Technical Guidelines & Information for Stone Construction In Uttarakhand

DMMC

Disaster Mitigation and Management Centre, Dehradun,
(An Autonomous Institute of the Department of Disaster Management, Government of Uttarakhand)

This Document was prepared under the project –

Preparing for Disasters: Taking Traditional Building Practices Forward
Formulation of Technical Guidelines for Gujarat (Earth), Bihar (Bamboo) and Uttarakhand (Stone)

Project Holder - **Sahjeevan/Hunnarshala**
Funded by - **Ford Foundation**

Technical Guidelines & Information for
Stone Construction In Uttarakhand

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

Published By:
Disaster Mitigation and Management Centre
Department of Disaster Management
Government of Uttarakhand, Uttarakhand Secretariat
Rajpur Road, Dehradun - 248 001, Uttarakhand (India)
web : www.dmmc.uk.gov.in
http://www.facebook.com/pages/Disaster-Mitigation-and-Management-Centre--DMMC/220760361309448DMMC/220760361309448

Technical Guidelines & Information for Stone Construction in Uttarakhand

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 Eqk. Engineering, IIT, Roorkee	Member
Shri Rajendra Desai, Hon. Jt. Director, NCPDP, Ahmedabad	Member
ShriPawan 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 Eqk Engineering, IIT, Roorkee	Member
Dr. Girish Joshi, Senior Executive, DMMC, Dehradun	Member/Secretary

Project Team:

Rajendra Desai,
Structural Engineer NCPDP, Ahmedabad
Rupal Desai,
Architect, NCPDP, Ahmedabad
Pawan Jain,
Architect. Dehradun
R.K.Mukerji,
Geologist,TARN, Dehradun
Harshad Talpada,
Civil engineer, NCPDP. Ahmedabad

Disaster Mitigation and Management Centre, Dehradun,
(An Autonomous Institute of the Department of Disaster Management, Government of Uttarakhand)

Om Prakash, IAS
Principal Secretary

उत्तराखण्ड शासन

Government of Uttarakhand

Department of Disaster Management & Rehabilitation
Dehradun

FOREWORD

Uttarakhand is predominantly a mountainous state with significant forest cover. Wood and stone have therefore been the most common building materials and these are abundantly used for both walling and roofing. The State thus has an excellent tradition of wood and stone construction. This construction practice reflects the strength of the local community to house itself independent of any outside help and has taken the shape of the cultural heritage of the region.

Both Uttarkashi and of Chamoli earthquakes however inflicted severe damage to the traditional houses. Even though the post - earthquake technical studies revealed that the random rubble walls suffered damage primarily because of wrong construction methodology rather than inherent flaws in the traditional construction practices, the damage inflicted by the earthquakes shook peoples' confidence in the random rubble construction technology. This together with increasing restrictions on the availability of wood and stone, led to proliferation of new construction material without adequate transfer of technological know-how regarding the same. This has added to the seismic vulnerability of the building stock in the region.

It is however vitally important to note that the building material is no bar for constructing earthquake safe houses and adequately safe houses can well be constructed using wood and stone that are still cost effectively available in the remote areas. In view of the ground realities stated above it becomes important to communicate positive aspects of wood – stone houses to the masses and make available technical aspects that facilitate better seismic performance of these houses.

In order to educate and guide those involved in the construction of houses with the stone, the Disaster Mitigation and Management Centre (DMMC) of the Department of Disaster Management in collaboration with National Centre for Peoples' Action in Disaster Preparedness (NCPDP) has prepared a guideline that could show them how to build an earthquake resistant, long lasting house using the raw material available with them. This is envisaged to be useful to those wishing to demolish and rebuild their old unsafe stone house and also those in the faraway places where construction with bricks is not cost effective.

I suggest that the architects and engineers working in the State familiarize themselves with these guidelines so as to guide their clients as also the masons as this would help build their confidence in the traditional ways of house building.

I must add that when the whole world is worried about climate change and is looking for greener construction options, the random rubble masonry walls and Pathal roof could provide a green option to build hazard resistant long lasting houses.

23th January, 2013

Om Prakash

(Om Prakash)

Uttarakhand Secretariat
Dehradun

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
December, 2012

Acknowledgement

First and foremost we acknowledge the support that we received from Disaster Mitigation and Management 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, Ex. Prof. Emeritus, IISC,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, Ex. Principal Seismic Advisor to Ministry of Home, Government of India, and Prof. D.K.Paul, Department of Earthquake Engineering, IIT, Roorkee 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.

We graciously acknowledge The Ford Foundation for supporting 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. Finally, we acknowledge the principal role of Kutchh Navnirman Abhiyan, Hunnarshala-Bhuj and People in Centre-Ahmedababad in conceiving and initiating this project and in extending strong support in its undertaking, without which it would not have materialized.

Ahmedabad **Project Team**

December, 2012

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	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 earthquake	Forces in horizontal direction caused by earthquake
Modern materials	Construction materials like steel and cement
MSK intensity scale	Twelve-step scale to specify the intensity of earthquake based on human perceptions, structural damage & geo-technical effects observed in an earthquake.
Pathal	Shale, Schischst or Slate stone available in slab form used for roofing.
Pier width	Width of wall between two consecutive openings, or opening & 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 lentil used mainly as a food item
Vulnerable Building	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

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 they have 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. Incidentally, in the present day context of climate change and global warming, it must be noted that the traditional building system of Uttarakhand is a green technology, and the State has a huge potential of earning carbon credits through the use of this technology.

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.

1.3 Natural Hazards

According to the Seismic Zoning Map of Uttarakhand (Fig. 2.1) most areas of Uttarakhand state are situated in the following seismic zones with **seismic hazard** as shown - 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 **wind 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.

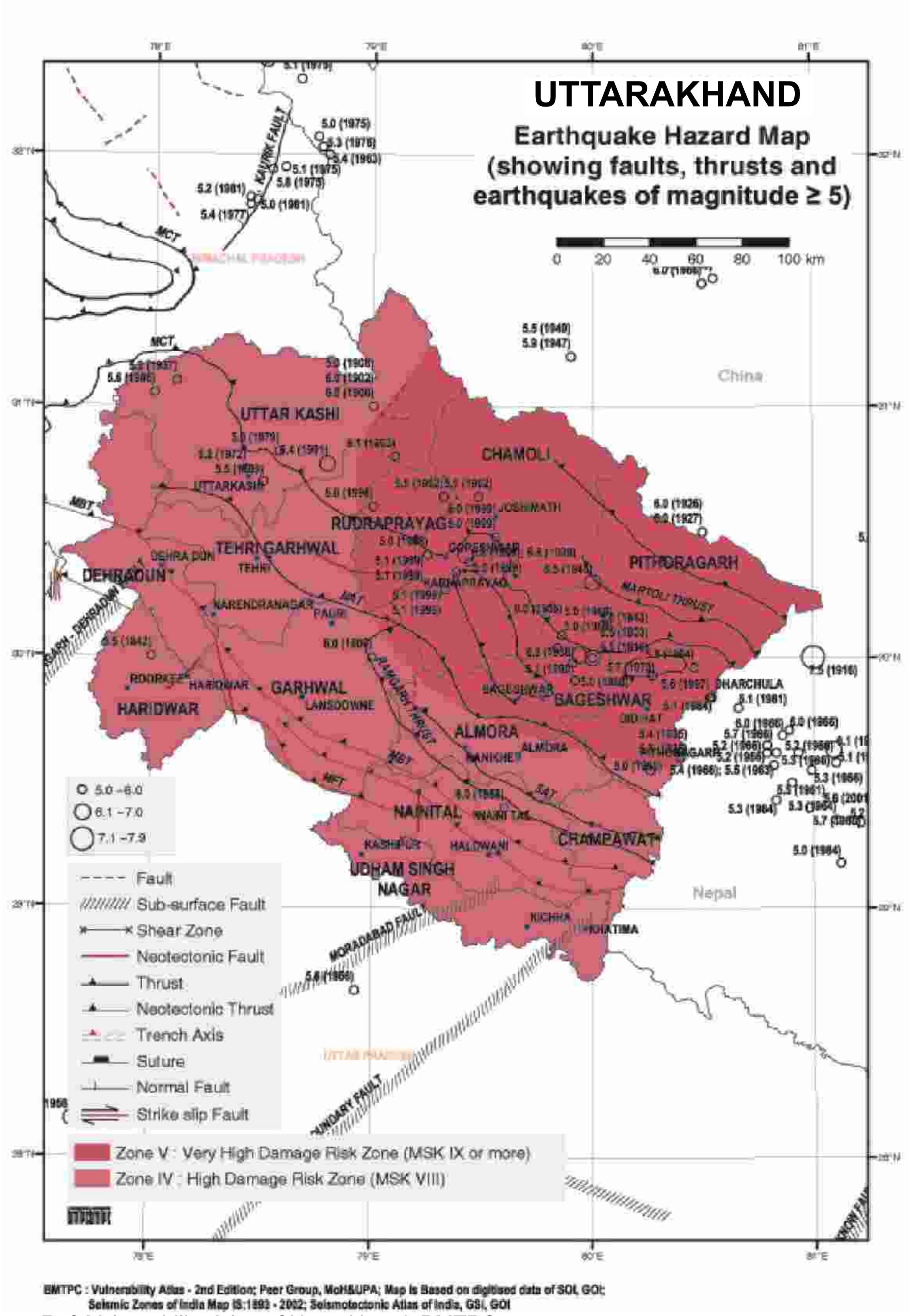
In the mountains, in areas with unstable hillside, the **landslide hazard** is also major.

2. Objectives

The main objective is to suggest the earthquake resisting construction measures that should be adopted in the traditional stone construction practice in accordance with the Seismic Zoning map of Uttarakhand based on a detailed survey of the traditional stone masonry building construction practices and in compliance with the Indian Codal Practices (IS: 4326: 1993, second revision BIS 2002 and IS: 13828 of 1993).

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**



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. 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 Zones V and IV respectively. Construction of walls using mud mortar as well as cement mortar is dealt with in this document.

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

There are a number of different types of stone masonry. They could be categorised in the following main groups.

- **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 in mud mortar

ii. Flat stones with small filler stones/chips placed in mud mortar or dry. At times the stones are very thin.

iii.Large undressed stones placed in the matrix of stone chips in 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 having undressed stones in matrix of stone chips has performed well in the past earthquakes while the first type having partially dressed stones along with small filler stones had performed the poorest.

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

- **Dressed stone masonry or "*Dharia Munia"* in 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 length and thickness

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.

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 procurement 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 performance of the structure depends not only on the material the walls are made of, such as stone or bricks or concrete blocks, but also on the quality of construction. 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.

4.2.1 Stonecrete Blocks

There is a 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 thick walls will have significantly lower insulation as compared to the thicker stone walls. In short, **the houses made of Stonecrete walls will not be as warm in winter as the houses with stone walls unless the outer walls are 300mm thick.**

4.2.3 Economics of Stonecrete wall House

Stonecrete blocks affect the economics of any house in three ways. Since, people are building 200mm thick walls, as against 450mm in case of stonewall, it affects its important parameters such as roof area, built-up area and floor area. and the site area required.

- A house built using Stonecrete block could have as much as 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. Based on Schedule of Rates for the planes, stone is 55% more expensive than bricks while in hills it is only 8% more expensive. But when stone is found one's own site, then this changes much in hills. In the hills stonecrete block could cost 85% of stone masonry and 93% of brick masonry. If, however, stones found on site are used then it could be still cheaper. Cost for various options dramatically change in the hills because of wide differences in access. If, instead of cement mortar if mud mortar is used the cost of stone masonry would drop drastically and be cheaper than bricks. With 300mm thick walls, which is desirable, these numbers will change significantly.

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 Schist) 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 eave 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.

7.1.5 Building construction must be avoided in the land-slide prone hill-side. Signs of small slips of the upper strata often give away the presence of this danger.

7.2 Foundations

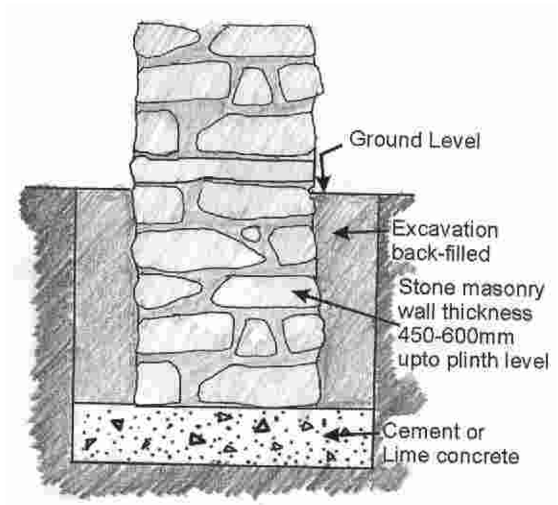
7.2.1 Rocky Ground Site

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.

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.

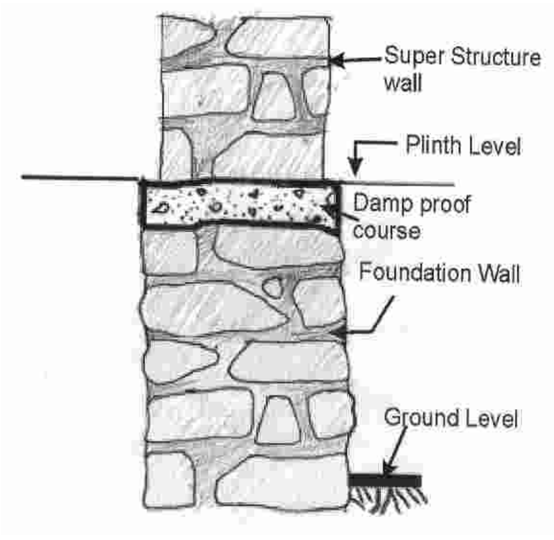
Figure 7.1 Strip Foundation



8. Treatment at plinth level

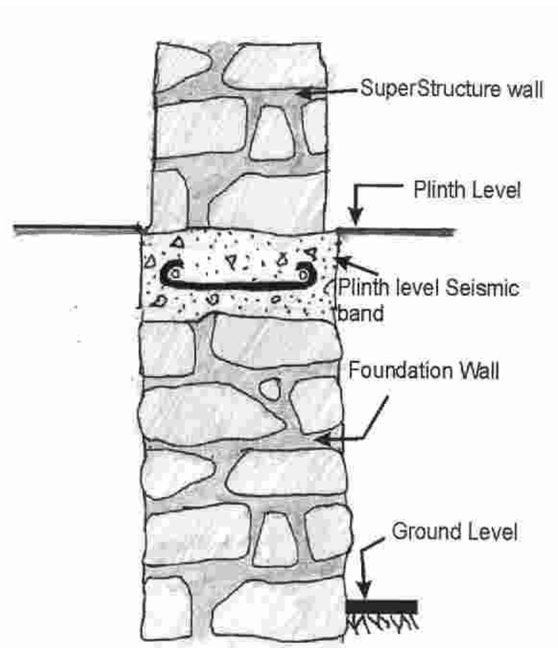
This will depend on site-soil condition as follows:

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

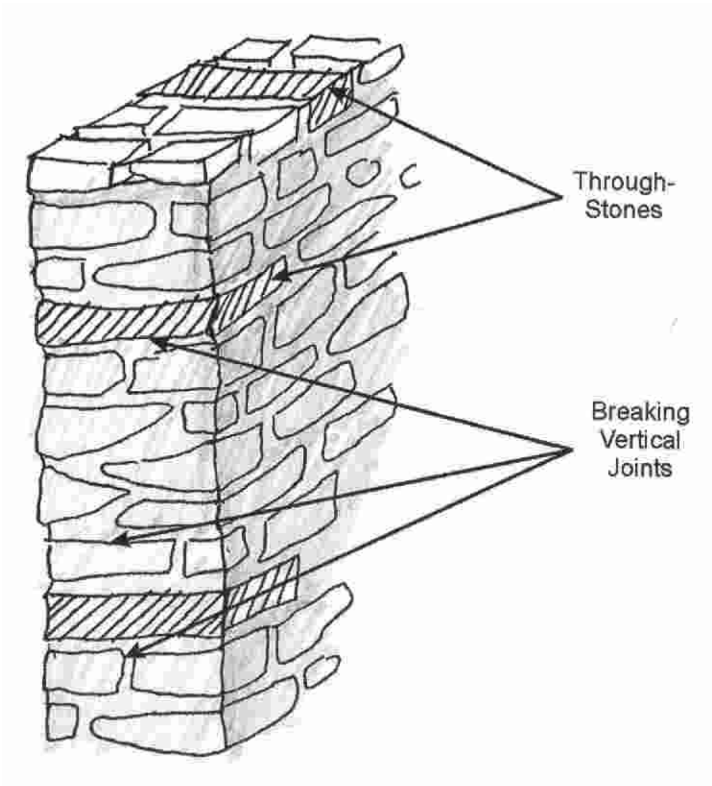


b. Boulder or Soil Site : In each case, use RC seismic band of 75 to 100mm thickness (See Fig.8.1.B) for detail of the band

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

Foundation masonry up to plinth having minimum crushing strength of 35 kg/cm^2.- 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 by breaking of joints and with the help of through-stones (Figure 9.1).

9.1.4 The masonry should preferably be laid in 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 not 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

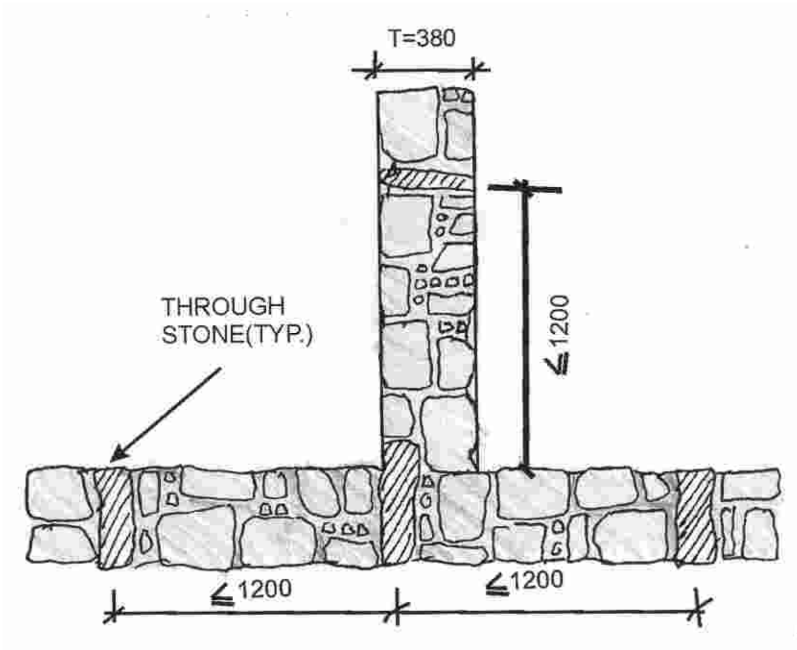


Figure 9.2.B – Vertical Section

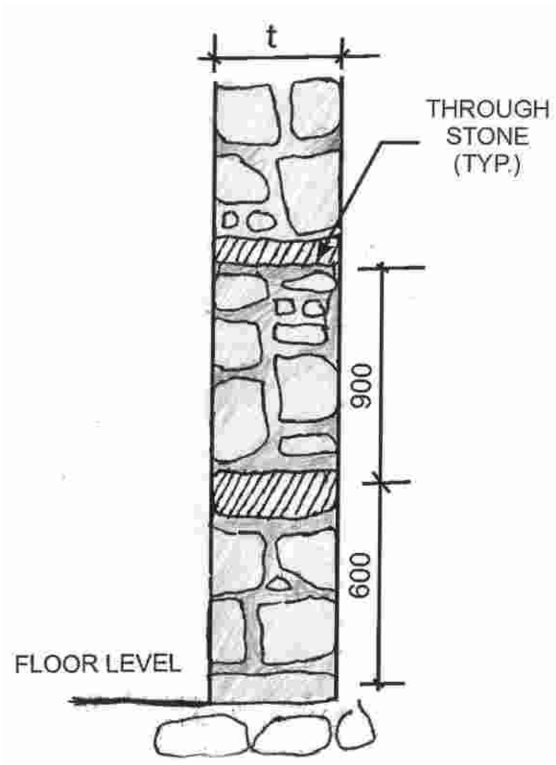


Figure 9.3.A – Pre-cast Concrete Through-block

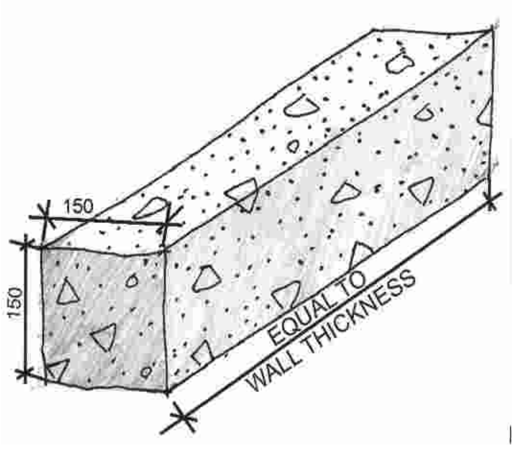


Figure 9.3.B – Pre-cast RC Through-block

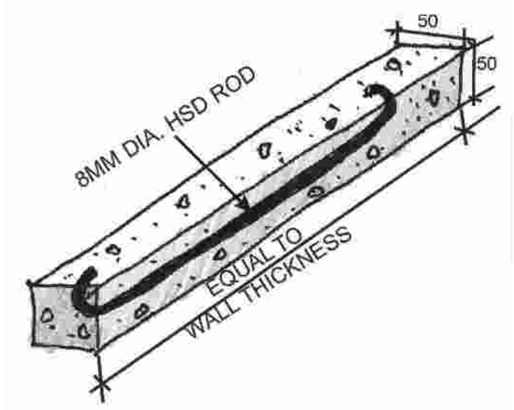
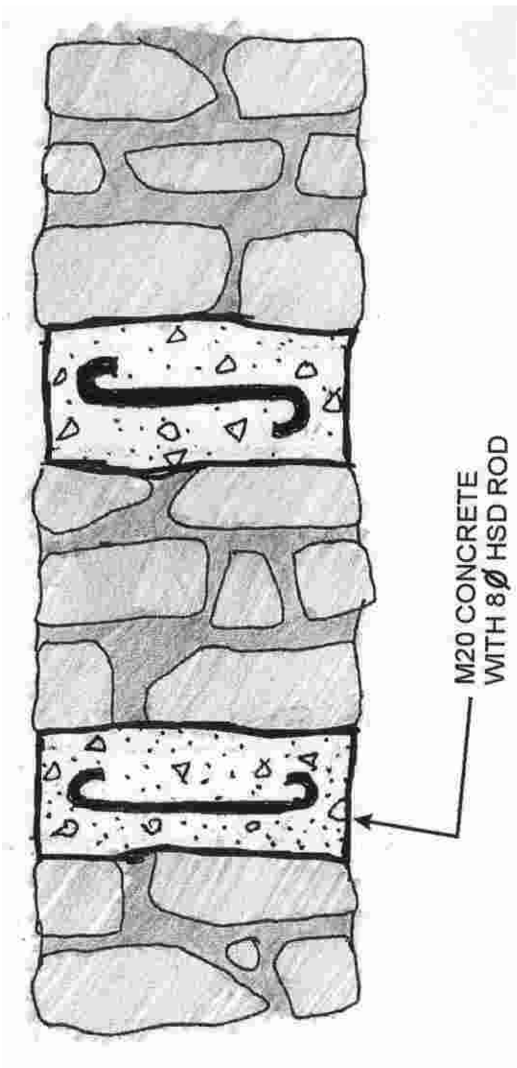


Figure 9.3.C Cast In-situ Through-block



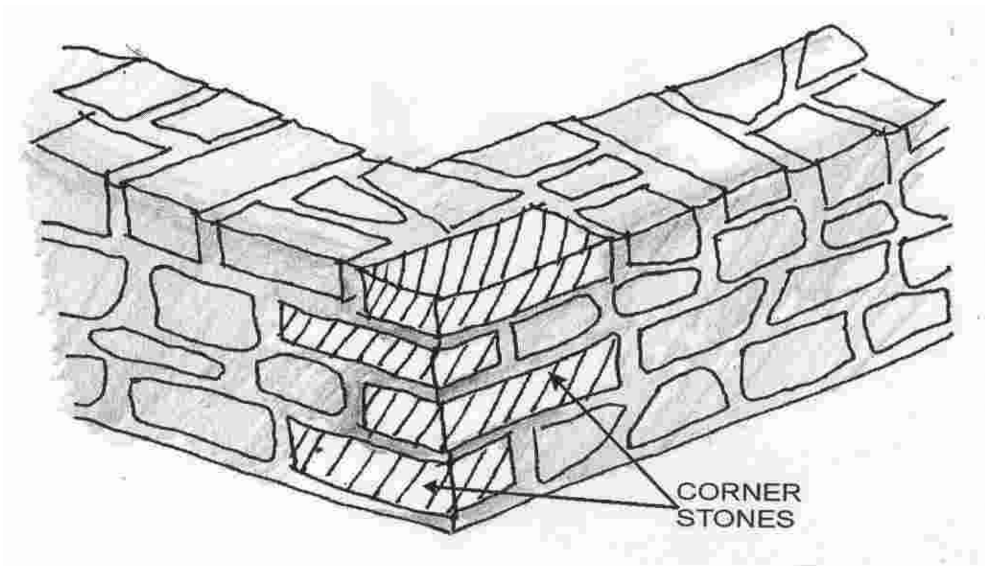
9.1.6 In place of 'Through-Stones', as the 'bonding elements' there are a number of options. These could be listed as under -

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.

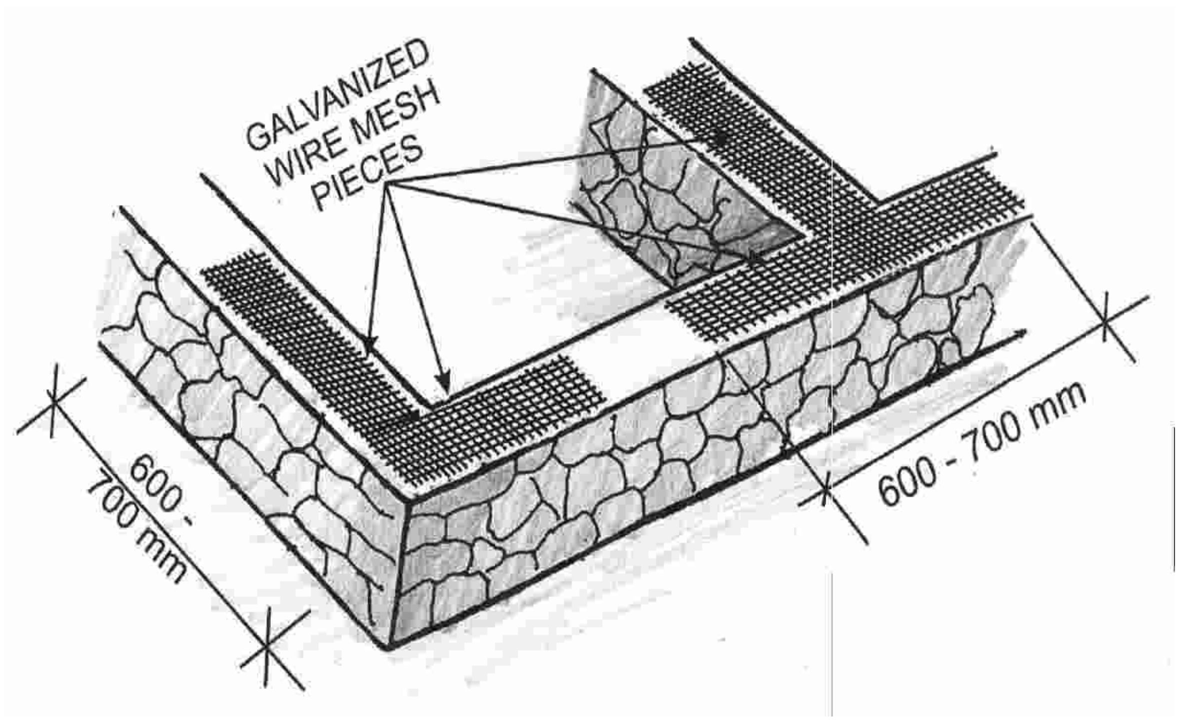
9.1.7 Stones of 600-700mm length should be used at "L" and "T" wall junctions. Alternatively use 150x150 solid concrete block 500-600mm long may be used to connect the perpendicular walls effectively as well as to break the joints (Figure 9.4 A).

Figure 9.4. A "L" Corner Masonry



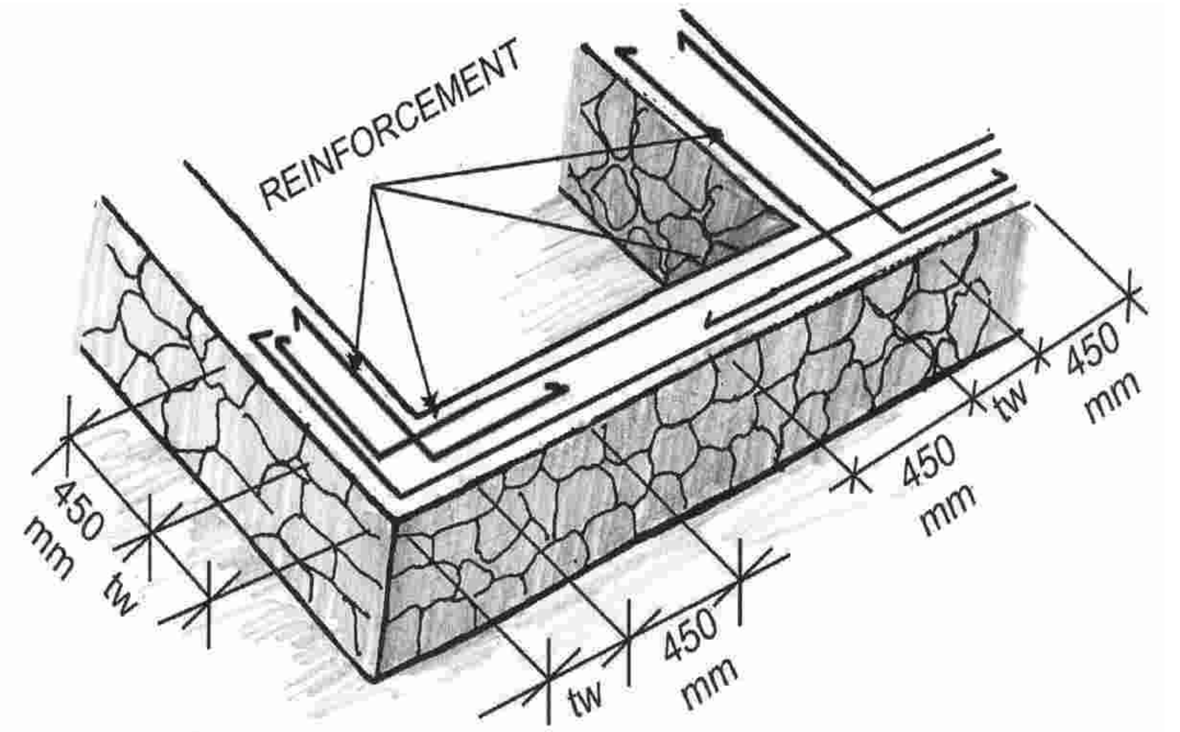
9.1.8 **Corner (Junction) Stiffeners** at sill level can be provided with pieces of galvanized welded mesh having width equal to that of the wall plus 900mm that could be placed in "L" and "T" formation at the wall junction (Figure 9.4 B).

Figure 9.4.B Galvanized Wire mesh stiffeners at "L" corner and T junction of walls.



Other option for **Corner (Junction) Stiffene**r 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 Steel bars stiffeners at “L” corners and T-junctions of walls.



Stone Masonry Walls Using Cement Mortar((cont.)

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

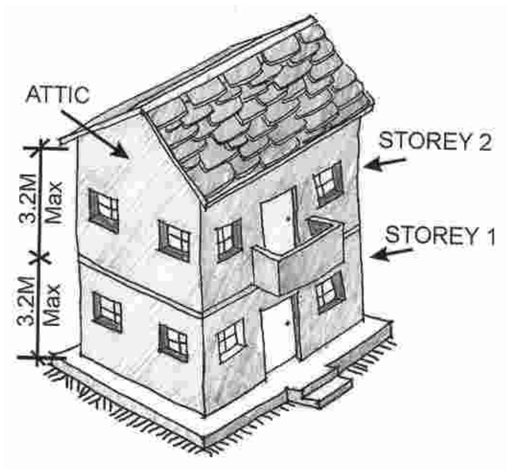
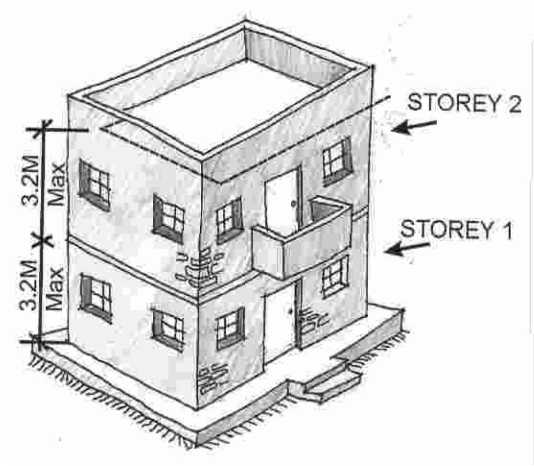


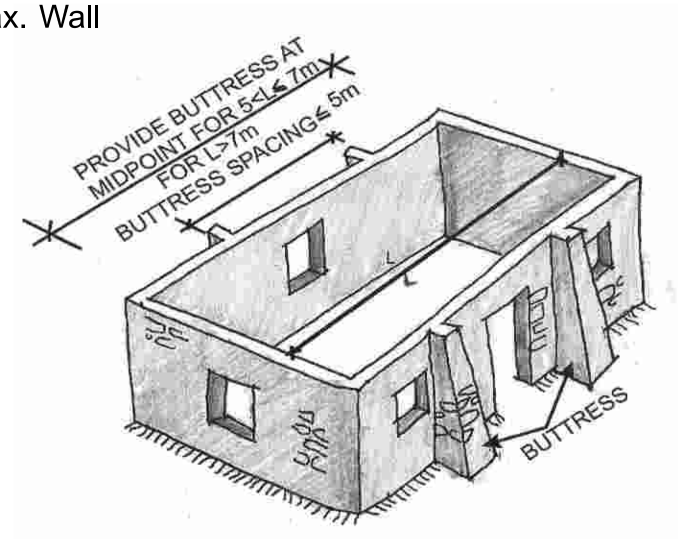
Figure 9.5.B – Height restrictions for flat roof building



- Category D – With all the earthquake resistant 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 earthquake resistant 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)

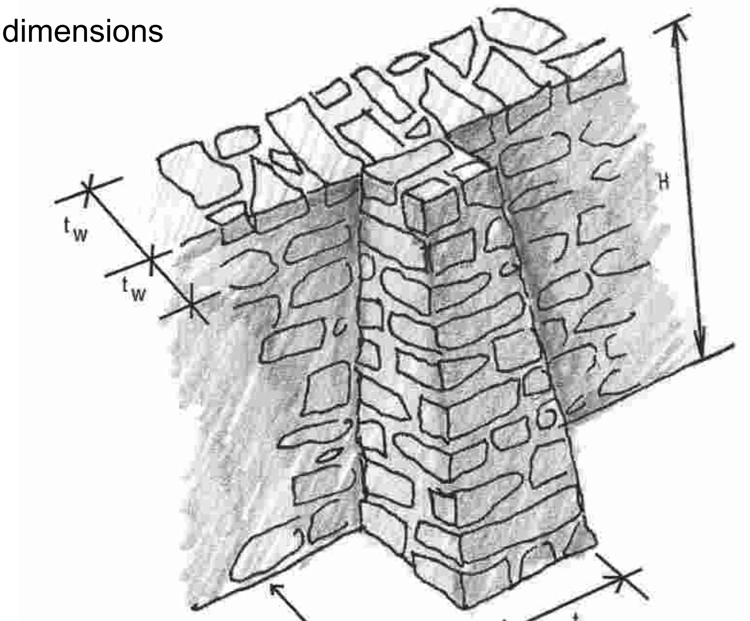
9.2.2 Length of coursed – rubble masonry walls in cement mortar to be restricted as follows

Figure 9.6.A – Rules for Max. Wall Length



- If length of wall between two conse-cutive 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 not greater than 5.0 m (Figure 9.6.A).
- Buttress size – The thickness to be maintai-ned uniform from bottom to top; width at top to be equal to the thickness 't_w' of main wall, and width at the base to be equal to 1/6th of wall height (Figure 9.6.B).

Figure 9.6.B – Buttress dimensions



Stone Masonry Walls Using Cement Mortar (cont.)

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 load-bearing walls. The lintel over doors and windows form a part of the lintel band while passing over the openings.

9.3.2 The use of arch over an opening is a source of weakness and it should 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. flat or pitched roof.

b. Distance of opening measured from inside corner – Shall be not less than or equal to 450mm.

c. Pier width between consecutive openings – Not less than or equal to 560 mm.

Figure 9.7 – Opening rules for single storey building with flat or pitched roof

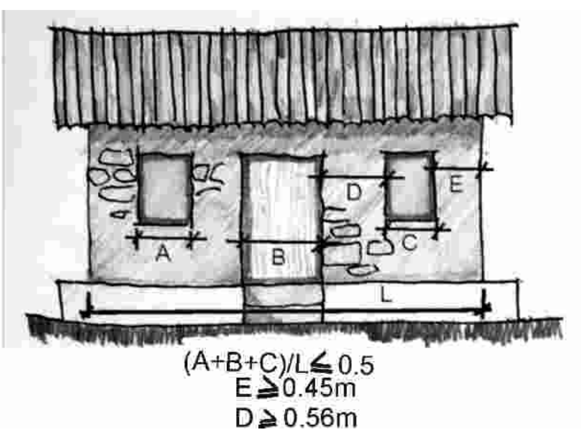
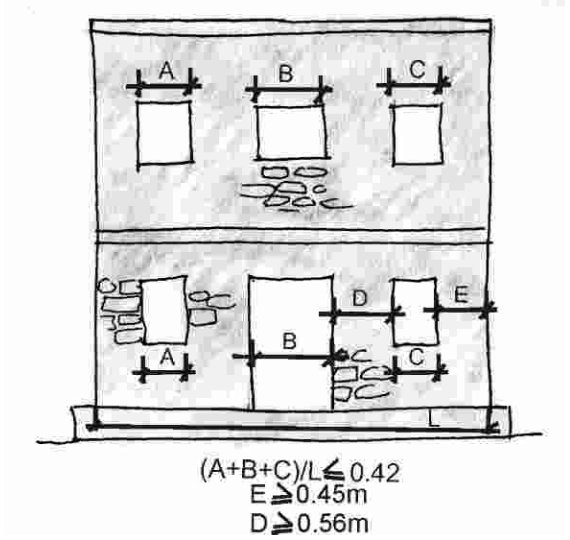


Figure 9.8 - Opening rules for double storey building with flat or pitched roof



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 Provision of earthquake resisting features: The principal strengthening arrangement of seismic reinforcing of masonry buildings consists of horizontal seismic bands at critical levels, vertical bars at corners and junctions of walls, and encasement of openings

Figure 9.9 A - Band locations in pitched roof building

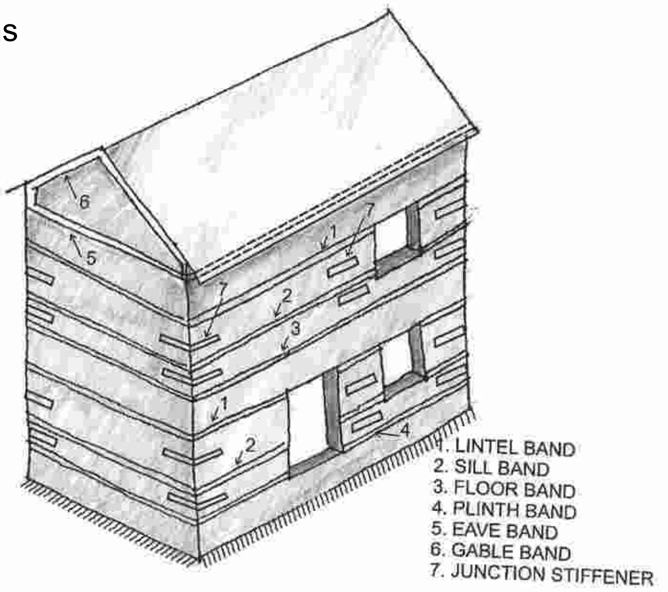
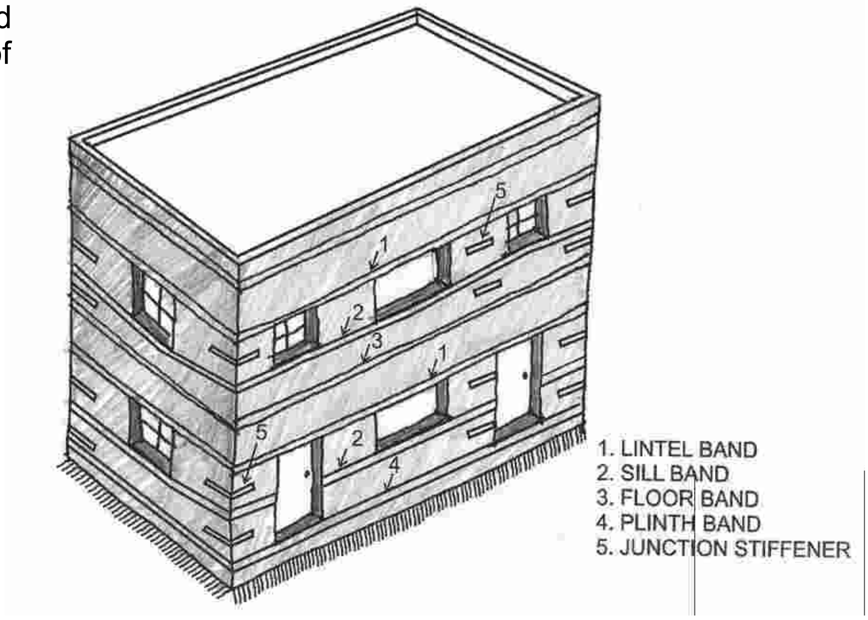


Figure 9.9 B - Band locations in flat roof building



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

- Seismic Bands shall be provided on all internal and external load-bearing walls, and shall be continuous 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

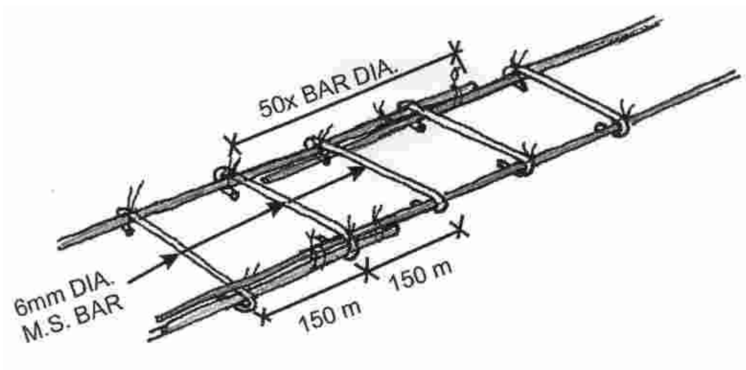
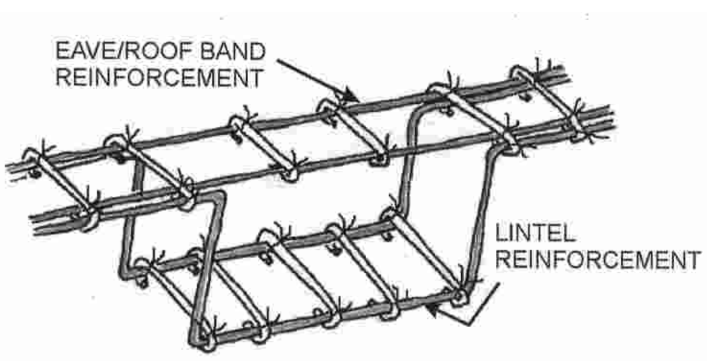


Figure 9.11 - Connection between reinforcement of lintel and lintel band

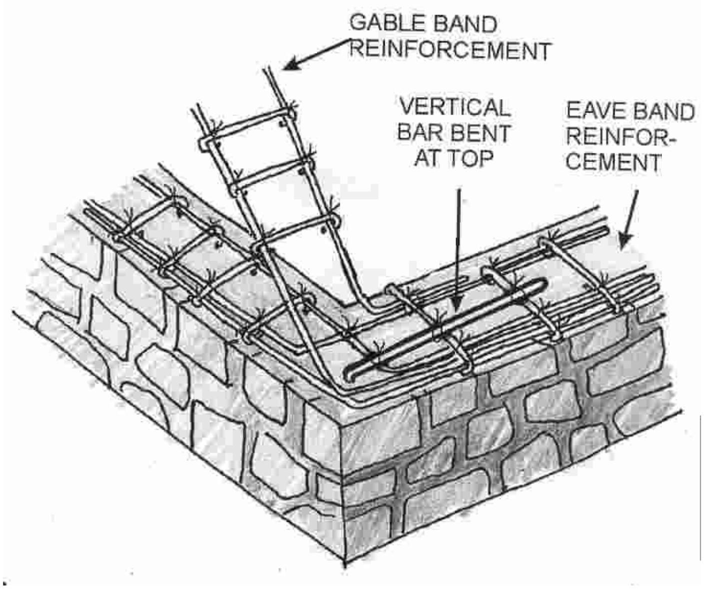


- **Eave Band**: It is provided at just below the Eave/Roof level in case of roof other than RC or RB slab, or if the slab does not cover the support walls fully
- **Floor Band**: It is provided at just below the Floor level in case of intermediate floor other than RC or RB slab, or if the slab does 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 (1:1.5:3).
- 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

Figure 9.12 Eave band to Gable band reinforcement connection



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 9.13 – "L" corner band reinforcement arrangement

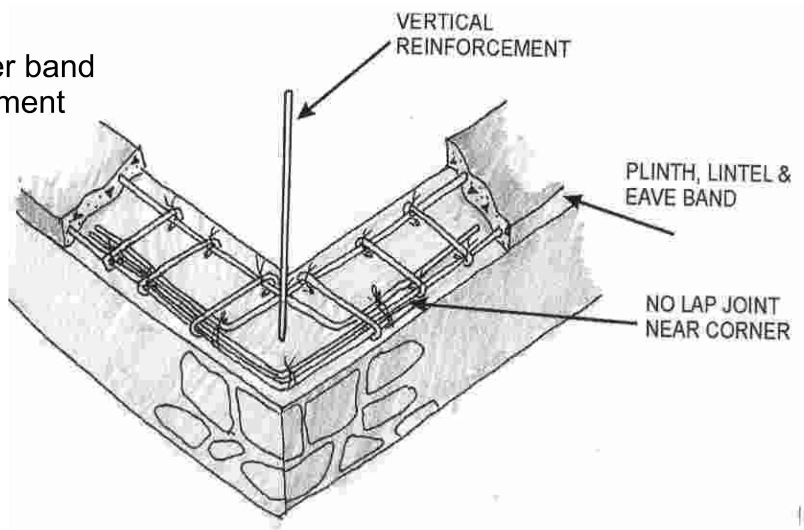


Figure 9.14– "T" corner band reinforcement arrangement

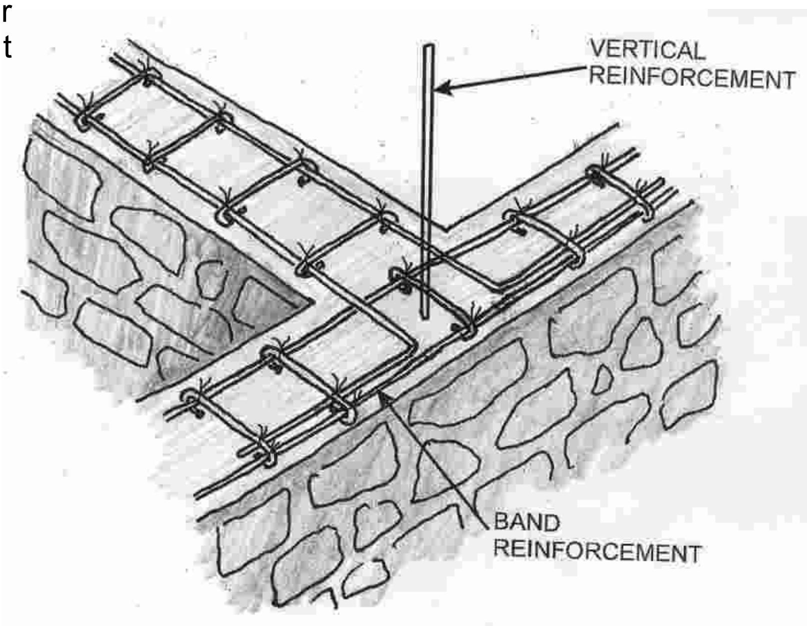


Figure 9.15.A – Shear Connector in RC Band

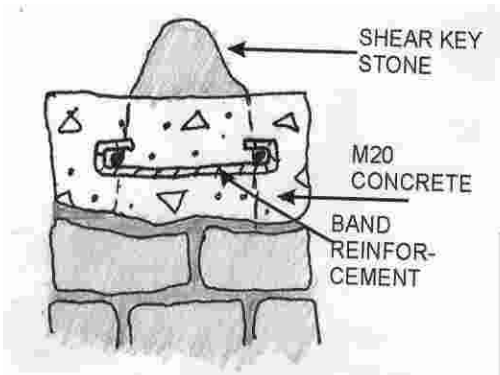
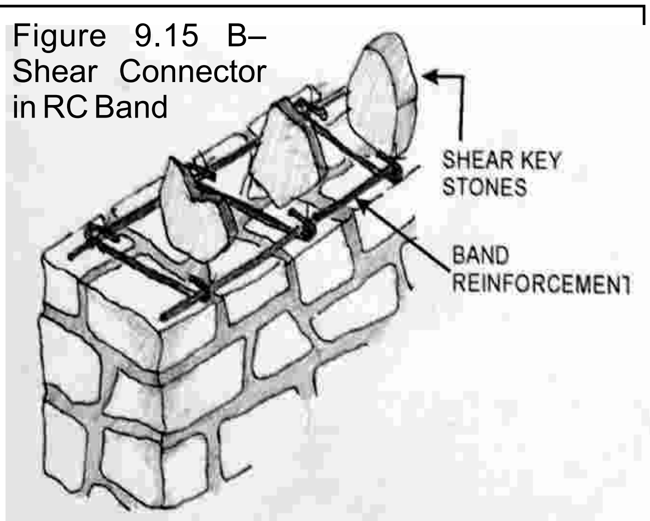


Figure 9.15 B– Shear Connector in RC Band



- In Category E structures provide the **Corner (Junction) Stiffening Elements** or Dowels made of RC at all the corners and wall junctions at two levels equidistant from the lintel band and plinth band as shown in Figure 9.9 A and 9.9 B These stiffening elements to have same cross-section as the relevant RC band and will extend to 0.45m from the inner face of corner or the junction. See Figure 30.
- For achieving good bond with masonry, the band should be cast directly on the masonry and its top surface should be made rough. The surface on which it is cast should be masonry that is not covered with hardened cement mortar. In case of Plinth and Lintel bands, small stones may be left projecting up approximately 100mm from the top surface of band concrete so as to provide shear keys with the stone wall above (Figures 9.15 A & B)

9.6 Vertical Reinforcement in walls

- Vertical steel at corners and junctions of walls which are up to 350mm thick should be provided as specified in the table below. For walls thicker than 350mm the bars should be proportionally increased.
- The vertical reinforcement should be properly embedded in the plinth masonry from foundation (Figure 9.16) up to roof band or roof slab so as to develop its tensile strength in bond. It should pass through the bands at various levels and floor slabs, where they exist in all storeys. Bars in different storeys may be welded or suitably lapped.
- 'L' shaped dowel of the same diameter as the vertical reinforcement with 45mm x 45mm leg lengths may be used to ensure good connection between the vertical reinforcement and the reinforcement of the bands and of RC slab that the bar is passing through (Figure 9.17).

Figure 9.16 – Vertical bar bottom anchor

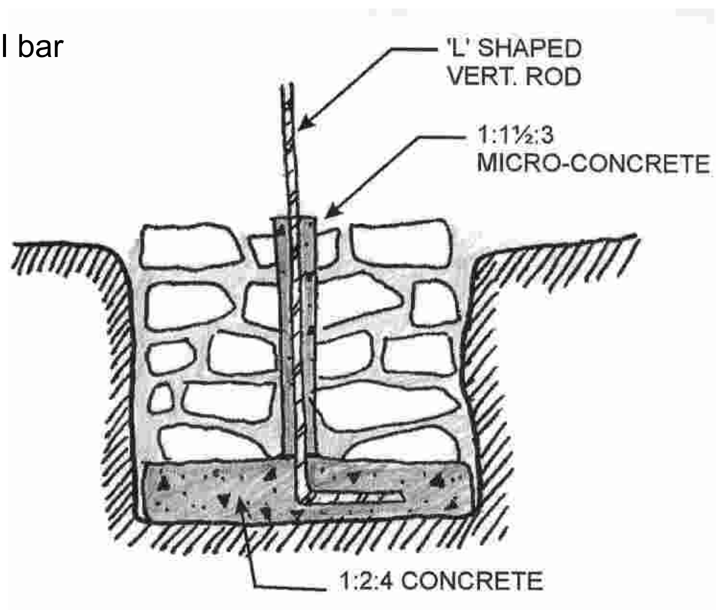


Figure 9.17 -- Vertical bar and band reinforcement connection

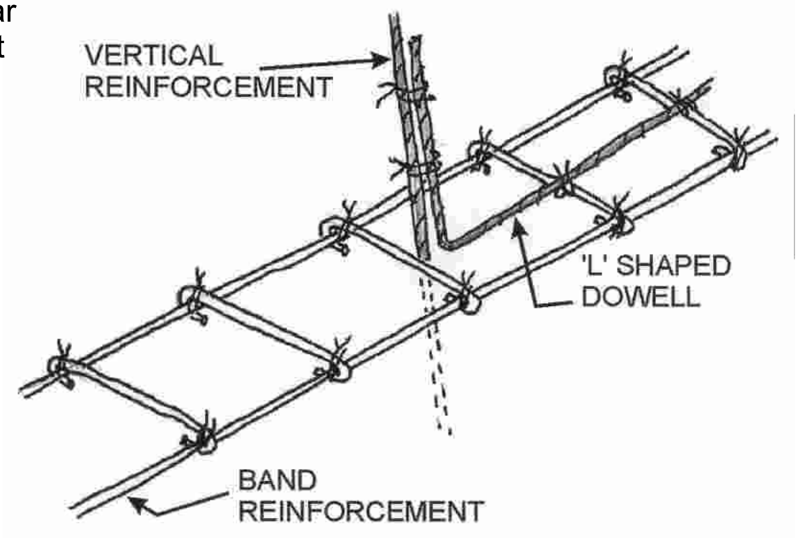
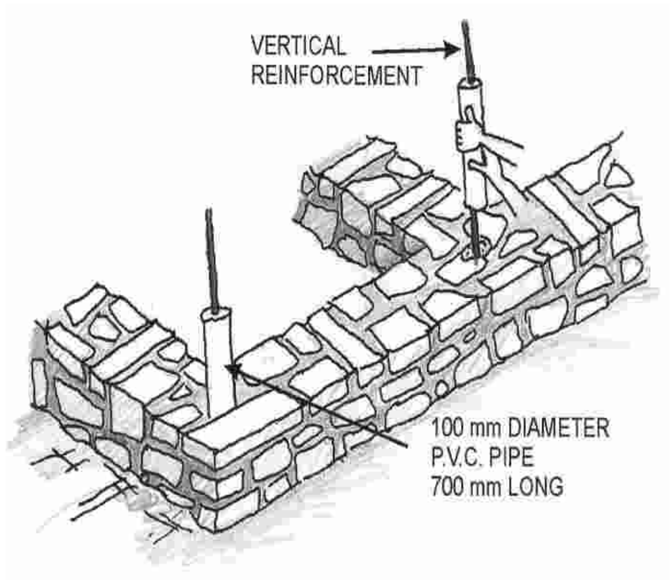


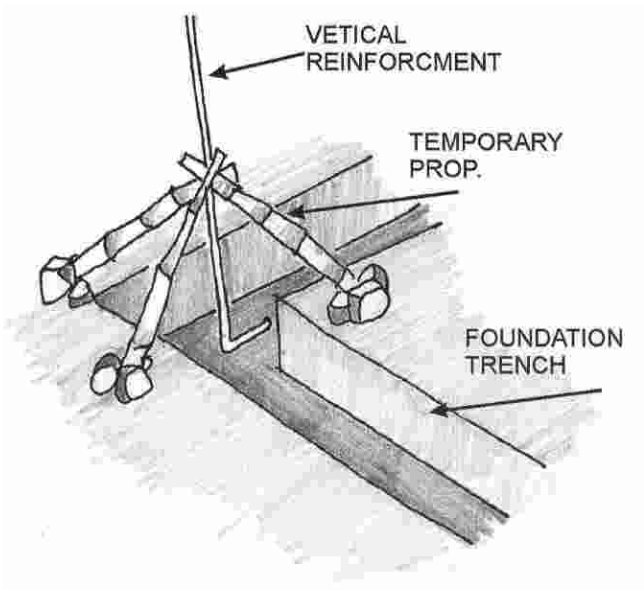
Figure 9.18 Vertical bar installation aided by the PVC tubes



- For installations of vertical bars in stone masonry, use of PVC casing pipe of 100mm dia, 600-700 mm long is recommended around which masonry be built to height 450-600 mm (Figure 9.18). The pipe is kept loose by rotating it during masonry construction. As the masonry hardens, the pipe is raised and the cavity is filled with M20 ($1:1^{1/2}:3$) concrete and fully compacted by rodding using 12mm dia. and 600mm long bar.

- Before casting the foundation, the vertical bars must be kept in correct position horizontally and vertically. For this purpose simple props or tripod may be erected using bamboos or spare reinforcing bars (Figure 9.19).
- The vertical reinforcing of walls consists of a single high strength deformed (HSD) bar located at each corners of rooms and the jambs of large openings. Diameter should be as specified in table below.

Figure 9.19 Vertical bar propping



No. of storeys	Storey	Diameter of single HSD bar at the corner of room in mm for Different Category Building	
		Category D	Category E
One	Bottom	10	12
Two	Top	10	12
	Bottom	12	16

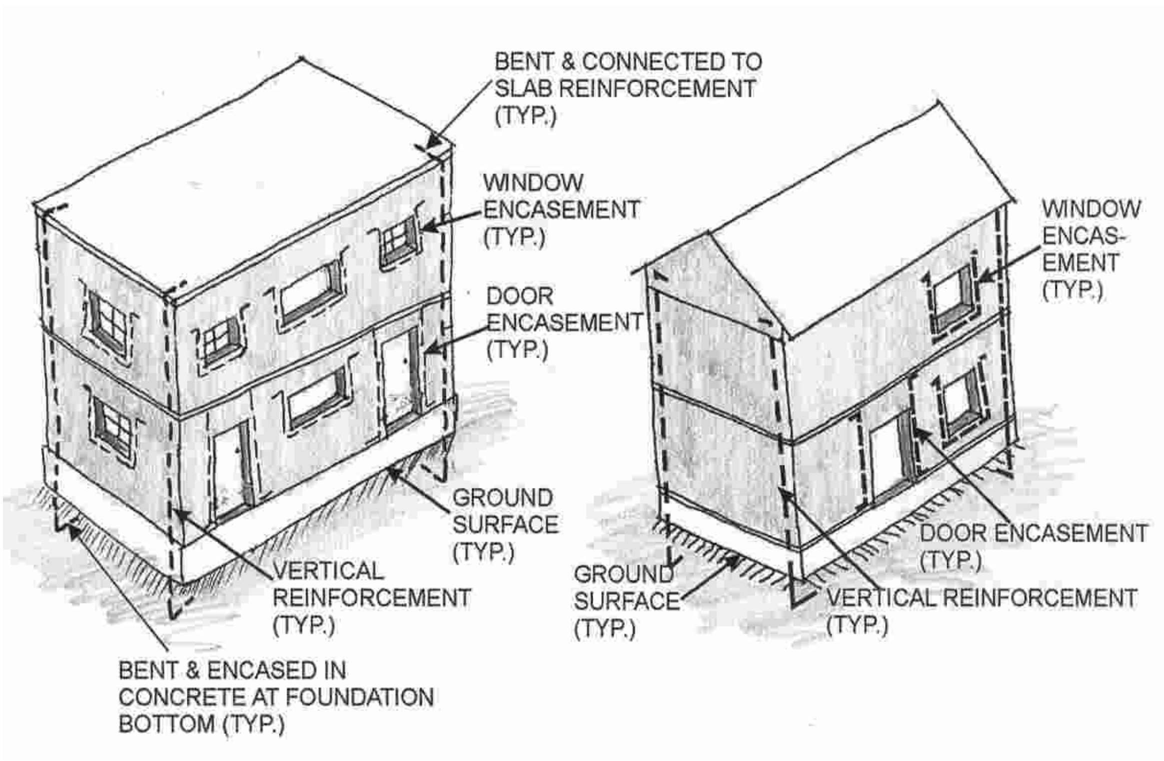
Ref. : "Earthquake resistant reconstruction and new construction of masonry buildings in Jammu and Kashmir State." Published by National Disaster management division, ministry of Home Affairs, Government of India, 2005

See Figures 9. 20 & 9.21.

- Each vertical bar should be encased in concrete M20 grade (1: $1^{1/2}$: 3) or with 1 : 3 (cement-sand) mortar in suitably created cavity around the bar. This will ensure their safety from corrosion and good bond with masonry.

Figure 9.20–Vertical Reinforcement rules

Figure 9.21 – Vertical Reinforcement rules

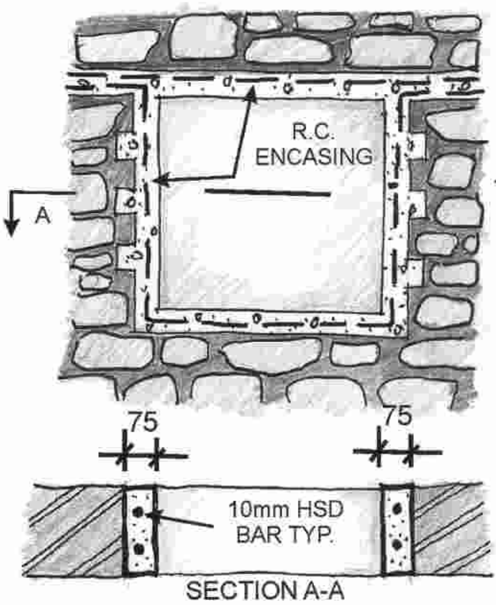


9.6.2 Vertical reinforcing bars at jambs of openings

The vertical bars are to be provided at the jambs of all openings in all Category E buildings. However, if the restrictions on the total allowable opening areas in a particular storey are not met then, the openings should be boxed in RC with minimum 75mm thickness and two HSD bars of 12mm dia. in Category D and E buildings as shown in Figure 22.

Note: Vertical reinforcement at jambs of small windows and ventilators provided in the central one-third of the wall length of a room may be omitted.

Figure 9.22 Window Encasement Elevation View & Section View



10. Stone Masonry Walls Using Mud Mortar or Weak Lime or Weak Cement Mortar

10.1 General

This section includes random rubble and half-dressed stone masonry construction using clay mud mortar, low strength lime-sand mortar or cement sand mortar.

- Building Categories & Applicability: Stone masonry walls built using mud mortar (clay mud) and other details as given in the following paragraphs, **should not be permitted for important buildings falling under Category E and should preferably be avoided for Category D**. But they could be used for constructing houses under Category D and E, for reasons of affordability or non-availability of cement, or the restricted availability of water for curing. Stone masonry in mud mortar should not be used for community buildings such as schools, hospitals, healthcare centers etc. The use of stabilized mud mortar consisting of Cement-Soil-Sand in 1:2:6 or Cement-Soil in 1:8 proportions is encouraged, if resources permit it, on account of its better performance.
- It will be useful to provide damp-proof course at plinth level to stop the rise of pore water in to the superstructure.
- Precautions should be taken to keep the rain water away from soaking in to the wall so that the mortar is not softened due to wetness. An effective way is to take out roof projections beyond the walls by about 500mm.
- Use of a water-proof plaster on outside face of walls will enhance the life of the building and maintain its strength at the time of earthquake as well.
- It will be preferred to avoid any free standing walls. Otherwise free standing wall should be checked for overturning.

Note: Round boulders should not be used for the construction of walls.

Interlocking of two wythes of stone wall

10.2 Construction Control

i. The mortar should contain clay mud of good quality.

ii. The wall thickness 't_w' should preferably be kept 400mm, but shall not be greater than 450mm. In any case, the stones of the inner and outer wythes must be so placed as to ensure interlocking among them as far as possible.

Note: If two wythes are not interlocked, they tend to delaminate during ground shaking, bulge apart and buckle separately under vertical load leading to complete collapse of the wall and the building.

I. The masonry should preferably be laid in lifts not more than 600mm lift.

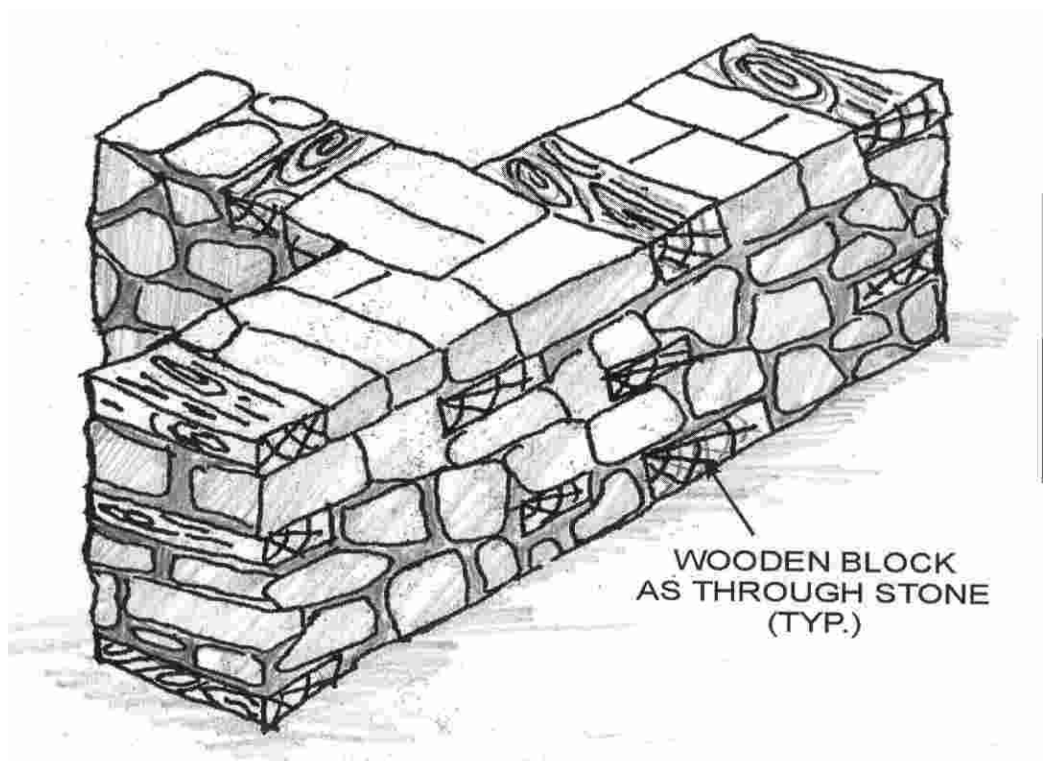
ii. 'Through Stones' of length equal to the wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally (Figures 9.2.A & B). If stones of such length are not available, then in place of one full length stone, the stones in pairs of about ¾ of the wall thickness may be used side by side so as to provide an overlap between them.

iii. In place of 'Through Stones', the 'bonding elements' consisting of **wood blocks** of 38mmX38mm cross section (Figure 10.1) or pre-cast concrete elements of 50x50mm cross-section and reinforced with a 8mm dia. HSD rod placed centrally may be used or solid concrete blocks of 150x150mm cross-section with length equal to the wall thickness (Figure 9.3.A & B) may also be used in place of 'Through Stones'. The wood should be well treated with appropriate preservative so that it is durable against weathering and insect attack.

iv. Use of 'bonding elements' of adequate length should be made at corners and junctions of walls to break the vertical joints and provide bonding between perpendicular walls. For this stones of 500-600mm 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).

v. Alternatively, seasoned and treated wooden blocks of 60mmX60mm cross section having length equal to the wall thickness may be used (Figure 10.1).

Figure 10.1 RR Masonry with Wood Block Through-stones



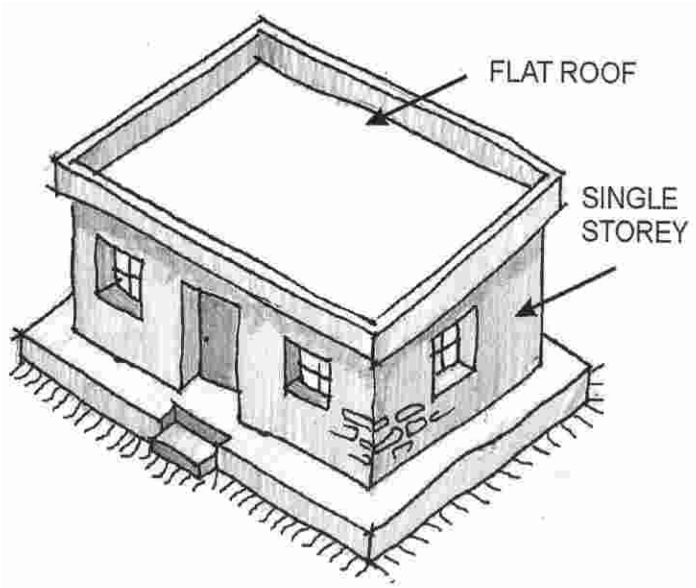
10.3 Controls on Wall Length and Building Height.

a. For a coursed rubble masonry wall in mud mortar the maximum permissible storey height will be 2.7m maximum, and the maximum possible span between cross walls will be 5.0m.

b. In case if the walls are longer than 5m, then provide buttresses at intermediate points with spacing no greater 3.5 m. The size of the buttress will consist of (a) top width equal to the wall thickness, (b) base width equal to one sixth of wall height, and (c) uniform thickness from bottom to top equal to wall thickness (Figure 9.6.A).

10.4 No. of storeys

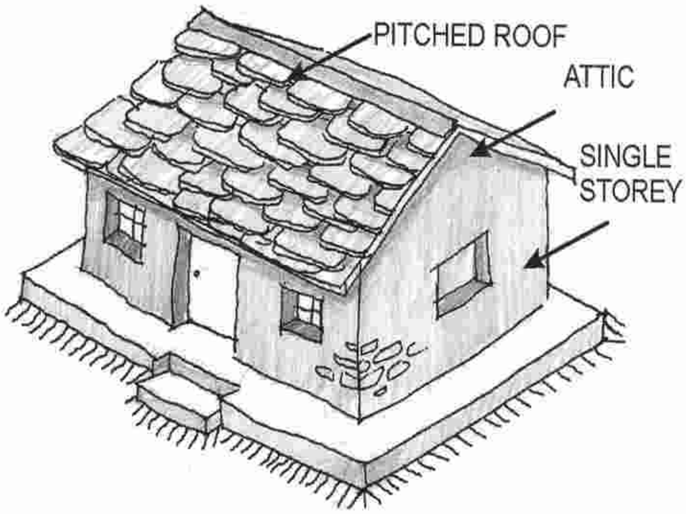
Figure 10.2.A Storey restriction rules



- Categories D – <u>buildings in mud or lime-cement mortar</u>
  - Flat roof - 1 storey
  - Pitched roof - 1 storey plus attic

  (Figure 10.2.A & B)
- Categories D- <u>buildings in lean cement mortar</u> 1:6
  - Flat roof - 2 storey
  - Pitched roof - 2 storey plus attic

Figure 10.2.B Storey restriction rules



- For Categories E – Buildings in m<u>ud Mortar or weak lime or weak cement mortar</u>
  - Flat roof structure - 1 storey
  - Pitched roof structure – 1 storey plus attic

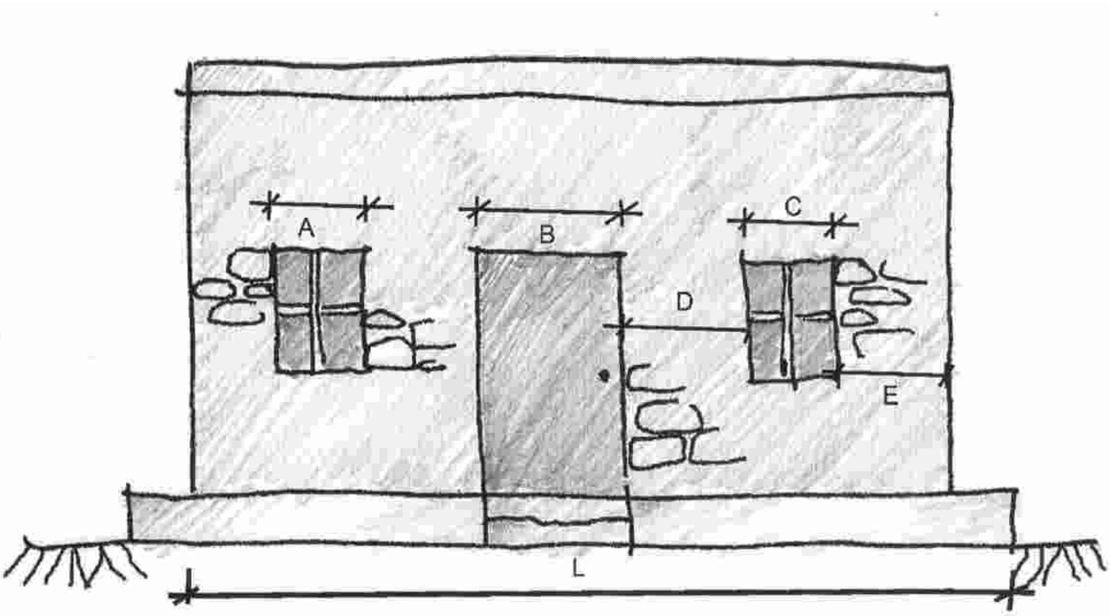
  (Figure 10.2.A & B)
  Storey height: 3m

10.5 Controls on Openings in Load Bearing Walls.

- 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.
- 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.
- 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 (Figure 10.3).

  a. Ratio of total length of openings in a wall to the length of the wall in a room should not exceed…
     1 Storied – 0.33.
  b. Distance of opening measured from inside corner – Shall be no less than or equal to 600mm
  c. Pier width between consecutive openings – No less than or equal to 600mm.
  d. Vertical distance between two openings one above the other shall be no less than 600mm.

Figure 10.3 – Opening Restrictions for buildings with flat or pitched roof



$(A+B+C)/L \leq 0.33$

$D \geq 0.6m$
$E \geq 0.6m$

- Where openings do not comply with the guidelines, they should be strengthened by providing reinforced concrete lining as shown in the Figures 9.9 A & B with 2 HSD bars of 10mm dia.

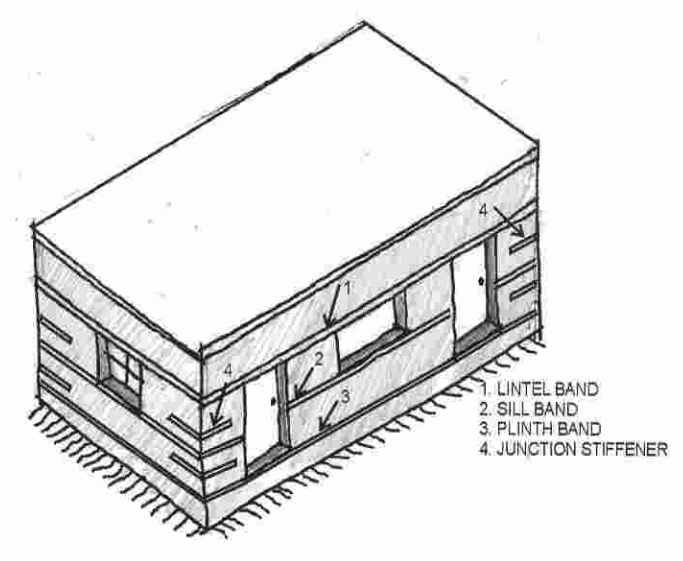
10.6 Required Earthquake Safety Provisions:

For the seismic Zones V, and IV (MSK Intensity IX or higher and Int. VIII respectively) following safety provisions are specified.

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

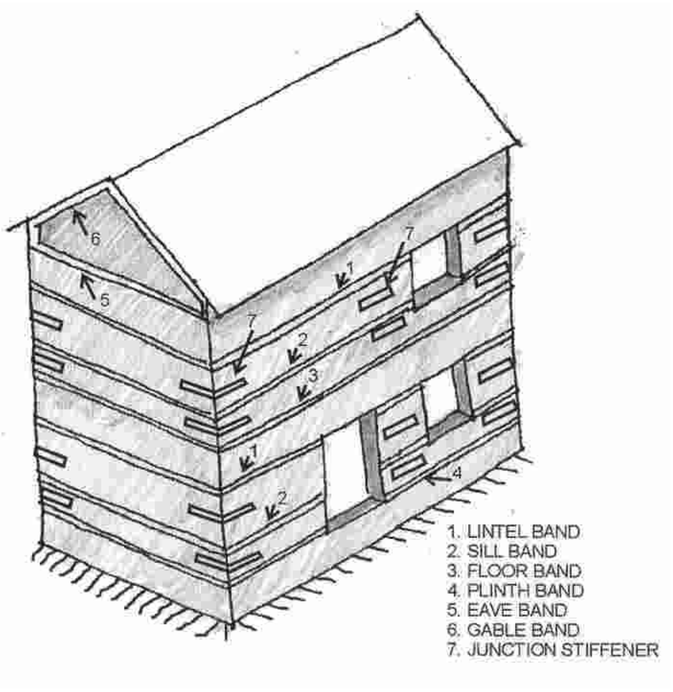
10.6.1 Seismic Bands

Figure 10.4.A – Bands for flat roof building



Figures 10.4.A & B show the horizontal seismic bands of reinforcements at critical levels for buildings with flat roof and for buildings with sloping roof.

Figure 10.4.B – Bands for pitched roof building



- The Seismic Band 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.

- 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 500mm (1.5') 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).
- 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 **Corner (Junction) Stiffening Elements** or Dowels at all the corners and wall junctions at one or two levels equidistant from the lintel band and plinth band may be provided. In Category E structures provide these Corner (Junction) Stiffening Elements at all the corners at two levels equidistant from the lintel band and plinth band as shown in Figures 10.4A & B. The stiffening elements to have same cross-section as the relevant band and to extend to 0.9m (3.0') from the outer face of the walls as shown in Figure 10.8.

10.6.2 RC Band

- The band should be made of reinforced concrete 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 9.11. Alternatively, 8mm dia. bar cross-links may be used at 300mm apart.

Table

Length of wall in room (m)	Reinforcing bars by Building Categories.			
	Cat. D		Cat. 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 bas must be High Strength Deformed (HSD) bars. But 6mm cross-links will be MS. See Figures 9.10.

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

10.6.3 Wooden Band

Requirements of wooden elements and the details of bands are given below.

- Make band that resembles a wooden ladder using 75x38mm timber sections placed longitudinally with cross members of 50x30mm at 500mm spacing. The band must be as wide as the thickness of the wall (Figure 10.5 A & B, and 10.6).

Figure 10.5 A
Timber Band

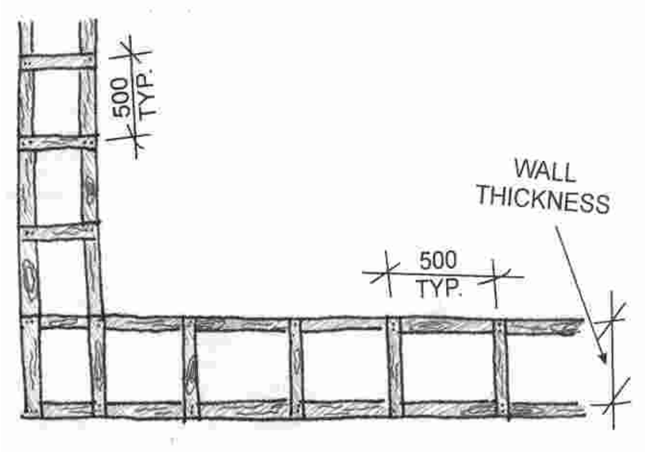


Figure 10.5 B Timber Band Corner Detail

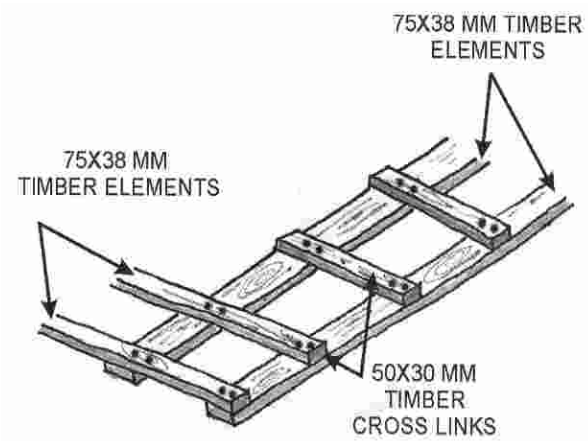
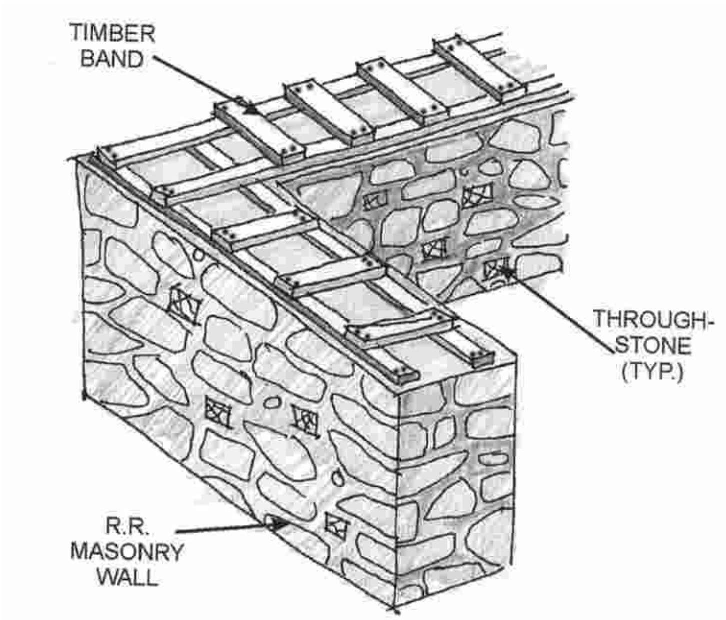


Figure 10.6
Timber Band on RR Masonry



Stone masonry house with wooden gable wall

- The stiffeners at wall corners and wall junctions having cross dowels of 30x50mm wooden member to be installed at various heights are to be as shown in the Figure 10.7. The cross dowels must be fixed to the longitudinal and lateral timber elements with long and broad-headed through nails bent at the other end.
- In case of sloping roofs, triangular gable masonry walls must be avoided. Instead, wooden planks or CGI sheets should be used to enclose the area. In case of masonry walls, confine them within Eave level band and the Gable top band. These bands must be made continuous as shown in Figure 9.12.
- For ensuring good bond with masonry, vertically placed small stone shear keys may be used in the open spaces between the cross members as in Figure 10.9.

Figure 10.7 Corner Stiffening Dowel - Timber

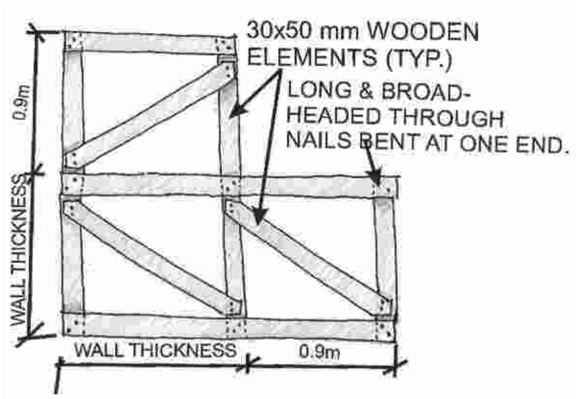


Figure 10.8 Corner Stiffening Dowel - RC

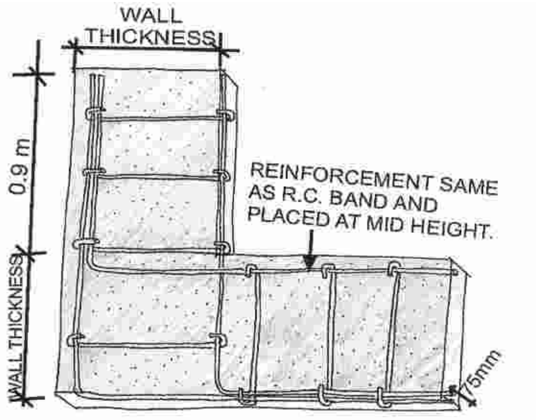
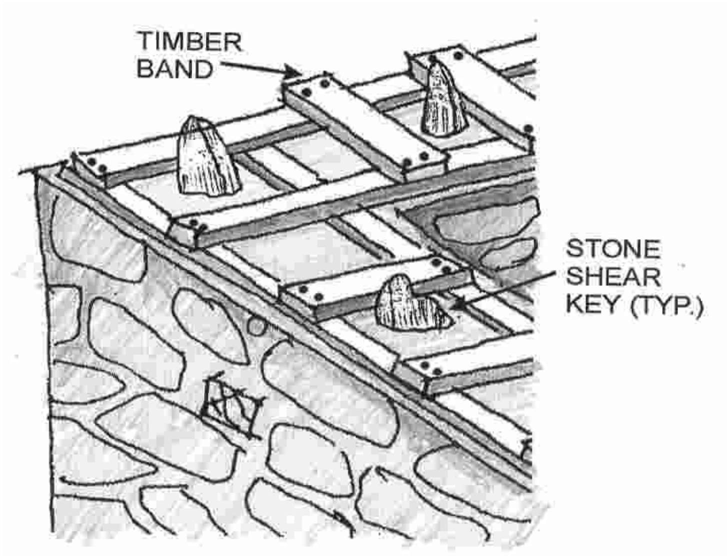


Figure 10.9 Stone Shear Connector in Timber Band



10.7 Vertical Reinforcement in walls

- Vertical steel at corners and junctions of walls which are up to 350mm thick should be provided as specified in the table below. For walls thicker than 350mm the bars should be proportionally increased.
- The vertical reinforcement should be properly embedded in the plinth masonry from foundation (Figure 9.17) up to roof band or roof slab so as to develop its tensile strength in bond. It should pass through the bands at various levels and floor slabs, where they exist in all storeys. Bars in different storeys may be welded or suitably lapped.
- L' shaped dowel of the same diameter as the vertical reinforcement with 45mm x 45mm leg lengths may be used to ensure good connection between the vertical reinforcement and the reinforcement of the bands and of RC slab that the bar is passing through (Figure 9.18).
- For installations of vertical bars in stone masonry, use of PVC casing pipe of 100mm dia, 600-700 mm long is recommended around which masonry be built to height 450-600 mm (Figure 9.19). The pipe is kept loose by rotating it during masonry construction. As the masonry hardens, the pipe is raised and the cavity is filled with M20 (1: $1^{1/2}$:3) concrete and fully compacted by rodding using 12mm dia. and 600mm long bar.
- Before casting the foundation, the vertical bars must be kept in correct in position horizontally and vertically. For this purpose simple props or tripod may be erected using bamboos or spare reinforcing bars (Figure 9.20).
- The vertical reinforcing of walls consists of a single high strength deformed (HSD) or 'TOR' bars located at each corners of rooms and the jambs of large openings. Diameter should be as specified in table below.

No. of storeys	Storey	Diameter of single HSD bar in mm at the corner of room in mm for Different Category Building	
		Category D	Category E
One	Bottom	10	12
Two	Top	10	12
	Bottom	12	16

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

See Figure 10.10.A & B.

- Each vertical bar should be encased in concrete M20 grade (1: $1^{1/2}$: 3) or with 1 : 3 (cement-sand) mortar in suitably created cavity around the bar. This will ensure their safety from corrosion and good bond with masonry.

Figure 10.10.A : Vertical reinforcement for Pitched roof building

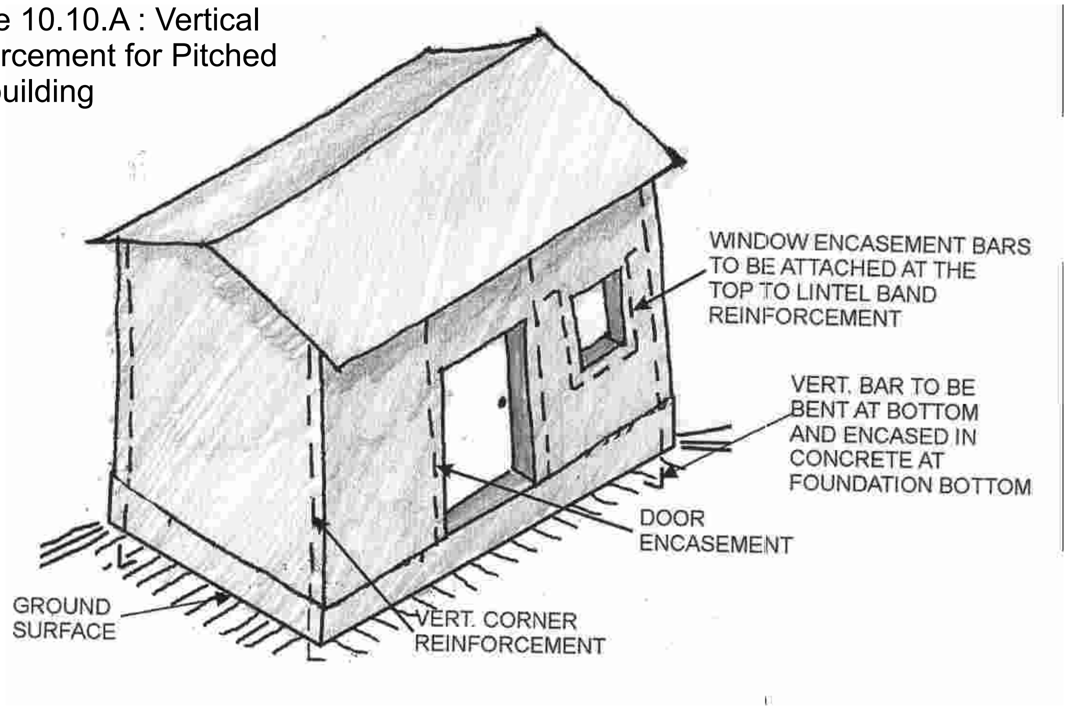
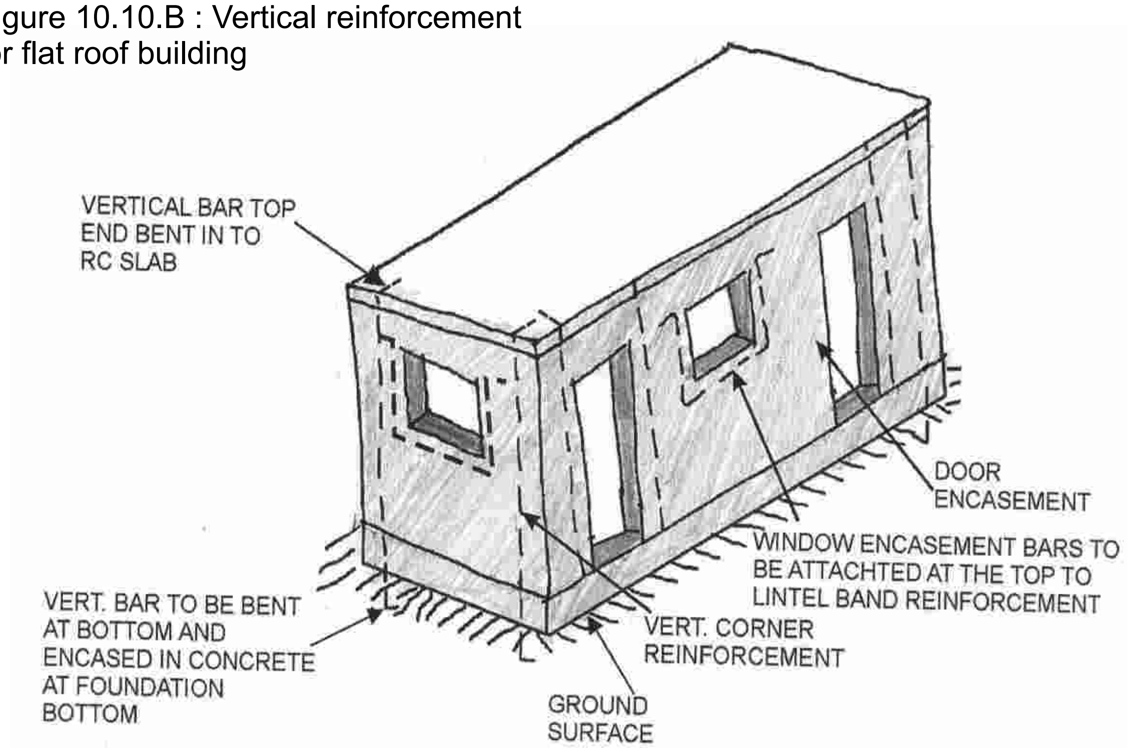


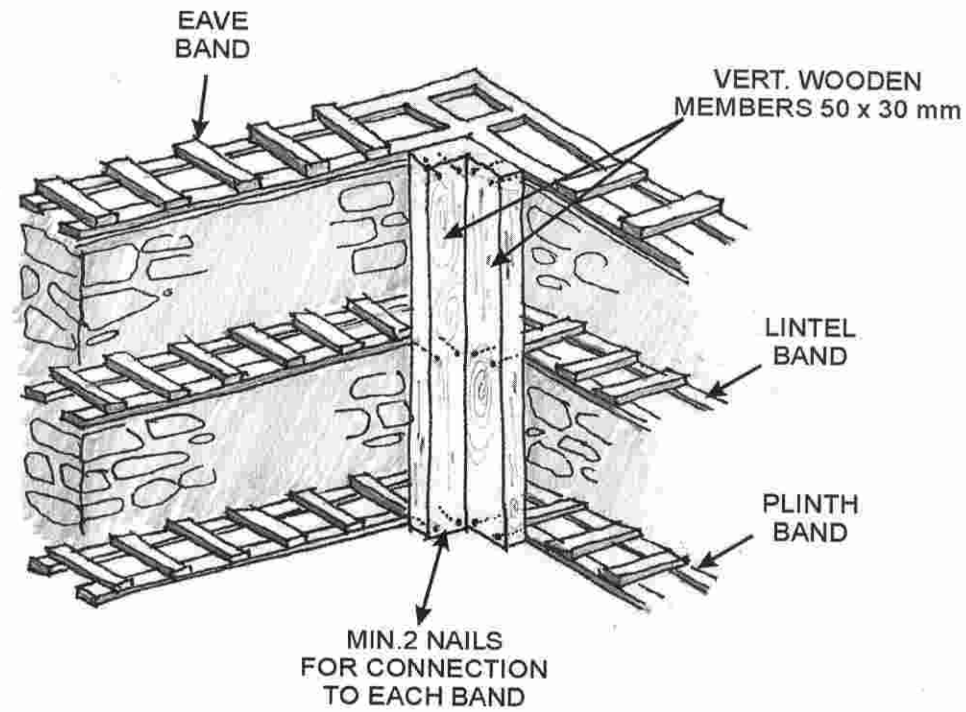
Figure 10.10.B : Vertical reinforcement for flat roof building



10.8 Vertical timber elements for vertical reinforcements

- The vertical reinforcements of timber planks provided at corners of rooms and the jambs of all opening, may be made of wooden planks of size 50X30mm and 80X30 mm joined together by nails forming a 'L' section. This vertical member is to be nailed to the wooden seismic bands at all levels (Figure 10.11).
- The vertical reinforcement is to be provided at all the corners of all the rooms.

Figure 10.11 – Vertical timber reinforcement connected to timber band,



10.9 Water Proofing

For protection of external walls against damage by water:

a. Take out roof projection approximately 500mm beyond the walls,

b. Use 1:6 cement-sand mortar pointing on external face of walls to seal the open joints,

c. While using mud plaster on exterior face of walls, use Non-Erodable Mud (NEM) plaster as follows:

i. Prepare bitumen cut-back by mixing 80/100 grade bitumen and kerosene in the 5:1 ratio. To make 1.8 kg cut-back, take 1.5 kg bitumen and melt it, and pour it in to a container having 300 milliliter kerosene, with constant stirring till it is completely mixed.

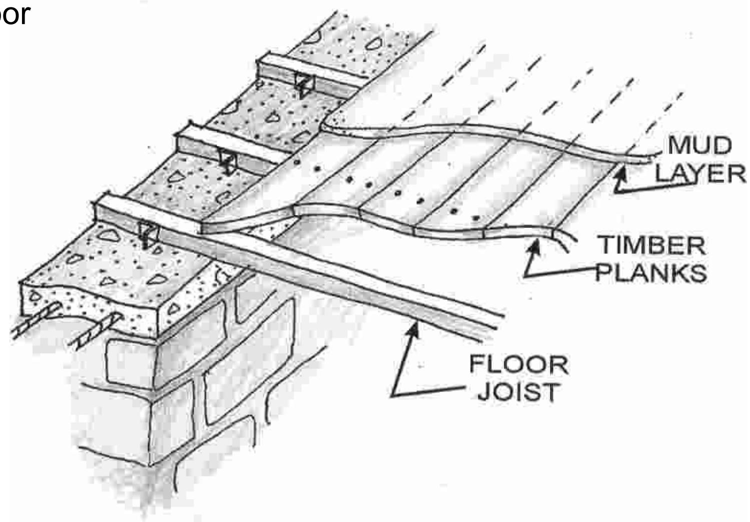
ii. Mix this mixture with 0.03m^3 (30 liters of mud mortar to make it, water resistant.

iii. The water resistant 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.

11. Earthquake Resisting Timber Floor Construction

11.1 Intermediate floors in stone buildings consist of decking made of wooden planks nailed on to timber floor joists that span from wall to wall with intermediate support from wooden beams. The decking often is covered with a layer of dry mud that serves as flooring. See Figure 11.1.A

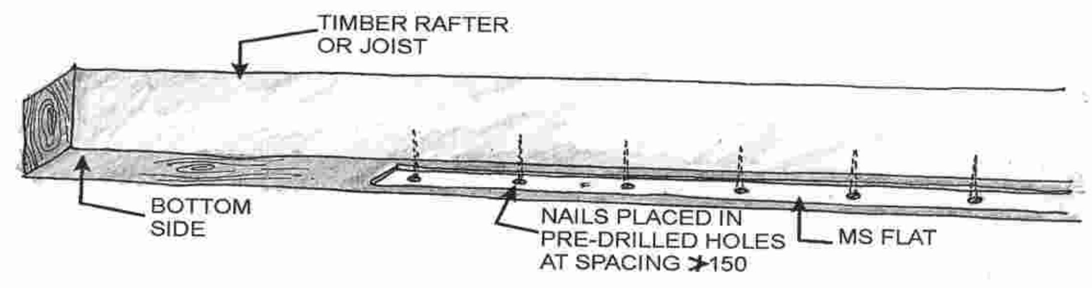
Figure 11.1.A Timber Floor with Mud Flooring



11.2 Floor Joists: Floor joists generally consist of timber elements approximately 100x100mm size.

11.2.1 The timber joists could be strengthened and stiffened by installing MS flat bar at their bottom along its full length or only partial length in the vicinity of the mid-point. Hence, timber joists of small size could be used when MS flat bar is installed along its bottom face (Figure 11.1.B). The connection between the bar and the joist must be adequate to resist the shear. Such elements could be improvised after on-site testing.

Figure 11.1 B Timber Steel Composite Joist



11.2.2 Alternatively, pre-cast RC joists, if found convenient, faster or economically beneficial, too could be used in place of timber joists. Arrangement to anchor the joists to the RC bands must be made prior to casting the joists.

11.2.3 Anchoring of Wooden Joists: The floor joists must be anchored to the band they are resting on. There are different options for this purpose.

11.2.4 Take MS angles 35x35x3mm 100mm long having 2 holes 14mm diameter and with a 6mm diameter MS rod 150mm long welded to it near one end. Install these angles vertically in the Eave level band, one each at the location of floor joists. Tie the angles to the band reinforcement using binding wires. See Figure 11.2.A & B.

11.2.5 While installing in the band concrete make sure that the holes are above the top of the finished surface of the band.

11.2.6 Anchor floor joists to MS angles using 2-12mm diameter bolts and two washers.

11.2.7 If the angles procurement creates a major logistic problem that could delay the construction program then take 6mm diameter MS bars bent at the bottom and having enough length so that approximately 250mm project up from the band.

Figure 11.2.A - Floor Joist Anchor - MS Angle

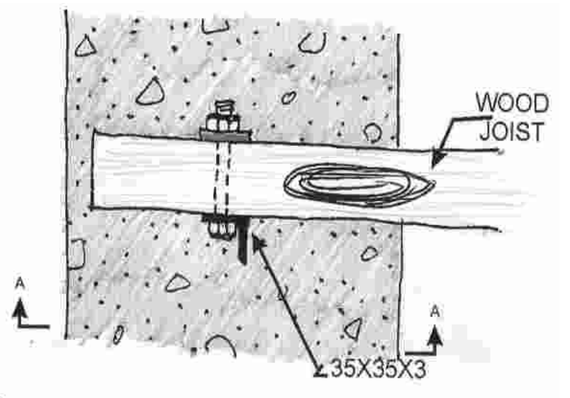
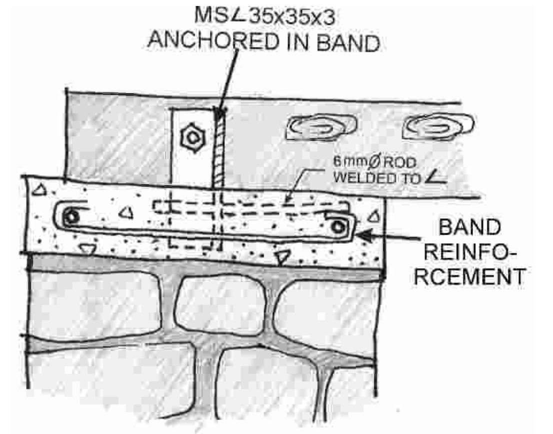


Figure 11.2.B - SECTION A-A



11.2.8 Place each floor joist in position, bend the protruding MS bar over it with hammer and use two nails to anchor down the bar to the joist. See Figure 11.3.

11.2.9 Alternatively, install doubled up galvanized 13 ga. GI wires on to the reinforcing bars in RC band before concreting projecting out approximately 300mm at the locations of the floor joists. See Figure 11.4.

Figure 11.3 Floor Joist Anchor - MS Rod

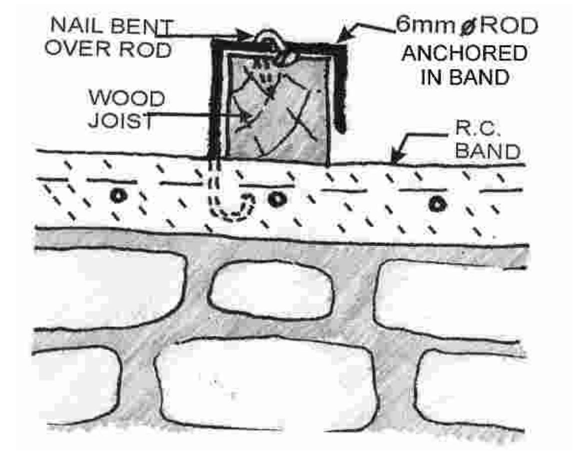
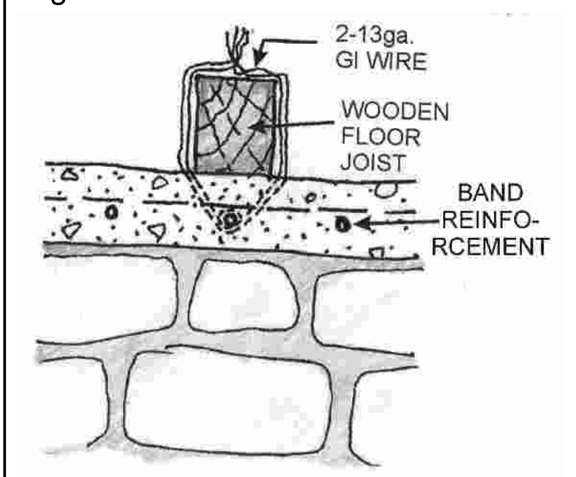


Figure 11.4 Floor Joist Anchor – GI Wire



11.2.10 Place the floor joist with the protruding wire strands on its either side, and tie down the joist by twisting the wires tight around it with the help of a pair of pliers.

11.3 Decking: Install timber planks on top of floor joists using minimum of 2 nails at each ends of each plank. This helps in imparting some rigidity to the timber deck. Pre-drill smaller diameter pilot holes in the planks and joists to minimize splitting of timber.

11.4 Diaphragm made of Struts & Bracings: To ensure better diaphragm action, it is desirable to install a system of struts and braces on the underside of the floor deck. They can be arranged in different ways.

11.4.1 Struts: Install 100x25mm struts (plank) on the underside of the floor joists adjacent to two long walls. Pre-drill the planks and floor joists to prevent splitting from the holes, especially those near the ends. Use minimum of two nails of 8-10 guage at each floor joist. See Figures 11.5, 11.6 & 11.7.

Figure 11.5 – Floor Diaphragm – K Bracing

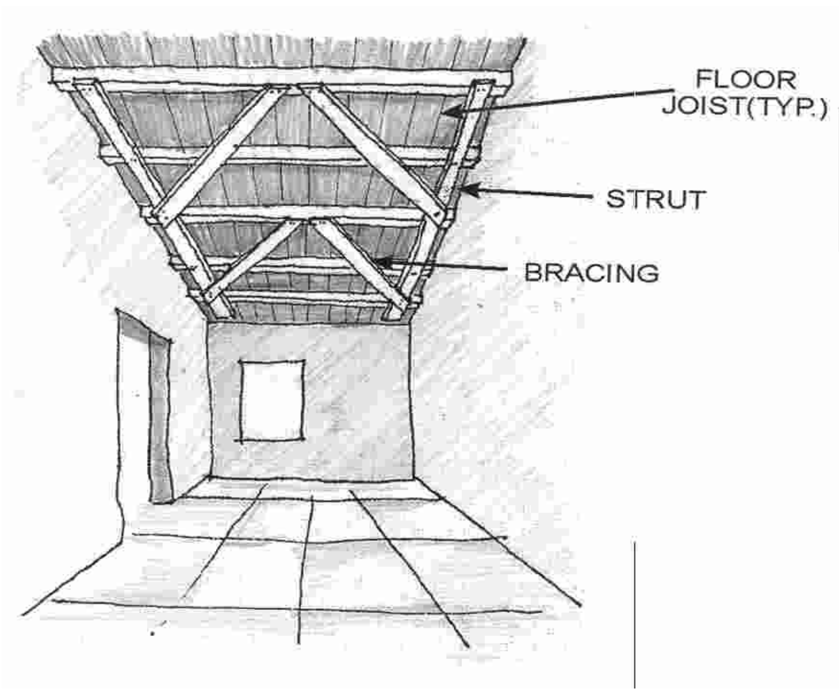
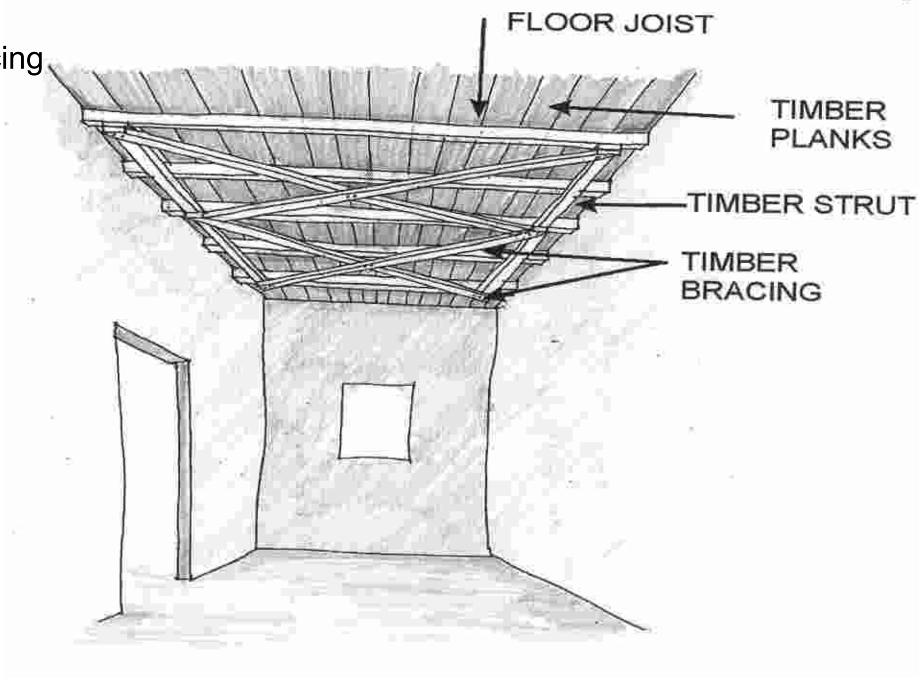


Figure 11.6 - Floor Diaphragm – X Bracing



11.4.2 Diagonal Bracings: Install diagonal bracings starting from one end of a strut to the far end of the opposite strut. The angle between the brace and the strut should be as close to 45^0 as possible while allowing bracings of equal length to be accommodated.

11.4.3 Alternate configurations such as 'K', 'X' etc. may be tried to adjust the length of bracings, especially if the length is more than 3m.

11.4.4 Install more sets of bracings in a similar arrangement to cover more floor area.

11.4.5 Bracings are installed in a manner similar to that for the struts. If, however, it is difficult to accommodate two nails at the ends, then gusset plates made of 3mm thick MS or 12mm thick plywood may have to be used with bolts. See Figure 11.8.

11.4.6 Nail the bracings to each one of the floor joists to reduce the effective length of bracing, and thus make it stronger.

Figure 11.7 –
Strut & Bracing Joint with Nails

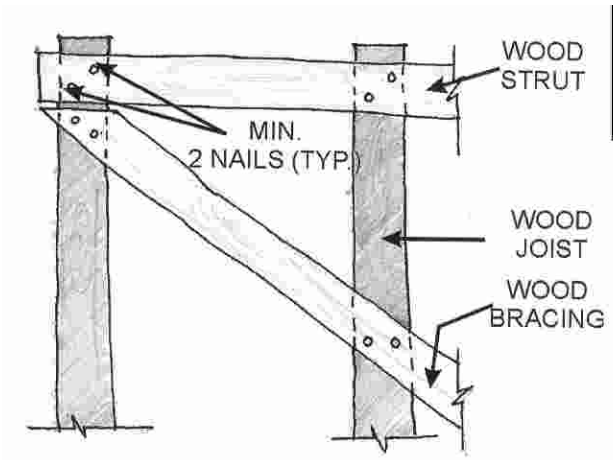
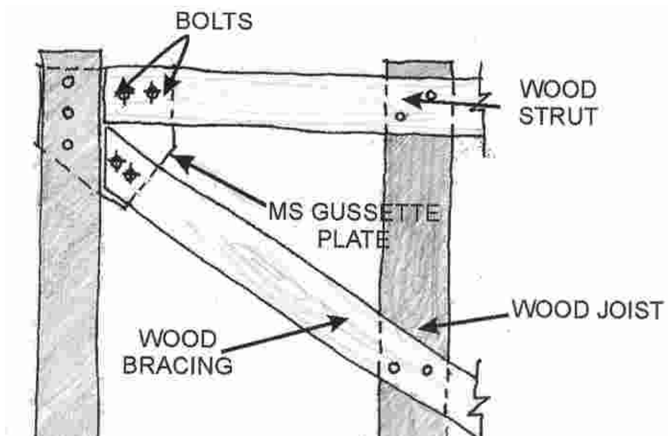


Figure 11.8– Strut & Bracing Gusseted Joint with Bolts



12. Earthquake Resistant *Pathal* Roof Construction

12.1 Roof Types: Two-way roofs are most commonly seen in the region. But four-way roofs are also built in some areas.

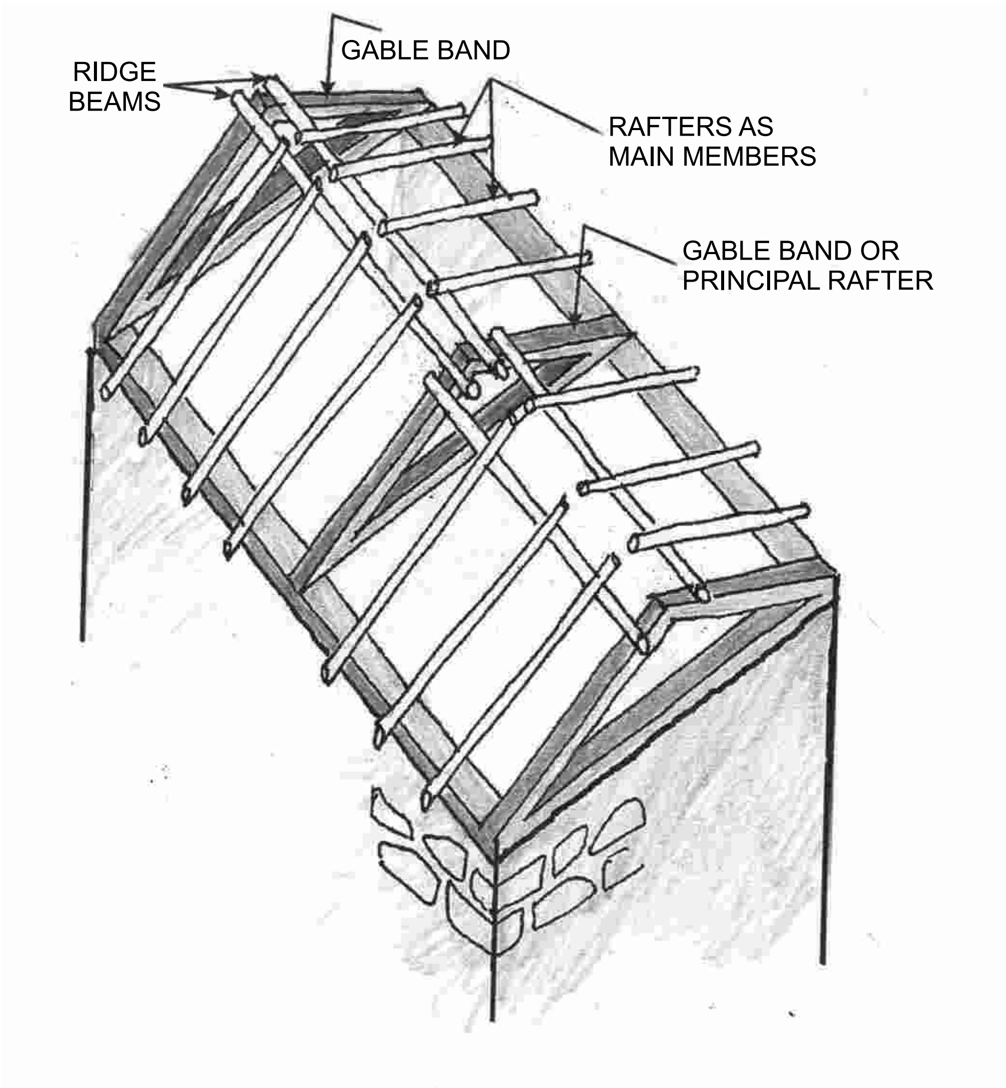
12.1.1 Four-way or hipped roof is better than two-way or doubly pitched roof, since in the former the free-standing gable wall gets eliminated. Adopt the configuration that the local roof artisan can most easily build.

12.1.2 In two-way roof, the diaphragm action in the plane of the roof becomes very important in order to restrain the free standing gable walls.

12.2 Different Roof Configurations: In Uttarakhand *pathal* roofs have two distinct configurations.

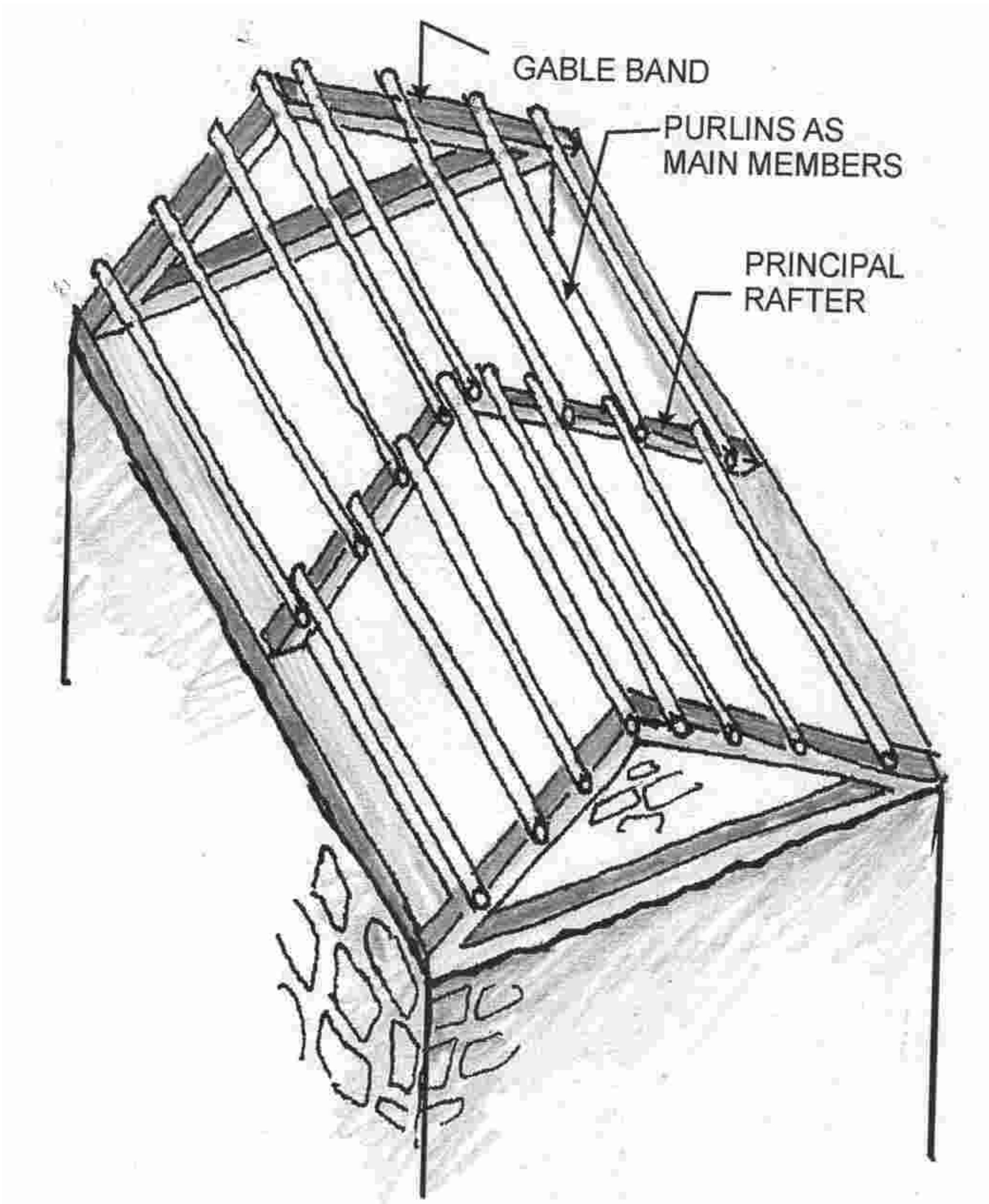
12.2.1 Rafters as principal components: This type of roof is more common in Kumoun region (See Figure 12.1). Rafters form the principal component of the roof understructure. *Pathals* rest on horizontally placed wooden elements of a variety of types that are parallel to the length of roof. These are supported on rafters of approximately 90-125mm diameter spaced at approximately 450mm to 600mm (2'). These rafters span from ridge beam that is 200-210mm in diameter to the eave level wall. Rafters generally of 100mm diameter have intermediate support on the Intermediate beams that are of the same size as the Ridge beam.

Figure 12.1 – Roof with Rafters as Principal Component



12.2.2 Purlin as principal components: This type of roof is more common in Garhwal region (See Figure 12.2). Purlins form the principal component of the roof understructure. *Pathals* rest on rough wooden elements that are sloping. They are supported on purlins of approximately 90-125mm (3.5”-5”) diameter spaced at approximately 450mm (1' 6”) to 600mm (2'). Purlins span from the one gable wall to the opposite gable wall and generally have intermediate support on the Principal Rafter.

Figure 12.2– Roof with Purlins as Principal Component

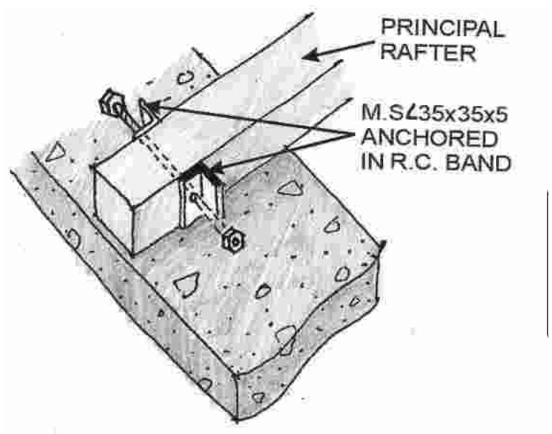


12.3 Principal Rafter: Principal rafters are commonly used to provide intermediate support to purlins. The spacing of two consecutive Principal Rafters within one span should not be more than 2m.

12.3.1 Anchor the Principal rafter to the Eave Band. Since the Principal rafter carries a larger load than floor joists or purlins, the anchoring device should be larger. 2-MS angle 35x35x5 may be used for this purpose as described earlier (See Figure 12.3).

12.3.2 At the top end, sometimes it rests on the ridge wall. In such case, a band is installed on the top of wall. The band is connected at its ends to the gable bands. The Principal Rafter must be anchored to the Ridge level band. If ridge wall does not exist, then the Principal Rafters from opposite side abutt each other. In such case the joint between the opposite Principal rafters must be made using a minimum of 4-12mm diameter bolts along with 3mm thick MS gusset plates (See Figure 12.4).

Figure 12.3 – Anchor for Principal Rafter



12.3.3 Collar Beam: In order to reduce the horizontal thrust on the support walls at eave level, install Collar Beam at 1/3rd rise or lower, on all principal rafters ensuring adequate vertical clearance.

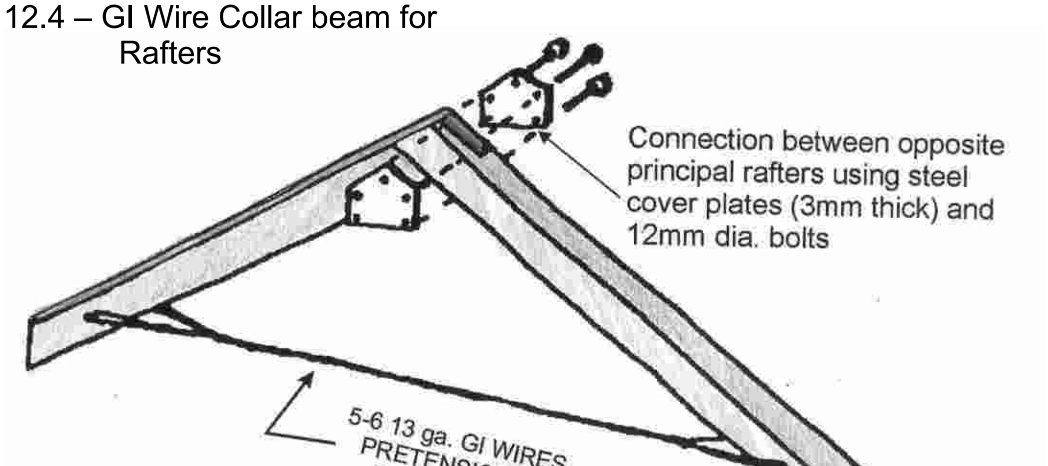
12.3.4 Collar beams, if made out of planks, should be installed on both faces of the Principal rafter.

12.3.5 This can be made of 100x50mm plank and connected to Principal rafter with a minimum of 2-10ga 75mm long nails on each face driven in only after pre-drilling of pilot holes .

12.3.6 The holes should be so aligned that the line joining them is not parallel to the length of the collar-beam.

12.3.7 It can also be made using 5-6 strands of 13 ga GI wires twisted to form a pre-tensioned cable and anchored to Principal rafter using bolt of diameter no smaller than 15mm (See Figure 12.4).

Figure 12.4 – GI Wire Collar beam for Rafters



12.4 Purlins: The Purlins rest on gable walls as well as on Principal Rafter.

12.4.1 At the gable end the purlins must be anchored down in the same way as was recommended for the timber floor joists.

12.4.2 At the Principal Rafter, the purlins must be anchored down using nails and light gauge iron straps. A minimum of two-10ga. nails must be used at each purlin, and pilot holes must be made through purlin and in to Principal rafter to reduce the possibility of splitting.

12.5 Intermediate Beam: It spans from a gable to gable in order to provide intermediate support to the rafters. In case of a four-way roof it could span from a sloping ridge beam to the opposite sloping ridge beam.

12.5.1 At the gable it should be anchored using various means as is recommended for the principal rafter.

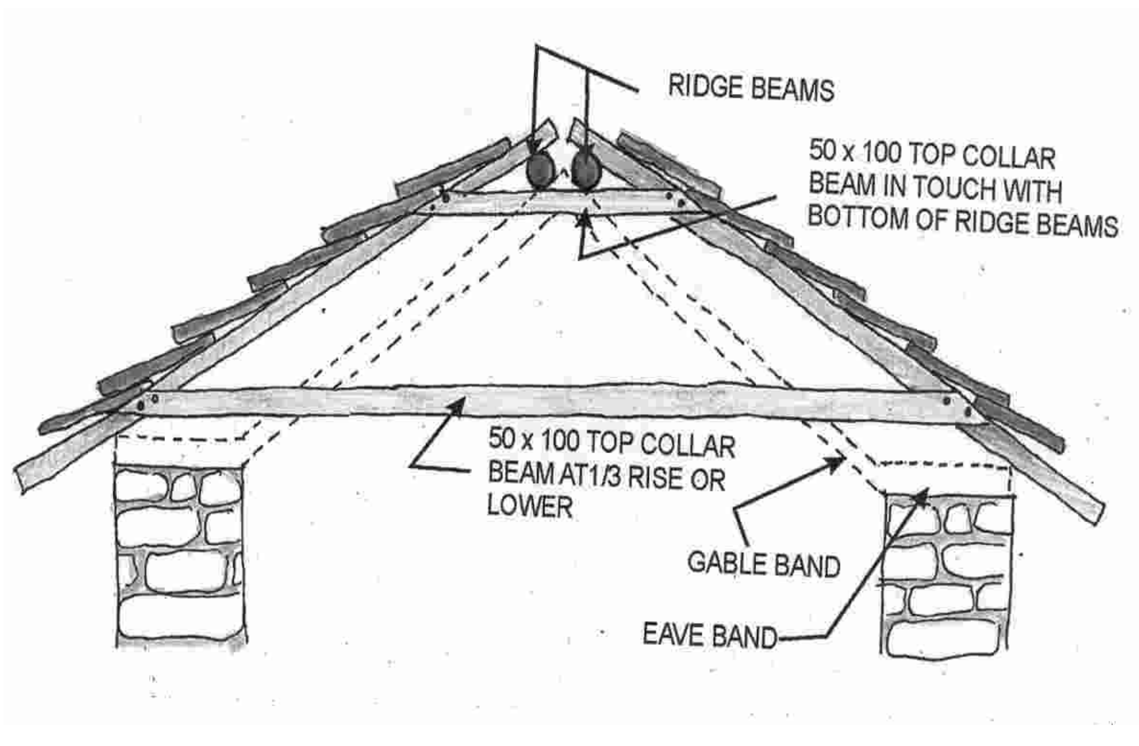
12.5.2 Its connection with the sloping ridge beams should be made using light gauge iron straps and a minimum of 4 -10ga 100mm long nails.

12.6 Rafters: The Rafters rest on Ridge beam and the eave wall. If they are of small diameter, often they are supported at mid-span on intermediate beam.

12.6.1 At the eave level wall support the rafters must be anchored down to the eave level band in the same way as was recommended for the purlins.

12.6.2 At the Intermediate beam, the rafters must be anchored down using nails and light gauge iron straps. A minimum of two nails must be used at each rafter and pilot holes must be made through rafter and in to Intermediate beam to reduce the possibility of splitting.

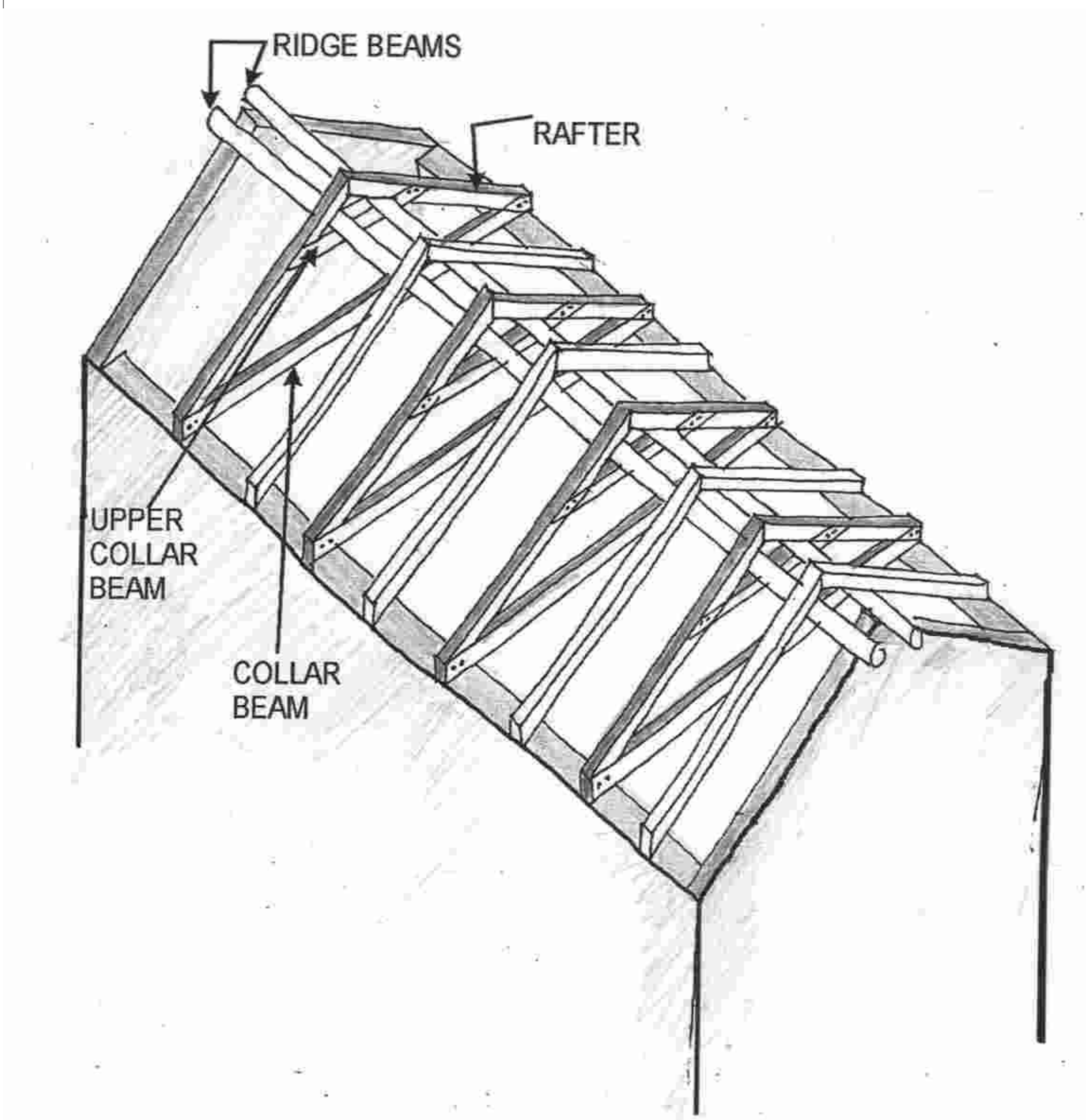
Figure 12.5 – Collar beams in Roof Assembly with Rafters



NOTE : SPACING OF COLLAR BEAM TRUSS TO BE NO GREATER THAN 1.2 m

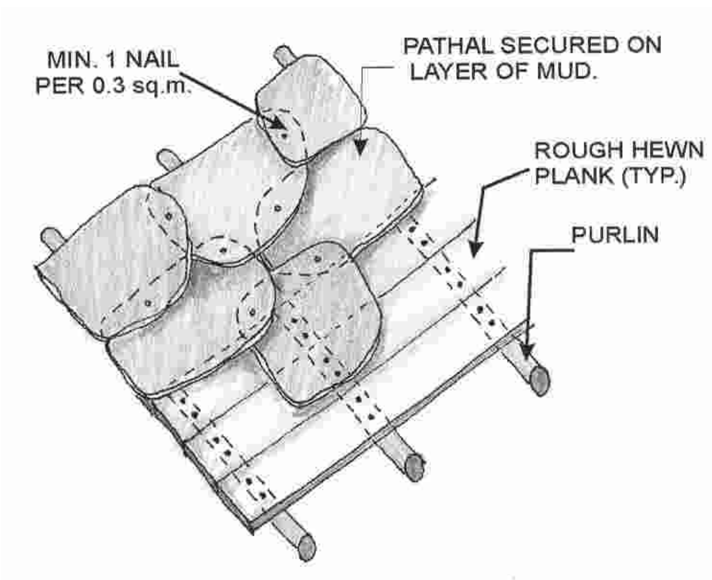
12.6.3 In order to reduce the lateral loads from the rafters to the support walls, Collar beam made of 50x25mm plank should be installed across every alternate pairs of opposite rafters (See Figure 12.5 and 12.6). Thus a truss is made at every alternate rafter location, at spacing no greater than 1.2m. This truss can be used to reduce the load on the Ridge Beam so that excessive deflections can be prevented in it. To achieve this, a support for the Ridge Beam can be created by installing a short horizontal element of 50x25mm plank parallel to the Collar Beam just at the under-side of the Ridge Beam so that it can take up some load from it through the truss action.

Figure 12.6 - Collar beams in Roof Assembly with Rafters



12.7 Pathal support: The elements that support *pathal* include, properly cut planks, rough hewn planks, small diameter branches, and *ringaal* (cane like grass that grows in the hills) depending upon what is available and affordable. In parts of Garhwal, these planks are 25-40mm thick and anywhere from 600-4000mm long (See Figure 12.7). In area around Joshimath *Ringaal is used since it* is found there, It is used in a tightly spaced manner. Pathal support adds to the insulating property of the roof.

Figure 12.7 – Pathal anchored to timber understructure



12.7.1 Anchor the ***pathal* supports** securely to the purlins or rafters that they are sitting on using nails or any other practical means that is reliable.

12.7.2 Planks: In this case the nailing will be the easiest and most practical way of anchoring. Pre-drilling of pilot holes is advisable.

12.7.3 Small diameter branches: In this case nailing would not be advisable. Instead 16-13ga. GI wire may be used for tying down the branches to the rafters and purlins.

12.7.4 *Ringaal*: It is tied down using ties made by splitting *ringaal*.

***12*.8 Pathal**: *Pathal* consists of a piece of rock that is naturally flat. Rock like slate can be as thin as 10mm while other rocks used as *Pathal* can be as thick as 50mm. Slate can be uniformly cut in to rectangular piece of varying size as required. But many other types of *pathal* can be highly irregular in shape. It is fully supported on one or more elements that it is placed on. In other words, it is not expected to span the gap between the purlins or rafters.

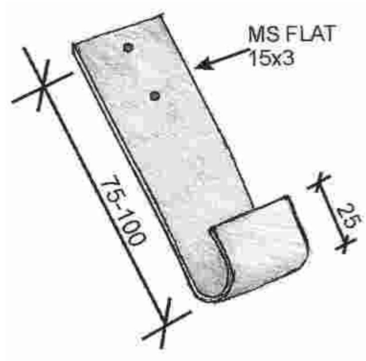
12.8.1 *Pathal* varies in size widely from being 15mm in thickness to 75mm. Its plan dimensions can vary from 300mm to 1000mm or even longer in some exceptions. This depends totally upon the type of rock found in the area.

12.8.2 *Pathal* is typically placed on a layer of mud that is spread over the *pathal* support elements. Mud works as an adhesive and also as a filler to make sure that there are no voids left under the uneven surface of the *pathal,* and it also adds to the insulating property of the roof.

12.8.3 *Pathal* placement is begun from lowest edge of roof at eave level, progressing upwards towards the ridge.

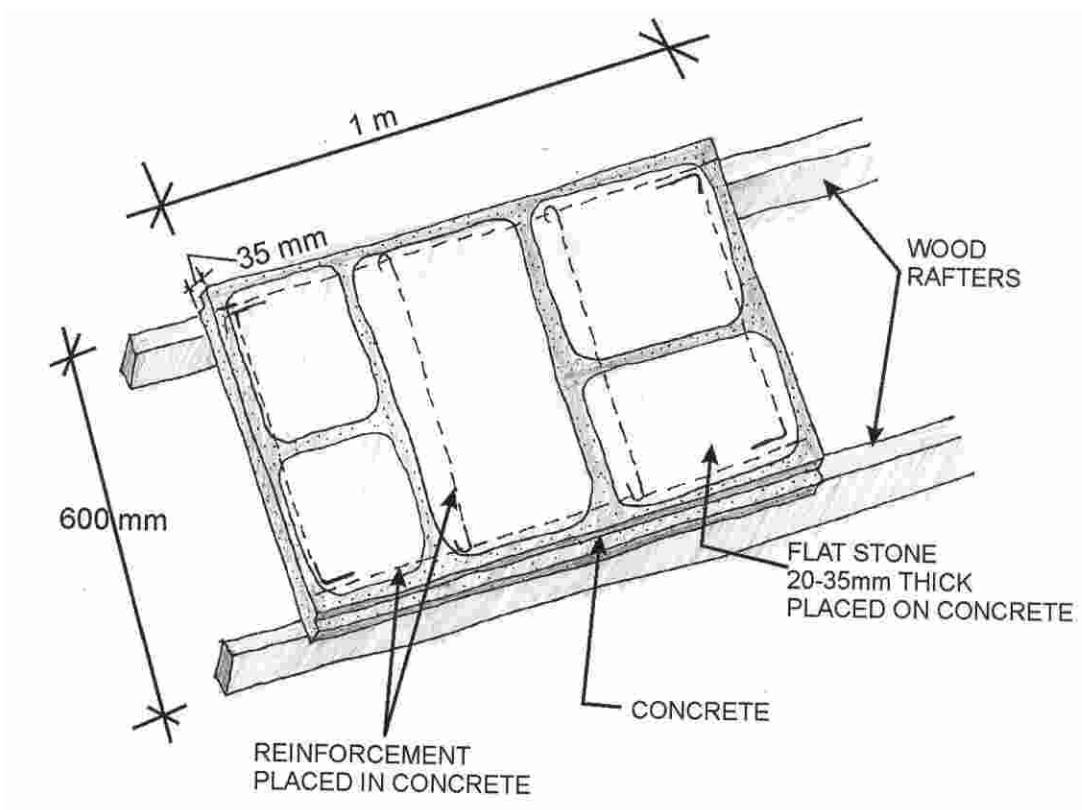
12.8.4 It is advised that *pathal* is positively anchored to the *pathal* support like planks using at least one nail per 0.2sq.m. area of *pathal.* In case it is not possible to nail the *pathal* then brackets made of MS flats could be used. (See Figure 12.8)

Figure 12.8 – MS Bracket for Pathal



12.8.5 MS brackets must be installed along the lowest row of *pathal* to prevent sliding of *pathal.*
12.8.6 In case of *pathal* support like small diameter branches or *ringaal* the nailing, if possible, could be done straight in to purlin or rafter since *ringaal* or the branches would not be able to hold nails.
12.8.7 Where pathal is not easily available, pre-cast concrete pathal can be made. In Yamkeshwar Mahadeo Valley, near Rishikesh, such *pathal* as old as 35 years, are found on many houses. These have been made by mixing locally available *bajri* (a mix of medium to coarse sand and fine gravel) with cement in a proportion varying from 1:4 to 1:8 right on the ground. The thickness of such *pathal* is found to vary from 12mm to 35mm depending upon the type of *bajri* available locally and their size ranges around 600x600mm to 600x750mm. If such *pathal* is made then care should be exercised to ensure good quality by maintain right material proportions, proper mixing, beating of rodding during concreting, and thorough curing for at least 15 days. This type of *pathal* is fully supported just like stone *pathal*. Provision to fix them to rafters/purlins can be easily made with the help of GI wires left projecting out during casting.
12.8.8 Alternatively, "pre-cast pathalcrete panels" with thin RC panel at the base and *pathals* stuck like tiles at the top also can be evolved after some experimentation. Provision to fix them to rafters/purlins can be easily made with the help of GI wires left projecting out while pre-casting. This option also requires some testing on prototypes before it can be implemented. A possible arrangement is shown schematically in Figure 12.9. Unlike the concrete or stone *Pathal,* this alternative is self supporting due to the reinforcement to span across the rafters or purlins.

Figure 12.9 – Pathalcrete Roofing Panel

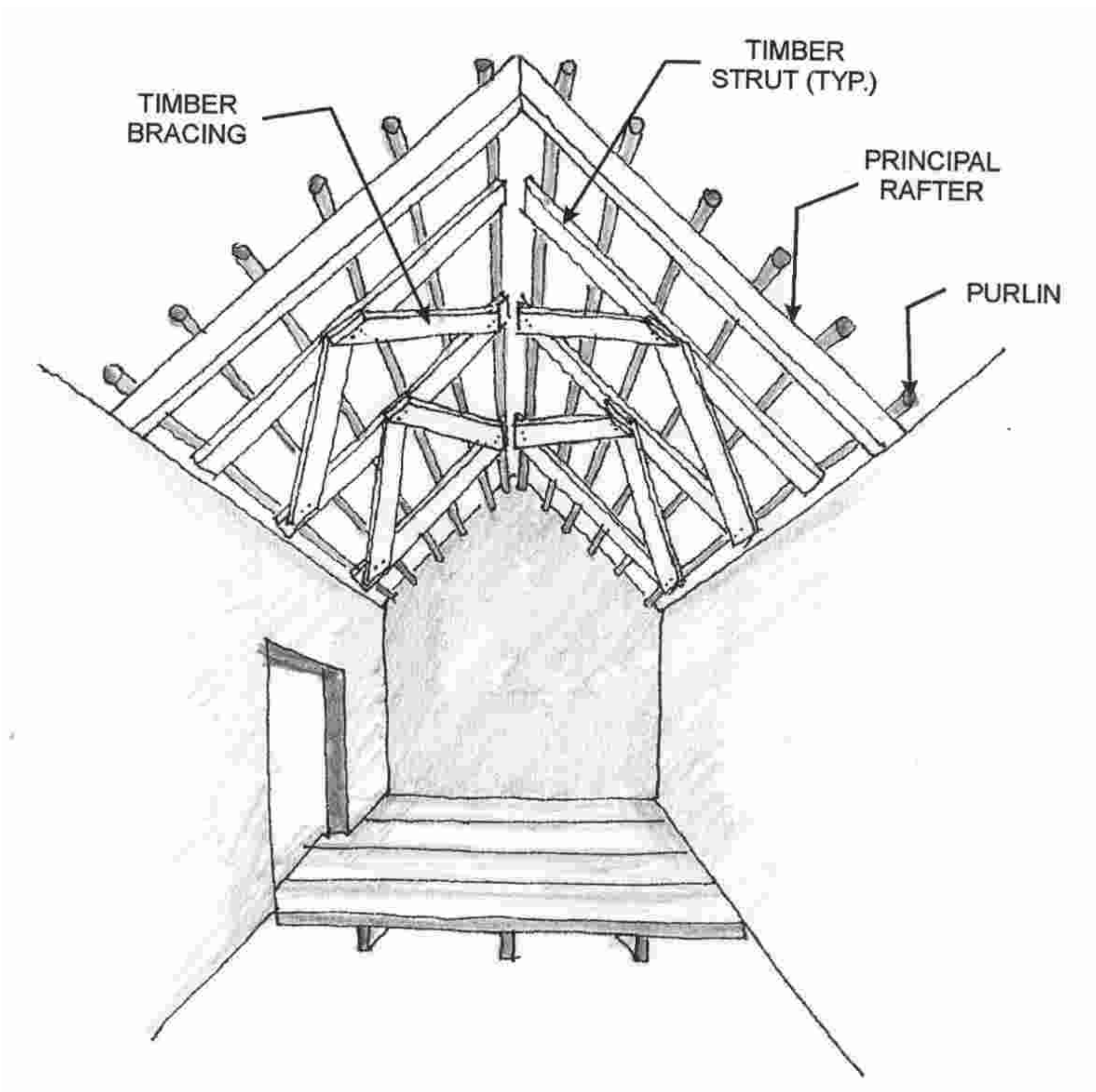


12.9 Installation of struts and diagonal bracings

12.9.1 Bracings can be installed in a variety of arrangements as shown in the diagram depending on available timber length. The continuity from ridge to eave level must be maintained. A single bracing may span this gap, or it may be done with more bracings.

12.9.2 Install a pair of 100x50mm struts parallel to principal rafter and connected to all the purlins, one adjacent to gable wall and one adjacent to the principal rafter (See Figure 12.10).

Figure 12.10 – Roof with Purlins – Timber K Bracings



12.9.3 The angle between the bracing and purlin should be as close to 45◖ as possible to optimize its effectiveness.

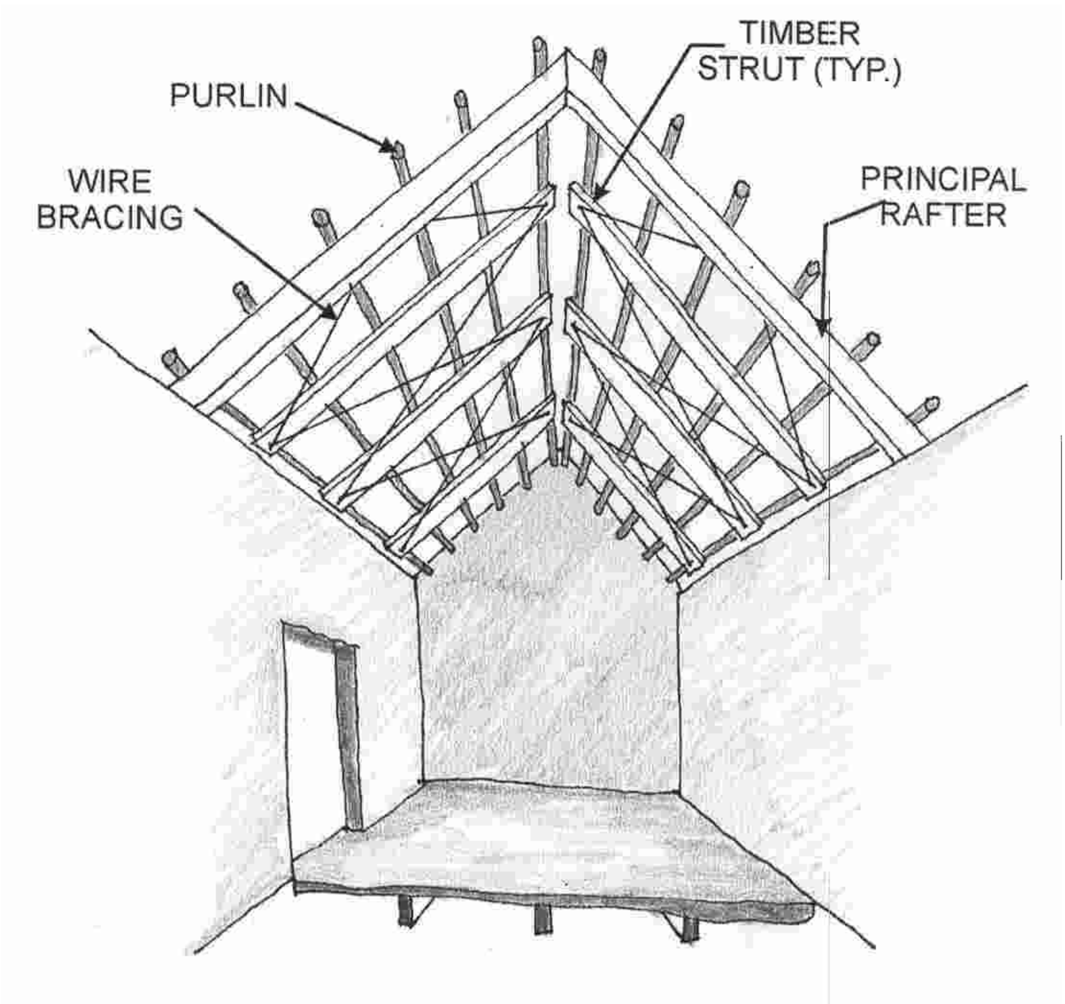
12.9.4 Bracing should be of 100x50mm or heavier planks. Pre-drill the planks to prevent splitting around the holes at the ends. Also pre-drill the principal rafters to minimize the problems of driving nails in them and causing them to split because of their age and dryness. Use minimum two nails at each rafter.

12.9.5 Bracings must be installed in a symmetrical fashion on either side of the ridge.

12.9.6 If the space is not adequate for two nails at the junction with strut, then 3mm gusset plate or 12mm plywood can be used.

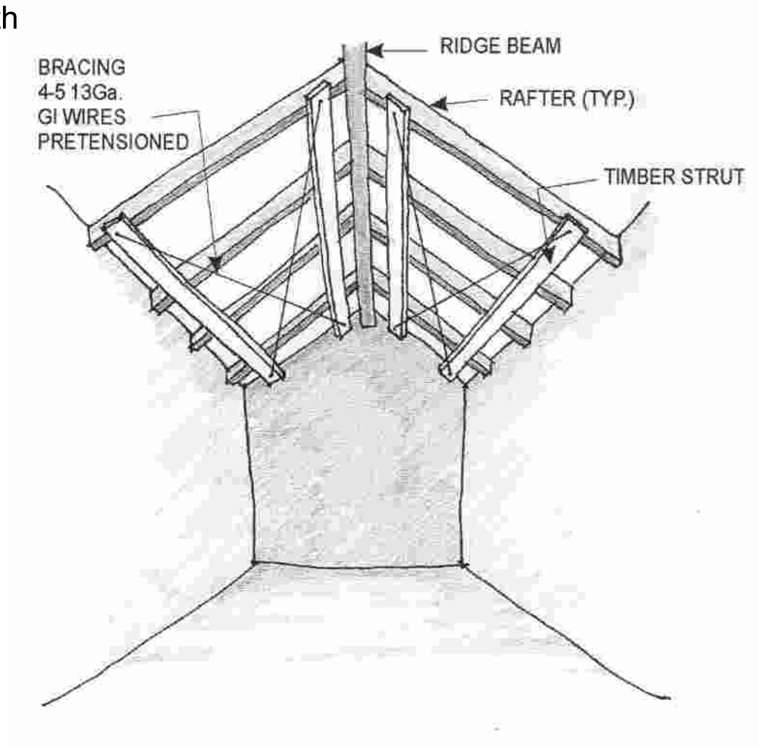
12.9.7. Alternatively, bracings can be made of 4-5 GI wires of 13ga. twisted to pretension (See Figure 12.11). This option is easier to execute in remote locations. The end connection is much easier than that in case of timber bracing. While using wires, only 'X' configuration can be used.

Figure 12.11 – Roof with Purlins – GI Wires X Bracings



12.9.8 In case of roof system having rafters as the principal component the arrangement of struts is different (See Figure 12.12).

Figure 12.12 – Roof with Rafters – GI Wires X Bracings



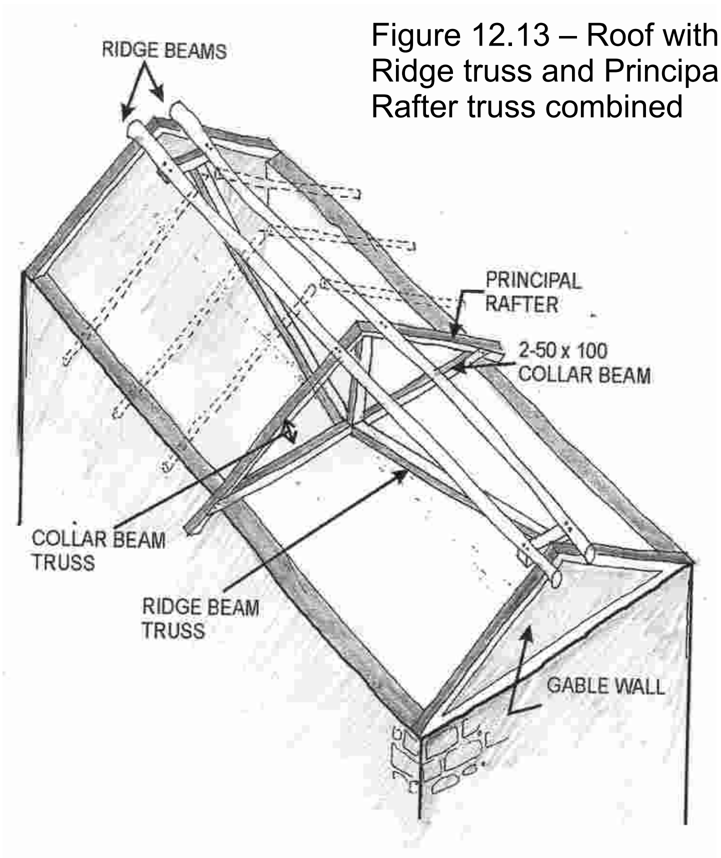


Figure 12.13 – Roof with Ridge truss and Principal Rafter truss combined

12.10 Installation of Ridge Truss

12.10.1 In case of sloping roof without ridge wall, provision of a ridge bracing, in addition to the roof bracing should be considered. It would create one more mechanism for transferring shear from the ridge beam down to eave level. It also helps in improving the safety against cyclonic winds (See Figure 12.13).

13. Closure

It is well-known that Uttarakhand has a number of potentially destructive natural hazards. These bring threat to life of its habitants as well to their dwellings. These Guidelines are prepared with a hope that they will help in reducing the vulnerability of a large number of these people that continue to live in stone houses in-spite of all odds.

Contrary to the belief that all the people in the State want to change over to the houses made of modern materials, and that houses made of traditional materials like stone and wood are neither in fashion nor economically viable, many people continue to rebuild their homes in stone, using materials recycled from their old homes and supplementing them with whatever they manage to procure through various means including '*Van-Panchaayat', 'Haqhukuk',* borrowing from friends etc.

The main body of this document contains necessary technical information. But in the appendices, there is some non-technical information including that pertaining to the advantages of the traditional stone construction. It is hoped that the reader will appreciate the fact that this offers the **greenest construction alternative** to the people of the state, and could help the state earn much valuable '**Carbon Credit**', and that it will help **reduce the drain of scarce valuable resources** from the state to other states for the purchase of non-local construction materials and their transportation.

It is envisaged that this document will….

- Prompt the engineers to encourage the people to opt for the stone construction, where feasible, and that too in a way that will bring them safety.
- Encourage the agencies, government and the non-government ones, to explore the avenues for the use of traditional stone construction to take care of their needs.
- Encourage the individuals and agencies, government and the non-government ones, to explore the avenues for the use of bamboo in the traditional construction.
- Help initiate the promotion of preservation of secondary and tertiary timber, as also the bamboo, on a decentralized scale, for their application in construction.

Finally, it is hoped that, directly or indirectly, the stone construction guidelines will help bring back the confidence among the people of the state, including its engineers, in their stone construction, and will also help preserve and reinforce the unique heritage and identity of the state, namely the *Pathal house.* Just in case, the stone house that is already built is unsafe against future hazards, it could be retrofitted to make it safer at a cost that would be a small fraction of the cost of dismantling and rebuilding. In other words, an existing vulnerable Stone-*Pathal* house could be preserved through its retrofitting.

References:

1. IS:13828 – 1993– "Improving earthquake resistance of low strength masonry buildings—Guidelines"

2. IS:4326 – 1993 – "Earthquake Resistant Design and Construction of Buildings – Code of Practice (Second Revision 2002)"

3. A. S. Arya Dr. "Guidelines for Damage assessment and Post-Earthquake action. Part-III: Reconstruction and New construction in Chomoli Earthquake affected areas of Uttar Pradesh", Published by Building Materials and Technology Promotion Council (BMTPC), Ministry of urban Employment and Poverty alleviation, Government of India. January 2000

4. A. S. Arya Dr. "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

5. A. S. Arya Dr. "Guidelines for reconstruction and new construction of houses in Kachch earthquake affected areas of Gujarat". Published by Gujarat State Disaster Management Authority, Government of Gujarat, 2001.

Annexure A

Difficulties experienced in building stone house

The past several decades have witnessed major changes in the way buildings get constructed in the hills.

- The state witnessed two destructive earthquakes, one at Uttarkashi in 1991, and the other at Chomoli in 1999. Both the earthquakes witnessed severe damage to many stone buildings. Other types of buildings also suffered damage, but their numbers were small and insignificant to begin with. The damage shook up peoples' confidence in the local construction materials and technologies. Instead of understanding the actual reasons for the damage and pursuing the remedial measures, in search of safety against future earthquakes a new trend emerged that involved the use of the modern materials, namely cement and steel. This happened because as most engineers in the area, because of their education that includes only the modern technologies and excludes the traditional ones, advised people to switch over to modern technologies, and it got further strengthened by the aspirations of many to 'go modern'.

- Over the past few decades, the access to stone has become increasingly more difficult on account of various laws. Nonetheless, the stone construction continues, but on a smaller scale than before. Stone for wall construction is easily available on small scale, for example, from the fields on the mountain side, while stone for roofing is hard to find since, according to many, the mining has been fully banned. At the same time, the availability of timber has also become difficult, on account of various laws that prevent one from cutting trees, even on one's own land. This is so, in-spite of the fact that *chid* pine is found in plenty and according to many, it's spread like a weed should be controlled through its scientific felling so that it does not take over the better timber species. Many prefer to opt for RC slab over *Pathal* with the understructure made of short lasting timber like *chid* pine. Unfortunately, there is no knowledge of the option of chemically treating timber to increase its life. The option of using treated bamboo for *Pathal* infrastructure is also equally obscure.

- Incidentally, since new Pathal is hard to come by, in some areas stone slabs from Rajasthan are brought in for use as Pathal. These slabs are more uniformly cut and shaped. The fact that they are being brought in to some areas implies that the people prefer them over RC slab, for one reason or another, and that bringing in from outside also is not a unviable option. In one area, even pre-cast-concrete *Pathal* has also been used for many years by the people.

- Flat land is at a high premium in the hilly regions. There are some people who feel compelled to build house with thinner walls since they have little land to build on. Some opt to build with locally produced concrete blocks using coarse sand and pebble mix readily available in the local streams. But due to lack of knowhow the quality of concrete blocks is rather poor. As a result many prefer to go for bricks that are carted in from the plains over long distance.

- The unwillingness of the new generation women to do the regular maintenance of the mud plaster on the inner face of the walls and on floor is also a factor that is prompting people to go for cement plastered brick construction and tiled flooring at the cost of their health since the latter option makes house colder.

- In short, the traditional construction is a difficult undertaking and it involves long time to get the permission and much hard work and expense on the part of the house owner for procuring the materials starting from the identification of the source, to get it cut or broken, carted to the site etc. and later in its regular maintenance.

- As against this, the modern construction materials are readily available for the payment, and even the infrastructure necessary for its execution also is easy to find, even in the villages.

- In-spite of these factors, even today, many continue with the traditional construction practice, to one extent or another, using few modern materials for the reason of economics or comfort or lifestyle. But, a major shortcoming with what people are doing is that, barring rare exceptions, much of it is highly vulnerable in the face of a potentially destructive phenomenon like earthquake.

- Global warming: It would be fair to state, that today when we are faced with the problems of unprecedented seriousness like 'global warming" and "climate change", the industrial processes like those involved in the production of cement, steel and bricks, and also the transportation of these materials over very long distances contribute significantly to these problems. As against this, the local extraction of stone and/or pathal contributes very little to those problems. Timber on the other hand is a renewable resource that, if used, efficiently, would help ensure sustainability to house building process at a very low burden on the environment. In short, the use of the stone-timber based traditional building system would help fight the problem of "climate change", and certainly not add to it.

Annexure B

Things you should know about Stone Masonry Walls

Why Stone Masonry Walls?
In the hilly areas, since stone is the most easily accessible material, people have been using stone as the principal material for wall construction. In most areas, it is found at a very shallow depth in the fields, or even outcropping. Looking at the local resources and the local context, this is certainly the most logical choice of walling material for the region.

i. Positive Attributes

- A truly Green alternative - environmentally most friendly - High potential for earning carbon credits for the State
- High local economy component that prevents the drain of the local wealth including that to other states through the use of local materials and local artisans.
- Uses skills available locally, thus providing much needed employment to the local artisans that are unemployed or under-employed at present; helping prevent outbound migration.
- Thermally superior to thinner brick/concrete block walls; helps ensure comfortable living conditions without the use of the artificial means. Easy to maintain locally at village level in the event of damage or need for modification.
- Stone has long life - almost indestructible in the face of the elements
- Can be 100% recycled – The attribute very much valued by all the people
- Permits greater role of the house owner in material procurement process, and hence, there is cost saving.

For the above reasons stone should be promoted as a building material and not discouraged. But it must be made resistant to the local hazards. People must be made aware about why the buildings collapsed in the past earthquakes in Uttarakhand, and what improvements they should do in their buildings to prevent such damage and destruction in the future disasters. Only if they understand this they are likely to adopt better way to build and ensure their own safety.

ii. Shortcoming of Stone Masonry Walls

- Stone masonry walls have inherent weaknesses against the lateral forces of earthquake. These weaknesses result in to inadequate performance in the face of earthquake.
- Mistakes are commonly committed in the construction of stone walls, especially in the Random rubble type masonry. These mistakes further erode the strength.
- When shaken, in the poorly constructed walls having inadequate interlocking between the inside and the outside faces (wythes), the faces begin to separate, resulting in to rapid weakening of the wall. This commonly leads to the collapse of one or both wythes, thus affecting the overall stability of the structure. This is more pronounced when either the cement mortar is poorly cured or the mud mortar is used.
- In the presence of excessive openings the wall becomes weak against the tearing action caused by the earthquake forces that are parallel to the length of the wall. This results in to diagonal cracking of varying severity in the walls.

Hence, while making a choice to construct a building with stone masonry walls, the owner must make sure that the measures required to counter these weaknesses are taken during the construction so that in the event of a potentially destructive earthquake, the structure is able to withstand its impact without suffering much damage.

Annexure C

Things You Should Know About *Pathal* Roof

Positive Attributes of *Pathal* Roof

- **The Greenest roofing alternative with high potential for earning carbon credits for the State.**
- Has high local economy component that helps **prevent the drain of the local wealth including that to other states** through reduction in the use of non-local materials.
- Uses available locally skills. Thus it provides much needed employment to the local artisans who are unemployed or under-employed at present.
- Possesses excellent thermal properties that help ensure comfortable living conditions without resorting to artificial means. In other words, thermally it is far superior to RC slab.
- Offers greater role for the house owners in material procurement process which results in to cost saving.
- Easy availability of skills makes it easy to maintain locally at village level.
- Pathal has long life (almost indestructible) in the face of the elements.
- It can be 100% recycled (attribute greatly valued by all villagers).
- It resists wind uplift.
- It is less fatal in case of an earthquake as compared to RC slab since it allows easier extraction of those trapped in debris

Shortcomings of *Pathal* Roof

The Uttarkashi earthquakes of 1991 and the Chomoli Earthquake of 1999 wreaked havoc on many *Pathal*-roof houses. As a result many people called these houses unsafe against earthquake. The detailed studies of the buildings that were most severely damaged, carried out by various experts, revealed a number of reasons for their poor performance.

It was observed that they were not made with best of the traditional construction practices. As a result many traditional structural features were excluded from the construction. It was also seen that not only the basic rules of construction were violated, but in many houses modern materials were used without having adequate knowledge of how to use them. Many old houses were in dilapidated state having roof timber that was highly degraded, and as a result even a small shock was enough to break the timber in the roof. Where walls were very weak, they simply gave way, bringing the roof down with them. The most important structural weakness that was responsible for the destruction was that the connections between various roof elements were either inadequate or simply non-existent. As a result, not only the roof lacked the much needed diaphragm action, but it was too loosely put together to maintain its integrity, even in moderate shaking.

All this, however, means that the roof could easily be made earthquake resistant if care is taken to ensure good quality, and to ensure that earthquake resisting features are not left out during the construction. On the other hand, if care is not exercised, even a newly built structure is vulnerable in the face of a moderate earthquake.

Degradation in timber floors and roof under-structures

The recent earthquakes have revealed that this timber based system has degraded greatly, and has resulted in to the increased vulnerability of the buildings. The principal causes are…

- Timber availability from the forest has become greatly restricted due to the enactment of the forest laws and Supreme Court Ruling.
- Timber from the fast growing trees like *Chir* Pine that can be obtained from forest succumbs to insect infestation rapidly and hence, people are afraid to use such timber.
- Unavailability of durable timber…
  - Prevents timely maintenance of sagging roof which results in to collapse of roof.
  - Results in to walls that are too weak to resist the lateral loads of earthquake, resulting in to collapse of walls as well as roof resting on them in the event of a major earthquake.
- The skill levels have degraded over past several decades resulting in to the dilution of construction standards and construction with many mistakes

Annexure D

Timber Preservation Treatment

There are two easy options for carrying out the treatment of timber at any location with minimum infrastructure.

1. **Dip Method:** This involves simply dipping of the cut timber in a bath of preservative for 48 to 72 hours.
2. **Hot-Cold Method:** This involves dipping first in hot water bath as described below and then dipping in the preservative bath for 48 to 72 hours.

The treated timber must be dried in horizontal position under pressure in shade to prevent bending and warping before using it. For this the timber is placed in multiple layers criss-cross to allow aeration. The top layer is weighed down with the help of sand bags to prevent timber from warping as it dries.

The following are the details of the Hot-Cold Method. For Dip Method, however, the heating part of the process is to be eliminated.

Equipments:

- Rubber hand gloves
- 2 troughs 2'wide X 1'deep with length 1'longer than the length of timber to be treated
- 1 cover for the trough
- 15 sand bags, 20 kilos each
- 1 bucket
- 1 weighing scale
- 1 thermometer which can read up to 100º centigrade
- 1 special hydrometer for this process

Material:

- Chemical-Copper Chrome Arsenic, OR Copper Chrome Boron - 3 kgs/cu.m. of timber
- Water
- Timber for fire

Process:

1. Remove bark, cut to the required length and shape as required, the timber to be treated.
2. Fill one trough with water so that all the timber to be treated can be soaked.
3. Fill second trough with chemical solution prepared by adding 10% (by weight) chemical in water. Use timber stick to thoroughly mix chemical with water.
4. Light fire under the water trough and bring the temperature of water up to 80º C.
5. Fill the trough with as much timber as possible, keep the fire going and soak the timber in water at 80º temperatures for one hour.
6. After one hour, transfer the timber immediately to the trough with chemical solution. Soak them in chemical for 24 hours. Make sure all timber is soaked completely in the chemical solution.
7. After 24 hours, timber must be removed from the chemical solution and placed in shade for drying. They must be placed flat on ground, keeping 6” space between them. Place sand bags on all the timber so that it does not warp during drying.
8. For best result dry timber in this manner for 60 days.

Note:

1. The chemical- Copper Chrome Arsenic is poisonous. so use gloves while working with this chemical. Copper Chrome Boron also requires care in handling and disposal. But it is not as toxic as the former. The trough with this chemical solution must be kept covered all the time. Keep children away from this area.
2. Once the treatment is finished, do not discard the chemical indiscriminately out in open since it may contaminate water sources.
3. It is preferable to store the used chemical solution in plastic drums for future use.
4. If, for any reason, the treated timber has to be cut then brush on the chemical on to the cut surfaces four to five times.
5. The trough can be made economically from metal drums, which can be cut and welded to form the trough. This does not need any support. It can be set on bricks placed in mud mortar. Only thing it needs is cross bars at three to four locations which can be inserted through holes made in opposite walls. This will help retain the shape and will be easy to immerse the timber in the trough.

DMMC

Disaster Mitigation and Management Centre, Dehradun,

(An Autonomous Institute of the Department of Disaster Management, Government of Uttarakhand)