Technical Guidelines & Information for Stone Construction In Uttarakhand

Disaster Management and Mitigation Center, Dehradun,
Govt. of Uttarakhand.

Technical Guidelines & Information for Stone Construction In Uttarakhand

Prepared as a part of project titled

Taking Traditional Technologies Forward – Preparing for Disasters

Guidelines Steering Committee

Principal Secretary, Disaster Management, GoUK –	Chair person
Prof. A.S.Arya, Former Seismic Advisor to GoI –	Member
Prof. D.K.Paul, Dept. of Earthquake Engineering, IIT, Roorkee –	Member
Shri Rajendra Desai, Hon. Jt. Director, NCPDP, Ahmedabad –	Member
Shri Pawan Jain, Architect, Dehradun –	Member
Dr. Piyoosh Rautela, Executive Director, DMMC, Dehradun –	Member/Secretary

Guidelines Review Committee

Prof.K.S.Jagadish, Former Professor IISc, Banglore –	Chair person
Prof. Y.K.Singh, Dept. of Earthquake Engineering, IIT, Roorkee –	Member
Dr. Girish Joshi, Senior Executive, DMMC, Dehradun –	Member/Secretary

Prepared By
Project Team: Rajendra Desai, Rupal Desai, Pawan Jain, R.K.Mukerji, Harshad Talpada
NCPDP, 103 Antariksh, Panjarapol Cross Roads, Ahmedabad, GUJ 380015
Tel: 079 2630 9712 E-mail: mitigation@ncpdpindia.org

Foreword

From DMMC

Preface

State of Uttarakhand is known to be seismically one of the most active regions of the country. In recent times the state was hit by two moderate earthquakes. On October 19, 1991 an earthquake of 6.4 on Richter scale had struck in the vicinity of Uttarkashi town and on March 29, 1999 of 6.8 had struck in the vicinity of Chomoli town. Both earthquakes caused extensive damage to the buildings having stone walls and *Pathal* roof.

The stone construction in the state has been transforming over the past several decades. During this period the traditional safety features such as the timber bands, vertical timber stiffeners and the timber upper storey gradually disappeared as access to good quality timber became restricted. During this period, the adherence to the basic rules of stone construction too faltered. This led to drastic decrease in the seismic resistance of the stone structures which resulted in to wide-scale damage in the past two earthquakes.

This damage badly shook peoples' confidence in the stone construction. As a result people began shifting from stone construction to that based on steel, cement and brick that they perceive to be safer. This has been at the cost of many important benefits of the traditional construction that people had enjoyed for centuries.

This document is made with the objective of guiding all those involved in the construction of buildings with stone including the engineers, contractors, building artisans and people, so that they are able to construct stone buildings that will resist future earthquakes and restore peoples' confidence in traditional stone construction.

It must be added that using good quality cement mortar in stone masonry is one of the important requirements. However, if mud mortar is desired to be used for any reason, reasonable earthquake resistance can be achieved by using appropriate measures. In place of mud mortar, the guidelines also cover other affordable alternatives that use cement in combination with lime while making mortar with sand or one that uses cement to stabilize mud. Similarly, the earthquake resisting features include those made of concrete and steel, as also those made from available timber.

It is hoped that all those involved in construction take full care in using the necessary disaster safety elements in the new construction, whether for housing or for important buildings such as schools, public health facility or community halls.

Finally, in today's context of global warming and climate change, it is important that virtues of the traditional building construction that predominantly use the local materials do not use large quantities of energy in their production and do not have to be transported over long distances are recognized and promoted.

Dehradun Project Team
February 28, 2011

Acknowledgement

First and foremost we acknowledge the support that we received from Disaster Management and Mitigation Centre, Government of Uttarakhand, notably from Dr.Piyoosh Rautela and Dr. Girish Joshi. Without their initiatives in coordinating the process of reviews and finalization the time taken in creating this document would have been much more.

Prof. K.S.Jagadish from Banglore and Prof. Y.K.Singh of IIT- Roorkee were most positive and supportive during the review process and helped improve the content of the initial draft through their invaluable input.

Finally, it was the detailed and painstaking scrutiny by Prof.A.S.Arya and Prof. D.K.Paul that helped us make a thorough technical document that is easy to comprehend.

In addition, we are thankful to a large number of people across the state that we met during our field study that helped us acquire a reasonable understanding of the vernacular building systems in the state and the transformations taking place.

Finally, we also acknowledge The Ford Foundation for initiating a multi-state project for studying the traditional building systems and developing suitable building typologies based on these, which is also integrated with the scientific validation of the building practices and preparation of the guidelines.

Ahmedabad **Project Team**
February 28, 2011

Glossary

Word	Meaning
Bajri	A mix of medium to coarse sand and fine gravel.
Bearing Wall	Wall which carries the weight of the floors, roof, and walls above it.
Bonding element	A masonry element of any material used to stitch two wythes of stone wall.
Chid pine	A variety of pine tree
Collar Beam	A tie member that is installed across the opposite rafters as well as
Continuity of reinforcement	The lapped ends of two reinforcing bars in one line to be tied together in such a manner that the two separate bars act as a one continuous bar.
Damp-proof course	A layer of impervious material provided at the plinth level to stop the rise of pore water in to the superstructure.
Delamination	Sep**aration of one or both w**ythes of stone walls.
Fire retardant	A material that makes other material resistant to catching fire.
Four-way roofs	Four sided sloping roof
Half-dressed	Stone with only one face properly shaped
Hipped roof	Four sided sloping roof
Intermediate Beam	It spans from a gable to gable in order to provide intermediate support to the rafters.
Lateral forces of	Forces in horizontal direction caused by earthquake
Modern materials	Construction materials like steel and cement
MSK intensity scale	A scale to specify the intensity of earthquake based on the damage.
Pathal	Shale, Schischst or Slate stone available in slab form used for roofing.
Pier width	Width of wall between two consecutive openings, or the opening and a corner.
Pre-cast-concrete Pathal	Pre-cast concrete panels sized and shaped like stone which is used for roofing
Principal Rafter	Roof under-structure member that is commonly used to provide intermediate support to purlins.
Purlin	Roof under-structure member that spans from the one gable wall to the opposite gable wall or to a Principal Rafter
Rafters	Roof under-structure member that spans from ridge beam to the eave level wall.

Glossary

Word	Meaning
Random rubble masonry	Stones of different and irregular shape fitted over each other to create masonry.
Ringaal	Cane like grass that grows in the hills.
Roding	Compacting concrete by means of rods to eliminate air bubbles.
Seismic Band	A Reinforced Concrete or Reinforced Brick or Timber runner provided in the walls to tie them together, and to impart horizontal bending strength in them.
Seismic feature	A particular strengthening arrangement for reinforcing of masonry buildings to enhance resistance against seismic forces.
Seismic zone	An area with a specific seismic hazard level as classified in IS 1893:1984
Shear resisting capacity	The capacity of the wall to resist lateral force in its own plane.
Stabilization of mud	Mud mixed with some material that helps preserve its strength in presence of water or reduces engross of water into mud
Stonecrete Block	Concrete block with large stones surrounded by the matrix of concrete.
Through-Stone	Stone of length equal to the thickness of wall and placed across wall's thickness
Traditional construction	The construction system based primarily on locally available materials evolved by the people without input of engineers and architects.
Two-way roofs	Two sided sloping roof
Urad daal	A variety of lintle used mainly as a food item
Vulnerable	Building too weak to withstand forces of natural hazards
Wythe	Vertical Face (vertical layer) of stone wall

Abbreviations

Abbreviation	Full form	Abbreviation	Full form
lvl.	level	kg.	Kilogram
AC	Asbestos cement	km.	Kilometer
Approx.	Approximately	lbs.	pounds
BB	Burnt brick	liq.	liquid
BBCM	Burnt brick in cement mortar	m.	Meter
BBMM	Burnt brick in mud mortar	max.	Maximum
BIS	Bureau of Indian Standards	min.	Minimum, minute
Bldg.	Building	mm.	Millimeter
CB	Concrete Block	MPT	Mangalore Pattern tile
CBRI	Central Building Research Institute	MS	Mild steel
Cem.	cement	No., no., nos.	Number, Numbers
CGI	Corrugated Galvanized Iron	OPC	Ordinary Portland cement
CM	Cement Mortar	PC	Pre-cast concrete
cm.	Centimeter	PCRC	Pre-cast reinforced concrete
cu.	Cubic	PPC	Pozzolonic Portland cement
cum.	Cubic meter	PVC	Poly Vinyl Chloride
CWM	Chicken wire mesh	RB	Reinforced brick
dia.	Diameter	RC	Reinforced concrete
dist.	Distance	reinf.	Reinforcement
ea.	Each	rmt.	Running meter
eqk.	Earthquake	RR	Random rubble
fdn.	Foundation	sec.	Second
ft.	Foot, feet	sft.	Square foot
ga.	Gauge	smt.	Square meter
GI	Galvanized Iron	sq.	Square
gr.	Ground	ssm.	seismic
horz.	Horizontal	st.	storey
hr.	Hour	UCRC	Un-coursed rubble masonry in cement mortar
HSD	High Strength Deformed	UCRM	Un-coursed rubble masonry in mud mortar
ht.	Height	vert.	Vertical
in.	Inch	wt.	Weight
ltr.	liter	WWM	Welded wire mesh
		yds.	Yards

Contents

1. Introduction

1.1 Traditional building system of Uttarakhand

People have been constructing stone buildings for their house and other service needs for hundreds of years in the hill areas of Uttarakhand, since stone has been the most abundantly found building material. Not only have they been using the stone for walls, but also for roofing. Timber, being the second most abundantly found material in the area, has also been in use in combination with stone for roof construction. In other words, the construction system based primarily on these two materials has been the backbone of the traditional construction of the region.

1.2 Impact of recent earthquakes

In the decade of 1990's the state witnessed two destructive earthquakes. Both the earthquakes witnessed severe damage to many stone buildings. As a consequence, peoples' confidence in the traditional construction got badly shaken. This resulted in many house-owners switching over to modern cement, steel and brick based construction which many find expensive.

These guidelines will be helpful in designing earthquake resistant buildings with stone as the principal material in all parts of the State of Uttarakhand including those falling in the Seismic Zones IV and V.

2. Objectives

The main objective of this guidelines is to illustrate the earthquake resisting construction measures that should be adopted in the traditional stone construction practice in accordance with the Seismic Zoning map of Uttarakhand using the building construction standards adopted in India, namely IS: 4326: 1993, second revision BIS 2002 and IS: 13828 of 1993

According to the Seismic Zoning Map of Uttarakhand (Fig. 2.1) most areas of Uttarakhand state are situated in the following seismic zones.
Zone V: MSK intensity IX or higher earthquake is probable to occur.
Zone IV: MSK Intensity VIII earthquake is probable to occur.

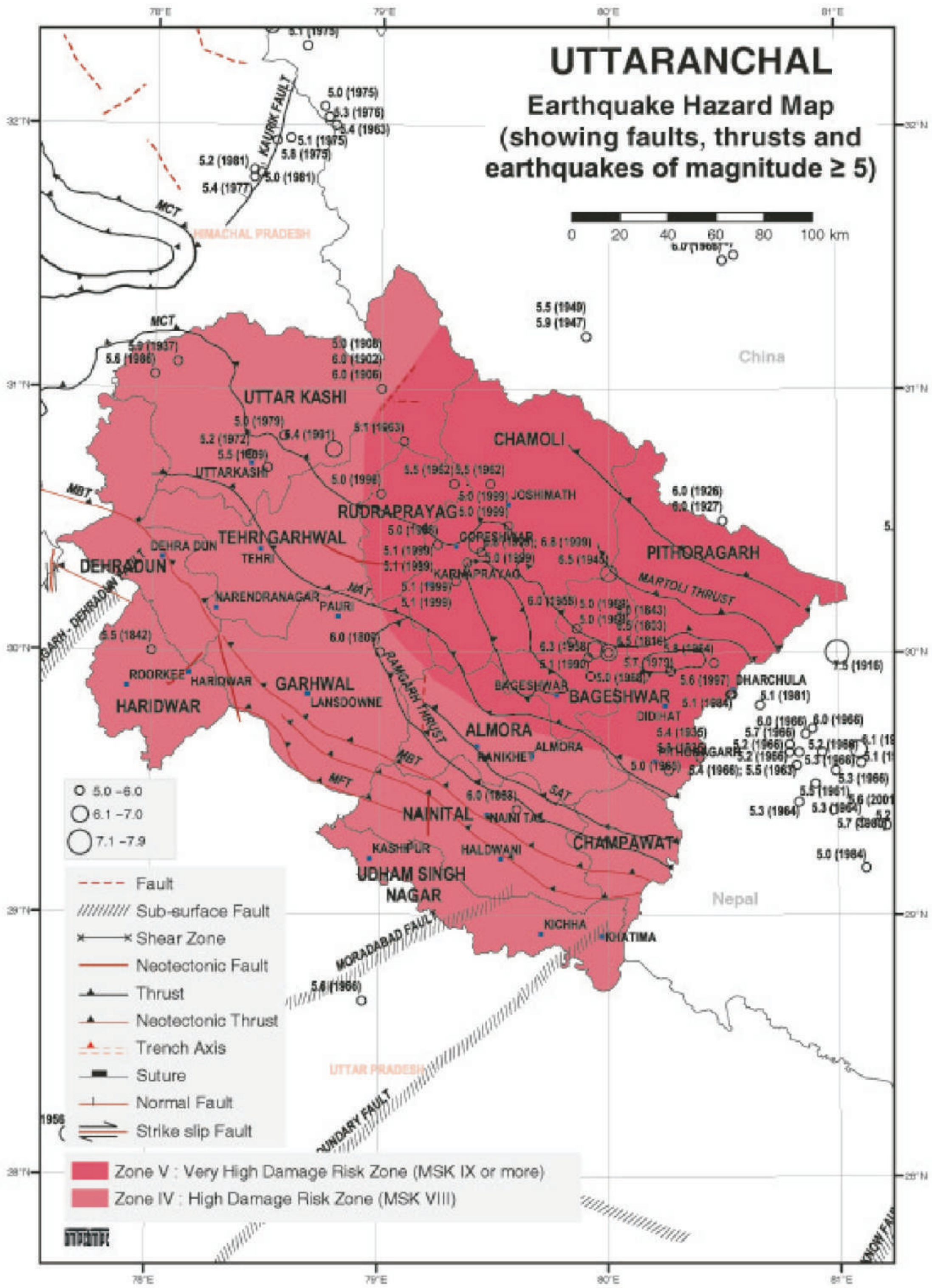
Other Hazards: In the plains, along the southern boundary of the state, as per the Wind Speed Zone map from the Vulnerability Atlas of Uttarakhand the wind speeds can reach high enough (47m/s) to bring moderate damage risk. In the hills this hazard is significantly less with maximum wind speeds of 39m/s.

Floods hazard can be present in isolated low spots, mainly due to flash flood phenomena or inundation due to inadequate drainage.

In the mountains, in areas where the hillside is unstable, the landslides also is a major hazards,

The recommendations contained herein are based on the abovementioned probable earthquake intensities for the design of buildings according to the codes. New construction of buildings will be safe if it would be in accordance with the specified intensities.

Figure 2.1 Seismic Zone Map of Uttarakhand**



BMTPC : Vulnerability Atlas - 2nd Edition; Peer Group, MoH&UPA; Map is Based on digitised data of SOI, GOI; Seismic Zones of India Map IS:1893 - 2002; Seismotectonic Atlas of India, GSI, GOI

Ref: Vulnerability Atlas of Uttarakhand, BMTPC.

3. Scope of the Guide

These guidelines cover the houses having load-bearing masonry walls of stone with pitched roof of *Pathal* having timber understructure and the intermediate timber floor, both resting on the walls in the hill regions of Uttarakhand State. Figures 3.1 and 3.2 show the important building components of a typical stone based construction. The recommendations cover the most likely hazards in the regions. The provisions for the earthquake resisting features are made for Seismic Intensities MSK greater than or equal to IX, and VIII as appropriate for the earthquake damage prone Zones V and IV respectively. Construction of walls using mud mortar as well as cement mortar is dealt with in this document. In any room the length of walls built in cement mortar shall be no greater than 7.0 meters and those built in mud mortar shall be no greater than 5.0 meters.

4. Options for Stone Walls

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

4.1. Types of Masonry used in different parts of Uttarakhand

Random rubble masonry

There are different types of Random Rubble masonry as shown below.

i. Partially dressed large stones along with small filler stones/chips and mud mortar

ii. Flat stones with small filler stones/chips and mud mortar

iii. Large undressed stones placed in the matrix of stone chips and mud mortar

The random rubble masonry is found in most parts of the hilly state. The local people report that the last of these three types has performed well in the past earthquake while the first had performed the poorest.

Dressed Stone Masonry with mud mortar or "*Dharia Munia*"

Dressed stone masonry or "*Dharia Munia*" with mud or Urad daal mortar: This is found in Munsiari – Dharchula area. It is a very high quality work that is laborious and time consuming. Every stone is 220mm wide, 150mm thick, and anywhere from 300mm to 900mm long. The walls are 450mm thick, thus making two wythes, each being 225mm wide.

This type of wall is known to perform very well in the earthquakes, and hence, buildings as old as 200 years are still found to be standing.

Partly dressed or "*Dharia Munia*" with no mortar: This option is also found in various areas of Kumoun. The stones are substantially dressed. Hence, the process is time consuming.

This type of wall is not as good as the fully dressed version.
But, its performance in earthquakes is far superior to the random rubble masonry.

Partly dressed Stone Masonry or "*Dharia Munia*" with no mortar

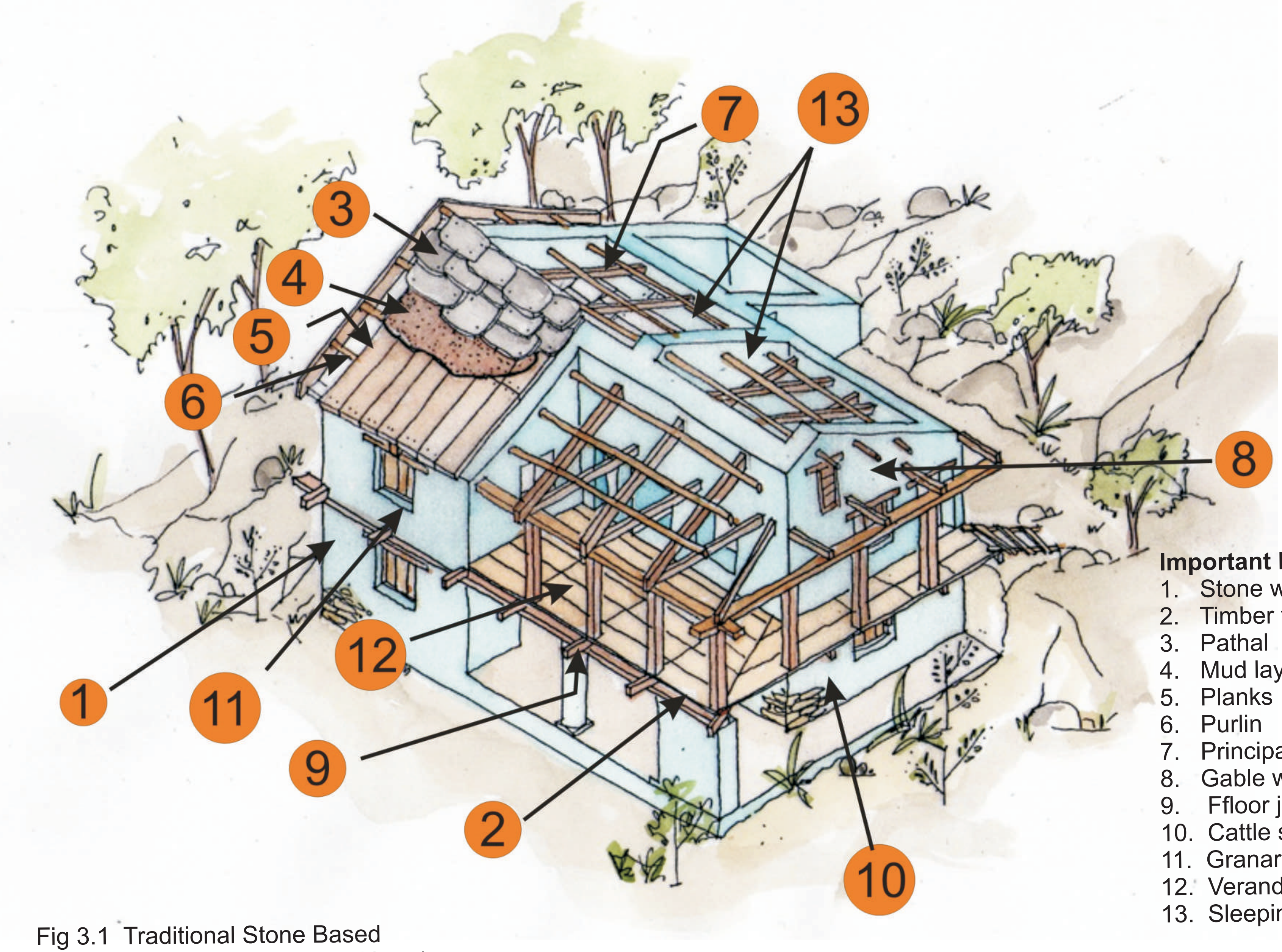
4.1.1 Wall Thickness

Although, most traditional walls are made 450mm (18") thick, it is not necessary to stick to this thickness. The thickness of random rubble walls could be safely reduced up to 375mm (15") without unduly sacrificing its strength. The insulation provided by these walls would be adequate to keep the cold out.

4.2 Alternatives for wall masonry

If procuring of construction quality, large size stone is difficult or if suitably skilled artisans to build good quality stone wall are hard to find, or if the house owner is keen to build thinner walls since they occupy less space, there are a number of alternatives including the brick masonry walls that have become quite popular in the state during the past decade and a half. In many areas concrete blocks are also being used, but on a smaller scale.

It should be noted that the seismic safety of the structure does not depend upon which material the walls are made of, such as stone or bricks or concrete blocks. The performance of a structure, however, depends primarily on the quality of construction carried out. If the cement mortar used in the masonry is not cured properly, or if it is used long after its initial setting, or if the vertical joints are not filled with the mortar then the wall could have high vulnerability. On the other hand, if in a random rubble wall stones are properly interlocked and if through-stones or the headers are used adequately, then the wall may perform well even in an earthquake.



Important Features
1. Stone wall
2. Timber floor
3. Pathal
4. Mud layer
5. Planks
6. Purlin
7. Principal Rafter
8. Gable wall
9. Ffloor joist
10. Cattle space
11. Granary
12. Verandah
13. Sleeping quarters

Fig 3.1 Traditional Stone Based Construction System of Uttarakhand

Important Features
1. Stone wall
2. Timber floor
3. Pathal
4. Mud layer
5. Planks
6. Purlin
7. Principal Rafter
8. Gable wall
9. Ffloor joist
10. Cattle space
11. Granary
12. Verandah
13. Sleeping quarters

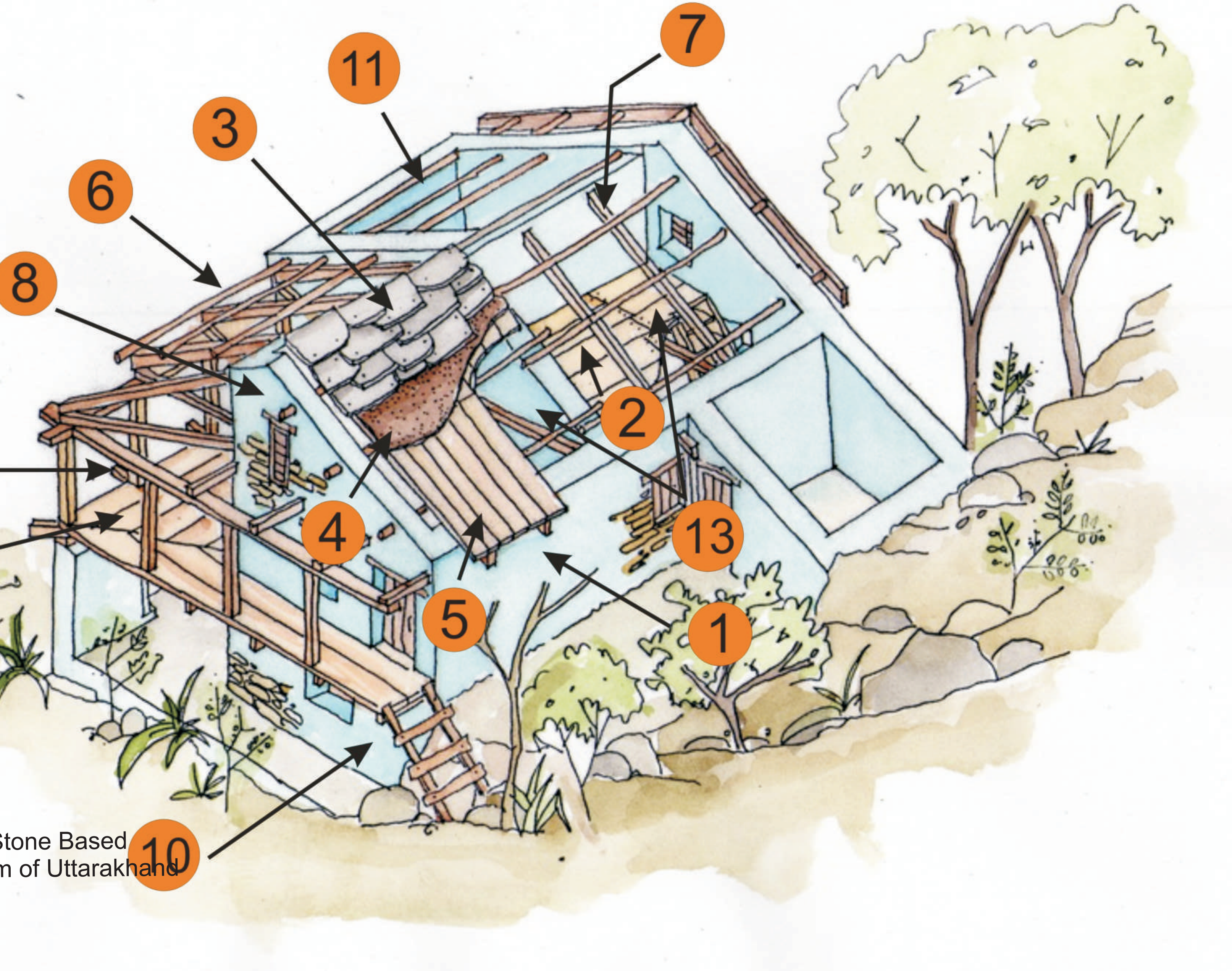


Fig 3.2 Traditional Stone Based Construction System of Uttarakhand

4.2.1 Stonecrete Blocks

There is good alternative that is significantly dependent upon the local materials instead of the bricks that are brought from long distance. It is also called "**Pre-cast Stone Block**". This option was developed by the Central Building Research Institute (CBRI) in Roorkee. The information on this is available from CBRI in its Building Research Note No. 7 titled "**Precast Stone Block Masonry**". This type of blocks are made by placing stones that are no bigger than 100 to 125mm in concrete. The use of stone results in to significant saving of concrete. Just like brick masonry, this option also allows fast construction. It is suitable where small stones are easily available. Larger stone too can be broken down to the required size for use in making these blocks. In comparison to the solid concrete block this option results into much saving in cement use since large stones replace significant amount of concrete.

Stonecrete Blocks are generally of 300x200x150 mm in size. As a result they produce walls that are 200mm thick. The stones can be fully encased in the concrete or they can be so placed as to be exposed on the long face. Such blocks with the exposed stone could be used to build wall that has the appearance of a stone wall if not plastered. In short, Stonecrete Block is made using moulds of appropriate size using cement, sand, aggregates and stone. It is generally viable where stones of 100 to 150mm size are easily available.

The blocks are used like solid concrete blocks to build masonry walls. In order to make sure that the structure built is hazard resistant, the quality of the blocks must be good, as recommended in the CBRI publication. All rules of hazard resistant construction must be adhered to and good quality must be ensured. In other words, attributes like the length, height, opening size, opening quantity, opening locations, number of storeys, RC bands, vertical reinforcements, encasement of openings, mortar mix etc. all should be done as per the rules applied to the rectangular building units in the latest edition of IS:4326.

4.2.2 Stonecrete walls and Cold Weather

It should be noted that for the cold region like Uttarakhand, the insulation quality of the wall is important. The 200mm and 225mm thick walls will have significantly lower insulation as compared to the thicker stone walls. In other words, the houses made of Stonecrete walls will not be as warm in winter as the houses with stone walls.

4.2.3 Economics of Stonecrete wall House

Stonecrete blocks affect the economics of any house in three ways. Since, the wall made from it is only 200mm thick, as against 450mm in case of stonewall, it affects the important parameters such as the required site area, roof area, built-up area and floor area as follows.

On a given site, a house built using Stonecrete block walls could have as much as approximately 25% more floor area.

For a house of a specific floor area, its built up area could be as much as 30% more in case of a stone wall house as compared to the Stonecrete block wall house.

For a house of a specific floor area, its roof area could be as much as 28% more in case of a stone wall house as compared to the Stonecrete block walls house.

Hence, if one wants the largest possible house on a given site, then the Stonecrete walls may be used. On the other hand, for a specific floor area if the decision is based on the construction cost, then the house owner will have to compare the cost of a house with stone walls against the one with Stonecrete walls.

In addition where stone is available cheaply stone wall would very likely be cheaper than brick wall. Similarly, where small stones needed for the Stonecrete blocks are available naturally, they would be cheaper than bricks carted from long distance. In other words in the hills the stone walls would cost ...% less than brick walls, and Stonecrete block wall would cost ... % less than brick walls. If one gets stone free of cost from ones own land, then the reduction is cost would be even greater.

5. Options for Roof and Floor

5.1 Pathal Roofs & Timber Floors

Pathal has been the **principal roofing material** in all hill areas since the stone (Shale, Slate, Phyllites or Schischst) suitable for *Pathal* has been available in plenty in most areas. As a result the local building artisans have been skilled in building *Pathal* roof.

After the earthquakes of 1991 and 1999 that witnessed much destruction and many deaths, peoples' confidence in the *Pathal* roof got shaken up. The post earthquake technical studies have revealed that roofs suffered damage and it collapsed primarily because of the absence of hazard resisting features in construction. The other reason was the dilapidated condition of many buildings in which the timber was in degraded condition.

6. Required Earthquake Safety Provisions for stone construction (Low Strength Masonry)

6.1 Building Categorization (As per IS:4326-1993 read with IS 1893-2002)

In accordance with the value of the design seismic coefficient, the Building Category may be taken as follows for selecting earthquake resistant features.

Table: 6.1

Building Categories		
	Zone IV	Zone V
Housing	D	E
Community buildings e.g. schools, hospitals and congregation halls	E	E

6.2 Measures for Achieving Seismic safety

6.2.1 For all Building Categories

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 Additional Measures for all building categories D 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 floor/roof is adopted:

(vi) Seismic band at ceiling level of floors or roofs consisting of joisted roofs or Jointed prefab elements.

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 (where such walls used).
(x) Bracing in roof structure of trussed as well as raftered roofs.
(xi) Vertical Steel bar at each corner and T junction of walls.

6.2.3 Additional measures for all buildings of Category E.
(xii) Seismic band or stiffeners or dowels at corners, and at T-junctions at window sill level.
(xiii) Vertical steel reinforcing bars at jambs of doors and large windows.
Note: The vertical reinforcement at jambs of small windows and ventilators (Approximately 600 mm x 600 mm, or less) may be omitted.

7. Siting & Foundations:

The land slide prone areas as determined by the geologist should be avoided for construction of buildings.

7.1 Siting

7.1.1 If the site is located on the hill slope, the stability analysis of the slope forming material may be carried out based on the following geotechnical/ geological parameters.

- Shear Strength of the slope forming material and bearing capacity of the proposed site.
- In case the slope is rocky then addition parameters need to be looked at as follows.
    - (I) Rock Mass Rating
    - (ii) Rock Quality Designation
    - (iii) Details of the joint sets (rock defects), additionally describing their mode of failure like i.e toppling, wedge, translational etc.

If the structure is an important public building i.e. School, Hospital, Government Building etc. the Geological / Geotechnical assessment is most essential and the assessment must be carried out by any experienced geologist.

7.1.2 In the absence of any analysis in case of a residence follow the simple thumb-rules.

- Construct building min. 1m away from the top of the slope.
  Construct building min. 1m away from the toe of the cut.
  When the building is located near a very steep cut slope on its down-hill side, construct retaining wall to support the slope to prevent a slope failure.

7.1.3 The Site must be located sufficiently away from the thrust/ fault as well as the rivers/ streams etc. if any one of these exists in the near vicinity of the proposed structures.

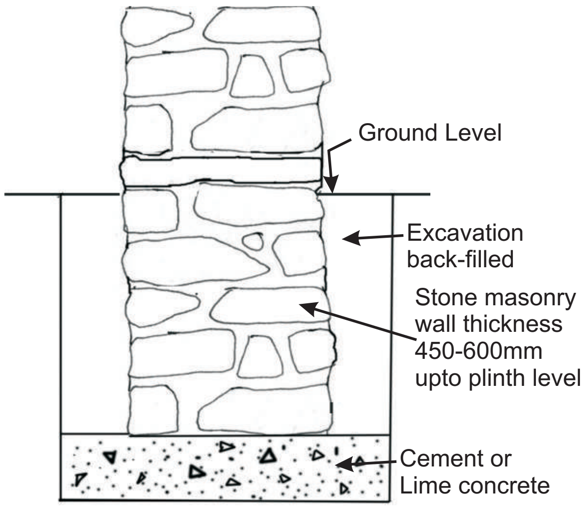
7.1.4 The hill slope above and below the site should preferably be covered with vegetation.

7.2 Foundations

7.2.1 Rocky Ground Site

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 storied 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.

Figure 7.1 Strip Foundation



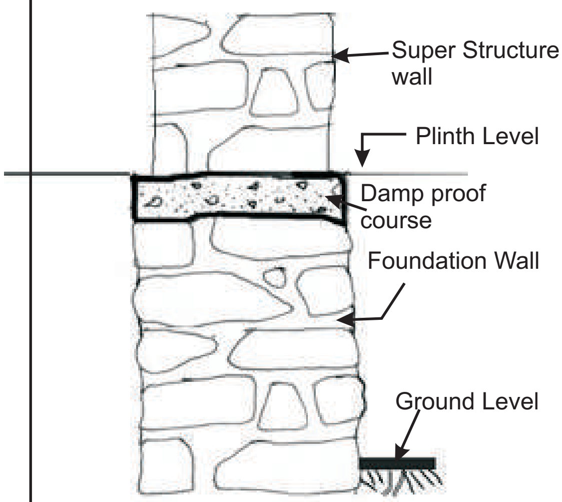
7. 2.2 Soil Site

Use stepped-strip foundation with minimum depth of 750 mm below ground level and width of 700 mm (up to 2 storied houses), Fig.7.1. For each additional storey, increase width by 300 mm. The footing masonry should be brought in steps up to the plinth level.

8. Treatment at plinth level

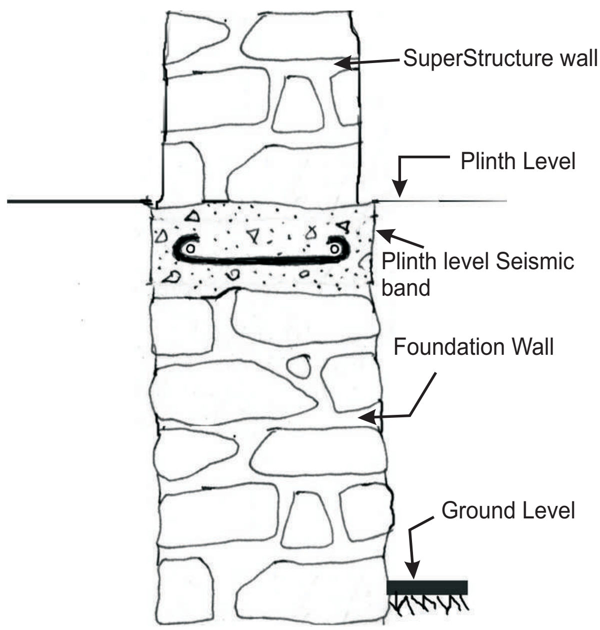
This will depend on site-soil condition as follows:

Fig 8.1.A Damp Proof Course at Plinth



a. Rocky Ground Site:The seismic band at plinth is not required. Use damp-proof course (DPC) 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.8.1.A).

Fig. 8.1.B RC Band at Plinth level

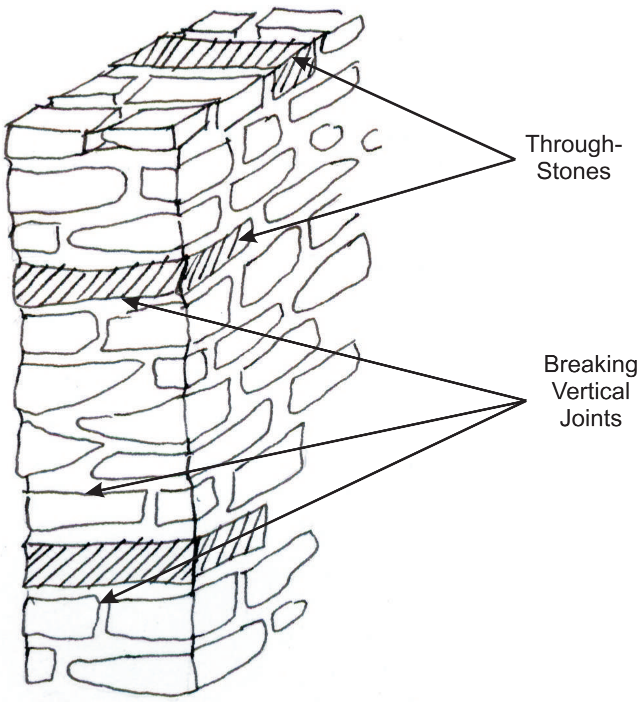


b. Boulder or Soil Site : In each case, use RC seismic band of 75 to 100mm thickness (See Fig.8.1.B) for detail of the band

9. Stone Masonry Walls Using Cement Mortar

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

Figure 9.1 Interlocking of Wythes



9.1 Construction Controls

9.1.1 Mortars Superstructure Masonry

Category D – Cement-Sand 1:6

Category E – Cement-Sand 1:4

Having Crushing strength minimum of 35 kg/cm2Foundation masonry up to plinth – Cement-Sand 1:6 in all categories Alternatively instead of cement-sand 1:6 and 1:4 mortars, cement-lime-sand mortar of 1:2:9 and 1:1:6 respectively or Cement-Soil-Sand 1:2:6 may be used.

9.1.2 The wall thickness 't' to be no less than 380 mm and no more than 450mm. The thickness of 380mm will give good insulation in the cold weather.

9.1.3 The inner and outer wythes are to be interlocked with each other through proper stone placement (Figure 9.1).

9.1.4 The masonry should preferably be brought to courses at lifts not greater than 600mm.

9.1.5 'Through-Stones' of length equal to the wall thickness should be used in every 600mm lift at horizontal spacing no greater than 1.2 m apart horizontally (Figure 9.2 A &B) If stones of such length are not available, then in place of one full length stone, the stones in pairs of about ¾ of the wall thickness may be used side by side so as to provide an overlap between them.

Figure 9.2.A – RR Wall - Plan View

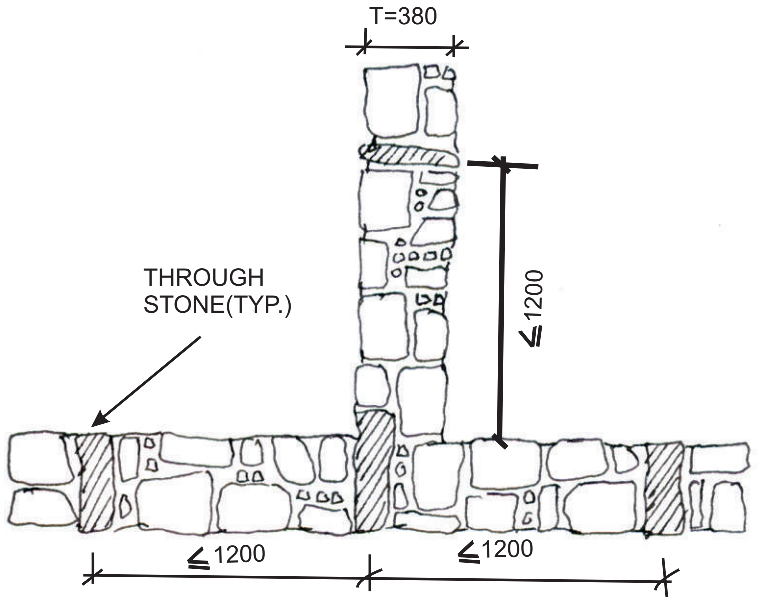


Figure 9.2.B – Vertical Section

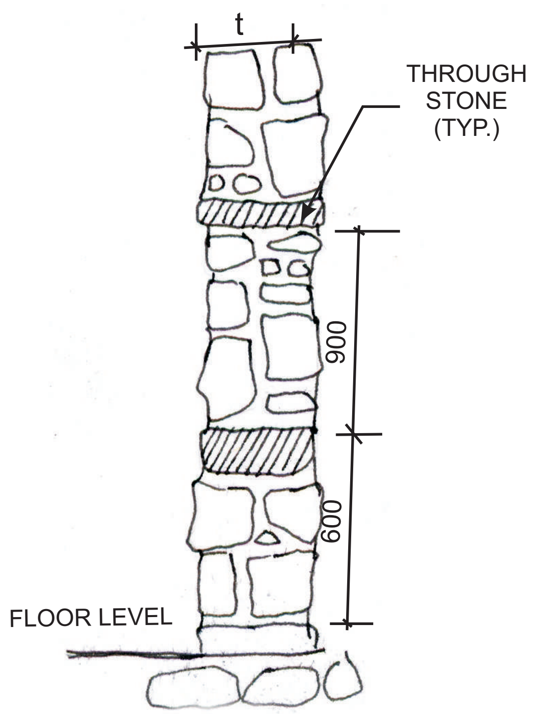


Figure 9.3.A – Pre-cast Concrete Through-Stone

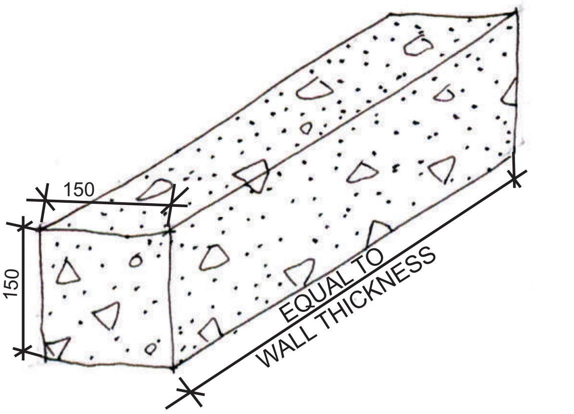


Figure 9.3.B – Pre-cast RC Through-Stone

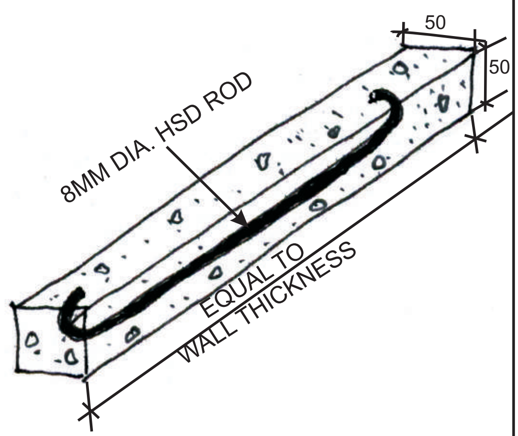
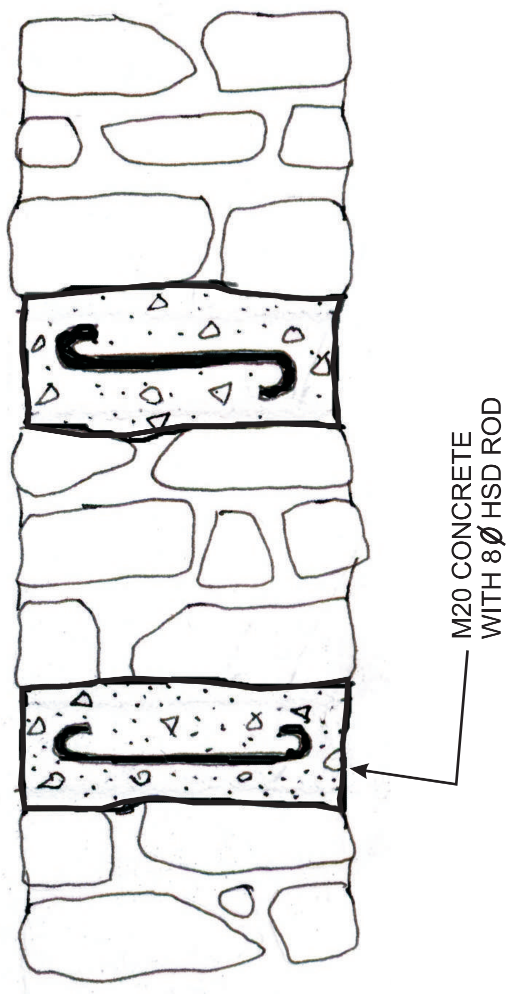
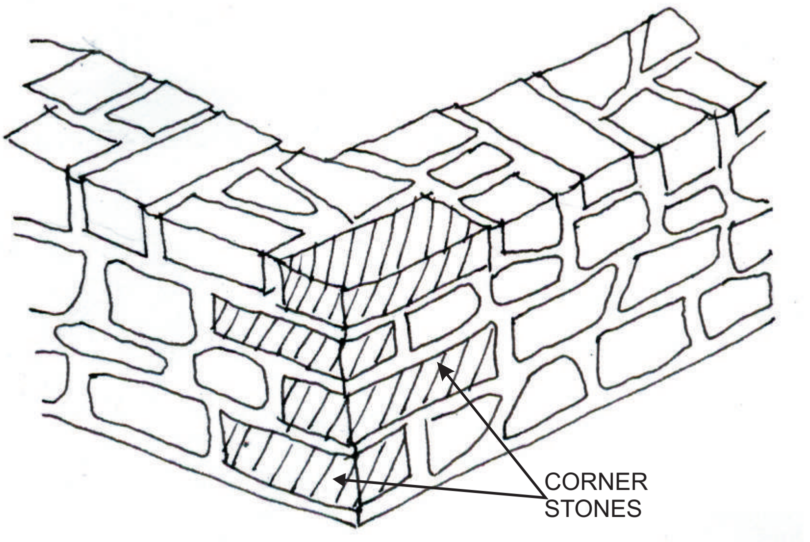


Figure 9.3.C Cast In-situ Through Stone



9.1.6 In place of 'Through-Stones', as the 'bonding elements' there are a number of options. These could be listed as under - The steel bars 8 to 10 mm dia. bent in to 'S'-shape or as links with hooks at both ends and encased in cement mortar may be used with a cover of 25mm from each face of the wall. Alternatively, pre-cast concrete elements of 50x50mm cross-section and reinforced with a 8mm dia. rod placed centrally may be used or solid concrete blocks of 150x150mm cross-section with length equal to the wall thickness may also be used in place of 'Through Stones' (Figure 9.3 A, B, C). Yet another alternative consists of pieces of Galvanized welded wire mesh that could be placed at intervals on top of each course of random rubble masonry.

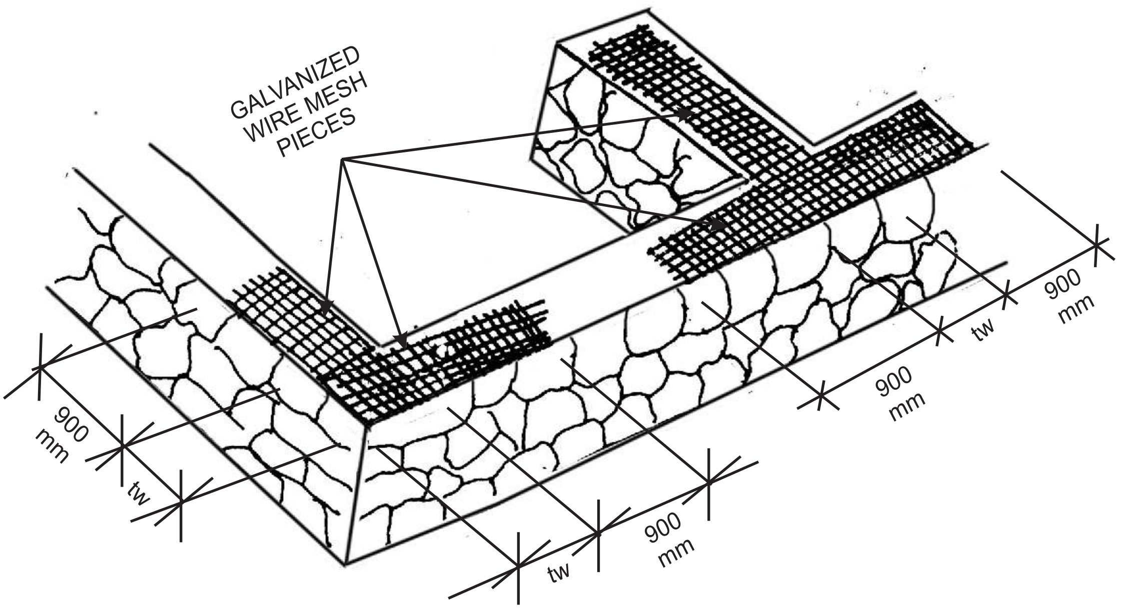
Figure 9.4. A "L" Corner Masonry



9.1.7 Stones of 600-700mm length should be used at "L" and "T" wall junctions. Alternatively use 150x150 solid concrete block bonding elements 500-600mm long to connect the perpendicular walls effectively as well as to break the joints (Figure 9.4 A).

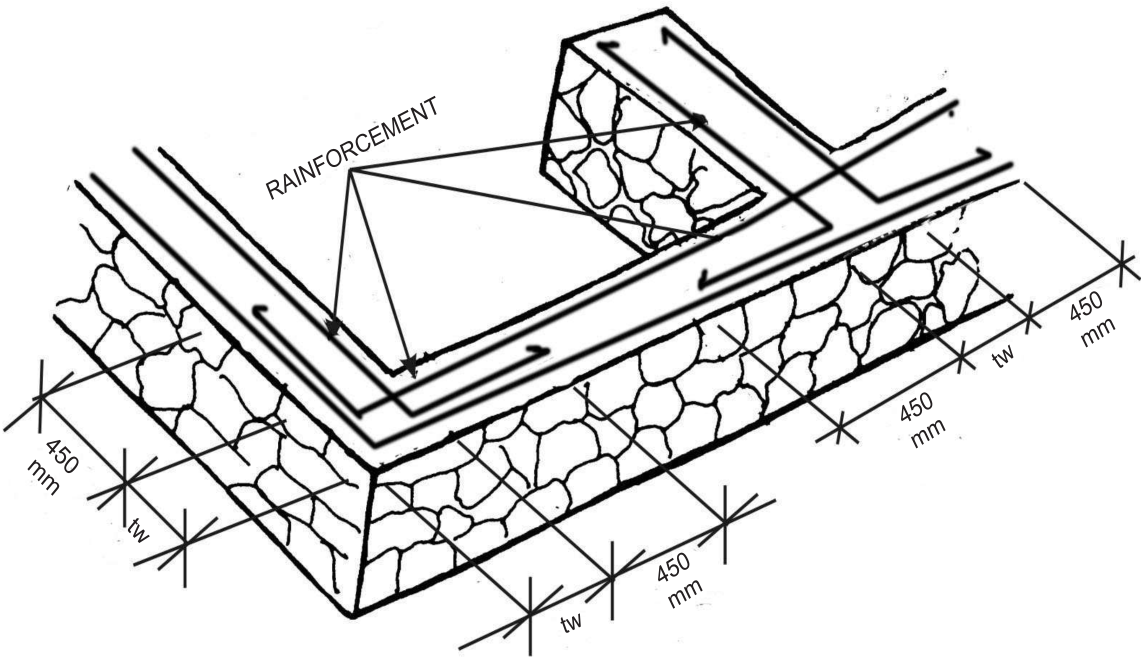
9.1.8 Corner stiffeners at sill level can be provided with pieces of galvanized welded mesh having width equal to that of the wall plus 900mm that could be placed in "L" and "T" formation at the wall junction (Figure 9.4 B).

Figure 9.4.B Steel bars stiffeners at "L" corners and T-junctions of walls.



Other option is to use steel reinforcement at corners and T-junctions of walls. Such bars may be in a form of U stirrups or in the configuration as shown in the Figure 9.4.C. The stirrups must be of 8mm dia. laid in 1:3 cement-sand mortar with a minimum cover of 10mm on all sides to minimize corrosion.

Figure 9.4.C Galvanized Wire mesh stiffeners at “L” corner and T junction of walls.



9.2 Control of No. of Storeys, Storey Height and Wall Length.

9.2.1 Height of the coursed-rubble masonry walls in cement mortar should be restricted as follows,

Figure 9.5.A – Height restrictions for pitched roof building

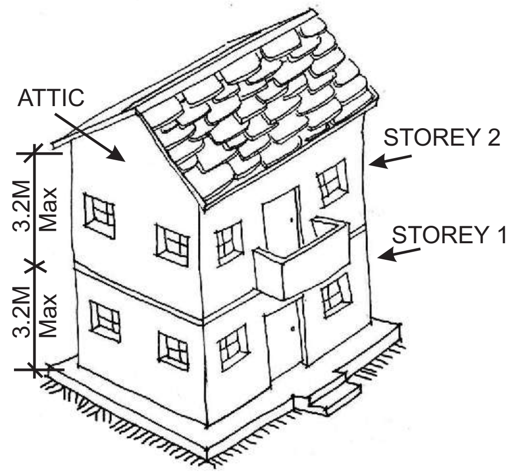
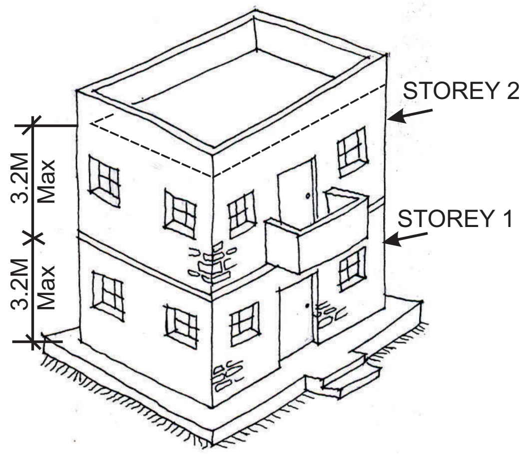


Figure 9.5.B – Height restrictions for flat roof building



Category D – With all the seismic features but without the corners and 'T' junction stiffeners at Sill level…

For Flat Roof - 2 storeys

For Pitched Roof - 2 storeys plus attic

With 'L' corner and 'T' junction stiffeners at Sill level …

For Flat Roof - 4 storeys

For Pitched Roof – 3 storey plus attic

Category E – With all the seismic features including the corners and 'T' junction stiffeners at Sill level…

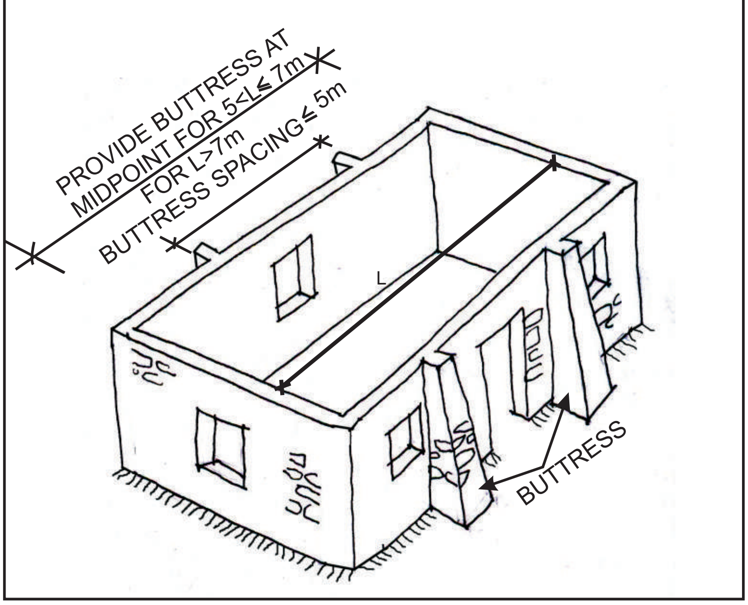
Flat Roof – 3 storeys and

Pitched Roof – 2 storey plus attic

Storey height – No greater than 3.2m (Figures 9.5 A & B)

9.2.2 Length of coursed – rubble masonry walls in cement mortar to be restricted as follows

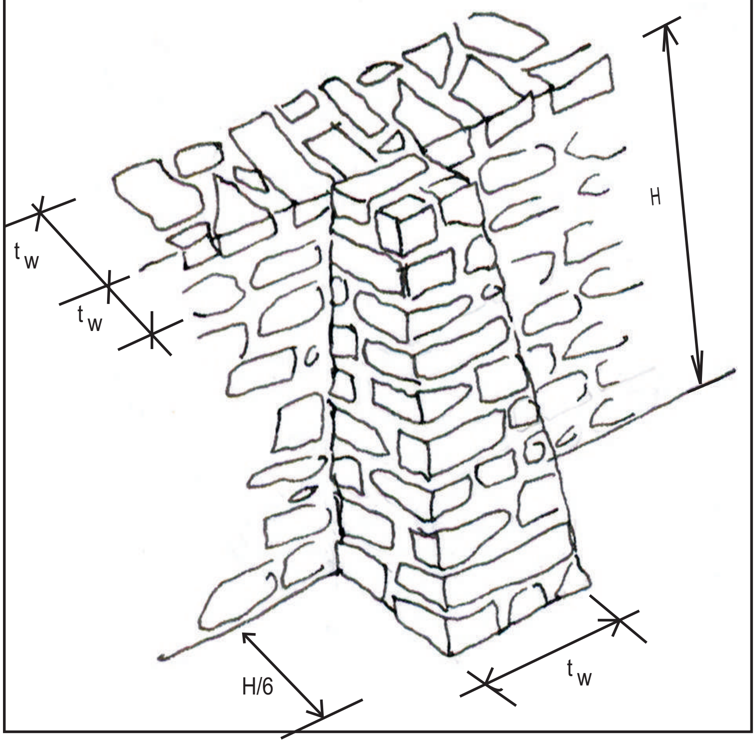
Figure 9.6.A – Rules for Max. Wall Length



If length of wall between two consecutive cross walls is > 5.0m but ≤ 7.0m then install one buttress at midpoint (Figure 9.6.A).

If > 7 m then install buttresses to the wall between the cross walls at intermediate points with spacing no greater than 5.0 m (Figure 9.6.A).

Figure 9.6.B – Buttress dimensions



Buttress size – The thickness to be maintained uniform from bottom to top; width at top to be equal to the thickness 't' of main wall, and width at the base to be equal to $1/6^{th}$ of wall height (Figure 9.6.B).

9.3 Control of Door Window Openings in Bearing Walls

9.3.1 Opening in any storey shall preferably have their top at the same level so that a continuous band could be provided over them in all the walls. The lintel forms a part of the band while passing over the openings.

9.3.2 The use of arch to span over an opening is a source of weakness and it better be avoided. Or else, steel tie should be provided across at the base of the arch.

9.3.3 Door and window openings in walls reduce the shear resisting capacity of the wall. Hence, to ensure adequate shear resisting capacity, the openings must be controlled. The openings size and position shall be as per guidelines below.

a. Ratio of total length of openings in a wall to length of the wall in a room should not exceed…

1-storeyed – 0.5

2-storeyed – 0.42 (Figure 9.7 & 9.8)

3 or 4 stored – 0.33

This is not dependent upon the type of roof, i.e. whether flat or pitched.

b. Distance of opening measured from inside corner – Shall be no less than or equal to 450mm.

c. Pier width between consecutive openings – No less than or equal to 560 mm.

Figure 9.7 – Opening rules for single storey building

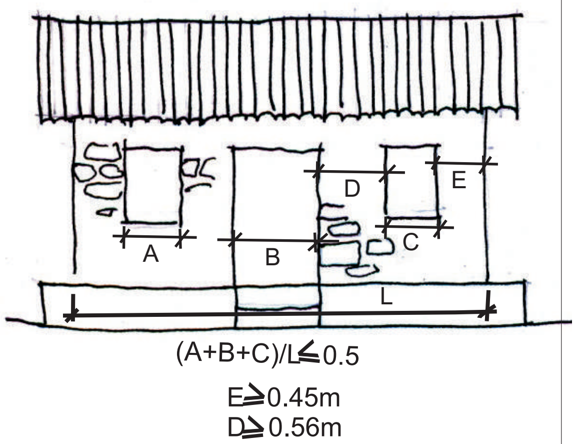
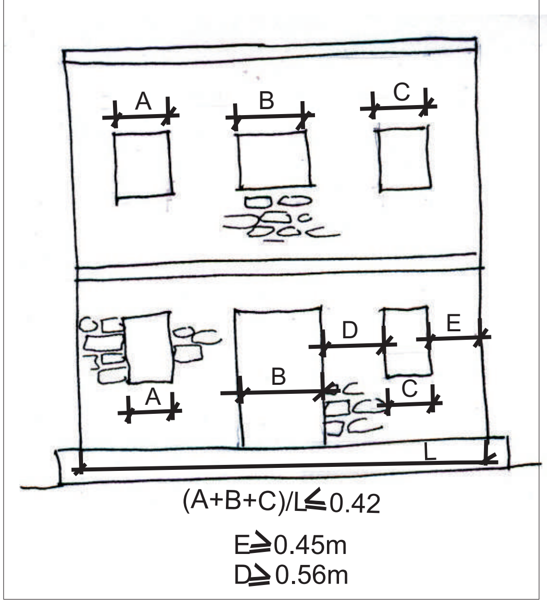


Figure 9.8 - Opening rules for double storey building



9.3.4 Where openings do not comply with the guidelines above, they should be strengthened by providing reinforced concrete lining as shown in Figure 9.22 with 2 HSD bars of 10mm dia.

9.4 Required Earthquake Safety Provisions: For Seismic Zones V and IV (MSK Intensity IX or higher, and VIII respectively) following safety provisions are specified.

9.4.1 Overall Seismic features arrangements: The principal strengthening arrangement of seismic reinforcing of masonry buildings consists of horizontal seismic bands of reinforcements at critical levels, vertical bars at corners and junction of walls, and encasement of openings

Figure 9.9 A - Band locations in pitched roof building

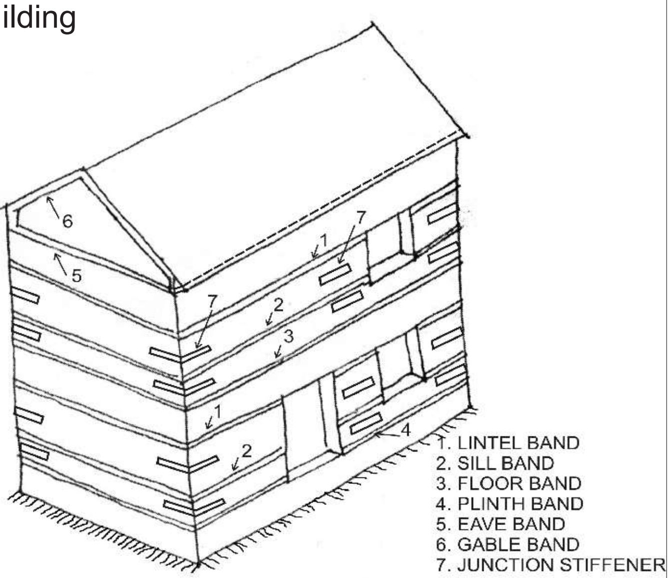
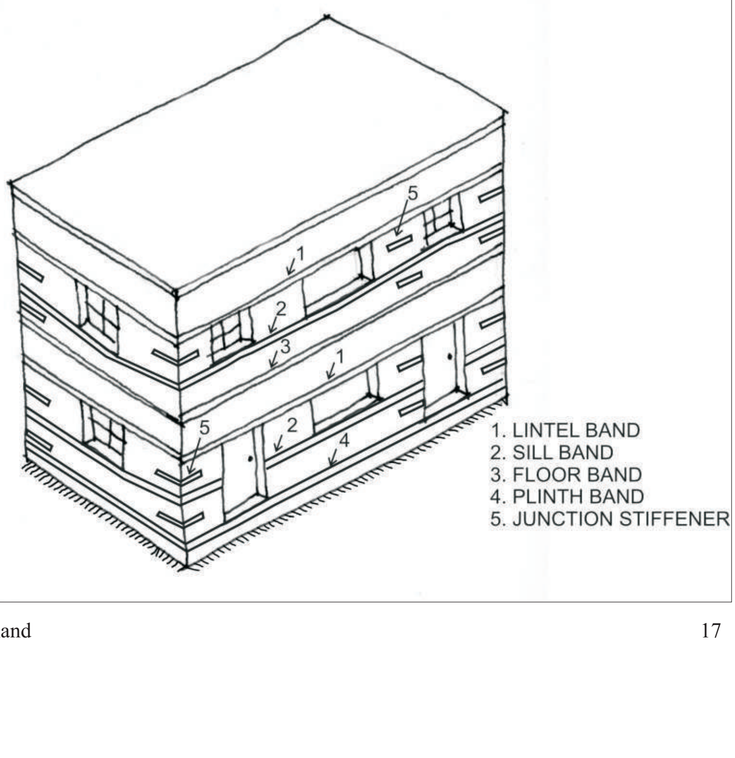


Figure 9.9 B - Band locations in flat roof building



9.5 Seismic Bands : Figures 9.9 A & B show the horizontal seismic bands of reinforcements at critical levels for buildings with flat roof and for buildings with sloping roof.

Seismic Bands shall be provided on all internal and external walls, and shall be uninterrupted at various levels as described below.

Plinth Band: It is provided at just below the Plinth level on top of masonry foundation wall that is resting on Strip Footing. It is strongly recommended where soils are soft or uneven as frequently happens in hilly tracts. This band serves as damp proof course as well.

Sill Band: It is provided at just below the window sill. It is needed in all buildings in Category E, but is optional in Category D buildings.

Lintle Band: It is provided at just above the Lintle level of doors and windows. If the gap between the lintel level and eave or floor level is 600mm (2') or less than this band can be avoided. In such a case the lintel is to be connected to the Eave or Floor level band immediately above it by extending the reinforcement of the lintel to the band (Figure 9.11).

Figure 9.10- RC Band reinforcement

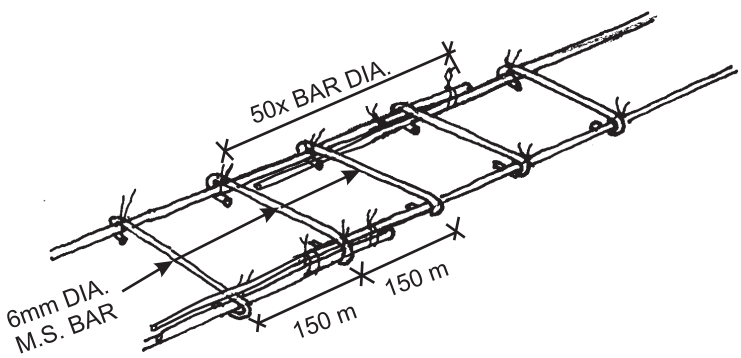
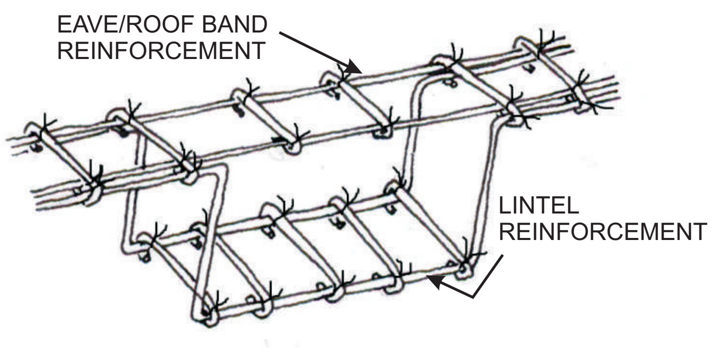


Figure 9.11 - Connection between reinforcement of lintel and lintel band



Eave Band: It is provided at just below the Eave/Roof level in case of roof other than RC or RB slab, or if the slab does not cover the support walls fully

Floor Band: It is provided at just below the Floor level in case of intermediate floor other than RC or RB slab, or if the slab does not cover the support walls fully

Gable Band: It is provided at Gable level along the sloping top of masonry Gable wall just below the purlins. It must be integrally connected to the Eave Band.

The details of the band are given below.

The band width should fully cover the thickness of the wall, and its depth shall be no less than 75mm.

The band should be made of RC of the grade not leaner than M20 (1:1$^{1/2}$:3).

Requirement of reinforcing bars in RC bands are given in the Table below.

All longitudinal bars may be welded or suitably lapped for continuity.

The bars must be held in position by 6mm dia. bar cross-links, installed at 150mm apart as shown in Figure 9.10. Alternatively, 8mm dia. bar cross-links may be used at 300mm apart.

Length of wall in room (m)	Reinforcing bars by Building Categories.			
	Category D		Category E	
	No.	Dia. (mm)	No.	Dia. (mm)
Less than or equal to 5m	2	8	2	10
More than 5m and less than 6m	2	10	2	12
More than 6m and less than 7m	2	12	4	10

All bars must be High strength Deformed (HSD) bars. But 6mm cross-links will be MS.

Ref. : "Earthquake resistant reconstruction and new construction of masonry buildings in Jammu and Kashmir State." Published by National Disaster management division, ministry of Home Affairs, Government of India, 2005

In case of sloping roofs, triangular gable masonry walls must be enclosed within eave level band and a band at the top of the gable wall. The Gable Band must be integrally connected to Eave Band (Figure 9.12).

For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands, continuity of reinforcement is essential. The details as shown in the Figures 9.13 & 9.14 are recommended.

Figure 9.12 Eave band to Gable band reinforcement connection

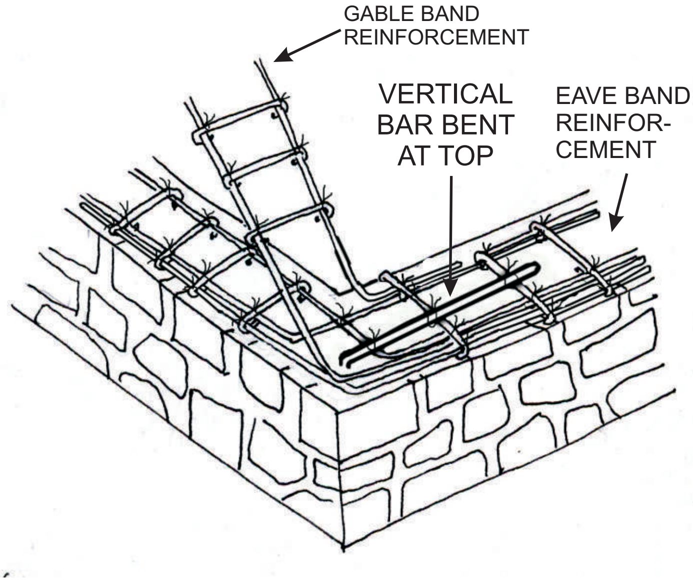


Figure 9.13 – "L" corner band reinforcement arrangement