Handbook

on Disaster-Resistant Construction in Jammu and Kashmir

Part B:
Confined Masonry

First edition 2019

Taru VMS JV LLP in collaboration with People in Centre

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Handbook

on Disaster-Resistant Construction in Jammu and Kashmir

Part B: Confined Masonry

Vivek Rawal
Rushank Mehta
Shweta Sundar
Hiranya Kallakuri

Reviewed by:
Alpa Sheth
Rupen Goswami

Jhelum and Tawi Flood Recovery Project (JTFRP)

Taru VMS JV LLP with People in Centre

Foreword

Acknowledgements

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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 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 prone to multiple natural hazards such as earthquakes, landslides, cloudbursts and flooding, many of which are in the severe category. Today, poor and unsafe construction practices, noticed in both engineered and non-engineered buildings, are prevalent in urban and rural areas, increasing people's vulnerability to natural hazards. Hence, there is a need to develop and propagate construction practices that make these buildings safe. It is imperative for these construction practices to be deeply rooted in the local context 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 under-structure. 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 RC or timber *framed construction* using infill materials such as brick, adobe and timber.

Most of the housing in India is non-engineered and led by masons, where the house-owner depends upon the head mason for guidance on the choice of materials, technology, design, construction and cost estimation. Their critical role thus demands their capacities be strengthened, to subsequently reduce vulnerabilities in buildings. It is with this objective that JTFRP is conducting trainings of masons and preparing handbooks on disaster-resistant construction in J&K. While there are multiple construction options for empirically designed homes, this manual covers Confined Masonry construction, a load-bearing system using modern materials such as concrete and steel, which has consistently proven to perform well in earthquakes across the world.

Confined masonry system is essentially a load bearing wall structure where walls are confined within vertical tie columns and horizontal tie beams. Unlike RC frame structures, for confined masonry, walls are constructed first and tie columns are cast later. These walls are the main structural system to resist gravity and lateral forces. The key components of a confined masonry house are shown below.

The choice of technology should be made keeping in mind the availability of good quality skills, materials and resources, otherwise, it may be not be the preferred option. The handbook is a reference material for the masons on how to practice good and safe construction in Jammu and Kashmir. 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 engineers and masons to apply these guidelines to different design layouts. The building codes must be referred to and should take precedence in case of any inconsistency or ambiguity.

This handbook includes details for a Ground and G+1 storey house with an attic floor, constructed using confined masonry. Though illustrations in this book show bricks, confined masonry can be done with concrete blocks as well. The materials required for this type of construction are bricks or concrete blocks, sand, aggregate, cement, steel, timber, CGI sheets. The topics covered are: safe siting of the house, the foundation, plinth, confining elements, walls, openings, intermediate floor and roof. They cover guidelines for hazard resistant features and steps for construction to reduce the vulnerability of the building. All dimensions in the handbook are in metric system.

The handbook is organised into fourteen sections. The first two sections are *Introduction* and *Hazard Risks in Jammu and Kashmir* respectively, establishing a premise for the need and relevance of this handbook.

The third section, *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 section, *Building Configuration and Layout*, enlists rules for designing a safe house, with respect to building dimensions, setbacks and layout.

The fifth section, *Construction Materials*, lists various points to be considered while choosing and using materials to ensure safe and good quality of construction. Rules for mixing cement mortar and concrete have also been covered in this chapter.

The sixth section, *Foundation*, includes basic guidelines for laying 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 section, *Plinth*, provides rules for determining plinth height and construction steps of the plinth-level tie beam.

The eighth section, *Confining Elements*, discusses basic principles for determining location of horizontal and vertical confining elements and their construction details.

The ninth section, *Walls*, includes fundamentals of brick masonry such as laying of Flemish bond and toothing details, followed by a step-by-step explanation of the construction process till roof-level tie beam.

The tenth section, *Openings*, discusses appropriate placement and design of openings in a house to reduce its vulnerability against horizontal seismic forces.

The eleventh section, *Intermediate Floor*, touches upon two construction systems; RCC slab and timber joists and planks. 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. Both guidelines and steps of construction have been discussed for timber joists and planks system, including additional features such as diagonal bracing.

The twelfth section, *Roof Construction*, includes design principles for a safe roof and a step-by-step process of constructing light-weight gable roof with timber under-structure and CGI sheets.

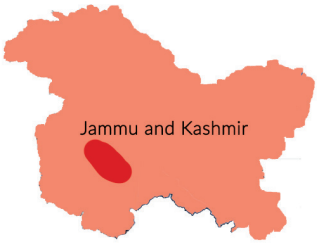
The thirteenth section, *Gable Wall*, covers guidelines for designing a gable wall.

The fourteenth section illustrates *A Completed House*, both ground and G+1 storey, with all the key hazard-resistant elements.

2. Hazard Zonation of Jammu and Kashmir

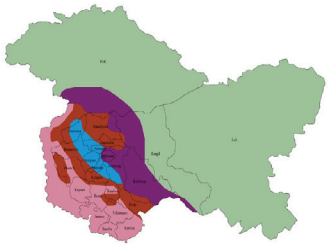
J&K is susceptible to the impacts of multiple hazards such as earthquakes, landslides, cyclonic winds and occasional cloud bursts. The following maps illustrate the intensity of the hazards faced by the state against these disasters.

Seismic zones: J&K falls under Seismic Zone 4 and 5, making it highly vulnerable to potentially devastating earthquakes.



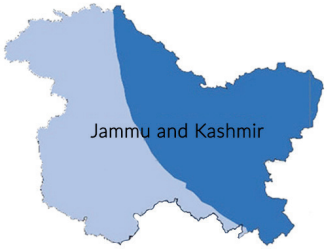
Zone - V (Highest)
Zone - IV (High)
Zone - III (Moderate)
Zone - II (Least Active)

Landslide zones: Due to the terrain, western parts of J&K are highly prone to landslides.



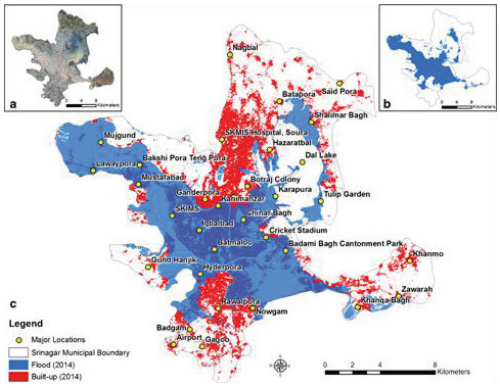
Very High Hazard
High Hazard
Moderate/Moderately High Hazard
Low Hazard
Very Low Hazard

Wind zones: Ladakh region faces high damage risk, whereas Jammu region and Kashmir region faces moderate damage risk.



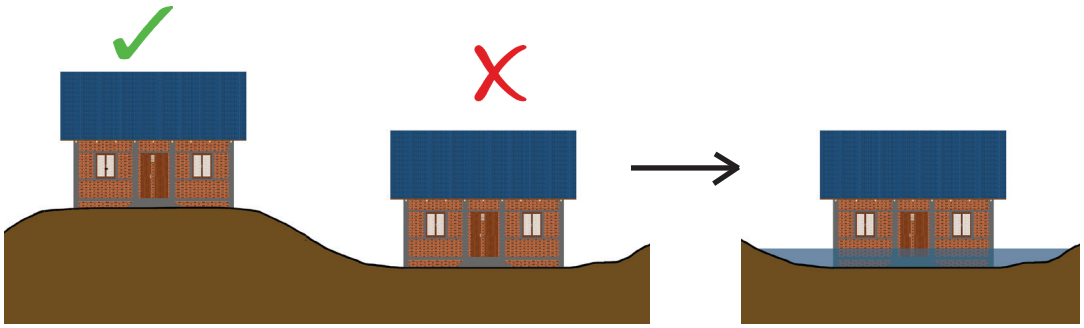
Very High Damage Risk Zone - A (V_b=55 m
Very High Damage Risk Zone - B (V_b=50 m
High Damage Risk Zone (V_b=47 m/s)
Moderate Damage Risk Zone - A (V_b=44 m
Moderate Damage Risk Zone - B (V_b=39 m
Low Damage Risk Zone (V_b=33 m/s)

Flood zones: This map is applicable to the Greater Srinagar, but the same inferences will be applied to all vulnerable areas of J&K. This area is highly prone to floods.



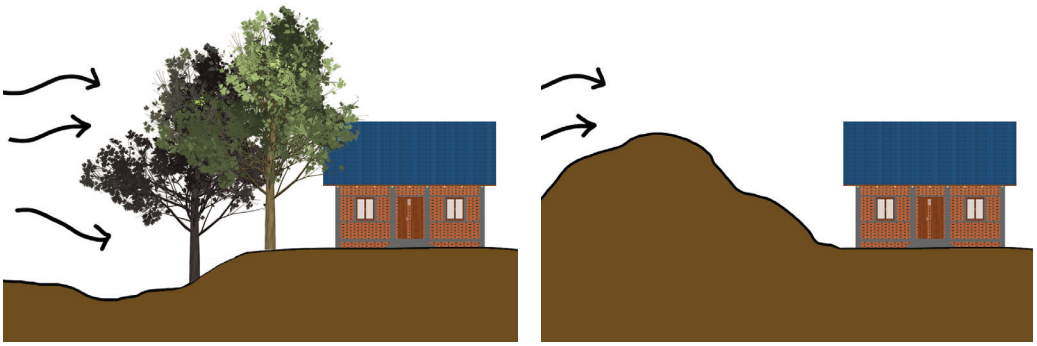
3. Site Selection

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



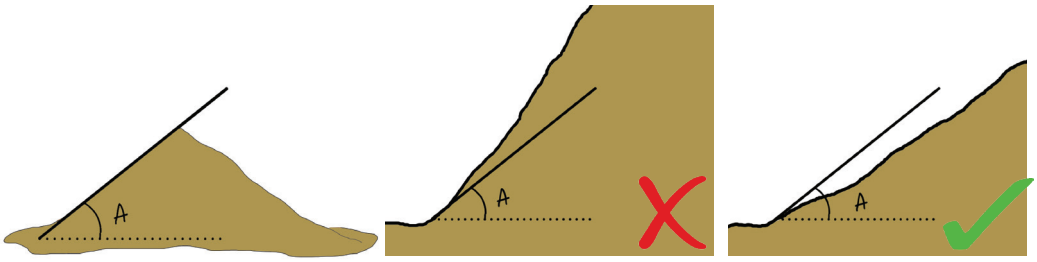
Elevated ground | Low-lying area | After rains

- To protect the house from excessive winds, it 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.

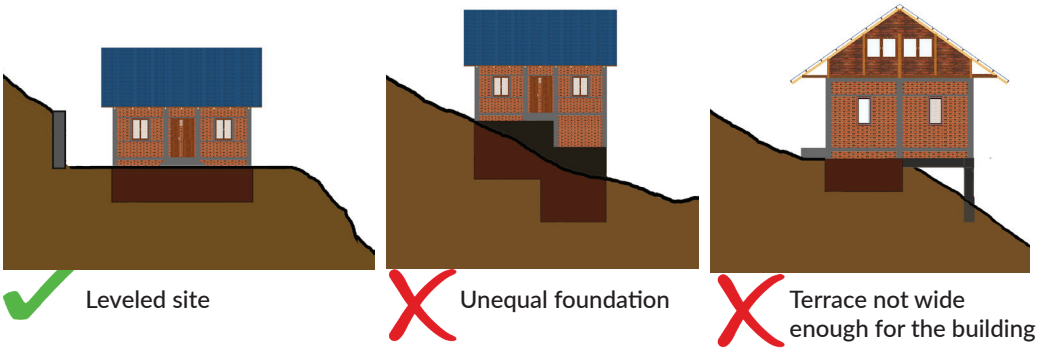


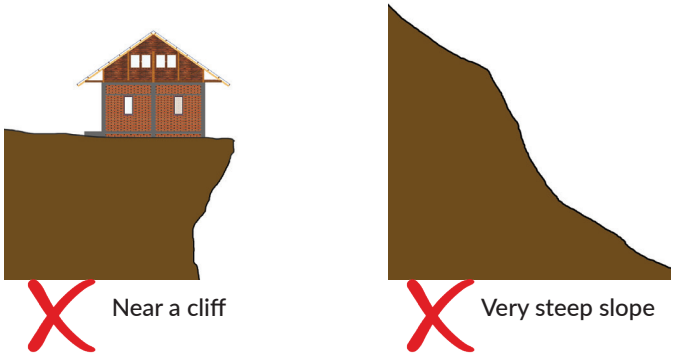
A = Angle of repose

Slope greater than angle of repose

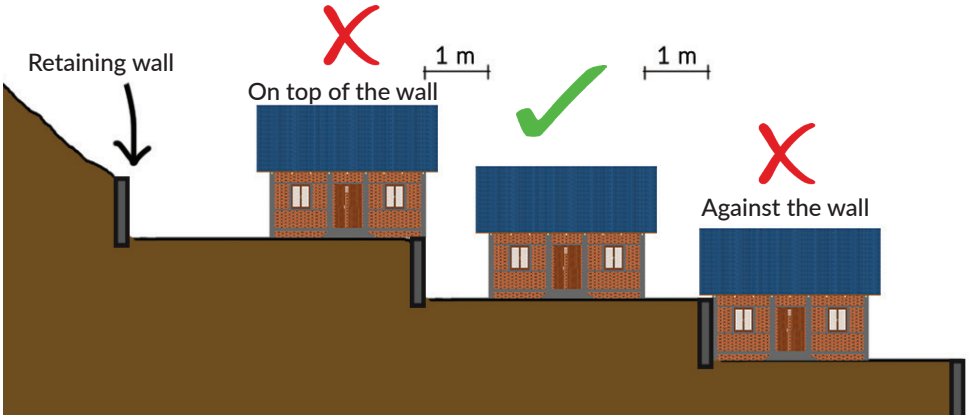
Slope lesser than angle of repose

- Building on sloped sites:
  - The site must always be levelled before commencement of construction.
  - The foundation must be of the same depth and at the same level throughout the building.
  - Terrace should be wide enough for the entire building.
  - Building on very steep slopes, near cliffs or building uneven foundations must be avoided.

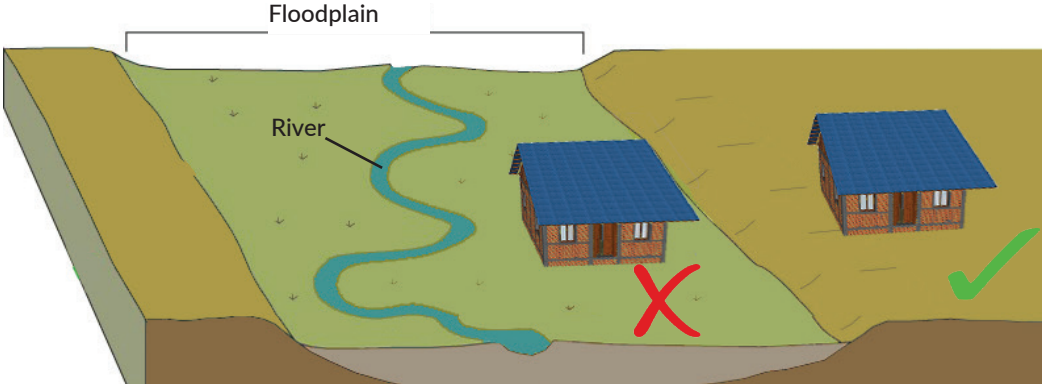




- The house must be at a distance of least 1m away from top of slope and 1m away from the edge. A retaining wall must be constructed to support steep cut slopes before building the house. The house must not be built on top or against a retaining wall. Safe distance must be maintained on both sides of the house from the retaining wall.

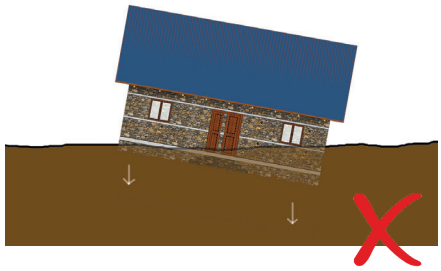


- The house must be built far away from the inundation lines of the water body. Building on flood plains must be avoided.



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

  Soil with high bearing capacity is suitable for construction. Low soil bearing capacity makes the house prone to sinking.

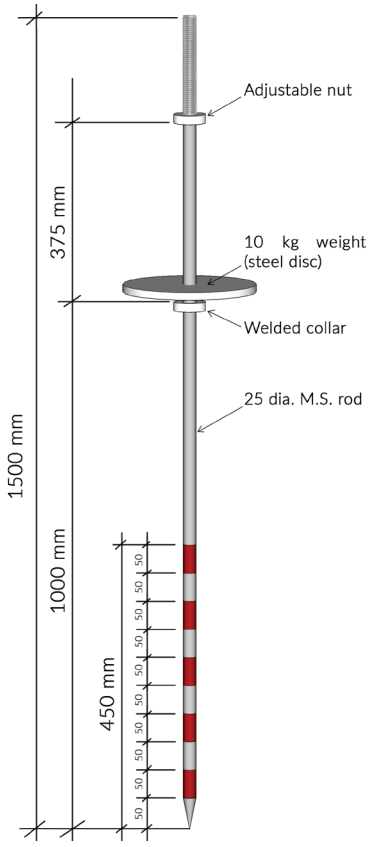


Identifying Soft and Hard Soil using a Hand Penetrometer

Soil bearing capacity in different sites may vary depending upon soil conditions. It is important that house is constructed on soils of sufficient bearing capacity. Hand Penetrometer is a tool for a reasonably good assessment of the bearing capacity of soil. The tool is useful for lightly loaded shallow foundations.

Hand penetrometer consists of following two components:

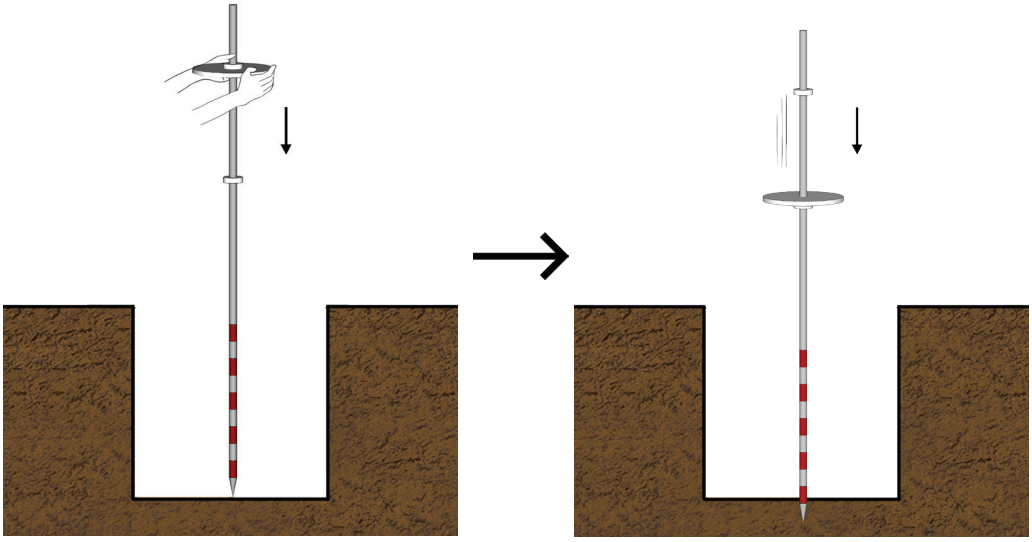
1. **A 1.5m long steel rod of 25mm diameter,** with the bottom end tapered in a conical shape and top end threaded. Tapered portion is 50mm whereas the threaded portion is around 200mm. A collar is welded at a distance of 1m from bottom of the rod. 500mm from the base of the rod, including the tapered portion, is painted in alternate yellow and black strips. Each strip is of 50mm.



2. **A circular steel disk** of 10 kg with an opening of 28mm at centre.

How to use a hand penetrometer:

1. Slide the disk through the rod to rest on the collar.
2. Place the adjustable nut and tighten in such a way that distance between top of disc and underside of the nut is exactly 375mm. To prevent movement of this nut, provide a check nut above it.
3. Perform the test at foundation level (the level at which footing will rest).
4. One person should hold the penetrometer vertical and the other person should lift the disk slowly upto bottom of the nut and release it fall freely on top of collar.



5. Repeat step 4 until the rod penetrates into the soil by 450mm. Number of blows required to penetrate first 150 mm are ignored to compensate any soil disturbance. Number of blows required for next 300mm penetration of rod are recorded as N_H value.

The correlation between Safe Bearing Capacity (SBC in T/Sq. m) and N_H value is summarised in following tables depending on type of soil:

i) Sandy Soil

N_H value	SBC (T/Sq. m)	Soil Consistency
<13	<10	Very loose
13-33	10-20	Loose
33-98	20-50	Medium dense
98-163	>50	Dense

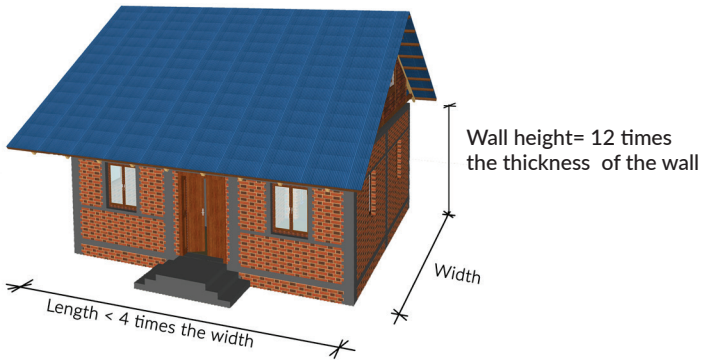
ii) Clayey Soil

N_H value	SBC (T/Sq. m)	Soil Consistency
<7	<5	Very soft
7-13	5-10	Soft
13-26	10-20	Firm
26-49	20-40	Stiff
>98	>80	Hard

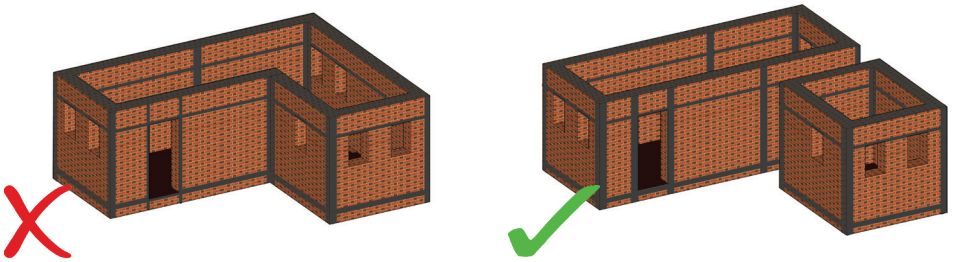
Note 1: Correlations in above tables are given for purely granular and purely cohesive soils only. For intermediate soil types, interpolations can be made.
Note 2: The test does not give satisfactory results in case of clayey soils. It is also not useful in areas where level of ground water table is high.

4. Building Configuration and Layout

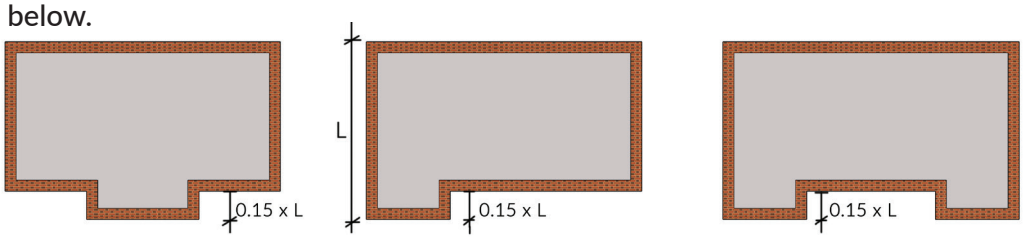
- The plan of the house must be symmetrical and not too long. The length should not exceed 4 times the width of the house.



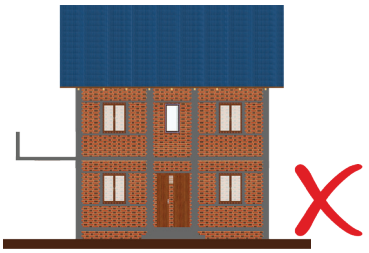
- Complex shapes of the house such as C and L should be broken into simple shapes, located at a safe distance from each other.



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



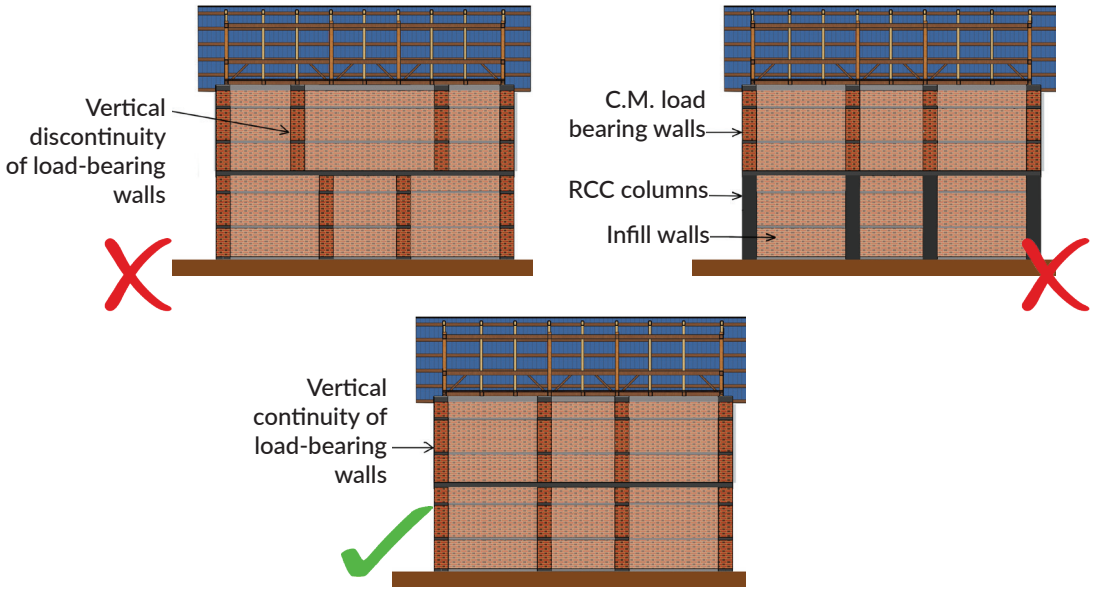
- All cantilevers must be supported using brackets or columns. Avoid building large cantilevers (more than equal to 900 mm).



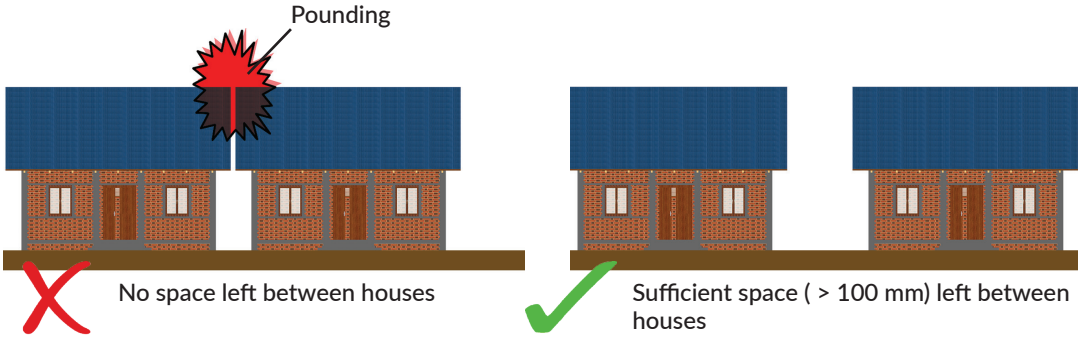
Large unsupported cantilevers

Small cantilevers (< 900mm) supported with brackets

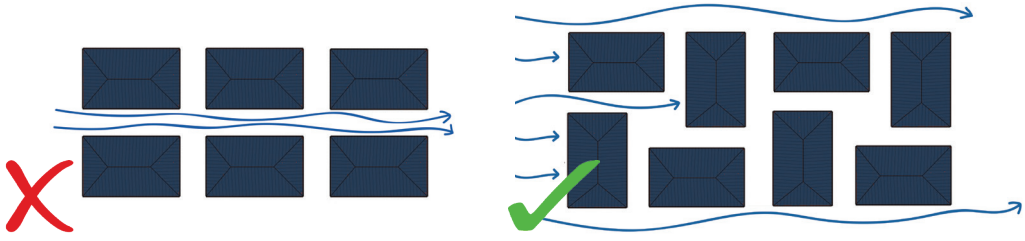
- Confined masonry (C.M.) walls on all floors must be placed one on top of each other such that they are continuous from the ground level up to the building height.
  An RC frame system must not be combined with confined masonry construction.



- Two houses should not be built too close to each other to avoid pounding. It is advisable to leave sufficient space (> 100 mm) 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

Bricks

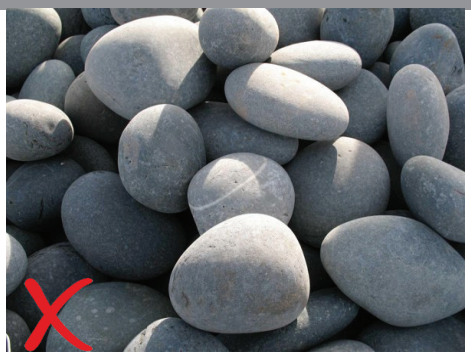
- The brick quality must comply with IS standards.
- Edges of the brick should be sharp, straight and at right angles.
- Shape and size of the bricks must be consistent.
- The surface of a good quality brick should be free from cracks, flaws, air holes and any defect or impurities.
- Bricks should be of uniform colour, proving it is well burnt.
- The brick should not break when dropped flat on hard ground from a height of about 1m.
- After the brick is immersed in water for 24 hours, it should not absorb water more than 20% by weight.
- All bricks must have a 'frog' to ensure good connection with the mortar.

Solid/ Hollow Concrete blocks

- The quality of concrete blocks must comply with IS standards.
- Edges of the block should be sharp, straight and at right angles.
- Shape and size of the blocks must be consistent.
- The surface of a good quality block should be free from cracks, flaws, air holes and any defect or impurities.
- The block should not break when dropped flat on hard ground from a height of about 1m.
- The side of the block to be bonded must be rough.
- Curing time of the blocks must be 7-10 days.

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.
- Sand must be free from mud and vegetation.

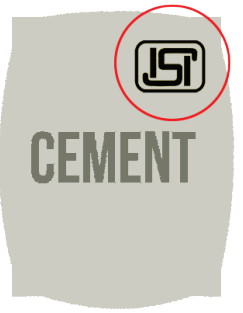
Aggregate

- A mix of aggregate sizes ranging from sand to 12.5 mm must be used.

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

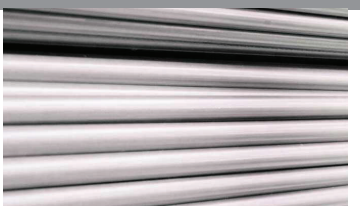
Cement

- 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 stored, it should be wrapped in plastic.
- Only cement bags with an ISI mark should be used.



Steel

Deformed steel for main bars



Mild steel for stirrups

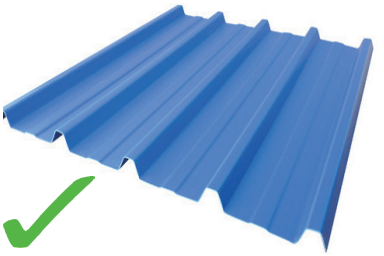
- Steel bars which have the ISI mark should be used.
- Bars which are corroded, rerolled or made out of recycled steel should not be used.

Timber

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

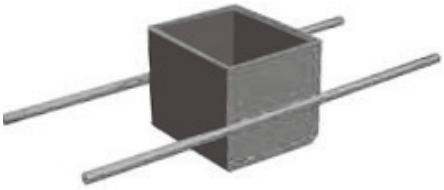
Corrugated Galvanised Iron (CGI) Sheets

- CGI sheets with the ISI mark should be used.
- The recommended thickness of 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

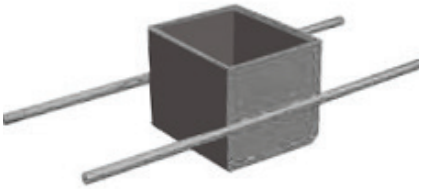


Measuring box

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 15
(to be used for all horizontal and vertical confining elements in confined masonry buildings)

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

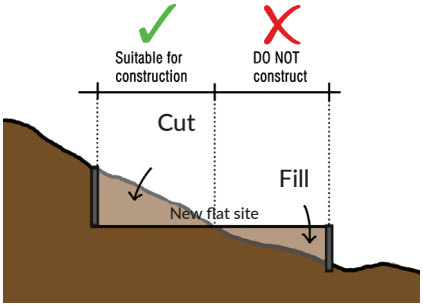
M 20
(to be used for RC slab in confined masonry buildings)

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

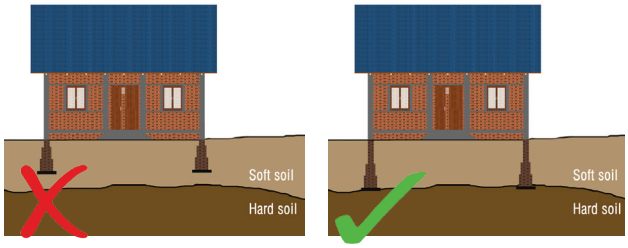
- A measuring box should be used to measure quantities.
- Dry cement, sand and aggregate must be mixed well together before adding water.
- The water quantity must be adequate but not excessive.
- A slump test must be performed using freshly mixed concrete.
- Only enough concrete should be mixed that 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.

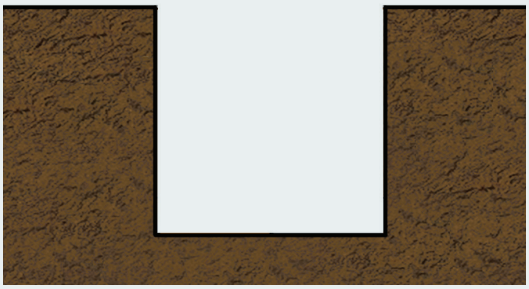


- The foundation depth must be such that the base hits hard ground. Minimum foundation depth is 900 mm, but it may be more depending on soil conditions.

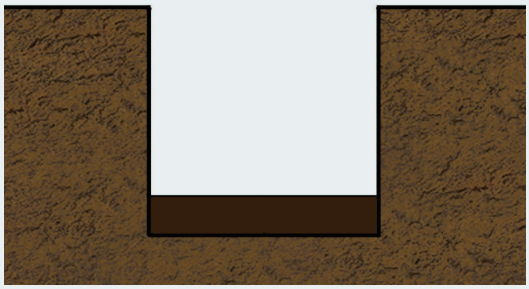


- Foundation depth should be measured from the natural ground line.

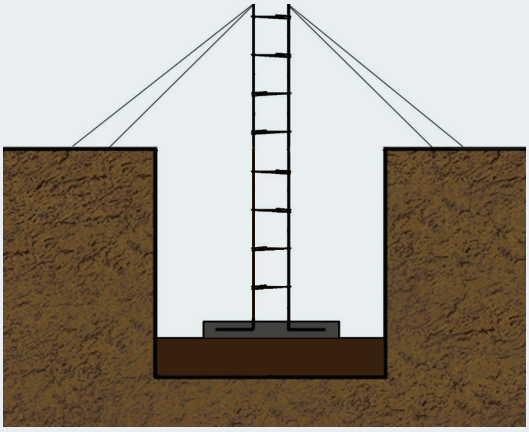
Construction Steps:

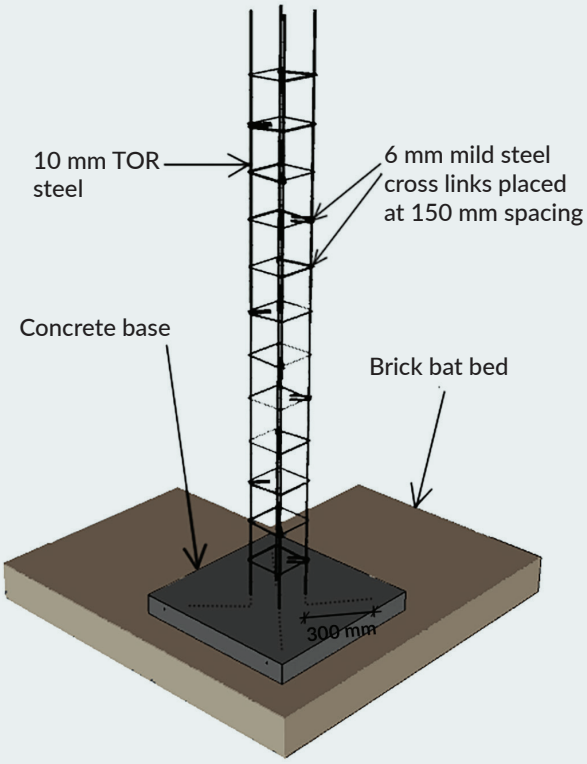


Step 1: Excavate minimum depth or till firm ground is reached, which ever is more. Ram and compact well.

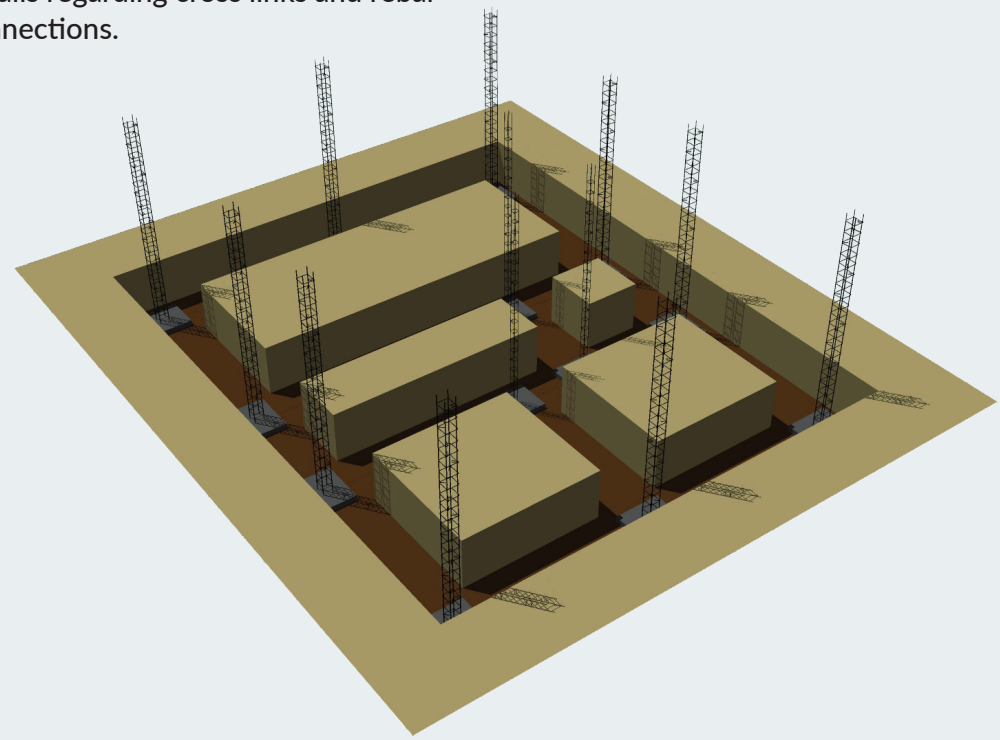


Step 2: Make a 150 mm thick base of stone and lean mortar (1:4:8).



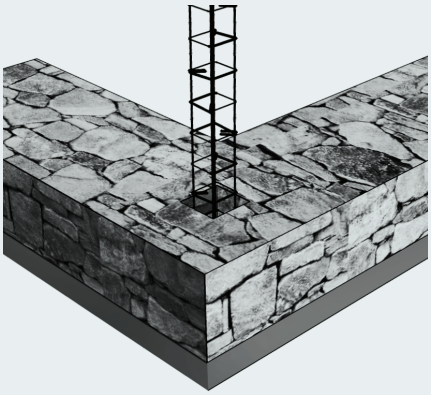


Step 3: Install a vertical reinforcement cage for RC elements. Use steel reinforcement bars of full height till the roof level, up to which RC vertical elements are required. At the base, encase the bent bar (300 mm) in M15 concrete and keep in place using strings or timber members. Refer to page 21 for details regarding cross links and rebar connections.

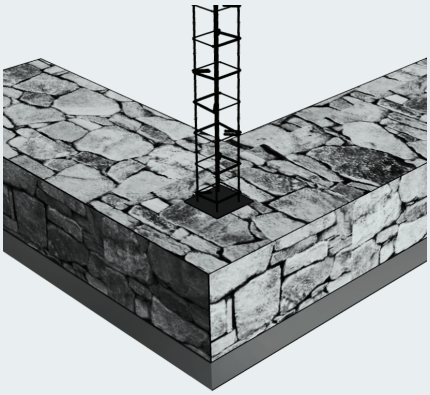


All reinforcement cages must be in place before laying brick masonry in the foundation.

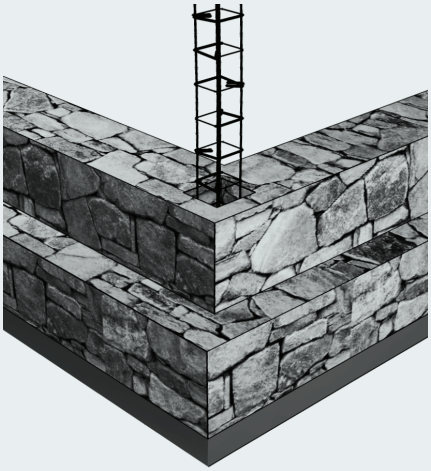
Option 1: Stone foundation



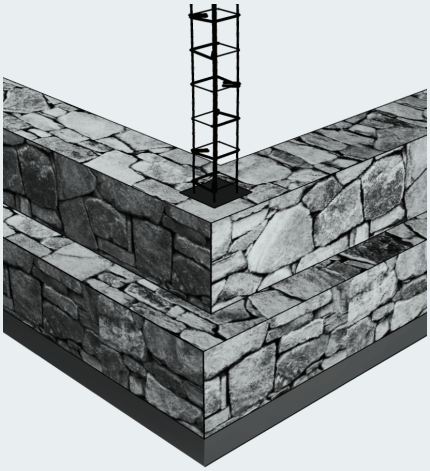
Step 4: Lay a 450mm high course of stone masonry as wide as the trench, leaving an offset of 25mm from the steel reinforcement cage. Level out the course with the help of a water tube.



Step 5: Pour M15 concrete around steel reinforcement cage up to the top level of masonry course made so far.



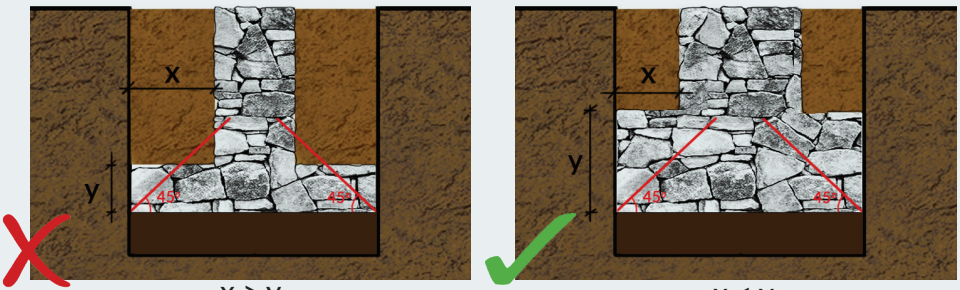
Step 6: Lay the next course of stone masonry till the ground level, reducing to wall width (450 mm). Leave an offset of 25mm from the steel reinforcement cage. Level out the course at ground level with the help of a water tube.



Step 7: Pour M15 concrete around steel reinforcement cage up to ground level.

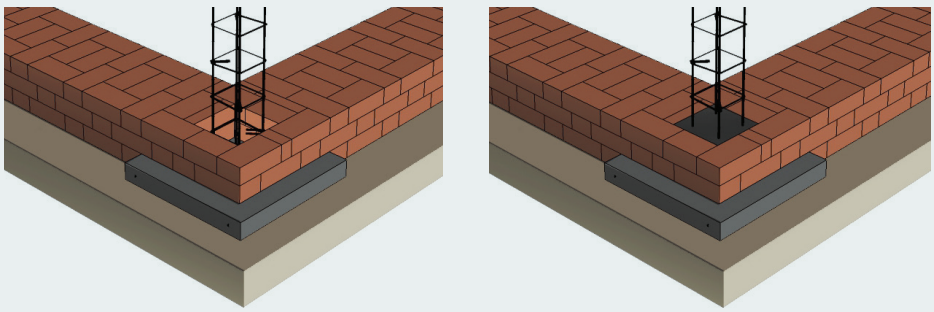
The stone in the foundation must be laid in masonry courses and not dumped in the trench.

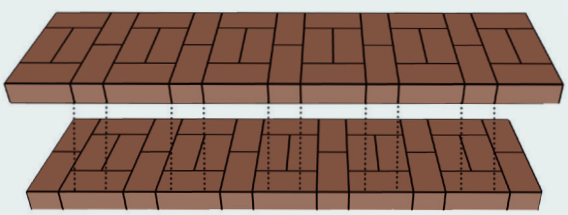
To save materials, the stone masonry can be stepped in courses by giving offsets such that x (offset) is lesser than y (course height). The backfilled earth must be compacted well.



x > y x ≤ y

Option 2: Brick foundation

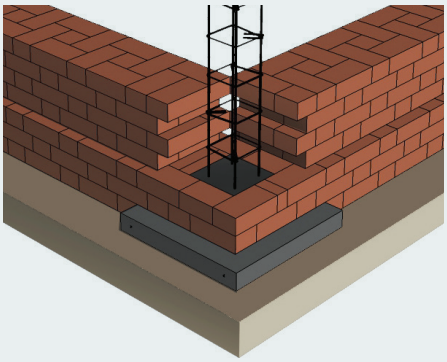


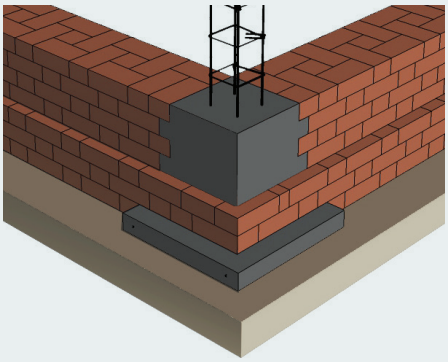


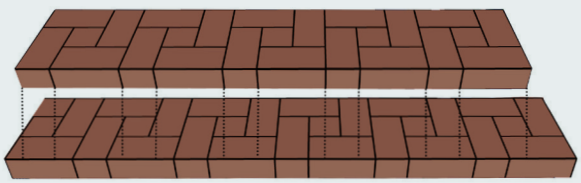
2 Brick thick Flemish bond masonry

Step 4: Lay first three masonry courses (2 brick wide) with cement mortar over brick bat bed, leaving sufficient gap near vertical steel reinforcements.

Step 5: Pour M15 concrete around steel reinforcement cage up to the top level of masonry course made so far.



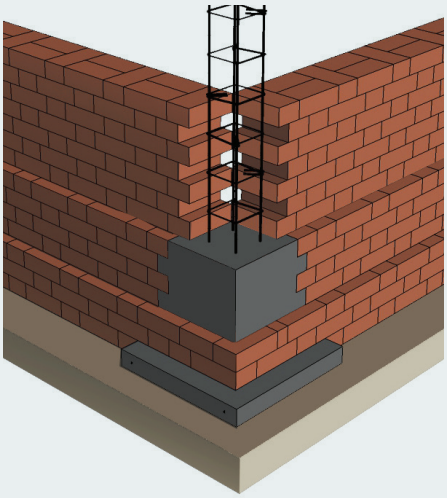


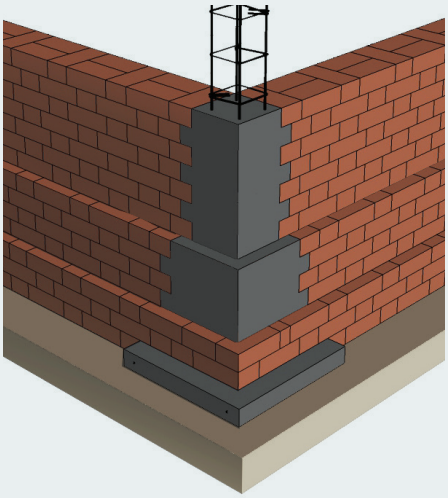


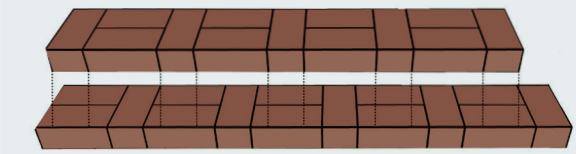
1.5 Brick thick Flemish bond masonry

Step 6: Place the next four masonry courses (1.5 brick wide) with cement mortar above the earlier brick masonry wall, leaving 60 mm offset on either side.

Step 7: Pour M15 concrete around steel reinforcement cage up to the top level of masonry course made so far.







1 Brick thick Flemish bond masonry

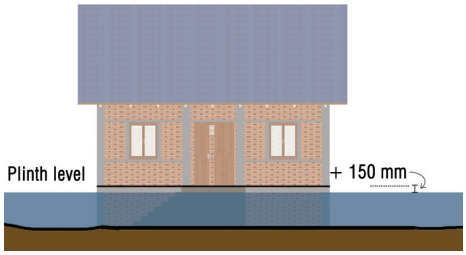
Step 8: Place masonry courses (1 brick wide) up to 150 mm below plinth level with cement mortar above the earlier brick masonry wall, leaving 60 mm offset on either side.

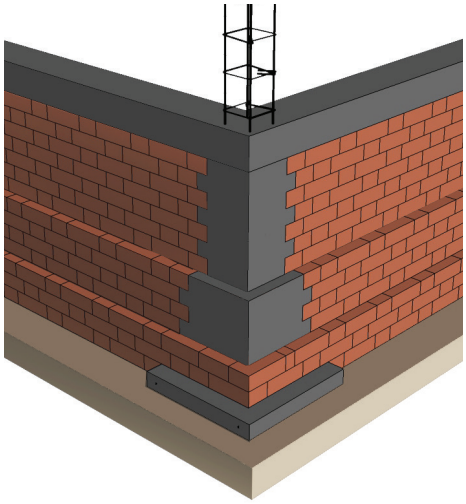
Step 9: Pour M15 concrete around steel reinforcement cage up to the top level of masonry course made so far.

7. Plinth

- Plinth height must be at least 150 mm higher than the known flood level or the submersion level as per the flood zonation maps or local knowledge.

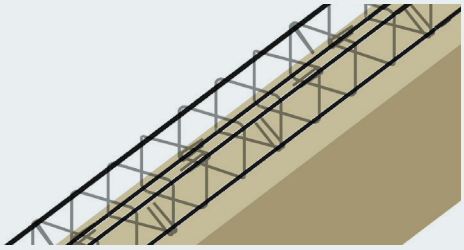
- A plinth-level tie beam 150 mm thick must be laid on top of the wall. The width of the beam must be equal to the width of the wall. It must be continuous and run over all walls.

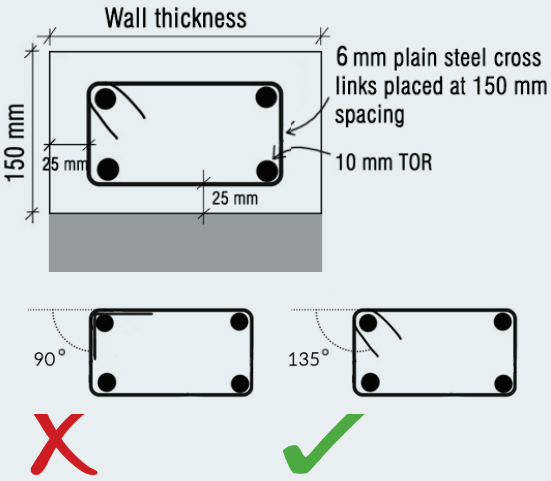


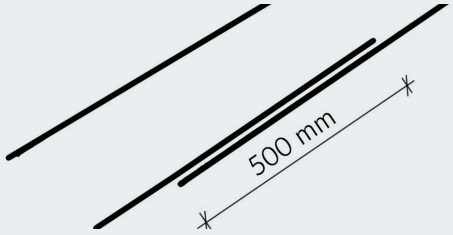


Construction Steps:

Step 1: Lay the reinforcement cage on the wall. Place four longitudinal bars 25 mm inside from the wall faces. Raise bars 25 mm from the wall using spacers, they should not touch the wall. They must be tied together using stirrups at a spacing of 150 mm, and the whole cage must be tied to the vertical reinforcement cage. Cast in M15 concrete and cure for atleast 7 days. Formwork can be removed after 2 days.

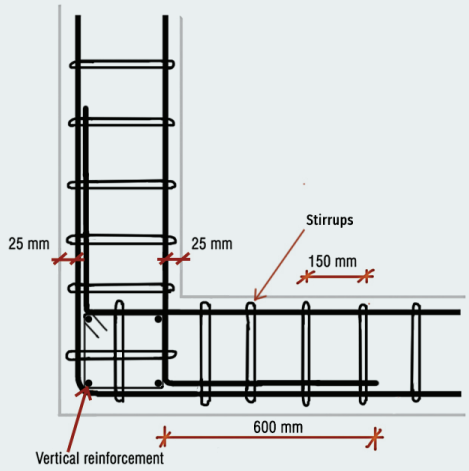


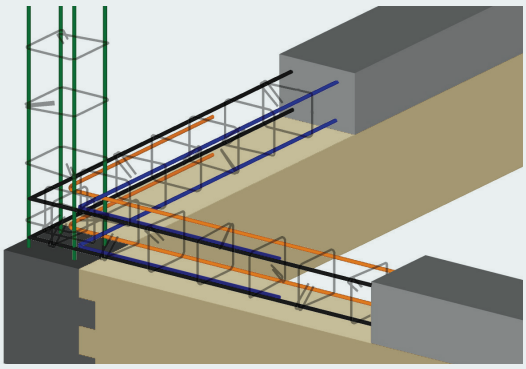




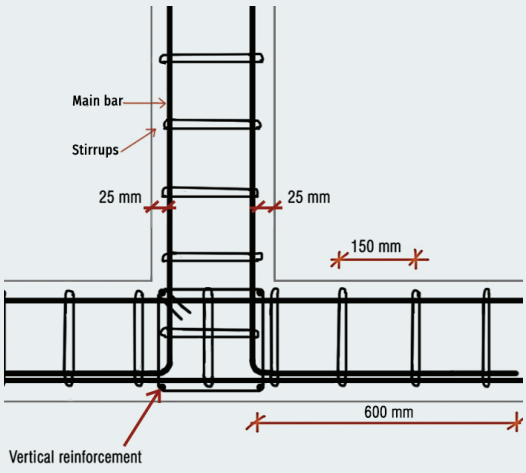
To connect two main bars, the overlap must be 500 mm and they should be tied well together.

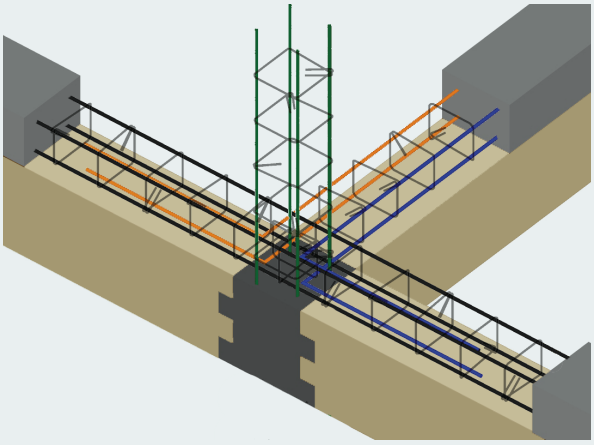
L junction detail (150 mm, 4 bars)



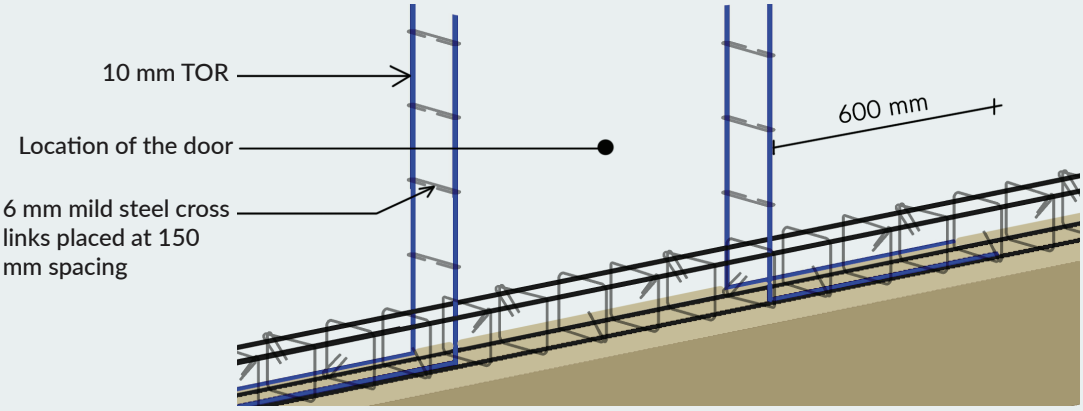


T junction detail (150 mm, 4 bars)



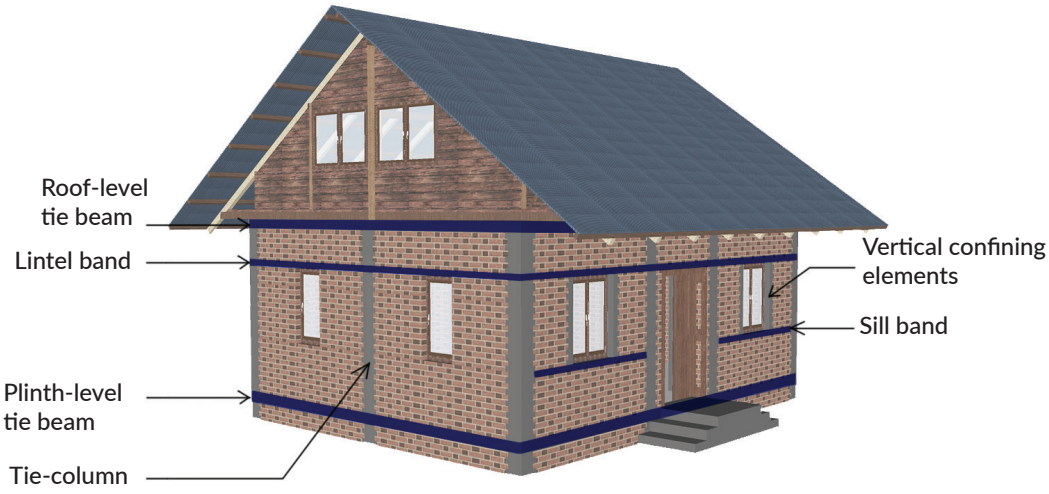


Step 2: Before casting the plinth-level tie beam, ensure that vertical reinforcement cage (2 bar) around doors is placed and fixed into the tie beam rebar cage.



8. Confining Elements

Following are the guidelines to determine the location of horizontal and vertical confining elements in confined masonry structures.

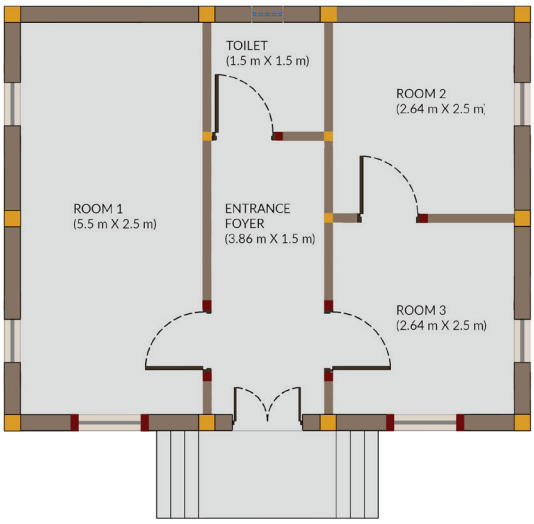


Horizontal Confining Elements- Tie Beams

1. Horizontal confining elements must be placed at four levels; Plinth, Sill, Lintel and Roof.
2. Plinth-level and roof-level tie beams should be continuous. Lintel bands should be continuous if the floor height is greater than 2.5 m. Sill bands must be provided as per opening conditions.
3. Horizontal confining elements must be connected properly with the vertical confining elements.

Vertical Confining Elements- Tie Columns

- There are mainly two types of tie-columns; for walls and for openings.
- The following guidelines can be used for selecting tie-column locations:
    1. All corners and junctions of wall intersections
    2. In long walls, where wall length exceeds 4m or 1.5 times the height of the storey, which ever is less
    3. Beside door openings
    4. Vertical confining elements beside window openings (as shown below)
    5. Free ends of walls (no free ended walls in our plan)



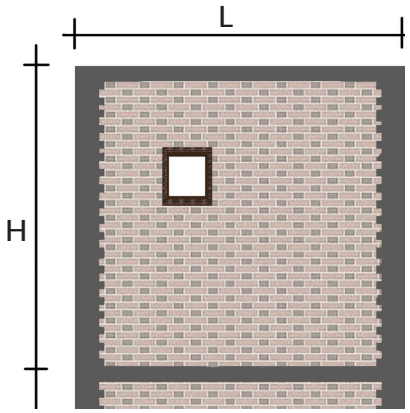
Tie-columns for walls
(See pg. 15)

Tie-columns for openings
(See page. 19, step 3 for door openings)
(See page. 23, step 3 for window openings)

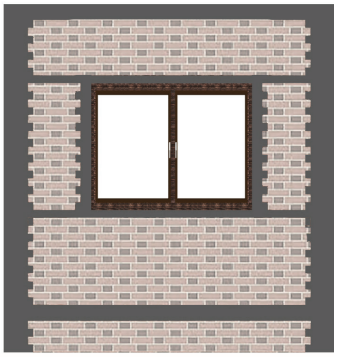
Plan of this confined masonry house indicating tie-columns

- Following are the guidelines to determine the placement of confining elements around openings with respect to the area of the opening.

Area of opening = A_{op}



Condition 1: $A_{op} < 10\%$ L x H

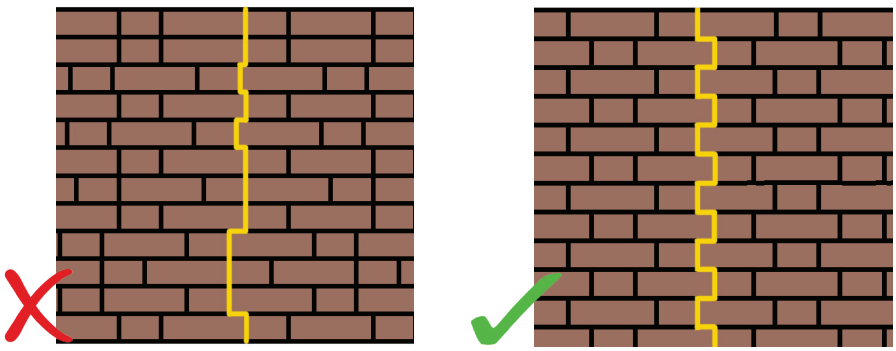


Condition 2: $A_{op} > 10\%$ L x H

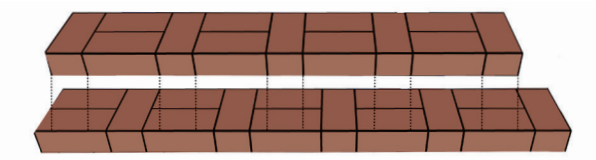
9. Walls

- Bricks should be thoroughly soaked in water and used wet when cement mortar is being used.
- Bricks should always be placed with its frog (groove mark) facing up to ensure placement of mortar in it for better bond between courses.
- The mortar joint must not be more than 10 mm thick.

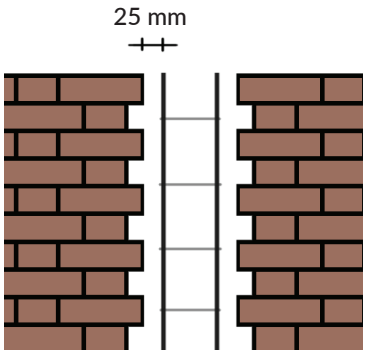
- Continuous vertical joints must be avoided. Joints should be staggered as much as possible.



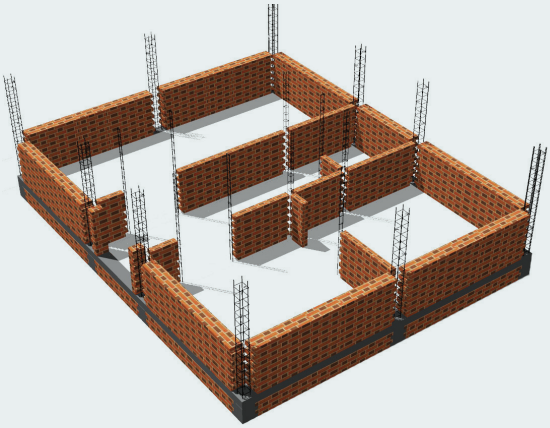
- Flemish bond must be used for masonry.



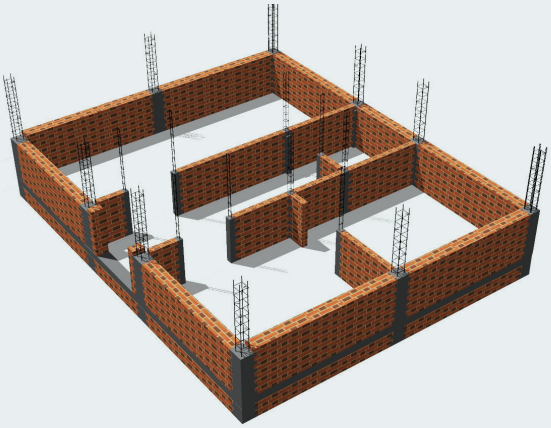
- Wall ends towards tie-columns must be toothed. Bricks must be kept 25 mm away from the stirrups to leave room for the concrete of the tie columns.



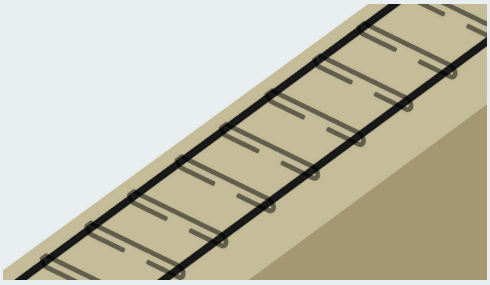
Construction Steps:

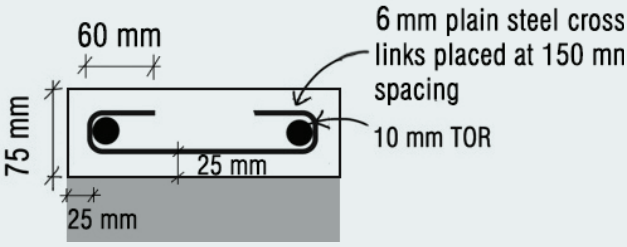


Step 1: Lay brick masonry till 75 mm below sill level. Construct a wall maximum of 1200 mm high in one day.

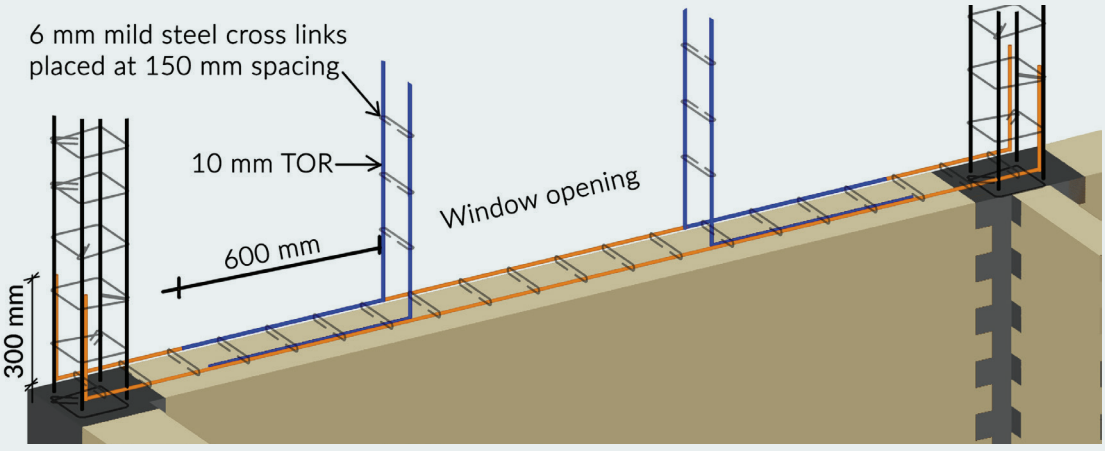


Step 2: Pour M15 concrete of vertical RC elements around reinforcement cage upto the level of top masonry course.

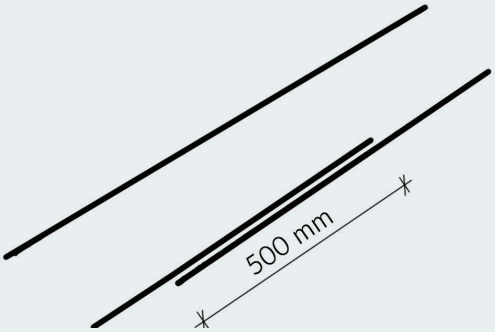




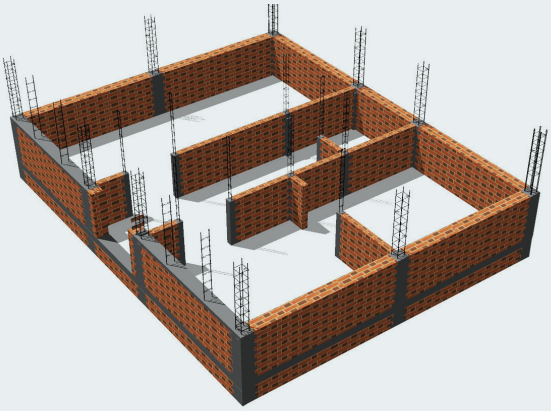
Step 3: Lay reinforcement cage for the sill band. Place two longitudinal bars 25 mm inside from the wall faces. Bars should raised 25 mm from the brick course using spacers and should not touch the course. They must be tied together using stirrups at a spacing of 150 mm, and the whole cage tied to the vertical reinforcement cage.



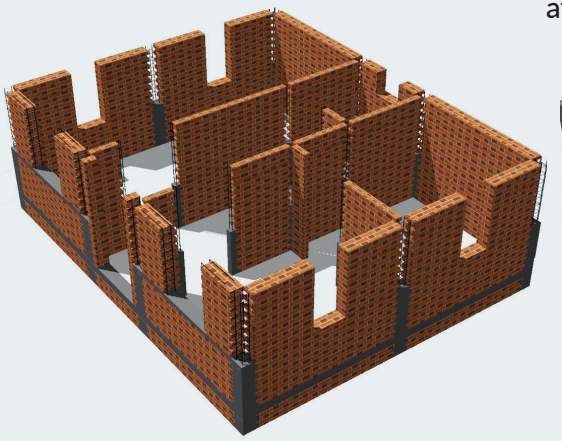
Step 4: Anchor the reinforcement for the vertical confining elements around windows to the reinforcement in the sill band before the concrete is cast.



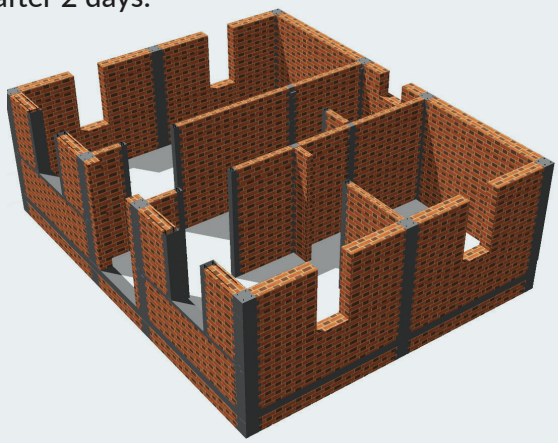
To connect two main bars, the overlap must be 500 mm and they should be tied well together.



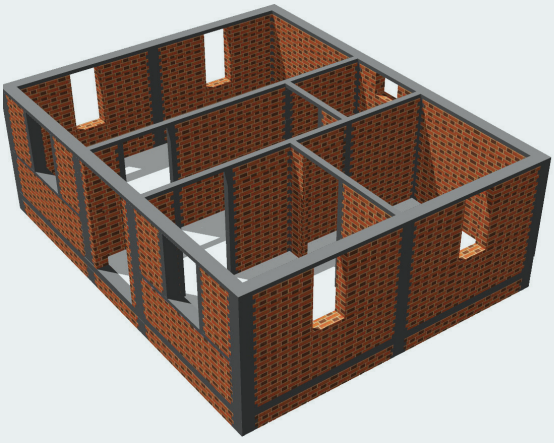
Step 5: Cast the sill band using M15 concrete. The concrete must be cured for atleast 7 days. Formwork can be removed after 2 days.



Step 6: Lay brick masonry till lintel level.

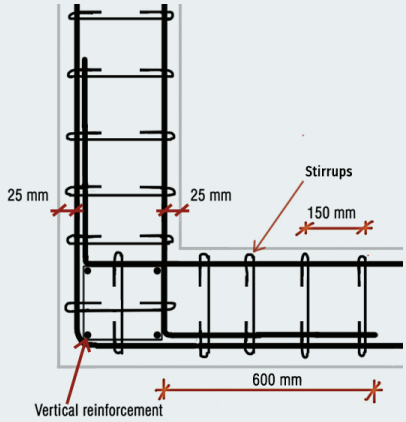


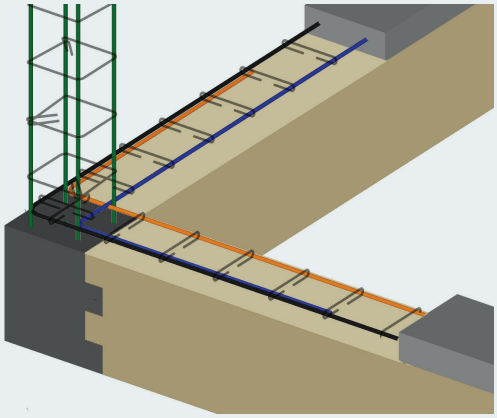
Step 7: Pour M15 concrete of vertical RC elements around reinforcement cage upto the level of top masonry course.



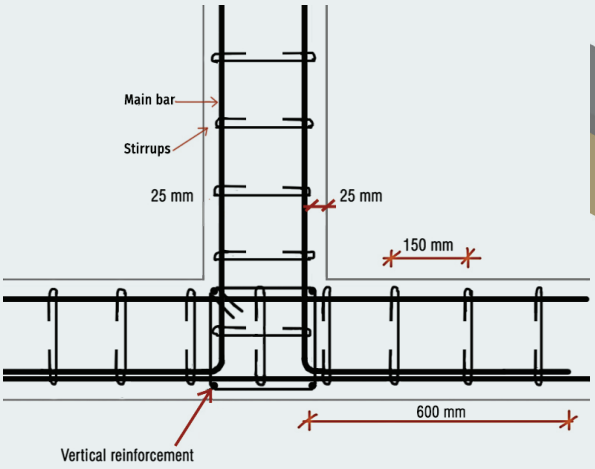
Step 8: Lay reinforcement cage for the lintel band in the same way as the sill band and cast it in concrete. This band must be continuous.

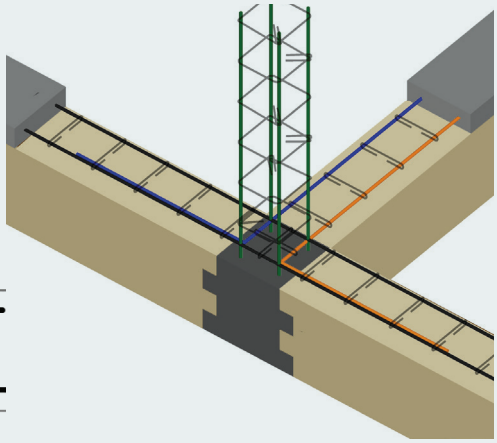
L junction detail (75 mm, 2 bars)

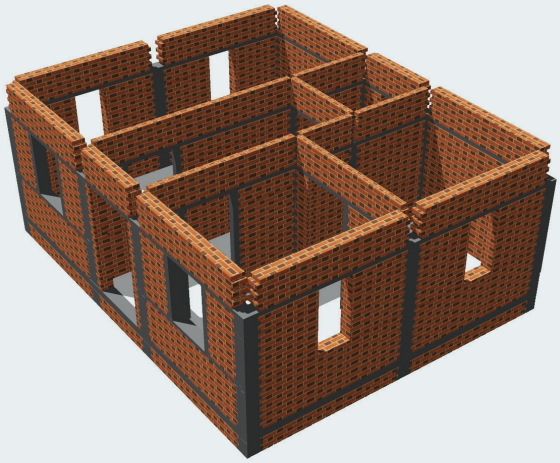




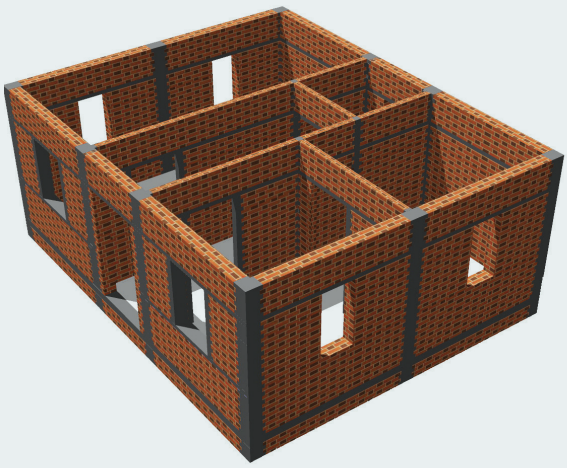
T junction detail (75 mm, 2 bars)







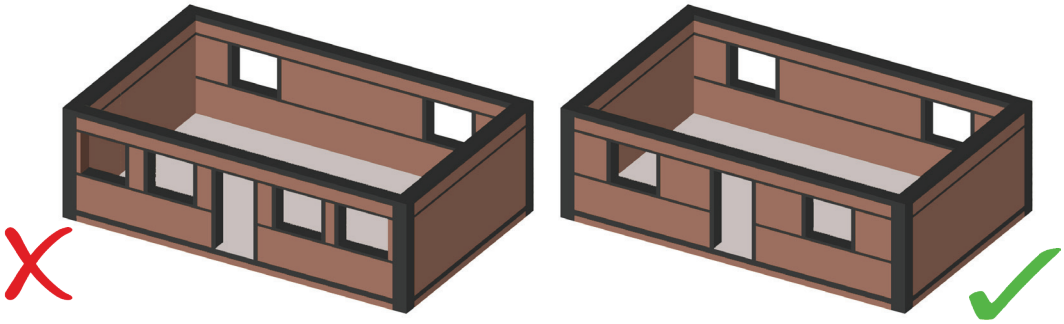
Step 9: Lay brick masonry till intermediate floor level.



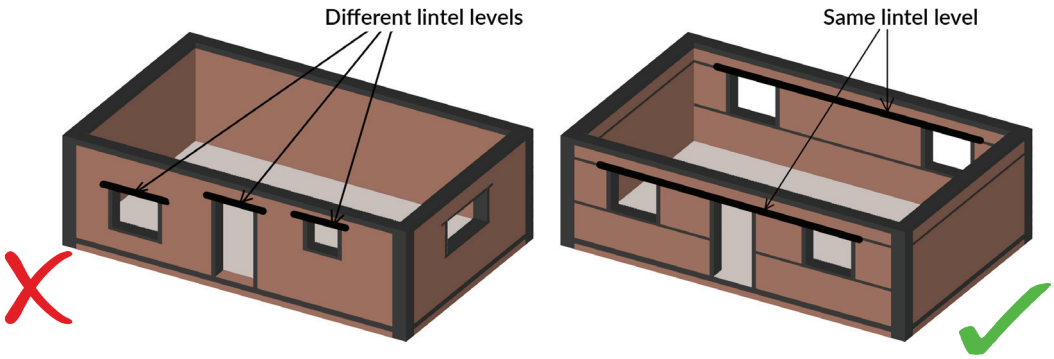
Step 10: Pour M15 concrete of vertical RC elements around reinforcement cage upto the level of top masonry course.

10. Openings

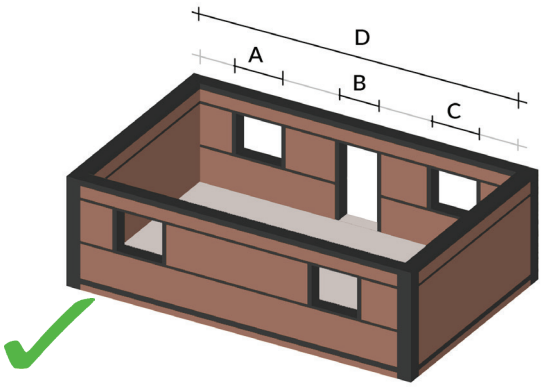
- Too many openings or large central openings on the same wall must be avoided.



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



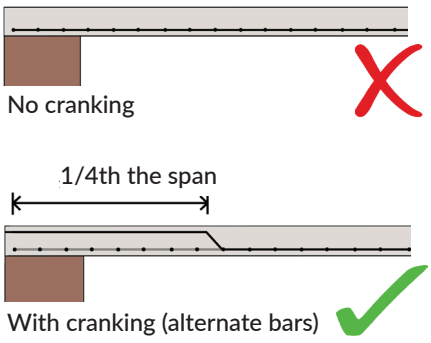
- A + B + C ≤ D/2
  Total length of the openings must be less than equal to half the length of the wall.

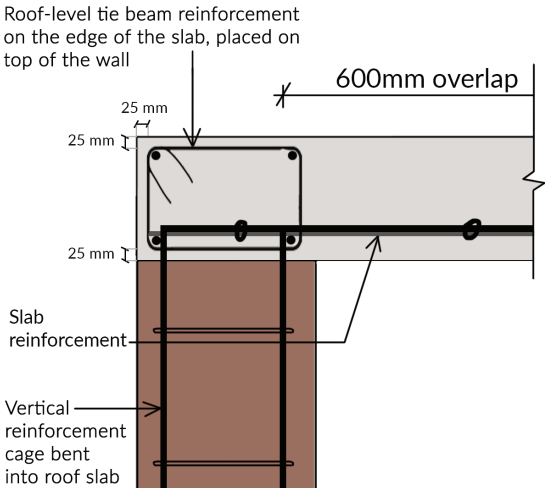


11. Intermediate Floor

11.1 RCC Slab

- Slab should be constructed only after due consultation with an engineer regarding the slab thickness and reinforcement.
- 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.
- M20 concrete should be used for slab construction.
- Rebars should be bent (cranked) alternatively in opposite directions as shown in figure below.





- Roof-level tie beam should be cast in the slab itself with reinforcement similar to plinth-level tie beam. The vertical reinforcement must be embedded in the slab.

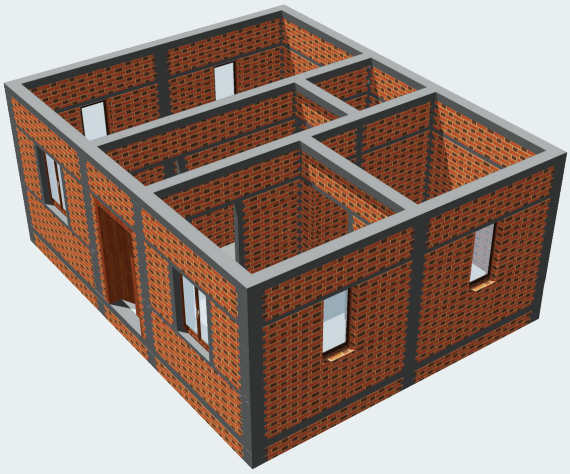
Construction Steps:

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 the 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.
10. De-shuttering should be done by removing the supports starting from the centre and moving towards the ends.

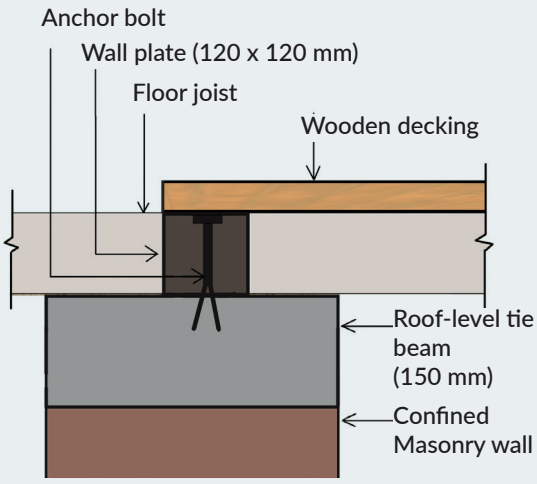
11.2 Timber Joists and Planks

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

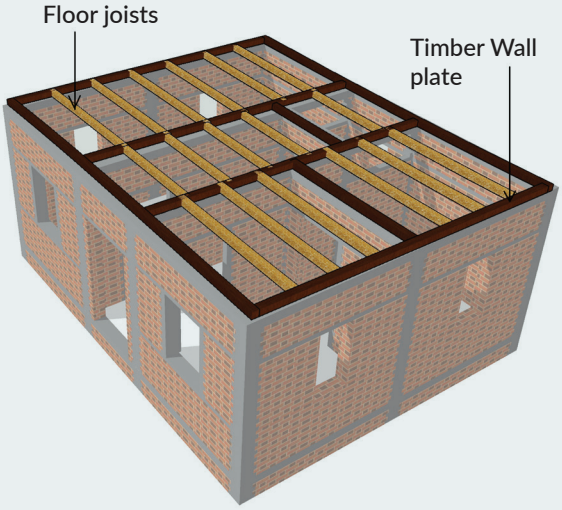
Construction Steps:



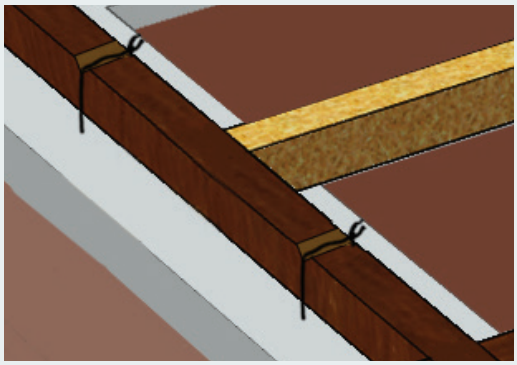
Step 1: Lay reinforcement cage for the roof-level tie beam in the same way as the plinth-level tie beam and cast it in M15 concrete. This band must be continuous.



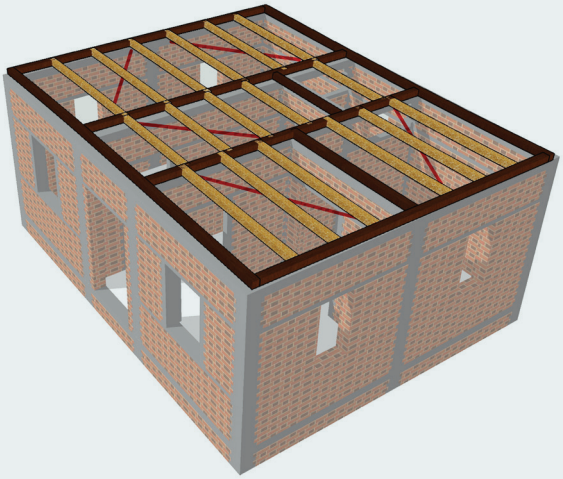
Step 3: Use anchor bolts to connect the timber wall plate to the roof-level tie beam.



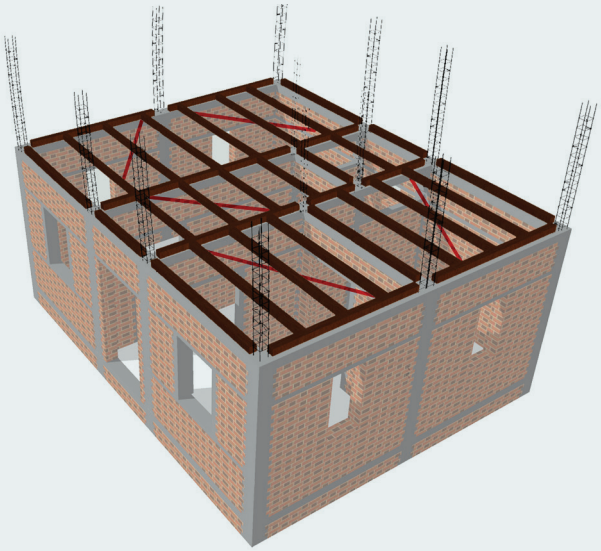
Step 2: Place a 120 x 120 mm wall plate on top of all walls in the centre. Place floor joists between them at regular intervals. The spacing between joists depends upon the length and cross-sectional size of the joist. Maximum spacing between joists should be 900 mm.



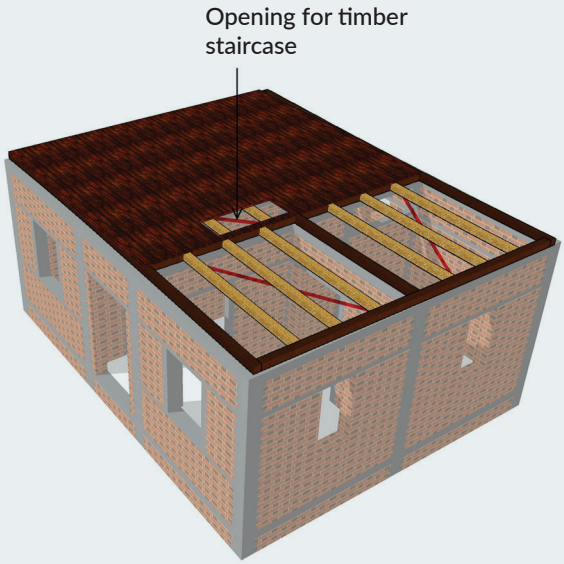
Alternatively, use double 3 mm wire to anchor the joist. Embed these wires while casting the roof-level tie beam. Make a notch in the wall plate to prevent movement.



Step 4: Install diagonal floor bracing 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.



If a G+1 house is being built, continue the vertical reinforcement till roof level. The wall plate should have grooves or can be discontinued to accommodate the reinforcement bars.

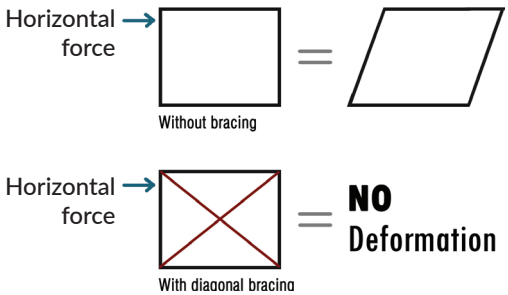


Step 5: Lay wooden decking on the floor joists and secure each plank using at least 2 nails in each joist location. The minimum thickness of the wooden planks should preferably be 40 mm.

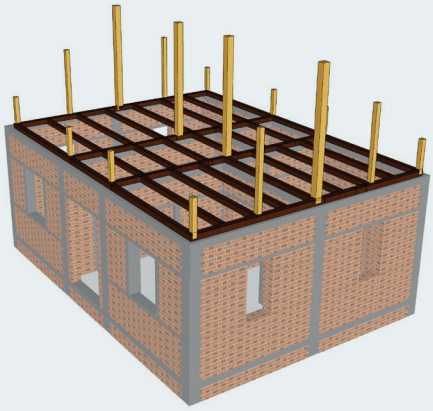
12. Roof Construction

(Gable roof using timber under-structure and CGI sheets)

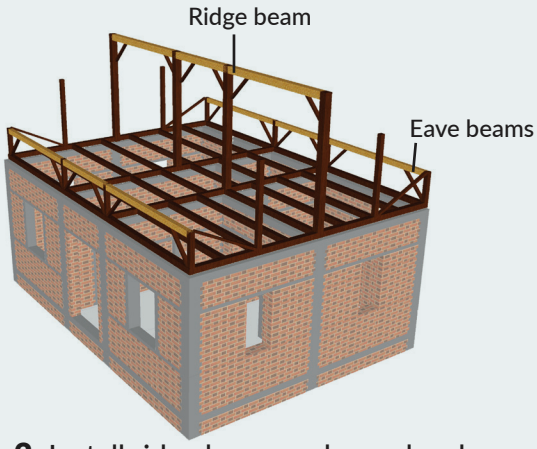
- The roof structure must be well connected to the wall plate and the floor joists.
- The roof must be able to resist horizontal forces, thus needing diagonal bracing.
- Good joinery between different elements of roof understructure is essential for good performance in hazards.
- Minimum slope of the roof should be 30°



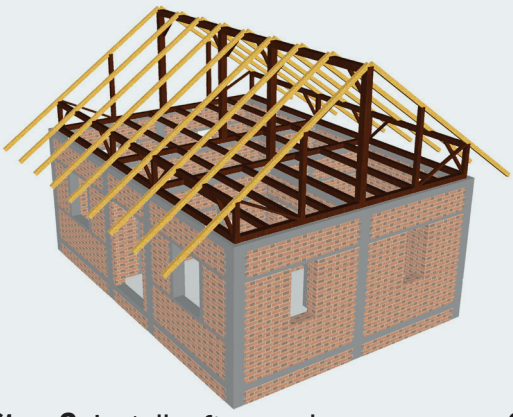
Construction Steps:



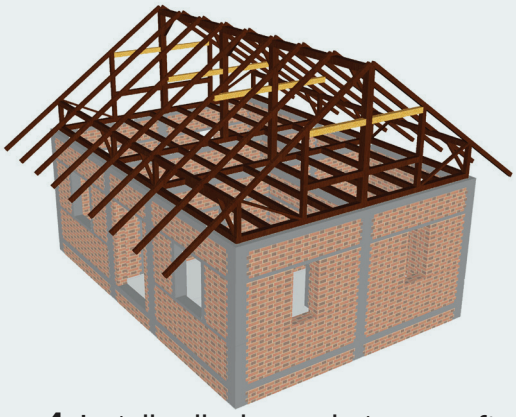
Step 1: Erect timber posts over the floor structure.



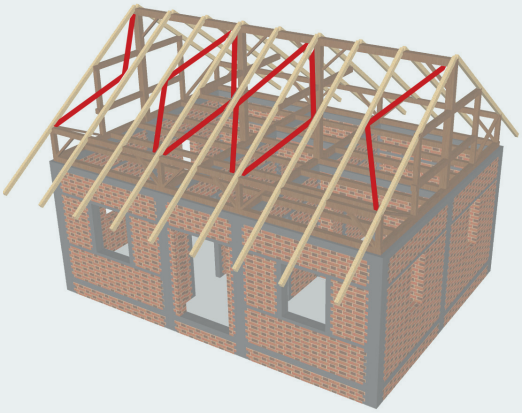
Step 2: Install ridge beam and eave level beams and level them using water tube. Brace the timber posts and beams using 100 x 25 mm struts, such that the attic space is usable as a room.

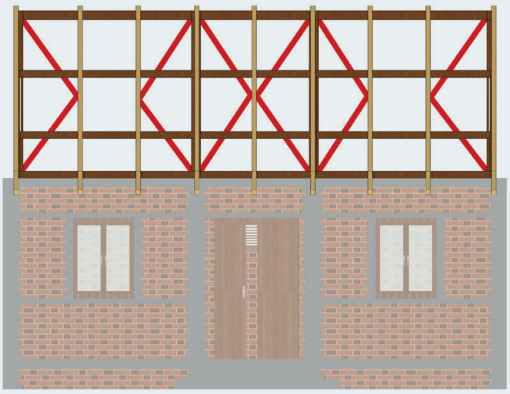


Step 3: Install rafters and ensure good joinery with the timber posts.

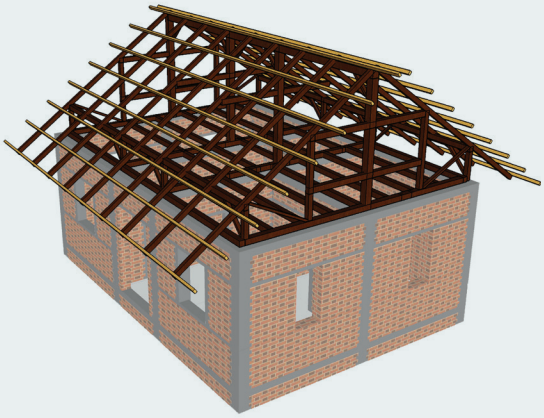


Step 4: Install collar beams between rafters at 2/3 rd height of the roof across opposite rafters and connect them securely.

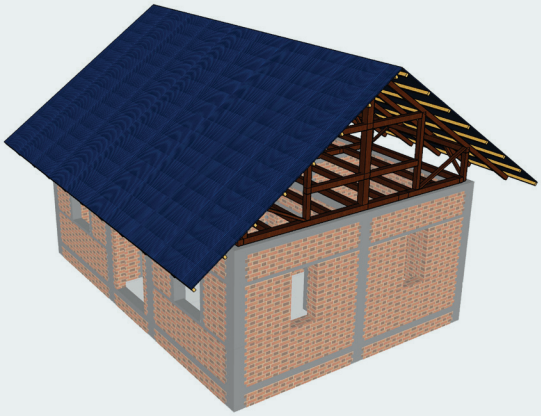




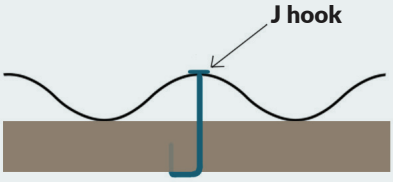
Step 5: Use 2 nails each, install 100 x 25 mm struts on the underside of purlins for in-plane bracing of inclined joists. Alternatively, use 3-5 strands of 13 gauge GI wires.



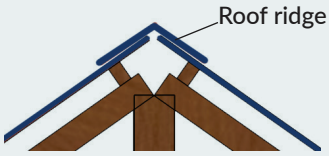
Step 6: Install 40 x 40 mm purlins and fix them well with the rafters. Extend an overhang of minimum 800 mm.



Step 7: Install CGI sheets with reasonable overlap to prevent any leaks. Secure them to the purlins using 'J' hooks and rubber washers.

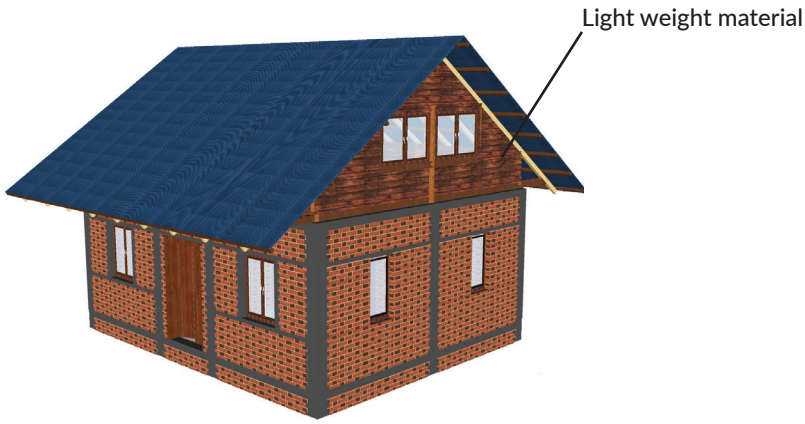


The holes in the sheet must be made in the ridges to minimise water leakages.

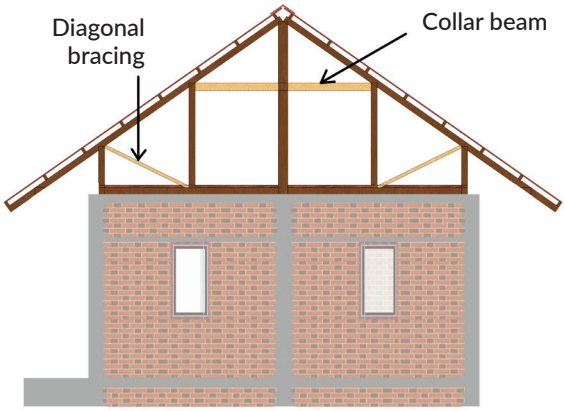


The overlap between the CGI sheets and the ridge cap should be at least 150 cm

13. 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.

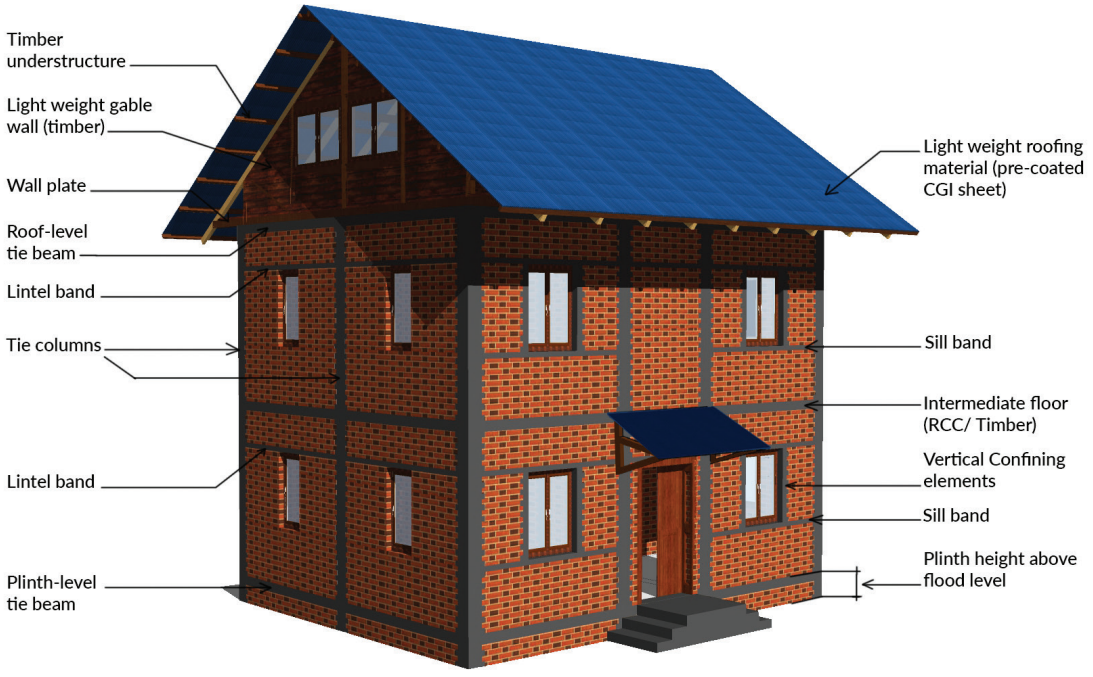


- Diagonal bracing and collar beams must be provided as wall under-structure.

14. A Complete House

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

Ground floor structure



G+1 structure

References

- Bothara, Jitendra; Brzev, Svetlana. 2012. A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings. Earthquake Engineering Research Institute (EERI).
- Brzev, Svetlana; Mitra, Keya. 2018. Earthquake-Resistant Confined Masonry Construction. National Information Centre for Earthquake Engineering.
- Bureau of Indian Standards. 2007. CED 39- Confined Masonry.
- Desai, Rupal; Desai, Rajendra. 2008. Manual on Hazard Resistant Construction in India. UNDP.
- Desai, Rupal; Desai, Rajendra. 2007. Manual for Restoration and Retrofitting of Rural Structures in Kashmir. UNESCO.
- Iyer, Kamu; Kulkarni, Shibani M; Subramaniam, Shantanu; Murty, C.V.R; Goswami, Rupen; Vijayanarayanan, A.R. n.d. 2013. Build a Safe House with Confined Masonry. GSDMA.
- Pandey, Bishnu; Brzev, Svetlana; Culbert, Robert; Schoenfeld, Glade. 2017. Illustrated Guidelines for Construction of Stone Masonry Houses in Seismic Regions of Nepal.
- Schacher, Tom. 2009. Confined Masonry. NICEE.
- UNDP, Mason's handbook for disaster-resistant construction in Nepal. 2018. UNDP-GOI.

Notes

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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 project aims at both restoring essential services disrupted by the floods and improving the design standard and practices to increase resilience.

Taru VMS JV LLP with People in Centre

TARU VMS LEADING EDGE