PART C

Earthquake Resistant Construction of Stone Buildings
CONTENTS – PART C

1.C INTRODUCTION ........................................................................................................................................... 81

2.C OBJECTIVES OF THE GUIDELINES ............................................................................................................. 81

3.C SCOPE OF THE GUIDELINES ......................................................................................................................... 81

4.C OPTIONS FOR WALL TYPES .......................................................................................................................... 82

5.C OPTIONS FOR ROOF AND FLOOR TYPES .................................................................................................... 82

6.C REQUIRED EARTHQUAKE SAFETY PROVISIONS .................................................................................. 83

   6.1.C Building Categorization
   6.2.C Measures for Achieving Seismic Safety
   6.3.C Measures for Achieving Seismic Safety

7.C FOUNDATIONS ................................................................................................................................................. 84

   7.1.C New Foundations
   7.2.C Use of Existing Old Foundation

8.C TREATMENT AT PLINTH LEVEL .................................................................................................................... 85

9.C STONE MASONRY WALLS IN MUD MORTAR .......................................................................................... 86

   9.1.C Construction Control
   9.2.C Control on Wall Length and Building Height
   9.3.C Control of Openings in Bearing Walls
   9.4.C Seismic Bands
   9.5.C Vertical Reinforcing Bars in Walls
   9.6.C Water Proofing

10.C STONE MASONRY USING CEMENT MORTAR ....................................................................................... 94

   10.1.C Construction Control
   10.2.C Control on Wall Length and Building Height
   10.3.C Control on Openings in Bearing Walls
   10.4.C Seismic Bands
   10.5.C Vertical Reinforcement

11.C FLOORS AND ROOF ...................................................................................................................................... 97

12.C MASONRY DOME .......................................................................................................................................... 98

13.C PARAPETS ....................................................................................................................................................... 98
1.C INTRODUCTION

These guidelines have been specially framed for the reconstruction of collapsed or severely damaged houses in the various affected Provinces of Afghanistan and also construction of new houses in these areas. The guidelines will also be helpful in earthquake resistant construction of houses in other parts of the country which fall in seismic Zones AB and C of the Seismic Zoning Map of Afghanistan.

2.C OBJECTIVES OF THE GUIDELINES

The main objective of these guidelines is to illustrate the earthquake resisting construction measures in accordance with the Seismic Zoning Map of Afghanistan using the building construction standards adopted in India, namely, IS: 4326, IS: 13827 and IS: 13828 of 1993.

According to Seismic Zoning Map of Afghanistan there are the following seismic zones (Fig. 9A):

Zone AB: MSK Intensity VIII or higher is probable to occur.
Zone C: MSK Intensity VII is probable here
Zone D: MSK Intensity VI is probable here.
Zone E: MSK Intensity V or lower is only considered probable.

The recommendations contained herein are based on these probable Intensities for the design of buildings according to the Codes. Reconstruction and new construction of buildings will be safe if it would be in accordance with the specified Intensities.

3.C SCOPE OF THE GUIDELINES

These guidelines cover those houses which are situated in the earthquake prone zones and whose bearing walls are built using coursed stone masonry and do not exceed 7.0 meters in length in any room and the number of storeys are no more than three. The roof can be flat or sloping. The earthquake resistant provisions are indicated for seismic Intensities MSK ≥ VIII, and VII as appropriate for the earthquake damage prone Zones AB, and C respectively. Construction of Rubble stone walls using mud mortar as well as cement mortars is dealt in this Guide. The earthquake resistant design principles as covered in Part A are made use of in working out the various design and construction details.
4.C OPTIONS FOR WALL TYPES

The following wall types are normally used in stone-building construction.

<table>
<thead>
<tr>
<th>Type of wall</th>
<th>Seismic Safety Grading</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Random rubble stone masonry in mud mortar.</td>
<td>Sixth</td>
</tr>
<tr>
<td>(ii) Courses rubble stone masonry in mud mortar.</td>
<td>Fifth</td>
</tr>
<tr>
<td>(iii) Random rubble stone masonry in cement mortar</td>
<td>Third</td>
</tr>
<tr>
<td>(iv) Coursed rubble stone masonry in cement mortar</td>
<td>Second</td>
</tr>
<tr>
<td>(v) Dressed stone (Ashlar) masonry in mud mortar</td>
<td>Fourth</td>
</tr>
<tr>
<td>(vi) Dressed (Ashlar) stone masonry in cement mortar.</td>
<td>First</td>
</tr>
</tbody>
</table>

From earthquake safety point of view, the above walls may be graded as shown against each. Unfortunately, their costs also vary more or less similarly except dressed stone masonry in mud may come second in order. In place of cement – sand mortar, appropriate mix of cement – lime – sand mortar may also be used if found economical and feasible.

Note: Dressed (Ashlar) stone masonry walls behave similar to other rectangular building units, such as bricks, and concrete blocks, and were dealt with in Part B of the Guidelines, hence not covered here.

5.C OPTIONS FOR ROOF AND FLOOR TYPES

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.C  REQUIRED EARTHQUAKE SAFETY PROVISIONS

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

6.1.C  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>
<thead>
<tr>
<th></th>
<th>Zone D</th>
<th>Zone C</th>
<th>Zone AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>Community Buildings</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
</tbody>
</table>

6.2.C  Measures for Achieving Seismic Safety

6.2.1.C  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.C  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 rafted roofs.

6.2.3.C  Additional measures for 2-3 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.C FOUNDATIONS

7.1.C New Foundations

7.1.1.C Rocky Ground

Weathered, jointed and fissured rock may be leveled by chiseling, in steps of about 150 mm and stepped strip footing built on it, with the foundation width of 600 mm for two storeyed houses. Boulder site may be leveled by removing small boulders but leaving large boulders in place. If the rock is massive, the surface should be roughened by chiseling and stepped-strip footing built on it. In all cases, the base concrete of sufficient thickness (with a minimum of 100 mm) should be used for leveling before starting the masonry.

7.1.2.C Soil Site

Use stepped-strip foundation with minimum depth of 750 mm below ground level and width of 700 mm (upto 2 storeyed houses), Fig. 1C. For each additional storey, increase width by 300 mm. The footing masonry should be brought in steps upto the plinth level.

Fig. 1C Strip foundation on soil sites.
7.2.C Use of Existing Old Foundation

Houses of pre-damage dimensions and heights could be built on existing foundation constructed in stone laid in compacted sand or mud mortar. The existing foundation may be excavated to about 230 mm below ground level where base concrete 150 mm thick in 1:4:8 mix is to be cast on the existing lower part of the footing (Fig. 2C).

Fig. 2C Strip Footing on Existing Foundation.

8.C TREATMENT AT PLINTH LEVEL

This will depend on site-soil condition as follows:

a. Rocky Ground

The seismic band is not required. Use damp-proof course (D.P.C.) as usual on the strip foundation. It may be cement-sand mortar of 1:3 mix 25mm thick or 1:2:3 micro concrete 38mm thick, with damp proofing compound mixed in each case (See Fig. 3C).

b. Boulder or Soil Site

In each case, use RC seismic band of 75 to 100mm thickness (See Fig. 9C for detail of the band).
9.C STONE MASONRY WALLS IN MUD MORTAR

Stone masonry walls built using mud mortar and other details as given in the following paras, could be used for housing only, for reasons of affordability or non-availability of cement supply. Stone masonry in mud should not be used for community buildings such as schools, hospitals, mosques, etc.

9.1.C Construction Control

(i) The mortar should be clay mud of good quality.
(ii) The wall thickness ‘t’ should preferably be kept 450mm, but not to be larger than 500mm. In any case, the stones of the inner and outer wythes should be interlocked with each other as far as possible.

(iii) The masonry should preferably be brought to courses at not more than 600 mm lift so as to achieve ‘coursed rubble masonry’.

(iv) ‘Through’ stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2m apart horizontally (Fig. 4C).

(v) In place of ‘through’ stones, ‘bonding elements’ of concrete bars of 50mm x 50mm section with an 8mm dia rod placed centrally or solid concrete blocks of 150 x 150 x ‘wall thickness size’ may be used. (Fig. 4C). Alternatively, tree branches of 60 mm dia, or seasoned wooden battens of 50 mm x 50 mm size may be used as bonding element.

(vi) Long stones of 600 mm length or solid concrete blocks of 150 x 150 x 600 mm size should be used at wall corners and T-junctions every 600 mm height to connect the perpendicular walls effectively (Fig. 4C). Alternatively, branches of 65 mm dia, or seasoned wooden batten of 60 mm x 60 mm size may be used.

9.2.C Control on Wall Length and Building Height

Height of the coursed rubble masonry walls in mud mortar should be restricted, with storey height to be kept 2.7m maximum, and span of walls between cross walls to be limited to 5.0 m as follows:
In Zones C and D: preferably up to two storeys, but not more than three storeys in any case.

In Zone AB: preferably one storey but not more than two storeys in any case.

If walls longer than 5m are needed, pilasters or buttresses may be used at intermediate points not farther apart than 3.5m. The size of the pilaster or buttress be kept of uniform thickness with top width equal to the thickness of main wall ‘t’ and the base width equal to t or one sixth of wall height. See Fig. 5C.

![Fig. 5C Long stone walls in mud mortar with buttresses](image_url)

9.3.C Control of Openings in Bearing Walls

For coursed rubble stone masonry built in mud mortar, the door and window opening may be located in the walls as follows (Fig. 6C).

Total length of openings in a wall = 0.33 of wall length in Category D and E and 0.42 in Category C buildings.

Distance of opening from inside corner: \( b_5 \geq 600 \text{ mm in Cat. D & E and } 450 \text{ mm in Cat. C building} \)

Pier width between consecutive openings \( \geq 600 \text{ mm} \)
9.4.C  Seismic Bands

The overall arrangement of seismic reinforcing of masonry buildings is shown in Fig. 8C for buildings with flat roof and in Fig. 8C for building with sloping roof consisting of horizontal seismic brands and vertical bars. The seismic bands at various critical sections shall be as follows:

(i) Seismic bands at plinth, and lintel, ceiling levels in buildings with flat roof will be provided in all internal and external walls continuously without break in all storeys. Requirement of reinforcing bars in RC bands are given in Table 2C and the details of bands are shown in Fig. 9C.

(ii) In case of sloping roofs, triangular gable walls must be enclosed within eave level band and a band at the top of the gable wall. These bands must be made monolithic and continuous as shown in Fig. 10C.
Fig. 7C  Overall arrangement of earthquake resisting elements in double storeyed houses having flat roof (Roof not shown)

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

Fig. 8C  Overall arrangement of reinforcing in masonry double storey building having pitched roof (Roof not shown)

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
### Table 2C: Longitudinal Bars* in RC Bands (Stone Masonry in Mud or Cement Mortar)

<table>
<thead>
<tr>
<th>Length of wall in room (m)</th>
<th>Reinforcing Bars in Building Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cat. B</td>
</tr>
<tr>
<td></td>
<td>No. Dia (mm)</td>
</tr>
<tr>
<td>&lt; 5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

*High Strength Deformed (Tor) bars

### Fig. 9C Longitudinal Bars and links/stirrups in R.C. Bands

- **Section with four bars**
  - ø 6 @ 150
  - 2
  - 1

- **Section with two bars**
  - ø 6 @ 150
  - 2
  - 1

1. Main bars
2. Latera tiles/stirrup

- **Corner joint plan**
- **T-Joint plan**
(iii) For achieving good bond with masonry, the bands should be cast directly on the masonry and its top surface should be made rough. In the case of plinth and lintel band, stones may be cast in the concrete to project out of the concrete by 50 to 75mm.

(iv) **Wooden Bands.** In stone (or brick) walls constructed using mud mortar, bands can be made using wood or timber (see Part E sub-section 12.2.E for details).

### 9.5.C Vertical Reinforcing Bars in Walls

The vertical reinforcing of walls consists of a single high strength deformed (HSD) or "TOR" bar (See Table 3C for required diameters) located at each critical point as stated in 6.2.3.C.

#### Table 3C : Vertical Bars at Corners of Room

(Stone Masonry in Mud or Cement Mortar)

<table>
<thead>
<tr>
<th>No. of Storeys</th>
<th>Storey</th>
<th>Diameter Of Single HSD (TOR) Bar at Corners of Room</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cat. B.</td>
<td>Cat. C.</td>
</tr>
<tr>
<td>One</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Two</td>
<td>Top</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>---</td>
</tr>
<tr>
<td>Three</td>
<td>Top</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>10</td>
</tr>
</tbody>
</table>

Three storeyed building, nor permitted in mud mortar

---

![Fig. 10C Continuity of reinforcement in eave and gable bands.](image-url)
9.5.1.C Installation of Vertical Bars

For installations of vertical bars in stone masonry, use of PVC casing pipe of 100mm external dia, 600-750 mm long is recommended around which masonry be built to height 450-600mm (see Fig. 11C) and the pipe made loose by gently rotating. As the masonry hardens, the pipe is raised and the cavity filled with M20 concrete (nominal mix of 1:1.5:3) and fully compacted by rodding using 12mm dia and 600mm long bar.

![Fig. 11C Installing vertical steel bars in stone masonry walls](image)

9.5.2.C Keeping the Bar Vertical

Before casting the foundation, the vertical bars must be kept in correct in position horizontally and vertically. For this purpose tripods may be erected using bamboos or spare reinforcing bars (See Fig. 12C).

![Fig. 12C Keeping the bar vertical](image)

$t = 380$ for cement mortar, 450 for mud mortar
9.6.C Water Proofing

9.6.1.C For protection of external walls against damage by water

(i) Take out roof projection beyond the walls by about 300mm, and

(ii) Use cement-sand mortar pointing on external face of walls; OR

Use waterproof mud plaster on external face of walls, which may be done as per
9.6.2.C.

9.6.2.C Water Proof Mud Plaster

(i) Prepare cut-back by mixing bitumen 80/100 grade and kerosene oil in the ratio 5:1. For 1.8 kg cut-back, 1.5 kg bitumen is melted and is poured in a container having 300-millilitre kerosene oil, with constant stirring till complete mixing.

(ii) Mix this mixture with 0.03 cu.m (30 litres) of mud mortar to make it both, water repellent and fire resistant.

(iii) The waterproof plaster is to be applied in 20 to 25mm thickness and allowed to dry. It may then be coated twice with a wet mixture of cow-dung and waterproof plaster in the ratio of 1:1 and allowed to dry again.

10.C STONE MASONRY USING CEMENT MORTAR

Stone masonry using cement mortar and other details as set out in the following paras may be used for all building categories in the area.

10.1.C Construction Control

10.1.1.C Mortar. The mortar in superstructure masonry should be cement-sand (1:6 in zones C & D and 1:4 zone AB).

In the foundation masonry upto plinth, the mix 1:6 may be kept in all cases.

10.1.2.C Composite Mortar. In place of cement–sand 1:6 and 1:4 mortars, cement–lime–sand mortar may be used as 1:2:9 and 1:1:6 respectively.

10.1.3.C Wall Thickness. The wall thickness should not be larger than 380 mm (not more than 450 mm in any case) and the stones on the inner and outer wythes should be interlocked with each other as far as possible.

10.1.4.C Coursed. The masonry should preferably be brought to courses at not more than 600 mm lift.

10.1.5.C ‘Through’ Stone. ‘Through’ stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally (Detail as per Fig.13C)
In place of ‘through’ stones, ‘bonding elements’ of concrete bars of 50mm x 50mm section with an 8 mm dia rod placed centrally or solid concrete blocks of 150 x 150 x walls thickness, can also be used.

10.1.6.C Corner Stones. Long stones of 500-600mm length should be used at wall corners and T-junctions of walls. Alternatively use of 150x150x(500 to 600) solid concrete blocks to connect the perpendicular walls effectively (Detail as per Fig.13C).

10.2.C Control on Wall Length and Building Height

10.2.1.C Height

The height of the coursed-rubble masonry walls in cement mortar should be restricted as follows:

(i) For Categories C and D: Three storeys with flat roof or two storey plus attic.

(ii) For Categories D and E: Two storeys with flat roof or one storeys plus attic for pitched roof.

The storey height to be kept 3.2m maximum, and span of walls between cross walls to be limited to 7.0m. If rooms longer than 7m are needed, buttresses may be used at intermediate points not farther apart than 5.0m. The size of the buttress be kept of uniform thickness with top width equal to the thickness of main wall and the base width equal to one sixth of wall height. (See Fig. 14C for arrangement of pilasters or buttresses).
Fig. 14C  Long walls with buttresses (cement mortar)
10.3.C Control of Openings in Bearing Walls

For stone masonry built in cement mortar and brought to courses, the door and window openings should be controlled as follows: (Fig. 15C).

**Fig. 15C  Control on length, height and openings of wall (cement mortar)**

- Ratio of total length of openings in a wall to length of the wall in a room should not exceed 0.5 in single storeyed, 0.42 in 2-storeyed and 0.33 in 3 storeyed buildings.
- Distance of opening from inside corner $\geq 450$mm
- Pier width between consecutive openings $\geq 600$mm

10.4.C Seismic Bands

The seismic bands at various critical sections should be as provided in sub-para 9.4.C (Figs. 9C, 10C).

10.5.C Vertical Reinforcement

The vertical bars to be provided at corners of rooms and the jambs of large openings should be as specified in 9.5.C (See Figs. 11C, 12C).

11.C FLOORS AND ROOF

The construction of floors and roofs with earthquake resisting features as described in Part B Section 13.B will be suitable for use in stone masonry buildings.
12.C MASONRY DOME

The masonry domes are usually made of Hemispherical or segmental shape, which could cover large column free spaces. In most cases the domes are without any opening but sometimes an opening of cylindrical shape is created near the crown with a cover at the top, and vents on the sides. This is called the ‘lantern’ which permits entry of light and ventilation. So long as the domes are segmental with the angle of the radius measured from the vertical remaining 50 degree or less, the dome remains in the compression and does not require any reinforcement, except that a hoop capable of taking the horizontal thrust of the dome at the bottom periphery will be required. However if the dome is made fully hemispherical, the edges becoming vertical, the portion of the dome between 50 degrees and 90 degree angle comes under hoop tension.

The best way of reinforcing the masonry dome against seismic forces will be as follows:

(i) to construct the dome using the specified cement mortar or cement lime mortar mix in the construction of masonry, and

(ii) to provide horizontal seismic bands of circular shape at the springing of the dome as well as every six courses above the springing up to the critical angle of 50 degrees measured from the vertical. The reinforcement in these bands may be kept the same as specified for lintel bands of span equal to the diameter of the dome.

13.C PARAPETS

The suggestions given in Part B, Section 14B may be followed.