PART B

Earthquake Resistant Design and Construction of Rectangular Unit Masonry Buildings

CONTENTS – PART B

1.B INTRODUCTION

As stated in Part A Section 2.7.A Building Materials and Wall Construction in Afghanistan, good quality burnt brick is available near urban areas and main centers of provinces like Zalalabad, Kabul, Mazaresarif, Kandhar and Hearat. The bricks are usually of good quality with almost even size (not bent), giving metallic sound when struck with each other. The common size of brick is 20cm x 10cm x 5 to 6 cm. It is understand that in Afghanistan the compressive strength of burnt bricks ranges from 50 kg/cm^2 to 80 kg/cm^2.

Also experience in most developing countries shows that burnt brick is the preferred wall material with people as soon as they are able to afford it. The other rectangular units based on cement, for instance, solid and hollow concrete blocks, are becoming attractive where fuel for burning bricks becomes expensive and ecologically unacceptable. If availability of cement improves in Afghanistan, concrete blocks could be as easily made by village people as they make clay blocks.

The main purpose of this part is to deal with the earthquake resistant building construction using such rectangular masonry units.

2.B OBJECTIVES OF THE GUIDELINES

The following objectives are set for these Guidelines

1) To deal with the construction details of rectangular unit masonry appropriate to earthquake safety;

2) To provide architectural planning measures in masonry buildings suitable to good seismic performance;

3) To detail out the essential reinforcing elements for `non-collapse’ earthquake safety of the masonry buildings.

3.B SCOPE OF THE GUIDELINES

These guidelines cover the following features, from earthquake safety view point, in rectangular unit masonry buildings, such as, brickwork, concrete block work and ashler stone work, as may be used for upto four storeyed housing and community buildings in the seismic zones of Afghanistan (Fig. 9A):

a) Siting and foundations
b) Architectural design features
c) Construction and strengthening features in load bearing walls
d) Construction and strengthening features of roofs and floors

4.B BUILDING UNITS

Some building units for considered in this Guide are shown in Fig. 1B, as follows:

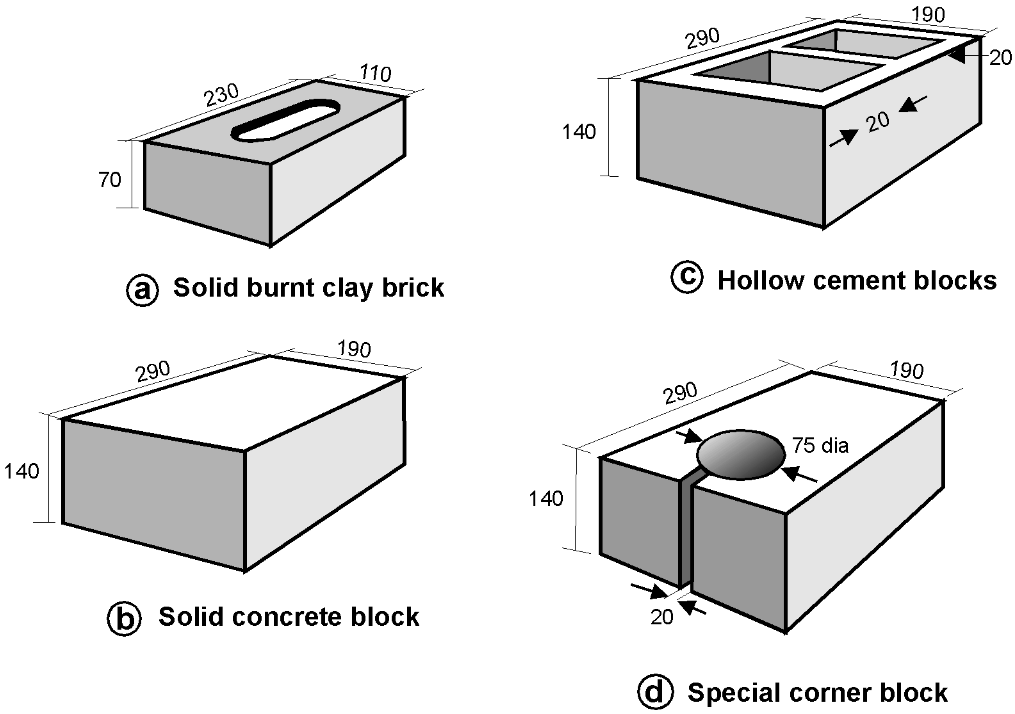


Fig. 1B Masonry Units

i. Burnt Bricks of nominal size 230 x 110 x 70mm
ii. Solid concrete blocks of nominal size 300 x 200 x 150mm.
iii. Hollow concrete blocks of nominal size 300 x 200 x 150mm

The minimum crushing strength of the masonry units on their gross area and the mortar mix should be as given in Table 1B.

Table 1B : Strength of Masonry Units

No. of Storeys	Storey	Wall thickness	Minimum crushing strength
1 and 2	Both	200 – 300 mm	3.5 Mpa (35 kg/cm^2)
3 and 4	Upper two	200 – 230 mm	3.5 Mpa (35 kg/cm^2)
	Next lower	300 – 340 mm	0 kg/cm^2)

4.1.B Burnt Bricks

i. Burnt bricks are normally used in English bond (Fig. 2Ba) giving wall thickness of 100 - 114 mm for partition walls to be built in 1:4 cement-sand mortar; and 200 - 230 or 300 - 340 mm for load bearing walls.

ii. For one storeyed lower cost houses, walls may be built using Rat-trap bond (see Fig. 2Bb) with Mortar of 1:4 mix. This will save about 25% of bricks and provide better thermal insulation also.

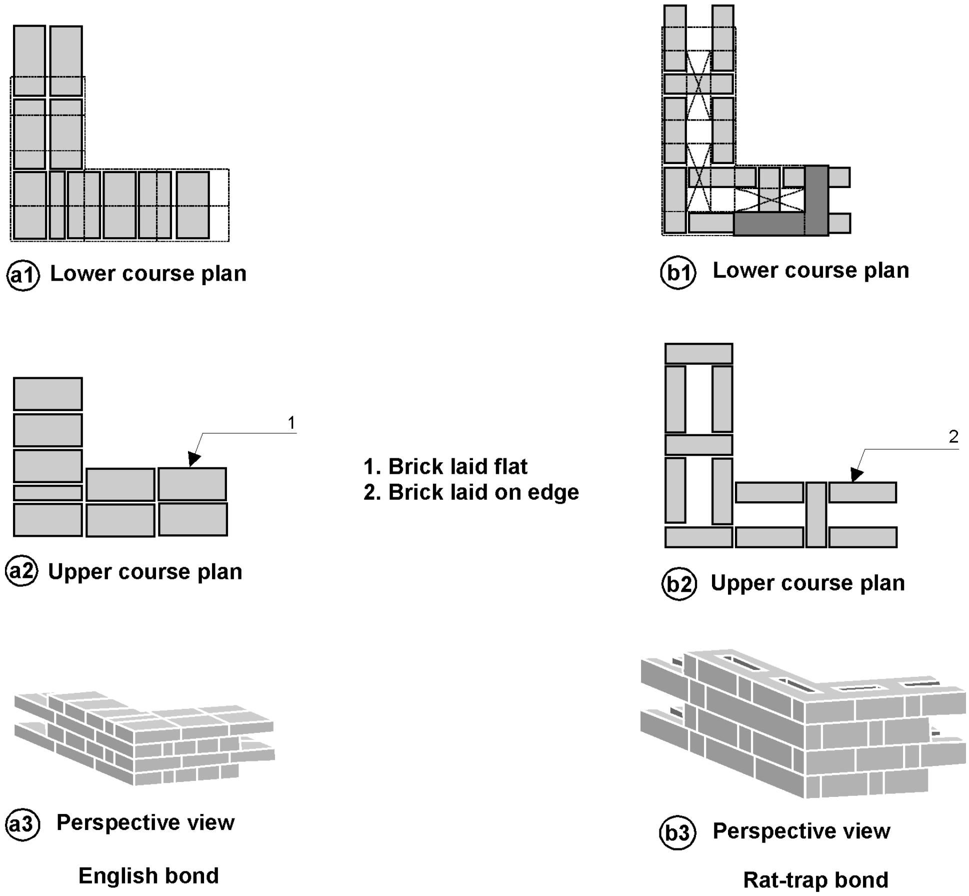


Fig. 2B English and Rat-trap bonds

4.2.B Solid Concrete Blocks

i. Using the concrete blocks of 300 x 200 x 150mm nominal size, non-load bearing walls of 150mm thickness and bearing walls of 200 and 300mm thickness may be built. The bearing surfaces of the blocks should be made rough in the casting procedure itself to develop good bond with the mortar.

ii. Since breaking of block is not convenient, special blocks having length of 150 mm and 100mm should also be cast and used to break the continuity of vertical joints (See Fig. 3B)

iii. Also, so as to fit the units without breaking, the size of doors, windows, built-in cupboard, open shelves, ete. and piers between them should be kept in multiples of modular dimension of 100 or 150 mm (See Fig. 3B).

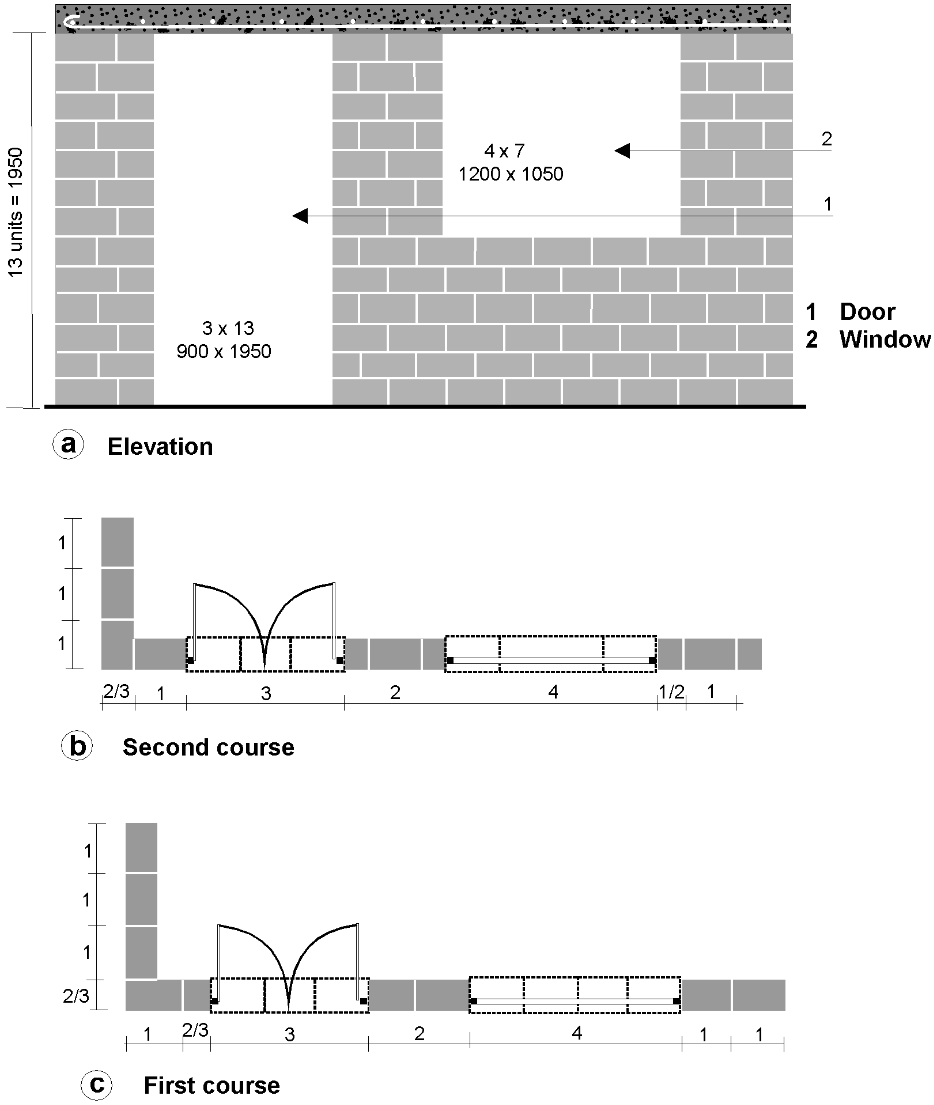


Fig. 3B Block Construction (Modular Dimensions)

4.3.B Hollow Cement or Microconcrete Blocks

Hollow blocks have the volume of hollows about half of the gross volume, hence also the unit weight is about 50%. But due to thin walls, they tend to get larger breakage loss during transportation than the solid blocks. Hence a higher crushing strength on the solid portion of the hollow block is essential. To achieve this, the minimum crushing strength of the blocks on the solid area should be kept 7.0 Mpa and on the gross area as 3.5 Mpa.

Hollow blocks give the advantages of better thermal insulation, less weight on the foundation and also less horizontal seismic force as compared to the solid blocks.

4.4.B Use of Dressed Stones (or Ashlar Masonry)

Fully dressed stones as used normally in various countries may be used just like the solid concrete blocks. Use of long `corner stones' at the wall junctions will very much enhance the seismic stability of the stone walls. Creation of surface grooves, about 6 mm deep, in the longitudinal direction of the stones at the top surface while dressing the stones, will create shear keys in the mortar, improving lateral shear strength of the walls to a great extent.

4.5.B Use of Cellular Light Weight Concrete (CLC) Blocks

CLC consists of Fly Ash, Sand, Cement, Stable Foam, Water and Additives. The quantity of the foam and fly ash in CLC determine its density hence its compressive strength. It does not require coarse aggregate nor vibration for compaction. CLC of 1200 kg/m^3 density gives 6.0 N/mm^2 (60 kg/cm^2) compressive strength and will be suitable for load bearing walls. Density of 800 – 900 kg/m^3 will give 2.5 – 3.5 N/mm^2 (25 – 35 kg/cm^2) strength and suitable for non-load bearing infill and partition walls. Normal sizes of blocks are 400x200x190, 500x200x190 and 600x250x200 mm. The CLC blocks can be cut, sawn and nailed like wood, hence very convenient to use in residential buildings. Due to reduced unit weight of units, they offer the same benefits as hollow concrete blocks.

5.B OPTIONS FOR ROOFS AND FLOORS

There are three main type of roofs and floors adopted in houses using stone masonry in Afghanistan. These are

1) Wood logs supporting reeds or wooden planks, topped with earth fill
2) Sawn wood joists with wooden planks topped with earth fill
3) Masonry domes

There is no tradition of using sloping roofs with light covering such as burnt clay tiles or sheet roofing. The main reasons may be the extreme temperature conditions under which such light roofs will not provide the necessary comfort which is admirably provided by earthen roofs of various types as mentioned above. Therefore the appropriate options of roofs and floors may be as follows:

A. Flat Roof Types

(i) Wood joist/log type traditional system with improvement
(ii) RC joist replacing wood joists/logs
(iii) Reinforced concrete joists + Precast RC planks + RC screed + earth cover
(iv) Cast in situ RC slabs with earth cover for insulation

The roof should have adequate slope for free drainage of rain water.

B. Choice of Floor Types

The same systems as stated above will be suitable for floors also except that instead of thick earth insulation, the finishing may be done with thinner layer of brick tiles, clay mud or plain concrete.

6.B REQUIRED EARTHQUAKE SAFETY PROVISIONS

For the Seismic Zones (Fig. 9A) AB, C & D (M.M. Intensity VIII or higher, Int. VII and Int. VI respectively) the following safety provisions are specified.

6.1.B Building Categorisation (as per IS: 4326-1993)

In accordance with the value of the design seismic coefficient (See Part A, 6.2.A), the Building Category may be taken as follows for selecting earthquake resistance features:

Table 2B : Building Categories

	Zone D	**Zone C**	**Zone AB**
Housing	B	C	D
Community Buildings	C	D	E

6.2.B Measures for Achieving Seismic Safety

6.2.1.B For all Building Categories **B** to **E**

In all seismic zones, the following measures should be adopted as per IS-4326 for masonry walls of all types.

(i) Control on length, height and the thickness of walls in a room.
(ii) Control on size and location of openings.
(iii) Control on material strength and quality of construction.

6.2.2.B Additional for all building categories **C** to **E**

(iv) Seismic band at plinth level (may be omitted if founded on rock or hard soil)
(v) Seismic band at door-window lintel level in all cases.

Where flat roof is adopted:

(vi) Seismic band at ceiling level of floors or roofs consisting of joisted roofs or jointed prefab elements.
(vii) Stiffening of prefab elements in roofs/floor where used (using peripheral seismic band and RC screed integrated together).

If and where sloping/pitched roof is used:

(viii) Seismic band at eave level of sloping roofs.
(ix) Seismic band at top of gable wall and ridge wall top.
(x) Bracing in roof structure of trussed as well as raftered roofs.

6.2.3.B Additional measures for 2-4 storeyed buildings of Category C and all buildings of Category D or E.

(xi) Seismic band or dowels at corners and T-junctions at window sill level.
(xii) Vertical steel reinforcing bars at jambs of doors and large windows.

Note: *The vertical reinforcement at jambs of small windows and ventilators (say 600 mm x 600 mm or less) may be omitted.*

7.B MORTAR MIX

From earthquake safe requirements, the masonry should have good tensile and shearing strength. These in turn depend on the strength of the mortar and its bond with the masonry units. The following mortar mixes are specified in IS: 4326-1993 for the superstructure masonry in various categories of buildings:

Table 3B : Mortar Mixes

Building Category	Cement-sand Mix	Cement-lime-sand
D & E	1 : 4	1 : 1 : 6
B & C	1 : 6	1 : 2 : 9

8.B CONTROL ON QUALITY OF CONSTRUCTION

Good quality of construction is the key to strength and durability of masonry as well as safer seismic performance. The following control measures will be significant for good quality construction:

1) Soaking the bricks in water and moistening the surface of other building units before laying;
2) Consuming the mortar fully within 60 minutes maximum after mixing of water in the cement mortar;
3) Filling of all vertical joints between the units in the walls fully (if in doubt, use mortar grout to fill, before the next layer of mortar is spread on the bedding plane).
4) Filling of all toothed joints, wherever used, fully with mortar while building the new masonry, (See Fig. 4B);
5) Curing the masonry by repeated sprinkling of water for at least 7 days after the masonry is constructed using cement mortar.

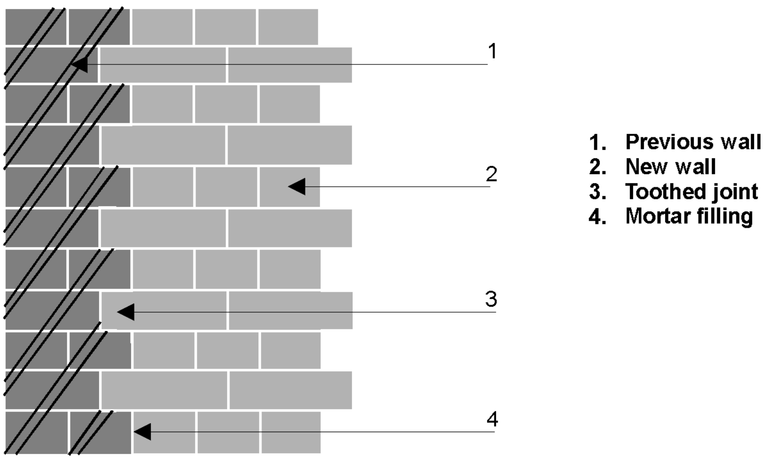


Fig. 4B Toothed Wall

9.B SITING AND FOUNDATIONS

9.1.B Building Site

- The building site should not be prone to flooding.
- Building should not be built on unstable sloping ground and where there is danger of landslides or rock falls due to rains or ground shaking.
- All wall footings should be set back from the edge of slope (Fig. 5B).

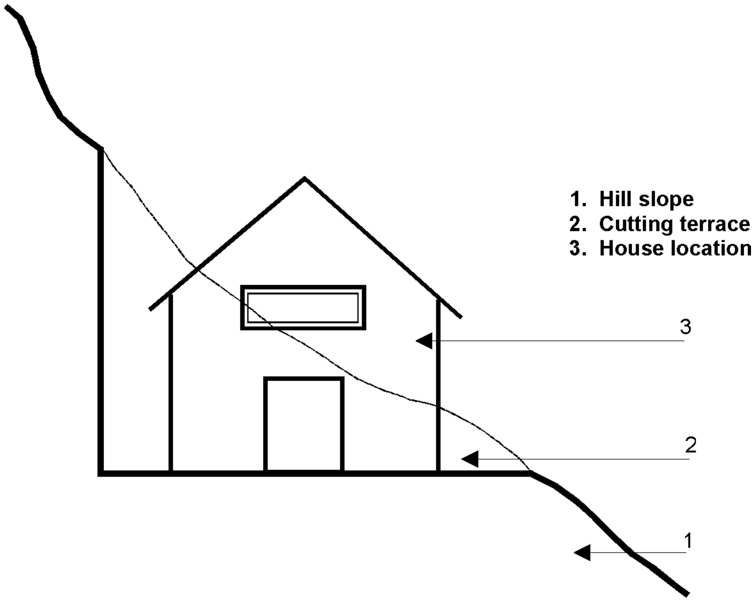


Fig. 5B House on hill slope

9.1.1.B Soil Investigation

(i) In relocated village sites it will be essential to carry out soil exploration using borelogs for soil classification and determining Standard Cone Penetration values "N" (SPT value "N") or Dynamic Cone Penetration Value.

(ii) In compact sites upto 0.4 ha, bores may be done one near each corner and one in the centre. In large sites, one bore each may be done at 100 m x 100 m grid point, the number to be increased if large variations in "N" values are observed.

(iii) For buildings up to 3 storeyed height, 3 m deep boring will generally suffice. "N" values should be recorded at every one meter depth below G.L.

(iv) Depth of water table should be recorded for each site by boring or by inquiries for dry as well as wet season.

9.1.2.B Liquefaction Potential

(i) If the water table is within 5 m depth below ground level in any season and the soil is sandy, liquefaction potential needs investigation upto 10 m depth particularly in Zone AB.

(ii) As per IS: 1893-2002, in Zone AB, the minimum field values of N to avoid liquefaction are 15 at 5 m depth increasing to 25 at 10 m depth. See 6.7.A in Part A.

(iii) If the above conditions are not satisfied, the site is liable to liquefaction and should be avoided for building construction. It may be used for playgrounds, parks, etc.

(iv) For any building to be constructed in liquefiable area, either the soil will have to be compacted to satisfy N value requirements as at (ii) or deep pile foundation will have to be used.

9.2.A New Foundations

a. Rocky Ground or Boulder Site

Weathered, jointed and fissured rock may be levelled by chiselling, in steps of about 150mm and stepped strip footing built on it, with the foundation width of 600 mm for houses upto two storeys. Boulder site may be levelled by removing small boulders but leave large boulders in place.

If the rock is massive, the surface should be roughened by chiselling and stepped strip footing built on it. Foundation width of 700mm will suffice for houses upto two storeys. In all cases, the base concrete of sufficient thickness (with a minimum of 100 mm) should be used for levelling before starting the masonry. For each additional storey, width may be increased by 300mm.

b. Soil Site

Stepped-strip foundation with minimum depth of 750mm below ground level and width of 700mm may be used (upto 2 storeyed houses), Fig. 6B. For each additional storey width may be increased by 300mm. The footing masonry should be brought upto the plinth level. This masonry can be done in coursed rubble masonry as shown or using bricks, concrete blocks or dressed stone as desired in 1:6 cement mortar.

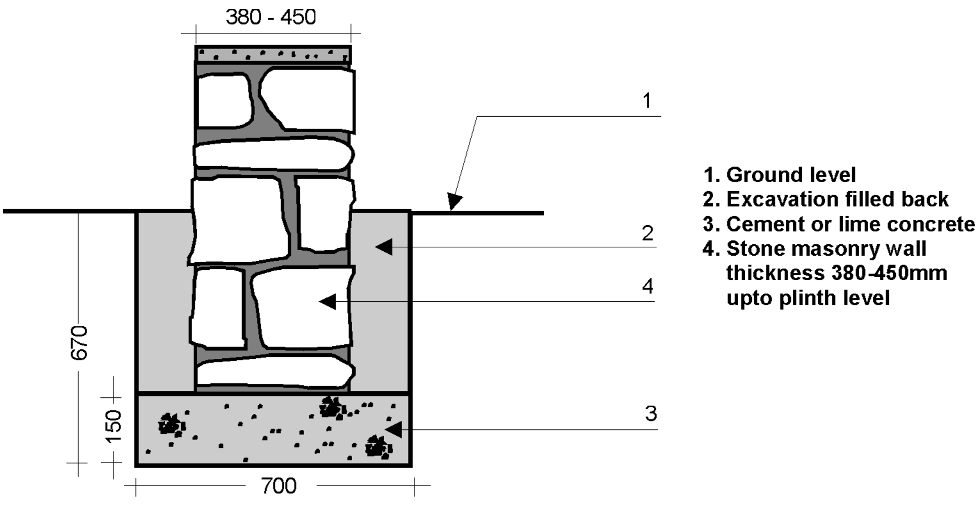
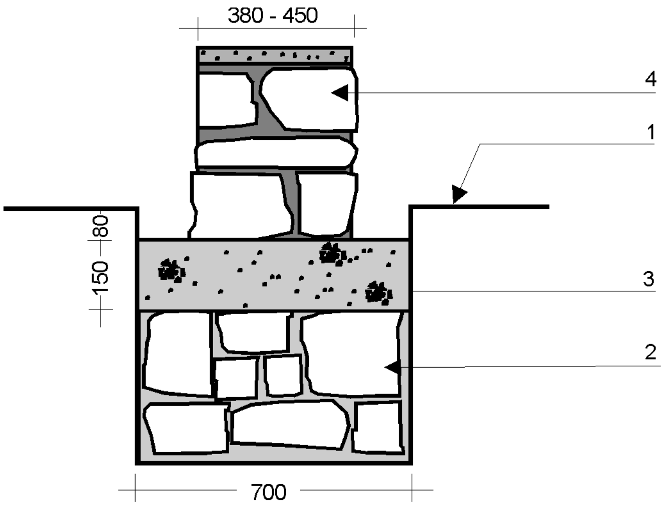


Fig. 6B Strip foundation on soil sites

9.3.B Use of Existing Old Foundation

Houses of pre-earthquake dimensions and heights could be built on existing foundation starting from 230mm below ground level where base concrete 150mm thick is to be cast on the existing lower part of the footing (Fig. 7B). Modifications required, if any, may be carried out by comparing the existing conditions with those recommended under 9.2.B for different soil types. The masonry upto plinth can alternatively be done in rectangular unit masonry of thickness equal to one unit length using the mortar specified for the building category.



1. **Ground level**
2. **Existing foundation**
3. **Concrete cast on existing foundation 230 mm below ground level**
4. **Stone Masonry wall 380-450 mm thick upto plinth level**

Fig. 7B New strip foundation on existing foundation

9.4.B Treatment at Plinth Level

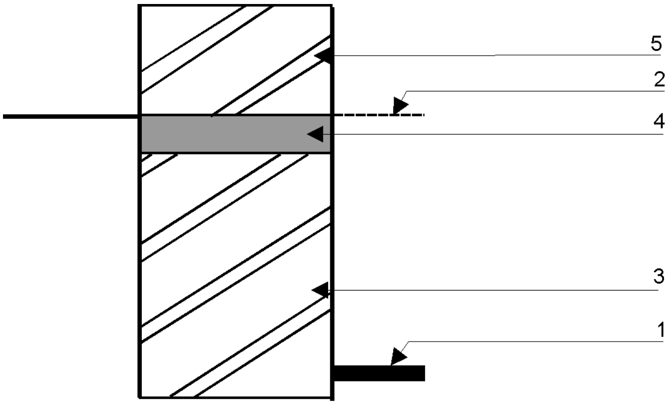
This will depend on site condition as follows:

a. *Rocky Ground*

No band or beam is required and only damp-proof course may be used as usual on the strip foundation. It may be in cement-sand mortar of 1:3 mix 25mm thick or 1:2:3 micro concrete 38 mm thick, with damp proofing compound mixed in each case (See Fig. 8B).

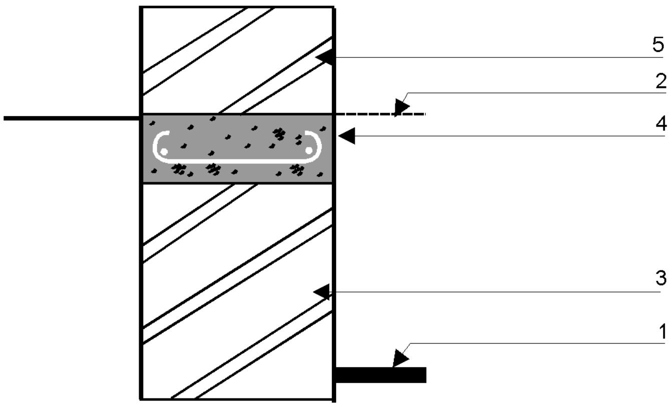
b. *Boulders or Soil*

RC seismic band of 75 to 100 mm thickness may be used in each case (see Fig. 13B for detail of band).



ⓐ **DPC with mortar**

1. **Ground level**
2. **Plinth level**
3. **Foundation wall**
4. **Damp proof course**
5. **Seismic band**
6. **Superstructure wall**



ⓑ **DPC made of CC acting as Seismic band**

Fig. 8B Damp proofing

10.B CONTROL ON WALL HEIGHT AND LENGTH IN ROOMS

10.1.B When cement mortar is used with masonry units, the wall height from floor to ceiling should not exceed 15 times the wall thickness, and the length between cross-walls in a room should be less than 35 times the wall thickness but not larger than 8.0m. See Fig. 9B.

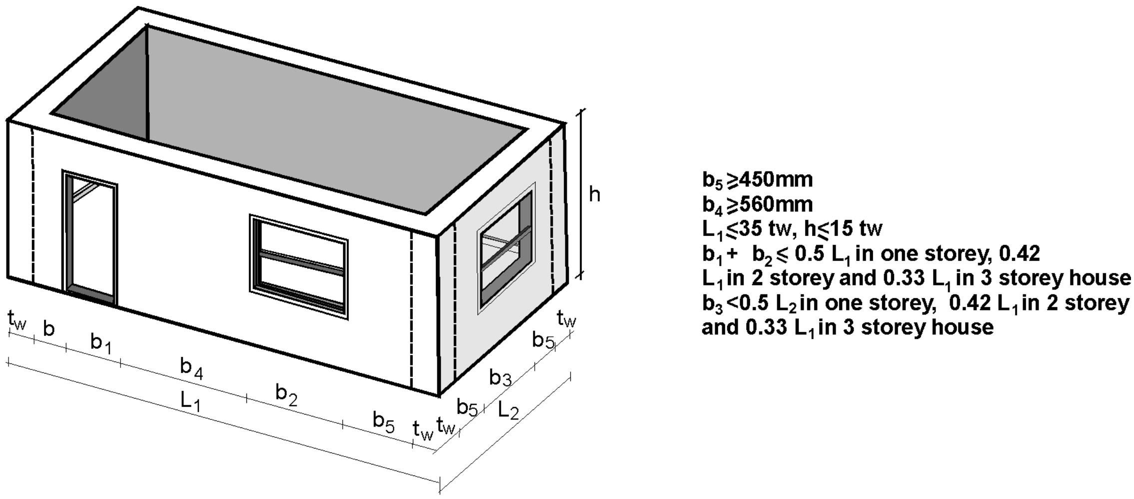


Fig. 9B Control on length, height and openings of wall

Note: *For houses, room height and length should preferably be restricted to 2.7m and 5.0m respectively in hilly areas and 3.2m and 6.0mm in plain areas.*

10.2.B If constraints of 10.1.B are not met, either the wall thickness should be increased or appropriately designed intermediate columns, pilasters or buttresses should be provided to take care of the lateral seismic force.

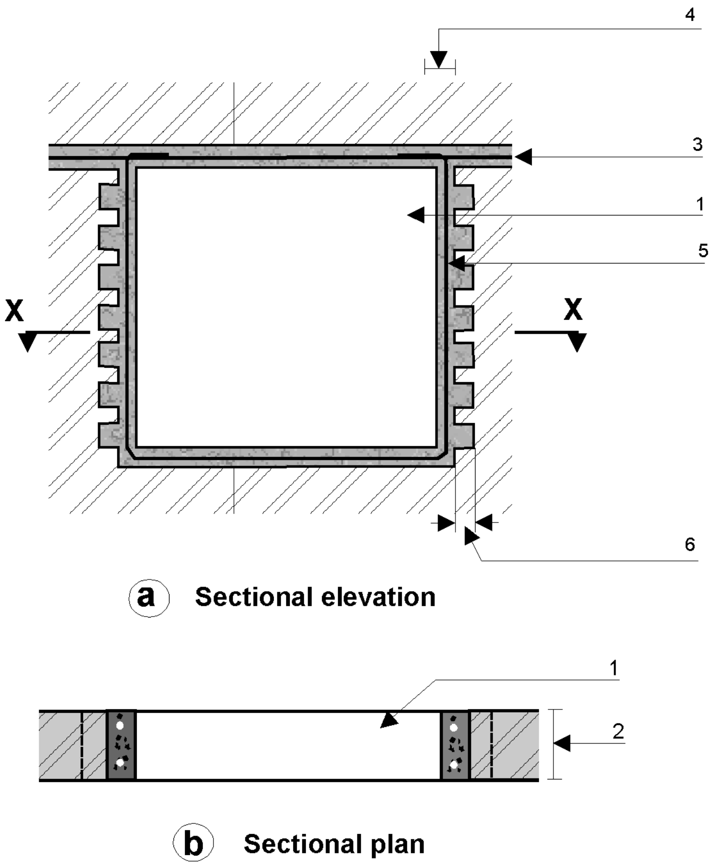
10.3.B Control on Door/Window Openings

10.3.1.B When cement mortar and rectangular units are used in the construction of houses, the following conditions should preferably be met (See Fig. 9B)

i. Ratio of sum of the widths of openings to the length of the wall in a room $(b_1+b_2)/l_1$ or b_3/l_2 should not exceed 0.50 in one storey, 0.42 in two storey and 0.33 in three or four storeyed building.

ii. Distance of the edge of an opening from the room corner should at least be 450mm and the pier width between two conservative openings atleast 560 mm.

10.3.2.B If the conditions of 10.3.1.B are not met, the openings should be boxed in R.C. with minimum 75 mm thickness and two H.S. bars of 8mm dia in Category C buildings and 10 mm dia in Category D and E buildings (See Fig. 10B).



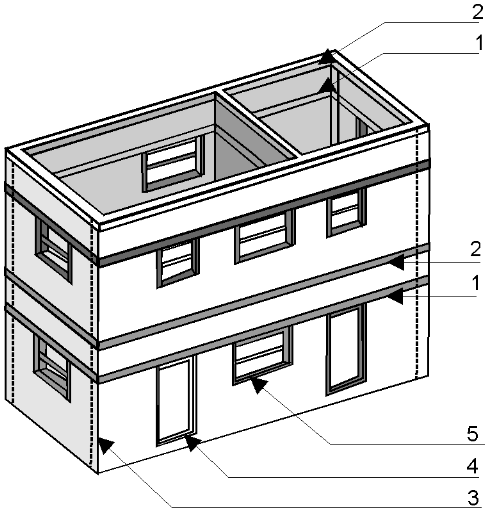
1. **Window**
2. **Wall thickness**
3. **Lintel thickness**
4. **Thickness or Jamb concrete**
5. **Vertical bar**
6. **1/4 of unit length**

Fig. 10B Strengthening masonry around window opening

11.B SEISMIC BANDS

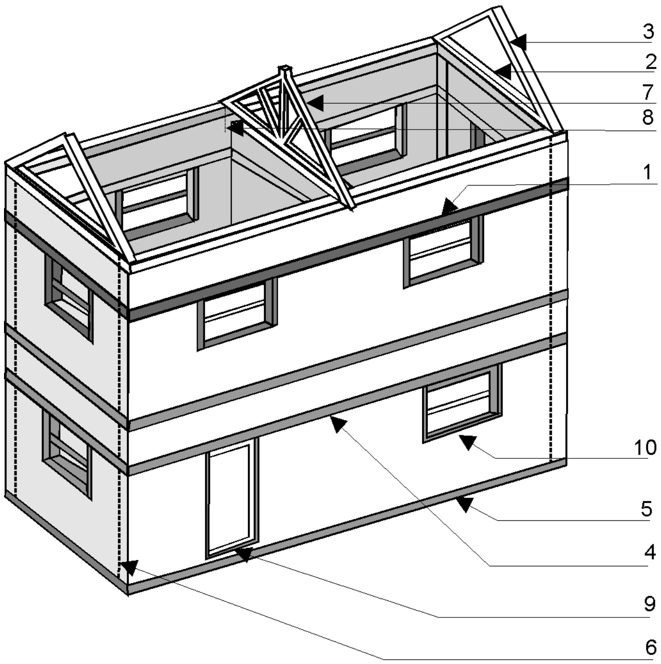
11.1.B The overall seismic reinforcing arrangements are shown in Fig. 11B for flat roof buildings and Fig. 12B for sloping roof buildings. These include horizontal seismic bands, vertical reinforcing bars, and bracings in sloping roof under-structure.

11.2.B The seismic bands at plinth, lintel, and ceiling levels, (see 6.2.B and Figs 11B and 132) must be provided in all internal and external load bearing as well as partition walls continuously without break. Requirement of reinforcing bars in RC bands are given in Table 4B and the details of bands are shown in Fig. 13B.



1. Lintel band
2. Roof/floord band
3. Vertical bar at corner
4. Door
5. Window

Fig. 11B Overall arrangement of reinforcing in masonry double storey building



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. 12B Overall arrangement of reinforcing in masonry double storey building having pitched roofs

Table 4B : Diameter and number of HSD (TOR) longitudinal bars in reinforced concrete bands

Length of wall in room (m)	Reinforcing Bars in Building Categories					
	Cat. C		Cat. D		Cat. E	
	Nos.	Dia (mm)	Nos.	Dia (mm)	Nos.	Dia (mm)
5	2	8	2	8	2	10
6	2	8	2	10	2	12
7	2	10	2	12	4	10
8	2	12	4	10	4	12

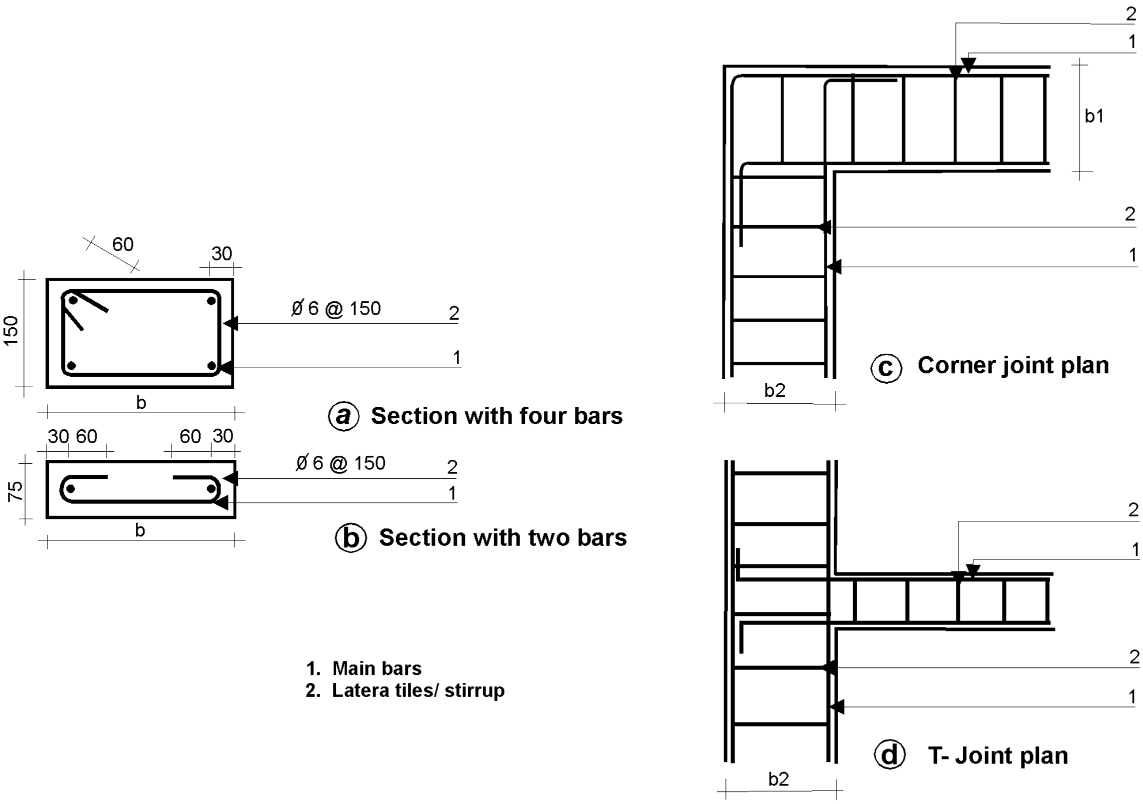
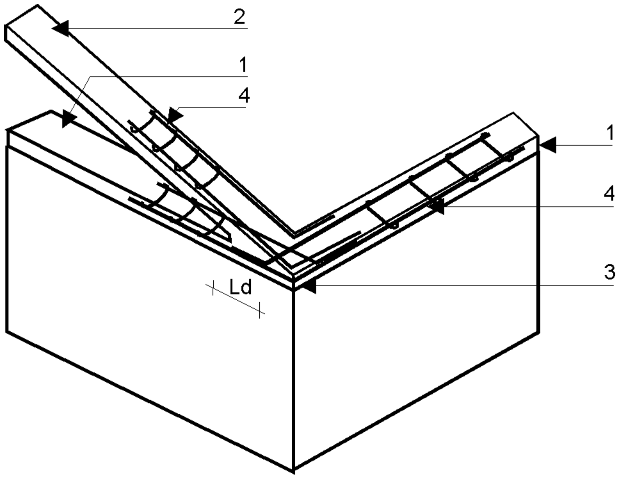


Fig. 13B Reinforcement and bending detail in R.C. band

11.3.B All gable walls, whether internal or external, must have the gable band at their top and made continuous with the eave level band. See Fig. 14B for details.



1. **Eave band**
2. **Gable band**
3. **Joint of Eave and Gable bands**
4. **Main reinforcing bars**

Ld. Overlap length

Fig. 14B Continuity of reinforcement in eave and gable bands

11.4.B For achieving good bond with masonry, the band should be cast directly on the masonry and its top surface should be made rough.

12.B VERTICAL REINFORCING BARS IN WALLS

The vertical reinforcing of walls consists of a single high strength deformed (HSD) or 'TOR' bar (see Table 5B for required diameters) located at each critical point as stated in 6.2.3.B and Figs. 11B and 12B.

Table 5B : Vertical Reinforcing Bars in Walls

No. of Storeys	**Storey**	**Dia of single HSD (TOR) Bar**			
		Category B	**Category C**	**Category D**	**Category E**
		mm	**mm**	**mm**	**mm**
One	-	Nil	Nil	10	12
Two	Top	Nil	Nil	10	12
	Bottom	Nil	Nil	12	16
Three	Top	Nil	10	10	12
	Middle	Nil	10	12	16
	Bottom	Nil	12	12	16
Four	Top	10	10	10	Four Storeyed Building not allowed
	Third	10	10	12	
	Second	10	12	16	
	Bottom	12	12	20	

All reinforced bars mentioned in Table 5B must have embedment in the foundation concrete and should be taken continuously and embedded in the roof band or the R.C. roof slab. For bonding with the masonry and providing protective cover against corrosion, the bar must be embedded in M20 grade concrete (1:1.5:3 nominal mix) filled in the surrounding pockets as follows:

12.1.B Vertical Bar in Brick Walls

In solid brick walls, a cavity of 114 x 114mm may be formed by suitably arranging the brick-bats around the bar. See Fig. 15B. When rat-trap bond is used, cavities at the corners are automatically available.

12.2.B Vertical Bar in Solid Concrete Block Walls

Since a cavity formation in solid block wall is not feasible, concrete blocks with one hollow are used at the bar-points. To avoid raising of the blocks high for enclosing the bar in a hollow, special blocks are cast as shown in Fig. 1Bd.

12.3.B Vertical bar in Hollow Block Wall

Here cavities for locating the Vertical bars are automatically available. Slit arrangement in the sides of the hollows for housing the bars will be required as shown in Fig. 15B.

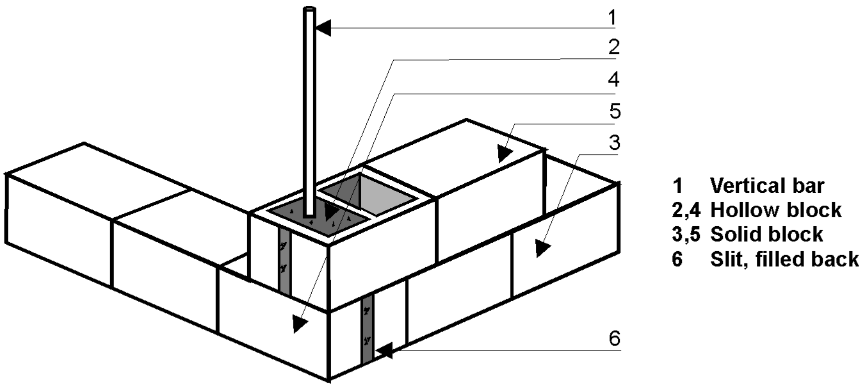
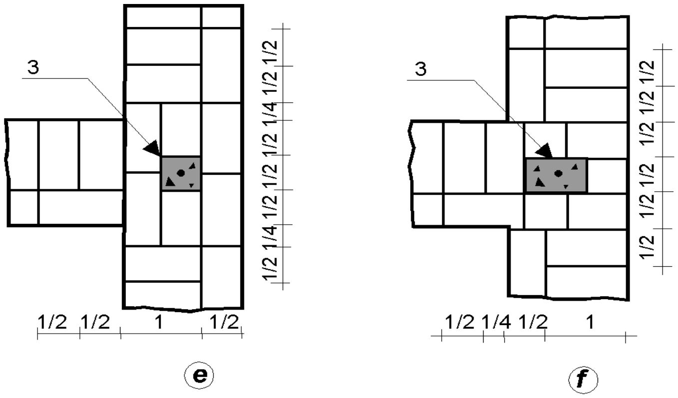


Fig. 15B Vertical bar in concrete block wall

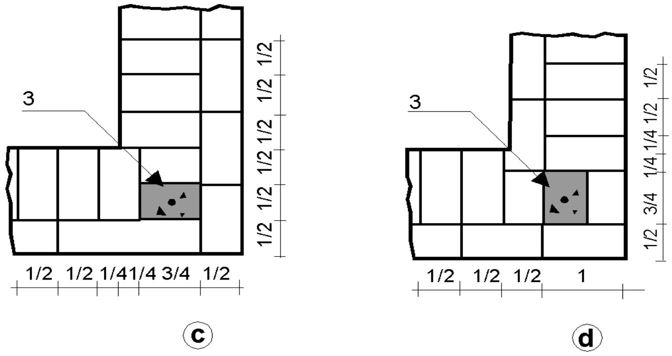
12.4.B Vertical Bar in Dressed Stone Walls

Since a cavity formation in the stone is not feasible, the following two ways may be adopted to provide and build the vertical bars in the stone walls:

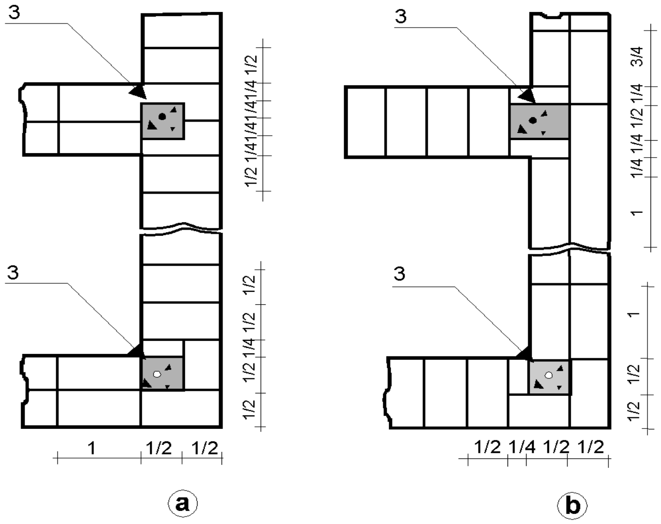
a. Special concrete blocks, with hollow and slit, (as for example in Fig. 1Bd) may be made in the size of the dressed stones and built in the stone wall courses along with the stones, at all the vertical bar locations.



e & f Alternate course at T-junction of one and a half brick wall



c & d Alternate courses in one and a half brick wall



a & b Alternate courses in one brick wall

1	**one brick length**
1/2	**Half brick length**
3	**Vertical steel bars with mortar/conc. filling in pocket**

Fig. 16B Typical details of providing vertical steel bars in brick masonry

b. After erecting the vertical bars, stone masonry may be built in three courses with toothed joint towards the bar, and the space around the bar may be filled with 1:1.5:3 concrete mix using wooden shuttering on two sides only forming a toothed concrete column with the masonry. For ensuring firm connection with the masonry, a hooked steel link 8 mm in diameter should be installed every third course which should engage the vertical bar at one end, the other end going into the masonry by about 200 mm (Fig. 16B).

12.5.B Construction Details

Before casting the foundation, vertical bars must be held in correct positions vertically by using tripods of bamboo or the spare reinforcing bars (See Fig. 17B).

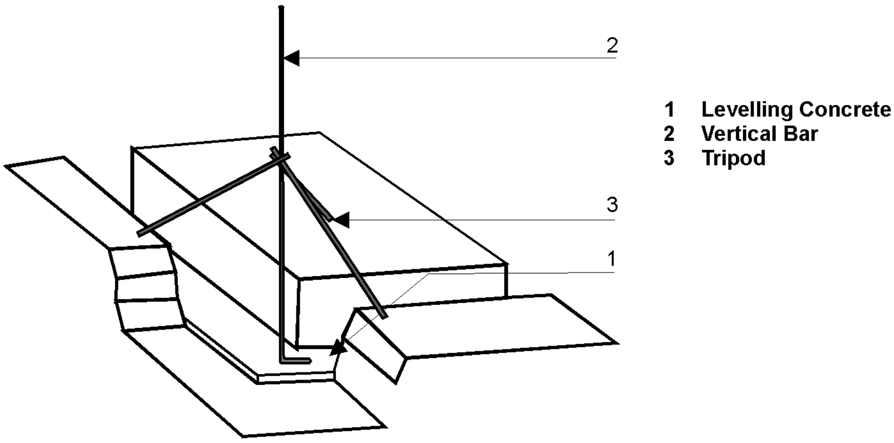


Fig. 17B Keeping the bar vertical

13.B FLOORS AND ROOFS

As stated in Section 5B, there are three main types of roofs and floors used in houses in Afghanistan:

1) Wood logs supporting reeds or wooden planks, topped with earth fill
2) Sawn timber joists with wooden planks topped with earth fill
3) Masonry domes or earthen domes

These roofs are constructed without any seismic resisting measures. These measures are to be specified for earthquake safety in future constructions. Also in view of the better new construction taking place, it will be appropriate to introduce new construction techniques which will make the roofs leakage proof and also more durable.

13.1.B Flat Roofs/Floors with Wood Logs or Timber Joists

The main deficiencies in this system of construction are :

(i) The different elements are not integrally connected, hence liable to separate out even in moderate earthquake shaking, and become unstable.

(ii) Due to insufficient bearing of the logs/joists on the walls, these are likely to leave the bearing and fall down under large displacement.

(iii) Unless carefully covered with water proof flooring, they will leak during rains.

Construction Safe Guards

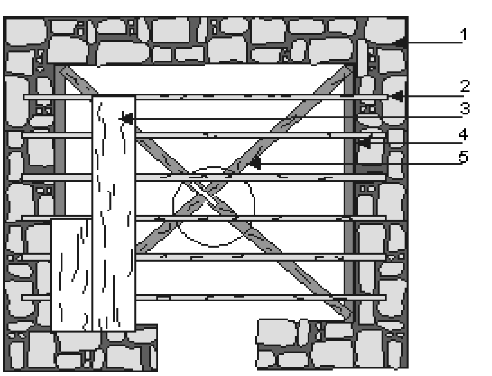
(i) All wood logs/joists should have two cross *bridging elements* across the logs/joists near their ends properly nailed or screwed to them. The cross section of the bridging member should a minimum of 40 mm x 70 mm.

(ii) All spaces between the logs/joists at the bearing points should be *blocked* using solid wooden blocks, having a width of atleast 40 mm and depth equal to full depth of the joists. These blocks should be screwed or nailed to the logs/joists.

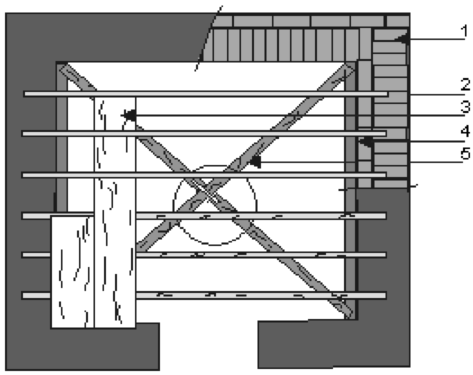
(iii) It will make the whole arrangement stable if the logs/joists are held down to the seismic band provided at the ceiling level.

(iv) In order to establish diaphragm action of such wooden grillage, diagonal bracing should be provided either on top or the bottom surface of the logs/joists and connected to bridging elements. See Fig. 18B.

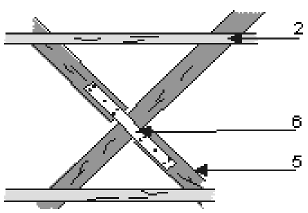
(v) In order to prevent rain/snow water seepage through the roofing earth fill, it will be appropriate to introduce heavy density black polythene sheet between the supporting wooden planks or reeds etc. and the earth fill. The thickness of the earth fill may be limited to about 150 mm on an average providing adequate slope towards the drainage spouts.



(a) Stone Building



(b) Brick Building



1. Wall
2. Wood joist
3. Wood plank
4. Tie plank under ends of joist
5. Diagonal ties
6. Joint by nailing through 3mm flat iron

Fig. 18B Earthquake resistant construction of timber joists floor

13.2.B Flat Roof/Floor Using Jack Arches

Multi panel jack arch roofs have to be provided horizontal ties atleast in the end panels and every fourth panel so that the thrust of the arches is balanced by the ties. In earthquake areas particularly in zones AB and C it will be necessary to provide the ties under all panels continuously. See Fig. 19B.

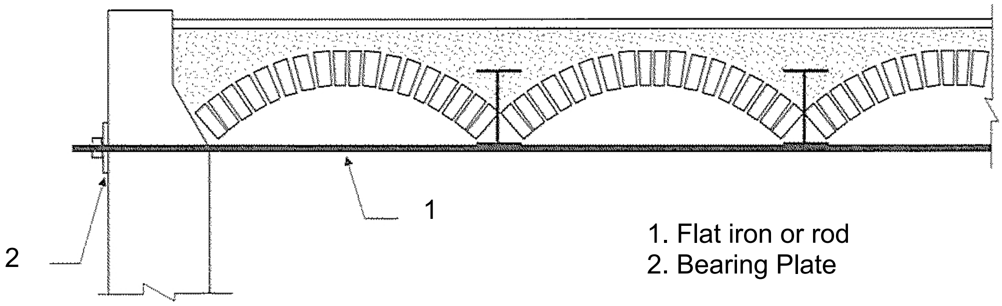


Fig. 19B Seismic Strengthening of Jack arch floor/roof

13.3.B Flat Floor/Roof Using Beams and Prefab Roofing Elements

A large number of schemes using precast roofing elements as well as precast reinforced concrete beams have been developed in India, whose seismic safety has been detailed in IS: 4326-1993. In order to integrate the prefabricated roofing elements and the reinforced concrete joists or inverted T-irons or steel joists, the following points are specified.

(i) The prefabricated plank/shell units when placed on the joists should be interconnected with the reinforcement of the joists, or the spacing between the joists has to be maintained by cross bridging elements.

(ii) The deck so prepared must be covered with reinforced concrete screed of minimum 38 mm thickness, reinforced with 4 mm diameter wires spaced at 60 mm on centers both ways or 6 mm diameter bars at 150 mm center to center both ways. This reinforced screed is to be connected to a peripheral reinforced concrete seismic band cast on the walls along with the screed. The screed performs the function of leak proof membrane as well as creating diaphragm action in the roof.

13.4.B Flat Floor/Roof Using Joists, Plank, RC Screed System

A system developed by the author and used in the reconstruction program after Chamoli earthquake of 1999 in Uttaranchal, India, is presented herebelow as illustration of prefabrication techniques. The advantage of such a techniques is that the shuttering work at site is very much reduced, the members are made in standardized forms and compaction and curing of the elements is properly taken care off. The casting of the screed is to be done in-situ on a ready deck formed on the precast beams and RC planks.

Details of Precast R.C.C. Joist Plank Screed System (Figs. 20B and 21B)

(a) Loading and Span

Two cases of loading and four spans are considered as follows:

Case I: Intermediate floor with R.C Screed, cemented floor or earth fill of 75 mm may be added if desired.

Case II: Roof with R.C Screed, on a gentle slope of 1 in 12, no other covering, thatch may be used for insulation.

The clear spans between walls are taken 2.44 m (8 ft); 2.74 m (9. ft); 3.05 m (10 ft) and 3.6 m (11'9"). Live loading on floor and roof is taken as per IS: 875.

The R.C. joists will be spaced at 0.9 m c/c. The R.C plank will be made 38 mm thick, 450 mm wide and 850 mm long. Concrete mix M20 (1:1.5: 3) will be used in Joists, Planks and the Screed.

(b) R.C Plank

450 x 850 x 38 mm with 4 mm dia reinforcing wires spaced at 60 mm c/c longitudinally with clear cover of 15 mm below. The reinforcement across will be 3 mm dia spaced at 140 mm c/c. The longitudinal bars will be kept protruding out by 50 mm both sides so as to bond with the joists through in-situ concrete filling.

(c) R.C Joists

The details are given in Table 6B and Fig. 20B for intermediate Floor and Roof both.

(d) R.C Screed

Use 38 mm thick, with 5 mm dia bars @ 225 mm c/c parallel to joists and 200 c/c across, at clear cover of 15 mm minimum above the bars. Alternatively Weld Mesh MW 62 (4 mm dia wires @ 200 c/c each way) may be used (Fig. 21B).

***IMPORTANT NOTE*:** The precast joist will be propped from below at mid-point of 2.44 m span and at about 1 m apart in case of 2.74 to 3.60 m spans until the screed and joint filling concrete has cured for at least 10 days.

Table 6B : R.C. Joist Dimensions & Reinforcement

S. No	Case	Clear Span m	Length of joist m	Overal l depth mm	H1 mm	D1 (Bottom) mm	D2 Top mm	D3 (Stirr.) mm	Minim. camber mm
1	Case I - Floor with R.C. Screed	2.44	2.74	166	90-6*	8 $\bar{\phi}$ TOR 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
2		2.74	3.04	225	149-6*	8$\bar{\phi}$ 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	15
3		3.05	3.35	225	149-6*	10$\bar{\phi}$ 8.5ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18
4		3.60	3.90	250	212-6*	10 $\bar{\phi}$	8 $\bar{\phi}$	6 ϕ	20
5	Case II - Roof with R.C. Screed Gentle Slope	2.44	2.74	166	90-6*	8$\bar{\phi}$ 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
6		2.74	3.04	166	90-6*	8$\bar{\phi}$ 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	12
7		3.05	3.35	200	124-6*	8$\bar{\phi}$ 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18
8		3.60	3.90	225	187-6*	8$\bar{\phi}$ 7ϕTK	8$\bar{\phi}$ 7ϕTK	5ϕ 4.75 TK	18

* Reduction of 6mm is indicated for 1:4 mortar for bearing under the R.C. plank

Notes: 1. 8$\bar{\phi}$ = 8mm dia High Strength Grip Bar like Tor steel with Fy = 415.N/mm^2
7ϕTK = 7mm dia Torkari bar with Fy=550 N/mm^2
Any of these could be used.
2. ***Important**:* The precast joist will be propped from below at mid-point of 2.44 m span and at about 1m apart in case of 2.74 to 3.60 m spans until the screed or joint filling concrete has cured for at least 10 days.
3. The stirrup will be made of triangular form

14.B PARAPET

Parapets above roofs are unstable vertical cantilever projections which are liable to topple over during earthquake motions. Therefore the height of the masonry parapet should be kept less than three times its base with and it should be constructed using the cement mortar specified for the zone.

Alternatively, the parapet should be vertically reinforced, the reinforcement being anchored into the roof slab or in the main wall below the parapet.

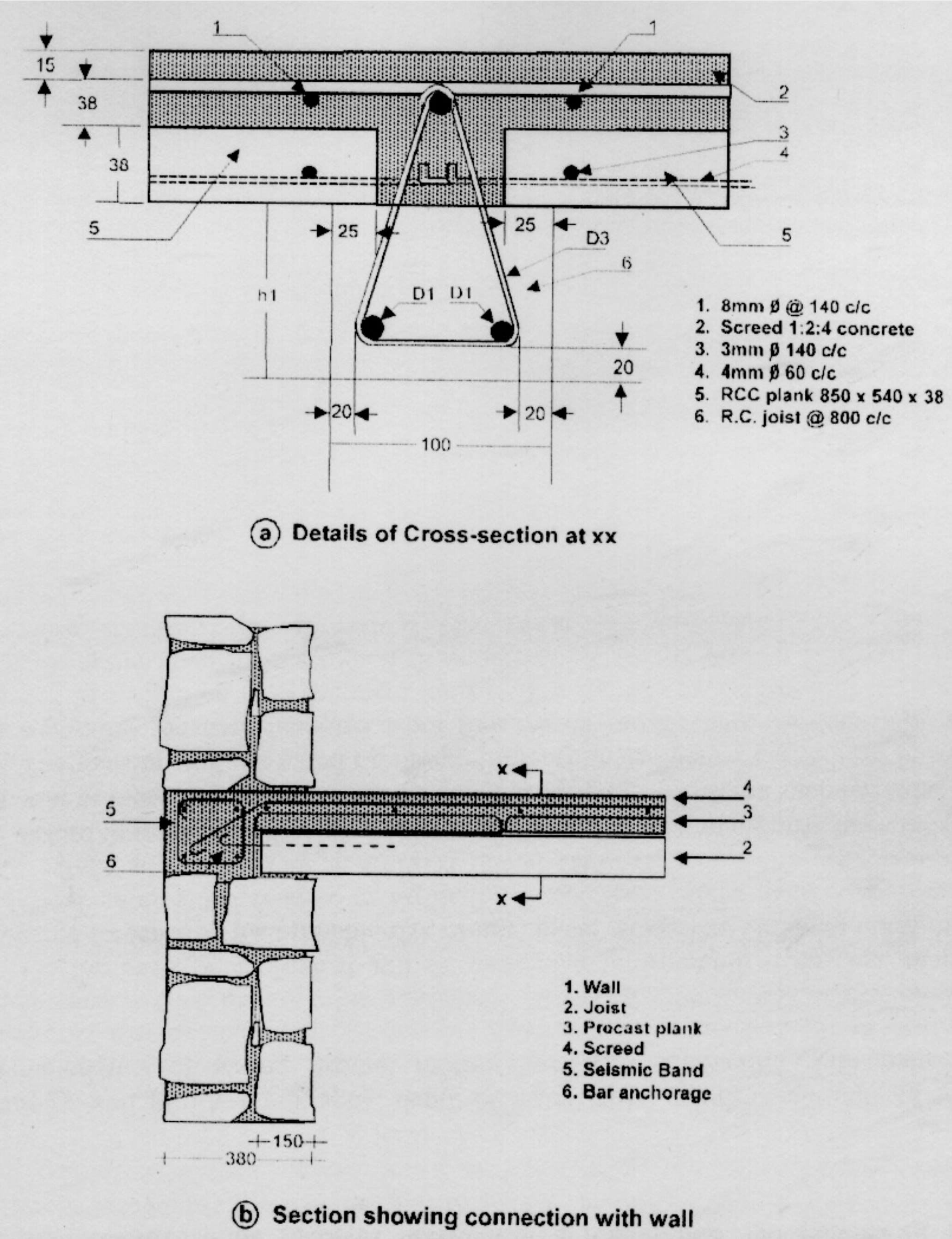
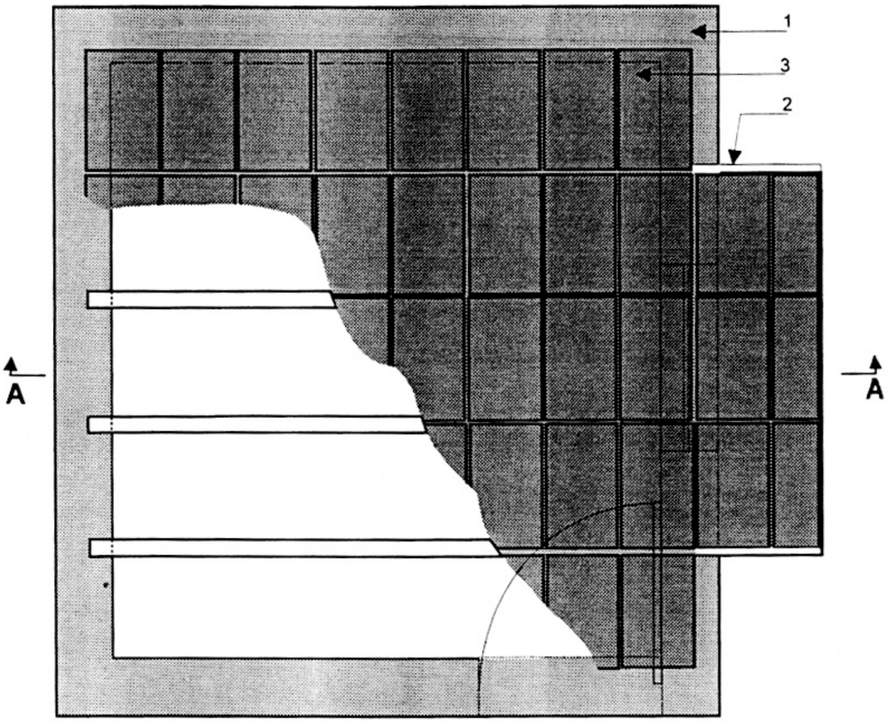
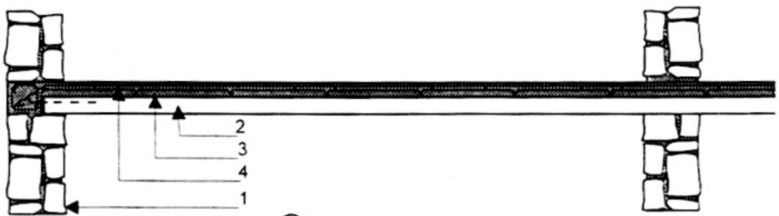


Fig. 20B R.C. Joist – Plank – Screed system details



(a) Plan of roof or floor

1. Wall
2. Joist (Precast RC or Prefab Steel)
3. RC Plank
4. RC screed



(b) Section AA

Fig. 21B Roof/Floor plan using RC Joist – Plank – Screed

REFERENCES

1. IS:1893-2002 "*Criteria for Earthquake resistant Design of Structures*" (Fifth revision).

2. IS:4326-1993 "*Earthquake Resistant Design and Construction of Buildings – Code of Practice*" (Second revision).

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

4. "Guidelines for Earthquake Resistant Non-Engineered Construction" A.S. Arya, et al, pub. by IAEE, 1986, reprinted by Indian Society of Earthquake Technology, Roorkee-247 667.

5. "Improving Earthquake Resistance of Buildings – Guidelines, by Arya, A.S. et al., pub. by Building Materials and Technology Promotion Council, New Delhi, 1999.