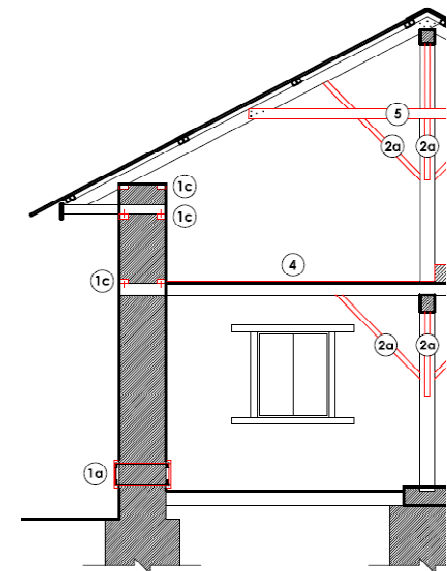
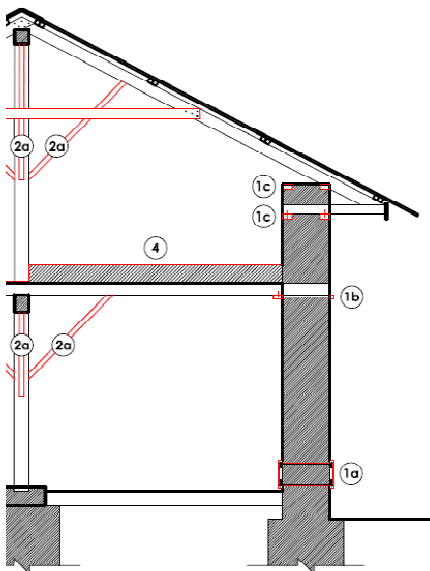




AWASUKA RETROFITTING MANUAL

FOR EARTHQUAKE-RESISTANT
STONE & MUD HOUSES

Autumn 2018



BHIMPHEEDI AWASUKA



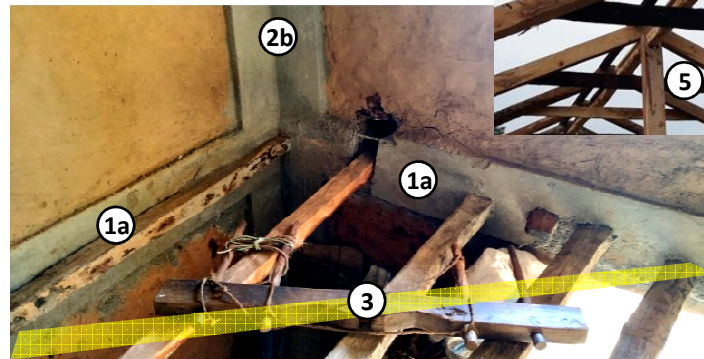
भीमफेदी आवासुका



MAIN RETROFITTING POINTS

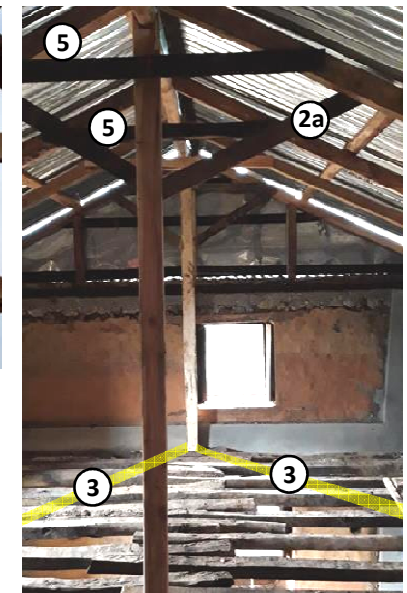
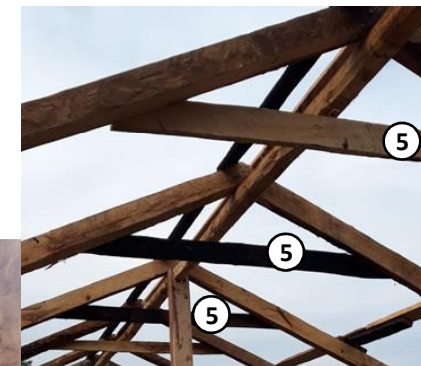
OUTER STONE-MUD STRUCTURE - WALLS

All stone & mud (*dhunga-mato*) walls must be connected horizontally (1) and vertically (2) by **connecting bands**, like a **package**. These bands also connect the inner and outer wythes of the wall, avoiding delamination.



INNER WOODEN STRUCTURE - PILLARS, FLOOR & ROOF

The inner wooden structure must be stiffened horizontally (3) and vertically (2) with **diagonals**. The roof structure must also be stiffened with **ties** (5).



MAIN RETROFITTING POINTS

1. HORIZONTAL STIFFENING of WALLS: RING BANDS. All *dhunga-mato* walls must be connected perimetally by horizontal bands to tie the whole building together like a package. These bands also connect the inner and outer wythes of the wall, avoiding delamination. The main levels to be connected are: plinth-level, floor-level, eave-level and roof-level.

Depending on the used materials, we will have different ways to do the RING BANDS:

- 1a** Ring Concrete Bands. *Very appropriate for plinth beam*
- 1b** Ring Wooden Bands under joists. *To be applied when all walls are kept and not demolished (1st floor walls)*
- 1c** Ring Wooden Bands on joists. *To be applied when part of the walls are demolished (1st floor walls)*

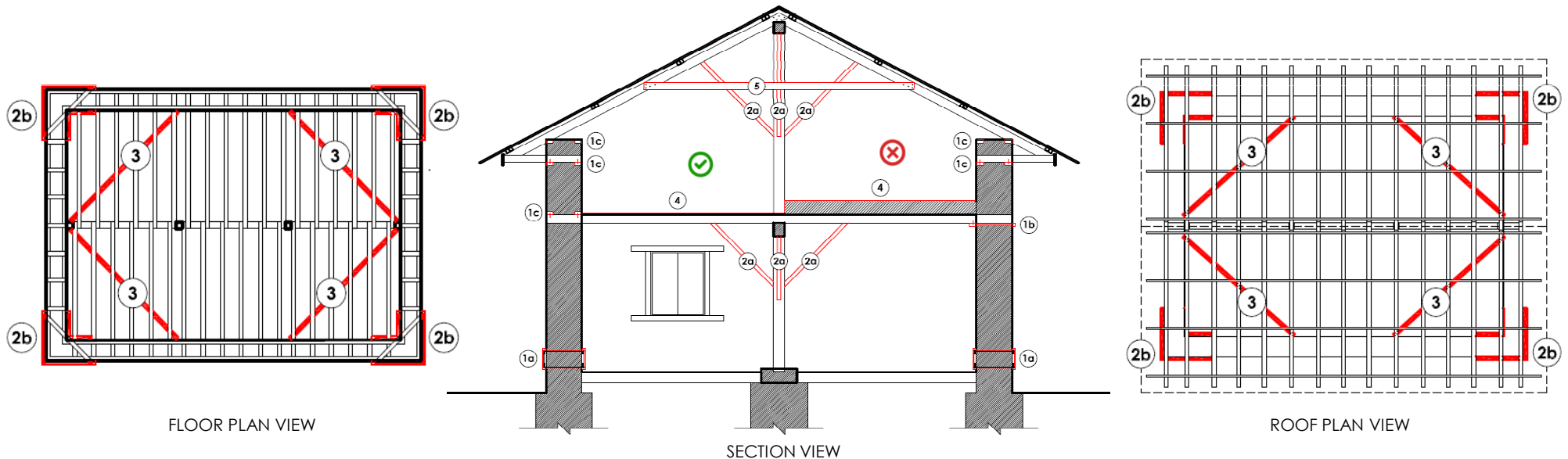
2. VERTICAL STIFFENING of PILLARS & WALLS: DIAGONALS & CORNER BANDS. Vertical planes must be stiffened in two directions. Wooden inner pillars must be braced in both directions with diagonal wooden braces. Wall corners must be stiffened with reinforced concrete bands inside and outside the house, connected by through-GI-wires and anchored by rods. These are the two types of vertical stiffening:

- 2a** Diagonal Braces
- 2b** Corner Concrete Bands

3. FLOOR STIFFENING: DIAGONAL BRACES. Horizontal planes (floors and roofs) must be stiffened by diagonal wooden braces. Their layout will be different in each case, as it will have to be adapted to the house shape.

4. FLOOR LIGHTENING: LIGHTER FLOOR FINISINGS. Floors usually have a thick layer of mud and stones, reaching a thickness of 8" or more. This dead-load must be cancelled as weight in higher floors makes the buildings more vulnerable to earthquakes. Floors can be made using wooden boards or plywood.

5. ROOF STRUCTURE: HORIZONTAL TIE. Wooden rafters and wooden trusses must always be connected by diagonal wooden braces. Their layout will be slightly different according to the case.



1. HORIZONTAL STIFFENING of WALLS

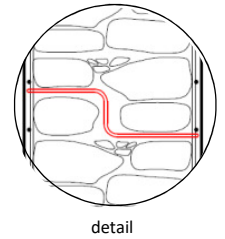
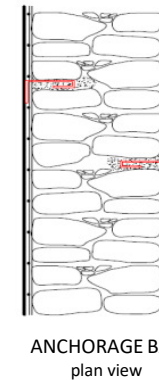
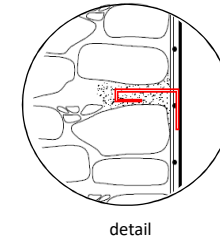
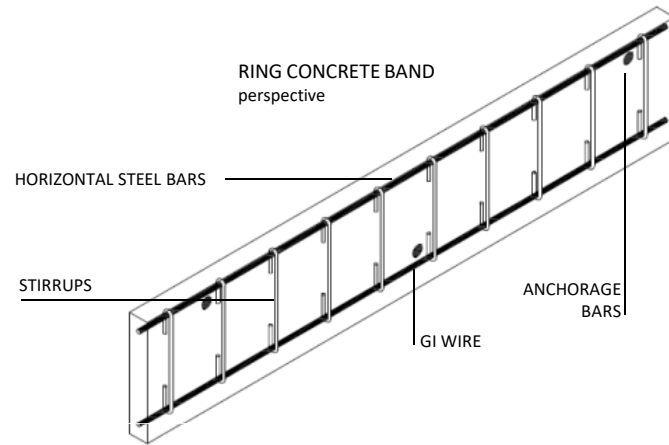
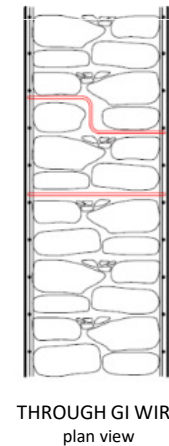
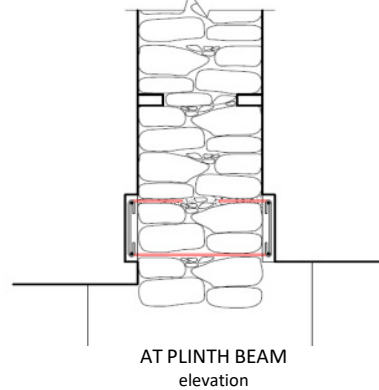
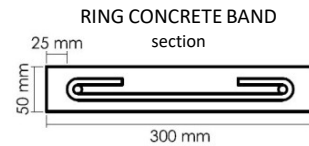
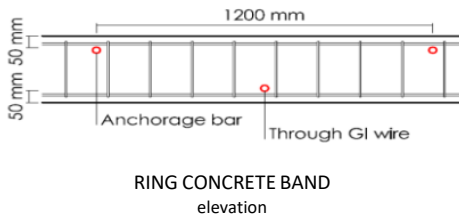
RING BANDS

1a RING CONCRETE BANDS

Addition of bandage on outer faces of wall when plinth/sill/lintel/roof bands are missing
Appropriate for plinth beams

DETAILS

ROD 10mm Ø, 600mm lap
STIRRUP 7mm Ø @150mm c/c, 420mm lap
CONCRETE M15 (1:2:4) (micro-concrete)



CONSTRUCTION PROCEDURE

a) Preparation of the area

- Remove plaster
- Clean surface without water
- Apply thin layer of cement

b) Placing of Reinforcement

- Place horizontal steel bar
- Place stirrups

c) Holes for anchorage, combining 2 types:

c1) THROUGH GI WIRE

- Make through holes using steel rod and hammer
- Insert GI wire
- * when it is not possible to make a straight hole: remove stone on one side of the wall / insert GI wire by bending it / place stone back using mortar

c2) ANCHORAGE BAR

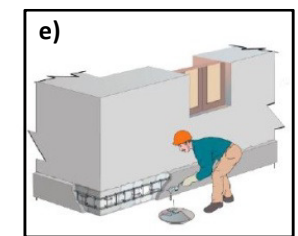
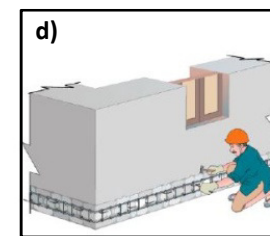
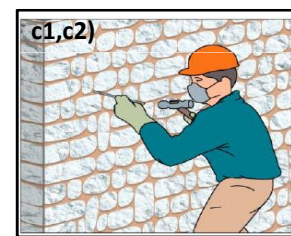
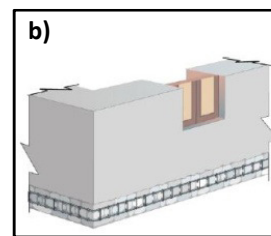
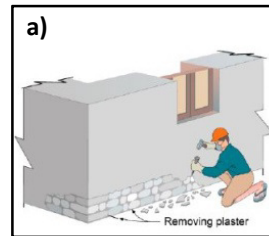
- Make holes using steel rod and hammer
- Insert steel anchorage bars
- * when it is not possible to make a straight hole: remove stone on one side of the wall/ place anchorage bar/ place stone back using mortar

d) Anchor reinforcing bar mesh

- Fix reinforcing bars with the inserted steel anchorage bars and seal them using cement slurry (c2)
- Connect inner and outer mesh using inserted through GI wires (c1)

e) Application of concrete

- Apply two layers of 20-25mm of micro concrete. **TOTAL: 40-50mm**
- Cure the concrete for **14 days** using jute bags/mats



1. HORIZONTAL STIFFENING of WALLS

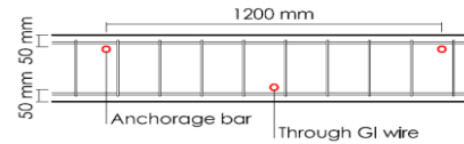
RING BANDS

1a RING CONCRETE BANDS

Ring Concrete Bands at Plinth Level, inside and outside views



Ring Concrete Bands at Floor Level, outside view

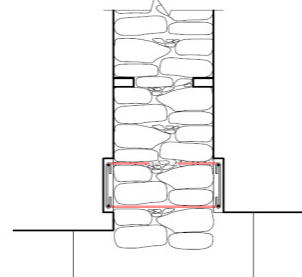


CONCRETE BAND AT FLOOR LEVEL elevation

Ring Concrete Bands at Plinth and Floor Levels



CONCRETE BAND AT PLINTH BEAM elevation



1. HORIZONTAL STIFFENING of WALLS

RING BANDS

1b RING WOODEN BAND UNDER JOISTS

Addition of bandage on outer faces of wall when floor bands are missing. To be applied when the first floor wall is not demolished. Tie joists together with wooden band (under joists) and then connect them to an outer wooden band.

CONSTRUCTION PROCEDURE

a) Surface preparation

- Remove plaster
- Clean surface without water
- Apply thin layer of cement

b) Holes for anchorage

THROUGH GI WIRE

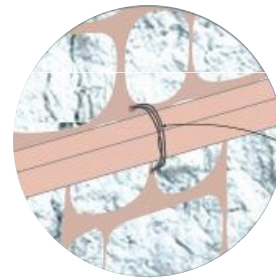
- Make through holes using steel rod and hammer
- Insert GI wire
- * when it is not possible to make a straight hole: remove stone on one side of the wall/ insert GI wire by bending it/ place stone back using mortar

c) Install horizontal wooden band

- Place **75mm x 38mm** horizontal wooden band on either side of wall

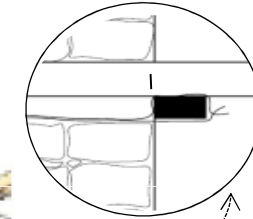
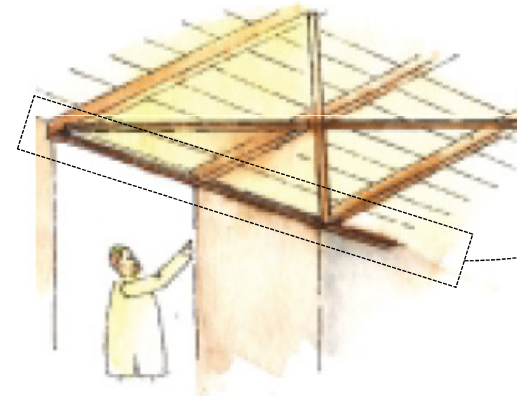
d) Anchor GI wire mesh

- Connect the horizontal wooden band with the wall using inserted GI mesh, seal the mesh using cement slurry or mud plaster.

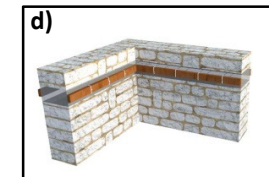
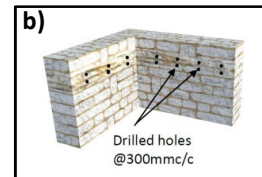
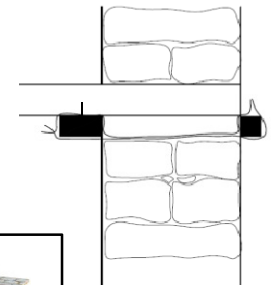


THROUGH GI WIRE (b)
perspective view

RING WOODEN BAND UNDER JOIST (inside)
perspective view



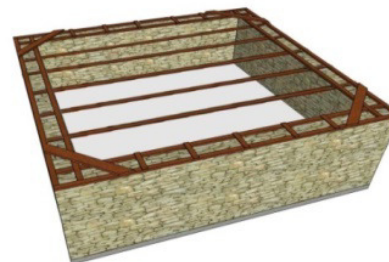
RING WOODEN BAND UNDER JOIST



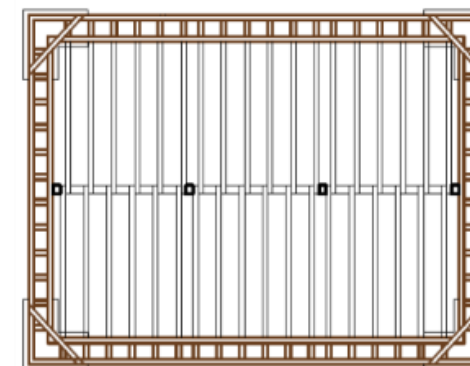
1c RING WOODEN BAND ON JOISTS

Addition of bandage inside the wall when floor bands are missing. To be applied when the first floor wall has been demolished. Tie all the joists together with wooden bands on joists in both sides of the wall.

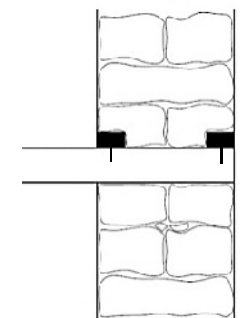
- Around all the perimeter
- Placing triangular slats in the corners



RING WOODEN BAND ON JOIST
perspective view



RING WOODEN BAND ON JOIST
plan view



RING WOODEN BAND ON JOIST
elevation

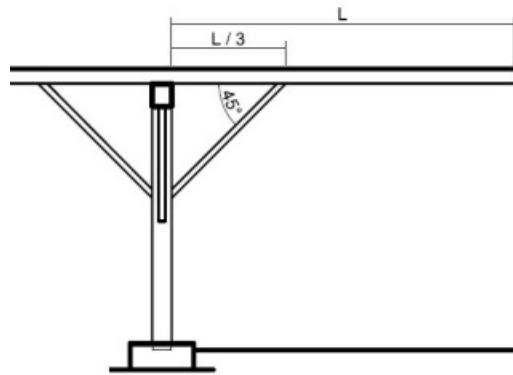
2. VERTICAL STIFFENING of PILLARS & WALLS

DIAGONAL BRACES & CORNER BANDS

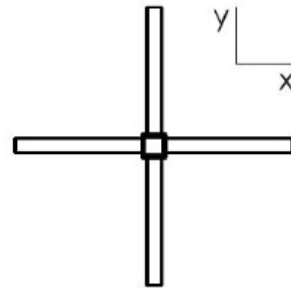
2a DIAGONAL BRACES

Addition of vertical diagonal braces to stiffen wooden pillars in all storeys (first floor and roof):

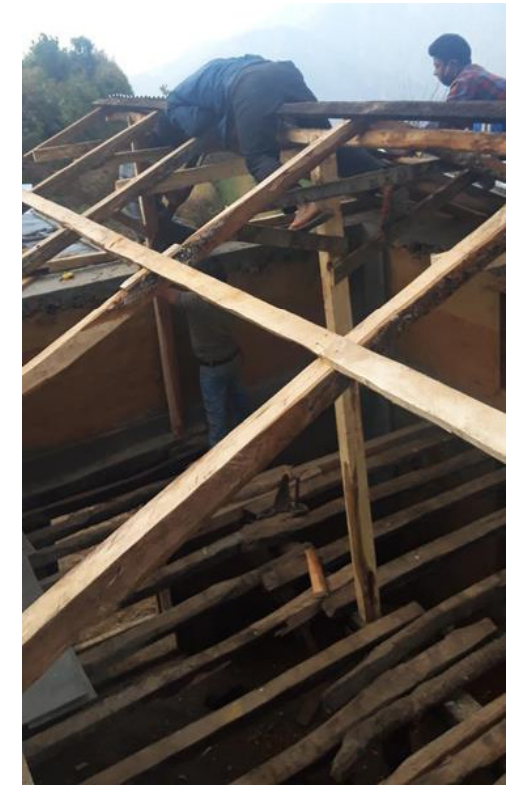
- both directions of pillars (x-y)
- $1/3$ of the beam span
- forming a 45° angle with the pillar



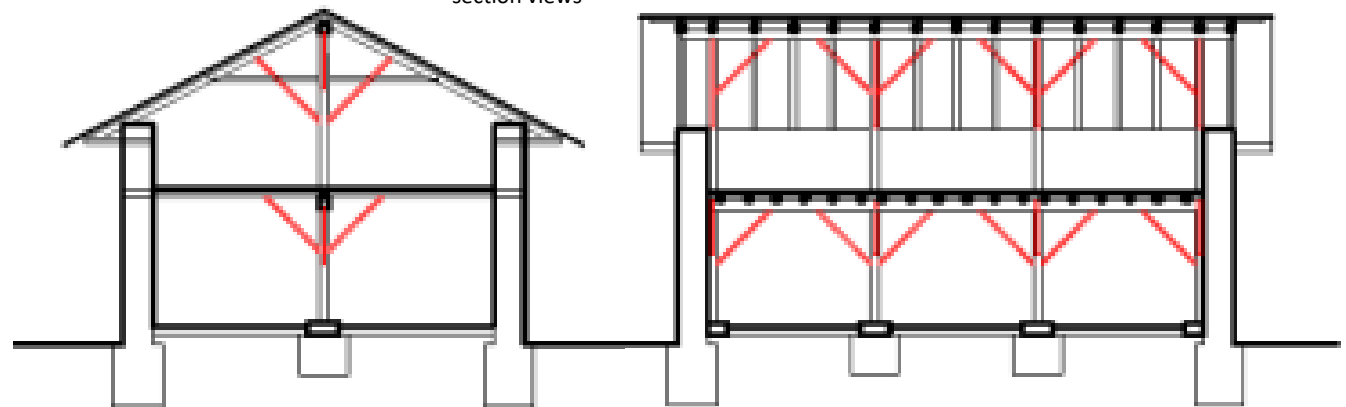
elevation



plan view



section views



2. VERTICAL STIFFENING of PILLARS & WALLS DIAGONAL BRACES & CORNER BANDS

2b CORNER BANDS

CONSTRUCTION PROCEDURE

a) Preparation of the area

- Remove plaster
- Clean surface without water
- Apply thin layer of cement

b) Placing of Reinforcement

- Place horizontal steel bar
- Place stirrups

c) Holes for anchorage, combining 2 types:

c1) THROUGH GI WIRE

- Make through holes using steel rod and hammer
- Insert GI wire

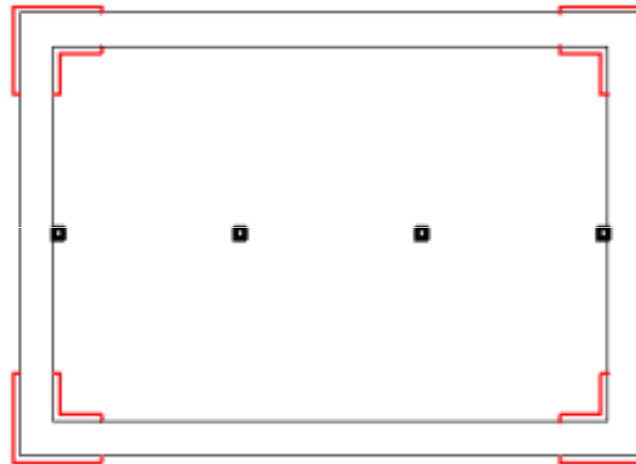
* when it is not possible to make a straight hole:
remove stone on one side of the wall/ insert GI wire by
bending it/ place stone back using mortar

d) Anchor reinforcing bar mesh

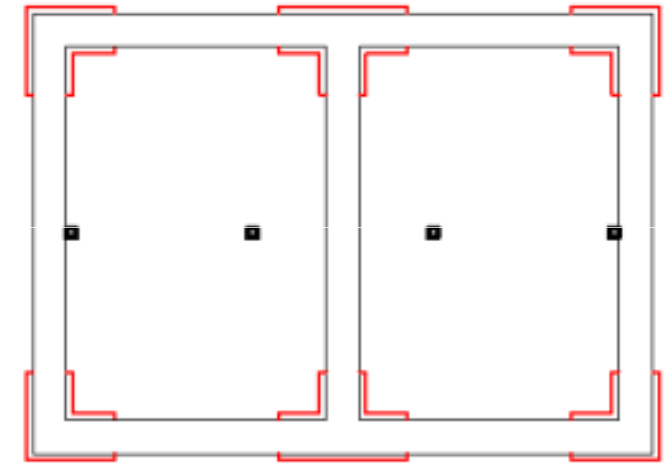
- Fix reinforcing bars with the inserted steel anchorage bars and seal them using cement slurry (c2)
- Connect inner and outer mesh using inserted through GI wires (c1)

e) Application of concrete

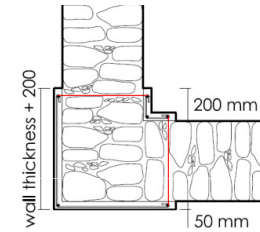
- Apply two layers of 20-25mm of micro concrete. **TOTAL: 40-50mm**
- Cure the concrete for 14 days using jute bags/mats



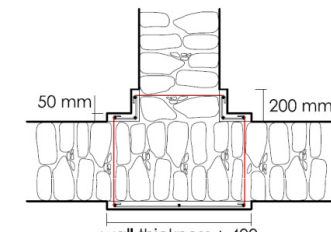
CORNER BANDS
plan view



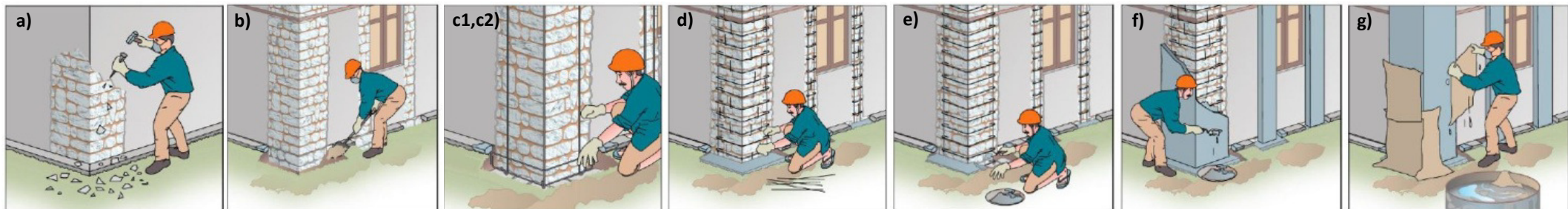
CORNER & T-JUNCTION
plan view



CORNER
plan view



T-JUNCTION
plan view

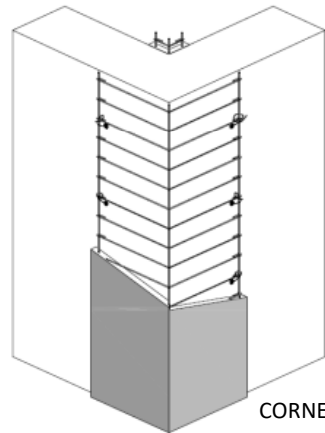


2. VERTICAL STIFFENING of PILLARS & WALLS

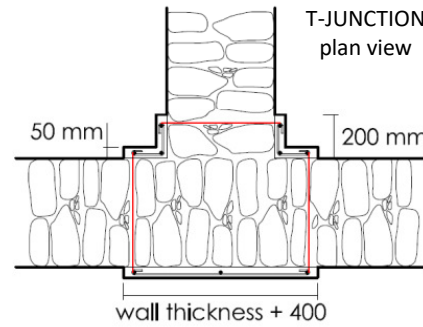
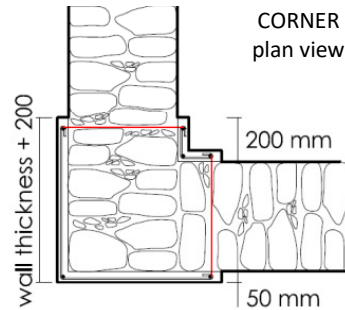
DIAGONAL BRACES & CORNER BANDS

2b CORNER BANDS

Must be applied to the four corners of the house, and also to the T-Junctions, if any. They must be connected to all the ring bands: plinth band, floor band and roof band.



CORNER BAND perspective



3. FLOOR STIFFENING

DIAGONAL BRACES

DIAGONAL BRACES IN FLOORS

Diagonal braces along with struts, if connected well on the underside of the deck, greatly reduce the in-plane deformation of the deck and thus significantly reduce the lengthening.

CONSTRUCTION PROCEDURE

- The bracings and struts can be installed in a variety of arrangements as shown.
- Install a **100 mm x 25 mm (4" x 1")** strut (plank) on the underside of the floor beams adjacent to a long wall. Install an additional strut parallel to this on opposite wall. Pre-drill these planks to prevent splitting from the holes at the ends. Also pre-drill pilot holes in the floor beams, if possible, to facilitate nail driving. Use a minimum of 2 nails at each end of the beam.
- Install diagonal bracings starting from one end of a strut to the far end of the opposite strut. The angle between the brace and the strut should be as close to **45°** as possible and also such that full sets of bracings are accommodated.
- Install more sets of bracings starting from the end points of the bracings already installed to cover more of the deck area.
- Installation of bracings can also be done in a manner similar to that of the planks. If it is difficult to accommodate two nails at each end, 3 mm thick steel gusset plates may be used with bolts.

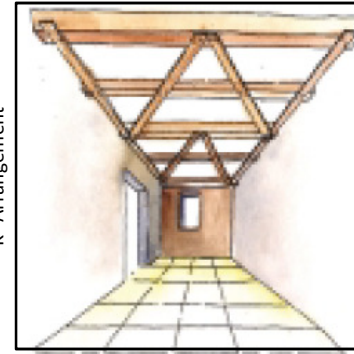
DIAGONAL BRACES IN ROOF

Diagonal bracings installed on the underside of the top chords of trusses or the principal rafters will prevent the in-plane distortion of roof in the event of seismic forces parallel to the ridge.

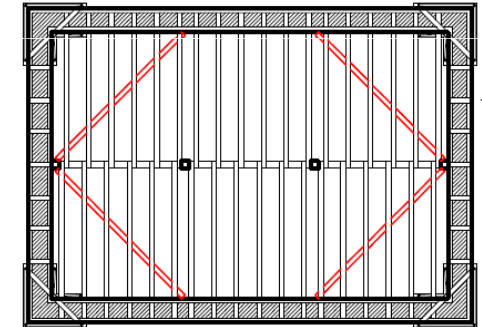
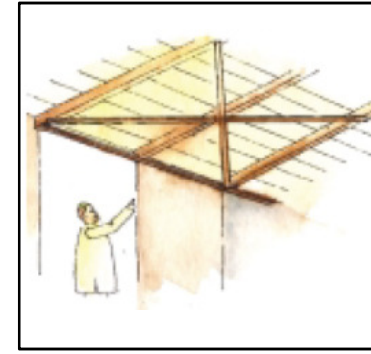
CONSTRUCTION PROCEDURE

- Bracings can be installed in a variety of arrangements as shown in the diagram, depending upon available timber length. Continuity from ridge to eave level must be maintained.
- The angle between the brace and top chord/rafter should be as close to **45°** as possible for optimal effectiveness.
- Bracing should be of **100 mm x 25 mm (4"x1")** or heavier planks. Pre-drill the planks to prevent splitting from the holes at the ends. Also pre-drill the top chord/principal rafters to minimize the likelihood of splitting because of their age and dryness. Use a minimum of two nails at each end.
- Install one or two more sets of bracings with similar arrangement between other sets of rafters, maintaining symmetry. Bracings must be installed in a symmetrical fashion on either side of the ridge.
- If the space is not adequate for two nails at each end, joints can be made using a 3 mm gusset plate.

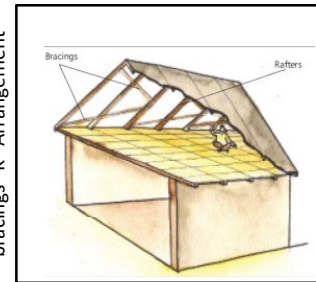
Floor deck timber bracings
"K" Arrangement



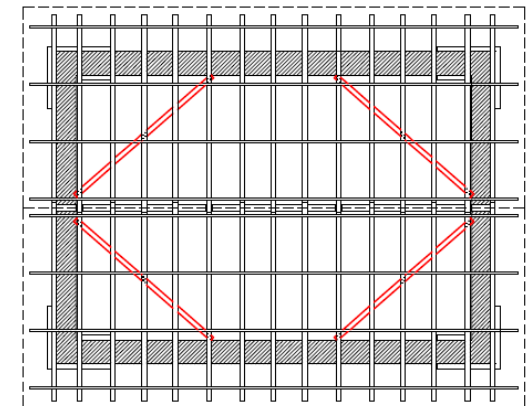
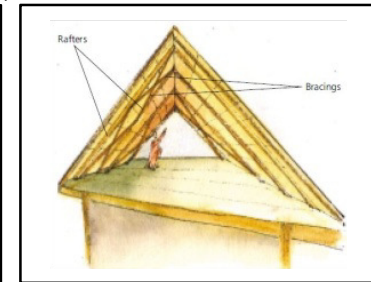
Floor deck timber bracings
"X" Arrangement



Roof retrofitted with in-plane
bracings "K" Arrangement

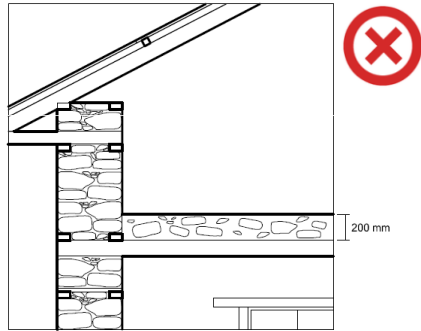


Roof retrofitted with in-plane
bracings "X" Arrangement

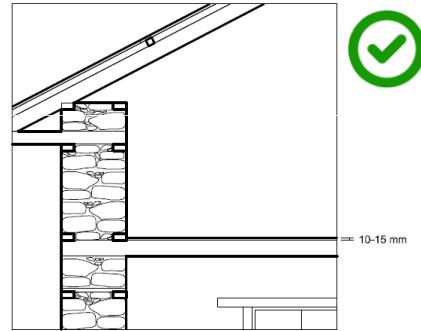


4. FLOOR LIGHTENING LIGHTER FLOOR FINISHINGS

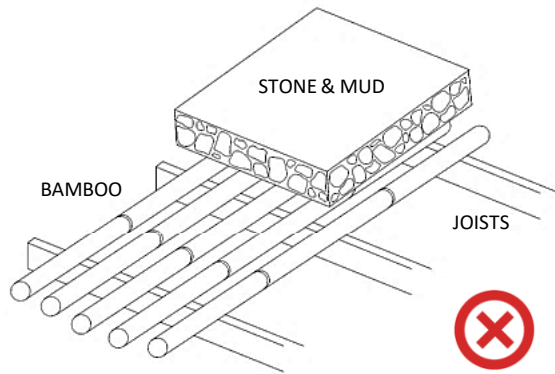
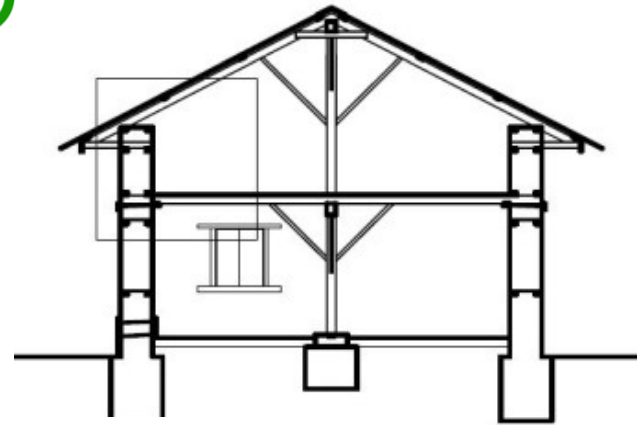
The old-style floor finishing formed by mud and stones must be removed, until the wooden joists are seen. Then, make a new floor out of plywood, in order to make the first floor of the building much lighter. Decreasing weight in upper floors prevents the building from strong shaking under seismic forces.



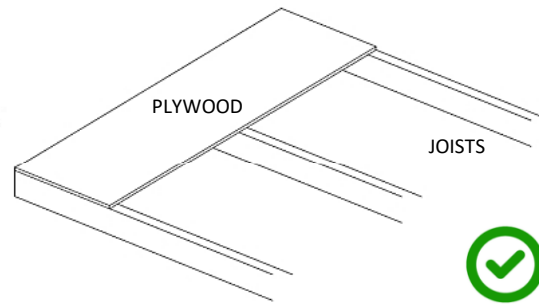
OLD "STONE AND MUD" FLOOR elevation



NEW PLYWOOD FLOOR elevation



OLD FLOOR perspective



NEW FLOOR perspective



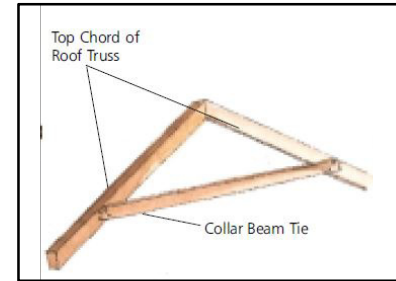
5. ROOF STRUCTURE

HORIZONTAL TIE

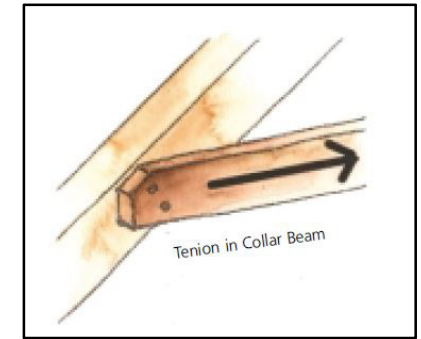
Horizontal Tie is necessary to restrain the main rafters in a horizontal direction, thus reducing out-of-plane roof deformation.



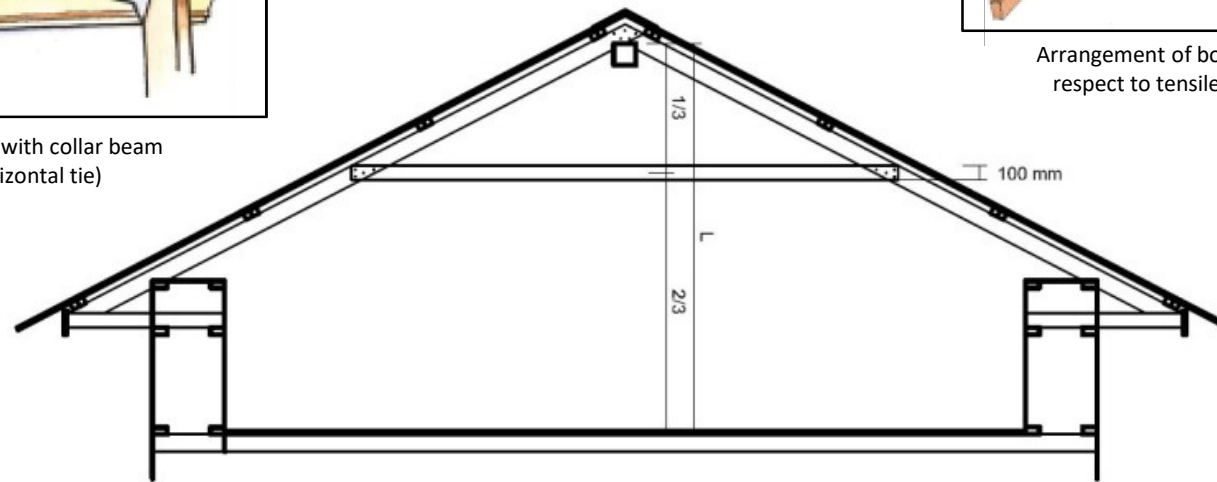
Roof truss with collar beam
(horizontal tie)



Arrangement of bolts with
respect to tensile force



Roof retrofitted with tying
by collar beams



Elevation

CONSTRUCTION PROCEDURE

- Mark installation points on the principal rafters at approximately **2/3 height** of the roof rise on both sides of the ridge. Ensure proper level using water tube.
- Prepare collar beam from **35 mm x 100 mm** plank. Pre-drill the plank to prevent splitting at ends. The holes should be so aligned that they are not in one line with the length of the collar beam. To avoid damage when nailing the wood, which may be dry and hard, pre-drill pilot holes in rafters also.
- Install collar beam plank stretching from one rafter to the opposite rafter.
- Use a minimum of **2-10g 75 mm nails** or **2-5 mm diameter bolts** at each end to fix plank to the principal rafter.

