SEISMIC ASSESSMENT OF BRICK MASONRY BUILDING
Situated Anywhere In Seismic Zone IV of India

1. Introduction

If you live in a house constructed using brick walls, without reinforced concrete columns, any where in the seismic zones IV of India, you should know, for your family's safety, whether the building will be safe under the next earthquake or could suffer severe damage. You can yourself assess the level of damageability of your building by filling a few simple data in the questionnaire framed herein. But before filling the data, you should go through the guideline provided below for better understanding of your building and the earthquake behavior of such buildings.

2. Seismic Zone IV and Estimated Maximum Intensity of Future Earthquake

Before using this document, make sure that your building is situated in Seismic Zone IV. For ready reference, the districts lying in Zone IV, either wholly or with more than 40% area are listed in Table 1. In seismic zone IV a maximum earthquake Intensity of VIII on MSK Intensity Scale is likely to occur. In terms of building damage, Intensity VIII is stated to cause the following types of damage:-

MSK Intensity VIII

Most kutcha buildings constructed using clay walls may be totally destroyed. Most masonry buildings constructed using brick walls with *mud* mortar may also be destroyed. But those constructed using good cement mortar may only have heavy cracking.

Buildings constructed in sandy soil with high water table are liable to more severe damage than in other areas.

Areas of Uttarakhand and many areas in Saurashtra are also placed in Seismic Zone IV where MSK Intensity VIII has actually occurred during 1991 Uttarkashi earthquake, 1999 Chamoli earthquake and the 2001 Kachchh earthquake resulting in wide spread loss of life and property due to collapse of masonry buildings.

3. Basis of Assessment

For the assessment of expected seismic performance of most of the existing load bearing masonry wall buildings in Zone IV of the Seismic Zoning Map of India, shown in fig. 1, the most direct approach will be to compare the safety provisions specified in the building code IS: 4326-1993, "Earthquake Resistant Design and Construction of Buildings – Code of Practice (Second Revision), Bureau of Indian Standards" for such buildings with the condition actually present in an existing building. Where the existing condition is found to *comply* with the code, it will be considered safe and acceptable. But where any existing condition is found deficient, hence *non-complying*, it will be considered as weak and *damageable*. Such a deficiency will require upgradation or strengthening or *retrofitting.*

Here the *residential* buildings situated in *Seismic Zone IV* only are considered.

4. Type of Building Construction

The following building types can be assessed by the simple procedure covered here:

(i) Brick wall buildings with any mortar and roof type.

(ii) Concrete block wall buildings with any mortar and roof type.

(iii) Fully dressed stone (Ashler masonry)wall buildings with any mortar and roof type

The number of storeys may be one to *four* only as *five* storeyed building are not considered in the Code. The building may be fully residential or with mixed use. *Only earthquake safety aspects* are to be assessed. It is assumed that the building is otherwise safe to carry the vertical weight of roof and floor as well as the use-related imposed loads of furnishings, partitions, people & the contents like merchandise, office equipments etc.

Table 1:- Districts with more than 40% area falling in Seismic Zone IV

DISTRICT NAME	% AREA	DISTRICT NAME	% AREA	DISTRICT NAME	% AREA	DISTRICT NAME	% AREA
BIHAR		**HIMACHAL PRADESH**				**DELHI**	
Paschim Champaran	100	Lahul & Spiti	96.4	Moradabad	100	North West	100
Purba	100	Solan	96.2	Rampur	100	North	100
Sheohar	92.8	Sirmaur	100	Jyotiba Phule Nagar	100	North East	100
Kishanganj	90.8	Shimla	100	Meerut	100	East	100
Purnia	95.9	Kinnaur	100	Baghpat	100	New Delhi	100
Katihar	100	**JAMMU & KASHMIR**		Ghaziabad	100	Central	100
Madhepura	46.8	Anantnag	92.5	Gautam Buddha Nagar	100	West	100
Saharsa	55.4	Leh	100	Bulandshahr	100	South West	100
Muzaffarpur	92.9	Kargil	100	Aligarh	56.3	South	100
Gopal Ganj	100	Doda	100	Mathura	49.4	**CHANDIGARH (UT)**	
Siwan	98.8	Udhampur	100	Pilibhit	77.2	Chandigarh	100
Saran	100	Punch	100	Kheri	49.9		
Vaishali	100	Rajuri	100	Bahraich	58.4		
Samastipur	100	Jammu	100	Shrawasti	93.3		
Begusarai	100	Kathua	87.1	Balrampur	97.4		
Khagaria	100	**MAHARASHTRA**		Siddhartnagar	100		
Bhagalpur	100	Raigarh	73.6	Sant Kabir Nagar	43.7		
Banka	91.7	Satara	53.6	Maharajganj	100		
Munger	100	Ratnagiri	54.1	Gorakhpur	57.9		
Sheikhpura	100	**PUNJAB**		Bareilly	46.1		
Nalanda	98.2	Gurdaspur	100	Kushinagar	100		
Lakhisarai	100	Amritsar	81.4	Deoria	71.9		
Patna	88.1	Kapurthala	100	**UTTARAKHAND**			
Jamui	73.7	Jalandhar	100	Tehri Garhwal	96.8		
GUJARAT		Hoshiarpur	100	Dehradun	100		
Banas Kantha	42.3	Nawanshahr	100	Garhwal	96.8		
Patan	66.1	Rupanagar	100	Champawat	100		
HARYANA		Fatehgarh Sahib	98.1	Nainital	100		
Panchkula	100	Ludhiana	78.4	Udhan Singh Nagar	100		
Ambala	89.1	**SIKKIM**		Hardwar	100		
Yamuna Nagar	100	North	100	**WEST BENGAL**			
Panipat	66.7	South	100	Darjiling	100		
Sonipat	83.1	East	100	Jalpaiguri	83.6		
Rohtak	56.2	West	100	Koch Bihar	88.8		
Jhajjar	100	**UTTAR PRADESH**		Uttar Dinajpur	100		
Rewari	100	Saharanpur	100	Dakshin Dinajpur	100		
Gurgaon	100	Muzaffarnagar	100	North 24 Parganas	64.7		
Faridabad	100	Bijnor	100	South 24 Parganas	82.8		

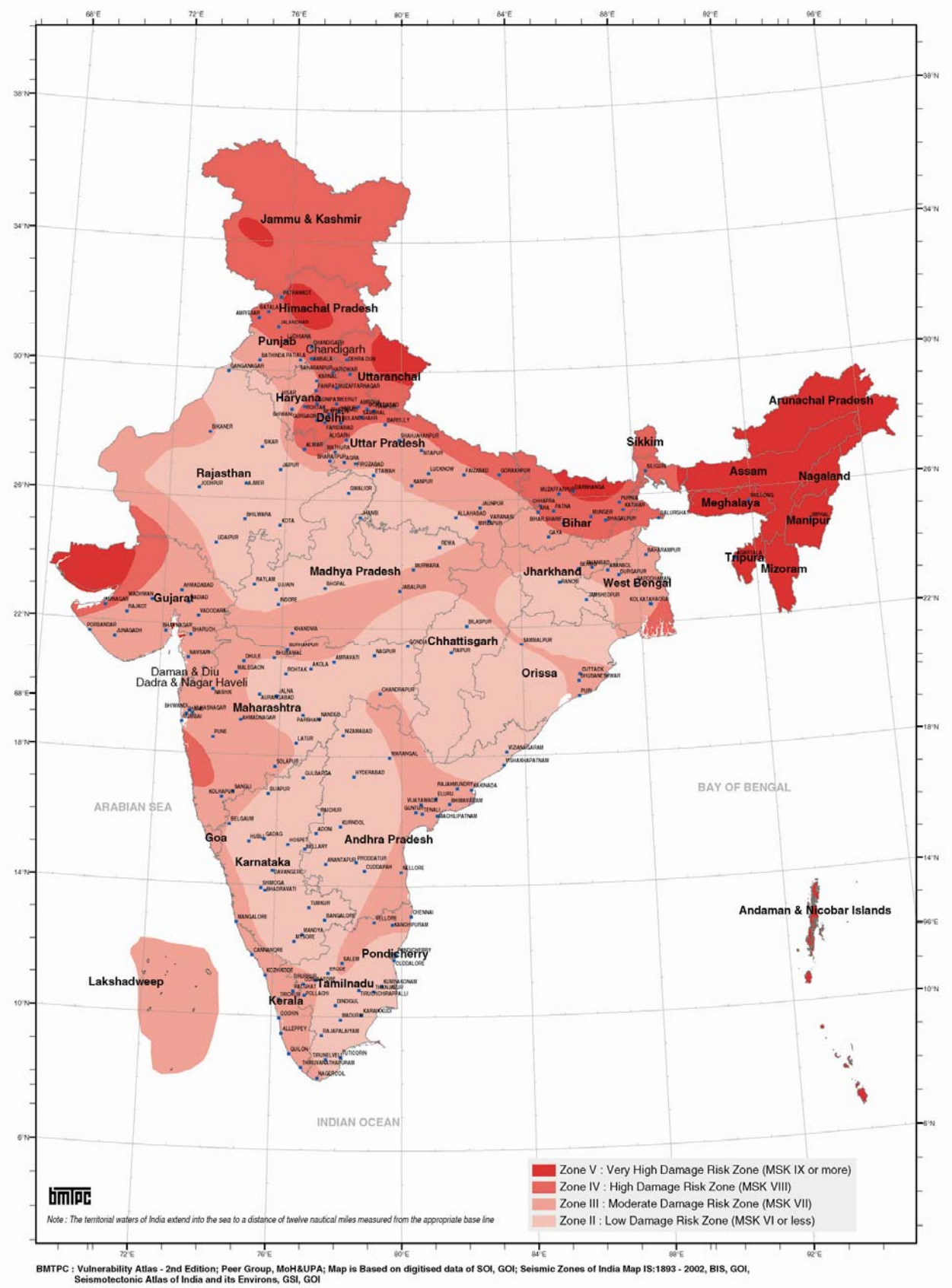


Fig.1:- Seismic Zoning Map of India

5. Factors Considered In Seismic Safety as Per Building Code IS: 4326-1993

The most important factors considered in the Code for ensuring seismic safety of various category buildings are the following:

I) For Safety of Walls

(i) Mortar used in foundations and walls

(ii) Size and placing of door, window openings in walls

(iii) Length of wall between cross walls

(iv) Height of wall above floor to ceiling

(v) Unconnected perpendicular walls.

(vi) Provision of horizontal seismic bands at

- (a) plinth level
- (b) door and window lintel level
- (c) ceiling of flat floor/roof, or eave level of sloping roofs
- (d) gable ends and top of ridge wall
- (e) window sill level

(vii) Provision of vertical steel bar

- (a) at each corner/junction of walls
- (b) at door & window jambs

II) For Safety of Roofs or Floors

(i) Roofs/floors with prefabricated or precast elements

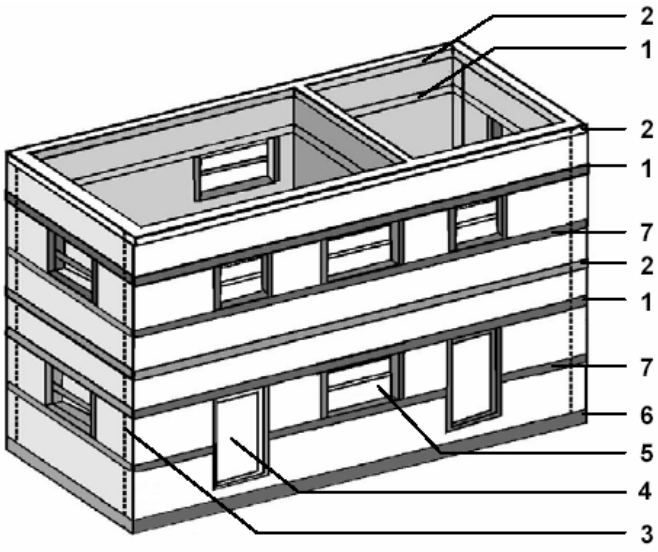
(ii) Cantilever balconies

(iii) Roofs/floors with wooden joists with various covering elements

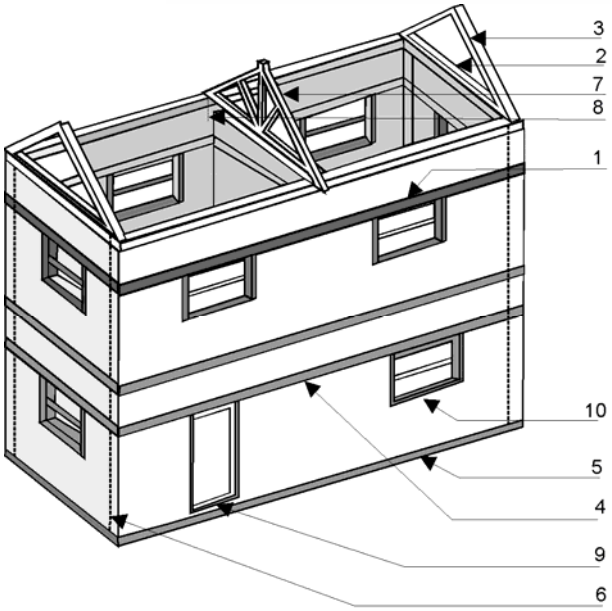
(iv) Jack arch roof or floors

(v) Sloping roofs with sheets or tile covering

(vi) Sloping raftered roofs



1. Lintel Band
2. Roof/ Floor Band
3. Vertical reinforcing bar at corner
4. Door
5. Window
6. Plinth Band
7. Window Sill Bands



1. Lintel band
2. Eave level (Roof) band
3. Gable band
4. Floor band
5. Plinth band
6. Vertical bar
7. Rafter
8. Holding downbolt/Vertical bar
9. Door
10. Window

Fig.2:- Essential elements for earthquake safety of masonry buildings

6. General guidance about Seismic Safety of masonry Buildings

- A single storeyed building using one brick thick walls will be relatively safer than three storeyed one. The fourth storey, if added, will be unsafe, and will make the lower storeys more vulnerable.
- Use of half – brick thick (10 to 11.5 cm or 4 to 4½" thickness) load bearing walls will make the storey very unsafe during seismic Intensity VIII on MSK Intensity scale and, if used in 3rd or 4th storey, it may have a catastrophic failure.
- Too many window openings make a wall weaker, and use of smaller size piers less than 18 inches (45 cm) in width between them will increase the damageability even higher.
- Richer cement-sand mortar of 1:4 mixture (1 part cement by 4 parts of sand) makes the masonry stronger against earthquake shaking as compared with 1:6 mortar by a factor of 2.5 to 3.0. Also 1:6 mortar is stronger than lime-cinder or lime-surkhi mortar.
- Use of clay mud mortar produces the weakest masonry. Its strength in dry condition reduces to less than 50 percent when the walls get wet during rains. Hence, use of good plastering is essential to protect such masonry during rainy months.
- Longer walls between consecutive cross walls are found weaker than shorter walls. The length is controlled for safety by limiting its *length to thickness ratio*.
- Taller walls between any two floors are found to be weaker than shorter walls. The storey height is controlled by limiting its *height to thickness ratio*.
- All four walls enclosing a room should be properly connected at each corner. Walls not so connected will easily separate at corners and overturn under the earthquake motion.
- The most important seismic safety requirement is provision of *seismic bands* in all storeys in all external as well as internal walls. These *bands* maintain the integrity of the whole building as one unit under earthquake shaking. Besides the earthquake safety, they also increase the stability of the walls under the vertical loads.
- The roof structure of the sloping roofs needs its integrity through bracing and proper connectivity with the walls. Such integrity is automatically provided by reinforced concrete slabs wherever used for floors and the roof.

The Indian Standard Code of Practice IS: 4326 – 1993 covers all these aspects in detail and gives specific guidance as to how to incorporate them in the earthquake safe construction of all types of new masonry buildings.

7. Form for Seismic Safety Assessment of Housing Units in Masonry Buildings

7.1 Guiding Notes for filling the Assessment Form

(i) Complete all data points. Tick mark columns of *complying & non-complying* as found by compliance.

(ii) BB stands for Burned Brick Construction and CCB for Cement Concrete Block Construction.

(iii) More than 4 storeys are not permitted by Code (IS: 4326 – 1993).

(iv) The compressive strength of building unit for one and two storey building to be not less than 35 kg/cm^2 , and for 3 & 4 storeys 50 kg/cm^2 . Note: Red bricks in the Indo-Gangetic plain are normally strong enough and

complying. But yellow colored bricks are found weaker, hence, *non-complying*. CCB strength can be ascertained from the manufacturers, or determined by testing in laboratory.

(v) Normal bricks in India are 230 mm (9 inch) in length and CCB 200 mm wide. Load bearing burnt brick walls are generally 230 mm thick and those using CCB are 200 mm thick. Smaller wall thickness for non-load bearing partitions and infill burnt brick walls are kept 115 mm (½ brick) or 100 to 150 mm for CCB.

(vi) Specified mortar mix is C:S = 1:6 or richer in cement-sand.

(vii) Length of wall between cross walls is to be less than 35 x thickness or 8 m maximum.

(viii) Height of wall from floor to ceiling to be not more than 15 x thickness nor 4m.

(ix) Following constraints for door and window openings are specified for Zone IV (see fig.3)

- End corner distance b_5 = 450 mm
- Pier width b_4 = 560 mm
- Ratio of overall length of openings in a wall to its overall length, that is $(b_1 + b_2 + b_3)/L$ =

  Is to be less than or equal to 0.5 for one storey building, 0.42 for two storey building, 0.33 for 3 & 4 storey building

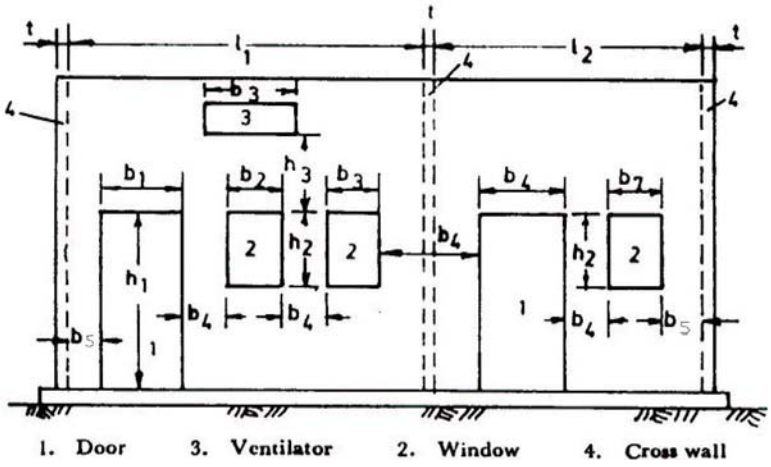


Fig.3:-Opening sizes as per IS: 4326 - 1993

7.2 The Assessment Form

Building Information:-

Address:-

Location/Area:-

Village/Town:- District:-

House Unit under Assessment:-

Name of Owner/Tenant living in the house:-

No. of storeys in the building including basement if any:-

Floor on which the house unit is located: - Ground / First / Second / Third

FORM FOR ASSESSING SEISMIC SAFETY

S.N (1)	Data of Building under Assessment (2)	Required as per Code (3)	*Tick if*		Action to be taken to save the building from collapse or severe damage
			Complying	Not complying	
1.	Number of storeys, S =	Equal to or less than 4			1. Extra upper stories may be removed. 2. For weaker building units, providing RC or steel columns may be considered. 3. For thinner walls pilasters of RC may be designed. 4. For weaker mortar case, providing Rc columns & beams may be considered. Note:- In cases 2, 3 & 4 above, strengthening the walls by ferro-cement plating of by FRP may be an option. 5 & 6 Provide buttresses at regular intervals for strengthening the wall. 7 (i) Consider closing one of the windows or reduce the width of window openings by adding additional thickness of piers. (ii) & (iii) strengthening the piers by ferro-cement plating. 8.(b)Use RC screed with peripheral RC beam in place of RC ceiling band 8. (c)Introduce cross ties with diagonal bracing underneath the floor. 8. (d)Provide cross ties welded to the steel joists along with diagonal bracing. 9(b) Use diagonal bracing in the plane of the ties and the principal rafters in every fourth panel. 9(c) As in 9 (b) 10 (i) Incase the plinth is high say 90 cm or higher provide seismic belt. 10 (ii) to (vi) Provide seismic belt on the walls at the level where seismic band was required. 11 (i) to (iv) Provide seismic belt or a vertical bars at the corners of the walls in the replacement of the required vertical reinforcement as per the code. 11 (v) & (vi) Strengthen the jambs with seismic belts.
2.	Wall building unit: (Tick one) BB/CCB (solid)/CCB (Hollow) Compressive strength = kg/cm^2	Compressive strength ≥ 35 or 50 kg/cm^2			
3.	Thickness of load bearing walls, t External wall = Internal wall =	BB = 230 mm CCB = 200 mm			
4.	Mortar used =	C:S = 1:6 or richer			
5.	Longest wall in room, L = …….m	BB ≤ 8 m CCB ≤ 7 m			
6.	Height of wall, floor to ceiling h = ……. m	BB = 3.45 m CCB = 3.0 m			
7.	Door, Window openings (See fig.3) Overall ($b_1 + b_2$+….)/l, (i) Give max in any room = (ii) b_4 min. = (iii) b_5 min.=	One storeyed 0.50 Two Storeyed 0.42 3 or 4 Storeyed 0.33 b_4 min 560 mm b_5 min 450 mm			
8.	Floor type *(tick mark)* a) ☐ RC or RB slab, b) ☐ Precast RC elements, (tick one) With/without RC screed c) ☐ Wood joists with tiles, (tick one) With/without bracing d) ☐ Jack arches, (tick one) With/without ties &bracing	 OK With RC screed With bracing With ties & bracing			
9.	Roof type *(tick as present)* a) ☐ Flat like floor (See item 8 a), b) ☐ Sloping trussed, (tick one) With/without bracing c) ☐ Sloping raftered, (tick one) With/without ties &bracing	 OK With bracing With ties &bracing			
10.	Seismic Bands *(tick as present)* (i) at plinth *provided / not provided* (ii) at lintel level *provided / not provided* (iii) at window sill level *provided / not provided* (iv) at ceiling or eave level *provided / not provided* *(v)* at gable ends *provided / not provided* (vi) at ridge top *provided / not provided*	 Required Required In 3 or 4 storey buildings only Required in cases 8 b, c & 9 b, c. Required in cases 9 b,c Required in cases 9 b,c			
11.	Vertical bar *(tick as present)* (i) at external corners *provided / not provided* (ii) at external T-junctions *provided / not provided* (iii) at internal corners *provided / not provided* (iv) at internal T-junctions *provided / not provided* (v) at jambs of door *provided / not provided* (vi) at jambs of windows *provided / not provided*	 Required in all masonry buildings			

Note: - Record all information for your housing unit and the building of which your unit forms part.

8. Deficiencies Vs Type of Damage

Among the assessment points indicating deficiencies in the building, different non-complying elements are known to create differential damage behavior of a building under MSK Intensity VIII earthquake. Some deficiencies are critical which lead to the total collapse and some lead to varying degrees of damage. An effort is made below to give indication of the likely damage scenario in case a masonry building is subjected to Intensity MSK VIII which is the basis of defining the areas under seismic Zone IV.

a) Buildings with wall thickness less than that specified in the *Code* or buildings constructed in weaker mortar, and those not having any horizontal seismic bands and/or vertical reinforcement at corners and wall junctions can *totally collapse*.

b) Those of one or two storeys constructed using specified minimum wall thicknesses, using cement sand mortar of 1: 6 mix and having RC/RB slab floor and roof but *without* any horizontal seismic bands and or vertical steel bars at corners, may have wide cracks in the walls particularly in the walls with window openings.

c) Three or four storeyed buildings with conditions similar to case (b) above may have more severe damage including partial or total collapse in certain storeys.

d) In buildings having conditions as at (b) above but with longer or higher than specified dimensions of the walls may also be subjected to severe damage, i.e. partial or total collapse as in case (c) above.

e) Buildings having Code specified wall dimensions as well as mortar, and reinforced with the horizontal seismic bands and vertical steel at corners and junctions of walls, will generally remain safe except for minor cracking seen in the piers between the openings and some walls.

9. Summary of Results of Comparative Assessment

The major deficiencies indicating *non-compliance* with Codal provisions should be noted and the house unit owner may understand the kind of damage to which his unit or the building as a whole may be subjected as explained in Para. 8 above. Those deficiencies will need to be considered for upgrading the seismic safety by retrofitting the building suitably to prevent the total or partial collapse of the building in future if and when the probable maximum earthquake Intensity MSK VIII will strike the area.

10. References

1. IS: 4326-1993 "Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision)".
2. IS: 13935- "Repair and Seismic Strengthening of Masonry Buildings - Guidelines" (First Revision……..).

Prepared By:

Professor Anand S. Arya and Ankush Agarwal

GoI – UNDP, Disaster Risk Management Programme

E-mail:- anand.s.arya@undp.org; ankush.agarwal@undp.org

NATIONAL DISASTER MANAGEMENT DIVISION

MINISTRY OF HOME AFFAIRS, NORTH BLOCK, NEW DELHI

Tel:91-11-23093178; Tele/fax: 23094019, Email:ndmindia@nic.in;Website:www.ndmindia.nic.in