Mason's Handbook

on Disaster-Resistant Construction in Jammu and Kashmir

Part A:

Stone Masonry

First edition 2019

Taru VMS JV LLP in collaboration with People in Centre Consulting

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Mason's Handbook

on Disaster-Resistant Construction in Jammu and Kashmir

Part A: Stone Masonry

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JEHLUM & TAWI FLOOD RECOVERY PROJECT

Jhelum and Tawi Flood Recovery Project (JTFRP)

Taru VMS JV LLP with People in Centre Consulting

Foreword

Acknowledgments

The authors are grateful to the following individuals involved with Jhelum and Tawi Flood Recovery Project (JTFRP), Government of Jammu and Kashmir for their valuable and timely inputs towards the development of this document:

Mr. Iftikhar Ahmad Hakim, Director Planning & Coordination
Mr. Iftikhar Ahmad Kakroo, Director technical
Mr. Shabeer Hussain Alamgir, Assistant Executive Engineer (Civil)

We are thankful to the teams from VMS Consultants and Taru Leading Edge Pvt. Ltd. who gave us inputs at various stages and provided us ground information regarding the current trends of construction practices in the state of Jammu and Kashmir.

We would also like to thank the team involved with the translation of this manual in Kashmiri, Hindi and Urdu, allowing a greater and effective outreach of information.

Contents

1. Introduction

Jammu & Kashmir is a state prone to multiple natural hazards such as earthquakes, landslides, cloudbursts and flooding, many of which are in the severe category. Poor and unsafe construction practices are prevalent in both urban and rural areas today, increasing people's vulnerability to natural hazards. This is noticed in both engineered and non-engineered buildings. Hence, there is a need to develop and propagate construction practices that make these buildings safe. It is also imperative for these construction practices to be deeply rooted in the local context of the state of J&K, such as prioritising use of locally available materials, skills and responding to the local climatic conditions. This should be done keeping in mind the lifestyles, habits, traditions, needs and aspirations of the people of J&K.

Some of the traditional construction practices in J&K use locally available stone, brick, adobe and timber for walls and primarily timber for roof understructure. Additionally, newer technologies such as cement blocks and RCC construction systems are being used in the recent times. For the purpose of this document, we broadly classify the construction practices in J&K under two categories: *load bearing construction* using stone, brick and adobe and *framed construction* using infill materials such as brick, adobe and timber.

Most of the housing in India is non-engineered and led by masons, House-owners depend upon the head masons to provide guidance on choice of materials, technology, design, construction and cost estimation. Since masons provide such critical services, it is important to strengthen their capacities to reduce the impacts of disasters. It is with this objective that JTFRP is conducting training of masons and preparing mason handbooks. Though there should be multiple construction options to choose from, the trainings and the handbooks cover two options; stone masonry, a traditional load-bearing option and confined masonry, a load bearing system using modern materials such as cement and RCC. It should be noted that the list of rules and measures given in this handbook are not exhaustive, though the most critical rules have been covered. The understanding of the underlying principles should help the mason to evolve measures for other situations.

This handbook includes details for a ground storey house constructed with stone masonry walls, timber understructure and CGI sheet sloping roof. The topics covered include: safe siting of the house, the foundation, plinth, walls, openings, intermediate floor and roof, covering guidelines, steps for construction and hazard-resistant features in each element to reduce the vulnerability of the structure when the disaster strikes. All dimensions in the handbook are in metric system.

The handbook is a reference material for the masons on how to practice good and safe construction in Jammu and Kashmir. However, the building codes must be referred to and should take precedence in case of any inconsistency or ambiguity.

The handbook is divided into thirteen chapters. The first two chapters are *Introduction* and *Hazard Risks in Jammu and Kashmir* respectively, laying a foundation for the need and relevance of this handbook.

The third chapter, *Site Selection*, enumerates various guidelines on safely locating a house on a particular site, while taking into consideration the natural features and properties of the site and soil.

The fourth chapter, *Building Configuration and Layout*, enlists the rules that must be kept in mind while designing a safe house, with respect to building dimensions, setbacks and layout.

The fifth chapter, *Construction Materials*, lists the various points that need to be kept in mind while choosing and using materials to ensure safe and good quality of construction. The materials covered in this handbook are stone, sand, aggregate, cement, steel, timber, CGI sheets. The rules for mixing cement mortar and concrete have also been covered in this chapter.

The sixth chapter, *Foundation*, includes the basic guidelines that must be followed while designing a foundation, as well as a step-by-step process of construction till the plinth level. Seismic-resistant features such as vertical reinforcement have also been discussed.

The seventh chapter, *Plinth*, includes rules for determining plinth height and construction steps of the plinth band.

The eighth chapter, *Walls*, includes the basics of laying stone masonry, including features such as through stones, corner stones and seismic bands and a step-by-step explanation of the construction process till the roof.

The ninth chapter, *Openings*, discuss the appropriate placement and design of openings in a house to reduce its vulnerability against horizontal seismic forces.

The tenth chapter, *Intermediate Floor*, primarily discusses two construction systems; timber joists and planks and RCC slab. Both guidelines and steps of construction have been discussed for the timber joists and planks system, including additional features such as diagonal bracing. Though basic rules for ensuring good quality of construction of an RCC slab have been discussed, we highly recommend consultation with a qualified engineer for the design of the RCC slab.

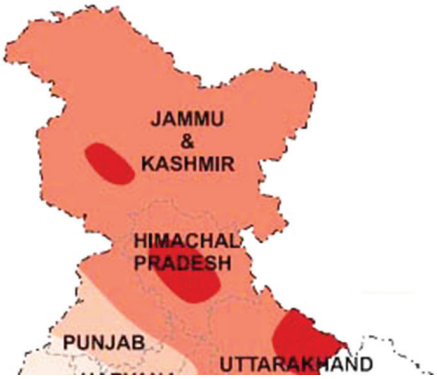
The eleventh chapter, *Roof*, includes the principles of designing a safe roof and a step-by-step process of constructing the roof.

The twelfth chapter, *Gable Wall*, mentions the points that should be kept in mind while designing a gable wall. The thirteenth chapter illustrates a completed house with all the hazard-resistant elements.

2. Hazard Risks in Jammu and Kashmir

The state of J&K is susceptible to the impacts of multiple hazards such as earthquakes, landslides, cyclonic winds and occasional cloud bursts. The following maps illustrate the intensity of the risks faced by the state against these disasters.

Seismic zones: J&K falls under Seismic Zone 4 and 5, making it prone to earthquakes of high magnitude and intensity.



Seismic Zonation

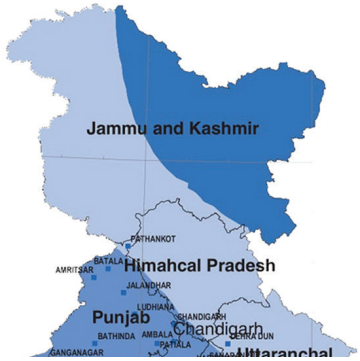
- Zone - V (Highest)
- Zone - IV (High)
- Zone - III (Moderate)
- Zone - II (Least Active)

Lanslide zones: All parts of J&K are highly prone to landslides.

Landslide Zonation

- Highly Affected
- Moderately Affected
- Marginally Affected

Wind zones: Ladakh region experiences high intensity cyclonic winds, whereas Jammu region and Kashmir region experience moderate intensity winds.

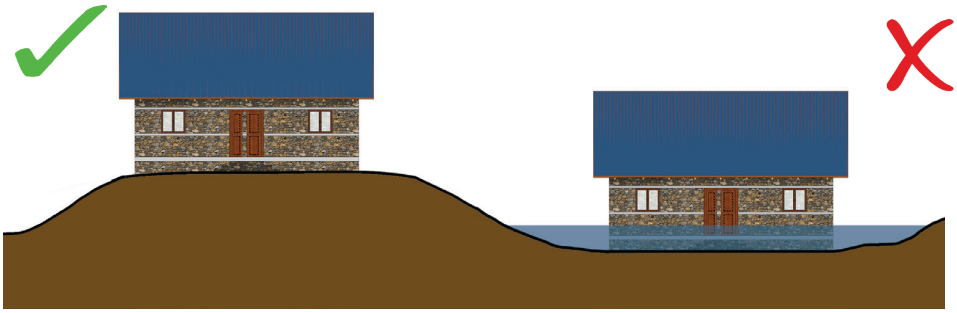


Wind and Cyclone Zonation

- Very High Damage Risk Zone - A (V_b=55 m/s)
- Very High Damage Risk Zone - B (V_b=50 m/s)
- High Damage Risk Zone (V_b=47 m/s)
- Moderate Damage Risk Zone - A (V_b=44 m/s)
- Moderate Damage Risk Zone - B (V_b=39 m/s)
- Low Damage Risk Zone (V_b=33 m/s)

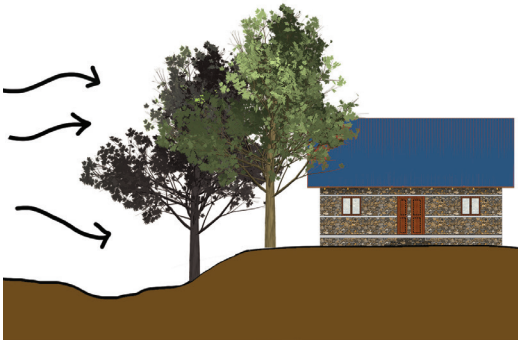
3. Site Selection

- Low lying areas of the region must be avoided. A site with good drainage and on high ground must be preferred.



The house on the left is on elevated ground and on the right is on a low-lying region.

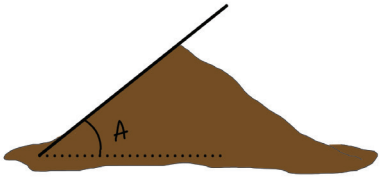
- To protect the house from excessive winds, the house must be built on the leeward side of natural features such as trees and/or mounds as they act as natural wind breakers.



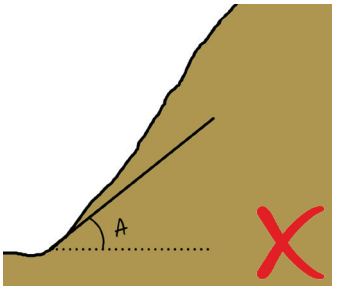
Beside natural tree cover

Beside natural mounds

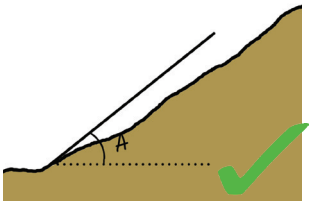
- To determine the suitability of the slope of the site, the angle of repose of the site must be checked. If a slope is steeper than the angle of repose of the soil, there is a concern regarding its stability against landslides.



A = Angle of repose

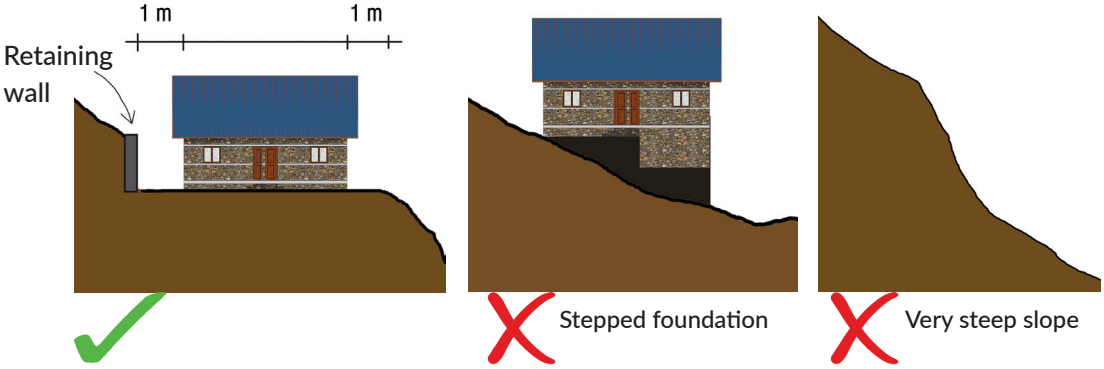


Slope greater than angle of repose

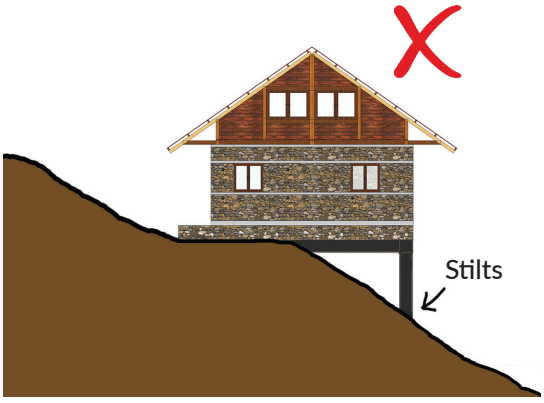


Slope lesser than angle of repose

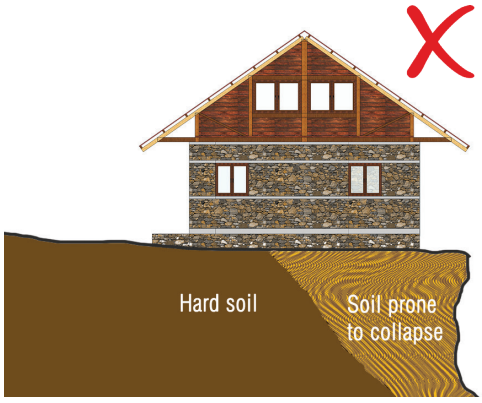
- The site must always be levelled before commencement of construction. The house must be at a distance of least 1m away from top of slope and 1m away from the edge. A retaining wall must be constructed to support very steep cut slopes before building the house. Avoid building on very steep slopes or using stepped foundations.



- Sites requiring supporting structures for the house or those at the edge of a cliff must be avoided.

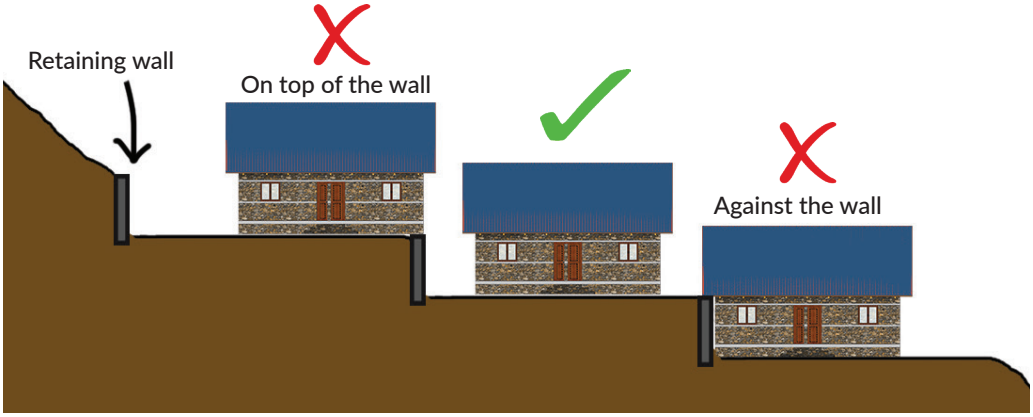


Site requiring supporting structures

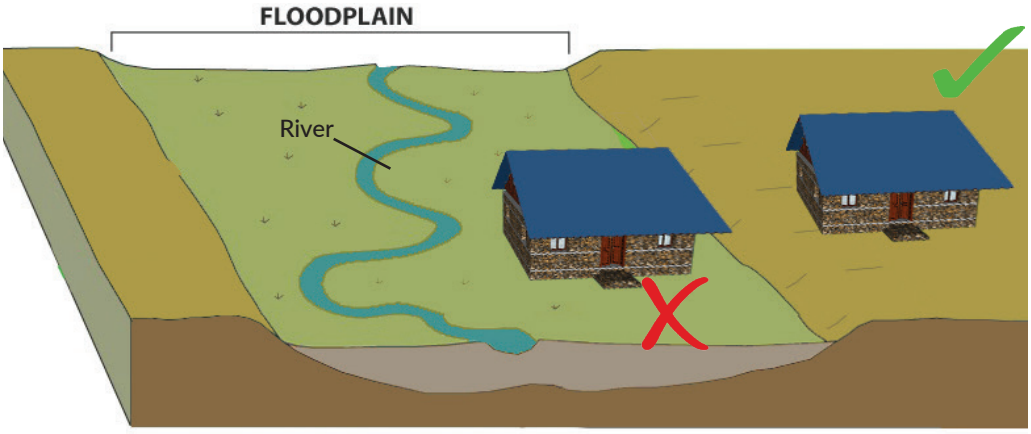


Near a cliff

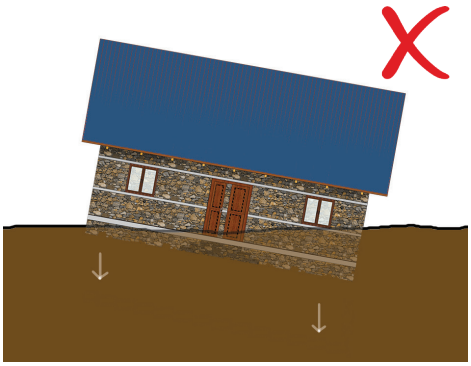
- The house must not be built on top or against a retaining wall.



- The house must be built far away from the inundation lines of the water body. Building on flood plains must be avoided.



- Bearing Capacity is the capacity of soil to support the loads applied to the ground. Soil with high bearing capacity is suitable for construction. A soft soil, which is not fully compacted, will have low bearing capacity whereas hard soil has high load bearing capacity.



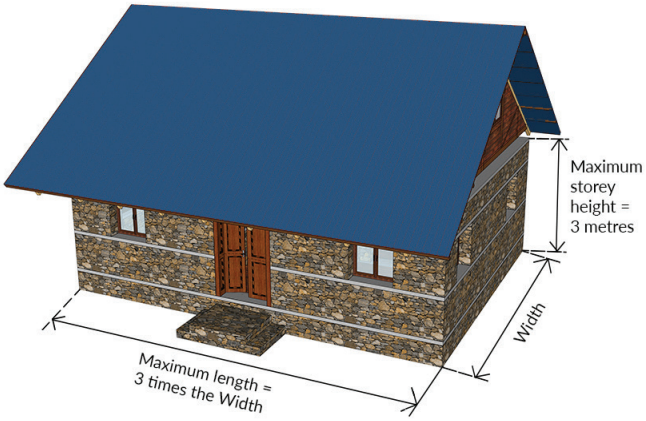
Low soil bearing capacity makes the house prone to sinking

Identifying Soft and Hard Soil:

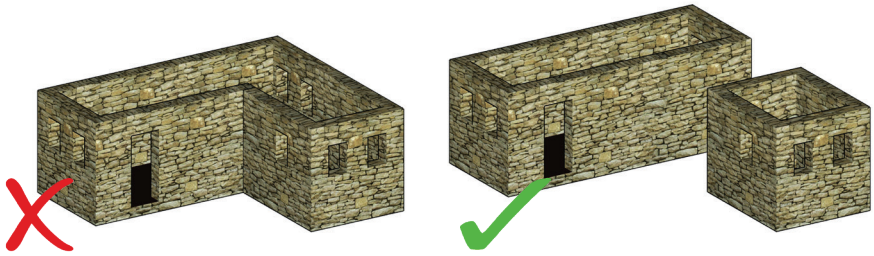
- Remove top 150mm of soil, and all the filled in soil so that natural soil is exposed.
- Take a crowbar of approximately 1.5m length and about 4.5 kg weight.
- Hold it vertically with its sharp point towards the ground, about 600 mm above the ground, and drop the bar.
- Ensure the bar falls vertically on the ground.
- Based on the penetration of the bottom end, determine if soil is hard or soft.
- Use a penetrometer if possible.

4. Building Configuration and Layout

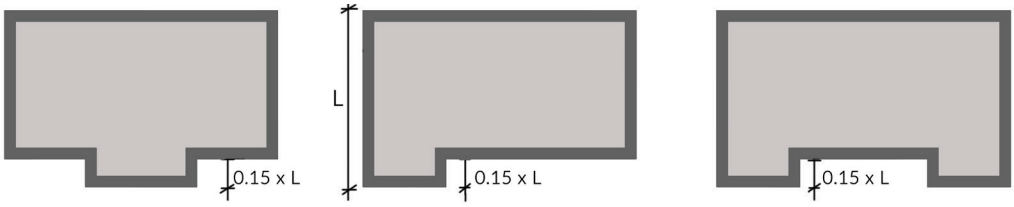
- The plan of the house must be symmetrical and not too long. The length should not exceed 3 times the width of the house.



- Complex shapes of the house such as H and L should be broken into simple shapes which are at a safe distance from each other.

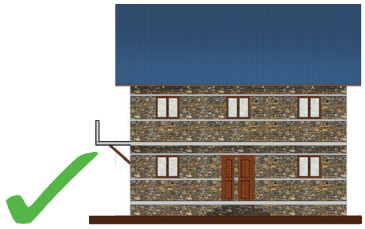


If such complex shapes are unavoidable, do not exceed the dimensions shown below.



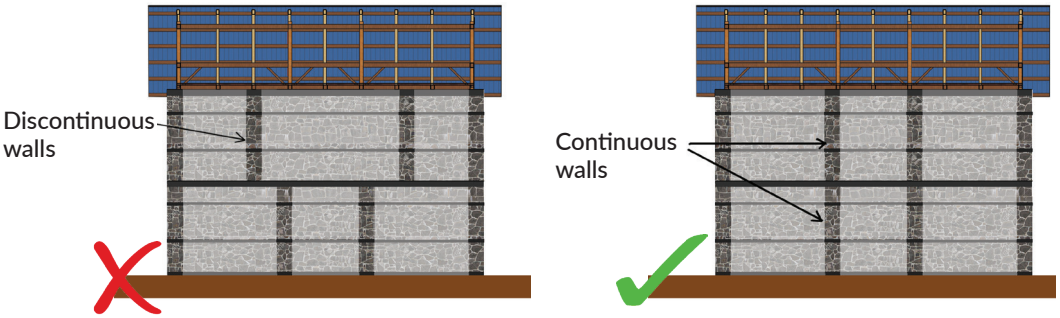
- All cantilevers must be supported using brackets or columns. Avoid building large cantilevers without supports.

Large unsupported cantilevers

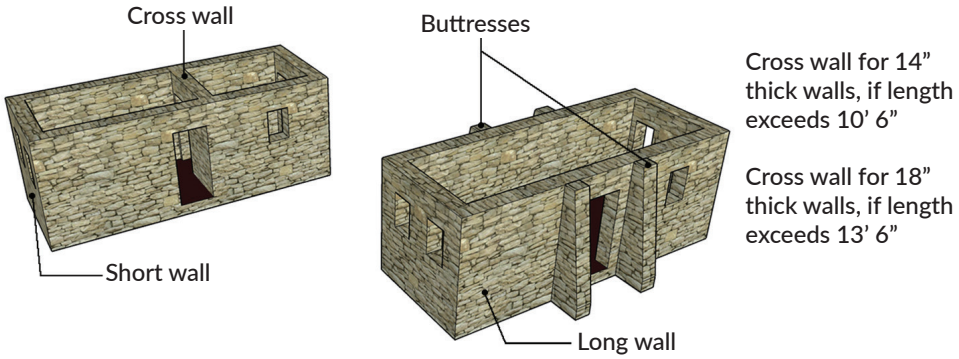


Small cantilevers (not more than 900mm) supported with brackets

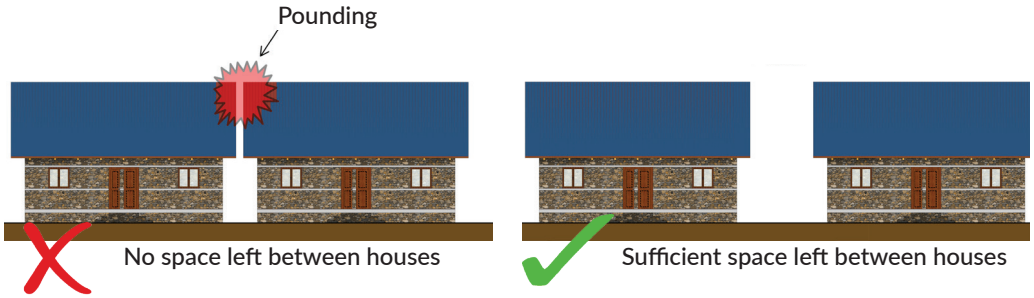
- Walls on all floors must be placed one on top of each other, such that they are continuous from the ground level up to the building height.



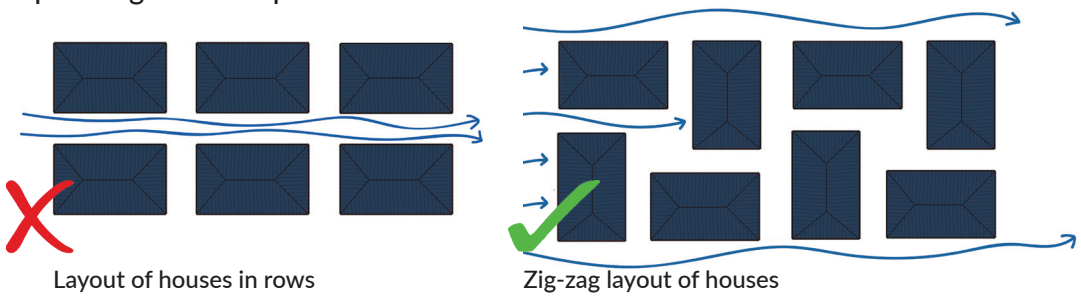
- If the length of either the long wall or the short wall exceeds 9 times the thickness of the walls or 7m, whichever is lesser, at least one cross wall or a buttresses must be built for lateral support.



- Two houses should not be built too close to each other to avoid pounding. It is advisable to leave sufficient space in between two buildings.



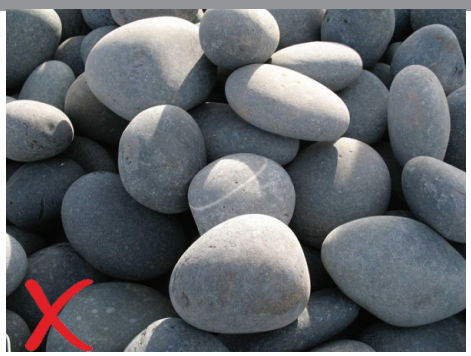
- Layout of houses in rows increases speed of wind and water while zig-zag planning reduces speed of wind and water.



5. Construction Materials

Stone

- Cut stones or well shaped mountain stones should be used.



- Round river stones with smooth texture or soft stones that can be scratched with a knife should not be used.

Sand

- Coarse sand for concrete and mortar, and fine sand for plaster should be used.
- Sand must be sieved and washed to remove dust, clay and other foreign matter.

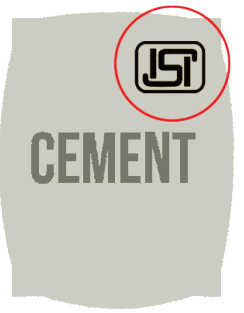
Aggregate

- A mix of aggregate sizes ranging from sand to 20 mm must be used.

- Round pebbles should not be used as aggregate in concrete.

Cement

- The cement in the bag must be dry and powdery.
- Cement should be stored in a cool dry place.
- Cement should be safe from ground moisture and air humidity. Therefore, cement should not be stored for long and if being stored, it should be wrapped in plastic.
- Only cement bags with an ISI mark should be used.



Note: Grade of cement: 53 grade cement achieves strength faster, making curing in the initial period critical. 43 grade cement takes longer to achieve the same strength.

Steel

Deformed steel for main bars

Plain steel for stirrups

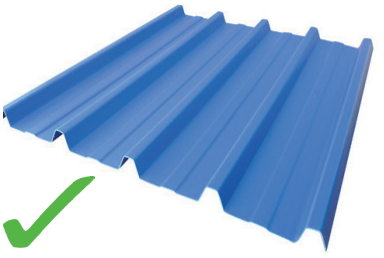
- Steel bars which have the ISI mark should be used.
- Bars which are corroded, rerolled or made out of recycled steel should not be used.

Timber

- Hard wood should be used for structural members.
- Timber used should be well seasoned and dry.
- The timber being used should not be infested by termites.

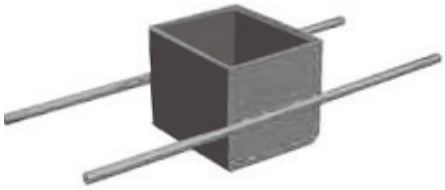
Corrugated Galvanised Iron (CGI) Sheets

- CGI sheets with the ISI mark should be used.
- The recommended thicknessof the sheet for roofing application is 0.63 mm (25 gauge)
- Sheets which are corroded or damaged in any way should not be used.
- Pre-coated CGI sheets are recommended due to their durability against corrosion.



Pre-coated CGI sheets

Mixing Cement Mortar

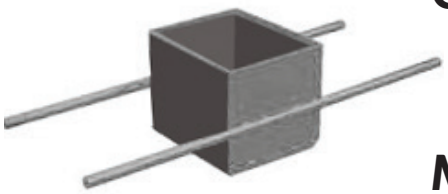


Measuring box

Cement : Sand
1 unit : 6 units

- A measuring box should be used to measure quantities.
- Dry cement and sand must be mixed well together before adding water.
- The water quantity must be adequate but not excessive.
- Dried mortar should not be refreshed by adding water.
- The mortar should be made into a ball to confirm its consistency.
- Only enough mortar should be mixed that can be used within 1.5 hours.
- Mortar that has started to harden should not be used.
- The mortar mixing area must be protected from wind, rain and sunshine.

Mixing Concrete



Measuring box

M: 20

Cement : Sand : Aggregate
1 unit : 1.5 units : 3 units

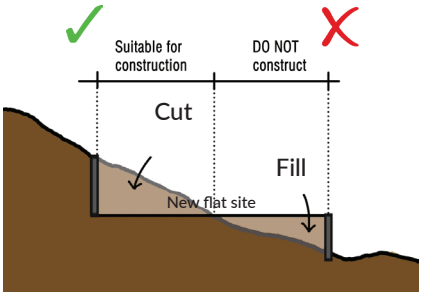
M: 15

Cement : Sand : Aggregate
1 unit : 2 units : 4 units

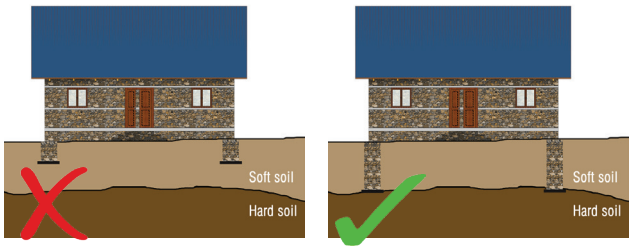
- A measuring box should be used to measure quantities.
- Dry cement and sand must be mixed well together before adding water.
- The water quantity must be adequate but not excessive.
- A slump test must be performed using freshly mixed concrete.
- Only enough concrete should be mixed that can be used within 2 hours.
- Dried concrete should not be refreshed by adding water.
- Concrete that has started to harden should not be used.
- Concrete should be cured for 7 days before removing formwork.

6. Foundation

- The site must be made flat, and the house must be constructed only on natural ground.

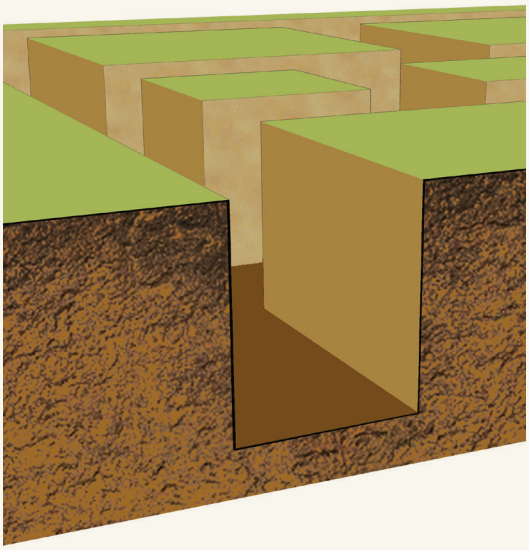


- The foundation depth must be such that the base hits hard ground. Minimum foundation depth is 750 mm, but it may be more depending on soil conditions.

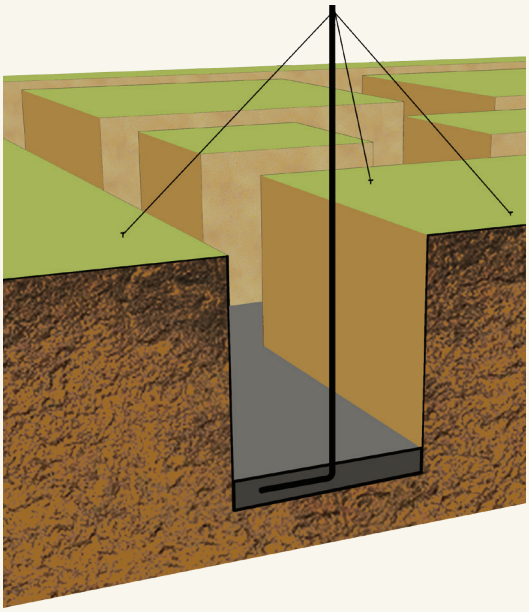


- Foundation depth should be measured from the natural ground line.
- Foundation width for single storey house is 750 mm, and 900 mm for two storey house.

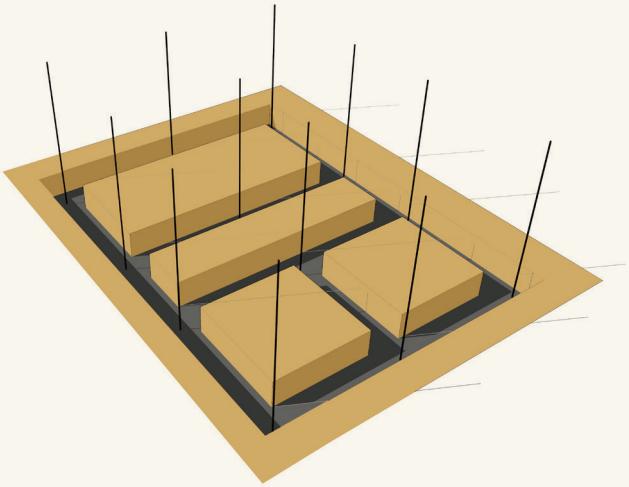
Construction steps:



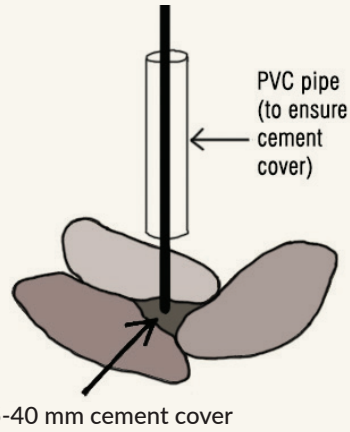
Step 1: Excavate minimum depth or till firm ground is reached, which ever is more. Ram and compact well.



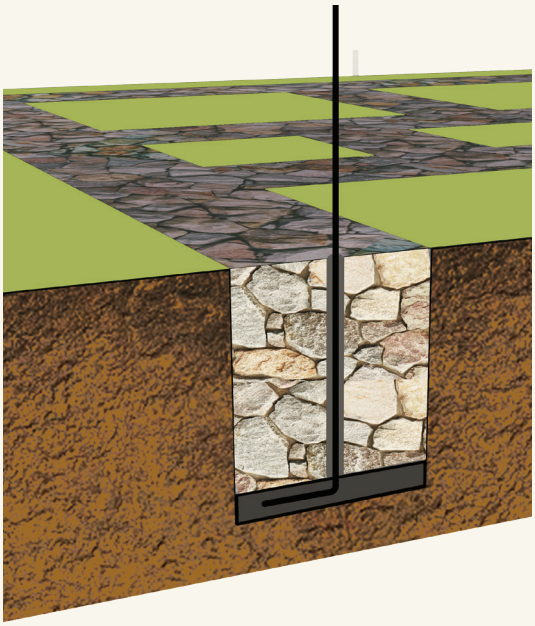
Step 2: Make a 100mm base of Stone and brick bats with lean mortar
Install 12 mm TOR vertical reinforcement at all corners and junctions, encase the bent bar in concrete and keep in place using strings or timber members.



Install all vertical reinforcements before filling the trench.



Step 3: Leave a cement cover of 25-40 mm on all sides of the reinforcement. Before starting masonry, place a PVC pipe 75 mm dia and 900 mm long starting at the cement base.

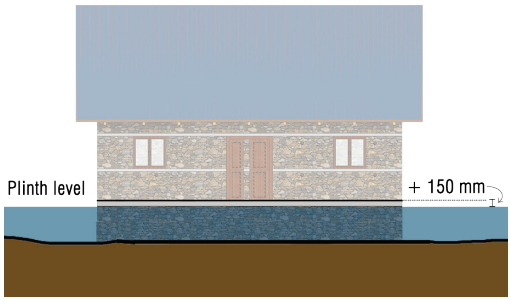


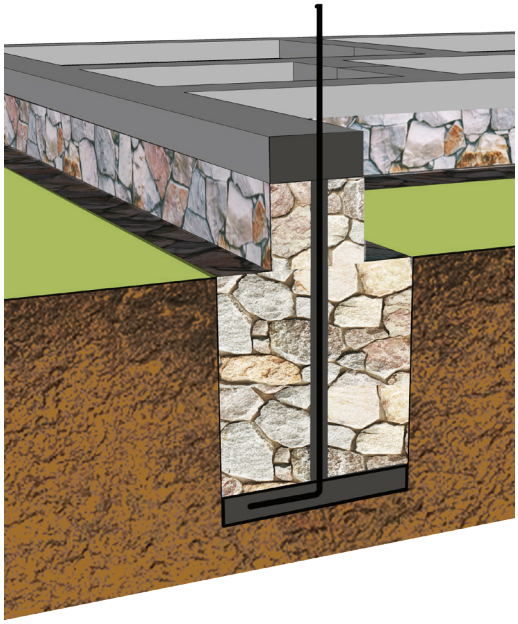
Step 4: Fill the entire trench with stone masonry. Level out the course at ground level with the help of a water tube. Lift the PVC pipe after every 900 mm of masonry and fill the void with concrete. Tap the bar with a hammer to settle the concrete to the bottom.

Step 5: Reduce masonry to wall width (400 mm) at ground level and lay stone masonry till 150 mm below plinth level and level it using water tube. Use basic principles of stone masonry (Pages 16-17).

7. Plinth

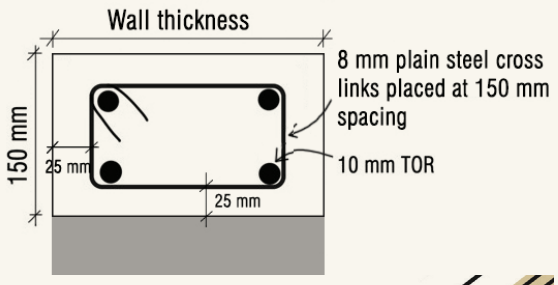
- Plinth height must be at least 150 mm higher than the known annual average flood level or the submersion level as per the flood zonation maps or local knowledge.
- An RC band 150 mm thick must be layed on top of the wall. The width of the band must be equal to the width of the wall. It must be continuous and run over all walls.

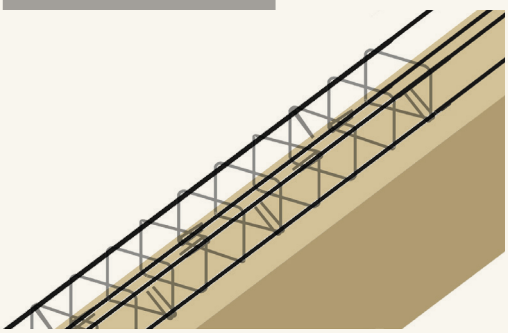


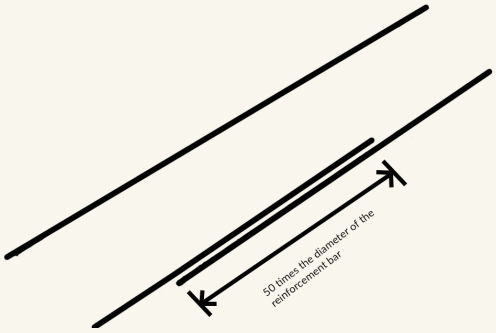


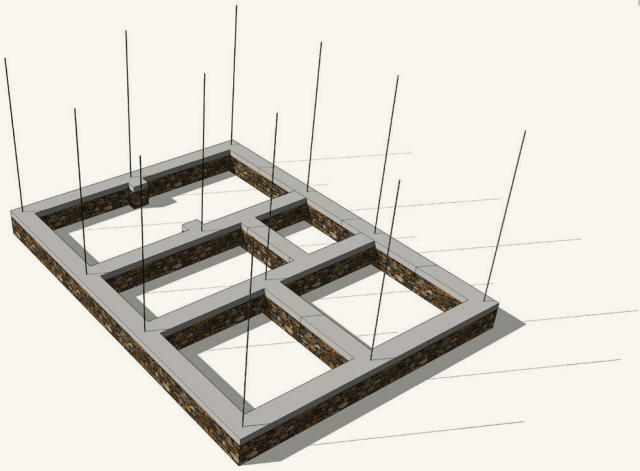
Construction steps:

Step 1: Lay the reinforcement cage on the wall. Four longitudinal bars are placed 25 mm inside from the wall faces. Raise the bars 25 mm from the stone course using spacers such that it doesn't touch the course. Tie the bars together using stirrups placed at a spacing of 150-200 mm, and tie the whole cage to the vertical reinforcement.





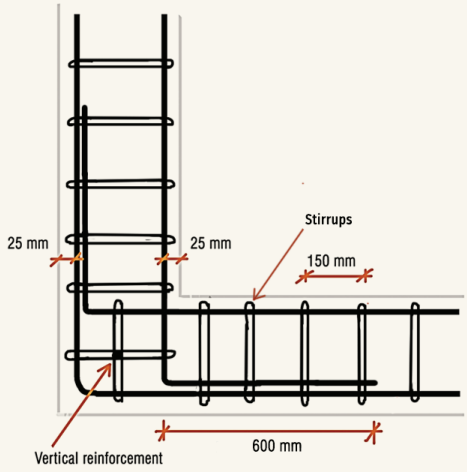


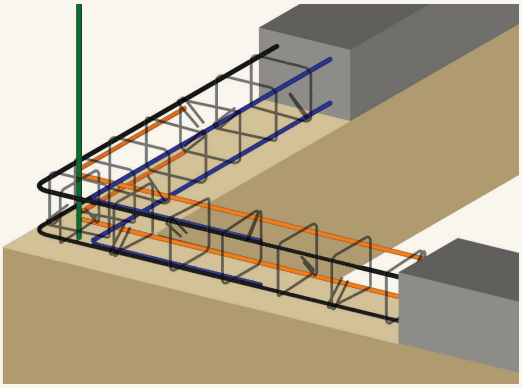


Step 2: To connect two main bars, the overlap must be 50 times the diameter of the main bar and tied well together.

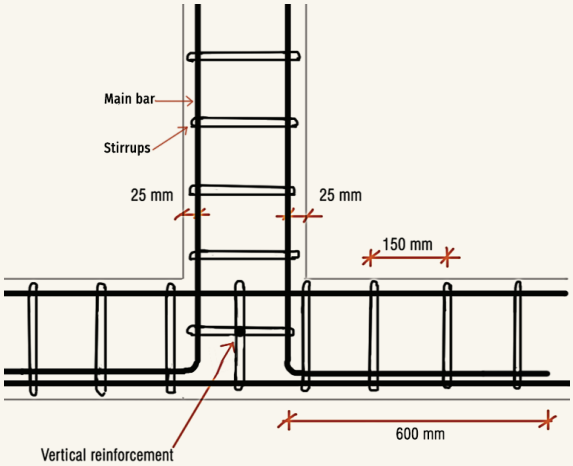
Step 3: Cast the cement and cure for atleast 7 days. Formwork can be removed after 2 days.

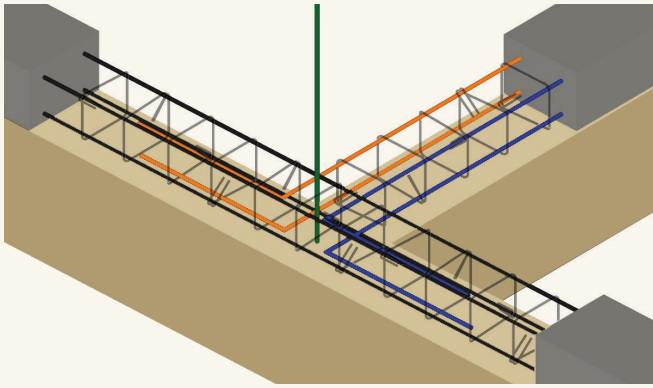
L junction detail (150 mm, 4 bars)





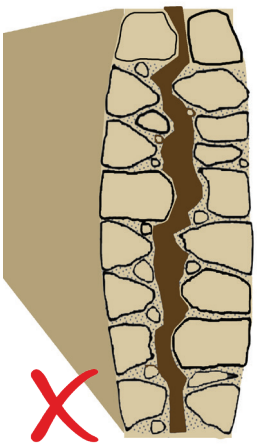
T junction detail (150 mm, 4 bars)





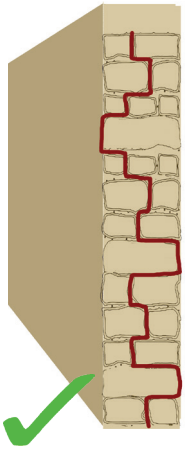
8. Walls

- Wall thickness should not exceed 450 mm.
- Each stone must be placed flat on its broadest face.
- All masonry must be in plumb and water levelled at regular courses.



Wall Section

- Continuous joints cause outward bulging of the wall, hence must be avoided



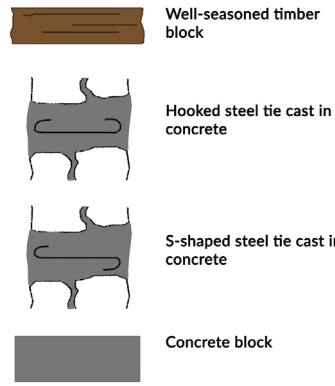
Wall Section

Plan

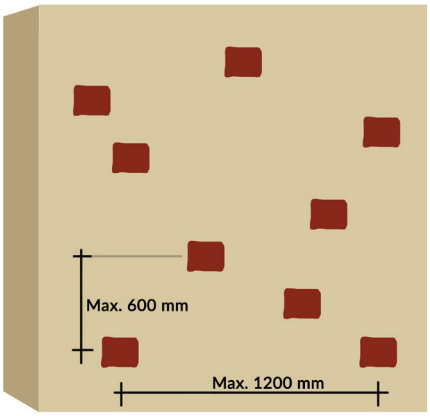
- The joints must be staggered both vertically and horizontally and all voids must be filled.

Through stones:

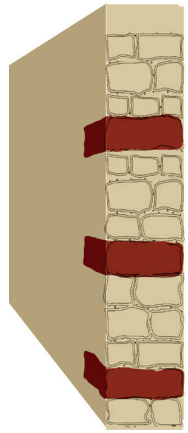
- The length of through stones must be equal to the width of the wall.
- The through stones must be placed every 600 mm in height of the wall and at 1200 mm throughout the length of the wall.



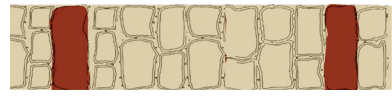
Alternatives to through stones



Elevation



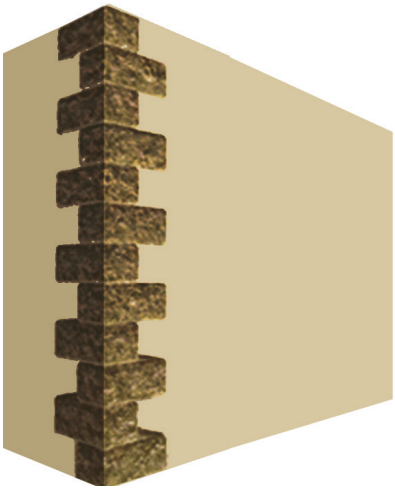
Wall Section

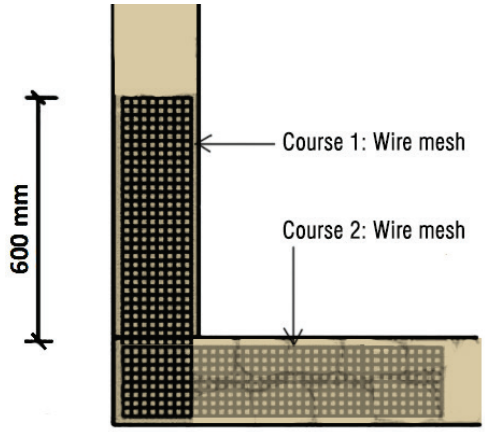


Plan

Corner stones

- To make the corners of the wall stronger, large corner stones must be used, longer than the wall thickness.
- Course stones at each corner should be water levelled.

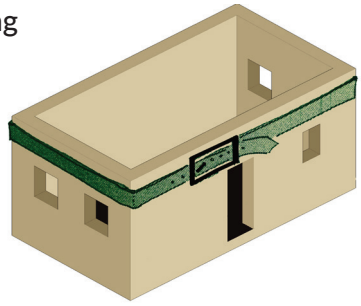




- Alternately wire mesh can be used. Lay them in opposite direction in every course and encase well in cement.

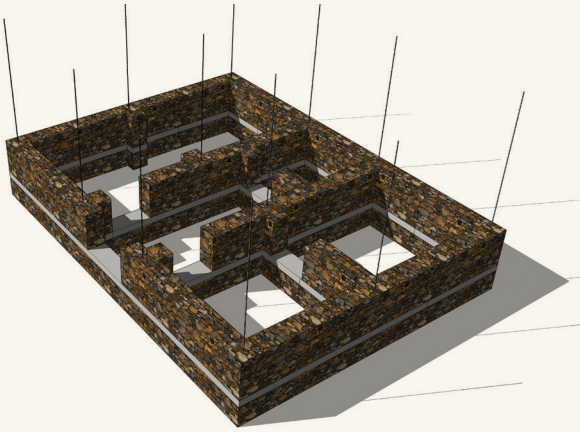
Seismic Bands

- Seismic bands tie the walls together such that, during an earthquake, they don't shake independently of each other and the whole structure shakes as one unit, causing lesser damage to the walls.

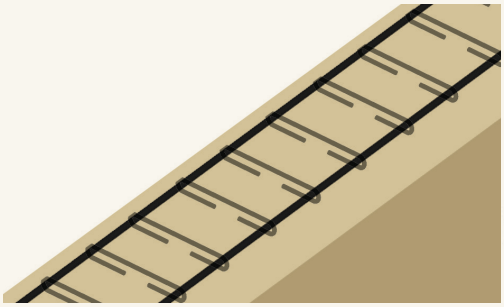


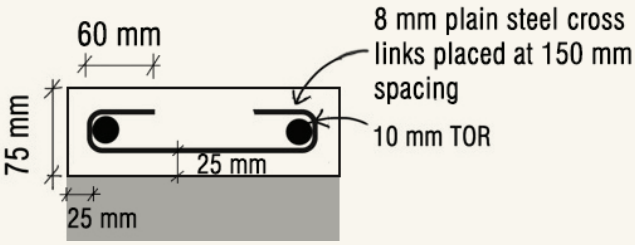
- Bands must be placed at four levels; Plinth, Sill, Lintel and Roof.
- Plinth band, lintel band and roof band should be continuous. Sill band will be broken at the door openings.
- Bands must be connected properly with the vertical reinforcement.

Construction steps:

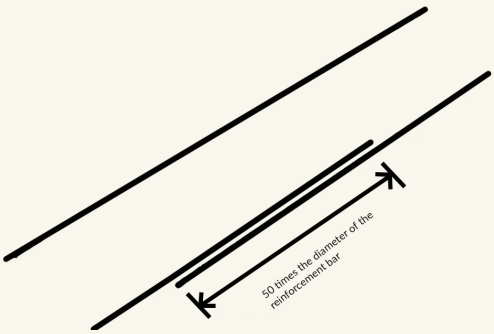


Step 1: Lay stone masonry till sill level (900 mm), with levelled courses at height intervals of 600 mm. Construct maximum of 900 mm in one day.

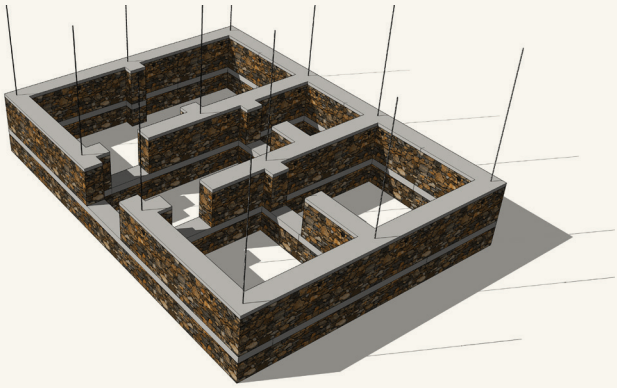




Step 2: Lay the reinforcement cage for the sill band. Place two longitudinal bars 25 mm inside from the wall faces. Raise the bars 25 mm from the stone course using spacers such that it doesn't touch the course. Tie the bars together using stirrups placed at a spacing of 150-200 mm, and tie the whole cage to the vertical reinforcement.

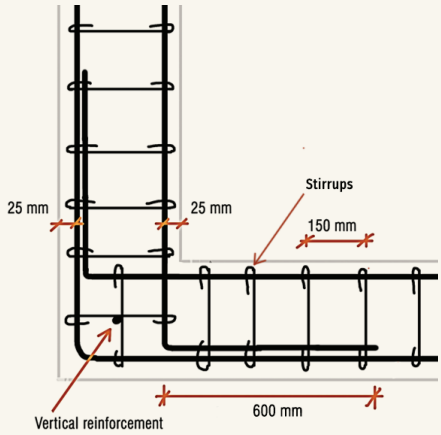


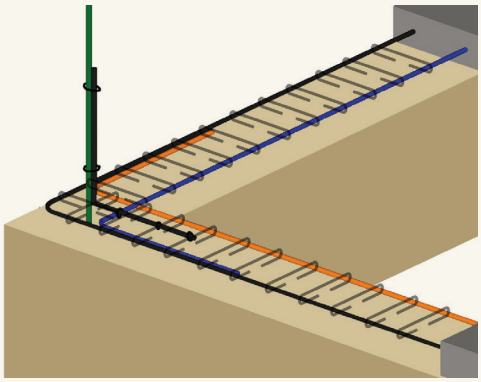
Step 3: To connect two main bars, the overlap must be 50 times the diameter of the main bar and tied well together.



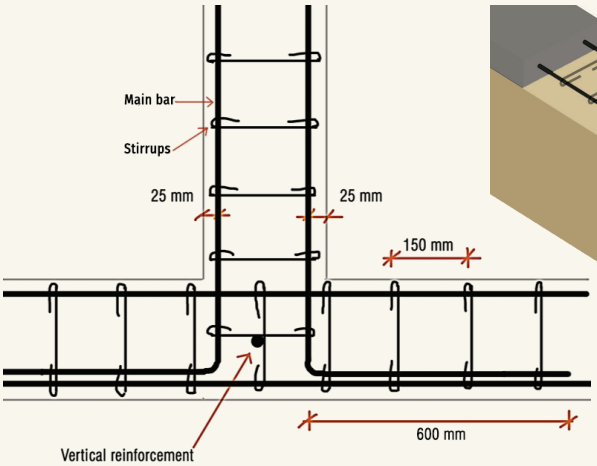
Step 4: The cement must be cured for atleast 7 days. Formwork can be removed after 2 days.

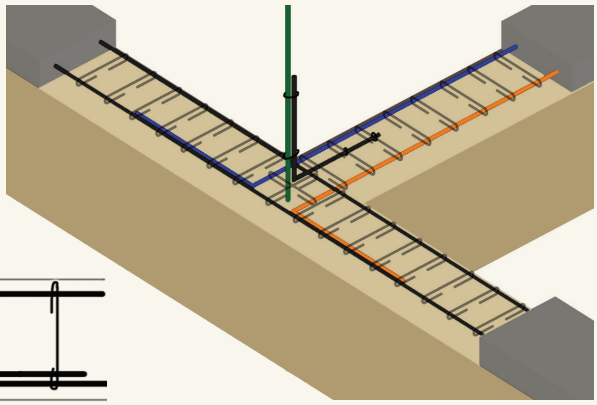
L junction detail (75 mm, 2 bars)

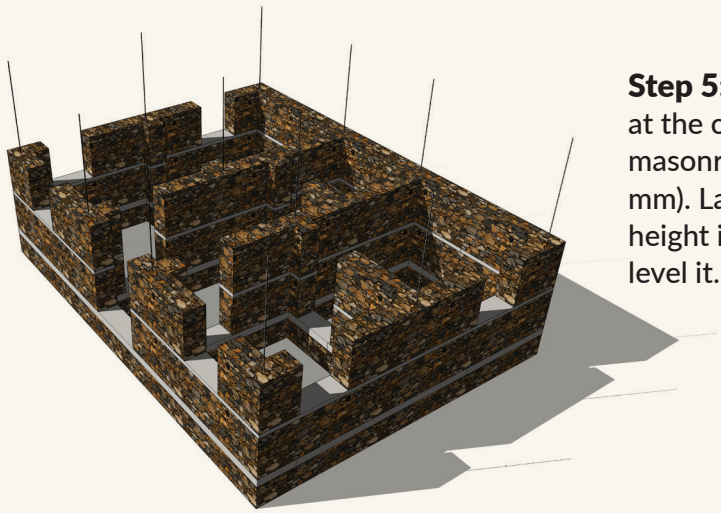




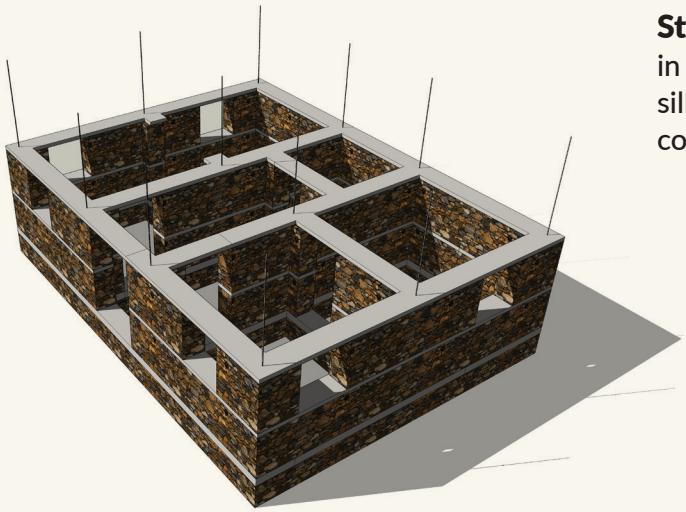
T junction detail (75 mm, 2 bars)



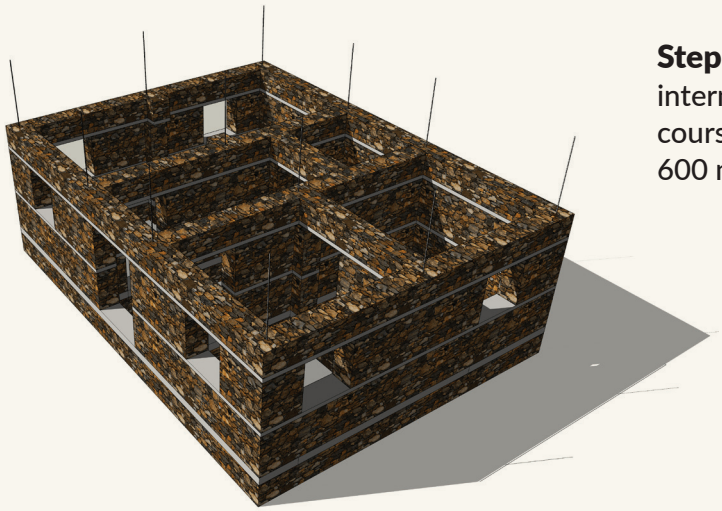




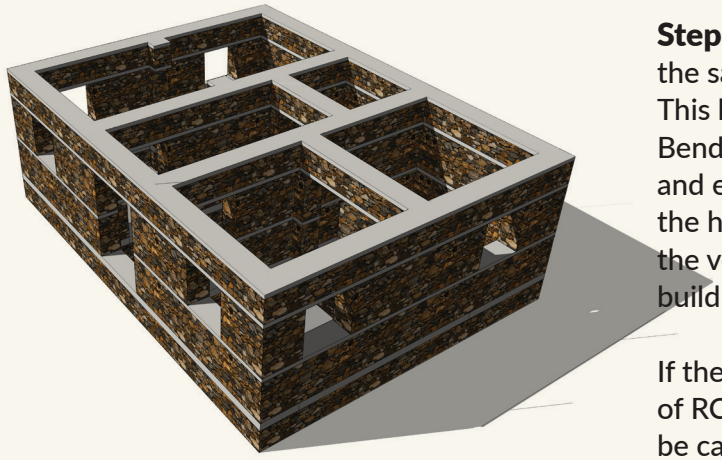
Step 5: Install the timber frames at the openings and lay stone masonry till lintel level (1800 mm). Lay coursed masonry at height intervals of 600 mm and level it.



Step 6: Lay lintel level RC band in the same manner as the sill band. This band must be continuous.



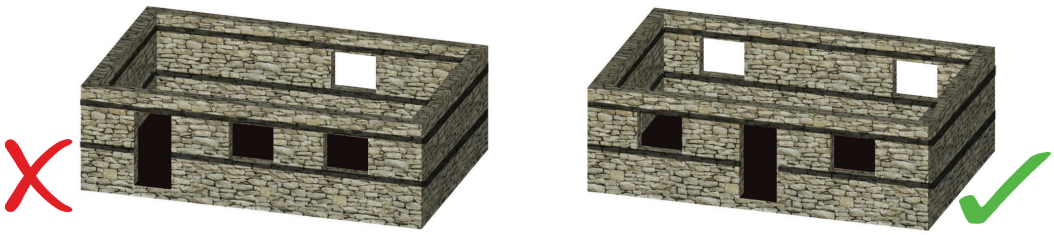
Step 7: Lay stone masonry till intermediate floor level, with courses at height intervals of 600 mm.



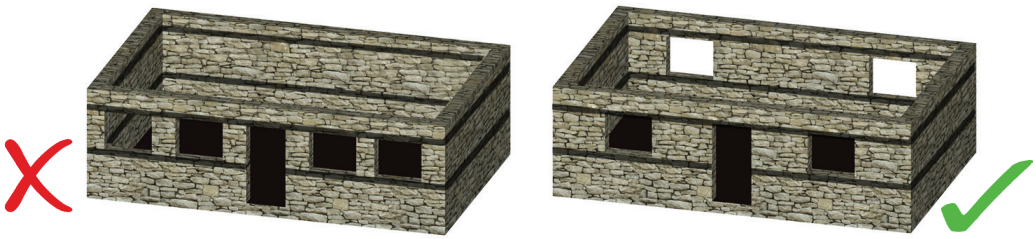
Step 8: Lay roof level RC band in the same manner as the sill band. This band must be continuous. Bend the vertical reinforcement and end it in the roof band. If the house is G+1, then continue the vertical reinforcement till building height.

If the intermediate slab is made of RCC, the roof band will not be cast as it is a part of the slab itself.

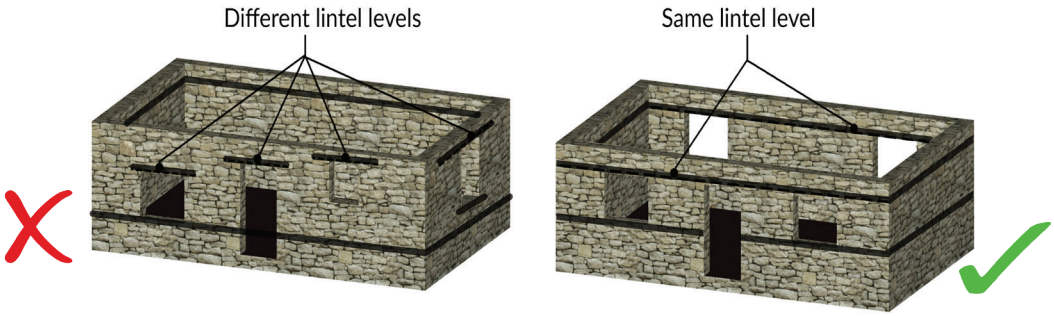
9. Openings



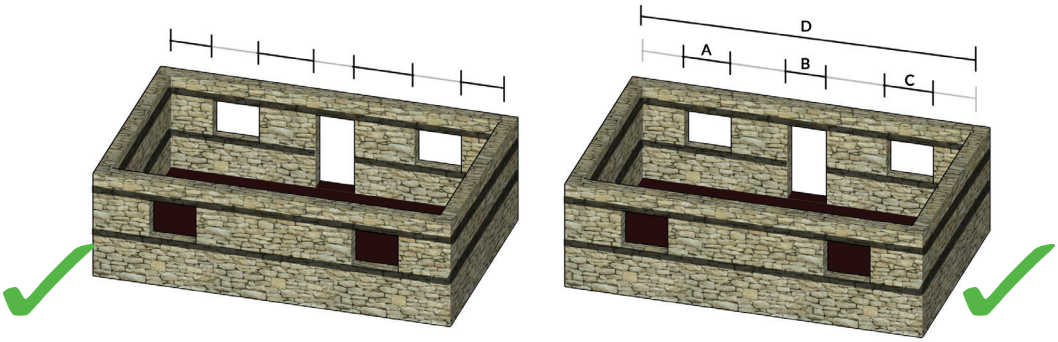
- Symmetrical and identical openings must be placed on opposite walls. Asymmetric openings cause uneven stresses on the wall and lead to more damage.



- Too many openings or large central openings on the same wall must be avoided.



- The same sill and lintel level should be maintained for all openings.



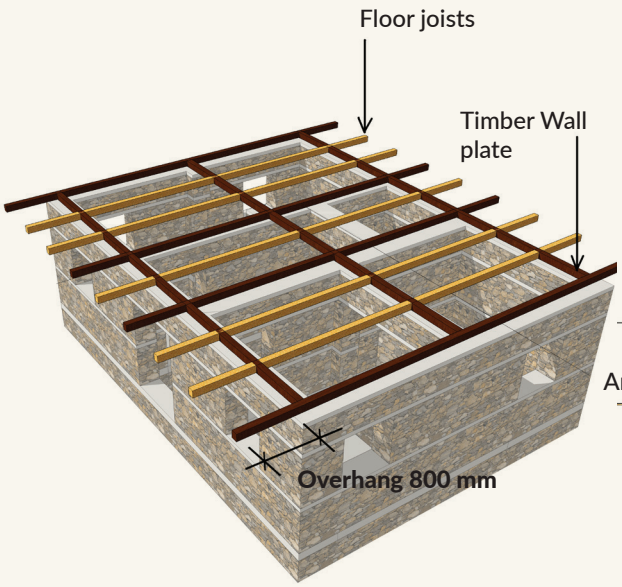
- Distance between inner edge of wall and the edge of the opening, and between two openings, should be atleast 600 mm.
- A + B + C = D/2
  A+B+C must be less than half the length of the wall

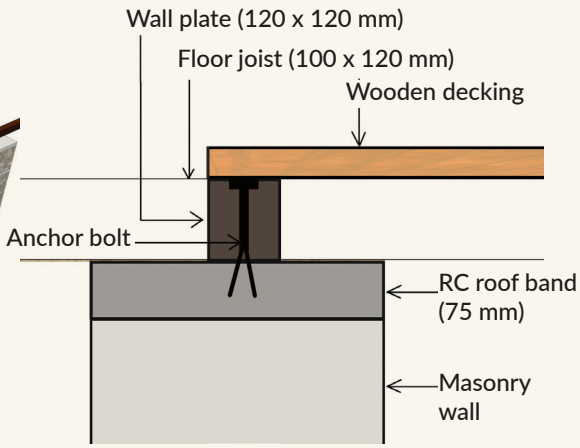
10. Intermediate Floor

10.1 Timber Joists and Planks

- The floor structure must be well tied to the RC roof band.
- The floor should act like a diaphragm to resist horizontal forces, thus needing diagonal bracing.

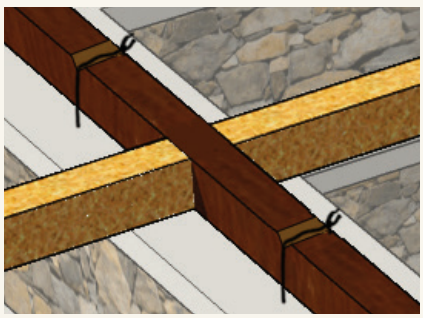
Construction steps:



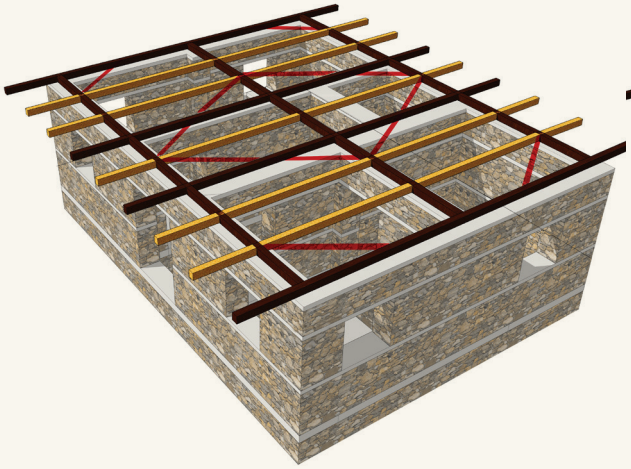


Step 1: Place a 120 x 120 mm wall plate on top of all walls in the centre. Place floor joists between them at regular intervals.

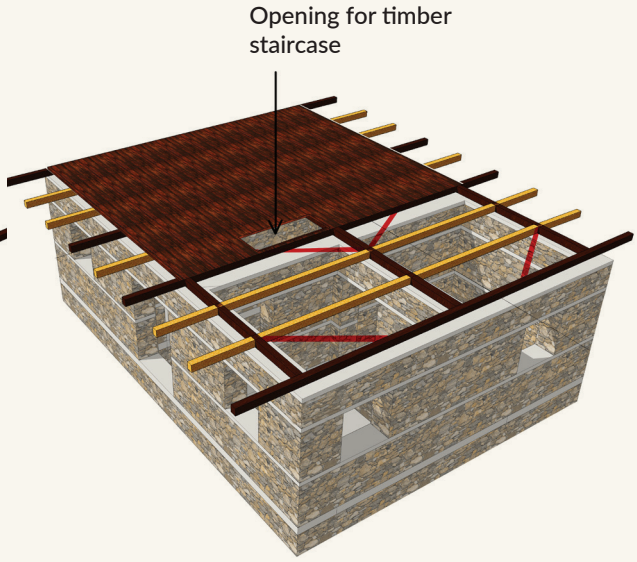
Step 2: Use anchor bolts to connect the timber wall plate to the RC roof band.



Alternatively, use double 3 mm wire to anchor the joist. Make a notch in the wall plate to prevent movement.



Step 3: Diagonal floor bracing is required if room length is more than 4.5 m. Using two nails at each end install a 100mm x 25mm plank on the underside of purlins adjacent to their ends. Alternatively, use 13 gauge GI wire (2.4 mm dia). Stretch them taut and fix them to the struts in X configuration.

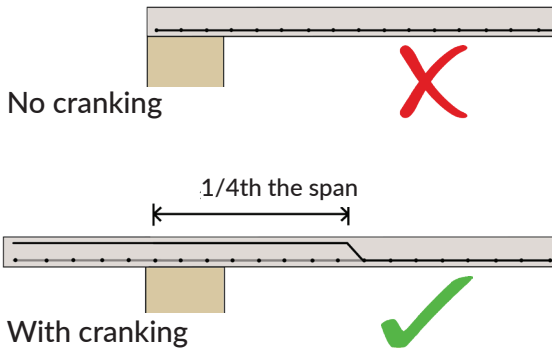


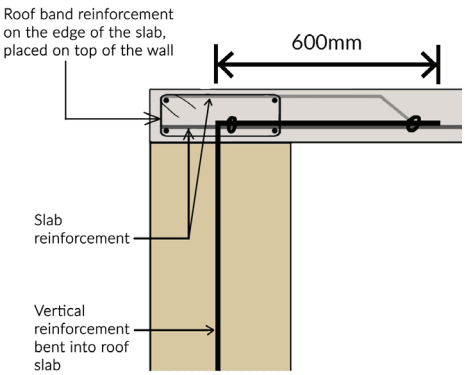
Step 4: Lay wooden decking on the floor joists and secure each plank using at least 2 nails in each joist location.

10. Intermediate Floor

10.2. RCC Slab

- Thickness of the RCC slab and re-inforcement detail must be designed by a qualified engineer, and must be constructed accordingly.
- Slab thickness depends on the width of the room. Larger the span, more the thickness of the slab and smaller spans allow thinner slabs. Under normal cases where room sizes are limited to 3.6 - 4.2 m, the thickness of the slab ranges from 100-150 mm.
- Rebars should be bent (cranked) alternatively in opposite directions as shown in figure below.





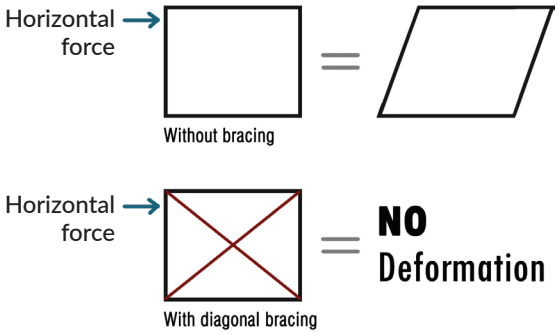
- The roof band should be cast in the slab itself with 4 bars of reinforcement.
- The vertical reinforcement must be embedded in the slab as shown in the figure on the right.

Construction steps:

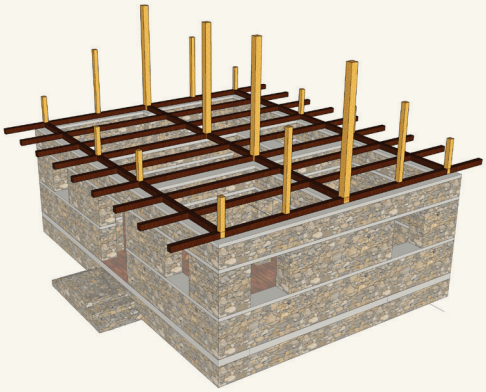
1. Ensure that the centering platform is at the same level as the wall top.
2. The centering platform should be supported with sufficient supports to prevent sagging. The supports should be able to carry the weight of the slab.
3. The vertical supports for centering must be diagonally braced for rigidity.
4. Ensure that the whole platform is at the same level using a water level.
5. While laying the reinforcement cage, ensure that all the rebars are straight before laying them.
6. Tie rebars using binding wire.
7. Ensure that the rebar cage is raised 25mm from the platform using spacers.
8. Lay the entire slab in one day, after which, avoid walking on top of it for atleast two days.
9. Ensure that the slab is cured for 20 days. Do not remove the shuttering for minimum 20 days, after the slab is laid.

11. Roof Construction

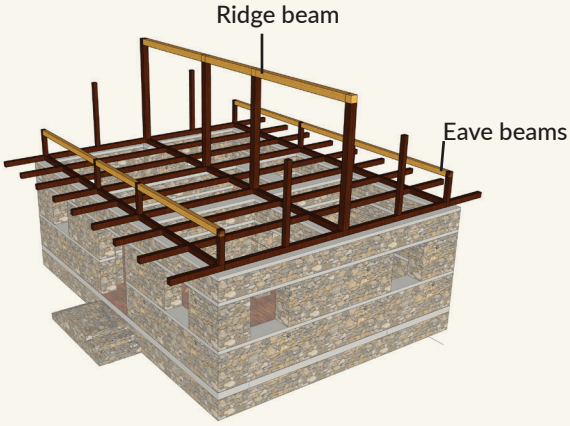
- The roof structure must be well tied to the wall plate and the floor joists.
- The roof must be able to resist horizontal forces, thus needing diagonal bracing.



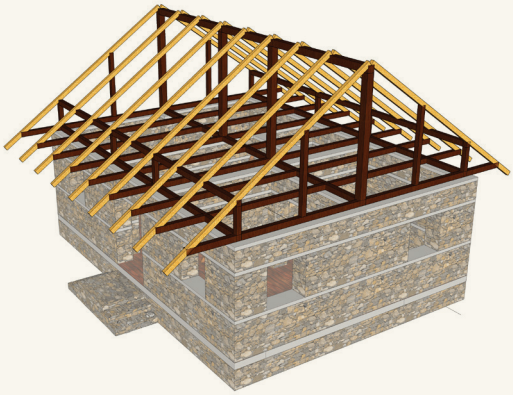
Construction steps:



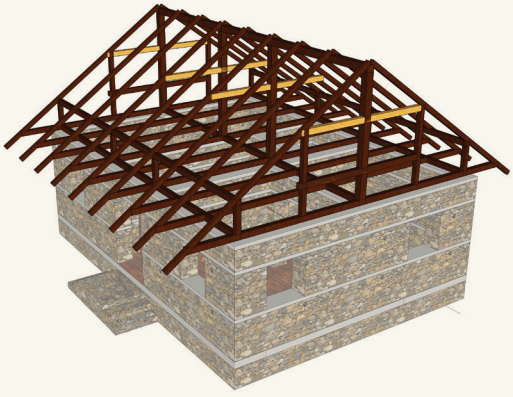
Step 1: Erect timber posts over the floor structure.



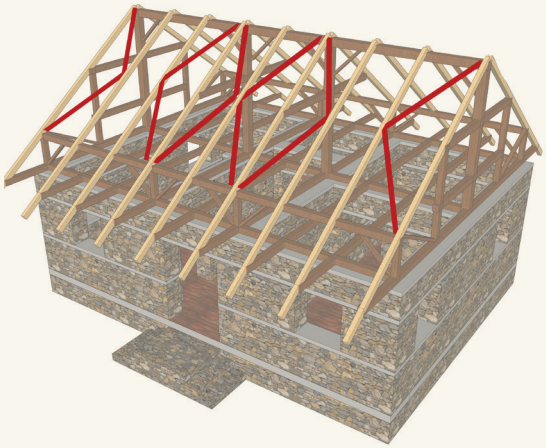
Step 2: Install ridge beam and eave level beams and level them using water tube.

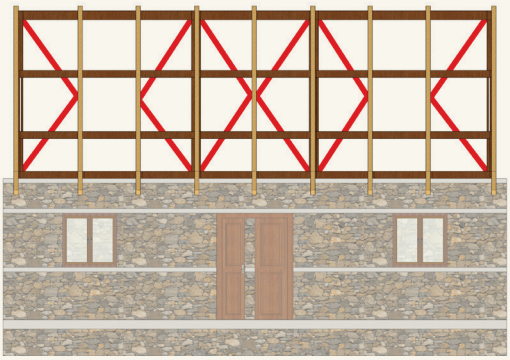


Step 3: Install rafters and ensure good joinery with the timber columns. For additional anchoring, tie all members using 10 gauge GI wires.

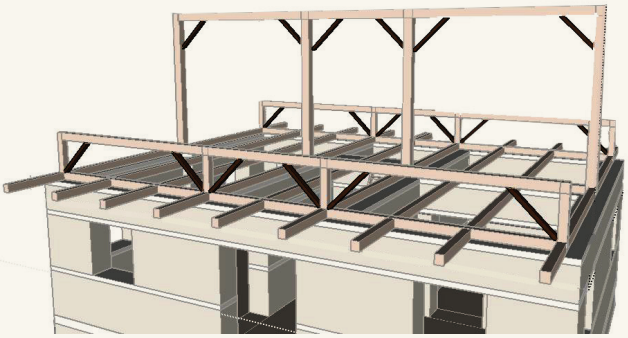


Step 4: Install collar beams between rafters at 2/3 rd height of the roof across opposite rafters and connect them securely.

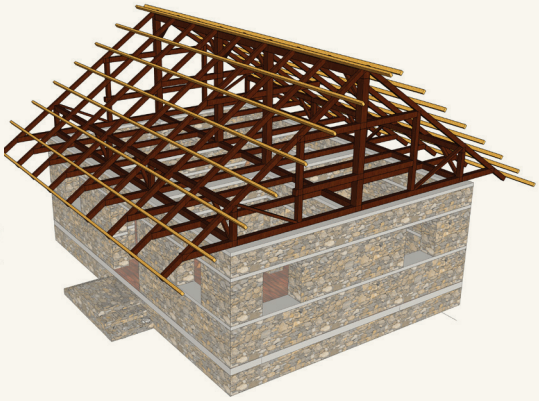




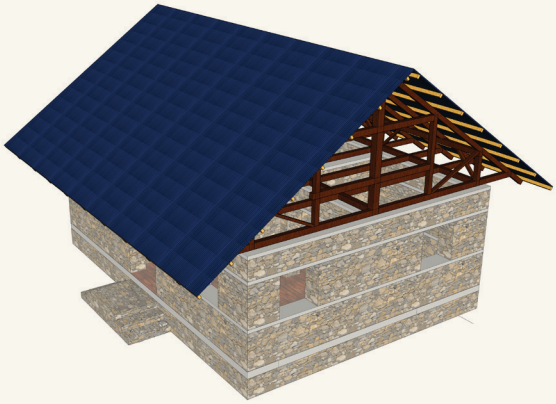
Step 5: Use 2 nails each, install 100 x 25 mm struts on the underside of purlins for In-plane bracing of inclined joists. Alternatively, use 3-5 strands of 13 gauge GI wires.

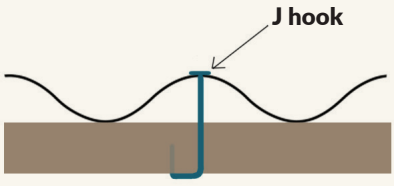


Step 6: Brace the timber posts and beams using 100 x 25 mm struts, such that the attic space is usable as a room.



Step 7: Install 50 x 50 mm purlins and tie them well with the rafters using GI wires. Extend an overhang of minimum 800 mm.



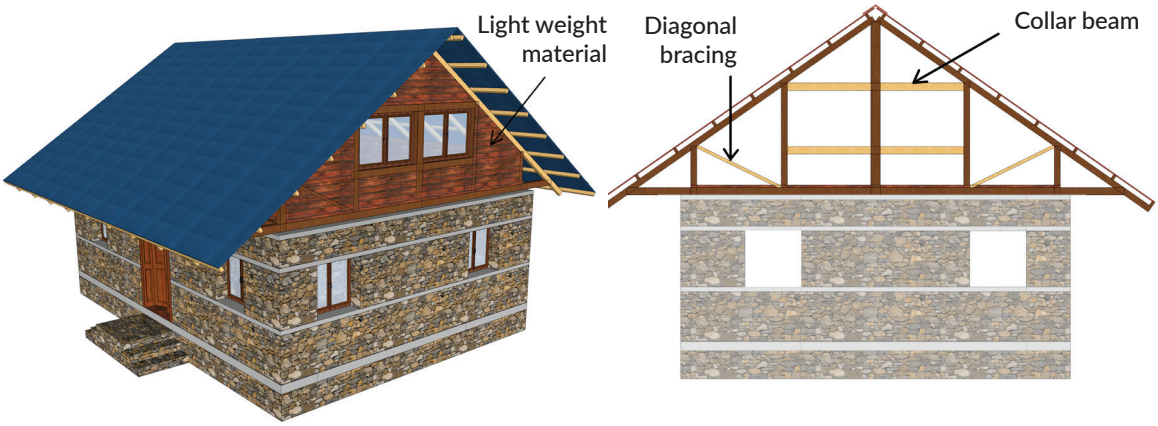


The holes in the sheet must be made in the ridges to minimise water leakages.

Step 8: Install CGI sheets with reasonable overlap to prevent any leaks. Secure them to the purlins using 'J' hooks.

12. Gable Wall

- The gable wall must be made using light materials such as timber or CGI sheets
- No masonry should be done for gable wall.
- Diagonal bracing and collar beams must be provided as wall under-structure.



13. A Complete House (G+1)

The figure below shows a complete G+1 storey stone masonry structure and roof with timber understructure and CGI sheets, displaying some essential disaster-resistant features.

References

- Bothara, Jitendra, and Svetlana Brzev. 2012. A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings. Earthquake Engineering Research Institute (EERI).
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Notes

Notes

JEHLUM & TAWI
FLOOD RECOVERY PROJECT

Jhelum and Tawi Flood Recovery Project (JTFRP) is a World Bank supported project for the Government of India. Its primary objective is to support the recovery and increase disaster resilience in Project Areas, and increase the capacity of the Project Implementing Entity to respond promptly and effectively to an eligible crisis or emergency.

The project focuses on restoring critical infrastructure using international best practices on resilient infrastructure. Given the region's vulnerability to both floods and earthquakes, the infrastructure is being designed with upgraded resilient features, and includes contingency planning for future disaster events. Therefore, the projects aims at both restoring essential services disrupted by the floods and improving the design standard and practices to increase resilience.

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