

GUIDELINE FOR REPAIR, RESTORATION AND RETROFITTING OF MASONRY BUILDINGS IN EARTHQUAKE AFFECTED AREAS OF JAMMU & KASHMIR



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PREFACE

The earthquake on 8th October, 2005 in Jammu & Kashmir State with Richter Magnitude 7.4 caused large-scale damage and destruction to residential and community buildings. In addition to 28939 buildings that collapsed, 83616 buildings were damaged to varying grades of damage. Such buildings will need minor and major repairs. Needless to say that simple and superficial repair to buildings will not restore the lost strength; it will only hide the cracks, leaving the building in a weakened state. Such buildings become vulnerable to the next earthquake, even with lesser Magnitude. Consequently, it is necessary, especially in the earthquake prone districts lying in Seismic Zone IV & V, that people take appropriate actions in order to achieve not only the restoration of the lost structural strength to pre-disaster level, but also to upgrade the earthquake resistance by retrofitting to the level envisaged by the Building Codes IS:4326 (1993)– “*Earthquake Resistant Design and Construction of Buildings – Code of Practice (Second Revision)*“, IS:13828 (1993)– “*Improving Earthquake Resistance of Low Strength Masonry Buildings - Guidelines* “ and IS:13935 (1993) – “*Repair and Seismic Strengthening of Buildings*”.

The present Guidelines on ***Repair, Restoration and Retrofitting of Masonry Buildings in Earthquake Affected Areas of Jammu & Kashmir*** will provide the much needed information to Engineers, NGOs and house owners so as to enable them to ensure long-time safety of rehabilitated houses and community buildings.

It may be mentioned that in earthquake engineering terminology, Repair, Restoration and Retrofitting have acquired the following meanings:

Repair : Actions taken for patching up of superficial defects and doing the finishes.

Restoration : Action taken for restoring the lost strength of Structural elements.

Retrofitting : Actions for upgrading the seismic resistance of an existing building, so that it becomes safer under the recurrence of likely future earthquakes.

Repair and restoration are applicable to damaged buildings. Retrofitting is relevant to ‘restored’ as well as existing undamaged buildings which are otherwise weak against earthquake forces likely to occur in future according to Indian Standard Codes IS:1893-2002 – “*Criteria for Earthquake Resistant Design of Structures (Fifth Revision)*”.

These Guidelines cover all three aspects as applicable to all types of *masonry buildings* as well as Dhajji Diwari constructions whether used for housing or community activities. It is suggested that the three types of action are taken in the following order:

First, **restore** the building structurally

Next, **retrofit** the building for upgrading seismic resistance

Last, **repair** the building architecturally.

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REPAIR, RESTORATION AND RETROFITTING OF MASONARY BUILDINGS IN EARETHQUAKE AFFECTED AREAS OF JAMMU & KASHMIR

1. INTRODUCTION

An earthquake of magnitude 7.4 occurred in Jammu & Kashmir on the 8th October, 2005 and caused massive destruction to property and loss of life in the towns and villages on both sides of the Line of Control. The high intensity earthquake was felt across northern India covering states of J&K, Uttaranchal, Himachal Pradesh, Delhi, Punjab, Haryana, Rajasthan and Uttar Pradesh. The initial reports indicate that about 28939 houses were fully damaged and 83616 partially damaged in the state of Jammu and Kashmir. The worst affected districts in Jammu and Kashmir are Srinagar, Baramulla, Kupwara, Anantnag, Pulwama, Budgam, Jammu, Kathua, Udhampur, Doda, Rajouri and Poonch. The area affected in the state was predominantly rural. The affected area lies in two high risk seismic zones (IV and V) of Indian seismic code IS:1893 (2002) with an expected MSK Intensity of 'IX or more' in Zone V and an intensity of 'VIII' in Zone IV. Damage to buildings corresponded with a maximum of 'IX' at Uri, Salamabad, Lachi Village, Sultan Taki Village and Kamalkot; 'VIII' at Rampur Cantt, Pandav Mandir, Buniyar, Data Mandir and Mohura, and 'VII' at Srinagar, Batmalu, Baramula and Chahalam. It is very apparent that poorly built stone and brick buildings failed miserably under Intensities IX and VIII. No earthquake resistant measures were incorporated in these buildings.

2 DAMAGE OBSERVATIONS

2.1 Building Construction Types: The buildings affected by the quake fall in the following types

(a) Better Quality Masonry having:-

- *Walling:* Load bearing Masonry consisting of Stone in cement mortar & lime mortar, or Brick in cement mortar
- *Roofing:* CGI sheeting on timber under-structure, or RCC slab
- *Intermediate flooring:* RCC slab

(b) Low Strength Masonry having

- *Walling:* Load Bearing Masonry consisting of:

Unburnt brick in mud mortar with Burnt brick cladding on exterior,
14" (35 cm) to 18" (46 cm) thick *or*
Burnt brick in mud mortar 9" (23 cm) to 14" (35 cm) thick

- *Roofing*: CGI sheeting on timber under-structure.

(c) Dhajji-Diwari Construction consisting of

- *Walling*: timber posts and timber diagonal bracings connected to floor and roof framing with intermediate space filled with:
Unburnt bricks in mud mortar 4" (10 cm) thick, *or*
Burnt bricks in mud mortar 4" (10 cm) thick, *or*
Burnt bricks in cement mortar 4" (10 cm) thick.
- *Roofing*: CGI sheeting on timber under-structure.
- *Intermediate flooring*: Timber plank on timber under-structure.

2.2 Damage Types: The damage is mainly observed in walls. The damage in roof, although rare, is because of the part or total collapse of wall.

- Bulging in case of stone walls and incase of brick walls thicker than 14" (35 cm).
- Delamination in case of stone walls and incase of brick walls thicker than 14" (35 cm) (*see photo. 1, 2 & 3*).
- Cracks in Vertical, Horizontal, and Diagonal directions (*see photo. 4 & 5*).
- Cracks at corners, separating the perpendicular walls (*see photo. 6*).



Photo. 1:- Uri town – Police Station – Delamination & collapse of Burnt Brick Cement Masonry walls and Un Coursed Random Cement walls



Photo. 2:- Uri town – Shops – Delamination of Un Coursed Random in Mud Masonry wall with Corrugated Galvanised Iron roof.



Photo. 3:- Uri town – Govt. Quaters – Delamination & collapse of Uncoursed Random Masonry walls (no ‘through’ stones) with intact Corrugated Galvanised Iron roof.



Photo. 4:- Uri town – Civil Defence Bldg.– Diagonal cracks in window openings and tilting of walls in Burnt Brick Cement Masonry wall.



Photo. 5:- Uri town – Shops –Collapse of Uncoursed Random Mud Masonry walls with Reinforced Cement Concrete slab.



Photo.6:- Uri town – Civil Defence Bldg.– Corner cracks and vertical cracks in Burnt Brick Cement Masonry wall.



Photo. 7:- Near Sultan Gaddi – House - Uncoursed Random Masonry wall with ‘through’ and long stones (saved from collapse).



Photo. 8:- Sultan Gaddi – School – Collapse & cracking of Uncoursed Random Cement Masonry walls with intact roof (walls can be rebuilt with safety features).



Photo. 9:- Salamabad House – Collapsed Uncoursed Random Masonry with intact roof.



Photo.10:- Srinagar – Dhajji type of wall – Old & new (more diagonal braces needed).

- e. Total collapse of stone or brick walls constructed using mud mortar (see *photo 7, 8 & 9*).
- f. Lateral deformation of Dhajji Diwari (see *photo 10, 11 & 12*).



Photo.11:- Srinagar – Combination of Dhajji type & wooden wall (More diagonal braces needed).



Photo.12:- Srinagar – Good example of Dhajji type of wall.

Although, stone walls have suffered the most amount of damage, the brick walls in mud mortar were also very badly affected.

Uri Town & Vicinity: In this area severe damage has been limited to the ground storey. The upper storey including the floor, walls and roof has been left unaffected by the earthquake in most cases. These will be classified in G 4 grade of damage that is “severely” damaged houses (see *photo 3*).

Public Buildings: Many of the public buildings such as hospitals, schools, PWD rest-houses etc. are damaged to the categories G1 to G3 but still standing. They either lack the earthquake resisting features, or if they are present, they are inadequate. This means they are vulnerable to a future earthquake and will need structural restoration as well as retrofitting.

3. CAUSES OF DAMAGE

- The damage and destruction in stone masonry and brick masonry walls is because of the **violation of the most basic rules of masonry** construction; such as absence of ‘through’ stones and ‘long corner’ stones in stone walls.
- Use of mud mortar in stone or brick masonry makes them very weak against severe or even moderate earth shaking.
- In case of stone and brick masonry in cement mortar, **inadequate curing** has been observed as one of the causes of failure.
- In all types of masonry construction, the **absence of earthquake resisting features** has also contributed significantly to the failures. Provision of such features will improve the earthquake resistance of even mud mortar masonry.

4. IMPACT ON PEOPLE’S PREFERENCE

Many individuals in the quake affected areas including some engineers talk about replacing stone construction by brick construction. But each brick costs from Rs.3 to Rs.6 a piece which will increase the reconstruction cost substantially. Similarly they also talk of replacing mud mortar with cement-sand mortar which should be done if affordable. But sand costs Rs.6,000/= to 9,000/= a truck in many areas. Some artisans talk of incorporating beams at foundation level as well as plinth level. Such beams are not necessary in masonry buildings. Only a seismic band needs to be provided at the plinth level. An NGO indicated plans to incorporate vertical MS angles in the construction of walls. The complete bonding of such angles with the walls will be necessary for earthquake resistance but may not be practical. It will be cheaper as well as fully collapse proof to rebuild the houses using the guidelines for “*Earthquake Resistant Reconstruction and New Construction of Masonry Buildings in Jammu & Kashmir State*” based

on IS:4326 and IS:13828 already published and supplied by Ministry of Home Affairs, Government of India.

5. STRATEGY RECOMMENDED FOR RECONSTRUCTION

A strategy recommended for reconstruction of houses and restoration & retrofitting of damaged buildings is given in Annexure – I.

A damage assessment proforma is attached at Annexure – II.

6. CATEGORISATION OF DAMAGE

As specified usually in the MSK Intensity scale, five categories of damage are recognized and named as G1 to G5; G1 referring to very slight damage without loss of structural strength and G5 refers to complete collapse of the building. Description of these categories of damage as applicable to masonry buildings is presented in Table 1.

Table 1:- Damage Categories*

	Category	Walls *	Roof / Floors
0	No Damage	No Damage	No Damage
G 1	Slight Non-Structural Damage	Thin cracks in plaster, falling of plaster bits in limited parts.	Thin cracks in small areas, tiles only slightly disturbed
G2	Slight Structural Damage to non-structural parts like <i>Chajjas</i> , parapets.	Small cracks in walls, falling of plaster in large areas: damage about 10% area; minor damage in under-structure of sloping roof.	Small cracks in slabs/ A.C. sheets; tiles disturbed in
G3	Moderate Structural Damage walls, columns and piers; or collapse of one wall. The load carrying capacity of structure is partially reduced.	Large and deep cracks in walls; widespread cracking of 25% tiles disturbed/fallen moderate damage to understructure of sloping roofs.	Large cracks in slabs; some AC sheets, broken; upto
G4	Severe Structural Damage collapse; Approximately fifty percent of the main structural elements fail. The building takes a dangerous state.	Gaps occur in walls; two or more inner or outer walls sloping roof heavily damaged part may fall; tiles badly affected & fallen.	Floors badly cracked, part may fall; under- structure of
G5	Collapse building collapses.	A large part or whole of the and roof collapse or hang precariously.	A large part or whole floor

* Based on I.A.E.E. Guidelines, further developed through observations in earthquakes in India, by Dr. A.S. Arya, Seismic Advisor, G S D M A., March 2002.

So far as repair, restoration of structural strength and seismic strengthening to meet the Codal requirements are concerned, Categories G1 to G3 are most relevant, since buildings or parts thereof subjected to category G4 in most cases have to be demolished and rebuilt, although in some cases (see photo) such buildings may be restored by rebuilding only the damaged walls incorporating earthquake resistant measures, while the undamaged portion is kept supported and later on retrofitted.

7. CONCEPTS OF REPAIR, RESTORATION AND RETROFITTING

There is a need to distinguish between the terms repair, restoration and retrofitting as described below:

7.1 Repair

It consists of *actions taken for patching up superficial defects*, re-plastering walls, repairing doors and windows and services such as the following

- i) Patching up of defects as cracks and fall of plaster and re-plastering if needed.
- ii) Repairing doors, windows and replacement of glass panes.
- iii) Checking and repairing electrical connections, gas connections, plumbing, heating, ventilation
- iv) Rebuilding non-structural walls, chimneys, boundary walls.
- v) Relaying cracked flooring at ground level and roofing sheets or tiles.
- vi) Redecoration work (White or color washing etc.)

It would be seen that *the repairing work carried out as above does not add any strength to the structure.*

7.2 Restoration

This includes *actions taken for restoring the lost strength of structural elements of the building*. This is done by making the columns, piers, beams and walls at least as strong as originally provided as follows:

- i) Removal of portions of cracked masonry walls and piers, and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
- ii) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it suitably with micro-concrete or 1:3 cement -coarse sand plaster.

- iii) Injecting neat cement slurry or epoxy like material, which is strong in tension, into the cracks in walls, columns, beams etc.

If the structural restoration is properly executed, the structure will be as strong as before the earthquake. It is also possible to strengthen a structure to take increased vertical loading, if required.

7.3 Seismic Strengthening (Retrofitting)

It will involve *actions for upgrading the seismic resistance of an existing building so that it becomes safer under the occurrence of probable future earthquakes.*

The seismic behavior of existing buildings is affected by their original structural inadequacies, material degradation due to aging and alterations carried out during use over time. The complete replacement of such buildings in a given area is just not possible due to a number of social, cultural and financial problems. Therefore, seismic strengthening of existing undamaged or damaged buildings is a basic requirement. Seismic strengthening *including* structural restoration and cosmetic repairs may some times cost upto 20 to 25 per cent of the cost of *rebuilding* although usually it may not exceed 12 to 15 per cent. Hence justification of strengthening work must be fully considered from cost point of view. The main items of seismic strengthening of masonry building could be some or all of the following actions:

- i) Modification of roofs,
- ii) Substitution or strengthening of floors,
- iii) Modification in the building plan,
- iv) Strengthening of walls including provision of horizontal and vertical bands or belts, introduction of 'through' or 'header' stones in thick stone walls, and injection grouting etc.,
- v) Adding diagonal bracings in Dhajji diwari panels,
- vi) Strengthening of foundations is rarely found necessary (but it is usually very difficult and expensive).

8. ASSESSMENT OF DAMAGE

The buildings to be restored and repaired should be thoroughly surveyed and various damages should be recorded on drawings. The width and length of each damage needs to be recorded so as to estimate the required materials and labor for restoration and repair properly. It should also be assessed if during the process of restoration, some of the service lines will need to be disturbed, and their temporary bypassing may be needed. The expenses should be included in the estimates.

9. USUAL DAMAGE TYPES IN MASONRY BUILDINGS.

The types of damage generally observed in various masonry buildings during the earthquake are listed in Table 2. Alongside, the actions to be taken for restoration of the lost strength are also suggested. Details of each such action are described in the following paragraphs.

Table - 2: Types of Damage in Masonry Buildings

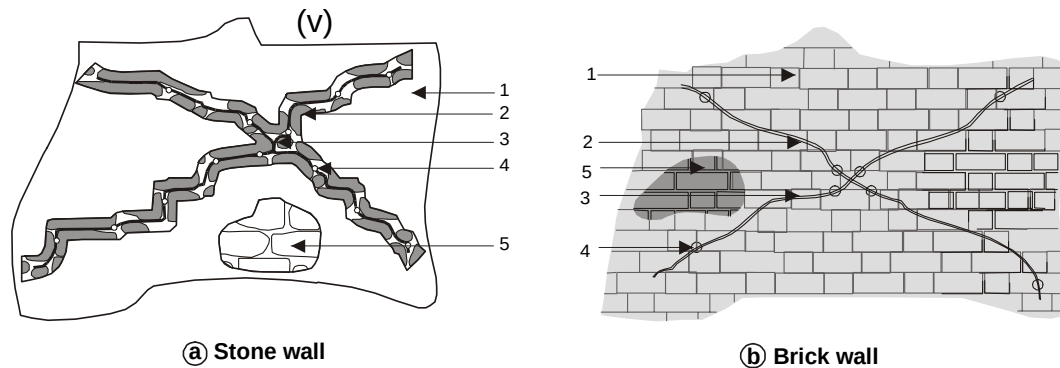
Damage Observed	Action for Restoration
a) Different types of cracks seen in masonry walls	a) i,ii. Cracks to be fully filled using appropriate grout or mortar.
i. Vertical cracks	iii. Cracks at the corners or T-junctions to be filled as above but before that the walls at right angles to be connected using ferro-cement corner plates.
ii. Inclined cracks	
iii. Cracks at the corners or T junctions, and separation of the cross-walls	
b) At some places, occurrence of many cracks close together in the walls, OR tilting of some wall portions out of plumb after separation OR bulging of stone wall after delamination, OR falling of some wall portions.	b) This type of cracked, fallen, tilted or bulged wall portion to be reconstructed using richer mortar after partial dismantling of wall as required.
c) Shifting of roofing tiles or buckling of roof sheeting OR falling down and being broken or twisted.	c) The roofing tiles or sheeting to be removed for further work & the rafters to be properly positioned. The opposite rafters to be tied together by horizontal braces; the purlins to be adjusted and the tiles or sheeting to be placed back properly.

10. METHODOLOGY FOR GROUTING OF CRACKS

10.1 Minor and medium cracks (crack width 0.5 mm to 5.0 mm)

Material/equipment required

- (i) Plastic / Aluminium nipples of 12 mm dia (30 to 40 mm long).
- (ii) Non-shrink cement (shrinkomp of ACC or equivalent).
- (iii) Polyester putty or 1:3 cement sand mortar for sealing of the cracks.
- (iv) Compressor for injecting the slurry or container with nozzle to contain grout held higher than grout port.



Procedure:- See Fig.1

- Step-1 Remove the plaster in the vicinity of crack exposing the cracked **Fig. 1 - Filling grout in cracks** bare masonry.
- Step-2 Make the shape of crack in the V-shape by chiseling out.
- Step-3 Fix the grouting nipples in the V-groove on the faces of the wall at spacing of 150-200 mm c/c.
- Step-4 Clean the crack with the Compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
- Step-5 Seal the crack on both faces of the wall with polyester putty or cement mortar 1:3 (1-cement: 3-coarse sand) and allowed to gain strength.
- Step-6 Inject water starting with nipple fixed at higher level and moving down so that the dust inside the cracks is washed off and masonry is saturated with water.

- Step-7 Make cement slurry with 1 : 1 (1-non shrink cement: 1-water) and start injecting from lower most nipple till the cement slurry comes out from the next higher nipple and then move to next higher nipple.
- Step-8 After injection grouting through all the nipples is completed, replaster the surface and finish the same.
- Note:- Where grout pump is not feasible, use a tin container with a nozzle fixed, fill with grout, hold higher than the port in the wall so that grout flows into cracks under gravity. Keep stirring the grout with a rod to maintain fluidity of the grout.

10.2 Major crack (crack width more than 5.0 mm)

Material/equipment required

- (i) Plastic/Aluminium nipples of 12 mm dia (30 to 40 mm long)
- (ii) Polyester putty or 1:3 cement-sand mortar for sealing of cracks.
- (iii) Non-shrink cement (shrinkomp of ACC or equivalent).
- (iv) Compressor for injecting the slurry.
- (v) Galvanized steel wire fabric (16 to 14 gauge i.e. 1.5 to 2.03mm dia wire) with 25 mm x 25 mm mesh size.
- (vi) Galvanized steel clamping rod of 3.15 mm dia, or 5 mm dia 150 mm long wire nails.

Procedure:-

- Step-1 Remove the plaster in the vicinity of crack exposing the cracked bare masonry.
- Step-2 Make the shape of crack in the V-shape by chiseling out.
- Step-3 Clean the crack with compressed air.
- Step-4 Fix the grouting nipples in the V-groove in both faces of the wall at spacing of 150-200 mm c/c.
- Step-5 Clean the crack with the compressed air through nipples to ensure that the fine and loose material inside the cracked masonry has been removed.
- Step-6 Seal the crack on both the faces of the wall with polyester putty or cement mortar 1:3 (1-cement:3-coarse sand) and allow time to gain strength.

- Sept-7 Inject water starting with nipples fixed at higher level and moving down so that the dust inside the crack is washed off and masonry is saturated with water.
- Step-8 Make cement slurry with 1:2: W (1-non shrink cement : 2-fine sand : just enough water) or use readily available microcrete and start injecting from lower most nipple till the slurry comes out from the next higher nipple and then move to next higher nipple.
- Step-9 After injection grouting through all the nipples is completed, replaster the surface and finish the same.

Alternative Procedure: - See Fig.2

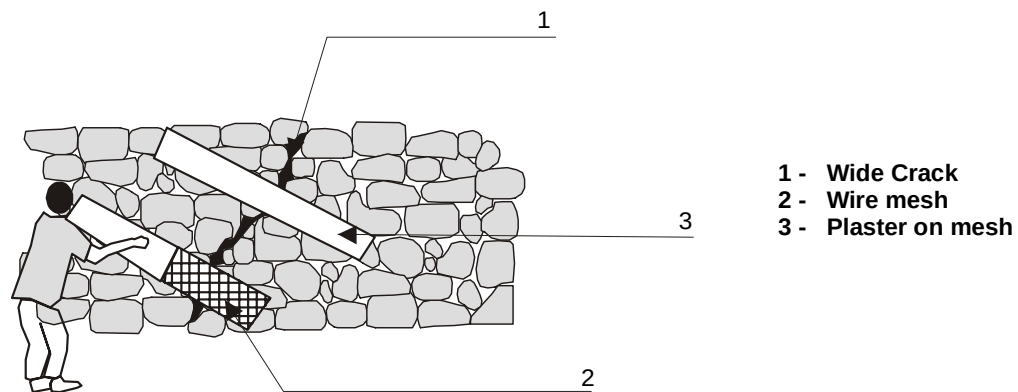


Fig. 2 - Fixing mesh across wide cracks

- Step-1 Remove the plaster in the vicinity of crack exposing the cracked bare masonry.
- Step-2 Make the shape of crack in the V-shape by chiseling out.
- Step-3 Clean the crack with compressed air.
- Step-4 Fill the crack with cement mortar 1:3:W (1-non shrink cement : 3-fine sand : necessary water) from both sides as deep as feasible.
- Step-5 Provide wire mesh ('g14' gauge) on both the faces of wall after removal of plaster in the region of repair to a width of 150 mm on each side of the crack.
- Step-6 Clamp the mesh with the wall using clamps or wire nails at the spacing of 300 mm c/c.
- Step-7 Plaster the meshed area with cement sand mortar of 1:3, covering the mesh by a minimum of 12 mm.

11. INSTALLING FERRO-CEMENT PLATES AT THE CORNERS

Before filling the cracks as in Para 10, use galvanized weld-mesh 'g14' (2.0mm wires @25x25mm mash) over a length of 500-600 mm on each side of the crack both inside and outside of the room in a depth of 300mm at windows sill on about 900 mm height above the floor (Fig.3) and another one at lintel level or about 2 m above the floor. But if horizontal seismic belt is to be provided at the lintel level, the second mesh is not required.

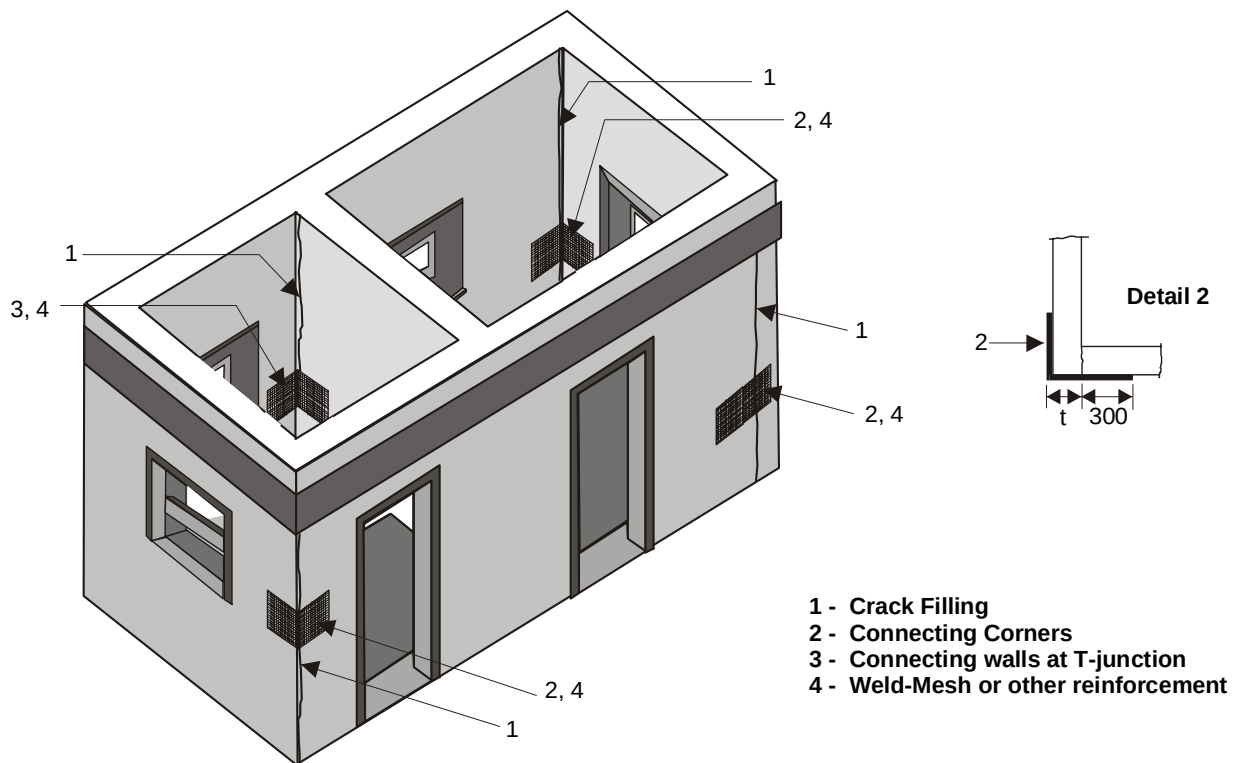


Fig.3 - Connection of cracked walls at corners and junctions

12. REBUILDING PORTIONS OF THE WALL

- (i) Generally the random stone walls are seen to be more than 450 mm thick, built by two wythes vertically (Fig.4.1). Brick walls of 450 mm thick built using mud mortar also behaved similarly in Jammu & Kashmir earthquake. During an earthquake, the wythes get separated and either one or both get bulged (Fig.4.2) which even fall away under further vibrations (Fig.4.3). For preventing such

delamination, it is necessary to use 'through' stones or RCC elements. These should be installed while rebuilding the wall (Fig.4.4).

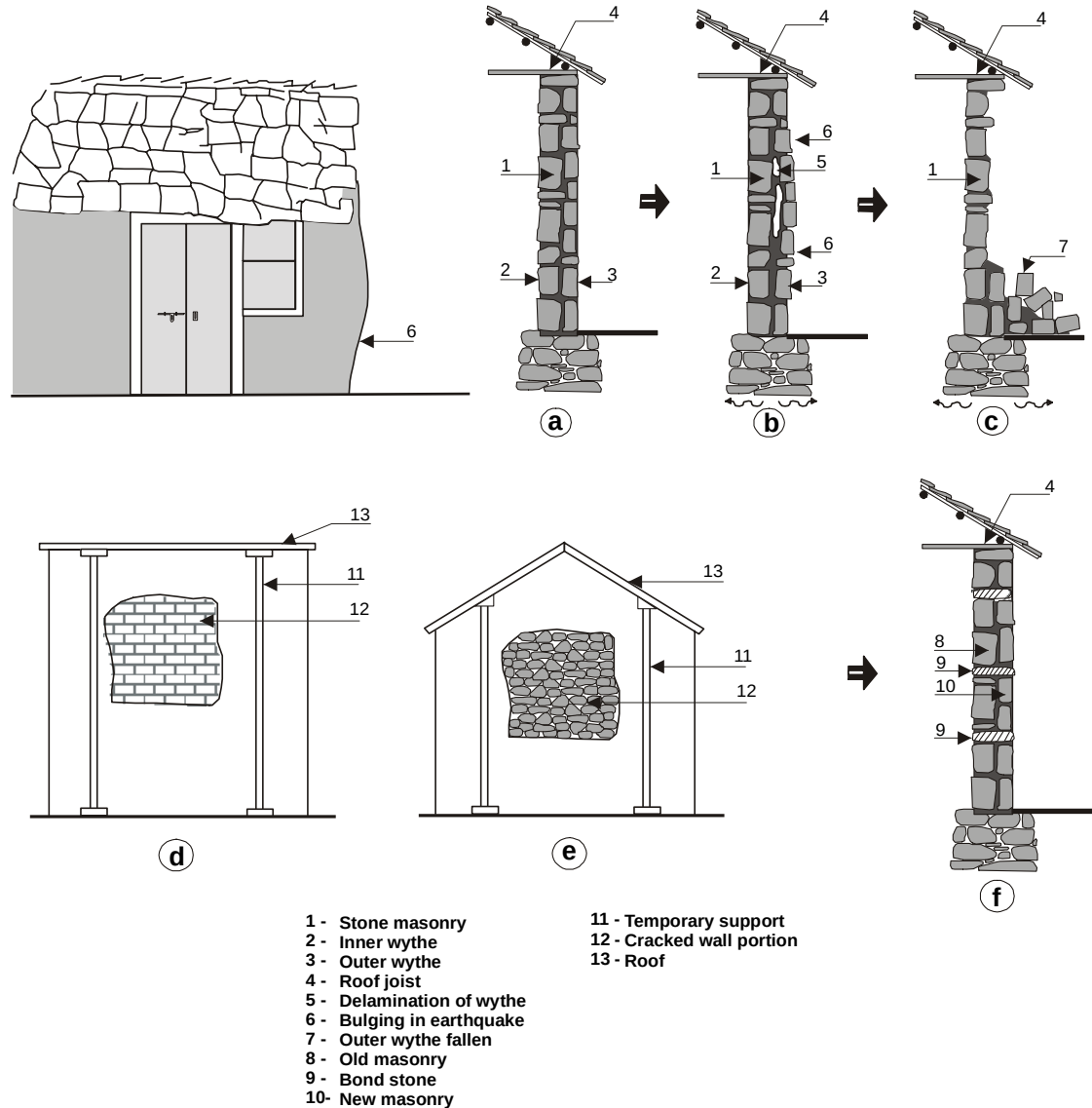


Fig.4 - Rebuilding part of wall

- (ii) Where portions of wall require rebuilding, the roof resting on the wall should first be supported by wooden struts, (Fig-4a,b). Then the damaged portion of the wall should be dismantled. The new portion of the wall should be constructed using 1:6 cement-sand mortar in walls built originally in weak mortar, but using 1:4 mix for walls originally built in weaker cement mortar.

13. EARTHQUAKE RESISTANT RETROFITTING OF BUILDINGS

For achieving safety of buildings against collapse in a future severe earthquake, the following retrofitting actions are recommended. The amount and placing of the retrofitting element depends upon the seismic zone, the importance of the building and the stiffness of the base soil. The Categorization of Buildings is given in Table 3.

Table 3- Simplified Building Categories in the Seismic Zones

Seismic Zone	Ordinary Buildings	Important Buildings
V	E	E
IV	D	E
III	C	D

1. This Categorization is in line with IS: 1893 - 2002 where the maximum response in short period range is taken as uniform for all soils.
2. Housing falls under Ordinary buildings. The community building like hospitals, schools, marriage halls etc. may be considered under important buildings.
 - i) Check length, height and thickness of walls and modify to conform to the Code: IS:4326 and IS:13828-1993 (see Table 4).
 - ii) Check the positions and sizes of openings in walls and modify as required, or provide reinforcement.
 - iii) If there are no 'through' stones in thick stone walls, then provide RC headers by making 'through' hole by removing the stones in opposite wythes, inserting an iron link and filling the hole with concrete.
 - iv) Provide seismic belt below roof and above door/window lintel level. For this use weld mesh reinforcement.
 - v) Provide vertical reinforcement at the corners and T-junction of walls, either using bars or ferro-cement with weld-mesh reinforcement.
 - vi) Modify the roof structure by providing additional bracing elements and fix it to the seismic band/belt.

14. CONTROL ON LENGTH, HEIGHT, THICKNESS OF WALLS

a) *R.R Stone Masonry.*

The wall length should not exceed 5m between cross walls in case of mud mortar and 6m in cement mortar case. If length exceeds these, provide internal wall at spacing not farther than 4m (see Fig.5). The thickness of new wall should not exceed 400mm. The wall height should not exceed 2.7m in mud mortar and 2.9m in cement mortar (see Table 4).

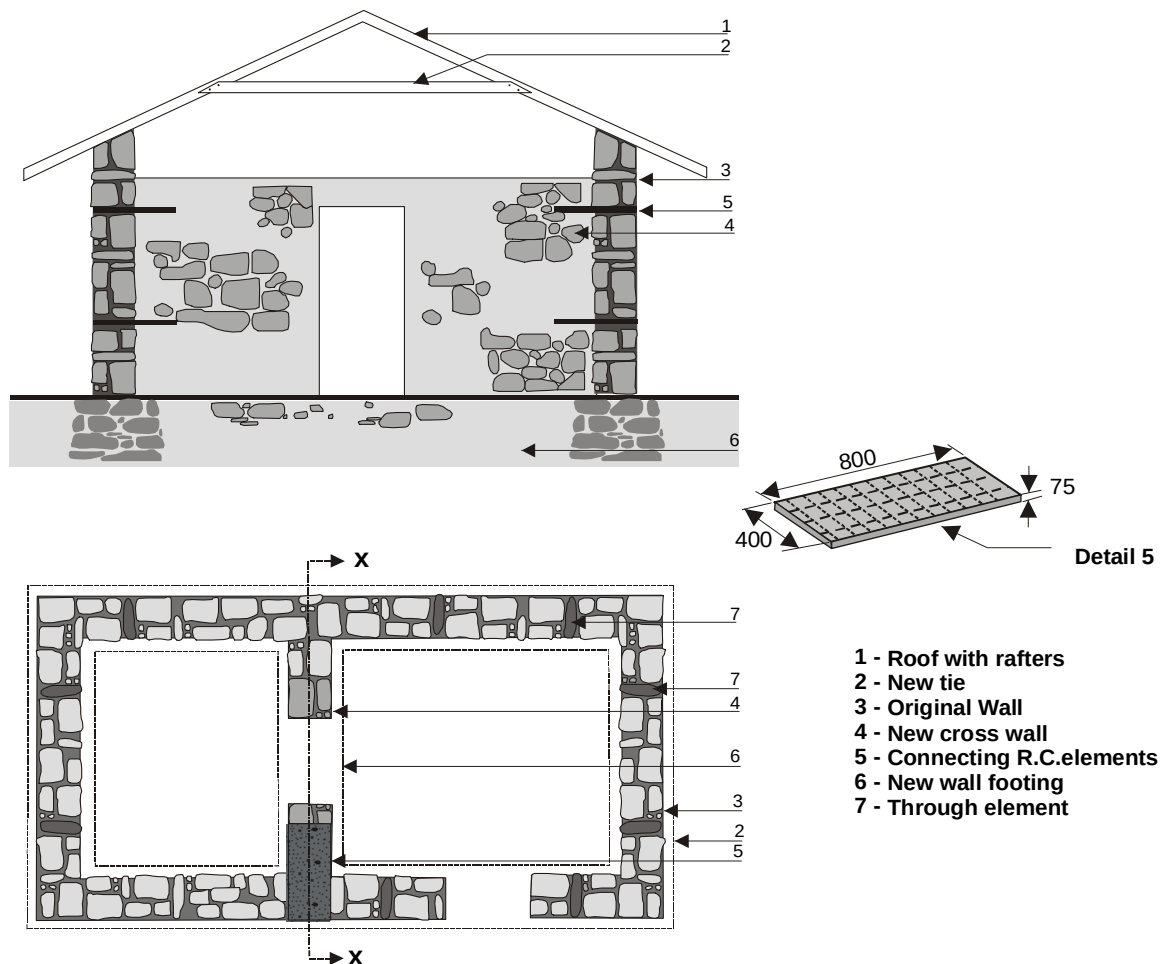


Fig. 5 - Strengthening of long walls by cross wall

b) *Rectangular Unit Masonry in cement mortar.*

The wall length should not exceed $35t$ and the height should not exceed $15t$ where t = thickness of wall. See Table 4.

Table 4- Control on Length, Height & Thickness of Walls

Type of Masonry	Maximum Length of Walls in Room	Maximum Height of Storey
(i) R R Stone Masonry		
- in Mud Mortar	5 m	2.7 m
- in Cement Mortar	6 m	2.9 m
(ii) Rectangular Unit Walls		
- in Mud Mortar	6 m	2.9 m
- in Cement Mortar	35 t but ≤ 7.0 m	15 t but ≤ 3.5 m
t = thickness of wall		t = thickness of wall

15. CONTROL ON DOOR AND WINDOW OPENINGS IN MASONRY

- i) Door and window opening should satisfy the following:

Distance of jamb from internal corner not less than 450mm and distance between two consecutive openings should be 600mm or more in case of R R masonry and 560mm in rectangular unit masonry. In case of RR

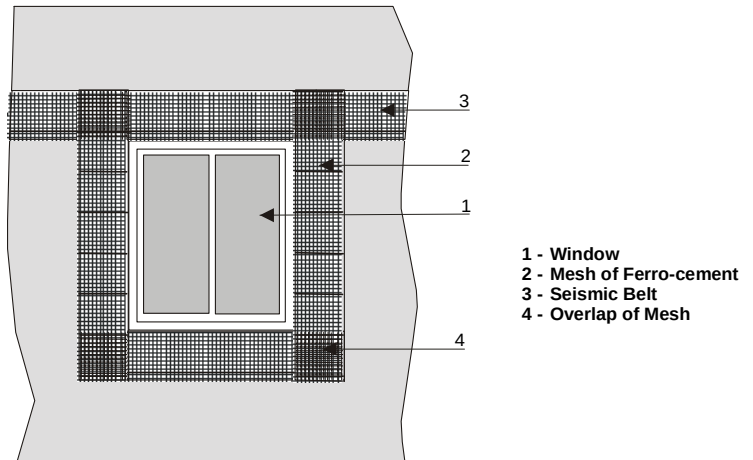


Fig. 6 - Reinforcing around opening

masonry in mud mortar, there should preferably be *only one* door or window in one wall not exceeding one-third of the wall length in the room. The combined length of openings in a wall of rectangular unit masonry building in cement mortar to be restricted to 0.5 L in one storey, 0.42 L in two storey and 0.33 L in three storey building where L is the length of the wall.

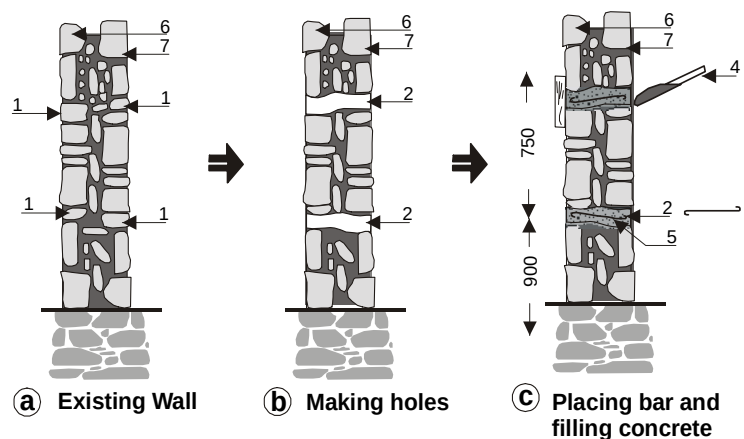
- ii) If the above conditions are not satisfied, action needs to be taken to close an opening or reduce its size. Otherwise, provide strengthening around the opening (Fig.6). For detail of reinforcement, see Para 19.

16. MAKING 'THROUGH' BOND ELEMENTS IN R.R. STONE WALL (Fig.7)

- a) Select points where 'through' stones will be installed at horizontal and vertical distance of about one meter apart, with 50cm horizontal stagger.
- b) Remove the plaster from the surface exposing the stones. Remove the mortar around the stone to sufficient depth gently, not violently, so as to expose the stone on all sides.
- c) Loosen the stone by means of gentle pushes side ways and up and down by means of a small crowbar, so that the other stones of the walls are not disturbed. Pull out the stone slowly, holding it by both hands.

- d) Remove inner material gradually so that a 75mm size hole can be made in the wall. Bigger hole is not needed.

- e) Locate position of the opposite stone on the other face of the wall by gentle tapping in the hole. Remove the identified stone slowly by same gentle process.



- 1 - Stones removed to make through holes
- 2 - Holes
- 3 - Hooked Bar
- 4 - Chute for pouring concrete
- 5 - Filled concrete
- 6 - Internal wythe
- 7 - External wythe

Fig. 7 - Providing R.C. 'through' elements for 'stitching' stone wythes

- f) The hole so made through the wall may be bigger in size on both faces and narrower inside resembling a dumbbell shape. This is good. It does not matter if the hole is inclined instead of being horizontal.

- g) Place concrete of 1:2:4 mix to fill half the depth of the hole from both sides and place 8mm dia. hooked mild steel bar in the hole and fill the hole completely.
- h) Cure for minimum 10 days by sprinkling water on the exposed surfaces on both sides.

17. PROVIDING HORIZONTAL SEISMIC BELTS

17.1 Seismic Belt Locations

- i) Seismic belts are to be provided on all walls on both the faces just above lintels of door and window openings and below floor or roof.

Note: On small wall lengths in a room (less than 5m) seismic band only on the outside face will suffice. In this case these should be connected by ties going across the rooms (see Fig.8).

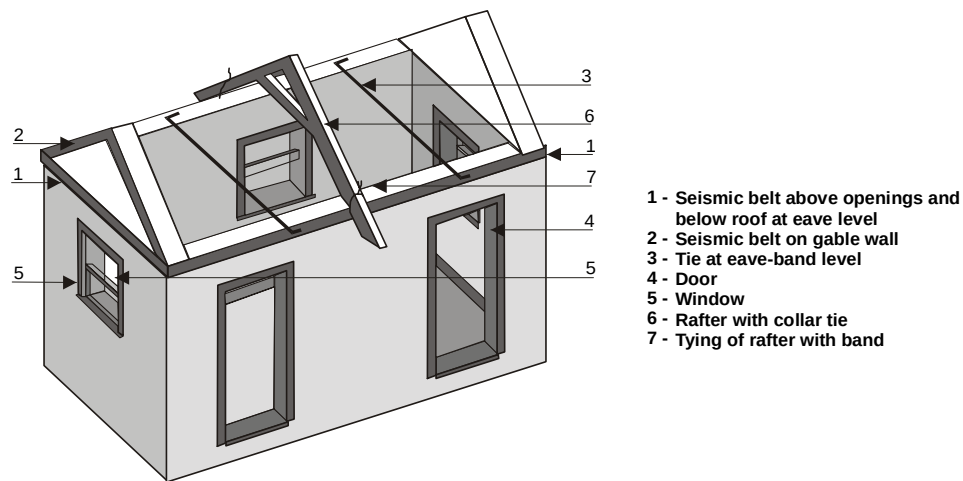


Fig. 8 - Overall arrangement of seismic belts (roofing removed)

- ii) The roof belt may be omitted if the roof or floor is of RCC slab.
- iii) Seismic belt is not necessary at plinth level, unless the plinth height is more than 900 mm.
- iv) Install similar seismic belt at the eave level of sloping roof and near top of gable wall, below the roof.

Note:- If the height of eave level above the top of door is less than 900 mm, only the eave level belt may be provided and lintel level band may be omitted.

17.2. Description of reinforcement in belt.

The reinforcement may be of mesh types as suggested in Table 4 or any other mesh of equivalent longitudinal wires. For example in Cat. **D** building with room length of 6 m, MW 21 weld mesh (with long wires 5 of 4.5 mm dia spaced at 75 mm apart; cross wires of 3.15 mm dia placed at 300 mm apart) can be used, the height of the belt being kept as 375 mm.

Note: Weld mesh has to be provided continuously. If splicing is required, there should be minimum overlap of 300mm.

Table 5- Mesh Reinforcement in Seismic Belts in Various Building Categories.

Length of Wall		Cat. D			Cat. E		
m		Gauge	N	H	Gauge	N	H
≤ 5.0		g10	8	230	g10	10	280
6.0		g10	10	280	g10	10	280
					<i>with 2 bars of 6 mm Ø</i>		
7.0		g10	10	280	g10	10	280
		<i>with 2 bars of 6 mm Ø</i>			<i>with 2 bars of 8 mm Ø</i>		
8.0		g10	10	280	g10	10	280
		<i>with 2 bars of 8 mm Ø</i>			<i>with 3 bars of 8 mm Ø</i>		

1. Gauges: g10=3.25 mm, g11=2.95 mm, g12=2.64 mm, g13=2.34 mm, g14=2.03 mm.
2. N = Number of made longitudinal wires in the belt at spacing of 25 mm.
3. H = Height of belt on wall in micro-concrete, mm.
4. The transverse wires in the mesh could be spaced upto 150 mm.
5. The mesh should be galvanized to save from corrosion.

18. VERTICAL SEISMIC BELT AT CORNERS

Vertical reinforcing is required at the corners of rooms and junctions of walls as per Table 6. Alternatively MW 21 weld mesh of equivalent longitudinal area could also be used. The width of this belt on each side of the corner has to be kept 25mm extra to the width of the mesh.

This reinforcement should be started 300mm below the plinth level and continued into the roof/eave level horizontal band. (See Fig.9).

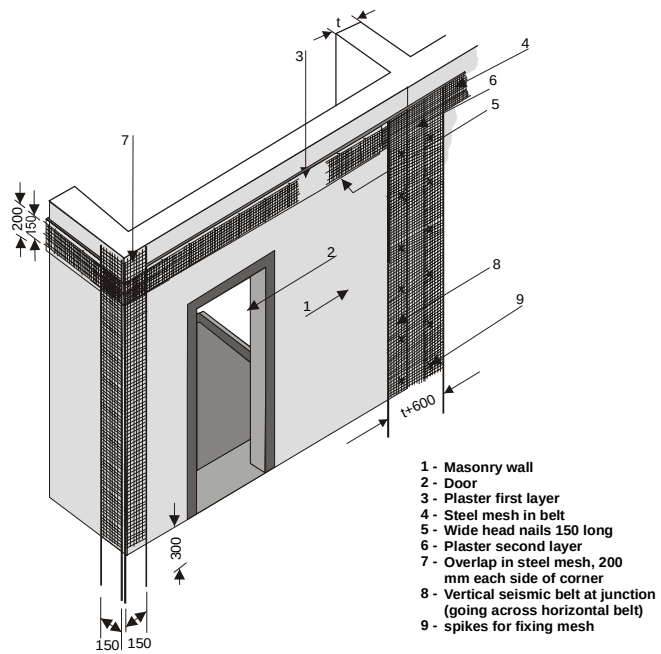


Fig. 9 - Vertical seismic belts at corner and junction

Table 6-Vertical Bar or Mesh Reinforcement in Vertical Belt at Inside Corners of Rooms

No. of Storeys	Storeys	Cat.D			Cat. E		
		Single Bar, mm	Mesh (g10)		Single Bar,mm	Mesh (g10)	
			N	B		N	B
One	One	10	10	300	12	14	400
Two	Top	10	10	300	12	14	400
	Bottom	12	14	400	16	14	400
Three							With 1 bars of 12 Ø
	Top	10	10	300	12	14	400
	Middle	12	14	400	16	14	400
						With 1 bars of 12 Ø	
	Bottom	12	14	400	16	14	400
						With 1 bars of 12 Ø	

1. Gauge 10 (3.25 mm dia) galvanized mesh with 25 mm spacing of wires shall be used.
2. Single bar, if used, shall be HSD or TOR type. If two bars are used at a T-junction, the diameter can be taken as follows. For one of 10 or 12 mm take 2 of 8 mm, and for one of 16 mm take 2 of 12 mm.
3. N = Number of longitudinal wires in the mesh.
4. B = Width of the micro concrete belt, half on each wall meeting at the corner or T-junction.
5. The transverse wires in the mesh could be at spacing up to 150 mm.

19. SEISMIC BELTS AROUND DOOR/WINDOW OPENINGS

The jambs and piers between window and door openings require vertical reinforcement in the following situations:

- i) In category **D** and **E** buildings for resistance against earthquake forces.
- ii) For restoring the strength of the piers in any building category when badly damaged in an earthquake.

The following mesh reinforcement is recommended to be used for covering the jamb area on both sides of an opening or for covering the pier between the consecutive openings.

Mesh of gauge 10 with 10 wires in vertical direction spaced at 25 mm in a belt width of 280 mm.

20. METHOD OF FIXING SEISMIC BELTS

The reinforcement specified in Paras 10, 15, 17 and 18 is to be finally attached to the stone or brick wall by nails or connectors and cement mortar. For this purpose either 1:3 cement-coarse sand mortar or micro-crete is used. It is applied in two layers like plaster as described below.

Steps to construct the Belt

Step-1 Remove plaster in the height of the belt.

Step-2 Rake out mortar joints to 12-15 mm depth.

Step-3 Clean the surface and wet it with water.

Step-4 Apply neat cement slurry and apply first coat of 12 mm thickness.
Roughen its surface after initial set.

Step-5 Fix the mesh with 150 mm long nails at about 300 mm apart while plaster is still green.

Step-6 Apply second coat of plaster of 16 mm thickness (or 16mm + diameter of longitudinal bars where used).

Note:

1. The mesh should be continuous with 200mm overlap at the corner or elsewhere.
2. Using galvanized binding wire, tie up the roof rafters with the nails of the eave level belt before applying the plaster over the mesh.
3. In brick and soft stone walls, it will be easy to drill or chisel out holes of 75 mm dia. In that case, instead of the nails, use 3 mm galvanized mild steel wires through the holes to hold and clamp the longitudinal wires every 450 mm c/c staggered in two layers.

21. PROVIDING VERTICAL REINFORCEMENT AT CORNERS, JUNCTIONS OF WALLS.

The vertical reinforcement consisting of TOR bar as per Table 6 or equivalent shall be provided on the inside corner of room starting from 750 mm below the

ground floor going upto the roof slab, passing through each middle floor through holes made in the slabs. (See Fig.10) The reinforcement

will be

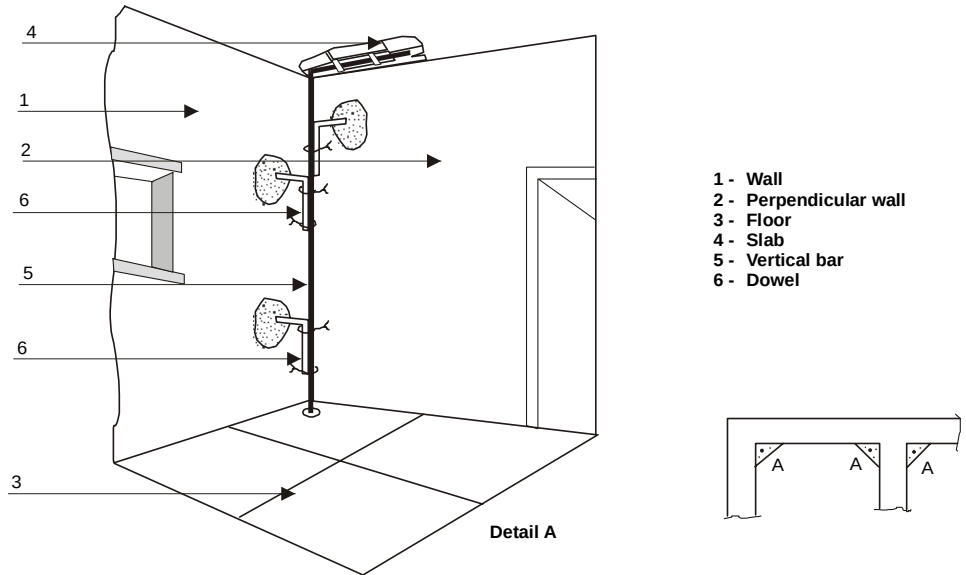


Fig. 10 - Vertical bar at inside corner

connected to the walls by using L shape dowels of 8 mm TOR bar, the vertical leg of 400 mm length firmly tied to the vertical reinforcement bars and the horizontal leg of minimum 150 mm length embedded in the walls through 75 mm dia. holes drilled in the wall into which the 8 mm dia. leg of the dowel will be grouted using non- shrink cement cum polymer grout. Such dowels will be provided, first one just above plinth level and then at about every 1 m distance apart. The corner reinforcement will be covered with 1:3 cement mortar or 1:1 1/2 :3 micro concrete fully bonded with the walls giving a minimum cover of 15 mm on the bar.

22. STIFFENING THE FLAT WOODEN FLOOR/ROOF

Where the damaged houses have flat floor or roof made of wood joists covered with wooden planks and earth, for making such roof/floor rigid, long planks 100mm **wide** and 25 mm thick should be nailed at both ends of the joists from below. Additionally, similar planks or galvanized metal strips 1.5 mm thick 50 mm wide should be nailed diagonally also. See Fig.11.

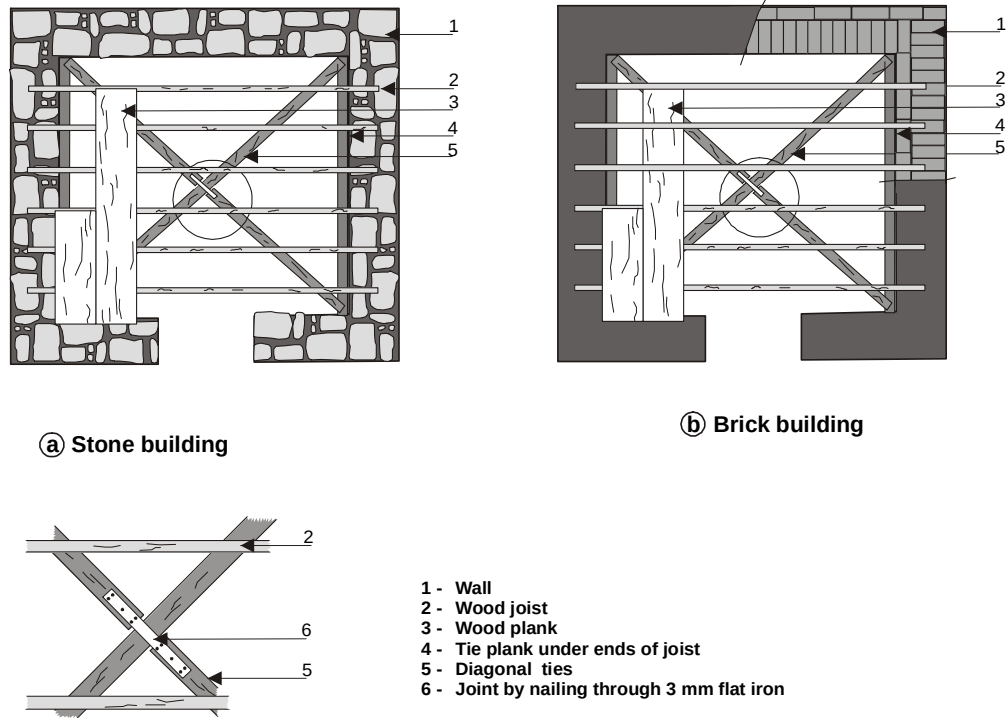


Fig. 11 - Stiffening flat wooden floor/roof

23. STIFFENING THE SLOPING ROOF STRUCTURE

Most of the sloping roofs are made of rafters, purlins, CGI sheets on top. But trusses were not formed which require the use of ties. Such roofs push the walls outward during earthquakes. For stiffening such roofs, the rafters should be tied with the seismic belt as in Note under para 17, and the opposite rafters, on both sides of the ridge need to be connected near about mid-height of the roof through cross ties nailed to the rafters (see Fig. 12).

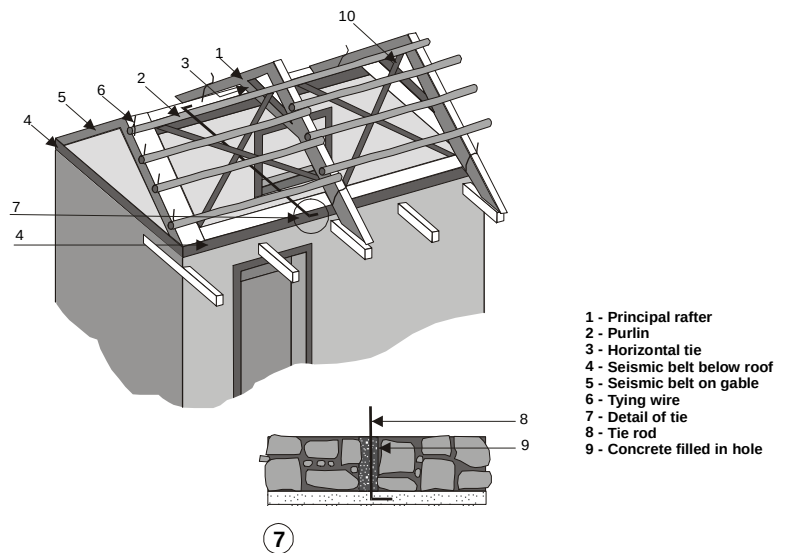


Fig. 12 - Stiffening of sloping roof structure

25. STRENGTHENING OF DHAJJI DIWARI CONSTRUCTION

The best example of Dhajji Diwari construction is shown in Photo 12 wherein every wood framed panel is braced diagonally to increase the stiffness as well as strength. Photo no. 11 shows Dhajji construction with inadequate bracing. Thus to increase the stiffness and strength of Dhajji walls, whether outside or inside the building, the rectangular wood frame panels should be strengthened by providing diagonal braces in all panels by external wooden planks properly nailed to the existing framing members (as shown in fig.13). The best location of the braces will be to connect the opposite corners. In most cases, the size of the diagonal brace may be 20 mm by 40 mm and minimum two nails of 10 gauge and 75 mm length should be used.

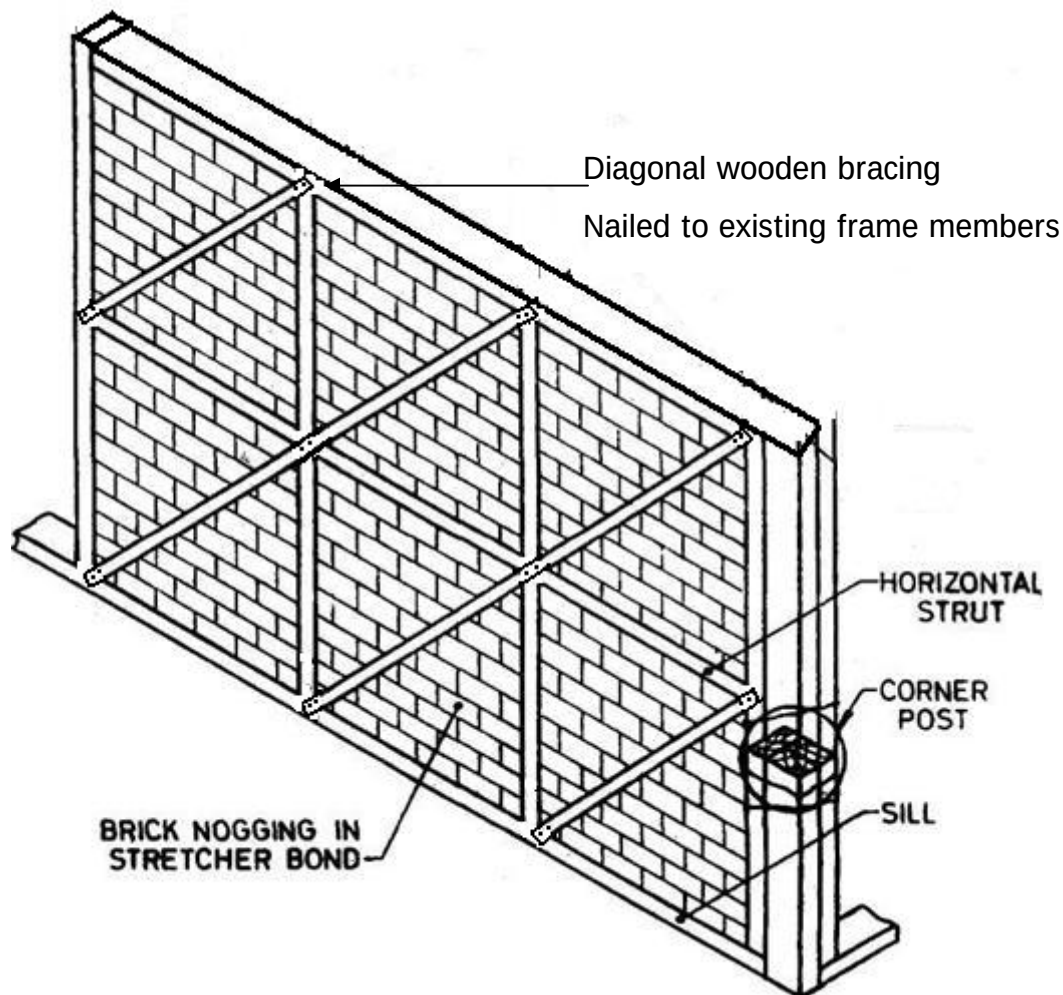


Fig.13:- Diagonal bracing fixed externally to existing wooden frame members

Annexure – I

STRATEGY RECOMMENDED FOR RECONSTRUCTION/RETROFITTING

Since households with severe or total damage (G5) are receiving Rs.1 lac as a government assistance package, and additionally approximately Rs.30000 being used to construct the mid-term shelters, house owners will be having Rs. One lac together with materials from collapsed house as well as that from the mid-term shelter to take care of the permanent house. All recommendations must take into consideration, the financial limitation, if any that the house owners may encounter. Use of **non-local materials** will have a direct impact on the expenditure that the house owners will incur. This will be even more acute in the villages situated away from the motorable roads. Hence, **extreme discretion** should be exercised in the promotion of such materials. Following recommendations will take this fact in to consideration.

- (i) *Stone, being the local material in many areas, is the most affordable material. Hence, its use in reconstruction must be promoted backed by **intensive campaign about the correct way of using it for the disaster resistant construction**. It should also be noted that in case of severely damaged or destroyed houses the debris contains stone, timber and sheeting among other things. The good quality stone can easily be salvaged from this debris, which otherwise, could cost several thousand rupees to cart away from the site. Similarly among those who want to use brick for reconstruction, similar campaign must be carried out.*
- (ii) *The capacity building of the government engineers must be carried out to take up such an awareness campaign long before the reconstruction phase begins.*
- (iii) *Giving due consideration to any financial constraints, the mud mortar should not be discouraged. Instead, the emphasis must be placed on incorporating the 'through' and 'long corner' stones and the earthquake resistant features. Shock table test conducted on half scale model specimen have shown that properly constructed stone houses using mud mortar and various earthquake resisting features (use of 'through' stones and various seismic bands) were found safe even under high earthquake intensity of MSK IX.*
- (iv) *The houses which are considered as total loss but where the roof and upper story are almost intact, (G4 category) such as those around Uri town, may be restored with earthquake resistant features rather than dismantling. This dismantling needs to be prevented using awareness campaign. Dismantling of a few houses may trigger a wrong trend of dismantling which will be difficult to stop there after. This could result in major permanent loss for the whole area and the people. With such a trend the people having a 6 room house could end up with a 2 room house.*

- (v) *House owners with light to moderate damage have been given Rs.30 thousand as government assistance. In many cases with low damage a substantial portion of this amount could be used towards the seismic retrofitting of these houses to permanently reduce their vulnerability. An intensive campaign focusing on Repair and Restoration with Retrofitting needs to be carried out at the earliest to prevent the misuse of the excess funds on non-structural items, such as new plaster or flooring which could be left for future.*
- (vi) *Awareness Campaign: The campaign may involve the following items.*
- Information dissemination through **printed materials** including (a) leaflets, (b) booklets, (c) posters, (d) videos, and **mass-media** including (a) talk shows on television, (b) news paper articles and advertisements.
 - Technology demonstration including
 - i. Demonstration of earthquake resistant construction using stone and brick masonry in mud and cement mortar. Single room structures could be built in as many settlements as possible for full-scale *real life demonstration rather than mock ups*.
 - ii. Demonstration of repair and retrofitting of damaged structures. Such demonstrations could be carried out on individual houses using their entitlement or on existing public buildings.
 - iii. Demonstration of restoration involving the saving of the undamaged roof and the upper story in the houses in Uri town and other areas with similar damage situation
- (vii) **On-site Capacity Building of Engineers:** To ensure the effectiveness of the engineers, the on-site capacity building programs need be carried out in all aspects of shelter rehabilitation. This will increase their ability to guide the people. Such programs could be taken up at the above-mentioned demonstration sites.
- (viii) **Hands-on Training of Masons & Carpenters:** In order to ensure the use of right technology and to prevent the repetition of old mistakes, the building artisans must be trained at the onset. Such training could be conducted at the demonstration sites mentioned above.
- (ix) **Awareness Program for People:** The above mentioned demonstration sites could be effectively used for organizing community level meetings of the people by the suitably trained engineers for ensuring basic understanding of the technologies among the people.

Annexure – II

Damage Assessment format for Masonry Buildings

Form no. _____ For Ordinary Camera Photo Roll no. _____ Snap Shot no. _____ For Digital Camera Snap Shot no. _____	Surveyor's sign: _____ Name: _____ Executive Engineer's Sign: _____ Name: _____ Date of Survey: _____	TYPE OF BUILDING AND DETAILS: 9 Number of storeys: 1 2 3 4 10 Outer Dimensions: Length _____ m, Width _____ m Plinth Area _____ sqm. Floor Area _____ sqm. 11 Plinth Masonry: Walls: Thickness _____ mm, Height _____ mm * RRS ☐ Dressed Stone ☐ DD ☐ Block ☐ Brick ☐ Kutcha ☐ Mortar: Mud ☐ Cement ☐ Lime ☐ 12 Ground Floor: Walls: Thickness _____ mm, Height _____ mm RRS ☐ Dressed Stone ☐ DD ☐ Block ☐ Brick ☐ Kutcha ☐ Mortar: Mud ☐ Cement ☐ Lime ☐ 13 First Floor: Walls: Thickness _____ mm, Height _____ mm RRS ☐ Dressed Stone ☐ DD ☐ Block ☐ Brick ☐ Kutcha ☐ Mortar: Mud ☐ Cement ☐ Lime ☐ 14 Second Floor: Walls: Thickness _____ mm, Height _____ mm RRS ☐ Dressed Stone ☐ DD ☐ Block ☐ Brick ☐ Kutcha ☐ Mortar: Mud ☐ Cement ☐ Lime ☐ 15 Roof: Sloping: Tiles ☐ CGI Sheets ☐ Concrete Slab ☐ Thatch ☐ Flat: Concrete Slab ☐ Wooden Joists, Planks, Earth ☐ Other ☐ 16 Intermediate Floors: First: Wooden Joists, Planks, Earth ☐ Concrete Slab ☐ Other ☐ Second: Wooden Joists, Planks, Earth ☐ Concrete Slab ☐ Other ☐
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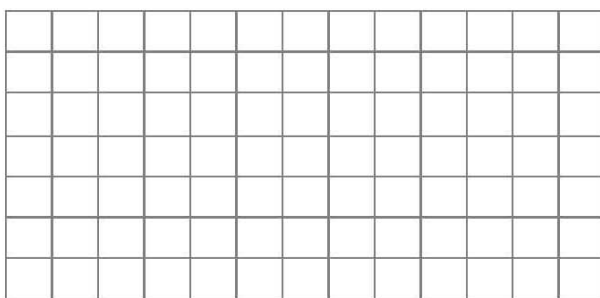
PHOTO OF THE BUILDING	*RRS – Random Rubble Stone, * DD – Dhajji Diwari
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Record Of Damage

17. Longitudinal walls on all floors							20. Earthquake Resistant Features Used (If any)							
Storey	Total no. of walls	No. of walls having Damage Type					Seismic Band	None All walls	Plinth External walls only	Lintel External walls only	Roof/Ceiling/Eave Jams of Door/window	Gable few		
		G1	G2	G3	G4	G5	Type of Band		RCC	Wooden				
Plinth Masonry							Vertical Bars		All corners	Few corners				
Ground Floor														
First Floor														
Second Floor														
18. Transverse walls on all floors							21. Quality of Construction							
Storey	Total no. of walls	No. of walls having Damage Type					Very Good Good Average Poor							
		G1	G2	G3	G4	G5	22. Overall Condition of Building							
Plinth Masonry							Normal		Sinking minor/major		Tilting minor/major		Shattered minor/major	
Ground Floor														
First Floor														
Second Floor														
19. Intermediate Floors & Roof on Rooms inc. Verandah							23. Retrievable Material if Building is to be Demolished							
Floor	Total no.	No. of walls with Damage Type					Material	Quantity	Any Other	Quantity				
		G1	G2	G3	G4	G5	Door & Window		Nos.					
First Floor							CGI/AC Sheet		Nos.					
Second Floor							Wooden Members		Nos.					
Roof							Tiles		Nos.					
							Stone/Bricks		Cum.					
FINAL CATEGORY OF BUILDING														
0 OR G1		G2		G3		G4		G5						

RECOMMENDATIONS:

- To be repaired and retrofitted ☐
- To be demolished and rebuilt. ☐



LINE PLAN OF GROUND FLOOR

NOTES FOR READY REFERENCE

Equipments to be carried by the Surveyor:-

1. Camera preferably digital
2. If ordinary camera then adequate no. of films.
3. Measuring Tape
4. Foot rule
5. Adequate no. of survey sheets
6. Pencil & eraser/ ball pen as found suitable.

Categorization Scale Adopted For Evaluation of Load Bearing Low-rise Buildings

Category	Damage	Extent of Damage in Bearing Walls	Suggested Post Earthquake Action
0	None	<i>No damage</i>	<i>Building need not be evacuated</i> • Seismic strengthening is advised for long-term seismic safety
G1	Slight non-structural damage	• Thin cracks in plaster • falling of plaster bits in limited parts.	<i>Building need not be evacuated</i> • Remove plaster across cracks and replaster. • Seismic strengthening is advised for long-term seismic safety
G2	Slight structural damage	• Small cracks in walls • falling of plaster in large bits over large areas • damage to nonstructural parts, such as flooring, parapets, dado, etc. <i>The load carrying capacity of the structure is not reduced appreciably</i>	<i>Building need not be evacuated</i> • Remove plaster & grout cracks with cement slurry or cement and sand (1:3 mixed mortar), depending upon the width of the crack. • Parapets rebuild $h/b \leq 3$, provide reinforcement tied to structural elements. • Repair various structural elements. • Seismic strengthening is advised for long-term seismic safety.
G3	Moderate structural damage	• Large & deep cracks in walls • widespread cracking of walls • tilting of walls • posts tilted or damaged piers cracked or tilted • Joist bent and/or cracked <i>The load carrying capacity of the structure is partially reduced</i>	<i>Building needs to be evacuated.</i> • It can be reoccupied after restoration and strengthening. • Structural restoration and seismic strengthening necessary before reoccupation.
G4	Severe structural damage	• Gaps occur in walls • Inner or outer walls collapse • Approx. 50% of the main structural elements, such as posts, joists, binders and girders fail <i>The building is in a dangerous state.</i>	<i>Building needs to be evacuated.</i> • Either the building has to be demolished or extensive restoration & strengthening has to be carried out before reoccupation.
G5	Collapse	<i>A large part of the entire building collapse.</i>	<i>Cleaning the site and reconstruction</i>

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