame structure with shear walls).

Bearing wall systems carry vertical and lateral loads with walls. Structural floor members such as slabs, joists, and beams, are supported by load-bearing walls. A bearing wall system is thus characterized by more or less solid walls and, a load-bearing wall will have more solid areas than openings. It also will have no wide openings, unless a structural lintel is used.

Some composite structures incorporate structural walls as well as columns, or are partly frame structures. This is especially popular in multistory commercial buildings in urban lots where girders and columns are used in the ground floor of a bearing wall structure to provide larger openings for retail shopping. Another example is where the loads are carried by both interior columns and a perimeter wall. Both of these examples should be considered and record as bearing wall structures, because lateral loads are resisted by the bearing walls. Bearing wall structures sometimes utilize only two walls for load bearing. The other walls are non-load-bearing and may have large openings. Therefore, the openness of the front elevation should not be used to determine the structure type. The Assessor should also look at the side and rear facades. If at least two of the four exterior walls appear to be solid then it is likely that it is a bearing wall structure. Whereas open facades on all sides clearly indicate a frame structure. Bearing walls are usually much thicker than infill walls, and increase in thickness in the lower storey of multi-storey buildings. This increase in wall thickness can be detected by comparing the wall thickness at windows on different floors. Thus, solid walls can be identified as bearing or non-bearing walls according to their thickness, if the structural material is known. A bearing wall system is sometimes called a box system. It is then useful to know that:

- unreinforced masonry buildings are usually bearing-wall type,
- steel buildings and pre-cast concrete buildings are usually frame type,
- Training by knowledgeable building design professionals, should assist the Assessor in the determination of lateral-force-resisting systems. There will be some buildings for which the lateral-force-resisting system cannot be identified because of their facade treatment. In this case, the Screener should eliminate those lateral-force-resisting systems that are not possible and assume that any of the others are possible.

Ideally, whenever possible, the Assessor should seek access to the interior of the building to identify, or verify, the lateral-force-resisting system for the building.

7.6.2 Importance of Building/Structure

In most earthquake building codes an importance factor I is defined which require enhancement of the seismic strength of buildings & structures. For example, school and hospital buildings fall in structures included in the category of important buildings. Other Important buildings include: *Monumental buildings; emergency communication buildings like telephone exchange, television, radio stations, lifeline buildings like railway stations, fire stations, large community halls like cinemas, assembly halls and subway stations, power stations, VIP residences & Residences of Important Emergency persons. Any building having more than 100- 1000 Occupants at any time of the day or night may be treated as Important for purpose of RVS.*

For these important buildings the value of I is specified differently in various Codes. IS:1893 (Part-1) - 2002 specifies I as 1.5, by which the design seismic force is increased by a factor of 1.5.

Now the seismic zone factors for MCE for zone II to V in the Indian Standard IS:1893-2002 are as follows.

Seismic Intensity Zone	*MSK VI*	*MSK VII*	*MSK VIII*	*MSK IX & More*
Zone Factor (Peak ground acceleration)	0.10	0.16	0.24	0.36

It is seen that one Unit change in Seismic Hazard Intensity increases the Zone Factor about 1.5 times.

Hence it may be argued that to deal with the damageability of important buildings in any Hazard Intensity zone, they should be checked for one unit higher Intensity Zone. As shown in Chapter 3, Para 3.1. MSK IX, VIII and VII intensities qualify to be taken for V**ery High, High and Moderate** hazard intensities for RVS purposes.

7.7 Building Attributes enhancing Earthquake Risk

There are some special hazardous conditions to be considered:

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

7.7.2 ***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 occurrences, special geological & geotechnical evaluation of the site and treatment for the safety of the building will be needed.

7.7.3 ***Irregular Buildings:*** Irregularities in buildings are defined in the building code IS:1893 Pat 1-2002 under the following sub- heads:

a. Plan Irregularities: These are generally defined as follows:

(i) Torsion Irregularity
(ii) Re-entrant Corners
(iii) Diaphragm Discontinuity
(iv) Out of Plane Offsets
(v) Non - Parallel Systems

The Geometric Irregularities in building plans which can be easily identified are shown in in Fig.7.1.

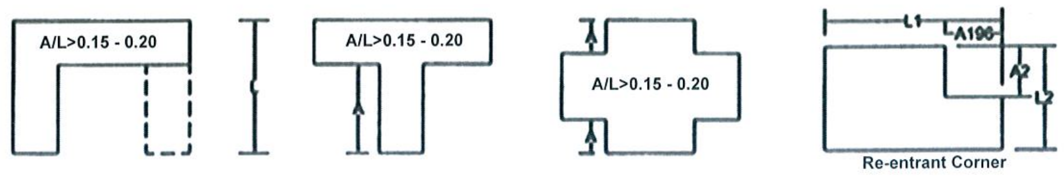


Fig. 7.1 Plan Irregularities

Plan Irregularity

If a building has a plan irregularity, as described above, the damageability becomes higher. Plan irregularity can affect all building types. Examples of plan irregularity include buildings with re-entrant corners, where damage is likely to occur; buildings with good lateral-load resistance in one direction but not in the other; and buildings with major stiffness eccentricities in the lateral force- resisting system, which may cause twisting (torsion) around a vertical axis.

Buildings with re-entrant corners include those with long wings that are E, L, T, U, or + shaped (see Figures 7.1. Plan irregularities causing torsion are especially prevalent among corner buildings, in which the two adjacent street sides of the building are largely windowed and open, whereas the other two sides are generally solid. Wedge-shaped buildings, triangular in plan, on corners of streets not meeting at 90°, are similarly susceptible. Although plan irregularity can occur in all building types, primary concern lies with wood, pre-cast frame, and unreinforced masonry construction. Damage at connections may significantly reduce the capacity of a vertical-load-carrying element, leading to partial or total collapse.

These irregularities may enhance the overall damage by one grade (increased grade of damage). Such a building may be recommended for detailed evaluation, or for retrofitting.

b. Vertical Irregularities: The following vertical irregularities may be seen in masonry buildings (see Fig. 7.2).

(i) Mass Irregularity
(ii) Vertical Geometric Irregularity
(iii) In-Plane Discontinuity in vertical Elements Resisting Lateral Forces.

Vertical Irregularity

Examples of vertical irregularity include buildings with setbacks, hillside buildings, and buildings with soft storey (see illustrations of example vertical irregularities in Figure 7.2). If the building is irregularly shaped in elevation, or if some walls are not vertical, then we have to enhance the damageability grade.

If the building is on a steep hill so that over the up-slope dimension of the building, the hill rises at least one story height, a problem may exist because the horizontal stiffness along the lower side may be different from the uphill side. In addition, in the up-slope direction, the stiff short columns attract the seismic shear forces and may fail.

A soft story exists if the stiffness of one story is dramatically less than that of most of the others.

Examples are shear walls or infill walls not continuous to the foundation. Soft storeys are difficult to verify without knowledge of how the building was designed and how the lateral forces are to be transferred from storey to storey. In other words, there may be shear walls in the building that are not visible from the outside and should be checked from inside. In many commercial buildings, the first story is soft due to large window openings for display purposes. If one story is particularly tall or has windows on all sides, and if the storeys above have fewer windows, then it is probably a soft storey. A building may be adequate in one direction but be "soft" in the perpendicular direction. For example, the front and back walls may be open but the side walls may be solid. Another common example of soft story is "stilt floor" parking commonly found in RCF buildings. Several past earthquakes in California, New Zenland and India have shown the vulnerability of this type of construction. Vertical Irregularity is a difficult characteristic to define, and considerable judgment are required for identification purposes.

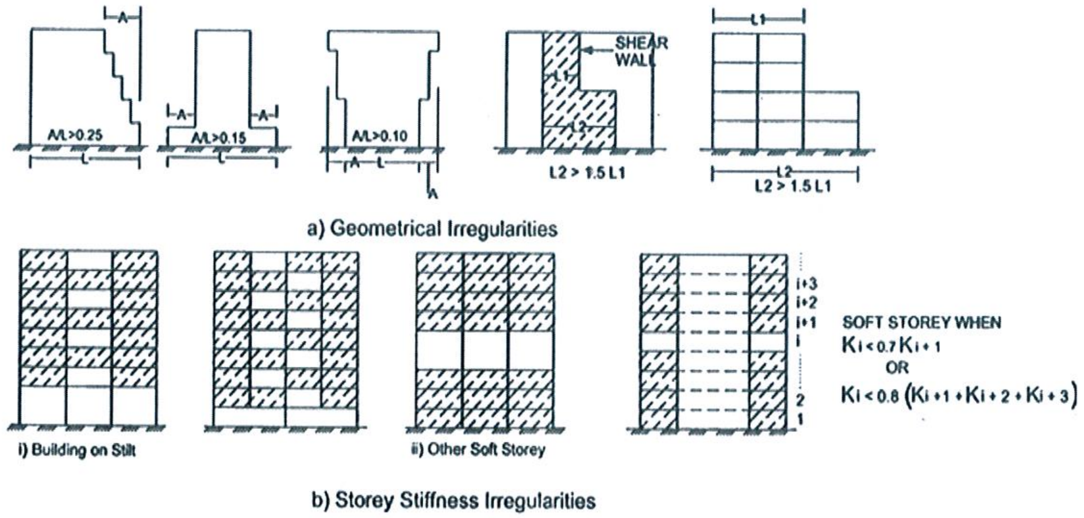


Fig. 7.2 Vertical Irregularities

If any of these irregularities are noticed, the building may undergo much more severe damage even upto Grade 4 or 5 and should be recommended for detailed evaluation or a Grade of damage by two units higher may be specified.

7.7.4 ***Falling Hazard:*** Where such hazards are present, such as high parapets, flower pots resting on parapet walls, particularly in High Intensity Zones, recommendations should make reference to these in the survey report as indicated. Such hazards will need to be removed or strengthened for stability.

Potential Non-structural Falling Hazards

Non-structural falling hazards such as chimneys, parapets, cornices, veneers, overhangs and heavy cladding can pose life-safety hazards if not adequately reinforced and anchored to the building. Although these hazards may be present, the basic lateral load system for the building may be adequate and require no further review. The falling hazards of major concern are:

- *Unreinforced Chimneys.* Unreinforced masonry chimneys are common in older masonry and wood-frame buildings. They are often inadequately tied to the building structure and fall when strongly shaken. If in doubt as to whether a chimney is reinforced or unreinforced, assume it is unreinforced.

- *Parapets.* Unbraced parapets are difficult to identify from outside. Parapets often exist on all sides of the building, their height may not be visible from any side of the structure. Climbing to the roof will indicate the situation correctly.
- *Heavy Cladding.* Large heavy cladding elements, usually precast concrete panels should be entered in the survey Data Form for documenting non-structural falling hazards. If improperly anchored, the loss of panels may also create major changes to the building stiffness (the elements are considered non-structural but often contribute substantial stiffness to a building), thus setting up plan irregularities or torsion when only some panels fall.

If any of the above non-structural falling hazards exist, the appropriate box should be checked in the RVS form.

If there are any other falling hazards, the type of hazard indicated in the comments section. The RVS authority may later use this information as a basis for action.

Note: Glass curtain walls may not be considered as heavy cladding in the RVS procedure.

7.7.5 ***Type of Foundation Soil:*** Normally earthquake resistant building codes define three soil types: hard/stiff, medium & soft.

No effect of these is seen in the design spectra of short period buildings, i.e. having T< 0.4 second, covering practically all masonry buildings, hence the soil effect may be considered not so significant in masonry buildings, but it will be prudent to specify one unit higher Grade of damage for Soft Soil condition.

The soft soils will be affecting performance of high-size RC buildings towards higher damage.

Table 7.1: Masonry load bearing wall buildings

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

IS:13828-1993, "Improving Earthquake Resistance of Low Strength Masonry Buildings --- Guidelines".
IS:4326-1993, "Earthquake Resistant Design and Construction of Buildings - Code of Practice BIS 2005

Table 7.2: Reinforced Concrete Frame Buildings (RCF) and Steel Frames (SF)

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

**IS:13920-1993, "Ductile Detailing of Reinforced concrete structures subjected to seismic forces-Code of Practice" BIS.2002".*
**IS:1893(Part-I) 2002, "Criteria for Earthquake Resistant Design of Structures", BIS 2007.*
**SP:6(6)-1972, "Plastic Design of Steel Structures-Handbook", BIS.1972.*

Notes: RCF = *Reinforced concrete column- beam frame system*
SF = *Steel column- beam frame system*
ERD = *Earthquake Resistant Design*
WRD = *Wind Resistant Design*
MR = *Moment Resistant jointed frame*

IMPORTANT NOTE: Buildings having severe vertical irregularity e.g. open plinth, stilt floor called soft storey & those having floating columns resting on horizontal cantilever beams are not covered in the above table & will require special evaluation.

Table 7.3: Grades of Damageability of Masonry Buildings

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

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

Table 7.4: Grades of Damageability of RCC Buildings

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 (shown in bold print in above Table 7.4). 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.*

Table 7.5: Damageability Grades of Masonry Buildings

Type of Building	Low Intensity MSK VII	Moderate Intensity MSK VIII	High Intensity (MSK IX or More)
A and A+	*Most* of grade 3 *Few* of grade 4 (rest of grade2 or 1)	*Most* of grade 4 *Few* of grade 5 (rest of grade 3, 2)	*Many* of grade 5 (rest of grade 4 & 3)
B and B+	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Most* of grade 3 *Few* of grade 4 (rest of grade 2)	*Many* of grade 4 *Few* of grade 5 (rest of grade 3)
C and C+	*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 and D+	*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)

NOTE:

1. *As per MSK scale, Few, Many and Most may be taken as: Few: about 5-15%, Many: about 50% and Most: about 75%.*
2. *While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many, for important buildings such as Schools and Hospital building the highest grade may be chosen even if indicated for Few.*
3. *Buildings having vertical irregularity may undergo severe damage in seismic High & Very High Intensity zones MSK (VIII and 'IX or more)' 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.*
4. *Buildings having plan irregularity may undergo a damage of one grade higher in the Moderate, High and Very High Intensity zones MSK VII, VIII& IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.*
5. *Masonry buildings of three storey height may have a damage grade one unit higher, as also buildings founded on Soft Soil.*

Table 7.6: Relationship of RCC Building and Damageability Grades

Type of Building	Low Intensity MSK VII	Moderate Intensity MSK VIII	High Intensity (MSK IX or More)
C and C+	*Few* of grade 2 (rest of grade 1 or0)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
D and D+	*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)
E and E+	-	-	*Few* of grade 2 (rest of grade 1 or 0)
F	-	-	*Few* of grade 1

NOTE:

1. *As per MSK scale, Few, Many and Most may be taken as: Few: about 5-15%, Many: about 50% and Most: about 75%.*
2. *While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many, for important buildings such as Schools and Hospital building the highest grade may be chosen even if indicated for Few.*
3. *Buildings having vertical irregularity may undergo severe damage in seismic High & Very High Intensity zones MSK (VIII and 'IX or more)' 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.*
4. *Buildings having plan irregularity may undergo a damage of one grade higher in the, Moderate, High and Very High Intensity zones MSK VII, VIII& IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.*
5. *Frame buildings of more than four storayes founded on Soft Soil may have a Damage Grade one unit higher.*

7.8 RVS Forms for various Buildings

The RVS Forms (Arya's Procedure) for Load Bearing Masonry Buildings as well as for Reinforced Concrete or Steel Frame buildings for each Hazard Intensity Moderate, High or Very High are given in this chapter. The forms are explained here by using the form for Masonry Building in High Hazard Area as example (see Fig 7.3). The following items may be identified in this form:

1.0 General Information: It deals with the seismic zone, building name, its address the use of the building, its ground coverage and the soil type, etc.

2.1 Foundation Type

2.3.1 Wall Type: Various types of wall types are included for identification.
2.3.2 Mortar Type.
2.3.3 Vertical Reinforcing Bars Provided in the Building.
2.3.4 Seismic Bands Provided in the Building at various levels.
2.3.5 Special Observations in regard to the building.

Every item has been assigned a digital number by which the data could be entered in digitized data base of each building.

Besides the above, other information is also to be verified as follows:

High Hazard MSK VIII

Photograph/ Sketch Plan with Length & Breadth

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

4.2 Land Slide Prone Site Yes ☐ No ☐

4.3 Severe Vertical Irregularity Yes ☐ No ☐ *(Increase damageability grade by 2 units)*

4.4 Severe Plan Irregularity Yes ☐ No ☐ *(Increase damageability grade by 1 unit)*

5.0 Non-structural Components*:- Whether the following non-structural elements has been properly anchored/fastened keeping into consideration the potential damages from earthquake

5.1 Falling Hazards *(Brick wall/wooden partitions, Façade elements, False Ceilings, Parapets, Chimneys, Signs, display boards etc.)* Yes ☐ No ☐

5.2 Equipments & Furnishings *[Medical equipment/lab equipments, Industrial equipment (generators/machines etc.), Office Equipments (Almirah, Computer, Photocopy Machine, Printer, Fax, Shelving (Library books/pharmaceuticals etc.)]* Yes ☐ No ☐

5.3 Basic Installation & Services *[Telecommunications (Roof top antennas, Satellite Dishes) Vacuum network, Drinking water (Roof top water tanks, Water coolers), Air conditioning plants/ducts]* Yes ☐ No ☐

*Assessment of 5.0 does not modify the damageability grade of the building.

6.0 Probable Damageability in Few/Many Buildings

Building Type	6.1 Masonry Building				
Damageability	A / A+	B / B+	C / C+	D	D+
in Intensity VIII	G5	G4 / G3	G3 / G2	G2	Nil

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.

RECOMMENDED ACTION:-

☐ If in the evaluation the damageability grades are G1/G2 the building may be considered seismically safe.

☐ If the damageability grade obtained is G3 the building will not be likely to collapse but subject to heavy damage. In such a case the building may be recommended for evaluation.

☐ If the damageability grade obtained are G4/G5 it indicates that the building is unsafe and will need retrofitting after re-evaluation..

☐ If any Special Hazard 4.0 found , re-evaluate for possible retrofitting.

☐ If any of the falling hazard (5.1) is present, either remove it or strengthen against falling. Items under 5.2 & 5.3 will generally need stabilization.

☐ Special observation (2.3.5) if not compliant may lead to more severe damage and will call for retrofitting.

Surveyor's sign:______ Name:__________________ Date: ______

SPACE FOR PHOTOGRAPH

1.0 General Information
1.1 Seismic Zone ____________________
1.2 Building Name____________________
1.3 Use____________________
1.4 Address:____________________
1.5 Other Identifiers____________________
1.6 No. of Stories__________ __________
1.7 Year Built ____________________
1.8 Total Covd. Area; all floors (sq.m) _____
1.9 Ground Coverage (Sq.m):____________
1.10 Soil Type: __________
2.1 Foundation Type
2.1.1 Strip footing Yes ☐ No ☐
2.1.2 Isolated pier footing Yes ☐ No ☐
2.3 Structural Components:
2.3.1 Wall Type
2.3.1.1 Earthen / clay mud / Adobe Yes ☐ No ☐
2.3.1.2 Bamboo Yes ☐ No ☐
2.3.1.3 Wooden Yes ☐ No ☐
2.3.1.4 UCR Masonry Yes ☐ No ☐
2.3.1.5 Dressed stone masonry Yes ☐ No ☐
2.3.1.6 Burnt Brick Yes ☐ No ☐
2.3.1.7 Cement Concrete Blocks Yes ☐ No ☐
2.3.1.8 Reinforce masonry wall Yes ☐ No ☐
2.3.1.9 Thickness of wall ____________
2.3.2 Mortar Type:
2.3.2.1 Mud mortar Yes ☐ No ☐
2.3.2.2 Lime Mortar Yes ☐ No ☐
2.3.2.3 Cement Mortar Yes ☐ No ☐
2.3.3 Vert. R/F bars provided (at corners, T-junctions & Jambs)
2.3.3.1 Using Wood Yes ☐ No ☐
2.3.3.2 Using RC Yes ☐ No ☐
2.3.4 Seismic bands in all internal & ext. walls (at plinth, lintel, eaves of pitched & gable wall top)
2.3.4.1 Using wood Yes ☐ No ☐
2.3.4.2 Using RC Yes ☐ No ☐
2.3.5 Special Observation
2.3.5.1 Length of wall between two cross walls are as per the national standards*. Yes ☐ No☐
2.3.5.2 Percentage of openings in walls are as per the national standard*. Yes ☐ No ☐
2.3.5.3 Ratio of height & width of wall is as per the national standard*. Yes ☐ No ☐
2.3.5.4 Whether through stones and corner stones provided. Yes ☐ No ☐

**For example Indian Standards IS:4326 & IS:13828 have specific provisions*

Very High Hazard MSK IX or Higher

Photograph/ Sketch Plan with Length & Breadth

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

4.2 Land Slide Prone Site Yes ☐ No ☐

4.3 Severe Vertical Irregularity Yes ☐ No ☐ *(Increase damageability grade by 2 units)*

4.4 Severe Plan Irregularity Yes ☐ No ☐ *(Increase damageability grade by 1 unit)*

5.0 Non-structural Components*:- Whether the following non-structural elements has been properly anchored/fastened keeping into consideration the potential damages from earthquake

5.1 Falling Hazards *(Brick wall/wooden partitions, Façade elements, False Ceilings, Parapets, Chimneys, Signs, display boards etc.)* Yes ☐ No ☐

5.2 Equipments & Furnishings *[Medical equipment/lab equipments, Industrial equipment (generators/machines etc.), Office Equipments (Almirah, Computer, Photocopy Machine, Printer, Fax, Shelving (Library books/pharmaceuticals etc.)]* Yes ☐ No ☐

5.3 Basic Installation & Services *[Telecommunications (Roof top antennas, Satellite Dishes) Vacuum network, Drinking water (Roof top water tanks, Water coolers), Air conditioning plants/ducts]* Yes ☐ No ☐

*Assessment of 5.0 does not modify the damageability grade of the building.

6.0 Probable Damageability in Few/Many Buildings

Building Type	6.1 Masonry Building				
Damageability	A / A+	B / B+	C / C+	D	D+
in Intensity IX	G5	G5 / G4	G4 / G3	G3	G1

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

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

RECOMMENDED ACTION:-

☐ If in the evaluation the damageability grades are G1/G2 the building may be considered seismically safe.

☐ If the damageability grade obtained is G3 the building will not be likely to collapse but subject to heavy damage. In such a case the building may be recommended for evaluation.

☐ If the damageability grade obtained are G4/G5 it indicates that the building is unsafe and will need retrofitting after re-evaluation..

☐ If any Special Hazard 4.0 found , re-evaluate for possible retrofitting.

☐ If any of the falling hazard (5.1) is present, either remove it or strengthen against falling. Items under 5.2 & 5.3 will generally need stabilization.

☐ Special observation (2.3.5) if not compliant may lead to more severe damage and will call for retrofitting.

Surveyor's sign:______ Name:__________________ Date: ______

SPACE FOR PHOTOGRAPH

1.0 General Information
1.1 Seismic Zone ____________________
1.2 Building Name____________________
1.3 Use____________________
1.4 Address:____________________
1.5 Other Identifiers____________________
1.6 No. of Stories__________ __________
1.7 Year Built ____________________
1.8 Total Covd. Area; all floors (sq.m) _____
1.9 Ground Coverage (Sq.m):____________
1.10 Soil Type: __________
2.1 Foundation Type
2.1.1 Strip footing Yes ☐ No ☐
2.1.2 Isolated pier footing Yes ☐ No ☐
2.3 Structural Components:
2.3.1 Wall Type
2.3.1.1 Earthen / clay mud / Adobe Yes ☐ No ☐
2.3.1.2 Bamboo Yes ☐ No ☐
2.3.1.3 Wooden Yes ☐ No ☐
2.3.1.4 UCR Masonry Yes ☐ No ☐
2.3.1.5 Dressed stone masonry Yes ☐ No ☐
2.3.1.6 Burnt Brick Yes ☐ No ☐
2.3.1.7 Cement Concrete Blocks Yes ☐ No ☐
2.3.1.8 Reinfoced masonry wall Yes ☐ No ☐
2.3.1.9 Thickness of wall ____________
2.3.2 Mortar Type:
2.3.2.1 Mud mortar Yes ☐ No ☐
2.3.2.2 Lime Mortar Yes ☐ No ☐
2.3.2.3 Cement Mortar Yes ☐ No ☐
2.3.3 Vert. R/F bars provided (at corners, T-junctions & Jambs)
2.3.3.1 Using Wood Yes ☐ No ☐
2.3.3.2 Using RC Yes ☐ No ☐
2.3.4 Seismic bands in all internal & ext. walls (at plinth, lintel, eaves of pitched & gable wall top)
2.3.4.1 Using wood Yes ☐ No ☐
2.3.4.2 Using RC Yes ☐ No ☐
2.3.5 Special Observation
2.3.5.1 Length of wall between two cross walls are as per the national standards*. Yes ☐ No☐
2.3.5.2 Percentage of openings in walls are as per the national standard*. Yes ☐ No ☐
2.3.5.3 Ratio of height & width of wall is as per the national standard*. Yes ☐ No ☐
2.3.5.4 Whether through stones and corner stones provided. Yes ☐ No ☐

**For example Indian Standards IS:4326 & IS:13828 have specific provisions*

Moderate Hazard MSK VII

Photograph/ Sketch Plan with Length & Breadth

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

4.2 Land Slide Prone Site Yes ☐ No ☐

4.3 Severe Vertical Irregularity Yes ☐ No ☐ *(Increase damageability grade by 2 units)*

4.4 Severe Plan Irregularity Yes ☐ No ☐ *(Increase damageability grade by 1 unit)*

5.0 Non-structural Components*:- Whether the following non-structural elements has been properly anchored/fastened keeping into consideration the potential damages from earthquake

5.1 Architectural *(Brick wall/wooden partitions, Façade elements, False Ceilings, Parapets, Chimneys, Signs, display boards etc.)* Yes ☐ No ☐

5.2 Equipments & Furnishings *[Medical equipment/lab equipments, Industrial equipment (generators/machines etc.), Office Equipments (Almirah, Computer, Photocopy Machine, Printer, Fax, Shelving (Library books/pharmaceuticals etc.)]* Yes ☐ No ☐

5.3 Basic Installation & Services *[Telecommunications (Roof top antennas, Satellite Dishes) Vacuum network, Drinking water (Roof top water tanks, Water coolers), Air conditioning plants/ducts]* Yes ☐ No ☐

***Assessment of 5.0 does not modify the damageability grade of the building.**

6.0 Probable Damageability in Few/Many Buildings

Building Type	6.1 RCF/SF Building			
Damageability in Intensity VII	C/ C+	D	E / E+	F
	G2/G1	G1	Nil	Nil

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.

RECOMMENDED ACTION:-

☐ If in the evaluation the damageability grades are G1/G2 the building may be considered seismically safe.

☐ If the damageability grade obtained is G3 the building will not be likely to collapse but subject to heavy damage. In such a case the building may be recommended for evaluation.

☐ If the damageability grade obtained are G4/G5 it indicates that the building is unsafe and will need retrofitting after re-evaluation..

☐ If any Special Hazard 4.0 found , re-evaluate for possible retrofitting.

☐ If any of the falling hazard (5.1) is present, either remove it or strengthen against falling. Items under 5.2 & 5.3 will generally need stabilization.

Surveyor's sign:______ Name:____________________ Date: ______

SPACE FOR PHOTOGRAPH

1.0 General Information

1.1 Seismic Zone ____________________

1.2 Building Name____________________

1.3 Use____________________

1.4 Address:____________________

____________Pin ______

1.5 Other Identifiers____________________

1.6 No. of Stories__________ __________

1.7 Year Built ____________________

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

1.9 Ground Coverage (Sq.m):____________

1.10 Soil Type: __________

3.0 RCF/Steel Frame Building Typology

3.1 Foundation Type

3.1.1 Individual footing Yes ☐ No ☐

3.1.2 As in 3.1.1 with interconnecting beams Yes ☐ No ☐

3.1.3 Beam raft footing Yes ☐ No ☐

3.1.4 Full Solid Raft Yes ☐ No ☐

3.1.5 Pile foundation Yes ☐ No ☐

3.1.6 Any other ____________________

3.3 Structural Components:

3.3.1 R.C. beam post buildings without Earthquake Resistant Design, built in Non-engineered way. Yes ☐ No ☐

3.3.2 Moment Resistant - RCF/SF of ordinary design without Earthquake Resistant Design. Yes ☐ No ☐

3.3.3 Moment Resistant – RCF/SF with ordinary Earthquake Resistant Design and with ordinary infill walls. Yes ☐ No ☐

3.3.4 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design and special details for ductility. Yes ☐ No ☐

3.3.5 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design and special details for ductility and with well designed infill walls/braces. Yes ☐ No ☐

3.3.6 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design, special details for ductility and with detailed RC shear walls/detailed steel braces & cladding. Yes ☐ No ☐

High Hazard MSK VIII

Photograph/ Sketch Plan with Length & Breadth

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes ☐ No ☐

4.2 Land Slide Prone Site Yes ☐ No ☐

4.3 Severe Vertical Irregularity Yes ☐ No ☐ *(Increase damageability grade by 2 units)*

4.4 Severe Plan Irregularity Yes ☐ No ☐ *(Increase damageability grade by 1 unit)*

5.0 Non-structural Components*:- Whether the following non-structural elements has been properly anchored/fastened keeping into consideration the potential damages from earthquake

5.1 Falling Hazard *(Brick wall/wooden partitions, Façade elements, False Ceilings, Parapets, Chimneys, Signs, display boards etc.)* Yes ☐ No ☐

8.2 Equipments & Furnishings *[Medical equipment/lab equipments, Industrial equipment (generators/machines etc.), Office Equipments (Almirah, Computer, Photocopy Machine, Printer, Fax, Shelving (Library books/pharmaceuticals etc.)]* Yes ☐ No ☐

8.3 Basic Installation & Services *[Telecommunications (Roof top antennas, Satellite Dishes) Vacuum network, Drinking water (Roof top water tanks, Water coolers), Air conditioning plants/ducts]* Yes ☐ No ☐

***Assessment of 5.0 does not modify the damageability grade of the building.**

6.0 Probable Damageability in Few/Many Buildings

Building Type	6.1 RCF/SF Building			
Damageability in Intensity VIII	C/ C+	D	E / E+	F
	G3/G2	G2/G1	Nil	Nil

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.

RECOMMENDED ACTION:-

☐ If in the evaluation the damageability grades are G1/G2 the building may be considered seismically safe.

☐ If the damageability grade obtained is G3 the building will not be likely to collapse but subject to heavy damage. In such a case the building may be recommended for evaluation.

☐ If the damageability grade obtained are G4/G5 it indicates that the building is unsafe and will need retrofitting after re-evaluation..

☐ If any Special Hazard 4.0 found , re-evaluate for possible retrofitting.

☐ If any of the falling hazard (5.1) is present, either remove it or strengthen against falling. Items under 5.2 & 5.3 will generally need stabilization.

Surveyor's sign:______ Name:____________________ Date: ______

SPACE FOR PHOTOGRAPH

1.0 General Information

1.1 Seismic Zone ____________________

1.2 Building Name____________________

1.3 Use____________________

1.4 Address:____________________

____________Pin ______

1.5 Other Identifiers____________________

1.6 No. of Stories__________ __________

1.7 Year Built ____________________

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

1.9 Ground Coverage (Sq.m):____________

1.10 Soil Type: __________

3.0 RCF/Steel Frame Building Typology

3.1 Foundation Type

3.1.1 Individual footing Yes ☐ No ☐

3.1.2 As in 3.1.1 with interconnecting beams Yes ☐ No ☐

3.1.3 Beam raft footing Yes ☐ No ☐

3.1.4 Full Solid Raft Yes ☐ No ☐

3.1.5 Pile foundation Yes ☐ No ☐

3.1.6 Any other ____________________

3.3 Structural Components:

3.3.1 R.C. beam post buildings without Earthquake Resistant Design, built in Non-engineered way. Yes ☐ No ☐

3.3.2 Moment Resistant - RCF/SF of ordinary design without Earthquake Resistant Design. Yes ☐ No ☐

3.3.3 Moment Resistant – RCF/SF with ordinary Earthquake Resistant Design and with ordinary infill walls. Yes ☐ No ☐

3.3.4 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design and special details for ductility. Yes ☐ No ☐

3.3.5 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design and special details for ductility and with well designed infill walls/braces. Yes ☐ No ☐

3.3.6 Moment Resistant – RCF/SF with high level of Earthquake Resistant Design, special details for ductility and with detailed RC shear walls/detailed steel braces & cladding. Yes ☐ No ☐

should take no more than one hour, the time and funds should also be allocated for pre-survey data collection. This can be extremely useful in reducing the total survey time and in increasing the reliability of data collected in the field. A good example of this is the age, or design and construction date, of a building. This might be readily available from municipality or building department files but is much more difficult to determine otherwise. Another issue to consider is travel time, if the distance between buildings to be screened is large. Other factors in cost estimation are training of personnel and the development and administration of a record keeping system for the screening process.

8.3 Pre-Field Planning

The RVS authority may decide the priorities that should be set for certain sectors within the chosen region on certain building types as for example, educational and health sector buildings that should be surveyed immediately, whereas other areas and buildings can be surveyed at a later time. An area may first be selected because it is older and may have a higher density of potentially seismically hazardous buildings relative to other areas. For example an older part of the region that consists mainly of unreinforced masonry buildings may be of higher priority than a residential section consisting of woodframe single-family dwellings.

Compiling and developing maps for the concerned region is important in the initial planning phase as well as in scheduling of the Assessor. Maps of soil profiles, maps of landslide potential, maps of liquefaction potential and those of active faults will be directly useful in the screening.

Discussions with Local Body Authorities should include the information about the dates when certain aspects of seismic design and detailing were adopted, and properly enforced.

Planning phase may include deciding how buildings are to be identified such as name of building. Its address, Census identification, lot number, and owner. Consideration should be given to developing a computerized database containing location and other building information to generate forms that incorporate unique information for each building. The advantage of using a computerized record generation and collection system is that graphical data, such as sketches and photographs, are increasingly more easily converted to digital form and stored on the computer, especially if they are collected in digital format in the field. This can be facilitated through the use of digital cameras.

8.4 Selection and Review of the Data Collection Form

The RVS Data Collection Forms are developed one for each of the seismicity regions: which may be called Low (L), Moderate (M), High (H), and Very High (VH) intensity seismic zones. Full-sized versions of each form are provided in chapter. Reference Guide that contains definitions and explanations for terms used on the Data Collection Form are also provided with the forms.

Each RVS Data Collection Form provides space to record the following:

- the building identification information,
- for drawing a sketch of the building (plan and elevation views),
- attaching a photograph of the building,
- to indicate the occupancy,
- to indicate the soil type,
- documentation of the existence of falling hazards,
- to develop a Final Structural Score and/for Damageability Grade for the building,

- to indicate if a detailed evaluation is required, and
- to provide additional comments.

8.5 Determination of Seismicity of the Region

To select the appropriate RVS Data Collection Form, it is first necessary to determine the seismicity of the region in which the area to be screened is located.

The seismicity region very (**H, M,** or **L**) for the screening area can be determined as follows:

The maximum ground motions considered in the scoring system of the RVS procedure should be consistent with those specified for detailed Seismic Structural Design procedure of India (Refer IS:1893 Part-I - 2002) the Country. Seismic Ground motions having a 2% probability of being exceeded in 50 years are commonly referred to as the Maximum Considered Earthquake (MCE) ground motions. MCE for each seismic zone of any country is specified in zoning Map specifications. Hence the location of the survey-region is to found on the seismicity map of the country or enlarged seismicity map of the state or province where available.

8.6 Qualifications and Training for Assessors

It is considered that a training program will be required to ensure a consistent, high quality of the data and uniformity of decisions among Assessors. The training should include discussion of lateral force-resisting systems and how they behave when subjected to seismic loads, how to use the RVS Data Collection Form, what to look for in the field such as the building attributes, and how to account for uncertainty. In parallel with a professional engineer (a structural engineer) experienced in seismic design, the Assessor trainees should simultaneously consider and score buildings of several different types and compare the results determined by the professional engineer. This will serve as a "calibration" for the Assessors. This process can easily be accomplished in a classroom setting with photographs and / or architectural and structural drawings of actual buildings to use as examples. Prospective Assessors should study the drawings and photographs and perform the RVS procedure as though they were in the field. Upon completion, the class should discusses the results and the trainees can compare how they did in relation to the rest of the class.

8.7 Acquisition and Review of Pre- RVS Data

Information on the structural system, age or occupancy may be available from Local Body Authority sources. These data may be selected from Municipal building department files, Building Census data and previous studies, if any should be reviewed and collated for a given area or building type under study, before commencing the field survey for that area. It is recommended that this supplemental information either be written directly on the RVS Forms as it is retrieved or be entered into a computerized database. The advantage of a database is that selected information can be printed in a report format that can be taken into the field, or printed onto structures labels that can be affixed to the relevant RVS Forms. In addition, RVS survey data can be added to the database and used to generate maps and reports.

8.8 Information about Foundation Soil Strata

Soil type has a major influence on amplitude and duration of shaking, and thus structural damage. Generally speaking, the deeper and softer the soils at a site, the more damaging the earthquake motion will be.

8.13 Sketching the Plan and Elevation Views

As a minimum, a sketch plan of the building should be drawn on the Data Collection Form. An elevation may also be useful in indicating significant features. The sketches are especially important, as they reveal many of the building's attributes to the Assessor as the sketch is made. In other words, it forces the Assessor to systematically view all aspects of the building. The plan sketch should include the location of the building on the site and distance to adjacent buildings. The sketch should note and emphasize special features such as existing significant *cracks* or *configuration* problems.

9. Quick Reference Guide for RVS in the Field

9.1 Quick Reference Guide for RVS of Masonry Buildings

RM 1. Equipment to be carried by the Surveyor:-

1) Camera, preferably digital.
2) Hard board with clip.
3) Adequate no. of survey sheets.
4) One copy of RVS guidelines.
5) One copy of Quick Reference Guide (Laminated for Repeated Use)
   Pencil & eraser/ ball pen (black), foot scale, measuring tape as found suitable

RM 2. Masonry Load Bearing Wall Buildings (Table RM 1)

Table RM 1: Masonry Load Bearing Wall Buildings

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

IS:13828-1993, "Improving Earthquake Resistance of Low Strength Masonry Buildings --- Guidelines".

IS:4326-1993, "Earthquake Resistant Design and Construction of Buildings - Code of Practice

9.2 Quick Reference Guide for RVS of RC Buildings

RC.1 Equipments to be carried by the Surveyor:-

1) Camera, preferably digital AND Binoculars for Tall Buildings.
2) Hard board with clip.
3) Adequate no. of survey sheets.
4) One copy of RVS guidelines.
5) One copy of Quick Reference Guide (Laminated for Repeated Use)

Pencil & eraser/ ball pen (black), foot scale, measuring tape as found suitable

RC.2 RC Building Types (Table RC 1)

Table RC 1: Reinforced Concrete Frame Buildings (RCF) and Steel Frames (SF)

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

**IS:13920-1993, "Ductile Detailing of Reinforced concrete structures subjected to seismic forces-Code of Practice" BIS.2002".*
**IS:1893(Part-I) 2002, "Criteria for Earthquake Resistant Design of Structures", BIS 2007.*
**SP:6(6)-1972, "Plastic Design of Steel Structures-Handbook", BIS.1972.*

Notes: RCF = *Reinforced concrete column- beam frame system*
SF = *Steel column- beam frame system*
ERD = *Earthquake Resistant Design*
WRD = *Wind Resistant Design*
MR = *Moment Resistant jointed frame*

RC.3 Grades of Damageability of RCF Buildings (Table RC 2)

Table RC 2 Grades of Damageability of RCC Buildings

Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	
Structural:	Nil
Non-Structural:	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)	
Structural:	Cracks in columns & beams of frames & in structural walls.
Non-Structural:	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)	
Structural:	Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods.
Non-Structural:	Large cracks in partition & infill walls, failure of individual infill panels.
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	
Structural:	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.
Non-Structural:	Failure of loosely filled partition and infill wall panels.
Grade 5: Destruction (very heavy structural damage)	
Structural:	Collapse of ground floor parts (e.g. Wings) of the building.
Non-Structural:	Total destruction of non-structural building components.

* *The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification (shown in bold print in above Table 5.2). Non-structural damage to infills would be the same as indicated for masonry infills in the above table 5.2. Structural damage grade in steel & wooden elements still needs to be defined.*

RC.4 Relationship of Buildings Types, Earthquake Intensity and Grades of Damage Grades of Damageability of RCF Buildings (Table RC 3)

Table RC 3 Relationship of RCC Building and Damageability Grades

Type of Building	Low Intensity MSK VII	Moderate Intensity MSK VIII	High Intensity (MSK IX or More)
C and C+	*Few* of grade 2 (rest of grade 1 or0)	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)	*Many* of grade 3 *Few* of grade 4 (rest of grade 2)
D and D+	*Few* of grade 1	*Few* of grade 2	*Many* of grade 2 *Few* of grade 3 (rest of grade 1)
E and E+	-	-	*Few* of grade 2 (rest of grade 1 or 0)
F	-	-	*Few* of grade 1

NOTE:

1. *As per MSK scale, Few, Many and Most may be taken as: Few: about 5-15%, Many: about 50% and Most: about 75%.*
2. *While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many, for important buildings such as Schools and Hospital building the highest grade may be chosen even if indicated for Few.*
3. *Buildings having vertical irregularity may undergo severe damage in seismic High & Very High Intensity zones MSK (VIII and 'IX or more)' 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.*
4. *Buildings having plan irregularity may undergo a damage of one grade higher in the, Moderate, High and Very High Intensity zones MSK VII, VIII& IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.*
5. *Frame buildings of more than four storeys founded on Soft Soil may have a Damage Grade one unit higher.*

RC.5 Plan Irregularity (Fig RC 1)

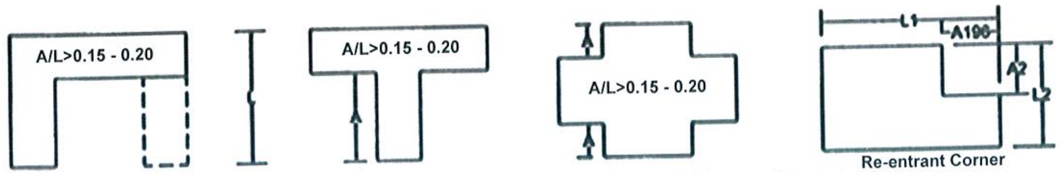


Fig. RC 1

RC.6 Vertical Irregularity (Fig RC 2)

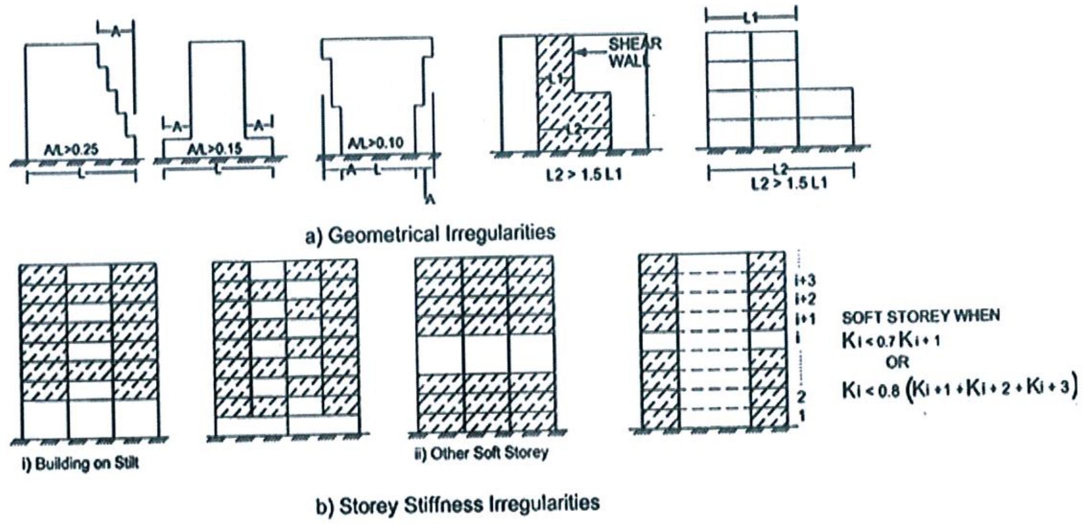


Fig. RC 2 Vertical Irregularities

RC.7 Important Notes regarding Damageability Grades

1. *As per MSK scale, Few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.*
2. *While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many.*
3. *For many important buildings such as Schools and Hospital buildings, the highest grade may be chosen even if indicated for* ***Few****, and checked for hazard Intensity of* ***next higher zone****.*
4. *Buildings having vertical irregularity may undergo one grade higher damage in seismic Moderate & High Intensity zones MSK (VIII and 'IX or more)' if not specifically designed.*
5. *Buildings having plan irregularity may undergo a damage of one grade higher in the Moderate, High and Very High Intensity zones MSK VII, VIII& IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.*
6. *Masonry buildings of three storey height may have a damage grade one unit higher, as also buildings founded on Soft Soil.*
7. *Buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.*

10. Template for RVS of Buildings

The total template is in two parts given in main sections 10.1 and 10.2 covering the following aspects:

Section 10.1 gives questionnaire through witch all the data about the general buildings including office, school and hospital buildings may be collected by the assessor. The data points are digitally numbered so that the whole data could be entered in the computer data base dealing with all the buildings. In the cases where all data has been obtained, rapid assessment of the seismic safety of the building could be carried out while sitting in office and site visit will be useful to verify and authenticate the data.

Section 10.2 deals with the RVS forms and quick reference guide for Masonry and R.C Frame buildings which was fully explained in Chapter 7 and only the RVS forms and quick reference guide are presented in this Section.

10.1 Questionnaire for Collection of Building Data

1.0 General Information

1.1 Seismic Zone ____________________

1.2 Building Name ____________________

1.3 Use ____________________

1.4 Address: ____________________

____________ *Pin* ____________

1.5 Other Identifiers ____________________

1.6 No. of Stories __________

1.7 Year Built __________

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

1.9 Ground Coverage (Sq.m): __________

1.10 Soil Type: __________

2.0 Masonry Building Typology

2.1 Foundation Type

2.1.1 Strip footing — *Yes* ☐ *No* ☐

2.1.2 Isolated pier footing — *Yes* ☐ *No* ☐

2.1.3 Any other ____________________

2.2 Roof whether flat or pitched with material

2.2.1 Flat Roof or Floor

2.2.1.1 Wooden joist with earth fill — *Yes* ☐ *No* ☐

2.2.1.2 Steel joist with stone slabs — *Yes* ☐ *No* ☐

2.2.1.3 Jach arch roof/ floor — *Yes* ☐ *No* ☐

2.2.1.4 Reinforced cement concrete/reinforced brick Concrete — *Yes* ☐ *No* ☐

2.2.1.5 Any other (please describe) ____________________

2.2.1.6 *Thickness of slab* Yes ☐ No ☐

2.2.2 *Pitched roof Understructure*

2.2.2.1 *Bamboo truss/rafter/purlin* Yes ☐ No ☐

2.2.2.2 *Wooden truss/rafter/purlin* Yes ☐ No ☐

2.2.2.3 *Steel truss/purlin* Yes ☐ No ☐

2.2.2.4 *Any other (please describe)*______________________________

2.2.3 *Pitched Roof Covering*

2.2.3.1 *Stone slates* Yes ☐ No ☐

2.2.3.2 *Burnt Clay Tiles* Yes ☐ No ☐

2.2.3.3 *Corrugated Galvanised Iron (CGI)Sheets* Yes ☐ No ☐

2.2.3.4 *Asbestos Cement (A.C.) Sheets* Yes ☐ No ☐

2.2.3.5 *Fibre sheets* Yes ☐ No ☐

2.2.3.6 *Any other* ______________________________

2.3 *Structural Components:*

2.3.1 *Wall Type*

2.3.1.1 *Earthen / clay mud / Adobe* Yes ☐ No ☐

2.3.1.2 *Bamboo* Yes ☐ No ☐

2.3.1.3 *Wooden* Yes ☐ No ☐

2.3.1.4 *Uncoursed Random Rubble Masonry* Yes ☐ No ☐

2.3.1.5 *Dressed stone masonry* Yes ☐ No ☐

2.3.1.6 *Burnt Brick* Yes ☐ No ☐

2.3.1.7 *Cement Concrete Blocks* Yes ☐ No ☐

2.3.1.8 *Any other (please state)* ______________________________

2.3.1.9 *Thickness of wall* ______________________________

2.3.2 *Mortar Type:*

2.3.2.1 *Mud mortar* Yes ☐ No ☐

2.3.2.2 *Lime Mortar* Yes ☐ No ☐

2.3.2.3 *Cement Mortar* Yes ☐ No ☐

2.3.3 *Vert. R/F bars provided*

2.3.3.1 *At Corners* Yes ☐ No ☐

2.3.3.2 *At T-junctions* Yes ☐ No ☐

2.3.3.3 *At Jambs of doors/windows* Yes ☐ No ☐

2.3.4 *Seismic bands in all external and internal walls*

2.3.4.1 *Plinth level* Yes ☐ No ☐

2.3.4.2 *Lintel level of doors and windows* Yes ☐ No ☐

2.3.4.3 *Eaves level of pitched roofs* Yes ☐ No ☐

2. 3.4.4 *Gable wall top* Yes ☐ No ☐

2.3.4.5 *Window Sill Level*

2.3.5 *Special Observation (as per IS:4326 and IS:13828)*

2.3.5.1 *Length of wall between two cross walls* Yes ☐ No ☐

2.3.5.2 *Percentage of openings in wall* Yes ☐ No ☐

2.3.5.3 *Ratio of height & width of wall* Yes ☐ No ☐

3.0 *Reinforced Concrete/Steel Frame Building Typology*

3.1 *Foundation Type*

3.1.1 *Individual footing* Yes ☐ No ☐

3.1.2 *As in 3.1.1, with interconnecting beams* Yes ☐ No ☐

3.1.3 *Beam raft footing* Yes ☐ No ☐

3.1.4 *Full Solid Raft* Yes ☐ No ☐

3.1.5 *Pile foundation* Yes ☐ No ☐

3.1.6 *Any other* ______________________________

3.2 *Roof whether flat or pitched with material*

3.2.1 *Flat Roof and Floor*

3.2.1.1 *Reinforced concrete flat slab on T beam* Yes ☐ No ☐

3.2.1.2 *Steel beam and steel plate deck* Yes ☐ No ☐

3.2.1.3 *Overall thickness of floor/roof*________________

3.2.2 *Pitched roof Understructure*

3.2.2.1 *Reinfoced Cement Concrete* Yes ☐ No ☐

3.2.2.2 *Steel truss/purlin* Yes ☐ No ☐

3.2.2.3 *Any other (please describe)*________________

3.2.3 *Pitched Roof Covering*

3.2.3.1 *Corrugated Galvanised Iron (CGI)Sheets* Yes ☐ No ☐

3.2.3.2 *Asbestos Cement (A.C.) Sheets* Yes ☐ No ☐

3.3.2.3 *Fibre Sheets* Yes ☐ No ☐

3.2.3.4 *Any other* ________________

3.3 *Structural Components: (ERD Earthquake Resistant Design)*

3.3.1 *'R.C. beam-post' buildings without ERD, (built in Non-engineered way).* Yes ☐ No ☐

3.3.2 *Reinforced Concrete Frame (RCF) of ordinary design for gravity loads without ERD.* Yes ☐ No ☐

3.3.3 *Moment Resistant - RCF/SF (steel Frame) of ordinary design without ERD.* Yes ☐ No ☐

3.3.4 *Moment Resistant - RCF/SF with ordinary ERD and with ordinary infill walls.* Yes ☐ No ☐

3.3.5 *Moment Resistant - RCF/SF with high level of ERD and special details as per IS:13920/Plastic Hand Book.* Yes ☐ No ☐

3.3.6 *Moment Resistant - RCF/SF with high level of ERD and special details as per IS:13920 or plastic hand book and with well designed infill walls/braces.* Yes ☐ No ☐

RVS Procedure of FEMA 154

A.1 Background

Basically the FEMA 154 procedure is based on Seismicity zone classification, building typology and soil classification used in USA and analysis for performance of buildings obtained during the earthquake occurrences in California.

The FEMA *Handbook 154* provided a "sidewalk survey" approach that enabled users to classify surveyed buildings into two categories: those acceptable as to *risk to life safety* or those that may be seismically hazardous and should be evaluated in more detail by a design professional experienced in seismic design.

A.2 Parameters considered in RVS

The following parameters are considered in the RVS Data Form for determing the total numerical score of building (See Fig. A.1)

1. Seismic Hazard Intensity
2. Building Type and Occupancy
3. Height of the building
4. Vertical Irregularity of the building
5. Plan irregularity of the building
6. Conformity to the seismic building code in the design or not
7. Soil Type in the foundation

Among the above parameters, each Hazard Intensity has a separate Form and the building type is assigned a Basic Score which is in fact related to its lateral load resisting structural system and earthquake performance observed in past earthquake. The other five parameters are used as Modifiers to the Basic Score. The final score is the total sum of the Basic Score and the Modifiers.

The other information on the data collection form is the following:

1. Address of the building and other relevant data, name of the Screener (Assessor)
2. Building Occupancy (use and maximum number of occupants).
3. Soil Type
4. Falling hazards

Space is provided for the Screener (Assessor) for making a sketch of the building, and attaching a photograph thereof. Beside giving the result 'Detailed evaluation required or not, space is provided for comments by the Assessor.

The building parameters forming part of the date collection form are explained below in brief.

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

LOW Seismicity

Address: ____________
____________ Zip ______
Other Identifiers ____________
No. Stories ____________ Year Built ______
Screener ____________ Date ______
Total Floor Area (sq. ft.) ____________
Building Name ____________
Use ____________

Scale:

PHOTOGRAPH

OCCUPANCY

Assembly, Govt, Office, Commercial, Historic, Residential, Emer. Services, Industrial, School

Number of Persons: 0 – 10, 11 – 100, 101-1000, 1000+

SOIL TYPE

A	B	C	D	E	F
Hard Rock	Avg. Rock	Dense Soil	Stiff Soil	Soft Soil	Poor Soil

FALLING HAZARDS

☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other: ______

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

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

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm
SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Fig. 6.1 RVS Format (FEMA 154)

A.3 Seismic Hazard Intensities

According to FEMA 154, the level of hazard intensity will be determined in the following manner. From the seismic hazard map of the country, find the design Spectral Accelerations (SA) for the time Period of 0.2 second and 1.0 second, then multiply the value by a factor of 2/3 and check the calculated values as below:

Table A.1 Definition of Hazard Intensities in FEMA 154 RVS Handbook

Level of Seismic hazard intensity	Calculated 2/3 SA for period of 0.2 second	Calculated 2/3 SA for period of 1.0 second
High Hazard	Greater than or equal to 0.50 g	Greater than or equal to 0.20 g
Moderate Hazard	Between 0.167 g and 0.5 g	Between 0.067 g and 0.20 g
Low Hazard	Less than 0.167 g	Less than 0.067 g

A.4 Building Types

The building types considered are given in Table A.2 along with the basic score assigned to them in the three Hazard Intensities area. It may be seen that these types are as seen in USA in general and California in particular. It will be only rare to find exactly similar buildings in India.

Table A.2 Building Types in RVS of FEMA 154

Building Identifier	Description	Basic Structural hazard Score		
		High Hazard	Mod. Hazard	Low Hazard
C2 Concrete shear wall buildings	Concrete shear- wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. Shear-wall thickness ranges from 6 to 10 inches (150-250 mm).	2.8	3.6	4.8
C3 Concrete frames with unreinforced masonry infill walls	Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. Usually masonry is exposed on the exterior with narrow piers (less than 4 ft, 1.2 m wide) between windows.	1.6	3.2	4.4
PC1 Tilt –up buildings	Tilt-ups are typically one or two stories high and are basically rectangular in plan. Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab.	2.6	3.2	4.4
PC2 Precast concrete frame buildings	Precast concrete frames are, in essence, post and beam construction in concrete. Structures often employ concrete or reinforced masonry (brick and block) shear walls.	2.4	3.2	4.6
RM1 Reinforced masonry buildings with flexible diaphragms	Walls are either brick or concrete block. Wall thickness is usually 8 inches to 12 inches (300 mm). Interior inspection is required to determine if diaphragms are flexible or rigid.	2.8	3.6	4.8

Building Identifier	Description	Basic Structural hazard Score		
		High Hazard	Mod. Hazard	Low Hazard
RM2 Reinforced masonry buildings with rigid diaphragms	Walls are either brick or concrete block. Wall thickness is usually 8 inches to 12 inches (200-300 mm). Interior inspection is required to determine if diaphragms are flexible of rigid.	2.8	3.4	4.6
URM Unreinforced masonry buildings	These buildings often used weak lime mortar to bond the masonry units together. Arches are often an architectural of older brick bearing wall buildings.	1.8	3.4	4.6
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 sq ft (465 m²)	Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). Most common exterior finish materials are wood siding, metal siding, or stucco.	2.8	5.2	7.4
W2 Light wood frame buildings greater than 5,000 sq ft (465 m²)	These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and rarely, as tall as six stories.	3.8	4.8	6.0
S1 Steel moment resisting frame	Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings.	2.8	3.6	4.6
S2 Braced steel frame	These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. Braced frames are sometimes used for long and narrow buildings because of their stiffness.	3.0	3.6	4.8
S3 Light metal building	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.	3.2	3.8	4.6
S4 Steel frames with cast-in-place concrete shear walls	Lateral loads are resisted by shear walls, which usually surround elevator crores and stairwells, and are covered by finish materials.	2.8	3.6	4.8
S5 Steel frames with unreinforceed masonry infill walls	Steel columns are relatively thin and may be hidden in walls. Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows.	2.0	3.6	5.0
C1 Concrete moment resisting frames	All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). A fundamental factor governing the performance of concrete moment resisting frames is the level of ductile detailing.	2.5	3.0	4.4

A.5 Height of Building

Two height ranges are considered: (i) Mid-Rise (4 to 7 storeys) and ii) High Rise (more than 7 storeys).

The height of a storey will generally be in the range 2.8 to 4 m. The storey may be counted from where the building is considered fixed near its base. In a stepped building, the face having the maximum number of storeys may be considered.

Some building types namely, URM, PCI, S3, W2 and W1 are generally low height, hence modification score for height are Not Applicable (N/A).

In this RVS procedure, the score modifiers for greater than 3 storeys are seen to be positive, that is, such buildings are considered safer against seismic hazard, possibly because of use of better quality material like concrete & better quality masonry, better design proficiency and higher skills in construction.

A.6 Plan irregularity

Plan irregularity (see Fig. A.3) also lowers the performance of a building under earthquake motions, hence the score modifier has a negative value.

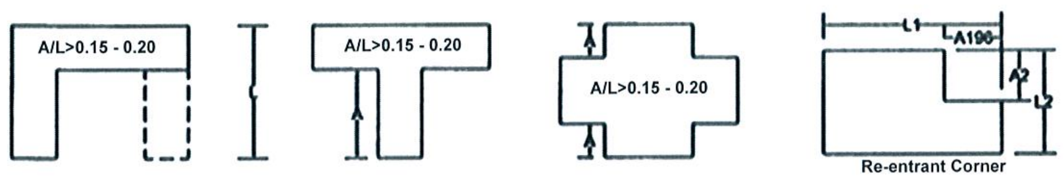


Fig. A.3 Plan Irregularities

A.7 Vertical Irregularity

Vertical irregularity (see Fig. 6.4) particularly in stiffness is considered a serious weakness and the corresponding score modifier is negative for all building types.

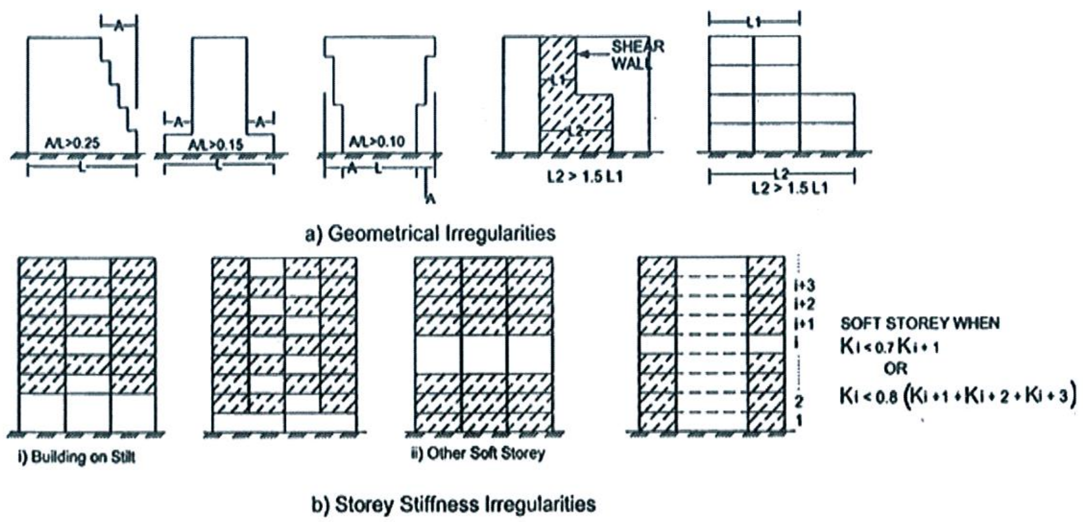


Fig. A.4 Vertical Irregularities

A.8 Conformity with earthquake Resistant Building Code:

Here a number of situations will arise:

(i) *Pre Code construction* - The design and construction of the building was done before the seismic building code was adopted. For example in India the earthquake codes were published as follows:

IS: 1893-1962, "Criteria for Earthquake Resistance Design of Structure".

IS: 4326-1967, "Earthquake Resistance Design and Construction of Buildings--Code of Practice".

All framed construction before 1963 and all masonry buildings before 1968 may be considered without Earthquake Resistant Design, that is, (without ERD).

(ii) *Code Revised and made more stringent* - The building may have been designed as per the then Earthquake Code but may be deficient in terms of the revised Code.

(iii) *Building not designed for the Earthquake Code* - This situation may be commonly found in India since the use of Code may not be mandatory in the Municipal Building Bylaws.

In the score modifiers, Pre Code and Post Benchmark are stated which will infact mean 'No ERD' and 'Code Compliant'. Obviously Pre Code (No ERD) will indicate decrease of seismic safety and will have negative score modifier. And Post Benchmark (Code Compliant) will increase seismic safety, hence positive score modifier.

A.9 Type of Base Soil

In the USA standard, six soil type are considered

Type A	Hard Rock
Type B	Average Rock
Type C	Soft Rock / Dense Soil
Type D	Stiff Soil
Type E	Soft Soil
Type F	Poor Soil

The Basic Score given in the Data Collection Form is for Rocks i.e., Types A & B. Soil type F if met under a building will be referred to a geotechnical expert for the site evaluation of the building. For the cases for Soil Types C, D and E, there is a negative effect on seismic safety, the **negative** effect being more as the soil becomes softer. Thus the score modifiers are negative, become more negative for soil type E and least for soil type C.

A.10 Falling Hazard

They include **unreinforced** smoke chimneys, parapets, infill and cladding walls. If present, the comments will have to specify the need for their stabilization using appropriate means.

A.11 The Basic Score, the Score Modifiers and the Final Score

The structural scoring system consists of a matrix of Basic Structural Hazard Scores (one for each building type and its associated seismic lateral force-resisting system) and Score Modifiers to seismic performance. The Basic Structural Hazard Scores and Score Modifiers are based on (1) design and construction practices in the California region of USA, (2) attributes known to decrease or increase seismic resistance capacity, and (3) maximum considered ground motions for the seismicity region under consideration. The Basic Structural Hazard Score, Score Modifiers, and Final Structural Score, S, all relate to the probability of building collapse, should the maximum ground motions considered by the RVS procedure occur at the site. Final S scores typically range from 0 to 7, with higher S scores corresponding to better seismic performance.

The maximum ground motions considered in the scoring system of the RVS procedure are consistent with those specified for detailed building seismic evaluation in the FEMA 310 Report, Handbook for the Seismic Evaluation of Buildings-A Pre standard. Such ground motions generally have a 2% chance of being exceeded in 50 years, and are multiplied by a 2/3 factor in the FEMA 310 evaluation procedures and in the design requirements for new buildings in FEMA 302, Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. (Ground motions having a 2% probability of being exceeded in 50 years are commonly referred to as the Maximum Considered Earthquake (MCE) ground motions).

Note: The Peak Ground Acceleration (PGA) values specified for MCE in each seismic zone (IS:1893-2002) are based on same definition.

Determination of Cut-Off Score:

Use of the RVS on a community-wide basis enables the RVS authority to divide screened buildings into two categories: those that are expected to have acceptable life safety seismic performance, and those that may be seismically hazardous and should be studied further. This requires that the RVS authority to determine, preferably as part of the pre-planning process, an appropriate "cut-off" score. The S score of 2 is suggested as a "cut-off", based on present seismic design criteria. Using this cut-off level, buildings having an S score of 2 or less should be investigated by a design professional experienced in seismic design, and S>2 may be taken as acceptable seismic safety of the building.

A.12 The Data Collection Forms

There is one form for each Hazard Intensity, namely **High** Seismicity, **Moderate** Seismicity & **Low** Seismicity.

Table A.2 Building Types in RVS of FEMA 154

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

LOW Seismicity

Address: ____________
____________ **Zip** ____________
Other Identifiers ____________
No. Stories ____________ **Year Built** ____________
Screener ____________ **Date** ____________
Total Floor Area (sq. ft.) ____________
Building Name ____________
Use ____________

Scale:

PHOTOGRAPH

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

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

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

COMMENTS

Detailed Evaluation Required

YES NO

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

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

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

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

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

MODERATE Seismicity

Address: ______________________________

______________________________ Zip __________

Other Identifiers ______________________________

No. Stories ______________________ Year Built ________

Screener ______________________ Date ________

Total Floor Area (sq. ft.) ______________________

Building Name ______________________________

Use ______________________________

Scale:

PHOTOGRAPH

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

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

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

COMMENTS

Detailed Evaluation Required

YES NO

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

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

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

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

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

HIGH Seismicity

Address: ______________________________

______________________________ Zip __________

Other Identifiers ______________________________

No. Stories ______________________ Year Built ________

Screener ______________________ Date ________

Total Floor Area (sq. ft.) ______________________

Building Name ______________________________

Use ______________________________

Scale:

PHOTOGRAPH

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

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

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

COMMENTS

Detailed Evaluation Required

YES NO

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

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

MRF = Moment-resisting frame
RC = Reinforced concrete
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SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)
Quick Reference Guide (for use with Data Collection Form)

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

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

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: ______

3. Occupancy Loads

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

4. Score Modifier Definitions

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

ABOUT BMTPC

Building Materials & Technology Promotion Council under the auspices of Ministry of Housing & Urban Poverty Alleviation is an autonomous organization dedicated to promote and popularize cost effective, eco-friendly and energy efficient building materials and disaster resistant construction technology. BMTPC works as a technology transfer council and helps various stake holders involved in the construction industry for technology development, production, mechanization, implementation, standardization, certification & evaluation, training & capacity building and entrepreneur development. Over the last two decades, BMTPC has expanded its activities and made commendable efforts in the area of disaster mitigation and management.

Ever since 1991 Uttarkashi earthquake, BMTPC has been pro-actively involved not only in seismic rehabilitation but also in the area of prevention, mitigation & preparedness as regards earthquake safety is concerned. The widely popularized publication of BMTPC entitled 'Vulnerability Atlas of India' is one of its kind which depicts the vulnerability of various man made constructions in different districts of India not only from earthquake hazards but also from Wind/Cyclone and Flood hazards. Efforts of BMTPC were applauded well and in the process UN Habitat selected the same as one of the Best Practices. It is being BMTPC's endeavour to constantly publish guidelines, brochures, pamphlets on natural hazards so as to educate the common man and create capacities within India to handle any disaster. BMTPC has recently published the following documents:-

1. Guidelines for Multi-Hazard Resistant Construction of EWS Housing Projects
2. Guidelines on "Aapda Pratirodhi Bhawan Nirman : Sampurn Bharat Ke Liye Margdarshika" (in Hindi)
3. Guidelines : Improving Earthquake Resistance of Housing
4. Guidelines : Improving Flood Resistance of Housing
5. Guidelines : Improving Wind/Cyclone Resistance of Housing
6. Manual on Basics of Ductile Detailing
7. Building a Hazard Resistant House, a Common Man's Guide
8. Manual for Restoration and Retrofitting of Buildings in Uttarakhand & Himachal Pradesh.
9. Seismic Retrofitting of MCD School Buildings at New Delhi

These documents are important tools for safety against natural hazards for various stake holders involved in disaster mitigation and management. Apart from publications, the council is also involved in construction of disaster resistant model houses and retrofitting of existing life line buildings such as Schools/Hospitals to showcase different disaster resistant technologies and also spread awareness amongst artisans and professionals regarding retrofitting and disaster resistant construction.

BMTPC joined hands with Ministry of Home Affairs to draft Model Building Bye-laws incorporating disaster resistance features so that State/UT Governments incorporate them into their municipal regulations and prepare themselves against natural hazards. One of the very basic publications of BMTPC with IIT, Kanpur has been 'Earthquake Tips' which was specially designed and published to spread awareness regarding earthquake amongst citizens of India in a simple, easy to comprehend language. The tips are being published in other languages also so that there is greater advocacy and public out reach regarding earthquake safety.

For further information, please contact:

bmtpc

Executive Director
Building Materials & Technology Promotion Council,
Ministry of Housing & Urban Poverty Alleviation, Government of India,
Core-5A, 1st Floor, India Habitat Centre, Lodhi Road, New Delhi - 110003
Phone: +91-11-24638096, Fax: +91-11-24642849
E-Mail: bmtpc@del2.vsnl.net.in; info@bmtpc.org
Website: http://www.bmtpc.org

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