2014

Integrated Rapid Visual Screening of Buildings for Seismic Hazard

A GUIDE BOOK FOR INTEGRATED RAPID VISUAL SCREENINGS OF BUILDINGS

TARU

TARU

TARU Leading Edge Private Ltd.

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Edited by: Anup Karanth

Author: Shashank Mishra

Preface

In recent past due to rapid growth of Indian cities, there is a tremendous increase on housing industry, especially in seismic Zone-IV & V. As most of these constructions are without earthquake resistant measures, the built environment in these zones has been found seismically vulnerable. Since Indian cities are built with varied varieties of building typologies, comprising of poorly designed and less maintained ones, the seismic safety of these constructions became the most challenging task. Seismic vulnerability is a measure of the seismic strength or capacity of a structure, hence it is found to be the main component of seismic risk assessment. Detailed seismic vulnerability evaluation is a technically complex and expensive procedure and can only be performed on a limited number of buildings. It is therefore very important to use simpler procedures that can help to rapidly evaluate the vulnerability profile of different types of buildings, so that the more complex evaluation procedures can be limited to the most critical buildings.

Different methods for seismic evaluation of existing buildings have developed in various countries. Most of the methods follow three level assessment procedures, (a) rapid visual screening (RVS), (b) preliminary assessment, and (c) detailed evaluation. RVS of buildings is the first step of the building vulnerability assessment. It was observed that few buildings scored well on available standard RVS format performed poorly in previous earthquake events. It was due to non- inclusion of building distress issues which severely affect the load carrying capacity of the buildings. An integrated RVS term is used here to include building distress parameters. Later preliminary and detailed vulnerability assessment can be carried out on the selected number of buildings according to the performance score of the buildings.

This guide book is developed on the basis of the TARU's experience of conducting building vulnerability assessment on large scale across different parts of the country. Their rich experience of conducting RVS training program in different states of the country contributed effectively in developing this guide book.

This guide book is intended to serve as guiding document of conducting the RVS of buildings in India. This guide serves the purpose of a reference book for building inspectors who may use it during field survey. This book provides detail of seismic safety features of both masonry and reinforced concrete frame (RC) buildings. Non-structural hazards are also covered briefly in this guide book as they share a large percentage in terms of economic damage and also pose threat to human safety. Some examples of RVS format and studies were also cited here.

TARU acknowledges all the people involved in their previous building vulnerability assessment studies in different states of India who have contributed directly or indirectly in the development of this guide book. Discussions on different aspect of RVS during training programs have been very useful in providing the final shape to this guide book.

Table of Content

Abbreviation

FEMA	Federal Emergency Management Agency
METU	Middle East Technical University
BIS	Bureau of Indian Standard
BVA	Building Vulnerability Assessment
RVS	Rapid Visual Screening
PVA	Preliminary Vulnerability Assessment
DVA	Detailed Vulnerability Assessment
NDT	Non Destructive Testing
NDMA	National Disaster Management Authority
NIDM	National Institute of Disaster Management
FEM	Finite Element Method
AEM	Applied Element Method
NBC	National Building Code
PS	Performance Score
BS	Basic Score
VS	Vulnerability Score
VSM	Vulnerability Score Modifier

Chapter 1. Introduction

1.1 Background: Past earthquake events in the last few decades like Jabalpur earthquake (1997), Uttarkashi earthquake (1991), Latur earthquake (1993), Bhuj Earthquake (2001), Jammu & Kashmir (J&K) earthquake (2005) and Sikkim earthquake (2011) have widely exposed the vulnerability of buildings in India. These earthquake events cause massive damage to buildings. Jammu & Kashmir (J&K) earthquake of 8th October 2005 caused massive destruction to lives and properties in Pakistan as well as Indian part of J&K. Official report confirms 1300 death and collapse of 37607 masonry buildings in Indian part of J&K (Source: Arya 2005). Bhuj earthquake of 26th January 2001 took the lives of 13805 people and 12, 05,198 houses were partially or severely damaged (Source: Govt. of Gujarat). Sikkim earthquake of magnitude M6.8 damaged around 55000 buildings (NDMA 2011).

Studies on the damage of buildings and other structures during the past earthquakes have clearly brought out the causes of severe damages which include either lack of earthquake resistant design, not following the provisions of the Bureau of Indian Standards Building Codes, faulty building practices and also poor maintenance of buildings. Lack of arrangement of proper drainage help rainy water to seepage through foundations and deteriorate it. This may cause the settlement of foundation which increases the risk of developing large cracks in the building. For safety from earthquake hazards in future, the seismic resistance of most of the existing buildings will need upgrading by retrofitting procedures. Vulnerability of the various existing buildings need to be assessed for prioritizing the buildings for seismic upgrading.

1.2 Building Vulnerability Assessment: Building vulnerability assessment (BVA) is required to assess the condition of building stock present across the state. BVA should be undertaken to identify the buildings and critical infrastructure which require special attention in order to make them more resistant against the natural disasters.

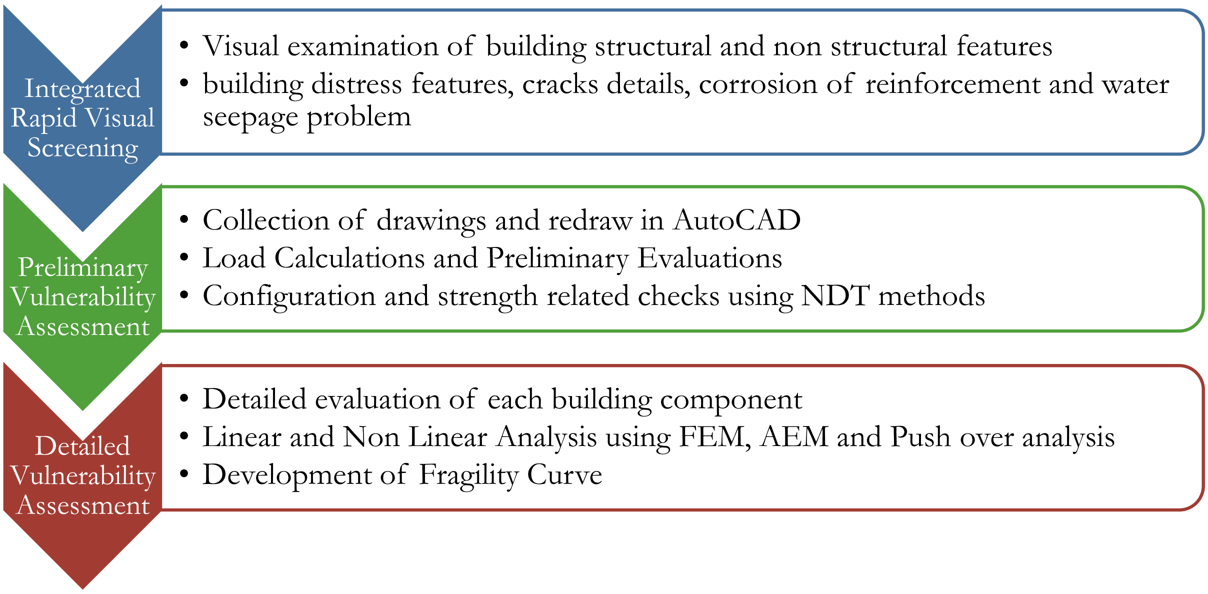


Figure 1: Building Vulnerability Assessment Process (TARU, 2013)

Building vulnerability assessment (BVA) is a three stage process. It includes rapid visual screening (RVS) of buildings, preliminary vulnerability assessment (PVA) and detailed vulnerability assessment (DVA). RVS is the first step towards assessing the vulnerability of buildings. RVS is used as a tool to identify the buildings which require further attention for strengthening their safety. PVA and DVA is carried out on selected number of buildings only due to their high cost, time consuming process and technical complexity. PVA procedure requires information obtained from visual information, architectural/ structural drawings or on-site measurement and material characteristics obtained from non-destructive testing of buildings. DVA procedure requires detailed computer analysis hence more complex in nature.

1.3 Integrated Rapid Visual Screening: Rapid Visual Screening (RVS) methodology was first developed by "Applied Technology Council" in the late 1980's and published in FEMA 154 in 1988. RVS format was first time introduced for masonry buildings in Indian building code in 2009 i.e. IS 13935:2009 "Seismic Evaluation, Repair and Strengthening of Masonry Buildings - Guidelines". This RVS format was designed for earthquake.

RVS is a form of survey to identify the buildings which are expected to be more vulnerable under an earthquake. It is used to prioritize the buildings in a jurisdiction for further evaluation and retrofit for seismic forces (CPWD 2007). RVS is designed to evaluate the primary lateral load resisting system and to identify the building attributes that modify the seismic performance of the lateral load resisting system along with the non-structural components. A building may require 15 to 30 minutes for RVS depending upon the size of the building. Data collection and decision making process will occur at the building site.

Table 1: Integrated RVS Process for Seismic Hazard

General Information	Name and Address of Building, Number of Storey, Built up area, Age of Building
Use of Building	Residential, Educational. Institutional, Assembly, Commercial, Emergency, Service, Important Government Office and Cowsheds
Geotechnical Characteristics	Site Morphology, Soil type, Soil Nature, Liquefaction Potential of soils, Slope of the ground
Building Types	Rammed Earth, Brick Masonry, Stone Masonry, RC Frame, Wooden Structures and Others
Vulnerability Factors	**Architectural Features:** Shape of the building, Dimension of building
	Material Characteristics: Material of wall, floor and roof, mortar, ratio of mix mortar
	Structural Features: orthogonal frame, presence of secondary beams, presence of horizontal band, ratio of wall length and height to the thickness of the wall
	Workmanship: Quality of concreting, quality of construction
	Building Distress: presence of cracks, cracks width and their shape, different deformation, level of corrosion
Source: TARU Analysis 2013	

Standard RVS format available in India does not capture the building distress features such as type and width of cracks in the building, foundation settlement, sagging of beam or floor etc. Other features such as water seepage problem, corrosion of reinforcement, lack of maintenance issues etc. did not appear in the format which may severely reduce the load carrying capacity of the buildings. It is found that buildings performed well on these standard RVS format may get severely damaged during earthquake due to non-inclusion of above mentioned factors. To avoid these shortcoming, integrated RVS is introduced which includes building distress and other important parameters also. This information may also be utilized in conducting preliminary and detailed vulnerability assessment of the buildings.

1.4 How to Use this Guide Book: This guide book has been designed to facilitate the building inspectors (engineers/ architects) in conducting the integrated rapid visual screening of buildings. Chapter 1 describes the need of vulnerability assessment of buildings and concept of integrated of rapid visual screening of buildings. Chapter 2 contains detailed information on the parameters to be looked upon while conducting integrated RVS. Subsections in chapter 2 describe the parameters needed about the general information of building, seismic safety of masonry and RC frame buildings, building distress and conditional assessment of the building and non-structural falling hazards. Chapter 3 provides guidance on data analysis and interpretation of result of RVS survey. Chapter 4 provides brief description of PVA and DVA which need to be carried out for selected buildings on the basis of performance score. Chapter 5 draws the conclusion.

Seismic zonation of India, IS code for seismic safety of buildings and some samples of RVS format have been described in annexure 1,2 & 3 respectively. Annexure 4 shows example of RVS/ performance scoring of masonry and RC frame buildings.

Chapter 2. Integrated Rapid Visual Screening of Buildings

This chapter describes the detail information of those structural and non-structural parameters which are required to be assessed during integrated rapid visual screening of the building.

2.1 General Information Required for RVS:

The first step in conducting the integrated rapid visual screening of buildings is to fill the general information about the building which is being surveyed. The information consists of name & address of the building, type of use, built up area, building type, type of mortar and type of material used in floor, wall and roof construction.

2.1.1 Building Name and Address: Name of the building and name of the owner of the building should be filled into the RVS form. Address of the building should be entered along with the name of the village/block, district and the state. This information will help to identify the building if it has to be further assessed for preliminary and detailed vulnerability assessment.

2.1.2 Use of Building: Purpose of occupancy of the building is important to know. Type of occupancy helps to prioritize the buildings for risk mitigation measures. Change in the occupancy of building over a period of time pose a threat as building originally designed to carry a certain load may cross the limit of designed load.

Building use can be defined in four different classes i.e. Residential, Institutional (schools, college, hospital, old age homes, training centre etc.), Commercial/office (offices, shops and industrial building, fire station etc.) and Mixed (buildings used for multiple purposes such as residential and commercial both).

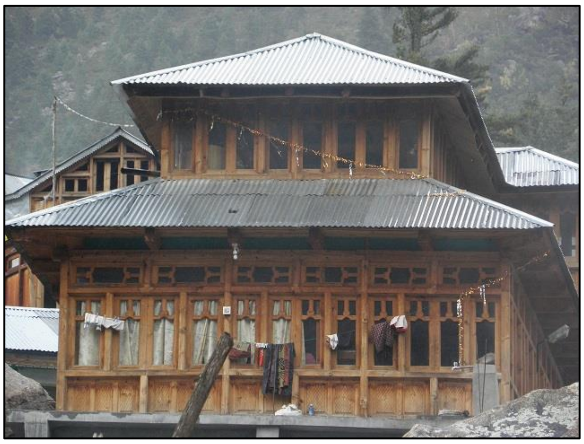
2.1.3 Building Types: Type of building should be identified as the first most important step before collecting the various relevant information during RVS. Major Building typologies can be classified into 6 different groups on the basis of the element which can take lateral load induced due to earthquakes. These 6 groups are Brick Masonry, Stone Masonry, RC Frame, Mud/Adobe buildings, Wood/ Bamboo, Hybrid type (polythene, grass, thatch, GI sheet etc.).

Rammed Earth/ Adobe Building (Kangra,2013)

Stone Masonry Building (Kinnaur,2013)

Brick Masonry Building (J&K,2013)

RC Frame Building (Kangra, 2013)



Wooden Structure (Rakcham Village, Kinnaur, 2013)

Hybrid Construction (J&K, 2013)

Figure 2: Type of Buildings (Source: TARU, 2013)

In masonry buildings, load bearing walls bear the lateral load generated due to earthquake while in RC frame structures, lateral load is taken by RC frame made of beam and column. Infill walls in RC frame structures are not supposed to carry any lateral load. Hybrid structures are more dangerous as there is no clear load carrying path in those buildings.

2.1.4 Number of Stories: Number of stories in the buildings are counted by assuming ground floor as the first storey. Taller building attract large earthquake forces hence they are unsafe in seismic zone IV and V. National building code of India (NBC2005) specifies that 4 stories buildings are not allowed in seismic zone V area.

2.1.5 Built-Up Area: It is the amount of space, the building floor plan covers. It is normally measured in square feet or square meters. If the building has multiple floors, the total built-up area of all floors is taken into account. All usable interior space is included in the build-up area, apart from outdoor balconies, but excluding elevator/staircase area.

2.1.6 Age of Buildings: Age of the buildings need to be find out from owner of the building or from the building drawings if available. Older buildings should be assessed more carefully for building distress elements. Age of the buildings also helps in getting the information about presence of seismic safety features in the buildings. Example: masonry buildings built before 1993 can be assumed that they do not have any horizontal seismic band as IS code describing horizontal bands was only published in 1993. Age can be classified into six groups of 10 years span.

Table 2: Age of the Building in years					
0-10	11-20	21-30	31-40	41-50	>50

2.1.7 Type of Wall, Roof and Floor Material: A wide variety of building materials are used in urban and rural areas of India. These include local material such as mud, straw, wood, semi engineered material such as burnt brick and stone masonry and engineered material such as concrete and steel. The seismic vulnerability of different building types depend upon the choice of building materials and construction technology adopted. Generally building vulnerability is highest with the use of local material without any engineering input and lowest with the use of engineered materials and skills.

Information about the type of material used in the construction of wall, roof and floor must be collected. Wall can be made of burnt/ unburnt brick, dressed/undressed stone, bamboo, wood, grass/thatch, mud/ rammed earth/adobe, GI sheet etc. Floor can be made of mud, cement concrete, tiles, wood/ bamboo etc. Roof is generally made of reinforced brick concrete, reinforced concrete, GI/ Asbestos sheet, Wood/bamboo, grass/thatch etc. Heavy roofs are dangerous to human safety.

2.1.8 Type of Roof: Roofs are divided into two category i.e. flat and slope roof. In masonry buildings, flat roof act as the roof band to keep the roof intact with all four walls while roof band has to be provided for sloping roof. Sloping roof may be of different kind such as gable roof, hip roof, shed roof (single sloped roof) etc. Some roof types are shown below:

Flat Roof (Una, 2013)

Shed Roof (Kangra, 2013)

Gable Roof (Dharmsala, 2013)	Hip Roof (Kangra,2013)

Figure 3: Type of Roof (Source: TARU.2013)

2.1.9 Type of Mortar: Type of material used in masonry construction play a major role in defining the crushing strength. Mortars used in the building construction can be mud, lime or cement. Few buildings are constructed without using any mortar and hence structurally very weak such as stone masonry buildings made of dressed stone. Buildings without mortar collapse easily during earthquake due to poor no bond strength of stones or bricks.

2.2 Geotechnical Characteristics:

This section describes the site morphology and soil characteristics.

2.2.1 Site Morphology: Topography affects the amplification of the ground motion in case of earthquake. Select the appropriate option whether the site is located in a flat topography, downward slope, trough or crest.
Flat: Site where the ground slope varies from 0 to 5 degree, is considered as flat.
Crest: Crest is the peak point of the hill.
Downward Slope: Building site located on the slope of the hill or mountain.
Trough: Trough is the narrow depression between two downward slopping hills.

2.2.2 Depth of Water Table: Depth of water table (in feet) has to be recorded for identifying liquefaction potential and potential damage of foundation both. A higher water table may cause the settlement of foundation due to softening of soil.

2.2.3 Type of Soil: IS 1893:2002 (Part 1) classifies the soil type into three category i.e. hard, medium and soft. The appropriate choice is to be selected after examining the soil condition. Generally soil found near the river bed are soft and soils with presence of boulders are considered as hard soil elsewhere it is considered as medium.

2.2.4 Expansive and Non Expansive Soil: Soils should be classified according to their expansive nature. Expansive soils are those soils which have a tendency to increase in volume whenever water/ moisture content are increased. Foundations resting on the expansive soil will heave and cause damage to the building by settlement or lifting of the building. Black cotton soil is the example of expansive soils. These soils can be identified by the cracks developed in the summers.

Figure 4: Crack pattern of expensive soil in dry season

(Source: www.irrigationtutorials.com)

The expansive nature of the soil can be recognized by observing the polygonal crack pattern in the dry season. Expansive soil contains organic material. Expansive soil will stick to the shoes or tires of a vehicle during the wet season.

All other soils which do not show above mentioned characteristics are termed as non-expansive soil.

2.2.5 Liquefaction Potential: Liquefaction is a state of soil when the effective stress of the soil is reduced to zero i.e. the complete loss of shear strength. Liquefaction can occur at the time of the earthquake when the soil starts behaving like a freely flowing fluid. Sandy soils with high water table (water table <3m from the ground surface) are susceptible to liquefaction.

Figure 5: Liquefaction (Bhuj Earthquake 2001, India) & Building damage due to liquefaction of soil (Niigata Earthquake 1964, Japan)

(Source: http://www.ceri.memphis.edu/gujarat/& en.wikipedia.org)

2.3 Seismic Safety Features of Masonry Buildings: This section describes the seismic safety features of masonry buildings.

2.3.1 Horizontal Plan Irregularity: Buildings with simple and regular plan configuration behave well in the earthquake. Shape of the building should be judged in the plan view to check whether it's regular or irregular configuration. Rectangular / square or circular buildings are regular configuration.

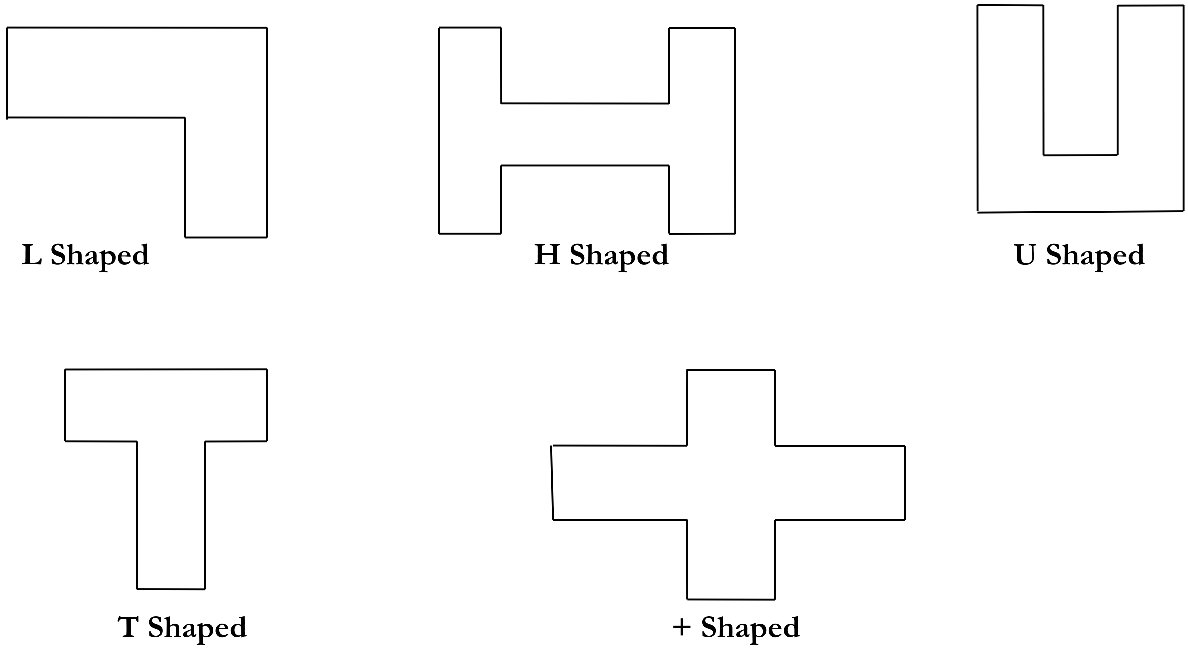


Figure 6: Shape of the Buildings (TARU Analysis, 2013)

A building shaped like a box, as rectangular both in plan and elevation, is inherently stronger than one that is L-shaped or U-shaped, such as a building with wings. An irregularly shaped building will twist as it shakes, increasing the damage. Buildings with shapes of L, H, U, T, E or + in plan are undesirable as they invite severe damage due to the presence of re-entrant corners. In these shapes, each wing of the building starts shaking separately in earthquake which can lead to potential collapse.

2.3.2 Vertical Irregularities: It is a deficiency of building that can be detected by observation on the elevation of existing buildings. Presence of step-back and setback in the buildings should be identified.

Setback is the step like recession of floor of the building in one horizontal direction.

Step-back is step like recession on the ground above which different building stories are constructed

Buildings constructed in hilly areas have peculiar structural configurations. Successive floors of such buildings step back towards the hill slope and sometimes, the buildings also set back. The stepping back of building towards hill slope results in unequal column heights in the same storey, which causes severe stiffness irregularities in along- and cross-slope directions.

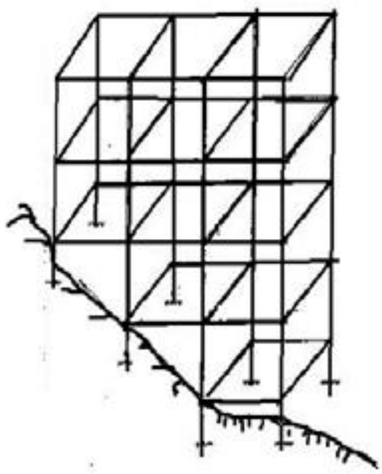


Fig. 32 Stepback building
(**Source:** WCEE, 2012)

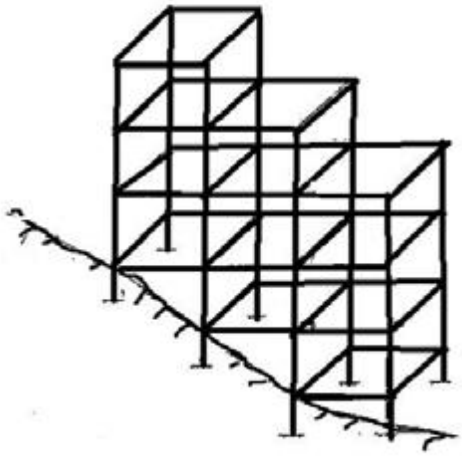


Fig.33 Setback and Stepback both
(**Source:** WCEE, 2012)

2.3.3 Horizontal Bands: Horizontal bands are provided in the masonry buildings to hold building as a single unit by tying all the walls together. There are four types of horizontal band i.e. plinth, sill, lintel and roof band. Absence of these bands with poor connection of wall at corner joints is the primary cause of the collapse of many masonry buildings during the earthquake.

Plinth band is used when there is susceptibility to uneven settlement of foundation soil.

Lintel band is the most important one as it ties the wall together and creates a support for walls loaded along the weak direction from walls loaded in a strong direction.

Sill band is used to keep the door and window intact with the wall.

Roof band is only required in case of sloped roofs to provide integral action between roof and wall. In flat reinforced concrete roofs or reinforced brick roofs, roof slab plays a role of roof band. These horizontal bands should be carefully observed in masonry building. These bands will not be observed in a plastered building. In such case, rear wall of the building should be observed to check these bands as people have tendency to leave the rear side of the wall without plaster.

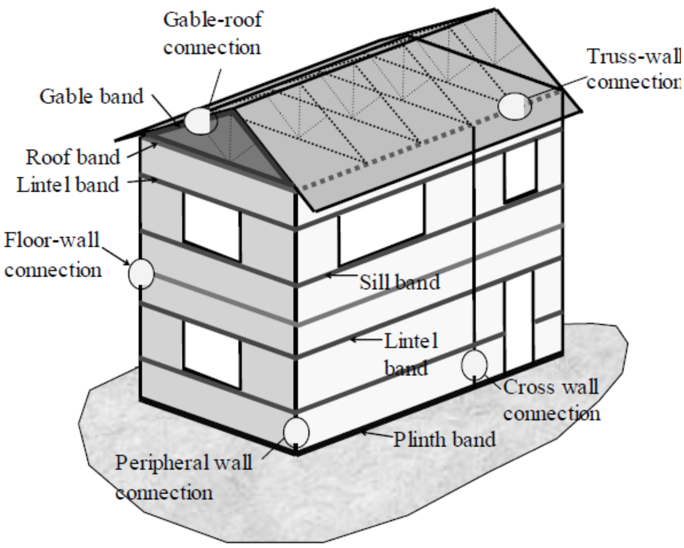


Figure 7: Building with all horizontal bands (Source: CPWD handbook, 2007)

2.3.4 Vertical Reinforcement in Jamb openings: Door and window opening reduces the stiffness of the wall and these areas are more prone to develop diagonal (shear) cracks during earthquake. Vertical reinforcement at the jamb openings reduces the possibility of developing these cracks.

All door and window openings wider than 600 mm will have vertical reinforcement in jambs as shown in figure. Vertical reinforcement should start from foundation of the floor and terminate in lintel band.

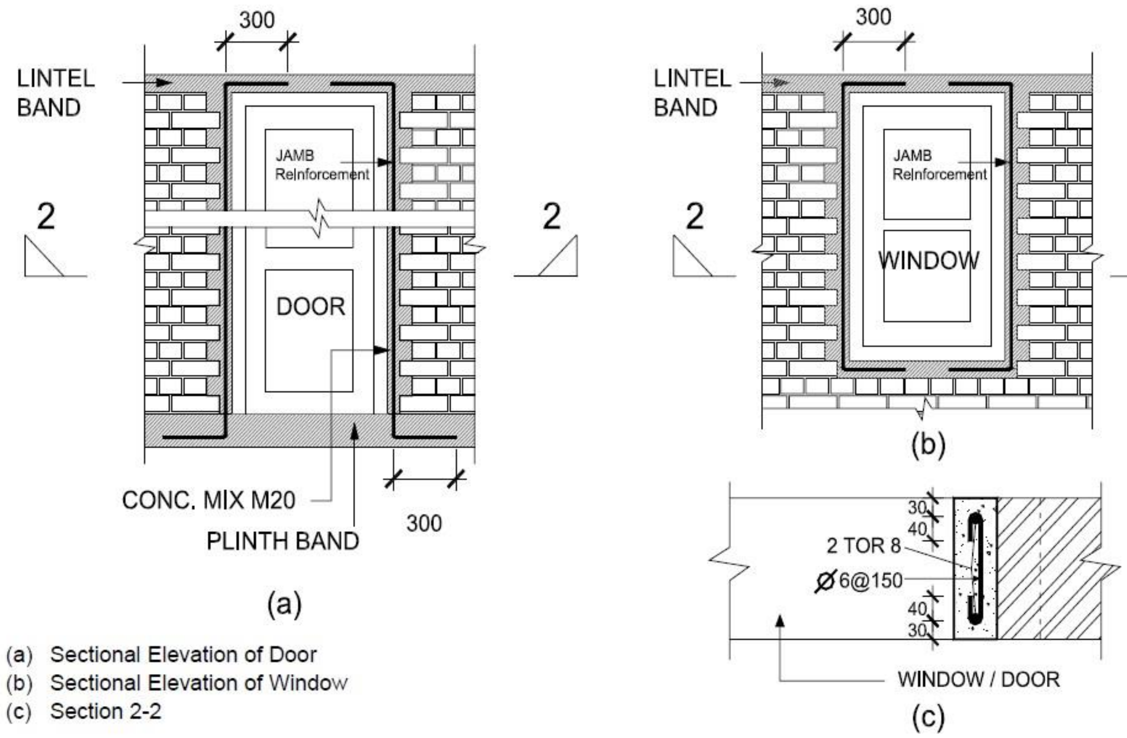


Figure 8: Details of Providing Vertical Steel Bars at door and windows opening (Source: Earthquake Safe Construction for seismic zone IV, NDMA)

2.3.5 Vertical Reinforcement at Corner of the wall: Vertical reinforcement at the corner of the walls forces the masonry pier to undergo bending by delaying the diagonal cracking. Vertical bars enhance lateral load carrying capacity of walls. If properly embedded, vertical steel bars protect the wall from sliding as well as from collapsing in weak direction. Vertical reinforcement shall start from foundation, passing through all seismic bands, it should be tied to roof slab/ roof band. In case of extension of reinforcement in multiple storey building, atleast 50 times diameter of overlap length should be provided. Diameter of the vertical bar depend upon the number of storey.

No. of storeys	Floor	**Residential buildings ***	**Important Public Buildings *** (Schools, Hospitals, Meeting Halls, Anganwadis, etc.)
		Dia of Single HYSD (TOR) Bar at corners of room (mm)	Dia of Single HYSD(TOR) Bar at corners of room (mm)
One	-	10	12
Two	Top	10	12
	Bottom	12	16
Three	Top	10	12
	Middle	12	16
	Bottom	12	16

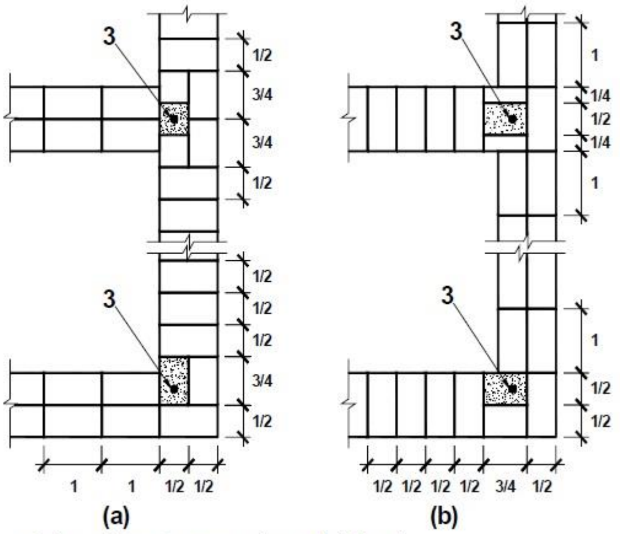


Figure 9: Recommended Size of Vertical Steel (Zone IV) & Typical Details of Providing Vertical Bars in Brick Masonry Buildings (Source: Earthquake Safe Construction for seismic zone IV, NDMA)

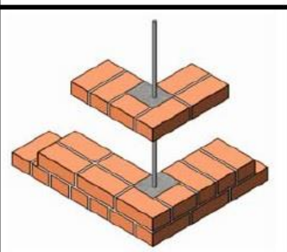
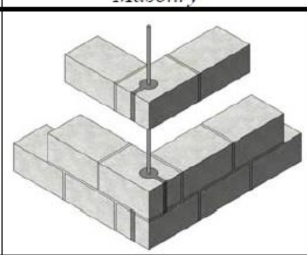
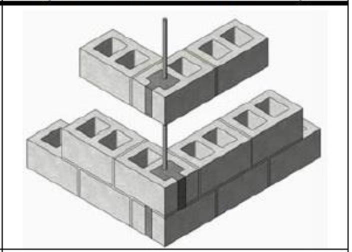
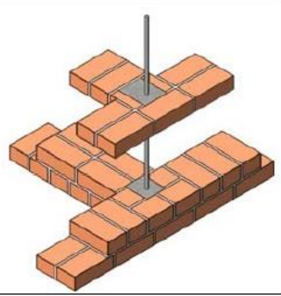
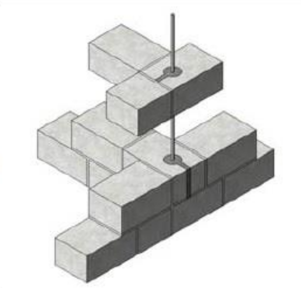
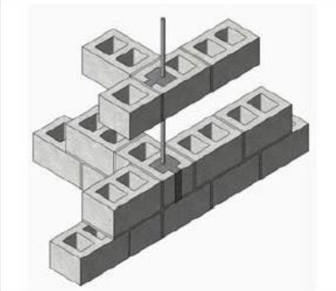
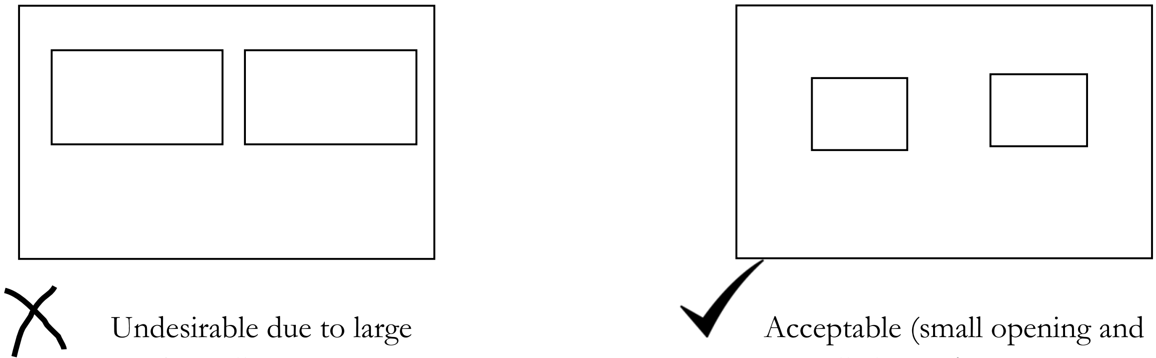
Type of *Joint*	Corner reinforcement in case of *Brick Masonry*	Corner reinforcement in case of *Solid Concrete Block Masonry*	Corner reinforcement in case of *Hollow Concrete Block Masonry* (see the hole and slit made)
L- Joint			
T- Joint			

Figure 10: Recommended joint details with the vertical reinforcement at corner for masonry walls using different kind of materials (Source: Earthquake Safe Construction for seismic zone IV, NDMA)

2.3.6 Diaphragm Opening: The horizontal forces generated by the ground motion at different locations of the floor must be transferred to the vertical elements such as walls. The floor must act as a diaphragm to accomplish this required action. Discontinuity in the diaphragm due to large cut outs reduces the ability of diaphragm to transfer lateral forces to the walls.

IS 1893:2002 table 3 describes the diaphragm discontinuity in terms of large cut out or opening more than 50% of the gross diaphragm area. These cut outs are provided for staircase and sometimes for providing the light with perforated steel sheets in the middle of the floor. Diaphragm opening can be located in the centre or corner. Opening near the corner is more dangerous. Diaphragm or diaphragm discontinuity can be identified only if access to a building is possible.

2.3.7 Distance Between two openings: IS 4326:1993 defines the criteria of minimum distance for opening from the corner of the wall and minimum distance to be maintained between two separate openings on a wall. Distance of opening from the corner of the wall should be minimum 450mm for brick masonry and 560 mm for stone masonry buildings. Minimum distance between two openings should be approximately 560 mm.



Undesirable due to large opening near the wall corner

Acceptable (small opening and centrally located)

Figure 11: Distance between Two Openings (Source: TARU Analysis, 2013)

2.3.8 Percentage of Opening in 1, 2 and 3 or more storey Building: Any wall opening more than 50% is highly undesirable and vulnerable for the earthquake. Large openings reduce the lateral resistance of the buildings. Opening should be small and centrally located in the buildings. Opening should be avoided near the column or at the corner of the wall. Large openings lead to cracking due to concentration of masses.

According to IS 4326:1993, percentage opening of the wall should decrease with the increasing number of stories. For second and third storey, opening should be restricted to 42% and 33% respectively.

2.3.9 Length of Wall Between two cross wall: IS 13935:2009 (table 3) defines the limit for length and height of the wall for a given wall thickness. If length of the wall between two cross walls is exceeding the defined limit, it is structurally unsafe for building situated in seismic zone IV and V. Long wall have the tendency of overturning due to out of plane movement. Buttress can be provided to reduce the length of long wall in existing buildings.

Table 3: Length and Height of wall between two cross wall (as per IS4326:1993)

Maximum length between two cross walls= 35× thickness of wall or 8m whichever less
Maximum height of the wall= 15× thickness of the wall or 4m whichever less

2.4. Seismic Safety Features of RC Frame Buildings: This section describe the seismic safety features of RC Frame building.

2.4.1 Frame Action: Proper frame action is the key to horizontal load transfer mechanism in RC frame buildings. Having RC frame in the building does not ensure the proper frame action during an earthquake. For a proper frame action, beams and columns should be orthogonal to each other. Secondary beams should be provided to transfer the load of the slab to primary beams and then primary beams transfer the load to columns.

Primary beams run through column to column.

Secondary beams are those beams which support the slab and runs between primary beams.

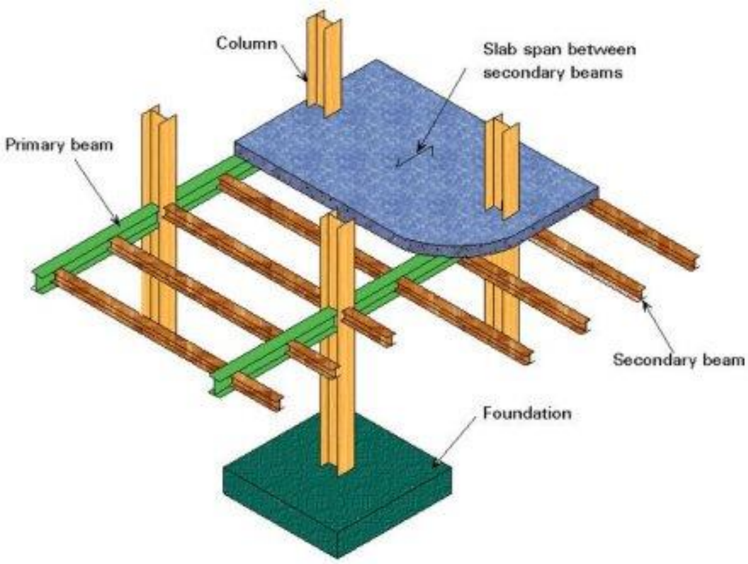


Figure 12: Arrangement of primary beam, secondary beam and columns (Source: www.petervaldivia.com)

2.4.2 Presence of Soft Storey: IS 1893:2002 defines that soft storey is the one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storey above. Buildings with open parking area on ground storey, stilt buildings or buildings with large windows and doors for commercial areas will come under soft storey.

2.4.3 Short Column Effect: Building on the hill slope can have unequal columns on the ground storey. Short columns being stiffer attract more horizontal forces and are susceptible to fail in shear if they are not designed to take care of this effect. Buildings in slope should be carefully identified for unequal height of the columns. If a column length cannot be fully utilized during earthquake sway due to restriction in its movement, it is also called as short column effect. It is observed in those column where free column length is reduced due to attached brick wall up to certain length.

Figure 13: Short Column Effect (Source: TARU, 2013)

2.4.4 Concept of Weak Beam Strong Column: Seismic lateral forces generated at the floor level are transferred through beam and columns to foundation. Failure of beam create a localized effect while failure of column can collapse the whole building. This is the reason why RC frame buildings are designed on weak beam-strong column concept. Slender cross section of column with large section of beam represents the strong beam and weak column concept which is dangerous for the overall safety of the building.

2.4.5 Pounding of Buildings: Two buildings should not be too close to each other as they have the possibility of collision to each other in case of vibration caused by earthquake. This effect is called as pounding and effect is more severe for tall buildings.

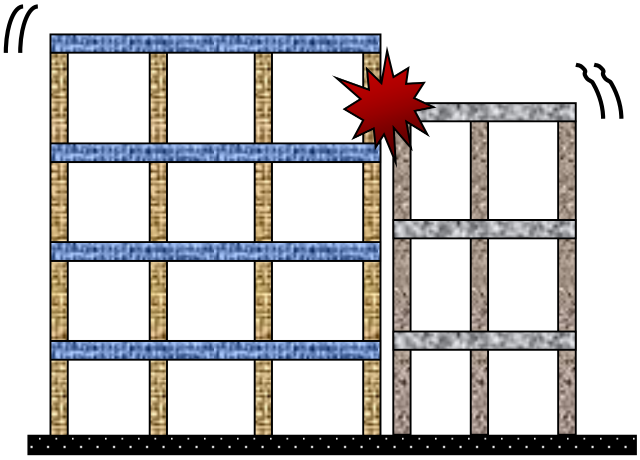


Figure 14: Pounding of Buildings during an earthquake (Reference: Learning Earthquake Design and Construction, IITK-BMTPC Earthquake Tip 6 by Prof. C.V.R. Murty)

2.5 Building Distress and Other important features: This section describes the building distress and other parameters related to building maintenance which reduces the safety of the building.

2.5.1 Cracks in the Building: Present condition of the building should be assessed properly. Cracks in the building elements (wall, beam and column) make buildings more vulnerable to natural disasters. Crack pattern defines the cause responsible for the formation of these cracks. Walls, beams and columns should be carefully examined to identify the structural cracks. If present, shape (horizontal, vertical or diagonal) and size of these cracks should be identified. Crack size is classified into two categories i.e. **M1= Minor (0-5mm), M2= Major (>5mm).** M2 size cracks show the advance state of damage in the buildings which require major interventions to prevent the partial or full collapse of the buildings.

2.5.2 Building Distress: Building distress can occur due to lack of maintenance, faulty design of buildings, poor quality of construction, corrosion of reinforcement, settlement of foundation or extreme loading. Various types of building distress are described below.

Settlement cracks run through the whole length of the wall and they appear on the building resting on the loose soil with inappropriate foundation.

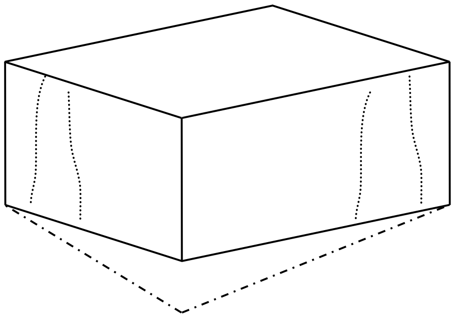


Figure 15: Settlement cracks in the wall of the building (Source: TARU Analysis, 2013)

In stone masonry construction, **wythe separation** occurs due to lack of through stones and the use of round boulders which prevent the proper interlocking of stones.

Figure 16: Type of damage: wythe separation and Shear cracks in the columns (from left to right) (Source: Visual Damage Identification Guide, TARU (1999))

Diagonal cracks develop near the opening of windows and doors due to shear failure. **Diagonal (shear) cracks in columns** can be found due to failure of stirrups which are used to bind the steel bars in RCC columns.

Bulging of the wall or column can occur if the thickness of the wall or column is insufficiently thick in comparison to the building height that lead to the wall/ column instability. This problem also occurs when additional floors are added to an existing building.

Figure 17: Bulging of Wall (Source: www.1stchoiceimages.co.uk) & Corner Crack in the wall (left to right)

Cracks in the corner of the wall are found if the walls are not jointed together at the corner joint by providing the sufficient reinforcement.
Wall overturning and column sway should be recorded as these defects reduce the load carrying capacity of the building elements.
Excess weight on the roof or excessive self-weight of the roof itself causes the **roof sagging** which can lead to collapse of the roof in the future. Sagging may also result due to problems in the roof framing members such as rafters. Rafter is a type of beam which support the roof of the building.
Horizontal cracks in the beam develop due to corrosion of reinforcement in the beam or due to insufficient concrete cover. **Vertical and diagonal cracks in the beam** develop due to increased bending stress and shear stress respectively.

2.5.3 Water Seepage: Buildings should be inspected for water seepage problem. Water seepage problems may occur due to defective water supply pipes, sanitary fitments or drainage pipes. It may also occur due to water seeping through roofs or exterior walls. This may cause damping of the concrete and may pose threat to the structural safety of the buildings.

2.5.4 Corrosion of Reinforcement: If there are cracks in the wall or roof, corrosion of reinforced steel bars may occur due to its exposure to rain water, moisture and air. If reinforcement is corroded in column and beam, vertical and horizontal cracks will appear on the column and beam respectively.

2.5.5 Quality of Construction: Construction of buildings with uniform size and shape of column and beams, without any structural defects or damages should be considered as good apparent quality. Construction with minor non-structural cracks but without any tilting of building element should be considered as moderate and buildings with structural cracks and non-uniform building elements should be considered of bad quality of construction.

2.5.6 Quality of Concrete:
If there is honeycombing in the concrete, it should be considered poor quality of concrete. Honeycombing can be seen only in fresh concrete. Concrete with very fine non-structural cracks is acceptable and can be considered moderate. A uniform non segregated concrete with smooth finishing should be considered of good quality.

Figure 18: Honeycombing in Concrete (Source: http://www.ecocem.ie)

2.6 Non Structural Falling Hazards: Amplification of ground motion occurs along the height of the structure and long structures attract more seismic force. Non anchored or poorly anchored things such as parapets, chimney, cladding, water tank, communication tower, heavy machines, big hoardings, heavy furniture etc., can fall down over the building leading to local damage or collapse due to increased accelerations or displacements. These falling hazards can cause both life loss and property damage.

Heavy wooden or steel cupboard and hanging big hoardings are very common falling hazard in public building like schools, hospitals and offices. In case of hospitals, non-structural elements contribute a larger percentage of total damage loss. Medical equipment on rollers and medicines on the racks should be properly anchored to avoid damage of medical facilities (fig.20).

Gangtok, 2013 (Source: TARU) Hamirpur, 2013 (Source: TARU)

Figure 19: Non-anchored water tank & Big hanging hoardings at the entrance (from left to right)

Gangtok, 2013 **Gangtok, 2013**

Figure 20: office with no space to escape in emergency & Non-anchored roller supported medical equipment (From left to right) (Source: TARU)

Chapter 3. Performance/RVS Score of the Building

3.1 Background: Indian seismic zone is divided into four category i.e. Zone II, III, IV and V. RVS scoring methods proposed in FEMA and METU are analysed to see their applicability for Indian conditions. In RVS score method of USA designed by FEMA, a Pre-Code penalty is given for buildings designed and constructed before the enforcements of seismic codes. Similarly a Post-Benchmark positive attribute is assigned to buildings constructed after the enforcement of seismic codes. It has heavy reliance on the year of construction and effective enforcement mechanism of seismic codes in building construction assuming that the building would surely fulfil the codal requirement applicable at the time of construction. This is not true in cases of India where often seismic codes are not followed during construction due to absence of effective building code reinforcement mechanism.

Turkey has the similar situation and hence METU does not take into account the year of construction in defining the RVS score methodology. As building construction practices in India are much similar to Turkey, METU method was taken as base to develop rational method for RVS scoring of Indian buildings.

Basic structural score of the building is based on the type of seismic zone and number of storey in the building. India seismic zone map (IS1893:2002) is based on past experience or expected intensity of earthquake ground motion in different parts of the country. It does not address the seismic hazard in terms of peak ground acceleration or peak ground velocity. Indian seismic zone V (expected ground motion of IX and above on MSK intensity scale) is assigned same basic scores as for zone I of METU method, zone IV (MSK intensity VIII) same as zone II of METU method and zone III (MSK intensity VII) & zone II (MSK intensity VI and lower) same as zone III of METU method.

3.2 Methodology: The RVS score evaluation is based on a few parameters of buildings. The parameters of the buildings are building height, frame action, pounding effect, structural irregularity, short columns, heavy overhang, soil conditions, falling hazard, apparent building quality, diaphragm action etc. On the basis of above mentioned parameters, performance score of the buildings has been calculated. The formula of the performance score is given as

$$PS = (BS) + \sum[(VSM) \times (VS)]$$

Where VSM represents the Vulnerability Score Modifiers and VS represents the Vulnerability Score that is multiplied with VSM to obtain the actual modifier to be applied to the BS or Basic Score. For RC Frame building, the base score, vulnerability score and vulnerability modified score are given in table 4 & 5 whereas the same parameters for masonry buildings are given in table 6 and 7. A building with higher seismic zone and more number of storey will get the low score i.e. building will be more vulnerable.

Table 4: Base Scores (BS) and Vulnerability Scores (VS) for RC Frame Buildings in India

	Base Scores			Vulnerability Scores								
No. of Storeys	Seismic Zone V	Seismic Zone IV	Seismic Zone III or II	Frame Action	Soft Storey	Vertical Irregularities	Plan Irregularities	Short Column	Pounding	Soil Condition	Apparent Quality	Heavy Overhang
1 or 2	100	130	150	10	0	-10	-5	-5	0	10	-5	-5
3	90	120	140	10	-15	-10	-5	-5	-2	10	-10	-10
4	75	100	120	10	-20	-10	-5	-5	-3	10	-10	-10
5	65	85	100	10	-25	-10	-5	-5	-3	10	-15	-15
>5	60	80	90	10	-30	-10	-5	-5	-3	10	-15	-15

(Source: Sudhir K. Jain and Keya Mitra 2008)

Table 5: Vulnerability Scores Modifiers (VSM) for RC Frame Building in India

Frame Action	Does not exist = -1; Exists = 1, Not sure = 0
Soft Storey	Does not exist=0; Exists = +1
Vertical Irregularity	Does not exist=0; Exists = +1
Plan irregularity	Does not exist=0; Moderate = +1, Extreme=+2
Short Columns	Does not exist=0; Exists = +1
Pounding Effect	Does not exist=0, Non-aligned Floors=+2, Poor apparent quality of adjacent buildings = +2
Soil condition	Medium=0, Hard =1, Soft = -1
Apparent quality	Good=0, Moderate=+1, Poor=+2
Heavy Overhang	Does not exist=0; Exists = +1

(Source: Sudhir K. Jain and Keya Mitra 2008)

Table 6: Base Scores (BS) and Vulnerability Scores (VS) of Masonry Buildings in India

	Basic Scores			Vulnerability Scores									
No. of Storeys	Seismic Zone V	Seismic Zone IV	Seismic Zone III or II	Soil Condition	Apparent Quality	Structural Irregularities	Wall Openings	Wall Orientation	Horizontal Bands	Arches	Diaphragm Action	Random Rubble Masonry	Pounding
1 or 2	100	130	150	10	-10	-10	-5	-2	20	-10	10	-15	0
3	85	110	125	10	-10	-10	-5	-5	20	-10	10	-15	-3
4	70	90	110	10	-10	-10	-5	-5	20	-10	10	-15	-5
5	50	60	70	10	-10	-10	-5	-5	20	-10	10	-15	-5

(Source: Sudhir K. Jain and Keya Mitra 2008)

Table 7: Vulnerability Scores Modifiers (VSM) for Masonry Buildings in India

Soil conditions	Medium=0, Hard=+1, Soft = -1
Apparent quality	Good=0, Moderate=+1, Poor=+2

Structural Irregularities	Absent/Do not know=0; Exists=+1
Wall openings	Small=0, Moderate=+1, Large=+2
Opening Orientation	Regular=0, Less regular=+1, Irregular=+2
Horizontal Bands	Present=+1, Absent=-1, Do not know=0
Arches	Present=+1, Absent/ Do not know=0
Diaphragm Action	Present/Do not know=0, Absent=-1,
Random Rubble Stone Masonry	Present=+1, Absent = 0
Pounding Effect	Does not exist=0, Poor quality of adjacent buildings=+2

(Source: Sudhir K. Jain and Keya Mitra 2008)

Chapter 4. Preliminary and Detailed Vulnerability Assessment

4.1 Preliminary Vulnerability Assessment: Preliminary vulnerability analysis is the second step of the building vulnerability process. Phase-II can broadly classified into two categories, (a) configuration-related and (b) strength related checks. The first tier involves a quick assessment of the earthquake resistance of the building and its potential deficiencies, with the objective to screen out the significantly vulnerable structures for the second tier detailed analysis and evaluation. The first tier evaluation typically consists of assessing the configurationally induced deficiencies known for unsatisfactory performance along with a few global level strength checks, whereas the next level of evaluation consists of proper force and displacement analysis to assess structural performance at both global and/or component level.

This phase involves the following tasks:

- Collection of drawings and redraw (if possible) in AutoCAD,
- Identification of the sizes of all columns and beams,
- Load calculations,
- Configuration related checks and strength related checks.

Non-destructive test (NDT) such as rebound hammer test, ultra-sonic pulse velocity method and rebar locator etc. are used to determine the material characteristics and strength related checks.

4.2 Detailed Vulnerability Assessment: Detailed vulnerability assessment (DVA) involves the modelling of selected buildings using both finite element method (FEM) and applied element method (AEM) to study the behaviour of buildings under different intensity of earthquake. Pushover analysis is done to simulate the inelastic behaviour of structures for a more realistic collapse mechanism. Pushover analysis is a type of nonlinear static analysis where the magnitudes of the lateral loads are incrementally increased, maintaining a predefined distribution pattern along the height of the building, until a collapse mechanism develop (CPWD 2007). Finally fragility curve or vulnerability function will be defined for most predominant building typologies as per the census 2011. The fragility curve is the graph between seismic ground acceleration in 'g' and damage. This relationship will estimate loss for different categories of buildings and intensities of earthquakes.

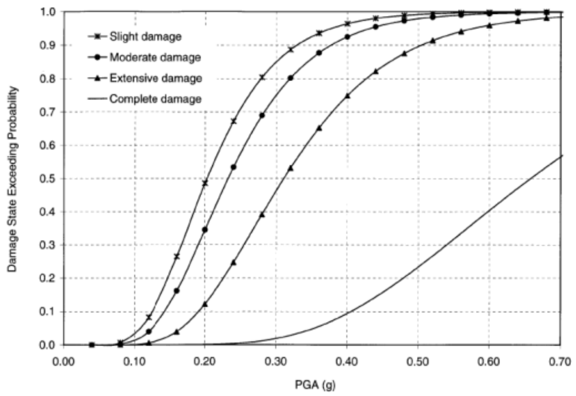


Fig. Fragility Curve (PGA Vs Damage Probability)

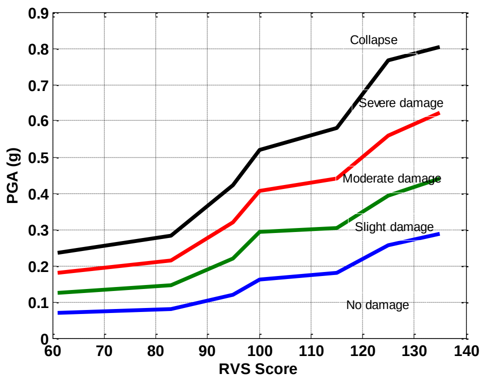


Fig. Fragility Curve (Relation between RVS score & PGA)
(Source: TARU Analysis, 2014)

Relationship between peak ground acceleration (PGA) and RVS score of the building is established to find out the probable damage of buildings for a particular intensity of earthquake.

References

- IITK-BMTPC, Earthquake Tips by Prof. CVR Murthy.
- IS 1893:2002 "Indian Standard Criteria for Earthquake Resistant Design of Structures"
- IS 4326:1993 "Earthquake Resistant Design And Construction Of Buildings -Code Of Practice"
- IS 13935:2009 "Seismic Evaluation, Repair and Strengthening of Masonry Buildings: Guidelines"
- 18 September 2011 Sikkim Earthquake: Post-Earthquake Reconnaissance Report by National Disaster Management Authority (NDMA), 2011.
- Singh Y., Gade P., Lang D.H. & Erduran E. (2012), " Seismic Behaviour of Buildings Located on Slopes- An Analytical Study and Some Observations from Sikkim Earthquake of September 18, 2011", World Conference in Earthquake Engineering.
- CPWD (2007), "Handbook on Seismic Retrofit of Buildings".
- Jain S K, Mitra K, KI Praseeda (2010), "A proposed rapid Visual Screening Procedure for Seismic Evaluation of Buildings in India".
- National Building Code of India (2005).

Annexure 1: Seismic Zone in India

IS 1893:2002 Part1 "CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES" divide the seismic zone of India into 4 divisions i.e. Zone II, Zone III, Zone IV and Zone V. It is estimated that 59% of the land area of India is liable to seismic damage. Seismic zone V is broadly associated with seismic intensity XI or more on MSK intensity scale while Zone IV, III and II are associate with seismic intensity of VIII, VII and VI respectively. Level of damage will differ within same zone due to difference in local soil condition which can alter the peak ground acceleration (PGA) and amplification factor.

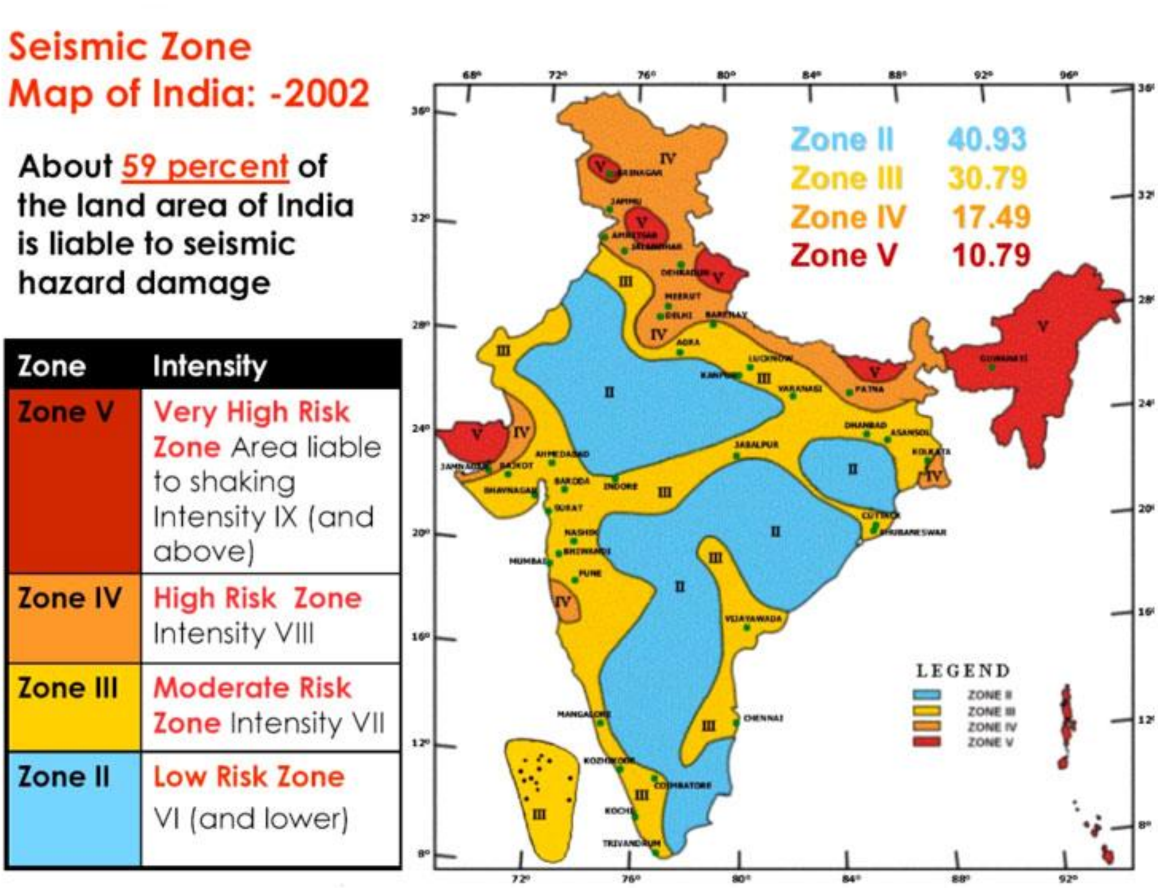


Fig. 1 Seismic zonation and intensity map of India

(Source: NIDM)

Annexure 2: BIS codes for Seismic Safety of Structures

Most of the countries with a history of earthquakes have well developed earthquake codes. It is only the implementation of codes which is lacking in the seismic safety of buildings. Countries like USA, Japan, New Zealand have detailed seismic code provisions. Indian seismic code also cover different type of structures from mud/adobe houses to modern day constructions like brick masonry and RC frame structures.

Earthquakes cause three dimensional vibrations in the structure. These vibration create forces and deformation over the structure. Seismic codes have been developed to design the structure to resist these forces and deformation up to an acceptable level. Enforcement of these codes in actual construction practices will reduce the significant loss of life and structures. These codes act as guidelines for the engineering community to refer them in their work and to create awareness about earthquake safe construction in the society also. Table 1 provides the detail of Indian standard codes for seismic safety of structures which are currently followed in different type of structures. IS code 1893 was first published in 1962 which was later updated/ revised many times to include the new findings/ learnings from the different earthquake events occurred in the country. IS 1893:2002 is the fifth revision of this code.

Table 1. Bureau of Indian Standard Codes for Earthquake Safety of Structures

IS Code No.	Name of the Code
IS 1893 (part1): 2002	Indian Standard Criteria for Earthquake Resistant Design of Structures
IS 4326:1993	Earthquake Resistant Design And Construction Of Buildings -Code Of Practice
IS 13827:1993	Improving Earthquake Resistance of Earthen Buildings: Guidelines
IS 13828:1993	Improving Earthquake Resistance of Low Strength Masonry Buildings: Guidelines
IS 13935:2009	Seismic Evaluation, Repair and Strengthening of Masonry Buildings: Guidelines
IS 13920:1993	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces — Code of Practice
IS 15988: 2013	Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings-Guidelines

Other IS codes which have to be referred along with above mentioned earthquake safety codes:

IS Code No.	Name of the Code
IS 456:2000	Code of Practice for Plain and Reinforced Concrete
IS 800: 1984	Code of Practice for General Construction in Steel
IS: 801-1975	Code of Practice for Use of Cold Formal Light Gauge Steel Structural Members in General Building Construction
IS 875 (Part 2):1987	Design loads (other than earthquake) for buildings and structures Part2 Imposed Loads
IS 875 (Part 3):1987	Design loads (other than earthquake) for buildings and structures Part 3 Wind Loads
IS 875 (Part 4):1987	Design loads (other than earthquake) for buildings and structures Part 4 Snow Loads

IS 875 (Part 5):1987	Design loads (other than earthquake) for buildings and structures Part 5 special loads and load combination
IS: 883:1966	Code of Practice for Design of Structural Timber in Building
IS: 1904:1987	Code of Practice for Structural Safety of Buildings: Foundation
IS1905:1987	Code of Practice for Structural Safety of Buildings: Masonry Walls
IS 2911 (Part 1): Section 1: 1979	Code of Practice for Design and Construction of Pile Foundation
IS 2911 (Part1): Section 2: 1979	Code of Practice for Design and Construction of Based Cast in situ Piles
IS 2911 (Part1): Section 3: 1979	Code of Practice for Design and Construction of Driven Precast Concrete Piles
IS 2911 (Part1): Section 3: 1979	Code of Practice for Design and Construction of Based Precast Concrete Piles
IS 2911 (Part 2): 1979	Code of Practice for Design and Construction of Timber Piles
IS 2911 (Part 3): 1979	Code of Practice for Design and Construction of Under Reamed Piles
IS 2911 (Part 3): 1979	Load Test on Piles
IS 14458 (Part 1): 1998	Guidelines for retaining wall for hill area: Part 1 Selection of type of wall
IS 14458 (Part 2): 1997	Guidelines for retaining wall for hill area: Part 2 Design of retaining/breast walls
IS 14458 (Part 3): 1998	Guidelines for retaining wall for hill area: Part 3 Construction of dry stone walls
IS 14496 (Part 2): 1998	Guidelines for preparation of landslide – Hazard zonation maps in mountainous terrains: Part 2 Macro-zonation

National Building Code of India (2005): National building code of India (NBC), is a national instrument providing guidelines for regulating the building construction activities across the country. It serves as a Model Code for adoption by all agencies (government and private both) involved in building construction works. The code mainly contains administrative regulations, development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design and construction (including safety); and building and plumbing services.

The Code was first published in 1970 at the instance of Planning Commission and then revised in 1983. Thereafter three major amendments were issued, two in 1987 and the third in 1997. The NBC 2005 contains 11 parts which are:

Part 0 Integrated Approach - Prerequisite for Applying Provisions of the Code

Part 1 Definitions

Part 2 Administration

Part 3 Development Control Rules and General Building Requirements

Part 4 Fire and Life Safety

Part 5 Building Materials

Part 6 Structural Design

Part 7 Constructional Practices and Safety

Part 8 Building Services

Part 9 Plumbing Services

Part 10 Landscaping, Signs and Outdoor Display Structures

Annexure 3: RVS Format

IS 13935 : 2009

FORM 3

RAPID VISUAL SCREENING OF MASONRY BUILDINGS FOR SEISMIC HAZARDS

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

Photograph

Sketch Plan with Length and Breadth

1.1 Building Name: ____________
1.2 Use: ____________
1.3 Address: ____________ Pin ____________
1.4 Other Identifiers: ____________
1.5 No. of Stories ______ **1.6** Year Built ______
1.7 Total Covered Area; all floors (sq.m) ______
1.8 Ground Coverage (Sq.m): ______
1.9 Soil Type: ______ **1.10** Foundation Type ______
1.11 Roof Type: ______ **1.12** Floor Type ______
1.13 Structural Components: ______
1.13.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐
1.13.2 Thickness of wall ______ **1.13.3** Slab thickness ___
1.13.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐
1.13.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐
1.13.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

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

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

RECOMMENDED ACTION:

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

Surveyor's sign: ____________

Name: ____________

Executive Engineer's Sign: ____________

Date of Survey: ____________

5.0 Probable Damageability in Few/Many Buildings

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

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

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

IS 13935 : 2009

FORM 4

RAPID VISUAL SCREENING OF MASONRY BUILDINGS FOR SEISMIC HAZARDS

Seismic Zone V All Building
(Also Seismic Zone IV Important Building)

Photograph

Sketch Plan with Length and Breadth

1.1 Building Name: ____________
1.2 Use: ____________
1.3 Address: ____________ Pin ____________
1.4 Other Identifiers: ____________
1.5 No. of Stories ____________ **1.6** Year Built ____________
1.7 Total Covered Area: all floors (sq.m) ____________
1.8 Ground Coverage (Sq.m): ____________
1.9 Soil Type: ____________ **1.10** Foundation Type ____________
1.11 Roof Type: ____________ **1.12** Floor Type ____________
1.13 Structural Components: ____________
1.13.1 Wall Type: BB* ☐ Earthen ☐ UCR* ☐ CCB* ☐
1.13.2 Thickness of wall ________ **1.13.3** Slab thickness ___
1.13.4 Mortar Type: Mud ☐ Lime ☐ Cement ☐
1.13.5 Vert. R/F bars: Corners ☐ T-junctions ☐ Jambs ☐
1.13.6 Seismic bands: Plinth ☐ Lintel ☐ Eaves ☐ Gable ☐

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

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

RECOMMENDED ACTION:

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

5.0 Probable Damageability in Few/Many Buildings

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

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

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

Surveyor's sign: ____________

____

Name: ____________

____

Executive Engineer's Sign: ____________

____

Date of Survey: ____________

____

RVS form for Masonry Building for Seismic Hazard (by Padmshree, Prof. Anand S. Arya)

Seismic Zone V, All Buildings (Also for Zone IV Important Buildings)

1.0 General Information

1.1 Seismic Zone____________________

1.2 Building name ____________________

1.3 Use Residential □ Office □ School □ Hospital □ Others □

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 (describe)______________

2.2 Flat Roof or Floor

2.2.1 Wooden joist with earth fill Yes □ No □

2.2.2 Steel joist with stone slabs Yes □ No □

2.2.3 Jack arch roof/ floor Yes □ No □

2.2.4 RCC or RBC Yes □ No □

2.2.5 Thickness of slab______________

2.2.6 Any other (describe)______________

2.3 Pitched roof Understructure

2.3.1 Bamboo truss/rafter/purlin Yes □ No □

2.3.2 Wooden truss/rafter/purlin Yes □ No □

2.3.3 Steel truss/purlin Yes □ No □

2.3.4 Any other (describe)______________

2.4 Pitched Roof Covering

2.4.1 Stone slates Yes □ No □

2.4.2 Burnt Clay Tiles Yes □ No □

2.4.3 CGI Sheets Yes □ No □

2.4.4 A.C. Sheets Yes □ No □

2.4.5 Fiber sheets Yes □ No □

2.4.6 Any other (describe)______________

2.5 Walls Type

2.5.1 Earthen □ Clay □ Mud □ Adobe □

2.5.2 Bamboo Yes □ No □

2.5.3 Wooden Yes □ No □

2.5.4 UCR Masonry Yes □ No □

2.5.5 Dressed stone masonry Yes □ No □

2.5.6 Burnt Brick Yes □ No □

2.5.7 Cement Concrete Blocks Yes □ No □

2.5.8 Thickness of wall ______________

2.5.9 Any other (state)______________

2.6 Mortar in Wall

2.6.1 Mud mortar Yes □ No □

2.6.2 Lime Mortar Yes □ No □

2.6.3 Cement Mortar Yes □ No □

2.7 Construction of Walls

2.7.1 Length of wall between cross walls, as per code* Yes □ No □

2.7.2 Wall openings % constraints, as per code* Yes □ No □

2.7.3 Wall height to width ratio, as per code* Yes □ No □

2.7.4 'Through' & corner stone provided, in stone walls Yes □ No □

** Refer Indian Standards IS:4326 & IS:13828 have specific provisions*

3.0 Check of Seismic Provisions

3.1 Seismic bands in all External & Internal walls

3.1.1 Plinth level Yes □ No □

3.1.2 Window Sill level Yes □ No □

3.1.3 Lintel level of openings Yes □ No □

3.1.4 Ceiling level of flat floor/roof Yes □ No □

3.1.5 Eaves level of pitched roofs Yes □ No □

3.1.6 Gable wall top (slopes) Yes □ No □

3.1.7 Top of Ridge Wall Yes □ No □

3.2 Vertical Reinforcing Bars provided

3.2.1 At Corners of rooms Yes □ No □

3.2.2 At T-junctions of walls Yes □ No □

3.2.3 At Jambs of doors & windows Yes□ No□

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes □ No □
(If yes, Increase damageability grade by 2 units)

4.2 Severe Vertical Irregularity in building Yes □ No □
(If yes, Increase damageability grade by 2 units)

4.3 Severe Plan Irregularity in the building Yes □ No □
(If yes, increase damageability grade by 1 unit)

4.4 Land Slide Prone Site Yes □ No □
(If yes, it may lead to damageability grade G5)

5.0 Non-structural Building Components

Whether the following non-structural building elements are present and stabilized against the earthquake?

5.1 Divisions/partition (brick wall/wooden partitions)
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.2 Façade elements (cladding/decorative elements)
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.3 False Ceilings
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.4 Brick parapets / pillars / planters etc.
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.5 Roof Chimneys
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.6 RC / Masonry Water Tank on Roof
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.7 Signs/display boards etc.
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

6.0 Probable Damageability in few / many Masonry Buildings

Masonry Building Type (*see Table-1*)	A / A+	B / B+	C / C+	D
Damageability Grade in Zone V, Very High Intensity (*see Table-2*)	G5	G5/G4	G4/G3	G3
Note: + sign indicates higher strength hence somewhat lower damage expected as stated. Also average damage in one building type in the area may be lower by one grade point than the probable damageability indicated. Surveyor will identify the building type, encircle it, also the corresponding damage grade.				

7.0 Recommended Actions during evaluation

If the **damageability grades** are:

- G1/G2 : building may be considered seismically safe.
- G3 : the building will not be likely to collapse, but subject to moderate to heavy damage. In such case, the building may be recommended for retrofitting.
- G4/G5 : the building is unsafe and will need re-evaluation and retrofitting.

If any **Special hazard** -

- Special hazard (4.0) is found, hazard should be removed or prevented.
- Special hazard (5.0) is present, either remove it, or stabilize against earthquake.

8.0 Attach Sketch Plan with section

9.0 Attach Photographs of the building

Surveyor's sign:____________ **Date:**________

Name:________________________

Notes:

1) Assessment of 5.0 does not modify the damageability grade of the building, but non-structural damage could be harmful to occupants.
2) Abbreviations: RC: reinforced concrete, RBC: Reinforced brick, CGI: Corrugated Galvanized Iron Sheets, A.C: Asbestos Cement Sheets, UCR: Un-coursed Random Rubble Masonry, R/F: reinforcement, Ext.: External, Int. : Internal

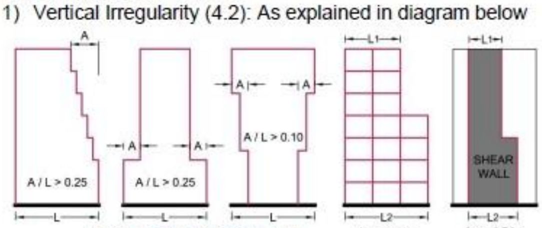
QUICK GUIDE FOR READY REFERENCE

Equipments to be carried by the Surveyor:-

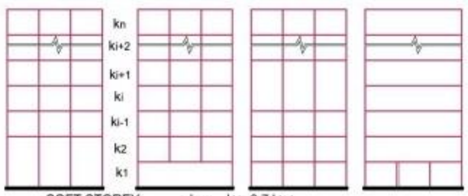
1) Digital Camera, Measuring tape
2) Hard board with clip, Pen (black), pencil, eraser
3) Adequate no. of survey sheets, RVS guidelines.

EXPALANTORY NOTE:-

1) Vertical Irregularity (4.2): As explained in diagram below



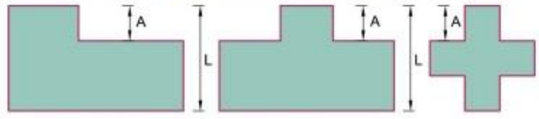
VERTICAL GEOMETRIC IRREGULARITY



SOFT STOREY, when ki > 0.7 ki+1,
or, when ki > 0.8 (ki+1 + ki+2 + ki+3) / 3
EXTREME SOFT STOREY, when ki > 0.6 ki+1
or, when ki > 0.7 (ki+1 + ki+2 + ki+3) / 3
or, when OPEN PARKING AT GF

VERTICAL STIFFNESS IRREGULARITIES

2) **Plan Irregularity (4.3)**: As explained in diagram below



PLAN IRREGULARITY : RE-ENTRANT CORNERS A / L > 0.15

Table 1: Building Types – Masonry load bearing wall buildings

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 2: Grades of Damageability of Masonry Buildings

Grade	Description
G1	*Negligible to slight damage (no structural damage, slight non-structural damage)* **Structural:** Hair-line cracks in very few walls. **Non-structural:** Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
G2	*Moderate damage (Slight structural damage, moderate non-structural damage)* **Structural:** Cracks in many walls, thin cracks in RC slabs and AC sheets. **Non-structural:** Fall of fairly large pieces of plaster, partial collapse of smoke chimneys on roofs. Damage to parapets, chajjas. Roof tiles disturbed in about 10% of the area. Minor damage in under structure of sloping roofs.
G3	*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).
G4	*Very heavy damage (heavy structural damage, very heavy non-structural damage)* **Structural:** Serious failure of walls (gaps in walls), inner walls collapse; partial structural failure of roofs and floors.
G5	*Destruction (very heavy structural damage)* Total or near total collapse of the building.

RVS FORM FOR REINFORCED CONCRETE FRAME (RCF) / STEEL FRAME (SF) BUILDINGS FOR SEISMIC HAZARD (by Padmshree, Prof. Anand S. Arya)

Seismic Zone V, All Buildings (Also for Seismic zone IV Important Buildings)

1.0 General Information

1.1 Seismic Zone________________________

1.2 Building name ________________________

1.3 Use Residential □ Office □ School □ Hospital □ Others □

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 RC / Steel Frame Building Typology

2.1 Foundation Type

2.1.1 Individual footing Yes □ No □

2.1.2 Individual footing with connecting beam Yes □ No □

2.1.3 Beam Raft foundation Yes □ No □

2.1.4 Full solid raft Yes □ No □

2.1.5 Pile foundation Yes □ No □

2.1.6 Any other (describe)________________

2.2 Flat Roof or Floor

2.2.1 RC slab or T beam Yes □ No □

2.2.2 Steel beam and plate deck Yes □ No □

2.2.3 Flat slab or flat plate Yes □ No □

2.2.4 Overall depth of floor / roof Yes □ No □

2.2.5 Any other (describe)________________

2.3 Pitched roof Understructure

2.3.1 RCC Elements Yes □ No □

2.3.2 Steel Truss / rafter / purlin Yes □ No □

2.3.3 Any other (describe)________________

2.4 Pitched Roof Covering

2.4.1 CGI Sheets Yes □ No □

2.4.2 A.C. Sheets Yes □ No □

2.4.3 Fiber sheets Yes □ No □

2.4.4 Any other (describe)________________

3.0 Structural Frame Types *

3.1 RC beam-post buildings without Earthquake Resistant Design, (built in Non-engineered way). Yes □ No □

3.2 C Steel Frame (RCF/SF) of ordinary design for gravity loads, without Earthquake Resistant Design Yes □ No □

3.3 Moment Resistant Frame –(RCF/SF) of ordinary design, without Earthquake Resistant Design Yes □ No □

3.4 Moment Resistant Frame – (RCF/SF) with ordinary Earthquake Resistant Design and with ordinary in-fill walls. Yes □ No □

3.5 Moment Resistant – (RCF/SF) with high level of Earthquake Resistant Design and special ductile details. Yes □ No □

3.6 Moment Resistant Frame – (RCF/SF) with high level of Earthquake Resistant Design and special ductile details and with well designed in-fill walls/braces.* Yes □ No □

3.7 Moment Resistant Frame– (RCF/SF) with high level of Earthquake Resistant Design, special ductile details and with detailed RC shear walls or, detailed steel braces & cladding. Yes □ No □

** Indian Standards IS:13920-1993, IS:1893-2002, and SP6(6)-1972*

4.0 Special Hazard

4.1 High Water Table (within 3m below ground level) & if sandy soil, then liquefiable site indicated. Yes □ No □
(If yes, Increase damageability grade by 2 units upto G5)

4.2 Severe Vertical Irregularity in building Yes □ No □
(If yes, Increase damageability grade by 2 units upto G5)

4.3 Severe Plan Irregularity in the building Yes □ No □
(If yes, increase damageability grade by 1 unit upto G4)

4.4 Land Slide Prone Site Yes □ No □
(If yes, it may lead to damageability grade G5)

5.0 Non-structural Building Components

Whether the following non-structural building elements are present and stabilized against the earthquake?

5.1 Divisions/partition (brick wall/wooden partitions)
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.2 Façade elements (cladding/decorative elements)
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.3 False Ceilings
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.4 Brick parapets / pillars / planters etc.
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.5 Roof Chimneys
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.6 RC / Masonry Water Tank on Roof
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

5.7 Signs/display boards etc.
Provided Yes □ No □
Stabilized against Earthquake Yes □ No □

Note: Assessment of 5.0 does not modify the damageability grade of the building, but non-structural damage could be harmful to occupants

Abbreviations:

RC: reinforced concrete, RCF: reinforced concrete frame, SF: steel frame, CGI: Corrugated Galvanized Iron Sheets, AC: Asbestos Cement Sheets, URM: unreinforced masonry, R/F reinforcement

6.0 Probable Damageability in few / many RCG/SF Buildings

RC or Steel Frame Building type(*See Table-1)*	C / C+	D	E / E+	F	URM Infill
Damageability in Zone V, Very High Intensity MSK IX or more *See Table-2)*	G4 / G3	G3	G2 / G1	G2 / G1	G4

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

7.0 Recommended Actions during evaluation

If the **damageability grades** are:

- G1/G2 : building may be considered seismically safe.
- G3 : the building will not be likely to collapse, but subject to moderate to heavy damage. In such case, the building may be recommended for retrofitting.
- G4/G5 : the building is unsafe and will need re-evaluation and retrofitting.

If any **Special hazard** -

- Special hazard (4.0) is found, hazard should be removed or prevented.
- Special hazard (5.0) is present, either remove it, or stabilize against earthquake.

8.0 Attach Sketch Plan with section

9.0 Attach Photographs of the building

Surveyor's sign:____________ **Date**:________

Name:___________________________

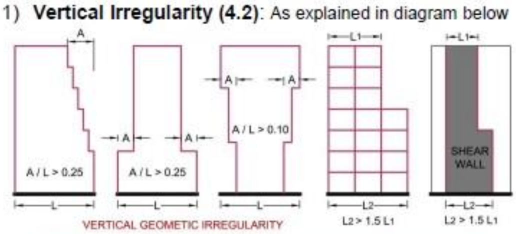
QUICK GUIDE FOR READY REFERENCE

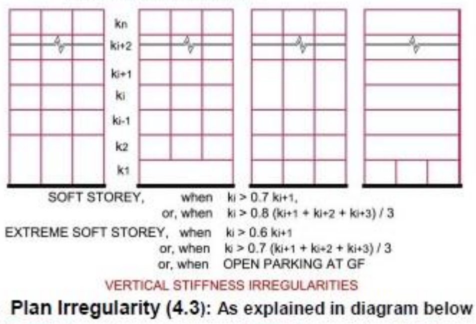
Equipments to be carried by the Surveyor:-

1) Digital Camera, Measuring tape
2) Hard board with clip, Pen (black), pencil, eraser
3) Adequate no. of survey sheets, RVS guidelines.

EXPALANTORY NOTE:-

1) **Vertical Irregularity (4.2)**: As explained in diagram below





2) **Plan Irregularity (4.3):** As explained in diagram below

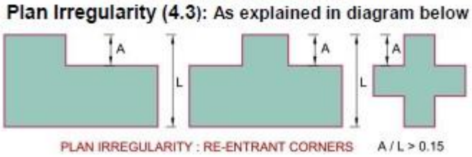


Table 1: Reinforced Concrete Frame Buildings (RCF) and Steel Frames (SF)

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" IS:1893(Part-I) 2002, "Criteria for Earthquake Resistant Design of Structures". SP:6(6)-1972, "Plastic Design of Steel Structures—Handbook"

Abbreviations*: ERD : Earthquake Resistant Design, WRD: Wind Resistant Design, MR : Moment Resistant jointed frame*

Table 2: Grades of Damageability of RCF/SF Buildings

Grade	Description
G1	*Negligible to slight damage (no structural damage, slight non-structural damage)* Fine cracks in plaster over frame members or in walls at the base. And Fine cracks in partitions & infills.
G2	*Moderate damage (Slight structural damage, moderate non-structural damage)* Cracks in columns & beams of frames & in structural walls. Cracks in partition & infill walls; fall of brittle cladding & plaster. Falling mortar from the joints of wall panels.
G3	*Substantial to heavy damage (moderate structural damage, heavy non-structural damage)* Cracks in columns & beam column joints of frames at the base & at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition & infill walls, failure of individual infill panels.
G4	*Very heavy damage (heavy structural damage, very heavy non-structural damage)* Large cracks in structural elements with compression failure of concrete & fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.
G5	*Destruction (very heavy structural damage)* Collapse of ground floor parts (e.g. Wings) of the building.

NOTES: 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 Table2. Non-structural damage to infills would be the same as masonry building.

Annexure 4: Example of RVS Scoring of Building

Brick Masonry

RAPID VISUAL SURVEY OF MASONRY BUILDINGS FOR EARTHQUAKE SAFETY				SEISMIC ZONE		Zone V ✓ Zone IV Zone II or III
Address/Location/Street	MEHAR SINGH BPO DHANOTU, SHAHPUR			CITY	KANGRA	FULL ACCESS ✓
Year of construction	1970			STATE	H.P.	PARTIAL ACCESS
Type of Construction	RC Frame	Brick Masonry ✓	Stone Masonry	Number of Floors – 1		NO ACCESS
Use	Residential ✓	Commercial /Office	Mixed	Other	Please specify	

CHECKLIST OF OBSERVABLES IN MASONRY BUILDINGS	Tick	COMMENTS
Structural Irregularities Lack of adequate walls in both orthogonal directions Heavy overhangs Reentrant Corners Corner buildings	✓ ✓ ✓ ✓	—
Apparent Quality Apparent quality of materials and construction Maintenance	✓ ✓	moderate
Soil Conditions	✓	Medium
Pounding Contiguous buildings Poor apparent quality of adjacent buildings	✓ ✓	
Openings Large openings in walls Irregularly placed openings Openings at corners of bearing wall intersections	✓ ✓ ✓	moderate Regular opening
Diaphragm Action Evidence of absence of diaphragms Evidence of large cut outs in diaphragms	✓ ✓	
Other features Horizontal bands at plinth level Horizontal bands at lintel level Horizontal bands at sill level Horizontal band at roof level Arches present/absent Jack Arch roofs Stone/masonry chimneys	✓ ✓ ✓ ✓ ✓ ✓ ✓	Band at Lintel and Plinth level present
Random rubble stone masonry walls Presence of thick walls 600mm and above Use of rounded stones Heavy roofs on URRM walls	… … …	
Falling Hazards Non-structural elements such as elaborate parapets, AC unit grilles, elevation features, advertisement hoardings, roof signs, marquees, etc.	✓	
ANY OTHER SPECIAL FEATURES		

Figure 1 (a). Proforma for Brick Masonry Buildings (First page)

RAPID VISUAL SURVEY OF MASONRY BUILDINGS FOR EARTHQUAKE SAFETY			CALCULATION SHEET MASONRY			
FALLING HAZARDS IDENTIFIER 'F'			Seismic Zone			Base Score
Marquees/Hoardings/Roof Signs	x	Stories	V ✓	IV	III-II	
AC Units/Grillework	x	1 or 2 ✓	100	130	150	100
Elaborate parapets	x	3	85	110	125	
Heavy elevation features	x	4	70	90	110	
Heavy Canopies	x	5	50	60	70	
Substantial Balconies	x					
Heavy Cladding	x					
Structural Glazing	x					

Number of storeys	1 or 2	3	4	5	Vulnerability Score Modifiers	
Vulnerability Scores (VS)					(VSM)	(VS X VSM)
Structural Irregularity	-10	-10	-10	-10	Doesn't exist/unsure=0 ✓ Exists=1	0
Apparent Quality	-10	-10	-10	-10	Good=0 Moderate=1 ✓ Poor=2	-10
Soil Conditions	10	10	10	10	Medium=0 ✓ Hard=1 Soft=-1	0
Pounding	0	-3	-5	-5	Doesn't exist=0 ✓ Normal apparent condition of adjacent building=1 Poor apparent condition of adjacent building=2	0
Openings						
Wall openings	-5	-5	-5	-5	Small (less than 1/3) = 0 Moderate (Between 1/3 and 2/3) = 1 ✓ Large (Above 2/3) = 2	-5
Orientation of openings	-2	-5	-5	-5	Regular = 0 ✓ Irregular = 1	0
Diaphragm Action	-10	-15	-15	-15	Present/Unsure=0 ✓ Lack of diaphragm action=1	0
Other Features						
Horizontal Bands	20	20	20	20	Exist =+1 ✓ Don't exist=0	20
Arches	-10	-10	-10	-10	Exist=1 Doesn't exist/unsure=0	0
Stone Masonry						
Random Rubble Stone Masonry Walls	-15	-15	-15	-15	Remedial measures exist= 0 Don't exist = 1	[illegible]
					∑ [(VSM) x (VS)]	+5

Performance Score= (BS) + ∑ [(VSM) x (VS)] where VSM represents the vulnerability score modifiers and VS represents the Vulnerability Score that is multiplied with VSM to obtain the actual modifier to be applied to the Basic Score (BS).	**Performance Score**	105
Field Survey by: Gugan	Reviewed by: [signature]	Approved by:
Date: 17/12/13	Date: 18/12/13	Date:

Figure 1 (b). Proforma for Brick Masonry Buildings (Second page)

RC Frame Building

RAPID VISUAL SURVEY OF RC FRAME BUILDINGS FOR EARTHQUAKE SAFETY				SEISMIC ZONE		Zone V Zone IV ✓ Zone II and III
Address/Location/Street : J R MODEL SCHOOL MEHATPUR,				CITY UNA		FULL ACCESS ✓
Year of construction : 2007				STATE H.P.		PARTIAL ACCESS
Type of Construction	RC Frame ✓	Masonry ✗		Number of Floors : 2		NO ACCESS
Use	Residential	Commercial /Office ✓	Mixed	Other	Please specify	EDUCATIONAL

CHECKLIST OF OBSERVABLES	COMMENTS
Soft Storey Open parking at ground level ✗ Absence of partition walls in ground or any intermediate storey for shops or other commercial use ✗ Taller heights in ground or any other intermediate storey ✗	
Vertical irregularities Presence of setbacks ✗ Building on slopy ground ✗	— —
Plan irregularities Irregular plan configuration ✗ Reentrant corners ✓	C Shape PRESENT
Heavy Overhangs Moderate horizontal projections ✓ Substantial horizontal projections	
Apparent Quality Apparent quality of materials and construction Maintenance	POOR
Short Column	
Pounding	—
Soil Condition	Medium
Frame Action	Not present
Falling Hazards Non-structural elements such as elaborate parapets, AC unit grilles, elevation features	—
PICTURES/SKETCHES	

Figure 2 (a). Proforma for Reinforced Concrete Buildings (First page)

RAPID VISUAL SURVEY OF BUILDINGS FOR EARTHQUAKE SAFETY | CALCULATION SHEET RC FRAME

Falling Hazard Identifier 'F'			Seismic Zone			Base Score
Marquees/Hoardings/Roof Signs		Stories	V	IV ✓	III-II	
AC Units/Grillework	✗	1 or 2 ✓	100	130	150	130
Elaborate parapets		3	90	120	140	
Heavy elevation features	✗	4	75	100	120	
Heavy Canopies	✗	5	65	85	100	
Substantial Balconies	✗	> 5	60	80	90	
Heavy Cladding	✗					
Structural Glazing	✗					

Number of storeys	1 or 2 ✓	3	4	5	> 5	Vulnerability Score Modifiers	
Vulnerability Scores (VS)						(VSM)	(VS X VSM)
Soft Story	0	-15	-20	-25	-30	Doesn't exist=0 ✓ Exists=1	0
Vertical irregularities Setbacks Buildings on Slopes	-10	-10	-10	-10	-10	Doesn't exist=0 ✓ Exists=1	0
Plan irregularities	-5	-5	-5	-5	-5	None=0 Moderate=1 ✓ Extreme=2	-5
Heavy Overhangs	-5	-10	-10	-15	-15	Doesn't exist=0 Exists=1 ✓	-5
Apparent quality	-5	-10	-10	-15	-15	Good=0 Moderate=1 Poor=2 ✓	-10
Short columns	-5	-5	-5	-5	-5	Doesn't exist=0 ✓ Exists=1	0
Pounding	0	-2	-3	-3	-3	Doesn't exist=0 ✓ Unaligned floors=2 Poor apparent quality of adjacent building=2	0
Soil Condition	10	10	10	10	10	Medium=0 ✓ Hard=1 Soft=-1	0
Frame Action	10	10	10	10	10	Doesn't exist=-1 ✓ Exists=+1 Not sure=0	-10
						∑ [(VSM) x (VS)]	-30
Performance Score= (BS)+ ∑ [(VSM) x (VS)] where VSM represents the vulnerability score modifiers and VS represents the Vulnerability Score that is multiplied with VSM to obtain the actual modifier to be applied to the Basic Score (BS).						**Performance Score**	100
Field Survey by: Swajit		Reviewed by: Neeraj				Approved by:	
Date: 19-12-13		Date: 20/12/2013				Date:	

Figure 2 (b). Proforma for Reinforced Concrete Buildings (Second page)