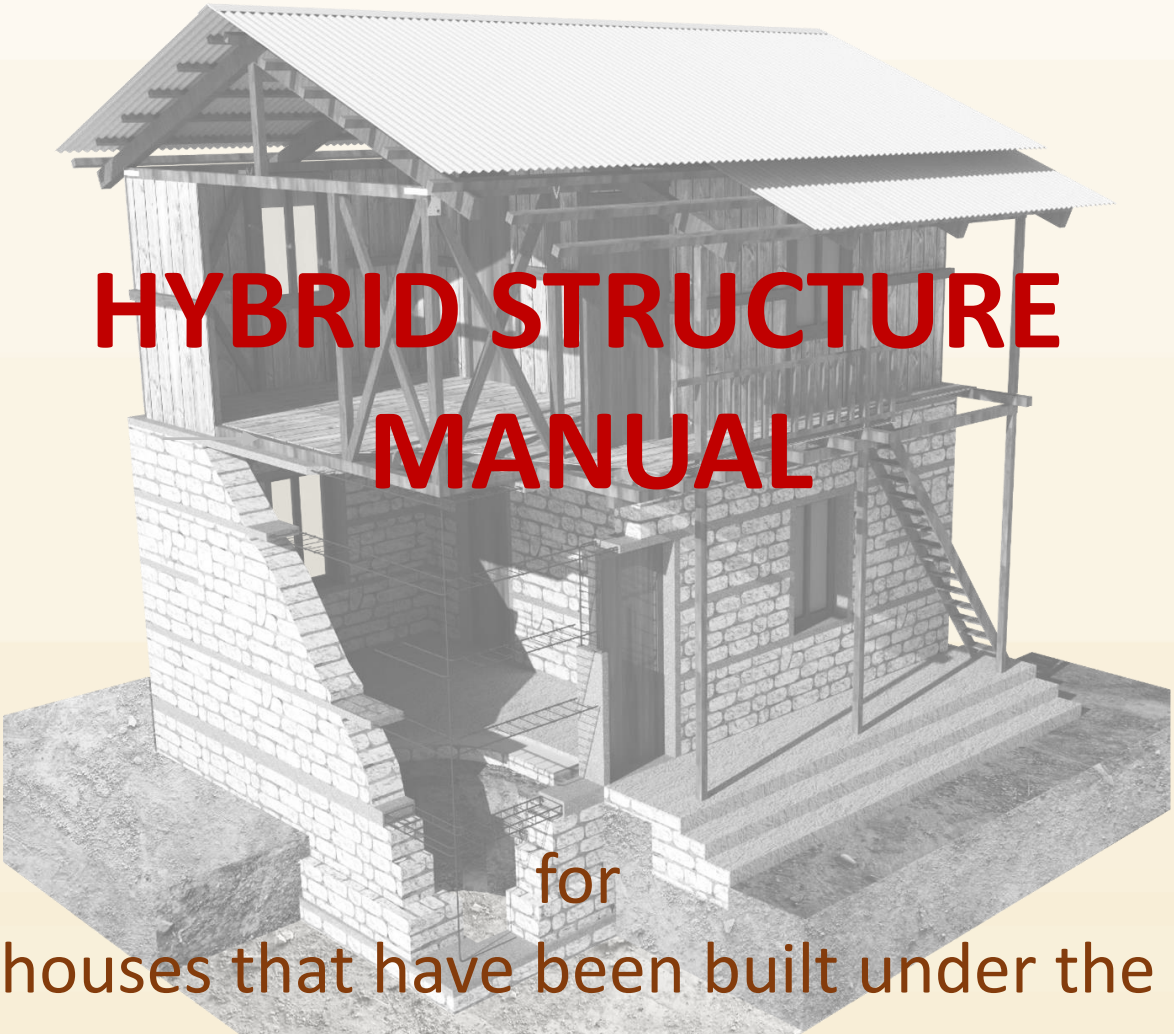
Government of Nepal
National Reconstruction Authority
Singhadurbar, Kathmandu



HYBRID STRUCTURE MANUAL

for
houses that have been built under the
HOUSING RECONSTRUCTION PROGRAMME

2017

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HOUSING RECONSTRUCTION PROGRAMME

Government of Nepal
National Reconstruction Authority
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PART-1: Background and Characteristics of Hybrid Structure

1. Background
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1. Background

On 25th April, an earthquake of magnitude 7.8 struck with epicenter in Barpak, Gorkha. Where several aftershocks were still being felt, meanwhile another major aftershock hit Sindupalchowk district on 12th May, 2015.

Two or more than two storey low strength masonry structure constructed with mud mortar are mostly damaged and destroyed. These structure are predominate in the rural area of Nepal.

Under Housing reconstruction programme, in order to make the earthquake resistance buildings that are to be constructed, NRA has formulated a minimum requirements (MRs) based on the NBC 105.
The MRs clearly stated that for the buildings with stone/brick masonry in mud mortar, the number of story is restricted to only one story if wooden band is used, whereas if RC band is used, allowable number of story is one story plus attic, based on structural analysis.

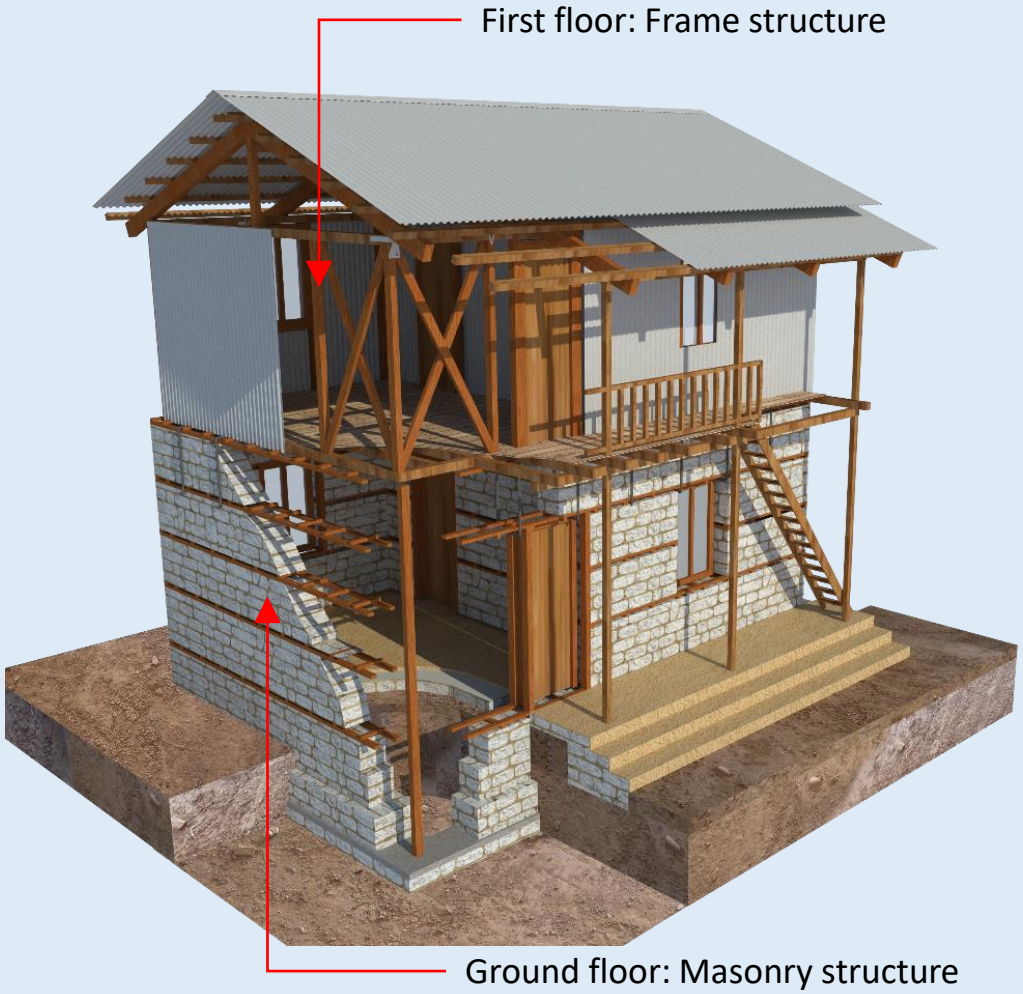
Nevertheless, the people tends to construct two story building to meet their living functional requirement. And other reason is people have felt risk of multi stotey building constructed with low strength masonry structure. Hence, they have built the upper story mostly with timber frame structure using the available materials such as CGI sheet on the masonry structure at ground floor.

Hybrid structure is huge demand in the reconstruction field..

Therefore, in order to ensure the safety of these building against earthquake load and wind load, it has become an urgent task to make the construction guideline along with proper connection details and standards of hybrid structures.

2. Definition of hybrid structure

Hybrid structure (Mix structure) is the combination of two or more type of structural system that is generally constructed with different technology and materials in accordance with level of floor.
The hybrid structure in this manual refer to such structures where the ground floor is constructed by masonry structure and the first floor by timber or steel frame structure with lightweight such as CGI sheet or wooden planks.










Current trend of hybrid structures

3. Limitation of this manual

Limitations

Under the GoN housing reconstruction programme, this manual covers only hybrid structure that are newly constructed or under construction.

This manual has certain limitations and is only relevant for buildings which are:

I. Residential and fall under category 'C' and 'D' of NBC.

- ✓ Category "A": Modern building to be built, based on the international state-of-the-art, also in pursuance of the building codes to be followed in developed countries.
- ✓ Category "B": Buildings with plinth area of more than One Thousand square feet, with more than three floors including the ground floor or with structural span of more than 4.5 meters.
- ✓ Category "C": Buildings with plinth area of up to One Thousand square feet, with up to three floors including the ground floor or with structural span of up to 4.5 meters.
- ✓ Category "D": Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass etc., except those set forth in clauses (a), (b) and (c)

Applicability

This manual is prepared on the basis of NBC105, NBC104 and IS 875. The designs mentioned in the manual are ready-to-use designs for all structural components.

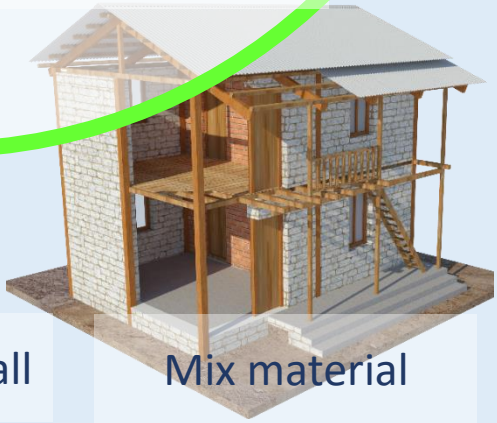
Masonry structure

Timber structure

Hybrid structure

This manual is intended to cover only those buildings that are constructed using load bearing masonry structures in ground floor and frame structure with light weight wall in first floor.

Timber structure + infill brick wall



Mix material

Construction methodology

The masonry structure at ground floor shall consist of all the earthquake resistant elements such as horizontal and vertical bands. R.C. or wood both can be used to construct these bands, but it shall be compliant with the respective minimum requirements.

The first floor shall be timber frame structure. Since, no any specific guidelines has been made till date, different construction technologies resulting from connection details to materials is used for construction of timber framed structures. Any construction details with reference to the provided specification shall be followed in first floor.

The first floor can be constructed with steel frame structure, but the strength of each structural items shall be equivalent to required strength mention in this manual.

Inspection methodology

Under reconstruction programme, if conditions of building are below, inspection shall be based on specification provided in this manual hence, structural calculation is not required.

1. Upto two storey, ground floor with masonry structure and first floor with timber structure.
2. First floor area shall not be more than ground floor area.
3. Height of building is less than 3m for ground floor and 2.5m for first floor.

However, if upper storey has attic, structural calculation is mandatory.

Construction Sequence of hybrid structure

1

1. Install base plate as horizontal member above the floor band of the masonry wall. Properly, connect these base plate with the floor band using the appropriate connecting materials.
   Incase of wooden floor band if the size of main wooden member is as per the required size of base plate then base plate can be ignored, else install base plate above the wooden floor band.

2

2. Install vertical member at required spacing on base plate with proper connection. It shall be continuous from base plate to top plate.

3

3. Install bracing member at each corners of building symmetrically using required size and number.

4

4. Construct wooden trusses for roof by properly connecting it with the top plate.

4. Failure pattern of hybrid structure

The horizontal ground motion is similar to the effect of a horizontal force acting on the building, hence the term “Seismic Load” or “Lateral Load” is used. As the base of the building moves in an extremely complicated manner, inertia forces are created throughout the mass of the building and its contents. It is these reversible forces that cause the building to move and sustain damage or collapse.

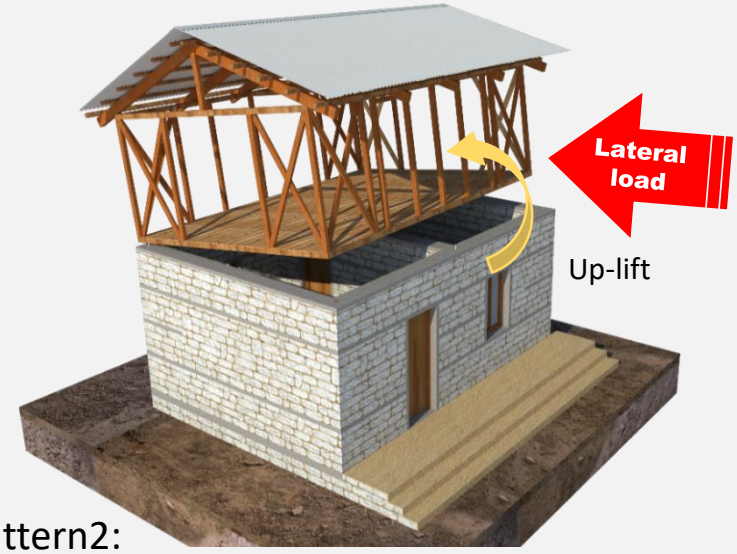
Failure of ground floor

Failure of first floor

Typical failure pattern of first floor

Failure pattern1:

If capacity of elements resisting against lateral loads is not enough, the building will be partially or totally collapsed.

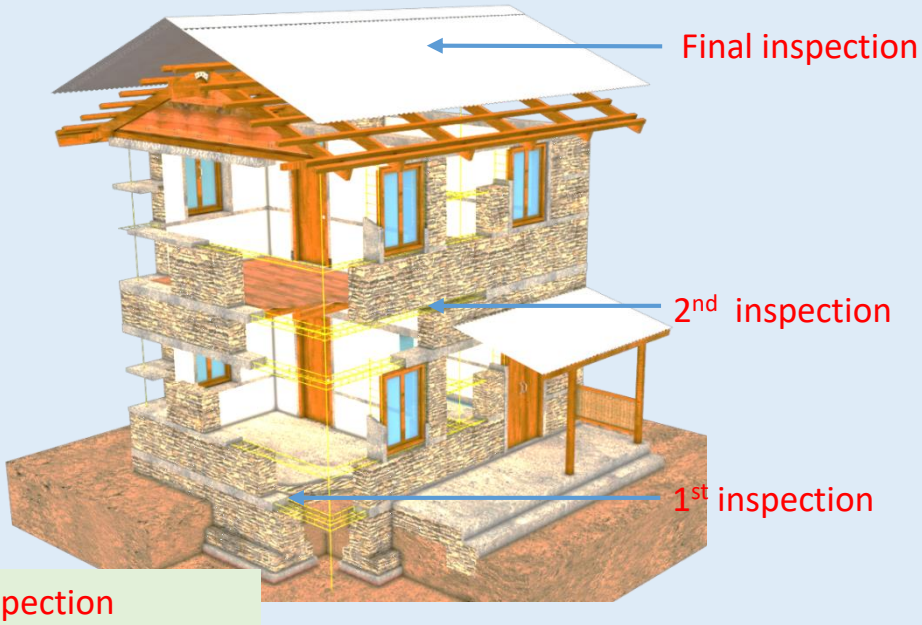


Failure pattern2:

If there is poor connection between the ground floor and first floor with rigid structure, the building might tends to uplifting/rocking or sliding behavior.

5. Timing of executing inspection

MASONRY STRUCTURE



1st inspection

The first inspection shall be done after completion of the construction up to plinth level. The appropriate inspection sheet according to the masonry typology mentioned in **annex 10** in inspection guidelines shall be used during the inspection. If the structure is found to be compliant then it can be certified for receiving 2nd tranche, else the correction order shall be given using the forms provided in **annex 11**.

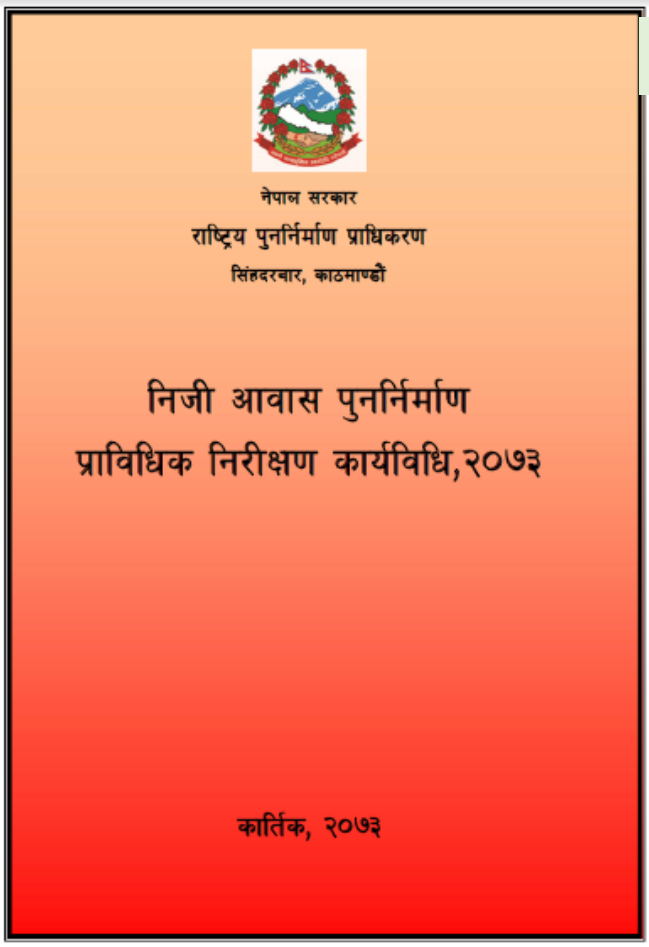
2nd inspection

The second inspection shall be done after completion of the roof band of one story and the first floor of the multistory house, the beneficiaries should apply for the inspection of the house and third installment using the form provided in **annex 6.** Technical Inspection Team should use the form in **Annex-13** to certify the house if the constructed house is according to earthquake resilient design and approved design.

If correction has to be made, **annex- 11** form shall be used by Technical assistance Team informing about the things to be correct.

Final inspection

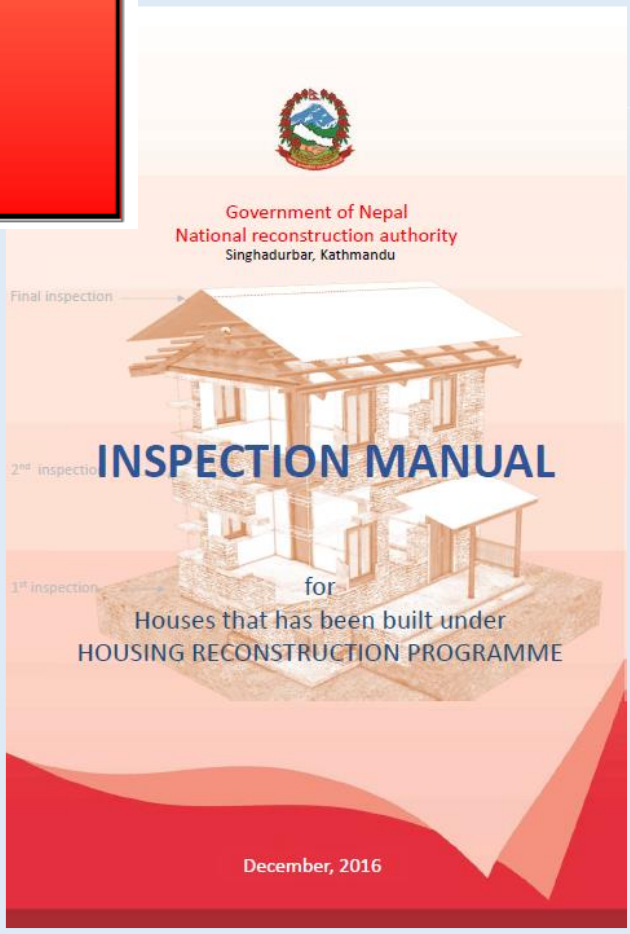
The final inspection shall be done after completion of the roof. Technical Inspection Team should inspect and fill the form as specified in **Annex-15** and if the constructed house is found to be as approved design and earthquake resilient then it is recommended for "House reconstruction completion certificate"



INSPECTION GUIDELINES

Inspection guidelines was publish by NRA under Earthquake affected building reconstruction Act, 2072 for inspection of under construction or constructed building under Housing reconstruction programme.

It consist of the procedure of the grant distribution along with several numbers of inspection forms for various typology of the buildings that needs to be used during inspection of each individual buildings.



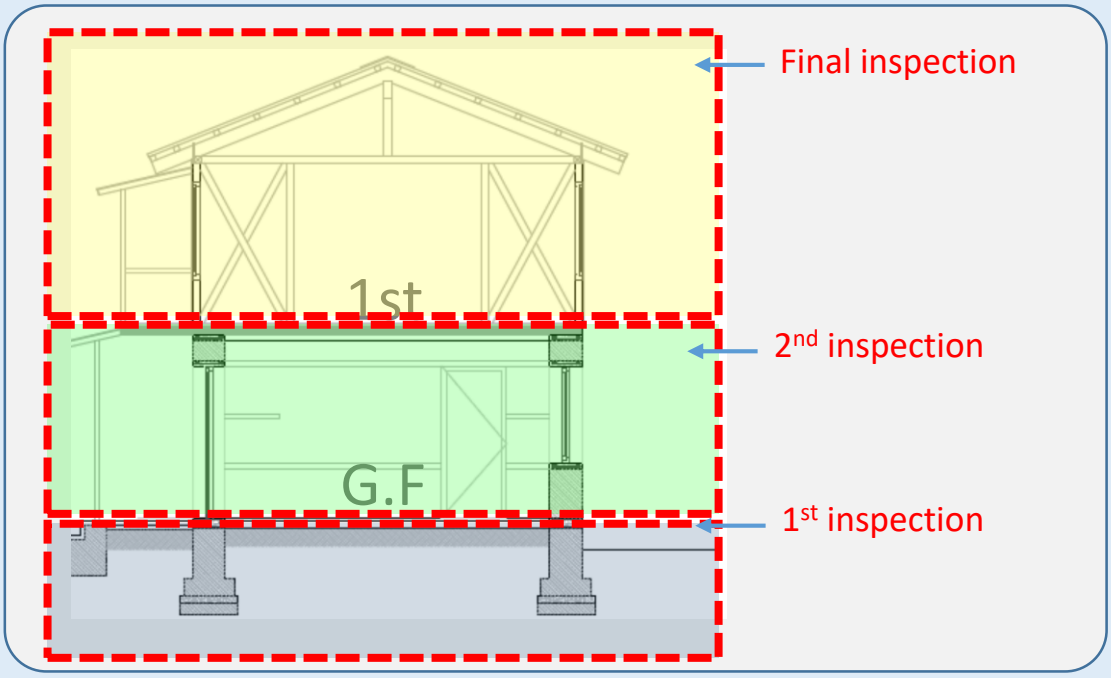
INSPECTION MANUAL

Inspection manual was prepared to make the inspection easy for masonry and RCC houses and systematic for safer ,strong construction on the basis of Grant Distribution Guidelines 2015.

It consist of the procedure to inspect the houses to ensure the reconstructed building to be earthquake resistant and inspector can choose eligible house owner for receiving the subsidy.

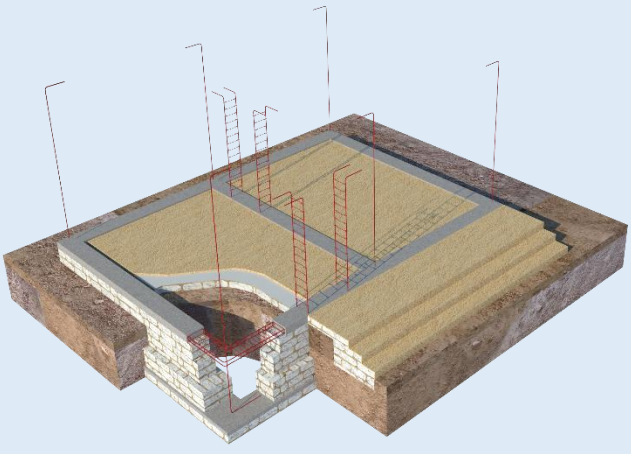
5. Timing of executing inspection

HYBRID STRUCTURE

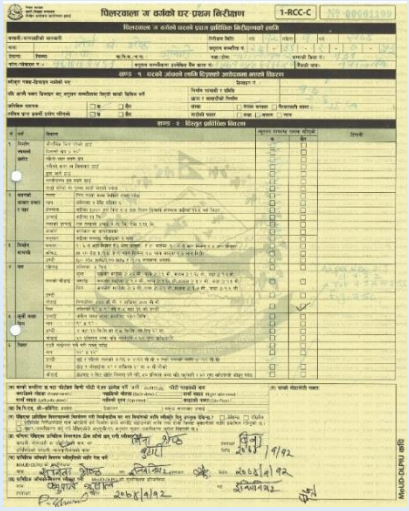


1st inspection

In order to carry out the first inspection of the hybrid structure, where the ground floor is constructed using load bearing masonry, the inspection shall be done on the basis of appropriate inspection forms (**Annex 10**) provided to inspect masonry building. Here, the structure shall be constructed on the basis of MRs. It shall be complaint to all the MRs or exceptional cases. If it is found to be non compliant correction order shall be given using the form provided in **annex 11.**



Timing for 1st inspection



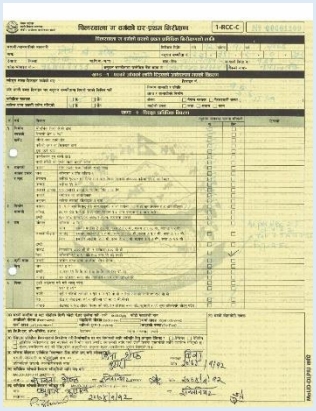
Sample from for 1st Inspection

2nd inspection

After completion of construction up to floor level, the 2nd inspection is carried out . Since, the ground floor is constructed using masonry structure, the forms that shall be used to inspect is same as the inspection forms used to inspect the masonry building (**Annex 13**) .

Here, the super structure shall have all the earthquake resistant features and constructed on the basis of MRs. If it is found to be non compliant correction order shall be given using the form provided in **annex 11**.

Timing for 2nd inspection



Sample form for 2nd Inspection

Final inspection

The final inspection shall be done using the inspection form for hybrid structure.
If all the description provided in the inspection sheet are found to be compliant then the building completion certificate (Annex 16) can be provided.

Timing for final inspection

Scenario of construction/inspection

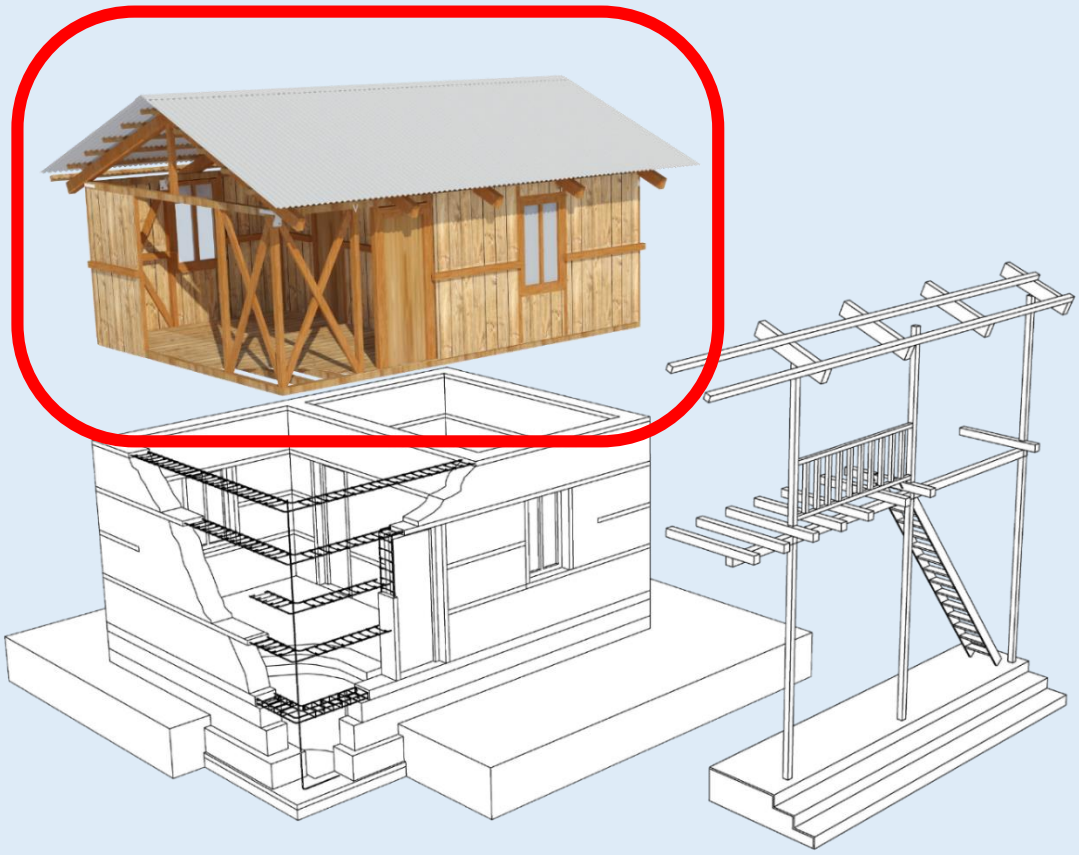
If second inspection of masonry structure is satisfied/compliant, upper structure as hybrid can be build.

Upper structure have to follow specification provided in this manual.

Scenario of construction/inspection

When upper story is completed, the final inspection shall be done using the form for hybrid structure.

Components of Inspection of hybrid structure



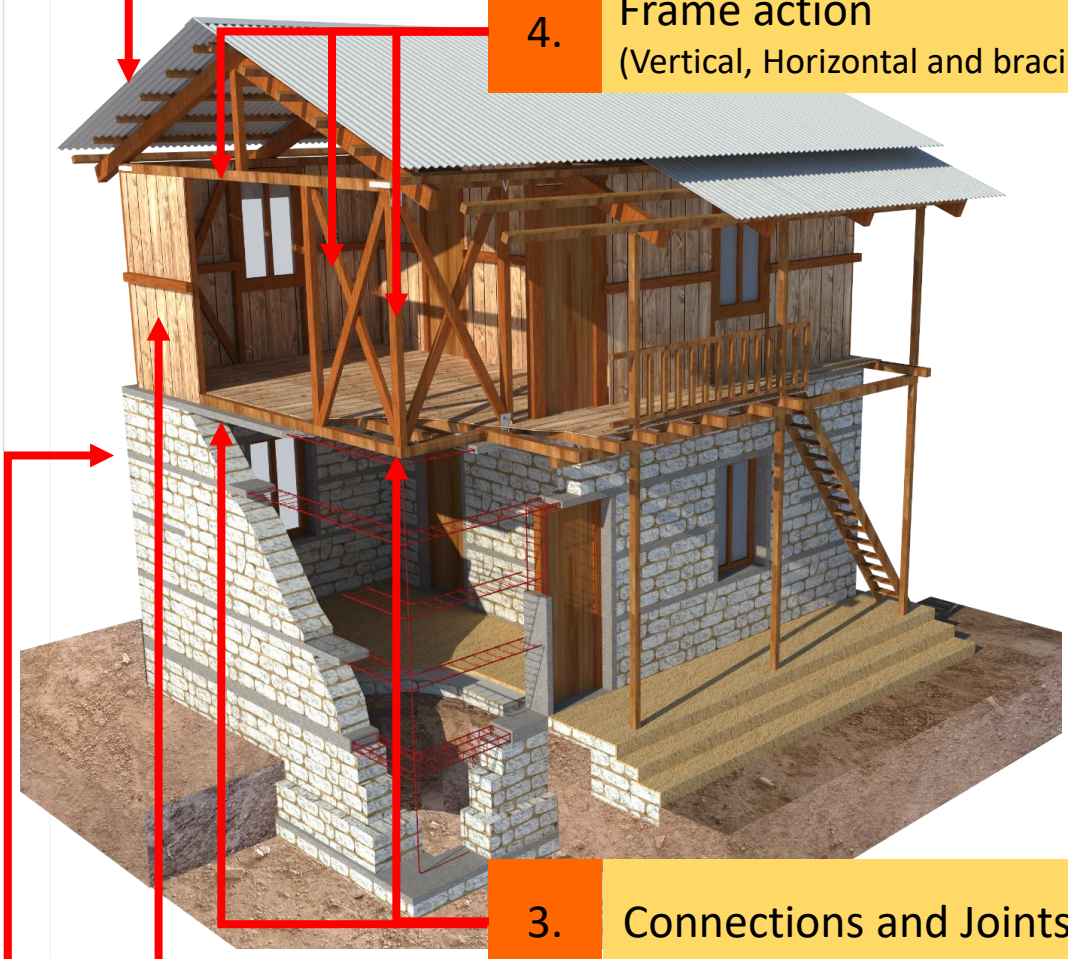
During the inspection of hybrid structures, the main structural part of first floor shall be inspected. Unless the projection of the building is within the MRs, the inspection of the verandah can be ignored. Since, this manual has been prepared on the basis of the MRs of masonry structures hence, if the projection (Verandah) in the first floor exceeds the MRs then the detail structural calculation shall be done separately to strengthen these areas.

PART-2: Technical Specification of Hybrid Structure

Key inspection items of hybrid structure

1. Shape and Size of building
2. Materials
3. Connections and Joints
4. Frame action
5. Roof

Key inspection items of hybrid structure



5. Roof

4. Frame action
(Vertical, Horizontal and bracing)

3. Connections and Joints

2. Materials

1. Shape and Size of building

Key inspection items of hybrid structure

1. Shape and Size of building

Simple rectangular shapes behave better in an earthquake than shapes with projections. The inertia forces are proportional to the mass (or weight) of the building and only building elements or contents that possess mass will give rise to seismic forces on the building.

2. Materials

Inadequate materials does not have sufficient stability and strength to withstand the lateral forces. Hence, use of these substandard materials might leads to the failure or ultimately collapse of the overall structure.

3. Connections and Joints

If there is poor connection between the ground floor and first floor with rigid structure, the building might tends to uplifting/rocking or sliding behavior, when the lateral load is imposed on to the structure.

4. Frame (vertical, horizontal and bracing)

Earthquake-induced inertia forces will be distributed to wall consist of vertical, horizontal member and bracing. Therefore, frame should support each other horizontally and vertically.
Wall framing should have diagonal braces, or sheathing boards so that the frame acts as a shear or bracing wall.
Diagonal braces are used to resist the frame against lateral loads due to earthquake and wind.

5. Roof

In order to resist against lateral forces, proper connection of roof to the vertical post and top plate shall be done. Depending upon the structures cross bracing is also required.

1. Shape and Size of building

Requirements

No.	Category	Sub Category	Description	
1.	Shape and Size of building	No.of storey	Not more than two storey	
		Shape of house, Span of wall	1st Floor	Regular shape. The wall line of upper storey shall be on the wall line of lower storey. The wall line shall not be cantilevered. Therefore, the span of wall shall be same as lower storey.
		Height of wall	1st Floor	It shall not be more than 2.5m.

Why important?

No. of storey: The seismic load is distinctly different from dead load and live load. If attic is used as storage, heavy weight will be on the top of building, hence, larger seismic force will be subjected.

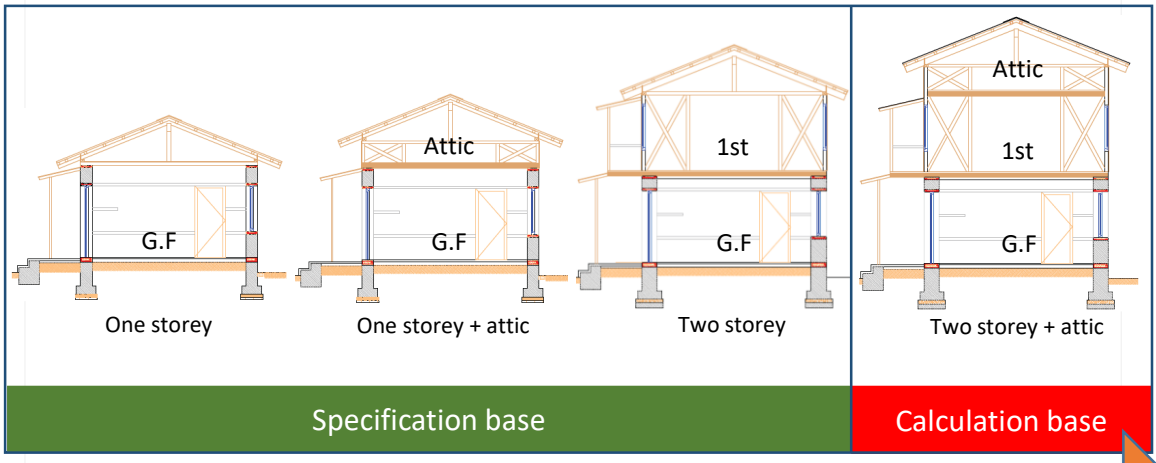
Shape and Size of building: Simple rectangular shapes behave better in an earthquake than shapes with projections. Torsional effects of ground motion are pronounced in long narrow rectangular blocks.

Exception

- If structure is found to be safe after structural calculation, two storey plus attic can be constructed by stone masonry with mud mortar in ground floor and timber in first floor.

Inspection methodology

- Upto two storey, inspection is specification base, however, if two storey plus attic, structural calculation is mandatory.



Simplified structural calculation is shown in P58

Shape of house, span of wall

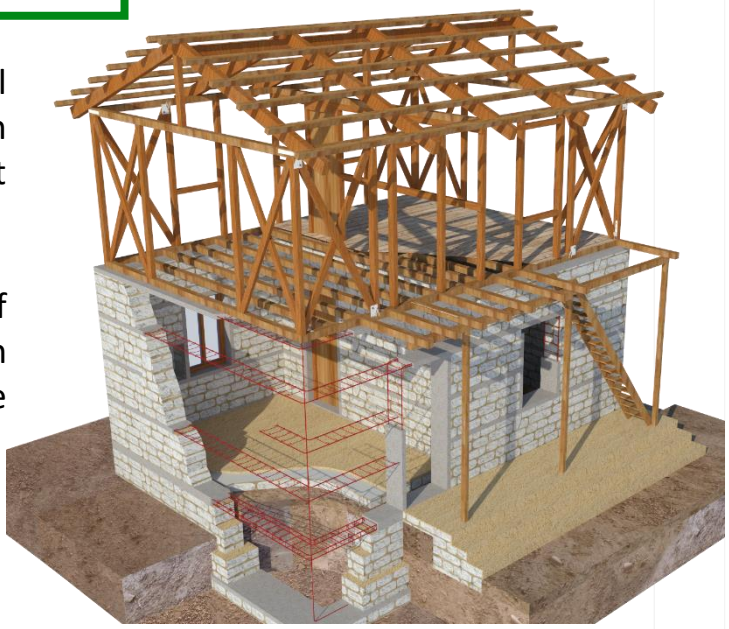
- The wall line of upper storey shall be on the wall line of lower storey.
- The vertical member should rest on the load bearing wall of lower storey.
- The wall line shall not be cantilevered.
  →Therefore, the span of wall shall be same as lower storey.

The wall line is on the wall line of lower storey

The wall line is not on the wall line of lower storey

Correction measures

- Provide vertical, horizontal member and bracing with proper connection at proper location.
- Provide additional beam if the area of the room in ground floor exceeds the MRs of masonry.



2. Materials

Requirements

No.	Category	Sub-category	Description
2.	Materials	Nail	Common wire nails shall be made of mild steel having a minimum tensile strength of 550N/mm2. Nails with appropriate diameter and length shall be provided.
		Bolt	It shall be used in such the number, diameter, length, spacing as each specification.
		Metal Plate	It shall be used in such the number, diameter, length, spacing as each specification.
		Rebar	High strength deformed bars with fy = 415 Mpa /500 Mpa.
		Timber	Treated and well seasoned hard wood or locally available wood without knots shall be used..

Why important?

- Inadequate materials does not have sufficient stability and strength to withstand the lateral forces. Hence, use of these substandard materials might leads to the failure or ultimately collapse of the overall structure.
- Moisture can cause wooden surfaces to swell and deform. Excessive moisture will lead the wood to decay, caused by decay fungi that ruin the material completely.
- Shrinkage of wood on drying is relatively large. Joint loosen easily due to contraction in the direction perpendicular to fibers. Therefore dry wood shall be used with moisture content less than 20 %.
- Wood can decay from repeated change of moistures. Therefore seasoned wood should be used in construction.

Inspection methodology

It can be checked by the observation and measurement.

2.1 Nail

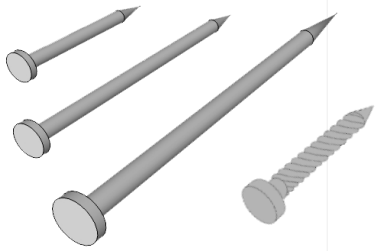
- The things that need to be checked in nail are as follows:

a) Nails diameter:

Nail diameter shall be in between 1/11 and 1/6 of the least thickest of the members to be connected.

b) Nails length:

The length of a nail shall be at least 2.5 times the thickness of the thinnest member and it shall penetrate the thicker member by 1.5 times the thickness of the thinner member, whichever is further.

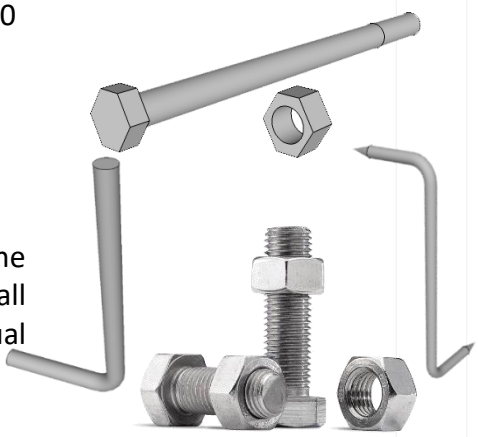


c) Number of nails:

The number of nails in a group should not exceed 10 in one rows in the direction of the force.

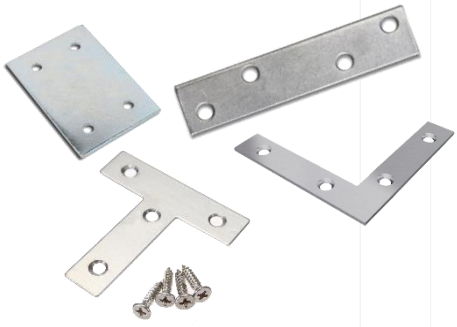
2.2 Bolts:

- When a number of bolts are used in a joint, the allowable load in withdrawal or lateral resistance shall be the sum of the allowable loads for the individual bolts.



2.3 Metal Plate:

- The bolts shall be arranged in such the size, thickness, spacing as each design/specification.



2.4 Rebar:

- Heavily rusted rebar should not be used.
- After rubbing the steel bar, if stain is present on fingers, but if the flakes doesn't come off then the rust is acceptable.
- The thickness of rebar is checked by using vernier caliper. Ductility of rebar can be checked by bending it at 90° and if small cracks are found ductility is insufficient.

2.1 Wood

Exception

Tolerances:

- Permissible tolerances in measurements of cut sizes of structural timber shall be as follows:

a) For width and thickness:

1) Up to and including 100mm	+3mm -0mm
2) Above 100mm	+6mm -3mm
b) For length:	+10mm -0mm

Inspection methodology

- Timber treatment can be identified by the observation or questionnaires survey with the house owner and mason.
- Typology of the wood can be identified by observation and field test.
- Defects in timber can be identified by observation.
- Moisture content in the timber can be identified by oven-dry method.

Wood can readily be identified as a hardwood or softwood by the following procedure:

- The color of hardwood is dark brown and light brown in softwood.
- When the thumb nail is pressed against hardwood it will not leave a mark but when it is pressed in softwood and pull it along a surface it leaves a scratch mark. Deeper the mark, the softer the wood.

When pressed by tip of nail leave a mark (Soft wood)

When pressed by tip of nail doesn't leave a mark (Hard wood)

Source: http://www.instructables.com/id/Hard-Wood-or-Soft-Wood%3F/

Table: List of Hardwood and softwood

HARD WOOD		SOFT WOOD	
Babul	Mesua	Chir	Simal
Blacksiris	Oak	Deodar	Uttis (Red)
Dhaman	Sain	Jack	Uttis (White)
Indian Rose Wood (Shisam)	Sal	Mango	
Jaman	Sandan	Salla	
Sissao	Teak		
Khair			

Source: NBC 203:2015

- Timber treatment
  It can be treated by using coal tar or any other preservative that prevent timber from being decayed and attacked by insects.

- Moisture content in Timber:
  Moisture content means the weight of water contained in wood, expressed as a percentage of its oven dry weight. It can be determined by the oven-dry method.

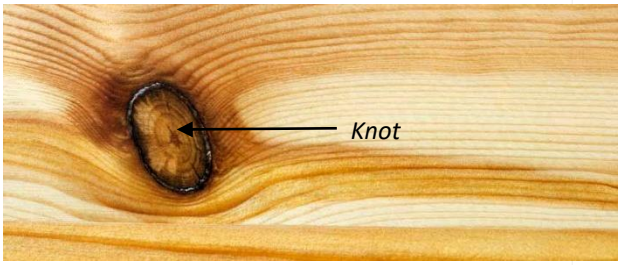
Table: Unit of weight of wood

S.N	Kinds of wood	Weight (12% moisture content) lb/cft
1	SAL (AGRAKH)	56
2	SISAU	50
3	KHOTE SALLA	33
4	GOBRE SALLA	32
5	UTTIS (RED)	36
6	UTTIS (WHITE)	34
7	CHAMP	33
8	SATISAL	38
9	ASNA	46
10	PHALAT	60
11	TOONI	37
12	SEMAL	25
13	OKHAR	45
14	OAK	64
15	KHAIR	60
16	BIJYASAL	49

Source: NBC 112:1994

Defects in Timber:

- Dead Knot: It is the knot in which the layers of annual growth are not completely intergrown with those of the adjacent wood. It is surrounded by pitch or bark. The encasement may be partial or complete.



Source: https://www.wagnermeters.com/wp-content/uploads/2012/12/knot.jpg

3. Connections and Joints

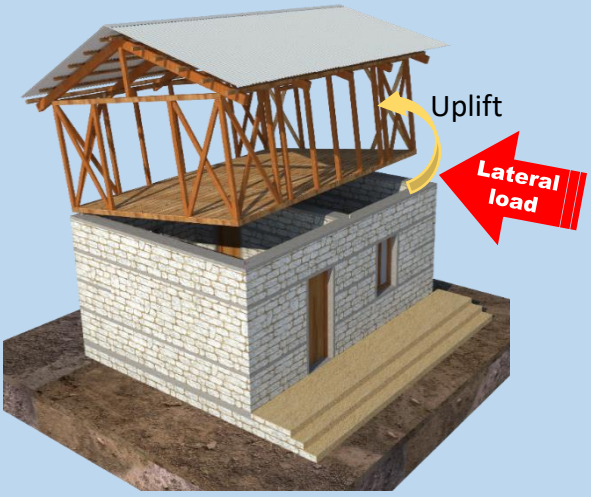
Requirements

No.	Category	Sub-category	Description
3.	Connections and joints	Connections between lower and upper structure	It shall be properly connected as per the specification.
		Joints of structural member	All the structural members shall be properly connected by nails, bolts and metal plate as per the specification.

Why important ?

Connections between lower and upper structure

- If there is poor connection between the ground floor and first floor with rigid structure, the building might tends to uplifting/rocking or sliding behavior, when the lateral load is imposed on to the structure.
- Bonding strength of stone masonry in mud mortar with wooden band is very poor, therefore, failure pattern mentioned above will occur easily.



Uplifting/Rocking

Sliding

Joints of structural member

- The failure of the joints connecting structural member such as vertical, horizontal and bracing frequently occurs. Structural member should be uniform, so that the frame will acts as earthquake resistance elements.

Connections between lower and upper structure

In case of floor band is made by Reinforcement Concrete

Construction methods are from P34

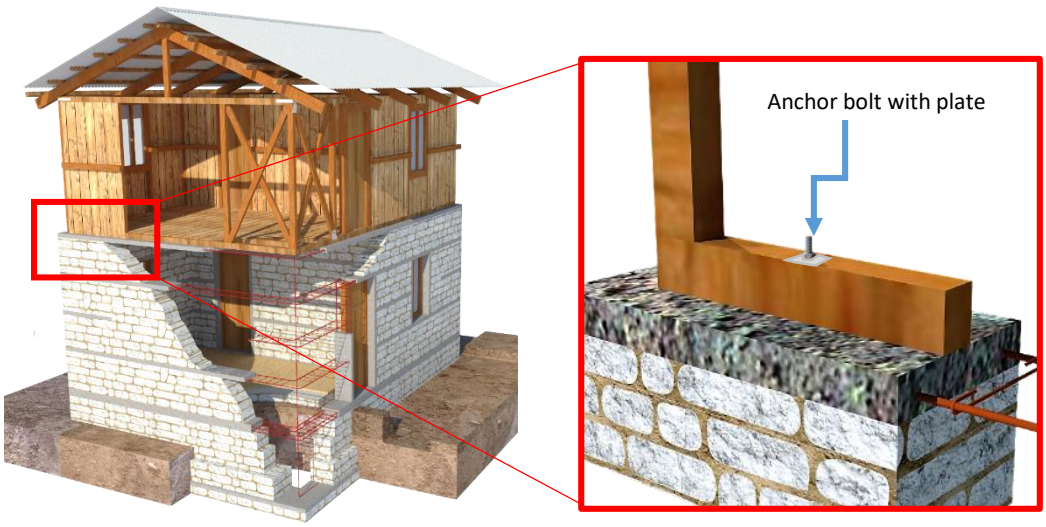
In case of stone masonry in mud mortar with wooden band

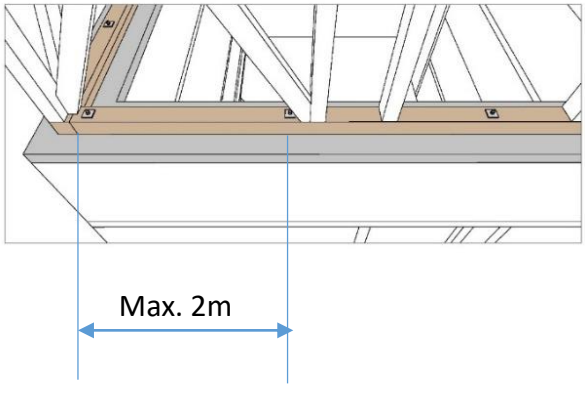
Construction methods are from P38

Connections between RC band and wooden base plate

In case of floor band is made by Reinforcement Concrete.

Option 1: Connecting by anchor bolt





Anchor bolts: Minimum diameter is 12mm (M12) and length 250mm with plate 40mm x 40mm x 4.5mm.

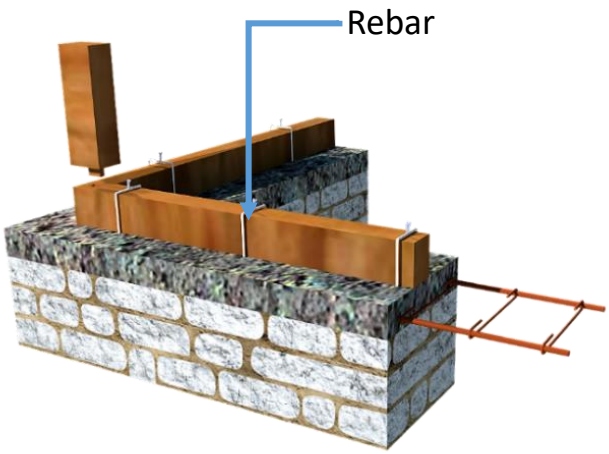
Connecting wooden base plate and RC floor bands by anchor bolts. The anchor bolt are installed at the maximum spacing is 2.0 meter.

Connections between RC band and wooden base plate

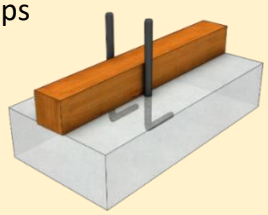
In case of floor band is made by Reinforcement Concrete.

Option 2: Connecting by anchoring rebar

Connecting base plate and floor bands by Rebar.



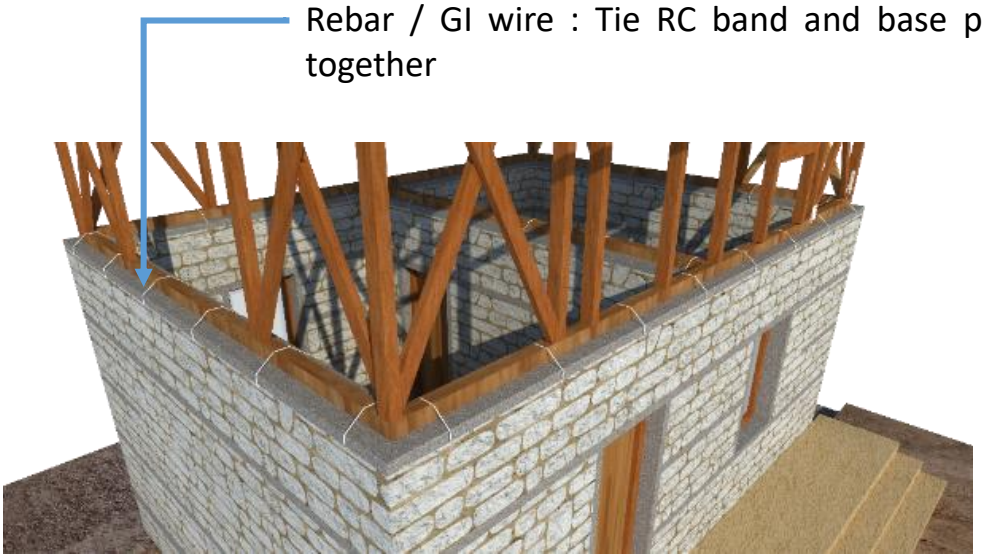
Steps



Anchor rebar in RC band

Bend rebar for tying

Option 3: Tying by GI wire



Connections between RC band and wooden base plate

In case of floor band is made by Reinforcement Concrete.

New construction/Correction measures

Option4 : from Retrofitting manual.
Connection fixed by anchor plate for existing building

3 mm thick Height and depth : 45mmx45mm, M12 of 4 number, M16 of one number in each face @ 3.00 mat centres

Details of Anchor plate

Connections between RC band and wooden base plate

In case of floor band is made by Reinforcement Concrete.

New construction/Correction measures

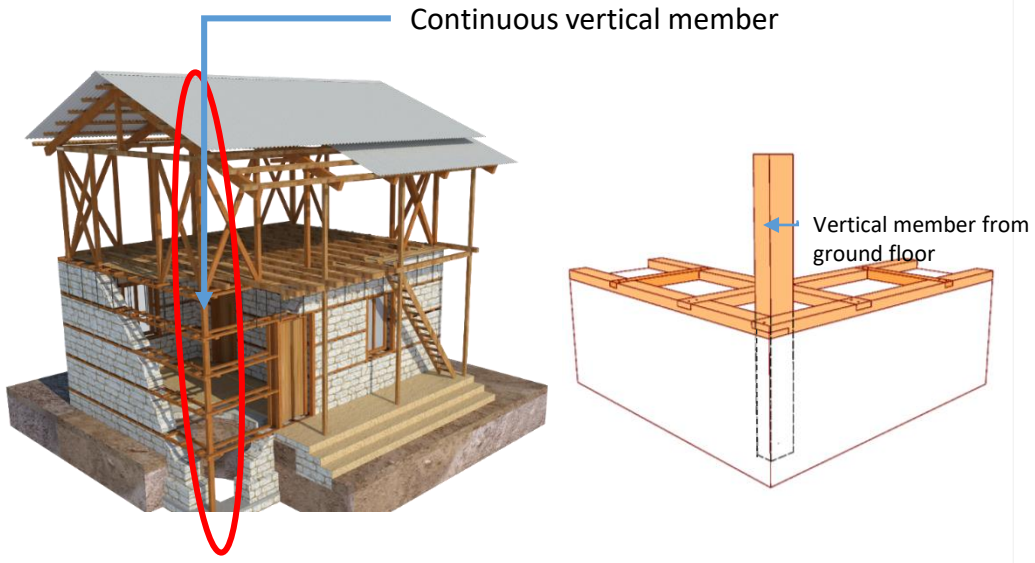
Option5 : from Retrofitting manual.
Connection fixed by metal strap at side of wall

Details of Anchor plate

Connections between wooden band and base plate

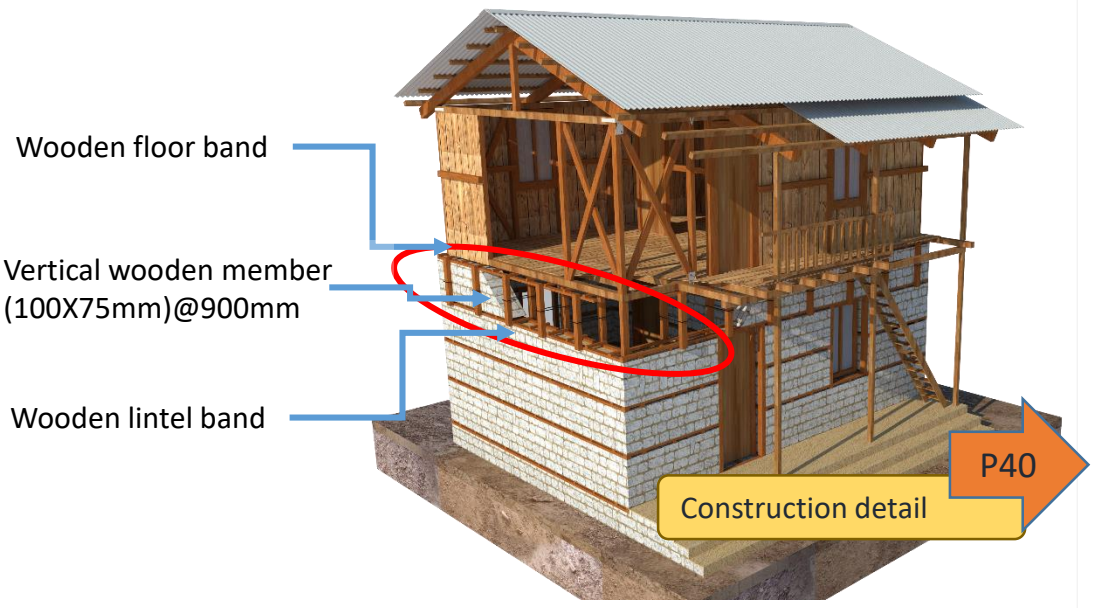
In case of Stone masonry in mud mortar with wooden band

Option 1: Continuous vertical member



The vertical member is continuous from ground floor to 1st floor.

Option 2: Connecting roof and lintel wooden band

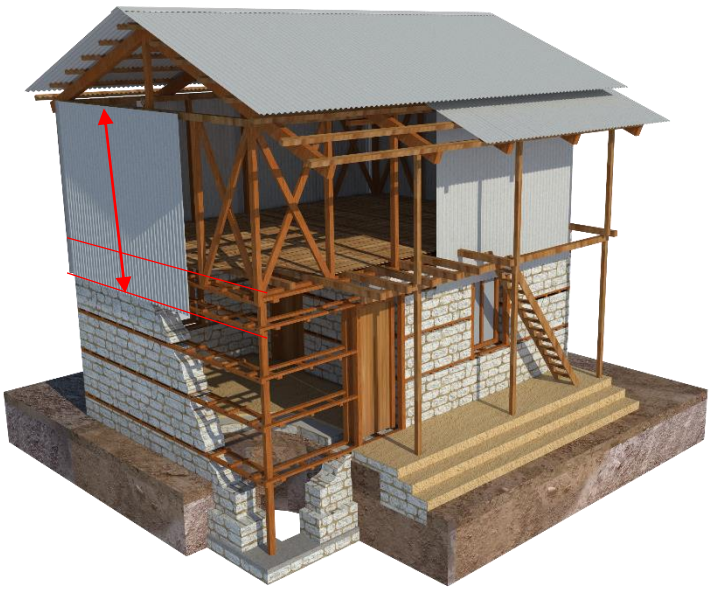


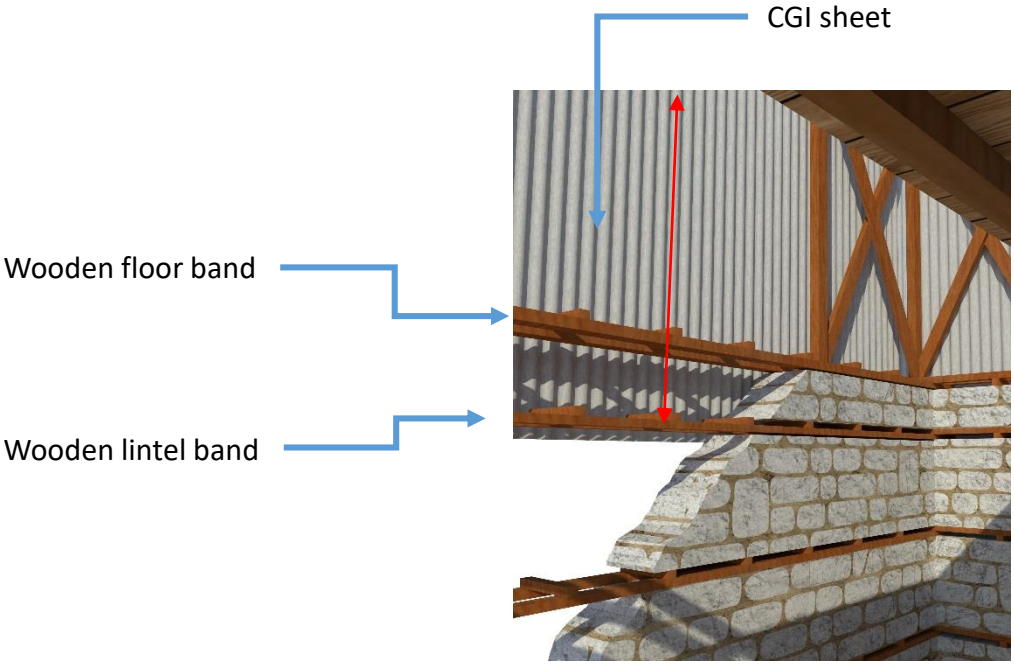
Wooden floor band and lintel band should be connected.

Connections between wooden band and base plate

In case of Stone masonry in mud mortar with wooden band

Option 3: Extending CGI sheet to lintel band





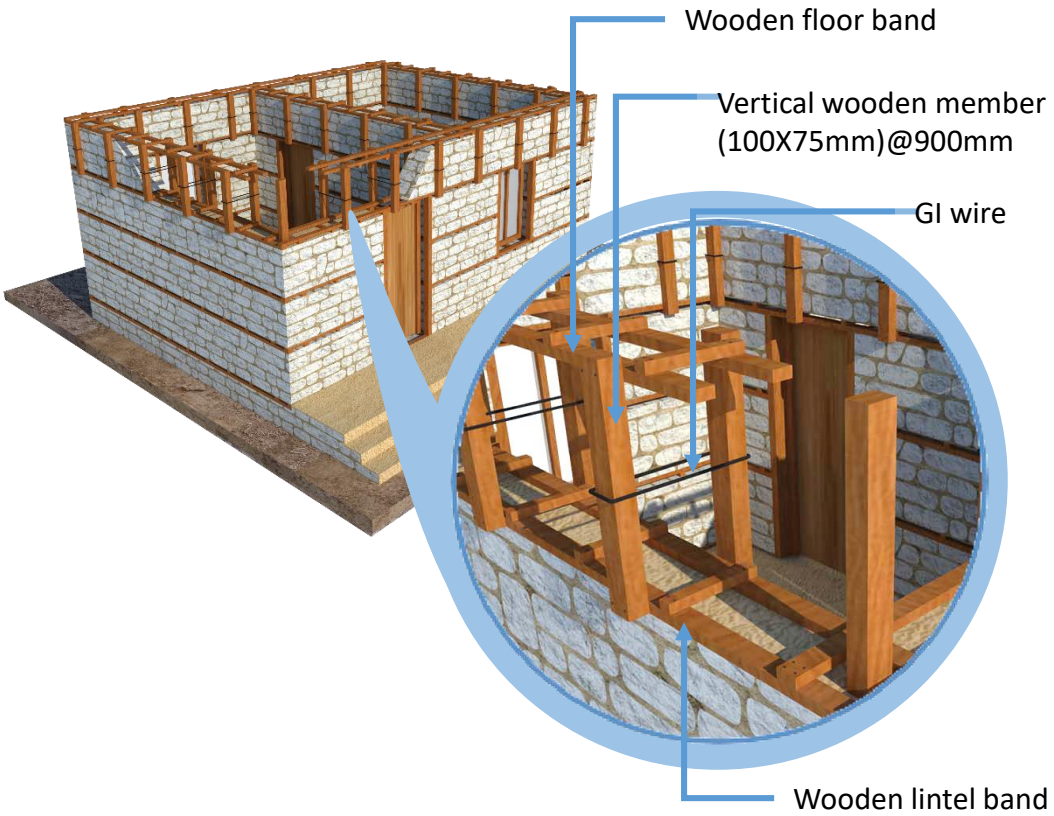
CGI sheet is extended to lintel band fixed by nail properly.

Connections between wooden band and base plate

In case of Stone masonry in mud mortar with wooden band

New construction/Correction measures

Option 2-1: Connecting wooden floor band and lintel band with vertical wooden member.



Steps:

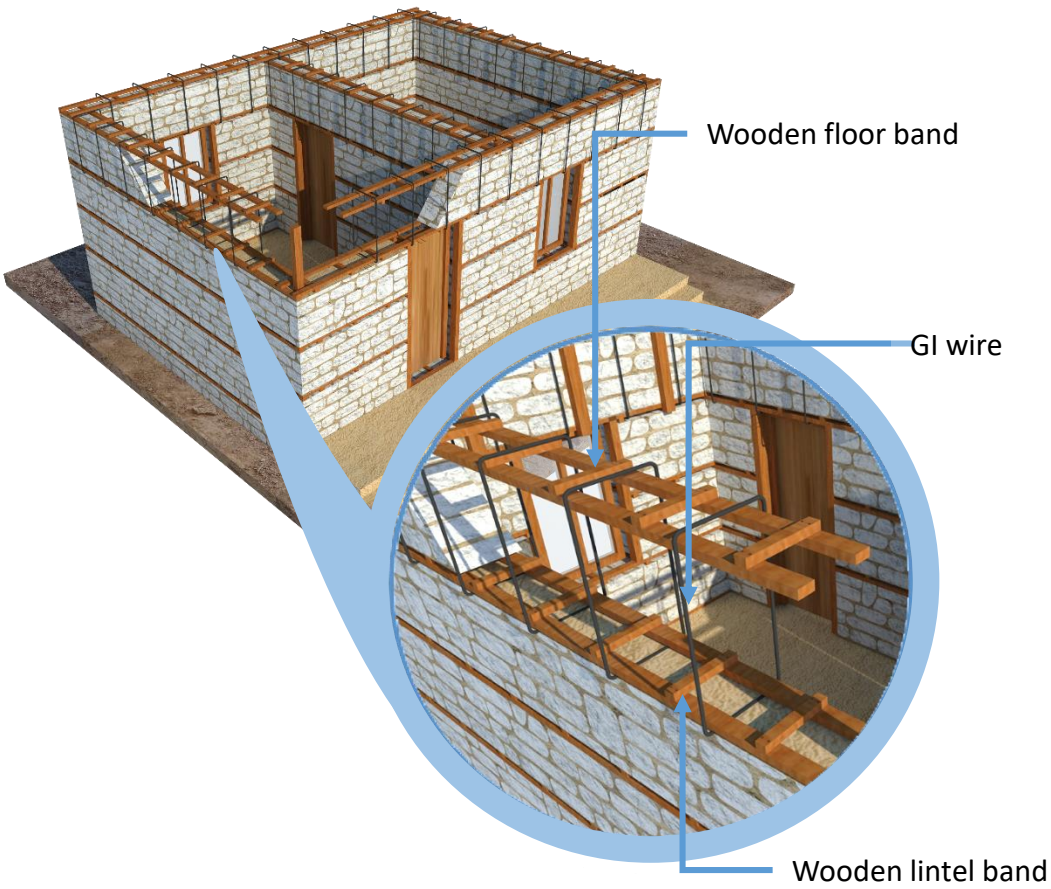
1. Connect lintel band and floor band with vertical wooden member on both side of the wall.
2. Place the vertical wooden member (100X75mm)@ 900mm c/c on both side of the wall.
3. Tie both vertical member with GI wire

Connections between wooden band and base plate

In case of Stone masonry in mud mortar with wooden band

New construction/Correction measures

Option 2-2: Connecting wooden lintel band and lintel band with GI wire

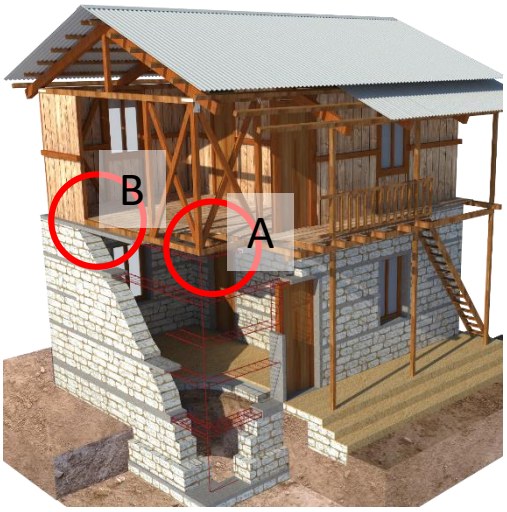


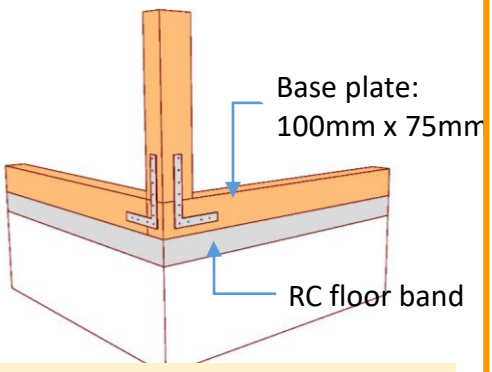
Steps:

1. Insert and tie the GI wire 3.25mm (10 Gauge) at the spacing of 450mm c/c. starting from lintel to the floor band through out the wall.

Connections between lower and upper structure

In case of RC floor band

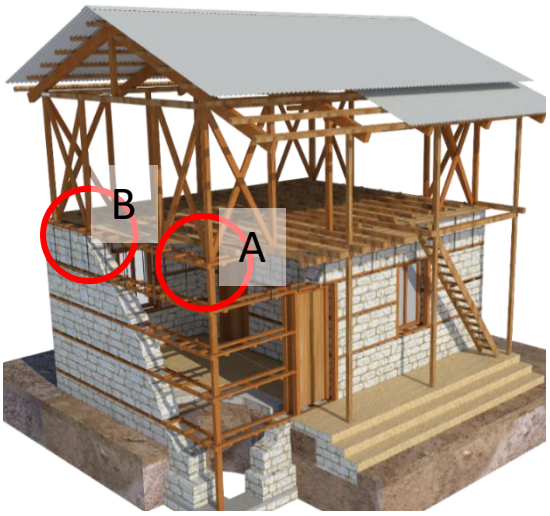


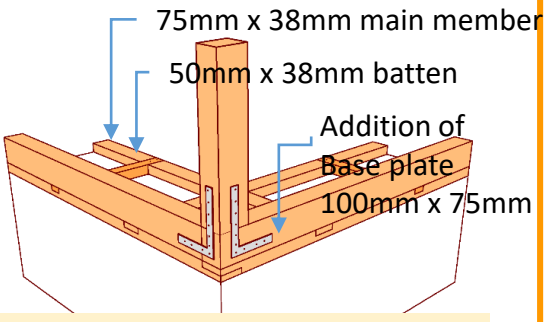


Wooden base plate should connect to RC floor band

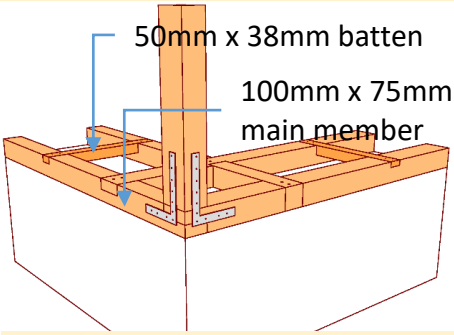
P34
Construction detail

In case of wooden floor band





If wooden band is minimum size, addition of base plate is needed.

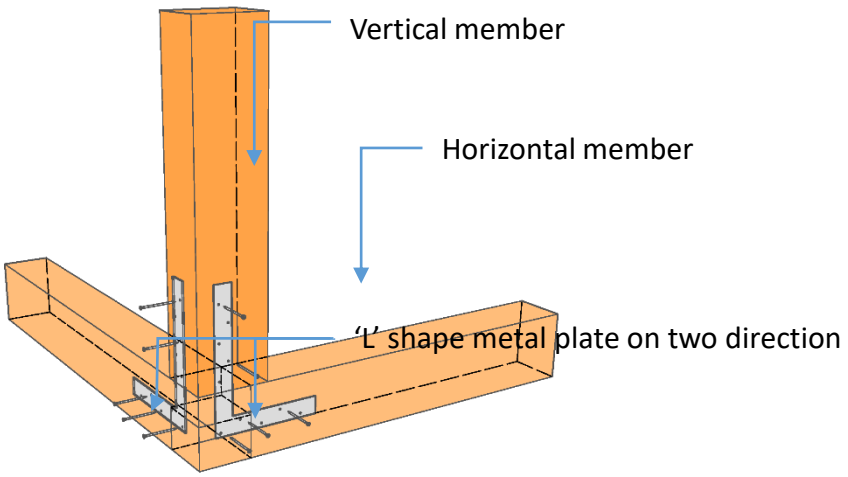


Use of larger horizontal member in floor band as per requirement of base plate

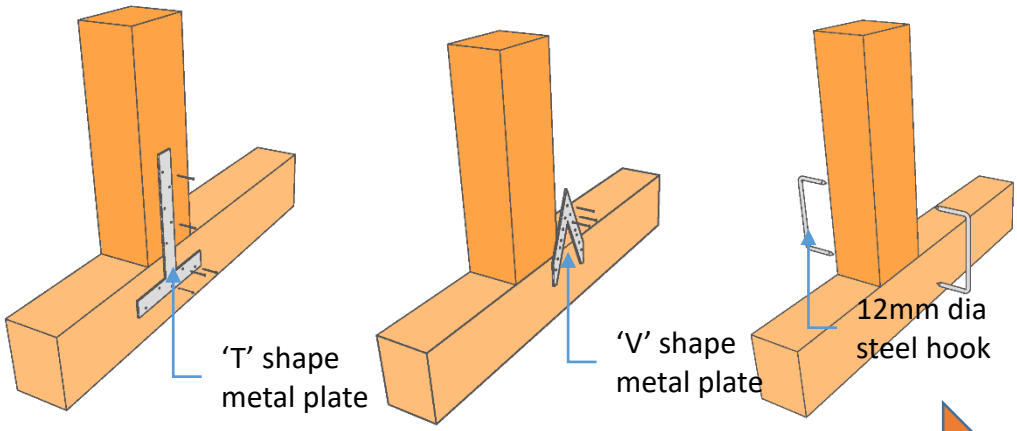
Connections between base plate and vertical member

Wooden vertical member should be properly connected to horizontal member as shown in figure.

Detail A: Connection of corner

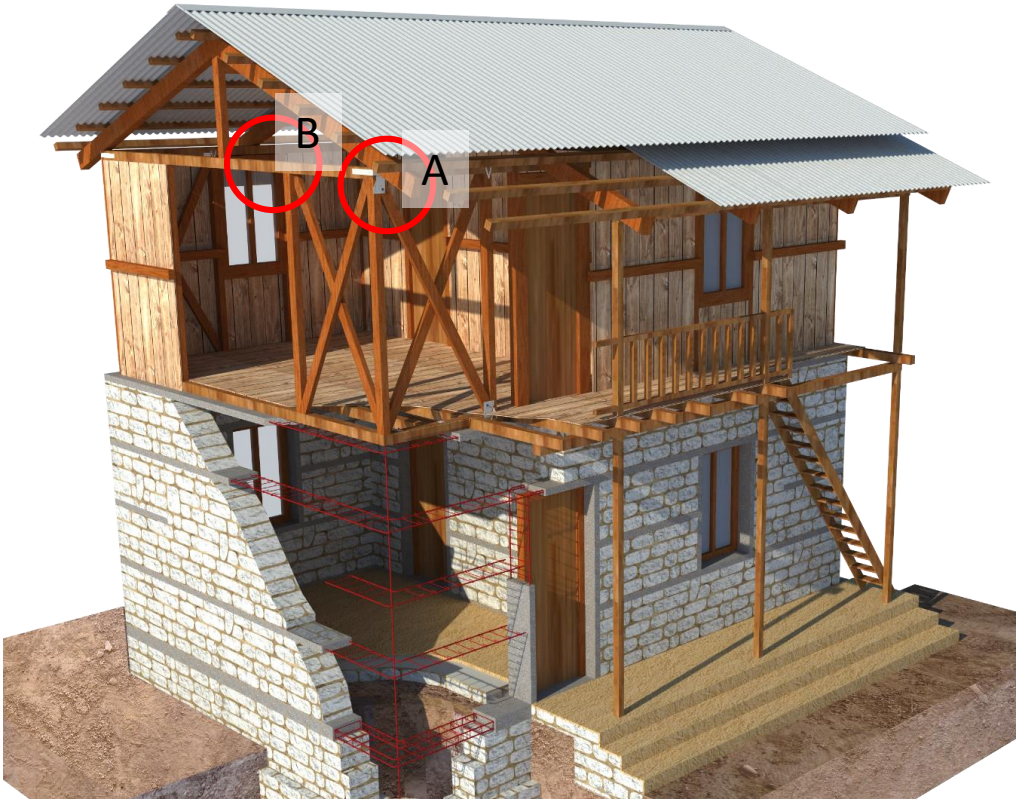


Detail B: Connection horizontal and vertical at middle

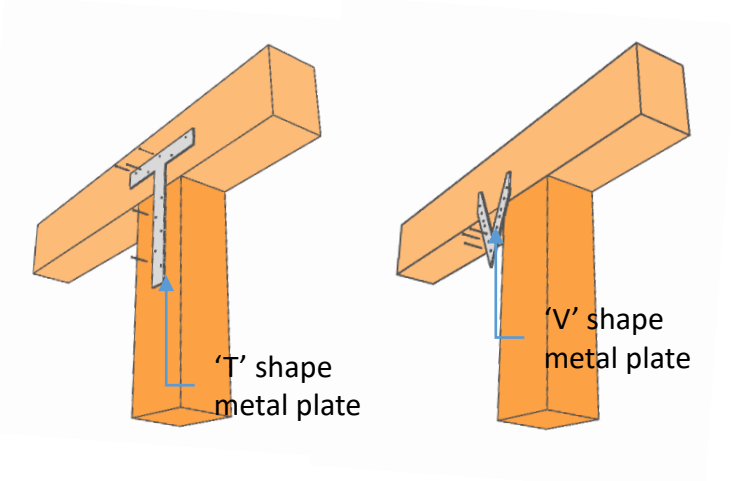


P46
Detail of metal plate

Connections between top plate, vertical and bracing member



Detail B: Connection horizontal and vertical at middle



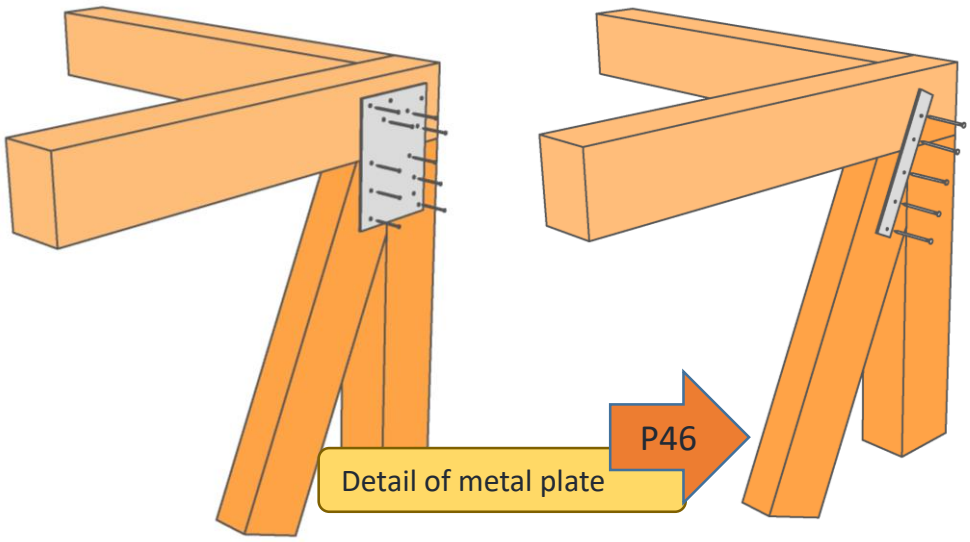
Detail of metal plate

P46

Connections between top plate, vertical and bracing member

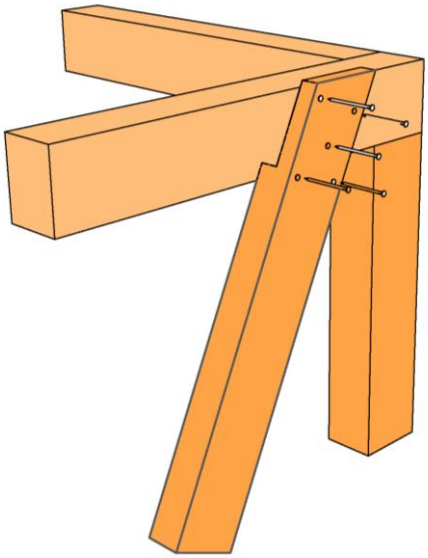
Wooden vertical member should be properly connected to horizontal member as shown in figure.

Detail A: Connection of corner



Connected by metal plate

Connected by metal plate



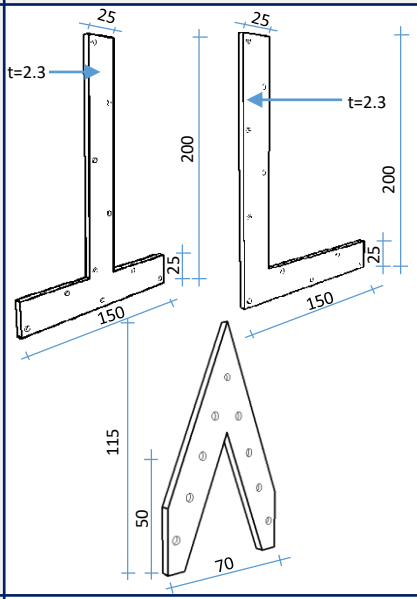
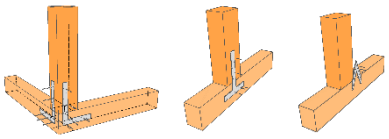
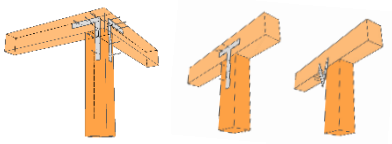
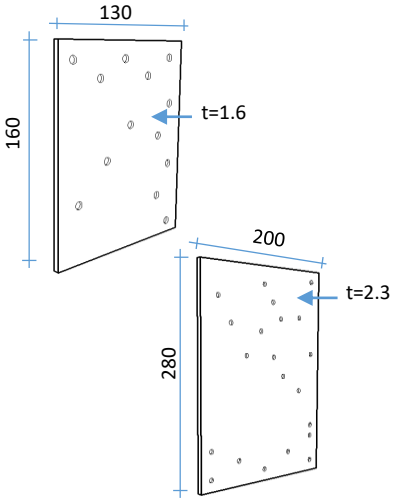
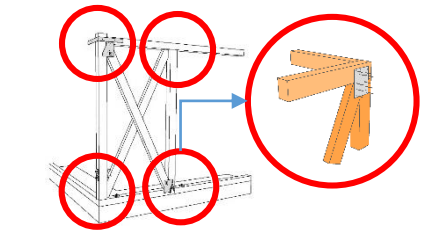
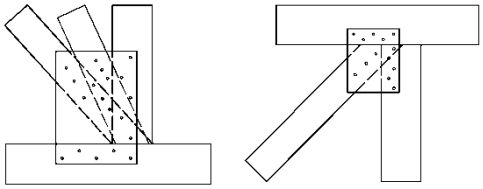
Connected by nail
Nail: length 75mm x 5

Joint between braces

It should be fixed by nail
Nail: length 75mm x 4

Joint of timber member

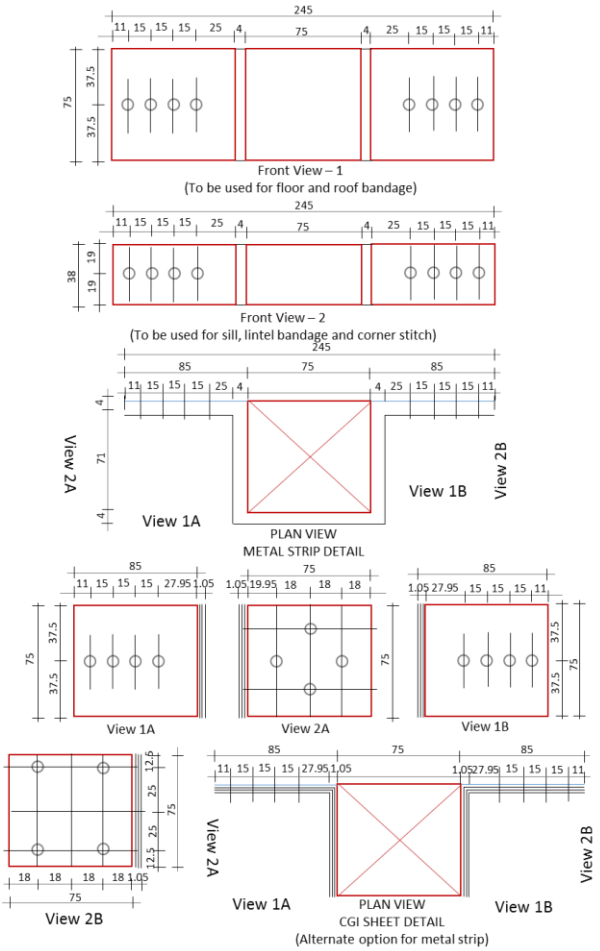
Detail of metal plates

Items	Detail	Location
T shape **L-shape** **V-shape**		Connections between base plate and vertical member  Connections between top plate and vertical member 
Metal plate 1 **Metal plate 2**	 **Note:** Instead of metal plate, three layers of 0.55mm GI sheet can be used.	Connections between horizontal, vertical and bracing member  

The length of a nail shall be at least 2.5 times the thickness of the thinnest member and it shall penetrate the thicker member by 1.5 times the thickness of the thinner member, whichever is further.

Joint of timber member

Metal plate for connection between horizontal and vertical member



Inspection procedure

The detail of connection that needs to be checked are:

- Connection between wooden member.
- Connection between wall plate and floor band.
- Connection of braces with the vertical and horizontal member (base and Top plate).
- Connection between wooden lintel and floor band.

4. Frame action (Vertical, Horizontal and Bracing member)

Requirements

No.	Category	Description		
4.	Frame			
		Vertical member	It shall be continue from base plate to top plate.	
			Size	It shall be more than 75x75(mm) in hard wood, 100x75(mm) in soft wood.
			Spacing	It shall be less than 1200mm.
		Horizontal member	It shall be continuous at same level.	
			Base plate/ Top plate	It shall be more than 75x75(mm) in hard wood, 100x75(mm) in soft wood.
		Bracing	location	It shall be symmetrical and located at each corners.
			Direction	It shall not be in same direction.
			Size/number	It shall be as per the specification.

Exception

- Steel can be used instead of wood, but its strength shall be equivalent to the required strength of wood.
- If structure is found to be safe after structural calculation.
- Size of vertical and horizontal member can be variable depending upon the span. Refer to NBC 203 and 204.
- If the size of main wooden member in floor band is as per the required size of base plate, then base plate can be ignored.
- roof band is using as per requirements of base plate, base plate can be ignored.

Why important?

Earthquake-induced inertia forces will be distributed to wall consist of vertical, horizontal member and bracing. Therefore, frame should be supported horizontally and vertically.
Wall framing should have diagonal braces, or sheathing boards so that the frame acts as a shear or bracing wall.

Diagonal bracing is main element to resist the frame against lateral loads due to earthquake and wind.

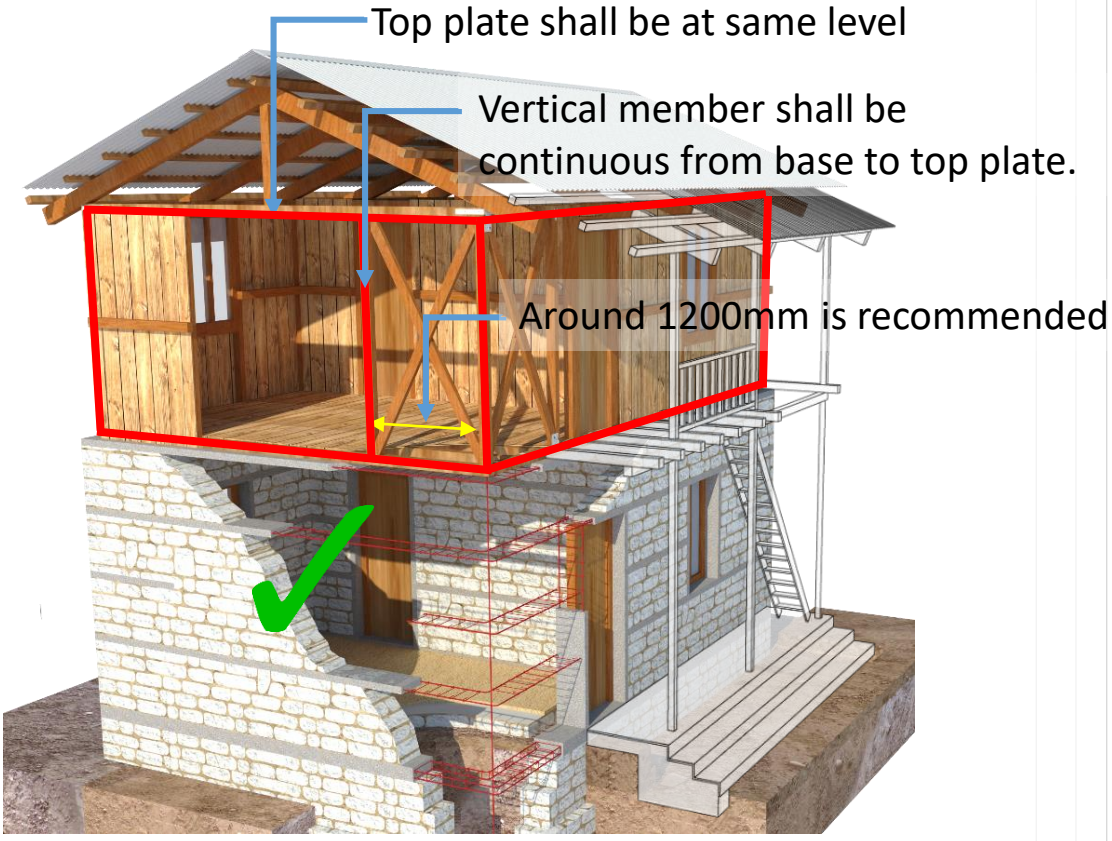
Fundamental items

1. Vertical, horizontal member and bracing shall be properly connected.
2. Vertical member shall continue from base to top plate.
3. The spacing of vertical member shall be appropriate.
4. Horizontal member shall be continuous at same level.
5. Bracing shall be symmetrical and located at each corners.
6. Bracing shall be properly connected and provided from base to top plate.

Correction measures

Vertical and Horizontal member

1. Standard type: Lower structure is minimum requirement



Discontinuous top plate at different level

Correction measures

Strengthen gap of top plate. Adding horizontal/vertical member with proper connection.

Vertical and Horizontal member

2. Traditional type: Lower structure is exceptional of minimum requirement

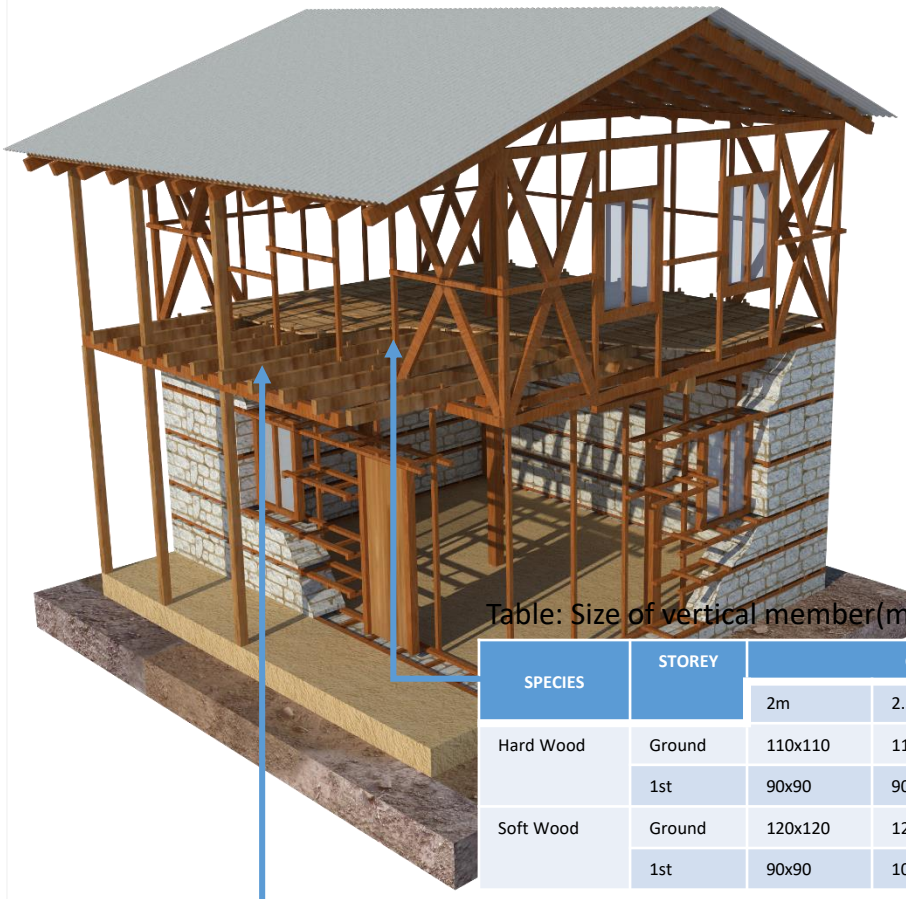


Table: Size of vertical member(mm) for Various Spans

SPECIES	STOREY	COLUMN SPACING			
		2m	2.5m	3m	3.5m
Hard Wood	Ground	110x110	110x110	120x120	130x130
	1st	90x90	90x90	100x100	100x100
Soft Wood	Ground	120x120	120x120	130x130	140x140
	1st	90x90	100x100	100x100	110x110

Table: Depth of Beams (mm) for Various Spans

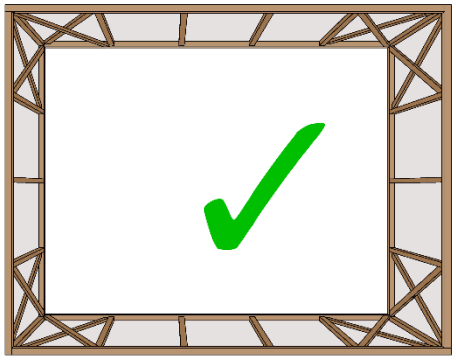
SPECIES	SPAN				
	2m	2 to 2.5m	2.5 to 3m	3 to 3.5m	3.5 to 4m
Hard Wood	190	220	240	270	300
Soft Wood	230	270	310	340	370

*The minimum dimensions of vertical members for different span shall be as tabulated in Table.
For hybrid structure, if span of vertical member is less than 1200mm, its size is 75x75(mm) in hard wood, 100x75(mm) in soft wood.

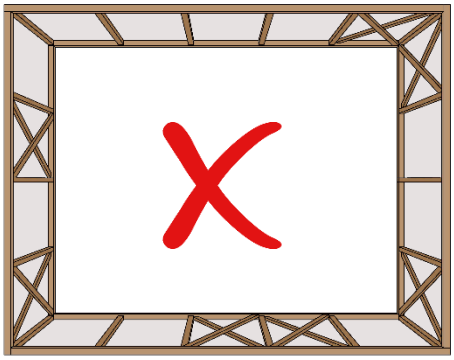
Bracing member

Location

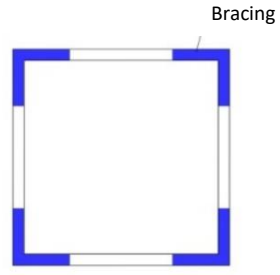
Diagonal bracing shall be located at each corner. Incase of unbalanced bracing the center of gravity will be shifted and the structure will be subjected to torsion.



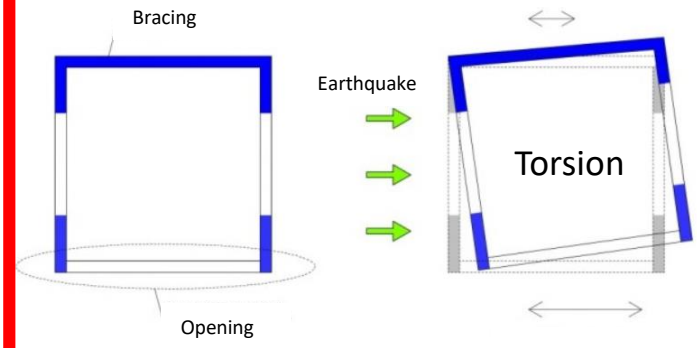
Balanced



Un-Balanced



Balanced



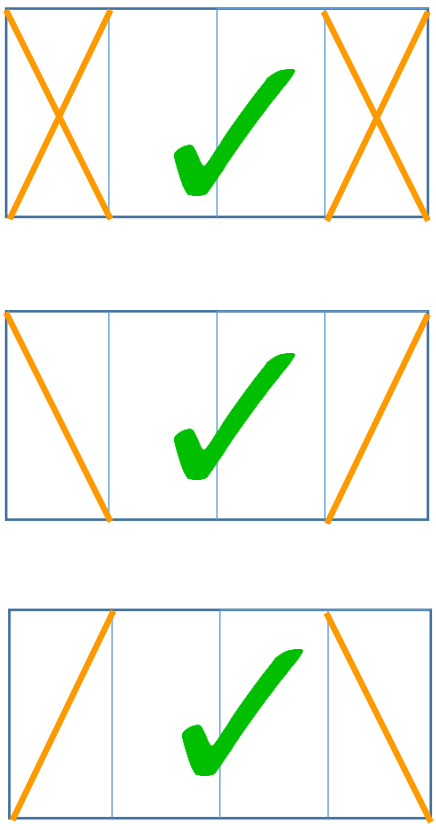
Un-Balanced

Bracing member

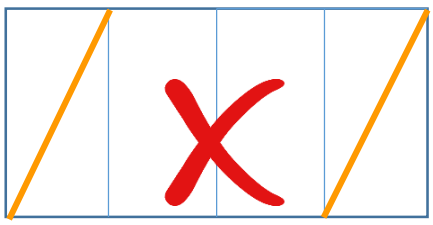
Direction

It shall not be in same direction.

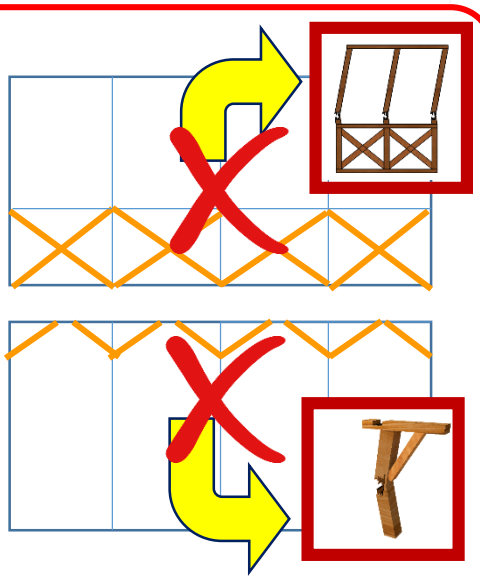
To achieve the adequate seismic resistance, provide diagonal bracing members in the planes of walls starting from base to top plate as shown in fig.



Balanced bracing



Same direction of bracing.
It shall be balanced.

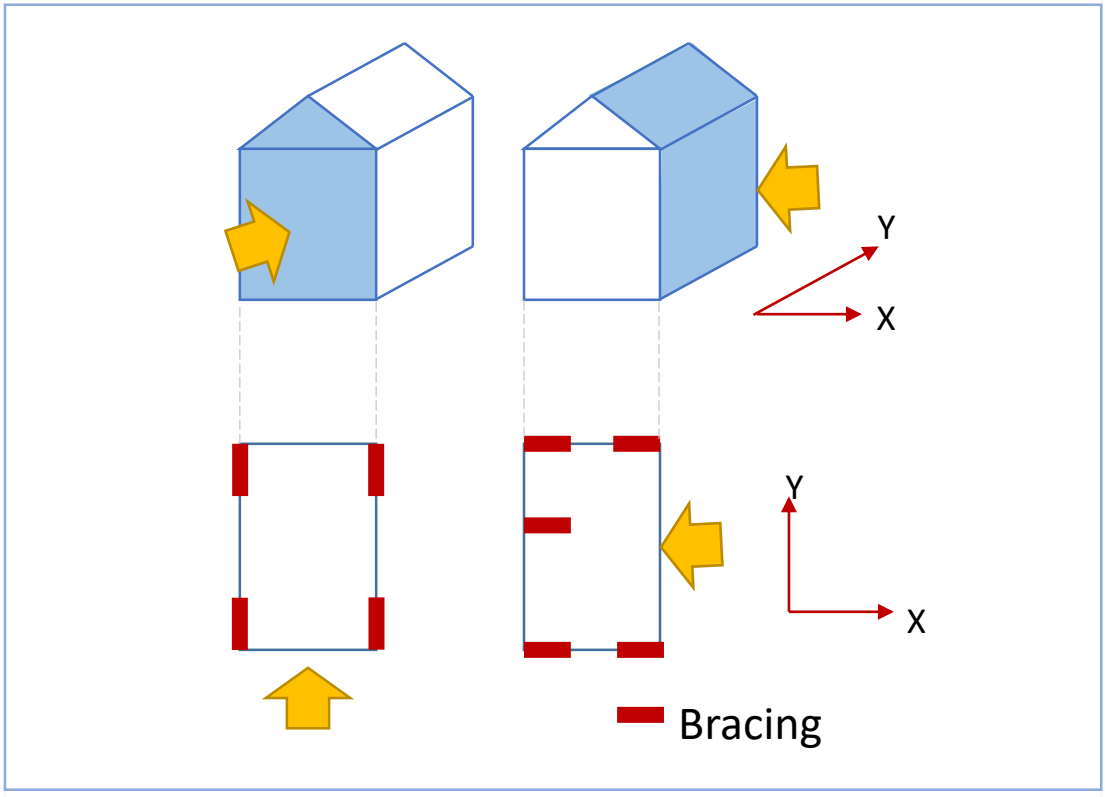


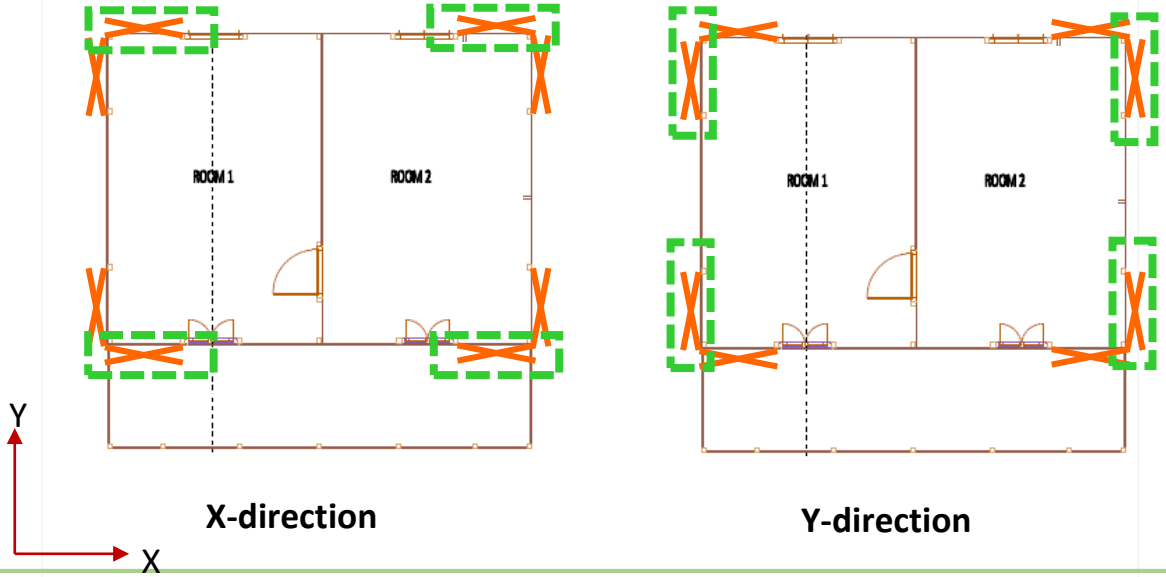
Bracing shall be continuous base plate top plate.

Bracing member

Size and Number of bracing member

Diagonal bracing is main element to resist the frame against lateral loads due to earthquake and wind.
Size and number of bracing should be consider at each X and Y direction.





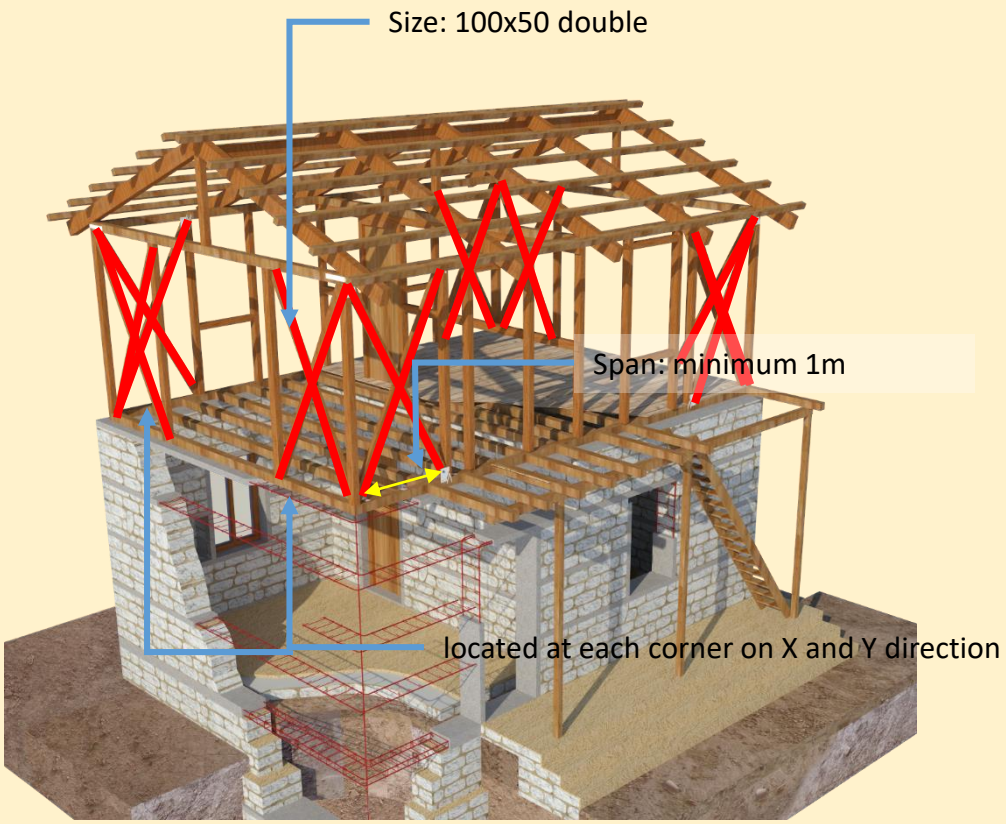
Bracing member

Size and Number of bracing member

Specification base. Inspection shall be as per the specification.

Under the following condition, inspection on the basis of specification is enabled.

- ✓ Area of building is less than 50 sq m.
- ✓ Upto 2 storey without attic.
- ✓ Wall height of first floor is less than 2.5m
- ✓ Using light weight material for roof and wall.
- ✓ And all other requirements of each item are fulfilled.



Size and Number of bracing member

Bracing member

Size and Number of bracing member

Specification base. Inspection shall be as per the specification.

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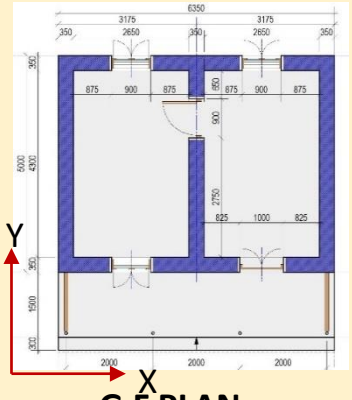
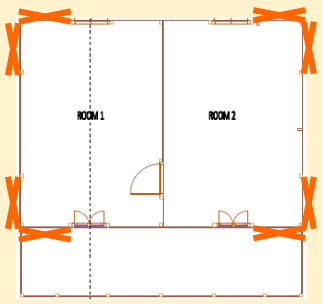
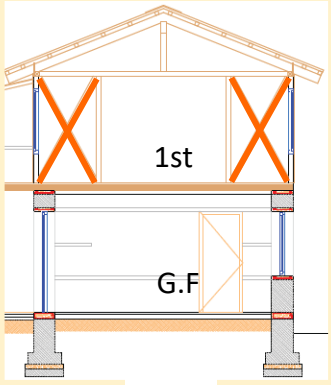


G.F PLAN



1F PLAN



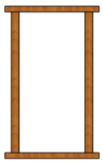
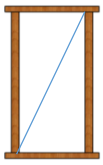
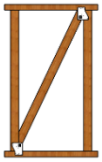
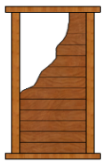
SECTION

Specification of size and number of brace			
Wooden Brace fixed by nail	Size	100 x 50 mm	double
	length	Minimum: 1meter	
	Number of each direction (X and Y)	4 （Located at each corner）	
Calculation	100x50: unit strength 2.6kN/m 2.6 x 2 (double) x 1 (meter) x 4 = 20.8kN		

If the materials and size of the bracing members vary then the simplified calculation shall be done using the shear strength provided in next page.

Bracing member

Size and Number of bracing member

Method of Bracing/ wall construction				Shear Strength of Unit wall (kN/m)
	No brace			0.0
	Mud wall	Thickness less than 50mm		1.5
		Thickness 50mm~70mm		1.8
		Thickness 70mm~90mm		2.2
		Thickness more than 90mm		2.5
	Brace rebar Φ9			1.6
  Single brace Double brace	Wooden Brace	90mm*15mm	Nail	1.6
		90mm*30mm	Steel Plate	2.4
			Nail	1.9
		90mm*45mm	Steel Plate	3.2
			Nail	2.6
		90mm*90mm	Steel Plate	4.8
	Wooden plank wall			0.8
	Structural Plywood	12mm		5.2
	Gypsum Board	9mm		1.1
	Plywood	3mm		0.9

Fundamental case: Wooden brace 100x50(double) fixed by nail:
2.6kN/m(unit strength) x 2 (double) x 1.0(meter) x 4 = 20.8kN

Option 1: Wooden brace 100 x 100(single) fixed by steel plate:
4.8kN/m(unit strength) x 1 (single) x 1.2(meter) x 4 = 23.04kN > 20.8kN OK
Option 2: Brace rebar Φ9 (double and 2pieces)
1.6kN/m(unit strength) x 2(pieces) x 2(double) x1.0(meter) x4 = 25.6kN > 20.8kN OK

Bracing member

Size and Number of bracing member

Simplified calculation of bracing member

CONCEPT

$$\frac{Qu}{Vu} \geq 1.0$$

Ultimate lateral strength of house shall be larger than required seismic load from code

Vu: Calculation of SEISMIC LOAD

Required Seismic force following NBC105

V=Cd * Wt

seismic coefficient

Cd=C*Z*I*K

- Dead load
- Live load
- Wind load
- Snow load

<

Qu: Ultimate lateral strength of house

- Wall ratio of each direction (Ground floor and First floor)

Required seismic load from NBC105

10.1 Horizontal Seismic Base Shear

10.1.1 The horizontal seismic shear force acting at the base of the structure, in the direction being considered, shall be :

$$V = C_d W_t \qquad 10.1$$

where C_d is as defined in **8.1.1**.

8.1 Design Spectra and Lateral Force Coefficients

8.1.1 Design Horizontal Seismic Coefficient for the Seismic Coefficient Method

The design horizontal seismic force coefficient, C_d shall be taken as :

$$C_d = CZIK \qquad 8.1$$

Where C is the basic seismic coefficient for the fundamental translational period in the direction under consideration.

Bracing member

Size and Number of bracing member

Calculation base

SEISMIC LOAD	Seismic coefficient	C:	Basic seismic coeffient		①	0.08	
		Z:	Zone factor		②	1	
		I:	Importance factor		③	1	
		K:	Structural performance facto		④	4	masonry structure
						2.5	frame struture
		Cd = CZIK		①x②x③x④	⑤	0.32	masonry structure
						0.2	frame struture
	Weight of building (only 1st floor)	Roof	Unit weight	Heavy	⑥	2.52	kN/sqm
				Light		0.79	kN/sqm
			Area		⑦		sqm
			Sub total	⑥x⑦	⑧		kN
		Wall	Unit weight	Heavy	⑨	2.52	kN/sqm
				Light		0.5	kN/sqm
			Volume	total length	⑩		m
				height	⑪		m
				thickness	⑫		m
			Sub total	⑨x⑩x⑪x⑫	⑬		kN
		Floor (If attic is there)	Unit weight	Heavy	⑭	2.52	kN/sqm
				Light		0.5	kN/sqm
			Area		⑮		sqm
			Sub total	⑭x⑮	⑯		kN
		TOTAL WT.		⑧+⑬+⑯	⑰		kN
	Seismic load = Cd x WT			⑤x⑰	⑱		kN

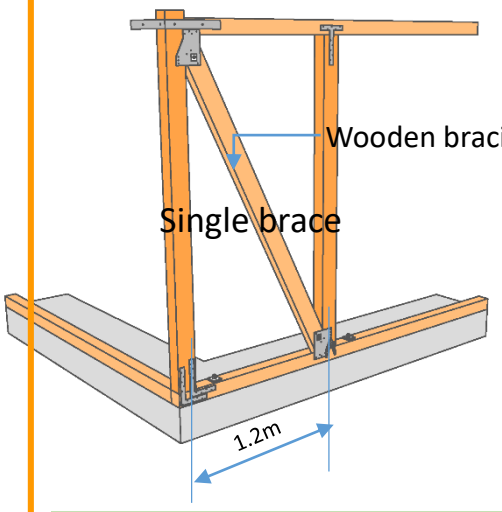
Allowable strenght	X-direction	brace	Type	refer from table no. 1	①		kN/m
				single	②	1	
				double		2	
			length		③		m
			Number		④		
			Total length	③x④	⑤		m
		Total strength		①x②x⑤	⑥		kN
	Y-direction	brace	Type	refer from table	⑦		kN/m
				single	⑧	1	
				double		2	
			length		⑨		m
			Number		⑩		
			Total length	⑨x⑩	⑪		m
		Total strength		⑦x⑧x⑪	⑫		kN

Allowable strength of each direction ⑥and ⑫ should be bigger than seismic load ⑱

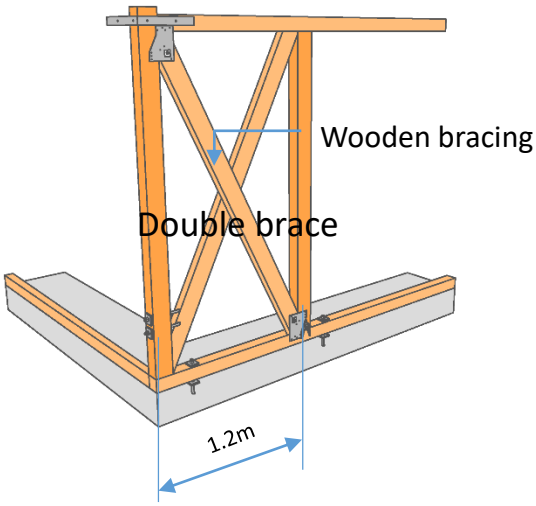
Bracing member

Size and Number of bracing member

Wooden bracing member

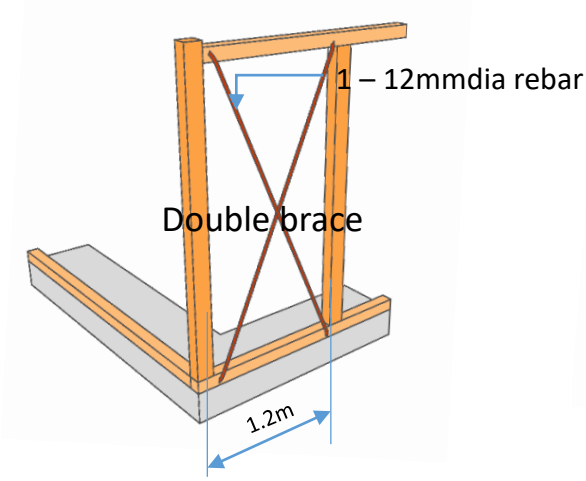


If wooden brace 100 x 100(single) fixed by metal plate:
Shear strength:
4.8kN/m(unit strength)x1(single) x1.2(meter) = 5.76kN

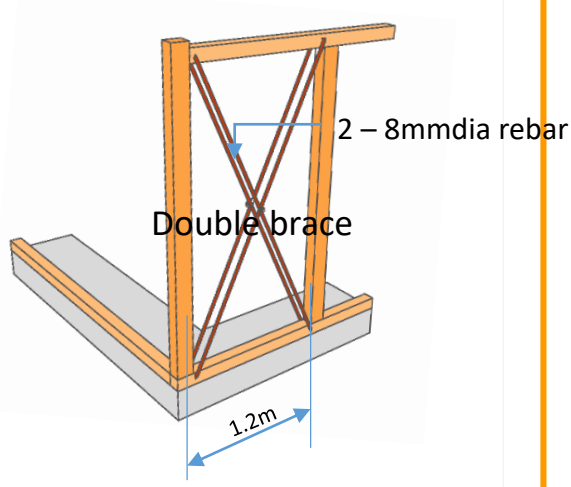


If wooden brace 100 x 50(double) fixed by metal plate:
Shear strength:
3.2kN/m(unit strength)x2(double) x1.2(meter) = 7.68kN

Rebar bracing member



If 1-12mm dia. Rebar:
Shear strength:
1.6kN/m(unit strength)x2(double) x1.2(meter) = 3.84kN

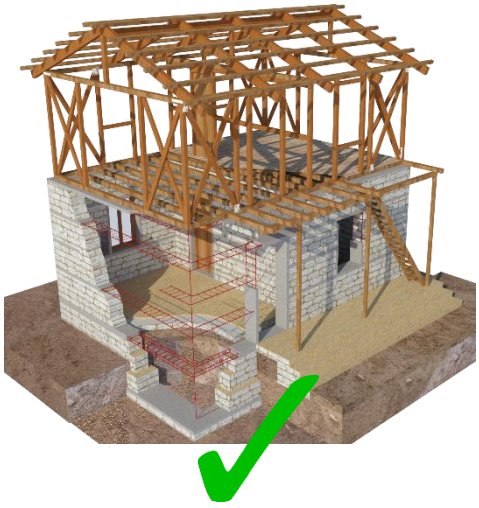


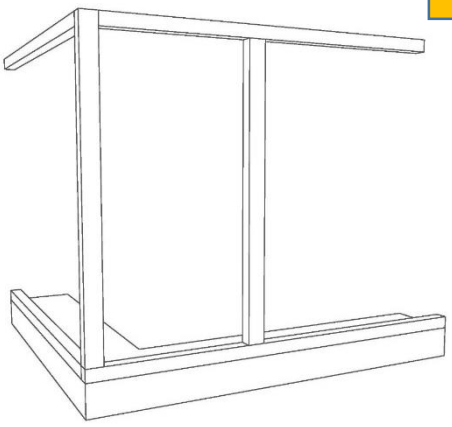
Instead of 12mm dia. 2number of 8mm dia. also can be used.

Bracing member

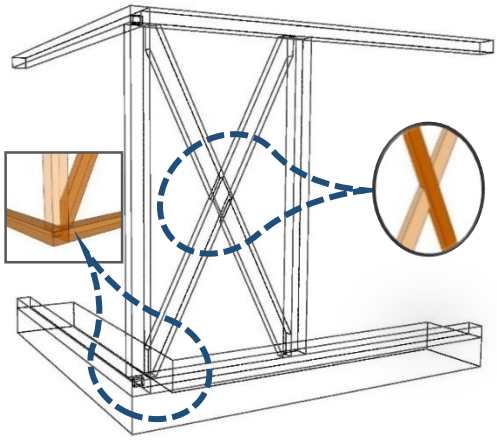
Size and Number of bracing member

Correction measures





No bracing member.



Steps

1. Add diagonal bracing
2. Connect vertical, horizontal member and bracing by proper connection materials such as metal plate.

5. Roof

Requirements

No	Category	Description		
7	Roof	Wood	Material	Use of light roof
			Connection	All member shall be properly connected.
			Bracing	For flexible diaphragm, diagonal bracing shall be considered.

Why important?

- If heavy weight is on the top of building it will be subjected to larger seismic force. Therefore, Light weight roof is required.
- The joints of wooden roof trusses need to be bolted together and tied with metal straps as it will provides flexibility and prevent from collapse.
- In order to resist lateral forces, depending upon the structures of roof, it might be need cross bracing at all levels. It provides strength against lateral forces so that the building does not collapse sideways but is held together.

Exception

- If structure is found to be safe after structural calculation.

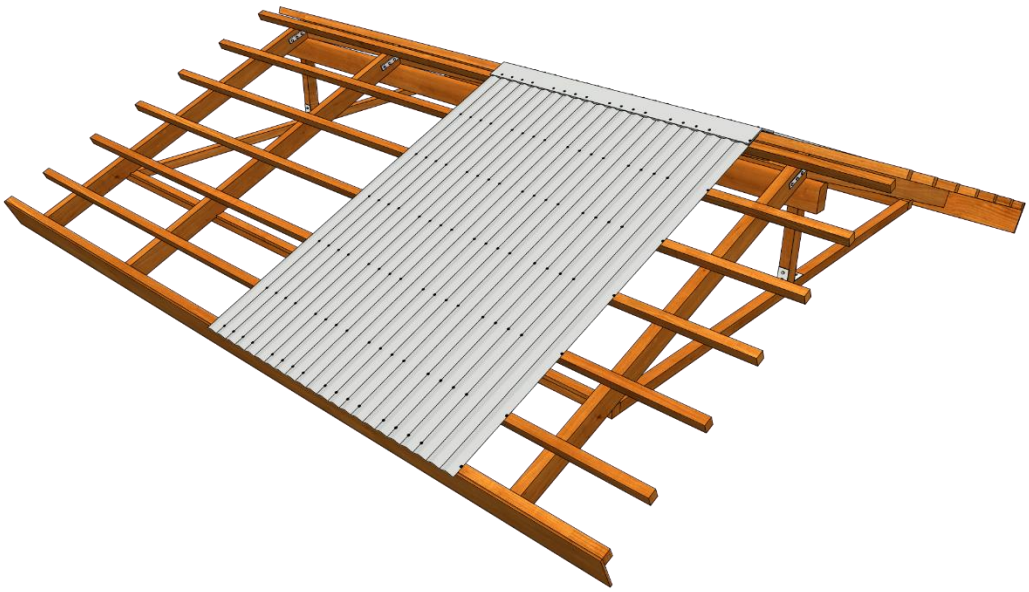
Inspection methodology

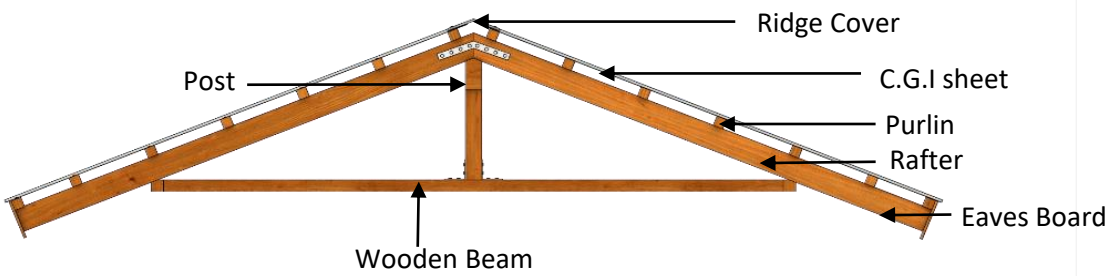
- The size of the main wooden member, batten can be identified by measurement.
- The spacing of the batten can also checked by the measurement whereas the connection can be checked by the observation.

Fundamental items

1. Use a continuous wall plate, ridge and purlins to tie the rafters or trusses together.
2. Stiffening of roof
   - Diagonal straps with steel nut bolts or metal nails
   - Diagonal steel truss with steel nut bolts or metal nails
   - Timber bracing with metal nails or timber nails

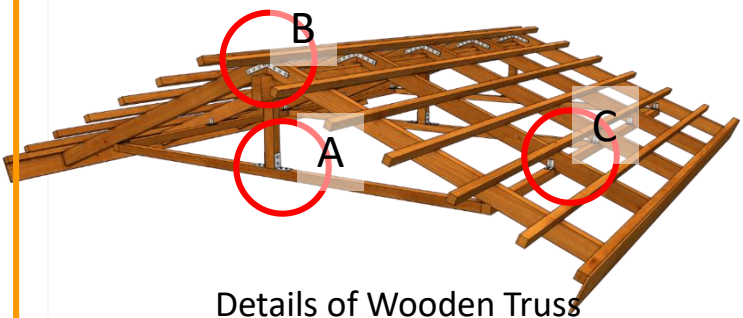
Wooden Roof truss



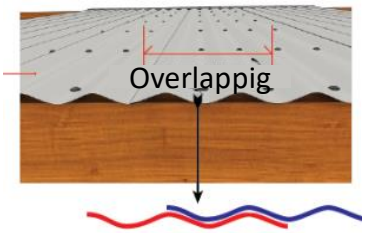


A **timber roof truss** is a structural framework of timbers designed to bridge the space above a room and to provide support for a roof. Trusses usually occur at regular intervals, linked by longitudinal timbers such as purlins.
Rafters are inclined timbers fixed between wall plate and ridge which transmit live and dead loads to wall plate.

Connection details

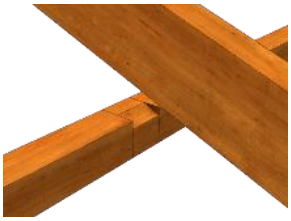


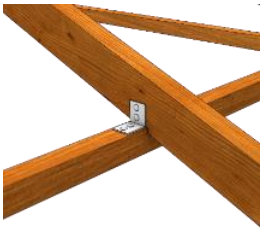
Details of Wooden Truss



Detail A: Joints of Wooden Truss

Detail C: Joints of Rafter





Detail B: Joints of Wooden Truss

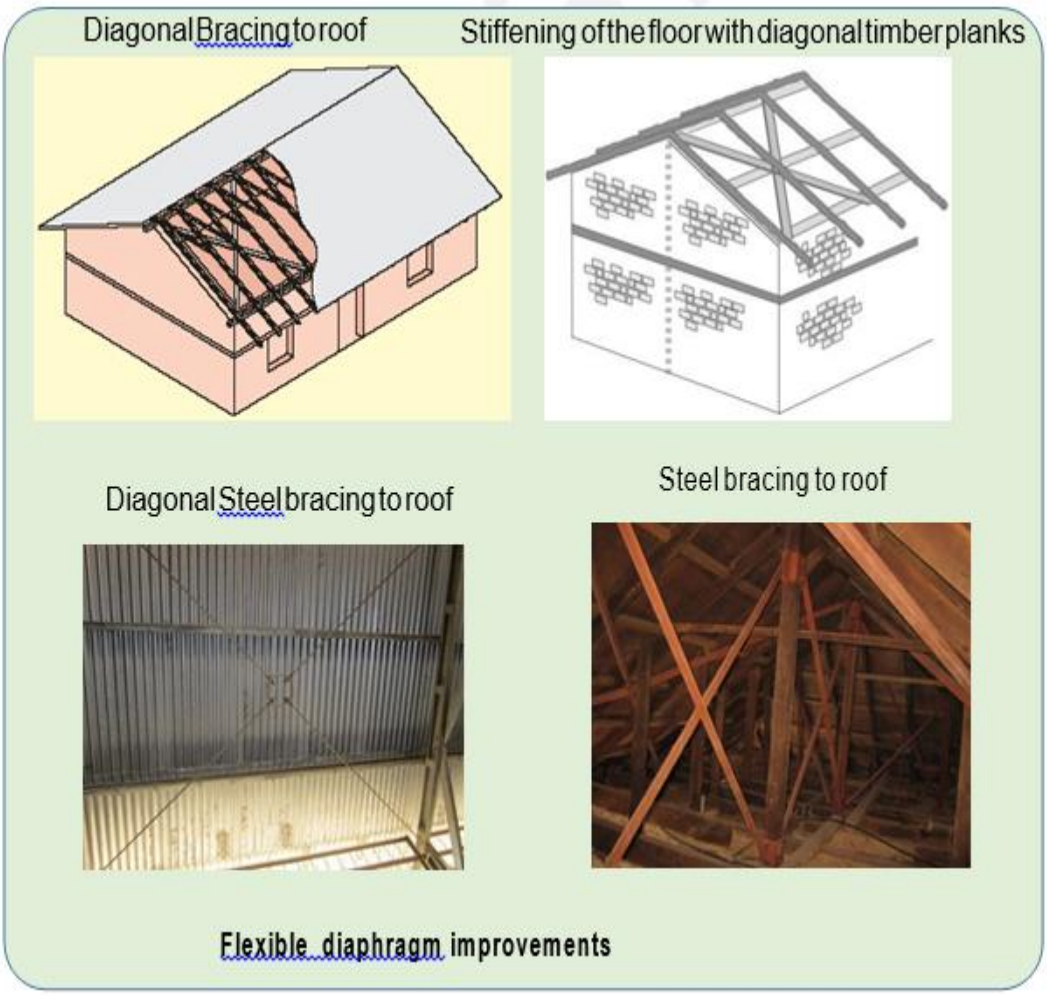
Strengthening roof

In case of Roof/floor bracing missing

Correction measures

Option : from Retrofitting manual.

- Provide X-bracing at end bays on each sloppy side
- Provide additional roof/floor member as needed



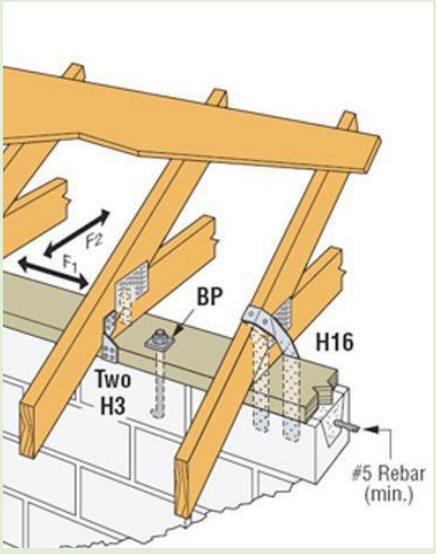
Strengthening roof

Connection improvement between wall to roof

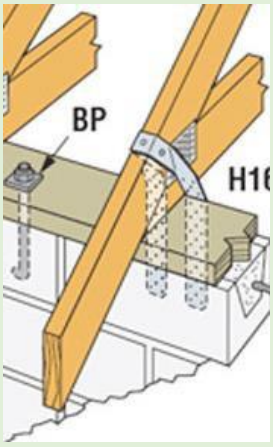
Correction measures

Option : from Retrofitting manual.

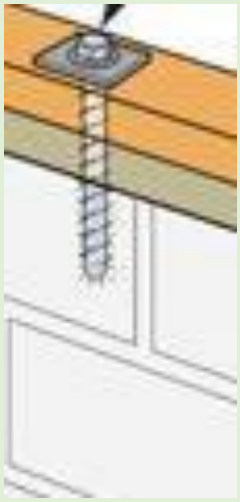
- Metal Strap with Screws



Note : 3 mmm thick metal strap, Minimum four numbers of 50 mm long nails (Fe250) with Floor member and Minimum four numbers of M16 grade expansion bolts with walling material



Details of Anchor plate



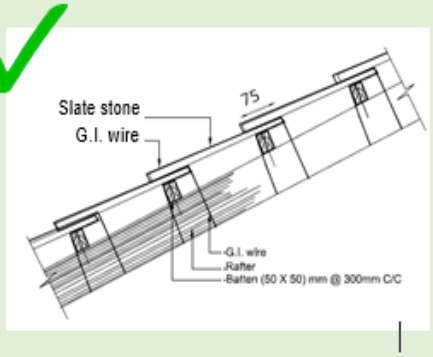
Strengthening roof

Sliding of Roofing materials

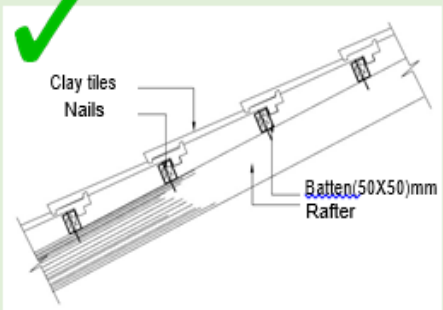
Correction measures

Option : from Retrofitting manual. Fixing roofing tile.

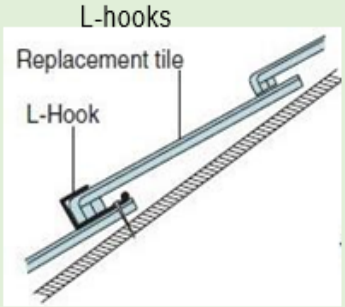
1.Replace damaged tiles.
2.Using appropriate correct fixing method for roofing materials.
3.Connect the roof with the roof band by inserting reinforcement or GI sheet.
4.Slatestone and clay tiles should be properly anchored to purlin as NBC.

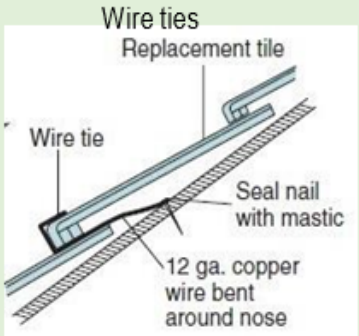


Detail of anchoring slate stone
Source: NBC203 2015, P44



Detail of fixing clay tile
Source: NBC203 2015, P45





Gently lift the overlapping tile and twist loose the damaged tile.
After filling any nail holes, slip in a new tile and secure with an L-hooks (left) or bent copper wire (right)

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APPENDIX

1. Inspection sheet
2. Prototype drawings
3. Structural Calculation
4. Structural Analysis

Final Inspection of Hybrid Structure

Government of Nepal
Ministry of Urban Development
Central Level Project Implementation Unit

INSPECTION SHEET OF HYBRID STRUCTURE FOR FINAL INSPECTION

Information of House Owner/Beneficiary					Date of Inspection	dd-mm-yyyy
Name:					Grand Agreement No.	
Address:	District	VDC/Municipality	ward	tole	Land plot No	

SECTION -1: DESCRIPTION PROVIDED IN THE APPLICATION TO SURVEY THE HOUSE

If use fix design from design catalogue,		Design No.	
If free design by house owner Fill construction typology from P.A form		Technique and Construction material	
		Construction of roof and materials	
Technical Assistant	☐YES, ☐NO	Organization	☐GoN, ☐NGO ( )
Trained Masons used	☐YES, ☐NO	Soil type	☐Hard, ☐Medium, ☐Soft

SECTION-2: DETAIL TECHNICAL INSPECTION

S.N	Category		Description			Comply YES	Comply NO	Remarks
1.	Shape of House		No. of storey	Not more than two storey		☐	☐	
			Shape of house/Span of wall	1st floor	Regular shape. The wall line of upper storey shall be on the wall of lower storey. The wall line shall not be cantilevered. Therefore, the span of wall also same as lower storey.	☐	☐	
			Height of wall	1st floor	It shall not be more than 2.5m.	☐	☐	
2.	Materials		Nail	Common wire nails shall be made of mild steel having a minimum tensile strength of 550N/mm2. Nails with appropriate diameter and length shall be provided.		☐	☐	
			Bolt	The number, diameter, length and spacing shall be as per the specification. (*refer hybrid manual)		☐	☐	
			Metal plate	The number, diameter, length and spacing shall be as per the specification.(*refer hybrid manual)		☐	☐	
			Rebar	High strength deformed bars with fy = 415 Mpa /500 Mpa.		☐	☐	
			Timber	Treated and well seasoned hard wood or locally available wood without knots shall be used.		☐	☐	
3.	Connection and Joints		Connection between lower and upper structure	It shall be properly connected as per the specification.(*refer hybrid manual)		☐	☐	
				In SMM or BMM with timber band, the floor band and lintel band shall be properly connected.		☐	☐	
			Joints of structural member	All the structural members shall be properly connected by nails, bolts and metal plate as per the specification.(*refer hybrid manual)		☐	☐	
4.	Frame	Vertical member	It shall be continue from base plate to top plate with proper connection.			☐	☐	
			Size	It shall not be less than 75X75(mm) for hard wood and 100 X 75(mm) for soft wood.		☐	☐	
			Spacing	It shall be less than 1200mm.		☐	☐	
		Horizontal member	It shall be continuous at same level.			☐	☐	
			Base plate/Top plate	It shall be (100 X 75)mm.		☐	☐	
				It shall be properly connected with floor band. It shall not be less than 75X 75 mm in hard wood and 100 X 75(mm) in soft wood.		☐	☐	
		Bracing member	Location	It shall be symmetrical and located at each corners.		☐	☐	

			Direction	It shall not be in same direction.	☐	☐	
			Size/number	It shall be as per the specification (*refer hybrid manual)	☐	☐	
5	Roof		Material	Use light roof	☐	☐	
			Connection	All member connected properly	☐	☐	
			Bracing	For flexible diaphragm, Diagonal bracing shall be considered.	☐	☐	

Others:

a) At least four number of photographs with their number
b) Tentative drawings of building:
c) After the detail description of the under constructed house, is it satisfactory to give completion certificate

Yes ☐ , No ☐

☐ It was passed through the inspection of the third inspection so the construction can be provided building completion certificate from VDC/Municipality.

☐ If was found to be corrected/retrofitted so correction order is given using Annex-6

d) Acceptation of Description provided agreeing that the technical details during inspection is correct:

House owner/Beneficiaries or representative name:.....Signature:.....

Relationship with house owner (In case of representative):.....Date:.....

e) Submit for Approval of the technical inspection:.....

MOUD-DLPIU Supervisor:.....

Name..... Designation:.....

Signature..... Date.....

f) Approved by:

MOUD DLPIU Supervision Engineer.....
Designation:.....

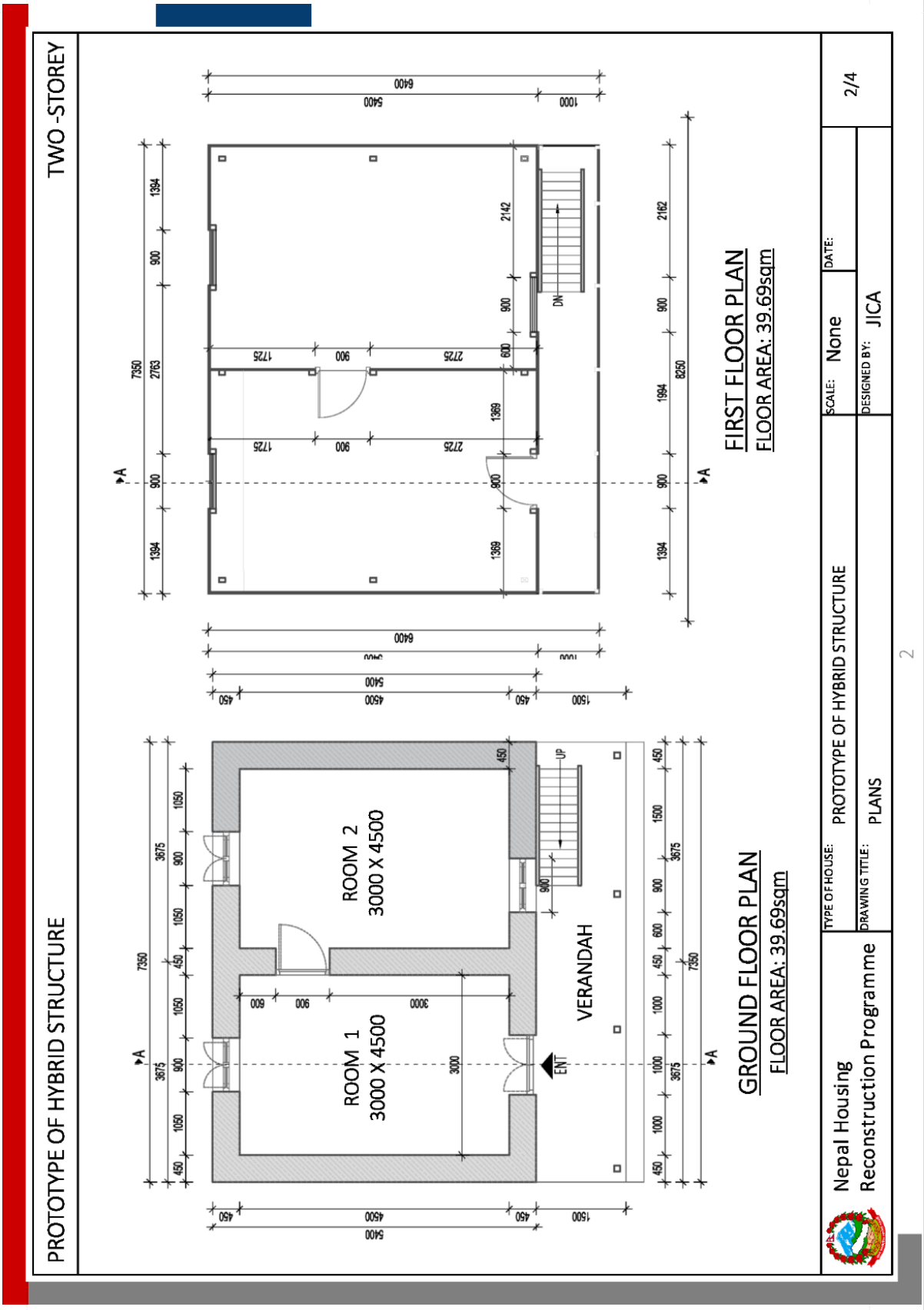
Signature..... Date.....

PROTOTYPE OF HYBRID STRUCTURE TWO -STOREY

Nepal Housing Reconstruction Programme	TYPE OF HOUSE: PROTOTYPE OF HYBRID STRUCTURE	SCALE: None	DATE:	1/4
	DRAWING TITLE: PERSPECTIVE(CUT MODEL)	DESIGNED BY: JICA		

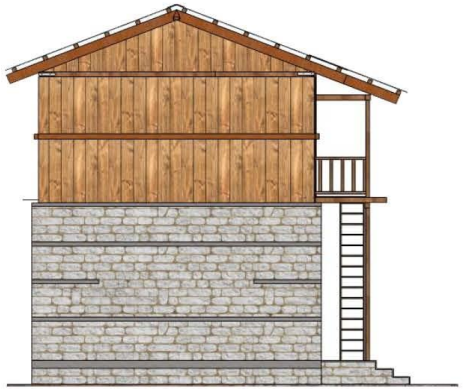
2

Prototype of hybrid structure



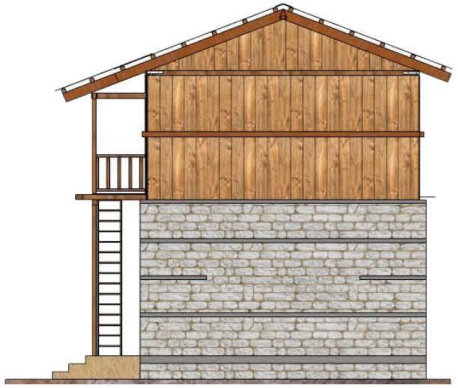
PROTOTYPE OF HYBRID STRUCTURE TWO -STOREY

Front Elevation



Side Elevation

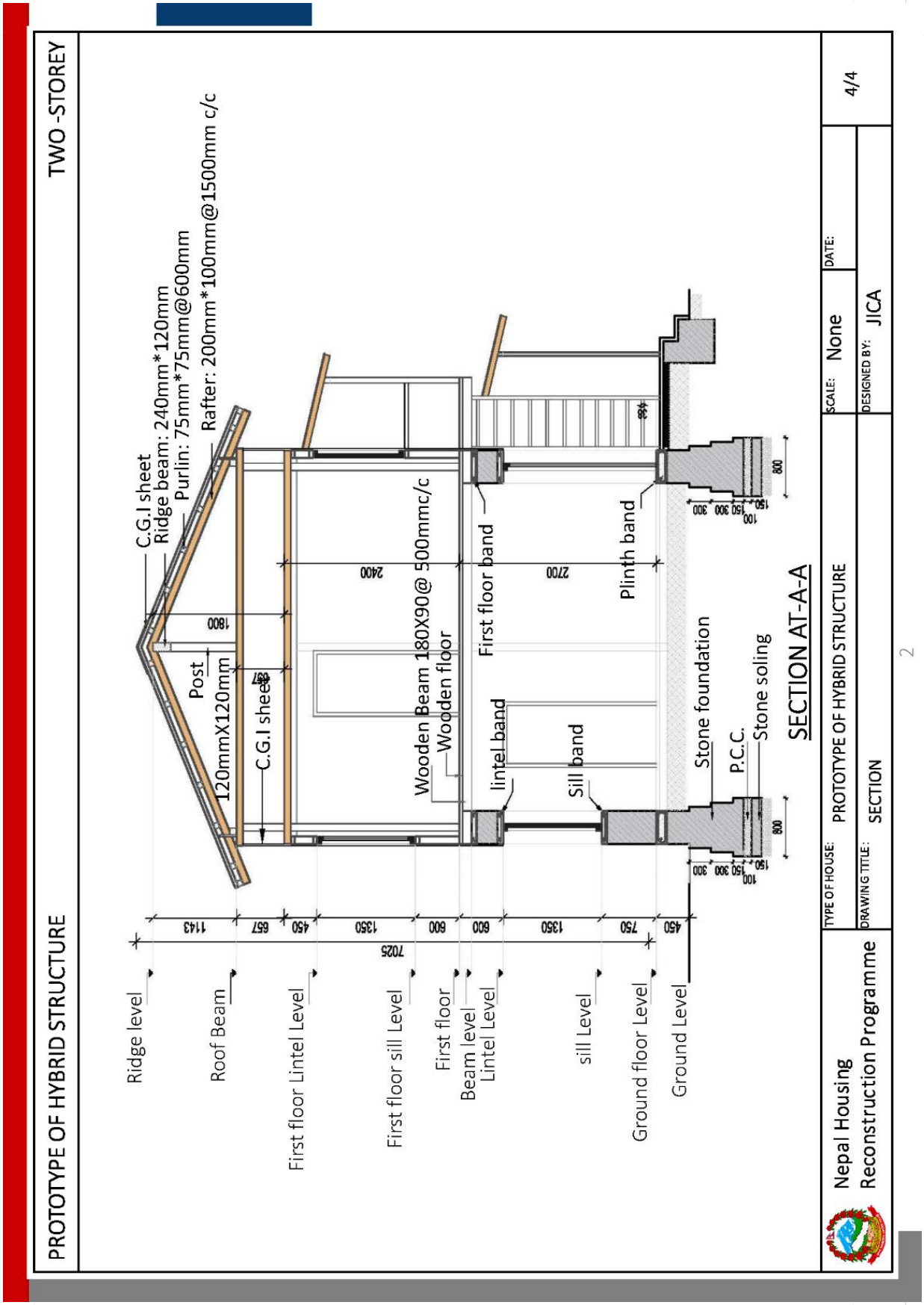
Back Elevation



Side Elevation

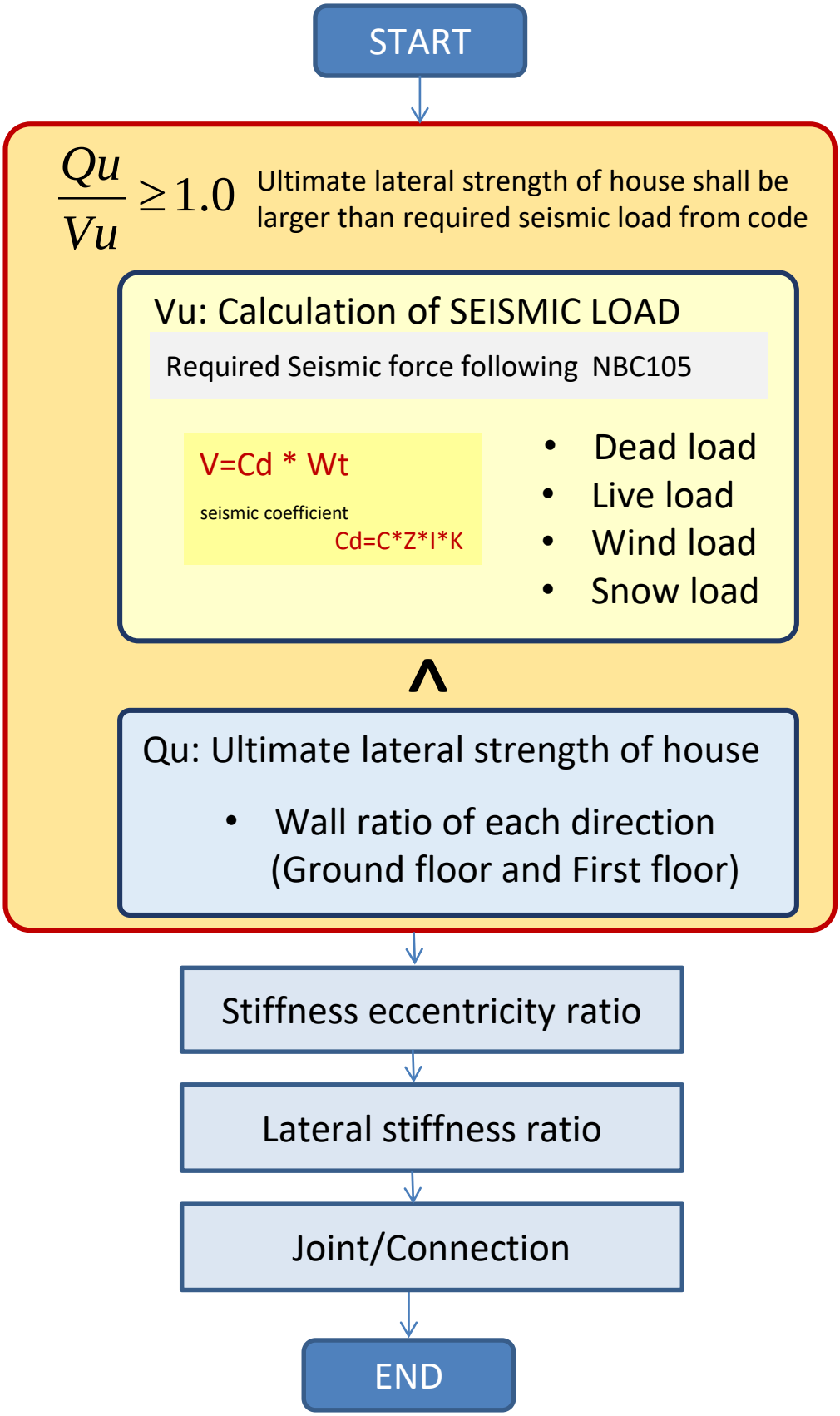
Nepal Housing Reconstruction Programme	TYPE OF HOUSE: PROTOTYPE OF HYBRID STRUCTURE	SCALE: None	DATE:	3/4
	DRAWING TITLE: ELEVATION	DESIGNED BY: JICA		

Prototype of hybrid structure

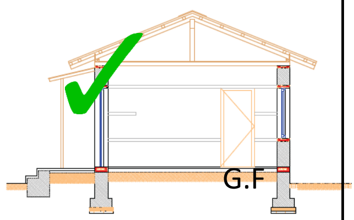
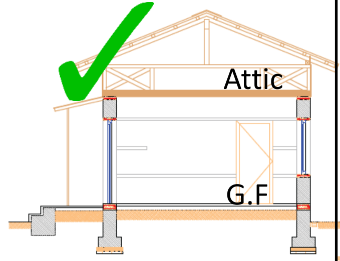
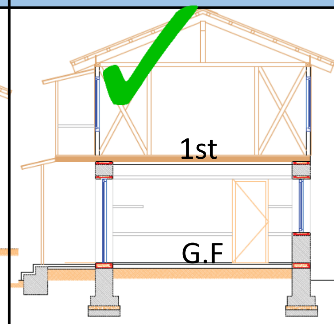
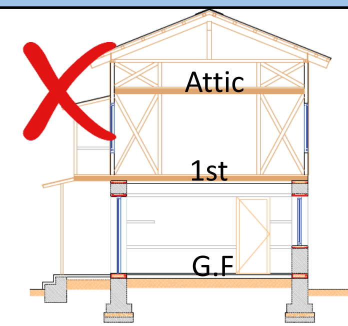


Structural calculation

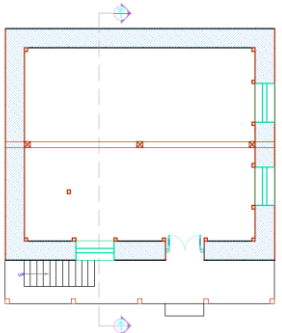
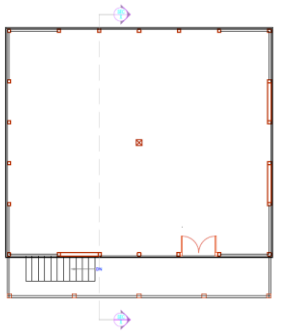
Outline

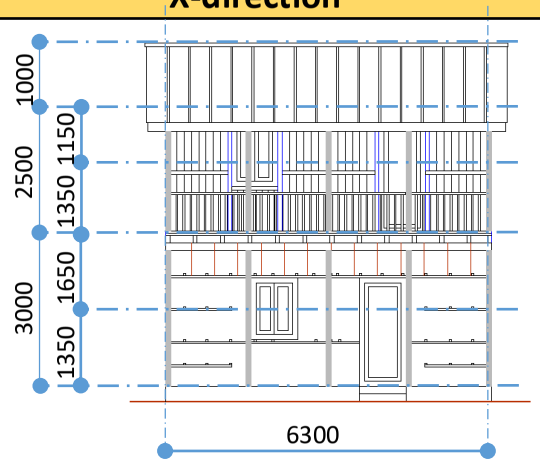
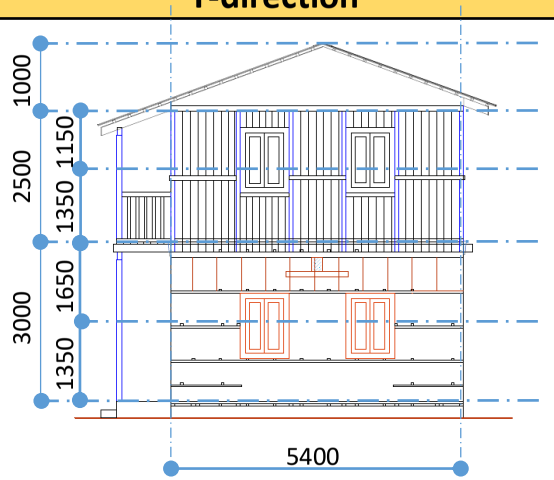
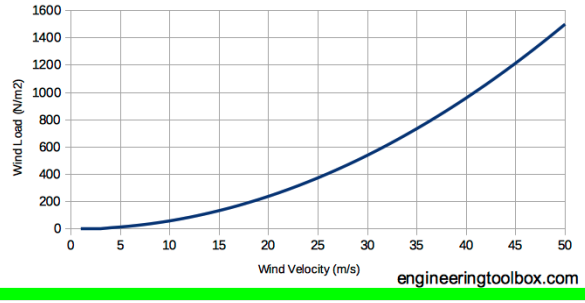


APPENDIX: Wall ratio calculation

STEP 1: CHECKING SEISMIC LAOD			ONE STOREY	ONE STOREY+ATTIC	TWO STOREY	TWO STOREY + ATTIC
HYBRID STRUCURE (JICA MODEL) Floor Area: 6.35m*5.0=31.75m^2			 G.F:SMM+Wooden band	 G.F:SMM+Wooden band Atitic:Timber frame	 G.F:SMM+Wooden band 1F:Timber frame	 G.F:SMM+Wooden band 1F:Timber frame
Area of wall on each direction	**Attic**	**X-direction**		L=12.7m A=1.27 m^2		L=12.7m A=1.27 m^2
		Y-direction		L=10 A=1m^2		L=10 A=1m^2
	1st floor	**X-direction**			L= 12.7 m A=1.27 m^2	L= 12.7 m A=1.27 m^2
		Y-direction			L=15m A= 1.5 m^2	L=15m A= 1.5 m^2
	Ground floor	**X-direction**	L= 8.4m, A=2.95m^2	L= 8.4m, A=2.95m^2	L= 8.4m, A=2.95m^2	L= 8.4m, A=2.95m^2
		Y-direction	L=13.05m, A=4.57m^2	L=13.05m, A=4.57m^2	L=13.05m, A=4.57m^2	L=13.05m, A=4.57m^2
Combination Load	**Roof**		0.79 KN/m^2 X 6.8m X 8.15m= **43.80 kN**	0.79 KN/m^2 X 6.8m X 8.15m= **43.80 kN**	0.79 KN/m^2 X 6.8m X 8.15m= **43.80 kN**	0.79 KN/m^2 X 6.8m X 8.15m= **43.80 kN**
	Floor	**Attic**		2.77 KN/m^2 X 6.0m X 4.65m= **77.28 kN**		2.77 KN/m^2 X 6.0m X 4.65m= **77.28 kN**
		1st			2.52 KN/m^2 X 6.0m X 4.65m= **69.75 kN**	2.52 KN/m^2 X 6.0m X 4.65m= **69.75 kN**
	Wall	**Attic**		0.50 KN/m^2 X 26.7m = **13.35 kN**		0.50 KN/m^2 X 26.7m = **13.35 kN**
		1st			0.50 KN/m^2 X 69.09m^2 = **34.54 KN**	0.50 KN/m^2 X 65.09m = **32.54 kN**
		G.F.	9.35 KN/m^2 X {(6.0m X 2+ 4.65 X 3)X2.7 −(0.9m X 1.35)X3- (0.9mX2.1m)X2}= **585.07 kN**	9.35 KN/m^2 X {(6.0m X 2+ 4.65 X 3)X2.7 −(0.9m X 1.35)X3- (0.9mX2.1m)X2}= **585.07 kN**	9.35 KN/m^2 X {(6.0m X 2+ 4.65 X 3)X2.7 −(0.9m X 1.35)X3- (0.9mX2.1m)X2}= **585.07 kN**	9.35 KN/m^2 X {(6.0m X 2+ 4.65 X 3)X2.7 −(0.9m X 1.35)X3- (0.9mX2.1m)X2}= **585.07 kN**
	TOTAL WT. (WT of 1st)		**628.87 kN**	**719.50 kN (57.15kN)**	**733.16 kN (78.34kN)**	**821.80 kN (166.97kN)**
SEISMIC LOAD	**G.F**		Cd=0.08*1*1*4=0.32, k=4(masonry) **V=628.87kN*0.32=201.24 kN**	Cd=0.08*1*1*4=0.32, k=4(masonry) **V=719.50kN*0.32=230.24 kN**	V=Cd X Wt, Cd=0.08*1*1*4=0.32 **V=733.16*0.32=234.61 kN**	V=Cd X Wt, Cd=0.08*1*1*4=0.32 **V=821.80kN*0.32=262.98 kN**
	F.F			Cd=0.08*1*1*2.5=0.2, k=2.5(Frame) **V=57.15*0.2*1.2=13.71 kN**	Cd=0.08*1*1*2.5=0.2 **V=78.34*0.2*1.2=18.80 kN**	Cd=0.08*1*1*2.5=0.2 **V=166.97*0.2=40.07 kN**
Allowable strength	**G.F**	**X-direction**	(2950000*0.096)/1000 =283.2 KN > 201.24kN ⇒OK	(2950000*0.096)/1000 =283.2 KN > 230.24 kN ⇒OK	(2950000*0.096)/1000 =283.2 KN > 234.61 kN ⇒OK	(2950000*0.096)/1000 =283.2 KN > 262.98 kN ⇒OK
		Y-direction	(4570000*0.096)/1000 =438.72 KN > 201.24 kN ⇒OK	(4570000*0.096)/1000 =438.72 KN > 230.24 kN ⇒OK	(4570000*0.096)/1000 =438.72 KN > 234.61 kN ⇒OK	(4570000*0.096)/1000 =438.72 KN > 262.98 kN ⇒OK
	1st /Attic	**X-direction**		Brace (X:100*50) =2.6*2*4 =20.8 kN > 13.71 kN ⇒OK	Brace (X:100*50) =2.6*2*4 =20.8 kN > 18.80 kN ⇒OK	Brace (X:100*50) =2.6*2*4 =20.8 kN < 40.07 kN ⇒NG
		Y-direction		Brace (X:100*50) =2.6*2*4 =20.8 kN > 13.71 kN ⇒OK	Brace (X:100*50) =2.6*2*4 =20.8 kN > 18.80 kN ⇒OK	Brace (X:100*50) =2.6*2*4 =20.8 kN < 40.07 kN ⇒NG

APPENDIX: Wall ratio calculation

STEP 1: CHECKING SEISMIC LAOD			TWO STOREY	
HYBRID STRUCURE (NSET MODEL)			 **G.F PLAN**  **1F PLAN**  **SECTION A-A'** GL:SMM+Wooden band, 1F:Timber frame Floor Area: 6.3m*5.4=34.02m^2, Wall thickness: 0.45m, Height: GL=3.0m, 1st= 2.5m	
Area of wall on each direction	1st floor	**X-direction**	L= 12.6 m A=1.276m^2	
		Y-direction	L=10.8m A= 1.08 m^2	
	Ground floor	**X-direction**	L= 8.73m, A=3.92m^2	
		Y-direction	L=7.74m, A=3.48m^2	
Combination Load	**Roof**		0.79 KN/m^2 X 8.4m X 7.5m= **49.77 kN**	
	Floor	**1st**	2.52 KN/m^2 X 6.3m X 5.4m= **86.07 kN**	
	Wall	**1st**	0.50 KN/m^2 X 63.9m^2 = **31.95 KN**	
		G.F.	9.35 KN/m^2 X {(5.85m X 2+ 4.95 X 2)X3.0 –(0.9m X 1.35)X3- (0.9mX2.1m)}= **585.51 kN**	
	TOTAL WT. (WT of 1st)		**753.30 kN (81.72 kN)**	
Design method			**Working Stress method** ✓	**Limit state method** ✓
SEISMIC LOAD		**G.F**	V=Cd*Wt, Cd=0.08*1*1*4=0.32 **V=753.30*0.32=241.06 kN**	V=Cd*Wt *1.25, Cd=0.08*1*1*4=0.32 **V=941.63 kN*0.32=301.32 kN**
		F.F	V=Cd*Wt, Cd=0.08*1*1*2.5=0.2 **V=81.72*0.2*1.2=19.61 kN**	V=Cd*Wt *1.25, Cd=0.08*1*1*2.5=0.2 **V=102.15*0.2*1.2=24.51 kN**
	Ground floor	**X-direction**	(3920000*0.096)/1000 =376.32 KN > 241.06 kN ⇒OK	(3920000*0.096*1.5)/1000 =564.48KN > 301.32 kN ⇒OK
		Y-direction	(3480000*0.096)/1000 =334.08 KN > 241.06 kN ⇒OK	(3480000*0.096*1.5)/1000 =501.12KN > 301.32 kN ⇒OK
	1st Floor	**X-direction**	Brace (X:100*50) =2.6*2*4 =20.8 kN > 19.61 kN ⇒OK	Brace (X:100*50) =2.6*2*4*1.5 =31.2 kN > 24.51 kN ⇒OK
		Y-direction	Brace (X:100*50) =2.6*2*4 =20.8 kN > 19.61 kN ⇒OK	Brace (X:100*50) =2.6*2*4*1.5 =31.2 kN > 24.51 kN ⇒OK

STEP 1: CHECKING WIND LOAD			X-direction	Y-direction
ELEVATION OF MODEL				
Related wall area	1st floor		7.5m*1.0m+6.3m*1.15m = 14.75m^2	5.4m*1.0m/2+5.4m*1.15m = 8.91m^2
	Ground floor		7.5m*1.0m +6.3m*(2.5m+1.65m) = 33.65m^2	5.4m*1.0m/2+5.4m*(2.5m+1.65m) = 25.11m^2
Wall ratio	1st Floor	Requirement	14.75m^2 *0.98kN/m=14.46kN	8.91m^2 *0.98kN/m=8.73kN
		Capacity	Brace (X:100*50) =2.6*2*4=20.8 kN	Brace (X:100*50) =2.6*2*4=20.8 kN
		Result	20.8 kN > 14.64kN ⇒OK	20.8 kN > 8.73kN ⇒OK
	Ground floor	Requirement	33.65m^2 *0.98kN/m=35.92kN	25.11m^2 *0.98kN/m=25.60kN
		Capacity	(3920000*0.096)/1000=376.32 KN ✓	(3920000*0.096*1.5)/1000=564.48KN ✓
		Result	376.32 KN > 35.92 kN ⇒OK	564.48KN >25.60k ⇒OK
Notes			1. **The requirement of wall ratio, In case of Japan, The requirement of the wall length is 50cm/m2 based on 1.96kN/m. Therefore, The requirement of wall ratio will be 0.98kN as per related wall area. The requirement is 0.98KN/m2.** 2. **Estimated wind speed : In Japan . Estimate wind speed is 34m/s (10min average), and In Indian Standard 55m/s (3second average). It can assume, 3 second average is equivalent 1.5 ~ 2.0 times of 10 min average. Therefore, Japanese method also applicable for wind check for ordinary house.**	

Lateral stiffness ratio

The lateral stiffness ratio *R*s of each story (except the basement) shall be equal to or greater than 0.6.

$$Rs = \frac{rs}{\overline{rs}.} \geq 0.6$$

rs= lateral stiffness ratio=$\frac{story\ drift}{story\ height}$

$\overline{rs}$= mean lateral stiffness= $\sum_{i=1}^{n} rsi$

where, *r*s is the lateral stiffness, which is defined as the story height divided by the story drift caused
by the lateral seismic shear for moderate earthquake motions, and r^{-}s is the mean lateral stiffness that is
defined as the arithmetic mean of *r*s's

Check for lateral stiffness ratio for load case Eqx of sample model:

Story	Story height	Interstory drift (mm)	Lateral stiffness (rs)	Mean lateral stiffness $\overline{rs}$	Lateral stiffness ratio Rs	Permissible Lateral stiffness Ratio	Status
1	3000	7.7	0.0025	0.0026	0.96	≥0.6	Ok
2	2500	7.68	0.0027		1.39	≥0.6	OK

Check for lateral stiffness ratio for load case Eqy of sample model:

Story	Story height	Interstory drift (mm)	Lateral stiffness (rs)	Mean lateral stiffness $\overline{rs}$	Lateral stiffness ratio Rs	Permissible Lateral stiffness Ratio	Status
1	3000	9.18	0.0031	0.0030	1.03	≥0.6	OK
2	2500	7.22	0.0029		0.97	≥0.6	OK

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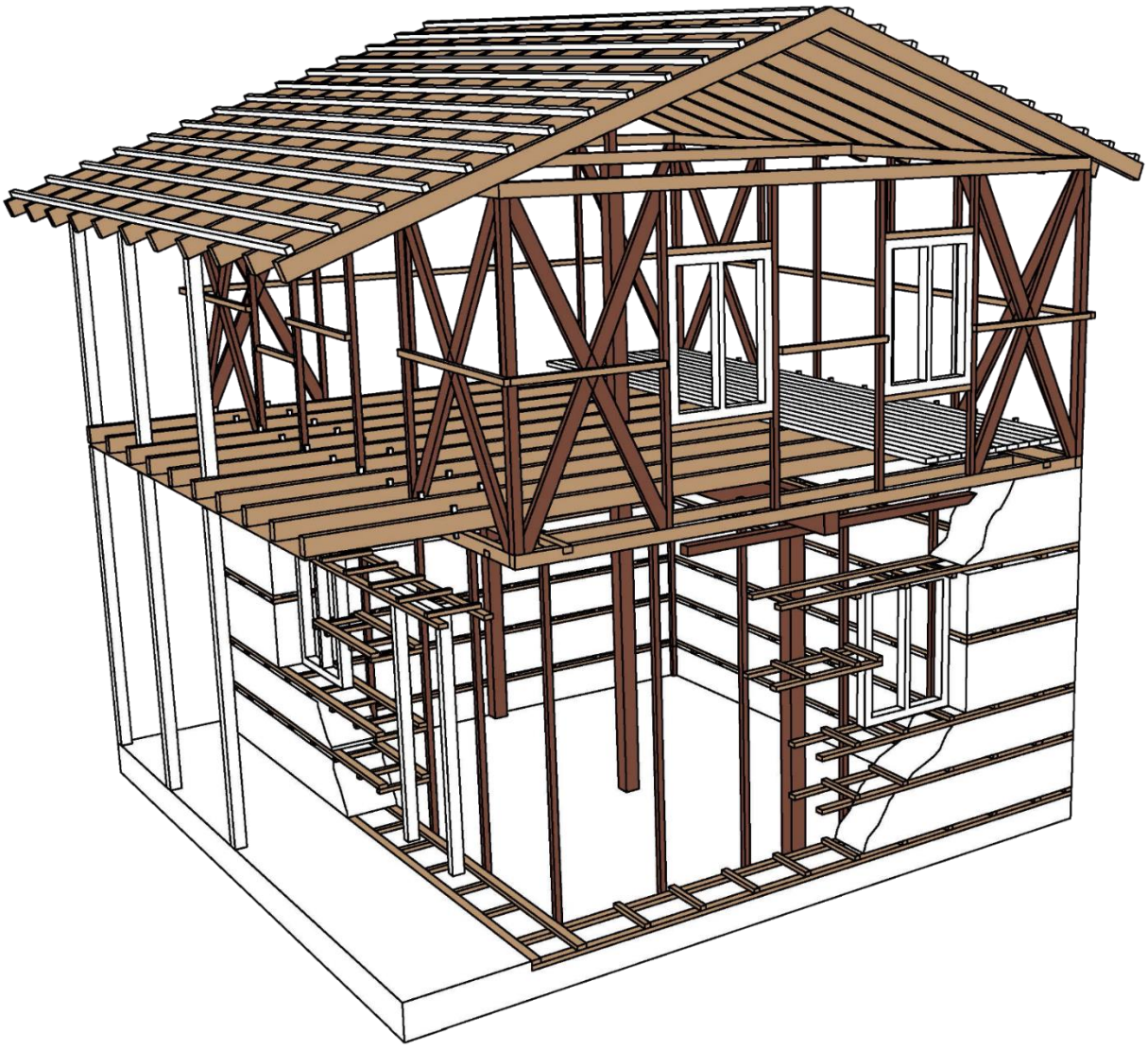
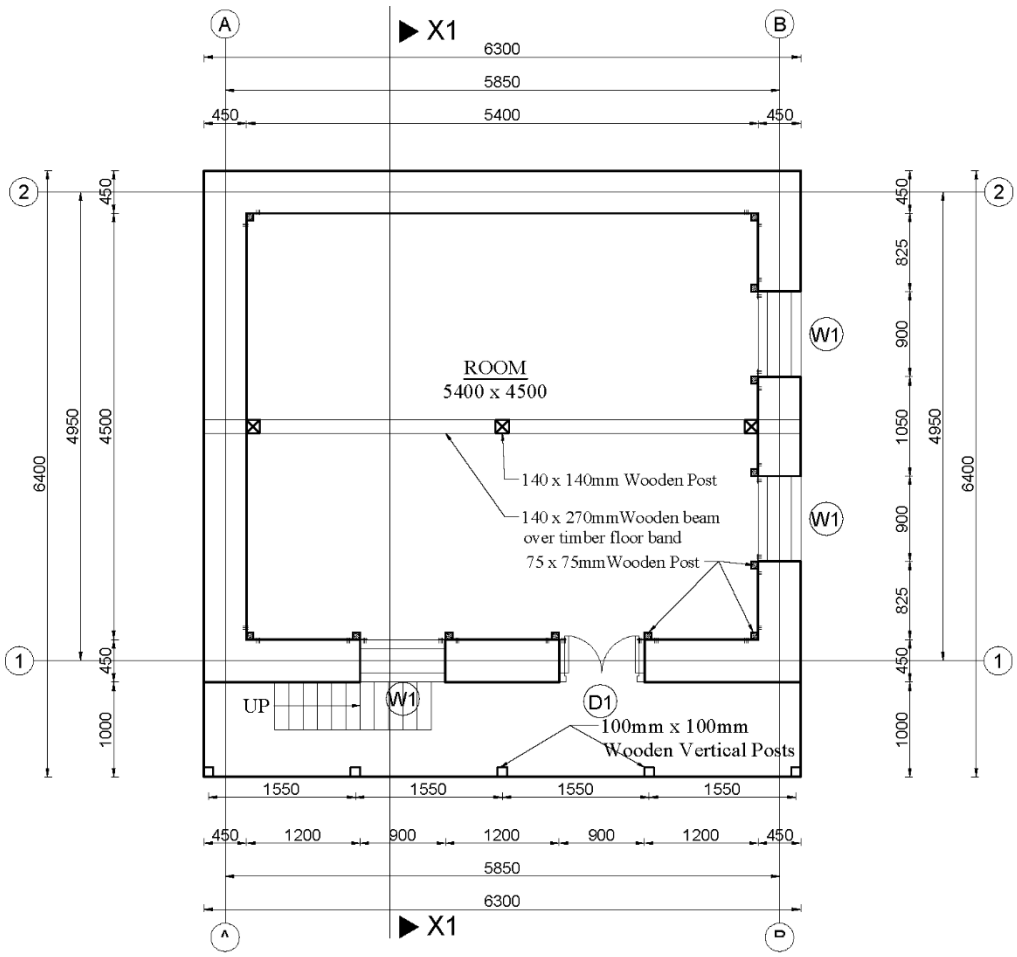
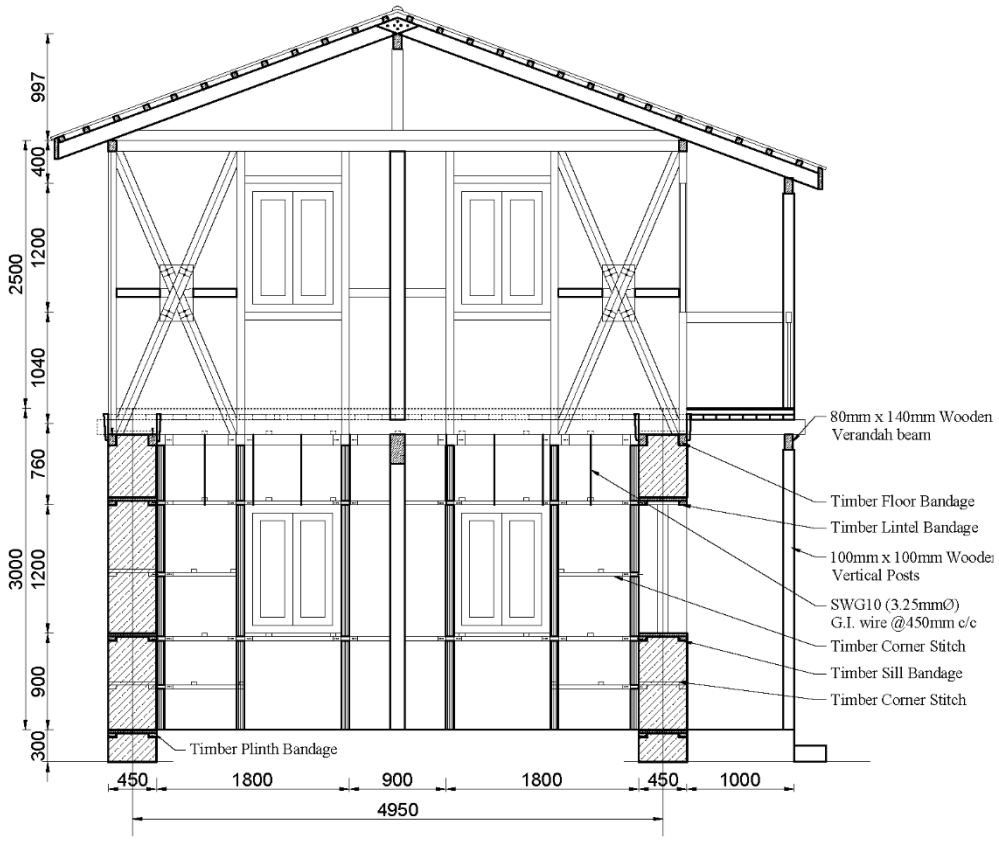


Building description:

Sample building used in this calculation is a Two Story Mix Structural System Building with Low Strength Stone Masonry in Ground Floor and Timber Structure in Upper Floor.

Building type: Residential building
Plan shape: Rectangular
Plinth area: 34.02 sq.m.
Number of storey: Two (Ground floor low strength masonry and upper storey timber structure)
Total height: 5.5m from plinth level
Inter storey height: Ground floor 3m and upper floor 2.5m
Building system: Mixed: Ground floor low strength load bearing masonry and upper floor timber structure.


A
B
X1
6300
5850
450
5400
450
2
1
W1
ROOM
5400 x 4500
140 x 140mm Wooden Post
140 x 270mmWooden beam
over timber floor band
75 x 75mmWooden Post
UP
D1
100mm x 100mm
Wooden Vertical Posts
6400
4950
4500
1000
825
900
1050
1550
1200
900
X1


997
400
1200
2500
1040
760
3000
1200
900
300
80mm x 140mm Wooden
Verandah beam
Timber Floor Bandage
Timber Lintel Bandage
100mm x 100mm Wooden
Vertical Posts
SWG10 (3.25mmØ)
G.I. wire @450mm c/c
Timber Corner Stitch
Timber Sill Bandage
Timber Corner Stitch
Timber Plinth Bandage
450
1800
900
1800
450
1000
4950

Basic Assumption

1.Unit weight of Materials

Unit weight of the materials is taken from IS 875 part I

Unit Weight of Masonry=	19.00	KN/m3
Unit Weight of Timber=	5.75	KN/m3
Unit Weight of Floor Covering =	19.00	KN/m3
Weight per m2 of CGI Sheet =	0.13	KN/m2

i. Material Properties

a. Stone Masonry Wall

Modulus of Elasticity (E) = 74 Mpa

Allowable Compressive Strength = 0.47 Mpa

(Calculated From IS 1905: Code of Practice for structural use of unreinforced masonry)

Allowable Tensile Strength= Neglected

Allowable Shear Strength= 0.096Mpa (From Shake table test of China)

b. Timber: Soft Wood (Chir) (As per NBC 112:1994)

Allowable Tensile Strength (ft)	=	6.9 Mpa
Allowable Compressive Strength (fc)	=	5.5 Mpa
Allowable Shear Strength (fs)	=	0.6 Mpa

Load calculation

Dead Load and Live Load:

Dead Load

Unit Weight of Masonry=	19.00	KN/m3
Unit Wt. of RCC=	25.00	KN/m3
Unit Weight Timber=	5.75	KN/m3
Unit Weight of Floor Covering =	16.00	KN/m3
Weight per m2 of CGI Sheet =	0.13	KN/m2
Load from Floor		
Length of Building	6.30	m
Width of Building	5.40	m
Width of Timber =	0.08	m
Depth of Timber =	0.10	m
Spacing of Timber in X direction	0.59	m
Total Length of timber(m)	58.15	m
Total Weight of timber =	2.51	KN
Depth of Floor Covering =	0.15	m
Weight per area of Floor Covering =	16.00	KN/m2
Total Dead Weight of Floor =	84.16	KN
Weight Density per m2 of Floor =	2.47	KN/m2

Load from Roof		
Length of Building	6.30	m
Width of Building	5.40	m
Height of Roof =	1.15	m
Inclined Length of One roof =	3.99	m
Spacing of Purlin=	1.00	m
Width of purlin =	0.05	m
Depth of Purlin =	0.05	m
Length of purlin =	34.02	m
Spacing of Rafter =	1.00	m
Width of Rafter =	0.080	m
Depth of Rafter =	0.14	m
Length of Rafter =	50.24	m
Weight of Purlin =	0.49	KN
Weight of Rafter =	3.24	KN
Weight of CGI Sheet =	7.51	KN
Total Wt of Roof =	11.23	KN
Wt per M2 of Roof =	0.33	KN/m2
Live Load		
Live load Intensity on floor =	3.00	KN/m2
Live load Intensity on Roof =	0.49	KN/m2
Load on Floor Rafter		
Live load =	1.755	KN/m
Dead Load =	1.447	KN/m
Load on roof rafter		
Live load =	0.287	KN/m
Dead Load =	0.193	KN/m
Timber Plank Wall load		
Width of plank =	0.038	m
Height =	2.5	m
Unit weight =	16	KN/m3
Weight =	1.52	KN/m

Seismic Load Calculation:

Seismic load calculation is done as per NBC: 105.

Table : Seismic Load Calculation

Zone Factor	Z	1		
Importance factor	I	1		cl 8.1.7, table 8.1, other structures
Structural performance factor	K	2.5		cl 8.1.8, table 8.2, Reinforced Masonry Building (Taken average of Unreinforced and RCC framed Structure)
Height of the building	h	5.5	m	
Dimension of the building along X	D_x	6.300	m	
Dimension of the building along Y	D_y	5.4	m	
Time period of the building along X	$T_x = 0.09h/\sqrt{D_x}$	0.197	sec	cl 7.3
Time period of the building along Y	$T_y = 0.09h/\sqrt{D_y}$	0.213	sec	cl 7.3
Soil type	Soft type	Type III		cl 8.1.5
Basic seismic coefficient along X	C_x	0.08		cl 8.1.4, fig 8.1
Basic seismic coefficient along Y	C_y	0.08		cl 8.1.4, fig 8.2
Design horizontal seismic coefficient	$C_d = CZIK$	0.2		cl 8.1.1

Wind Load Calculation:

Wind load is calculated as per NBC 104:1994 Wind load and IS 875(Part 3):1987.

Design velocity of Wind (Vb) = 55 m/s

(Considering Upper Part of Nepal, Figure 1.1, NBC 101:1994)

Probability factor (K1) = 1

(For general building and structure with wind speed =55 m/s, Table 1, Clause 5.3.1, IS 875(Part3):1987)

Terrine Category = 1 (Taking most severe)

Building Class = A (Lateral Dimension less than 20m)

For Building Class A and terrine category 1, Height is smaller than 10m)

Terrine, height and structure size factor (K2) =1.05

Assuming Slope angle = 20^0

C= 0.36 (Slope angle = $20^0 > 17^{0)}$

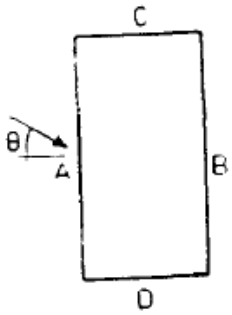
S= 1 (Most Severe Case)

Topography Factor (K3) = 1+CS =1+0.36*1 =1.36

Base on the building Dimension following coefficient is calculated

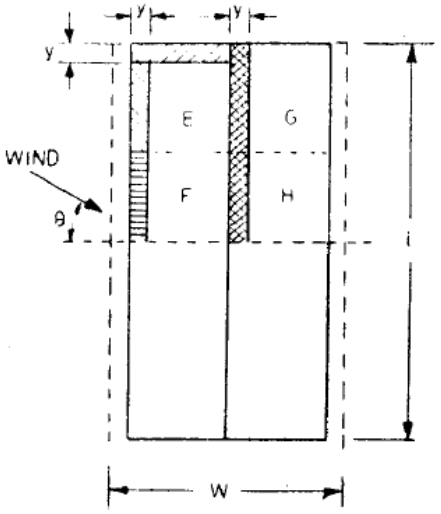
Load on Wall/Cladding of the building

Wall	Angle of wind =0^0			Angle of Wind =90^0		
	Cpe	Cpi	Cp	Cpe	Cpi	Cp
A	0.7	0.5	1.2	-0.6	-0.5	-1.1
B	-0.25	-0.5	-0.75	-0.6	-0.5	-1.1
C	-0.6	-0.5	-1.1	0.7	0.5	1.2
D	-0.6	-0.5	-1.1	-0.25	-0.5	-0.75



Load on Pitched Roof (Roof angle = 23^0)

Portion	Angle of wind =0^0			Angle of Wind =90^0		
	Cpe	Cpi	Cp	Cpe	Cpi	Cp
Wind Ward	-0.55	-0.5	-0.45	-0.8	-0.5	-1.3
Leeward	-0.5	-0.5	-1	-0.65	-0.5	-1.15



DETAILED STRUCTURAL ANALYSIS

•Finite Element Modeling of the building of Supreme is done by using the structural analysis and design software program SAP 2000vs19. For the analysis of the system, whole building is modelled. Load bearing stone masonry walls modelled as single layered shell elements. Timber member of roof and floor is modeled as the line element with 4 degree of freedom in each node ie. Pinned joint.

Nepal National Building Code NBC 105:1994 is used for the seismic load calculations and IS 875(part 3):1987 and NBC 104:1994 is used for the wind load calculation. 3D view of the analytical model is shown in Figure.

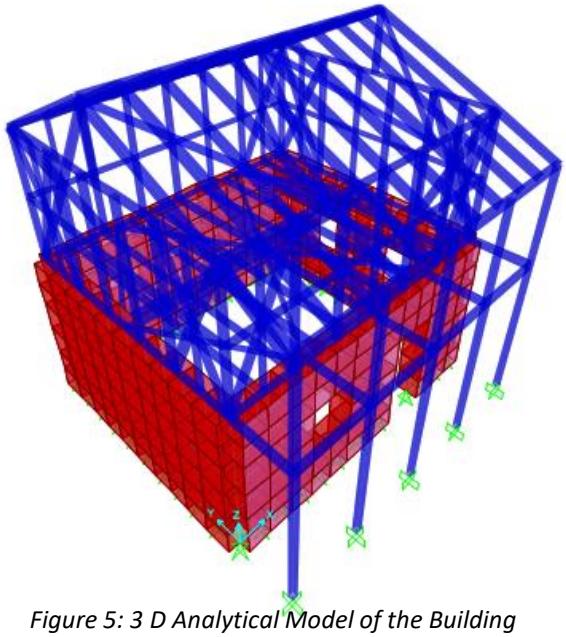


Figure 5: 3 D Analytical Model of the Building

SEISMIC ANALYSIS

The seismic analysis is a part of the detailed evaluation of an existing building. The steps involve in developing a computational model of the building include applying the external forces, calculating the internal forces in the members of the building, identifying deformations and capacity of the members and building, and finally interpreting the results. The structural analysis is carried out with the help of the available drawings and SAP 2000 vs 19. Seismic coefficient method is used to analyze the building.

Calculation of Base Shear

Base Shear in the building

Load Pattern	Type	Direction	C	Weight Used (KN)	Base Shear (KN)
EQX	Seismic	X	0.2	612.789	122.558
EQY	Seismic	Y	0.2	612.789	122.558

Load Combination for analysis of the building

Load Considered for the analysis:

- Dead Load (DL)
- Live Load (LL)
- Earthquake Load (EQ)

Load Combination: For Working Stress method As per NBC 105:

- DL+LL
- 0.7DL+EQx
- 0.7DL-EQx
- 0.7DL+EQy
- 0.7DL-EQy
- DL+LL+EQx
- DL+LL-EQx
- DL+LL+EQy
- DL+LL-Eqy

Check for Deflection

Deflection check is done as per the requirement of NBC 105 Clause 9. The design lateral deformations is taken as the deformations resulting from the application of the design force, multiplied by the factor 5/K. As per NBC 105 Clause 9.3 .The ratio of the inter-story deflection to the corresponding story height shall not exceed 0.010 nor shall the inter-story deflection exceed 60 mm. Detail check pf deflection is shown in table below.

Check For deflection for Load Case EQX

Story	Maximum Deflection	Story height	Structural Performance Factor	Design Lateral Deflection	Interstory Drift	Interstory Drift Ratio	Permissible interstory Drift Ratio	Status
	(D)mm	(h) mm	(K)	(D*5/K) mm	mm			
1	3.85	3000	2.5	7.7	7.7	0.0025	0.01	OK
2	7.19	2500	2.5	14.38	6.68	0.0027	0.01	OK

Check For deflection for Load Case EQY

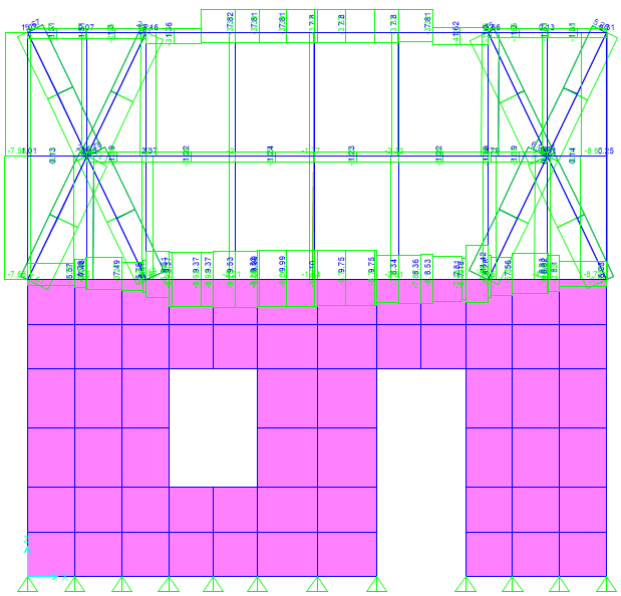
Story	Maximum Deflection	Story height	Structural Performance Factor	Design Lateral Deflection	Interstory Drift	Interstory Drift Ratio	Permissible interstory Drift Ratio	Status
	(D)mm	(h) mm	(K)	(D*5/K) mm	mm			
1	4.59	3000	2.5	9.18	9.18	0.0031	0.01	OK
2	8.2	2500	2.5	16.4	7.22	0.0029	0.01	OK

Modeling output for existing building

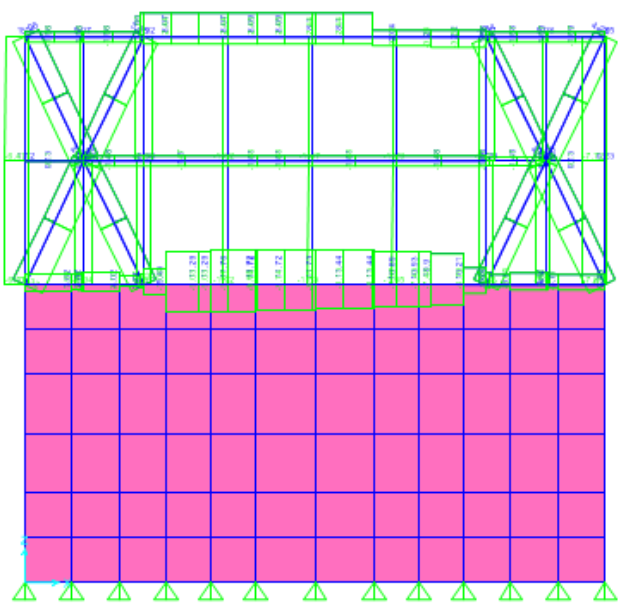
(Mention that the masonry building has been checked for stresses and found to be safe. Details of analysis and design is shown only for the upper story timber structure)

Initially, building is modeled and axial forces for different load combination is studied. The axial force develop for envelope combination is shown below.

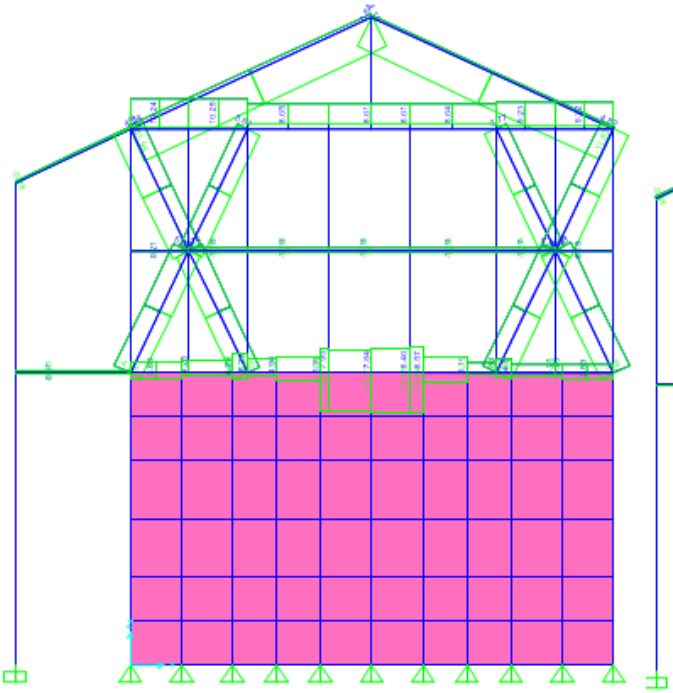
Axial Forces



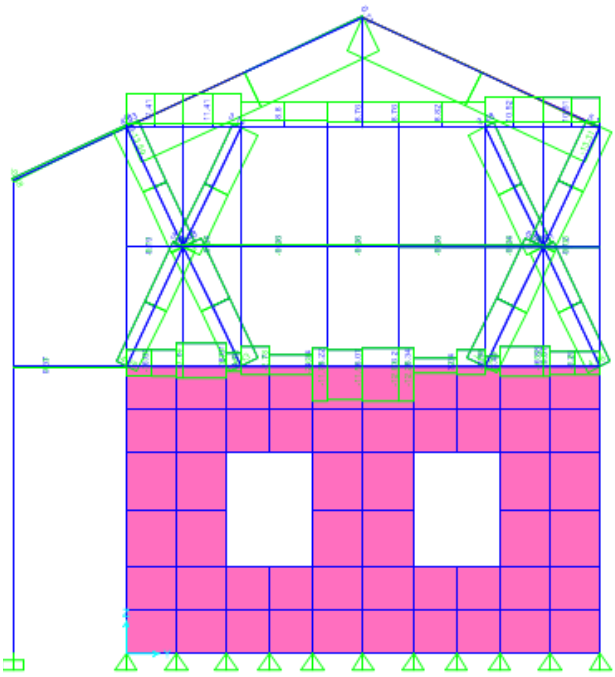
Envelope Axial Force (X-direction: Grid 1-1)



Envelope Axial Force (X-direction: Grid 2-2)



Envelope Axial Force (Y-direction: Grid A-A)



Envelope Axial Force (Y-direction-B-B)

WIND LOAD ANALYSIS

Wind load analysis is done as per IS 875(part 3) :1987 and NBC 104 :1994 .The steps involve in developing a computational model of the building include applying the external forces, calculating the internal forces in the members of the building, identifying deformations and capacity of the members and building, and finally interpreting the results. The structural analysis is carried out with the help of the available drawings and SAP 2000 vs 19.

1.Calculation of Wind load

2.Joint Reaction at the base of timber floor.

3.Load Combination for analysis of the building

4.Load Considered for the analysis:

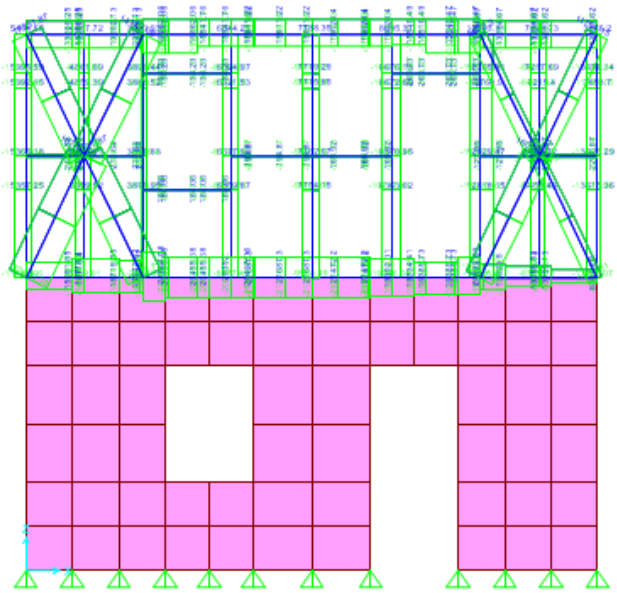
- Dead Load (DL)
- Live Load (LL)
- Earthquake Load (W)

Load Combination: For Working Stress method As per NBC 105:

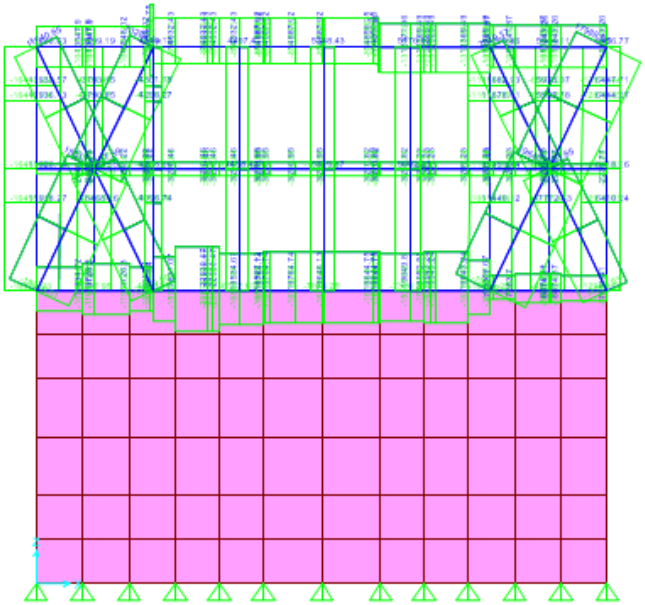
- DL+LL
- 0.7DL+W0
- 0.7DL+W0-
- 0.7DL-W0
- 0.7DL-W0-
- 0.7DL+W90
- 0.7DL+W90-
- 0.7DL-W90
- 0.7DL-W90-
- DL+LL+W0
- DL+LL+W0-
- DL+LL-W0
- DL+LL-W0-
- DL+LL+W90
- DL+LL+W90-
- DL+LL-W90
- DL+LL-W90-

Modeling output for existing building

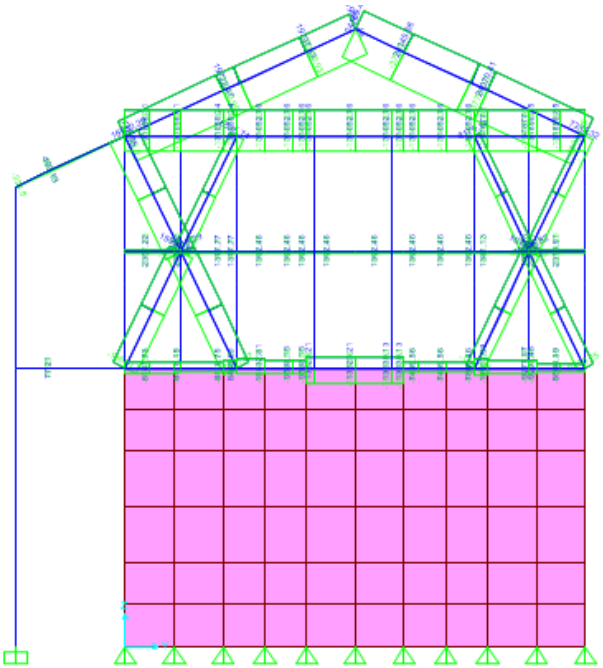
Initially, building is modeled and axial forces for different load combination is studied. The axial force develop for envelope combination is shown below.



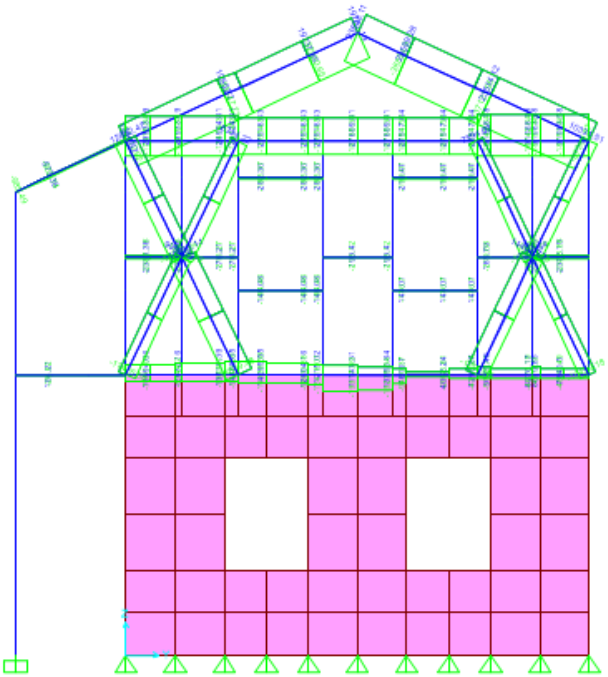
Envelope Axial Force (X-direction: Grid 1-1)



Envelope Axial Force (X-direction: Grid 2-2)



Envelope Axial Force (Y-direction: Grid A-A)



Envelope Axial Force (Y-direction-B-B)

1. Design of structure:

Timber members are mainly designed for the axial force induced due to envelope load combination of earthquake and wind load. Design force is taken from the maximum force due to earthquake and wind load. Working stress method is used for the design of timber element. Design force for different member is listed below

Member	Earthquake Load		Wind load		Design Force	
	Tension	Compression	Tension	Compression	Tension	Compression
	KN	KN	KN	KN	KN	KN
Bracing	6.94	7.14	19.64	23.42	19.64	23.42
Vertical Post	4.54	8.68	12.74	16.46	12.74	16.46
Wall Plate	11.72	13.11	31.05	21.3	31.05	21.3
Rafter	1.01	13.17	24.13	37.56	24.13	37.56
H. batten	1.51	2.06	3.21	3.51	3.21	3.51
Verandah Post	0	7.51	2.51	11.08	2.51	11.08

Design of Bracing

Induced tensile force =	19.64	KN	
Induced Compressive force =	23.42	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 50 X 115 mm Size of Bracing element			
Length of Member (L)=	1.3	m	
Width of Member (B) =	0.05	m	
Depth of Member (D) =	0.115	m	
Length / Width ratio (L/B) =	26		(<50 OK)
Sectional area of Bracing (A) =	0.0058	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	39.675	KN	>19.64 OK
Check for compression			
K8 = Constant = 0.702 E /fc =	12.37		
Since L/B ration is greater than K8 , Design as long Column			
Permissible Compression Stress, fc = $0.329*E/(L/d)^2$ =	4.57	Mpa	
Compression Capacity = A* fc=	26.31	KN	>23.42 OK

Design of Vertical Post

Induced tensile force =	12.74	KN	
Induced Compressive force =	16.46	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 75 X 75 mm Size of Vertical post element			
Length of Member (L)=	2.4	m	(Leff =2.4)
Width of Member (B) =	0.075	m	
Depth of Member (D) =	0.075	m	
Length / Width ratio (L/B) =	32		(<50 OK)
Sectional area of Bracing (A) =	0.0056	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	38.8125	KN	>12.74 OK
Check for compression			
K8 = Constant = 0.702 E / fc =	12.37		
Since L/B ration is greater than K8 , Design as long Column			
Permissible Compression Stress, fc = $0.329*E/(L/d)^2$ =	3.02	Mpa	
Compression Capacity = A* fc=	16.99	KN	>16.46 OK

Design of Rafter

Induced tensile force =	24.13	KN	
Induced Compressive force =	37.56	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 80 X 140 mm Size of Rafter element			
Length of Member (L)=	2.4	m	(Leff =2.4)
Width of Member (B) =	0.08	m	
Depth of Member (D) =	0.14	m	
Length / Width ratio (L/B) =	30		(<50 OK)
Sectional area of Bracing (A) =	0.0112	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	77.28	KN	>24.13 OK
Check for compression			
K8 = Constant = 0.702 E / fc =	12.37		
Since L/B ration is greater than K8 , Design as long Column			
Permissible Compression Stress fc = $0.329*E/(L/d)^2$ =	3.44	Mpa	
Compression Capacity = A* fc=	38.49	KN	>37.56 OK

Design of Wall Plate:

Induced tensile force =	31.05	KN	
Induced Compressive force =	21.3	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 75 X 100 mm Size of Wall plate element			
Length of Member (L)=	0.5	m	(Leff =2.4)
Width of Member (B) =	0.075	m	
Depth of Member (D) =	0.1	m	
Length / Width ratio (L/B) =	6.66667		(<50 OK)
Sectional area of Bracing (A) =	0.0075	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	51.75	KN	>31.05 OK
Check for compression			
K8 = Constant = 0.702 E / fc =	12.37		
Since L/B ratio is Smaller than K8 and 11 , Design as Short Column			
Permissible Compression Stress fc = $0.329*E/(L/d)^2$ =	5.50	Mpa	
Compression Capacity = A* fc=	41.25	KN	>21.3 OK

Design of Horizontal Batten:

Induced tensile force =	3.21	KN	
Induced Compressive force =	3.51	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 25 X 75 mm Size of Batten element			
Length of Member (L)=	0.975	m	(Leff =2.4)
Width of Member (B) =	0.025	m	
Depth of Member (D) =	0.075	m	
Length / Width ratio (L/B) =	39		(<50 OK)
Sectional area of Bracing (A) =	0.0019	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	12.9375	KN	>3.21 OK
Check for compression			
K8 = Constant = 0.702 E / fc =	12.37		
Since L/B ration is greater than K8 , Design as long Column			
Permissible Compression Stress = $0.329*E/(L/d)^2$ =	2.03	Mpa	
Compression Capacity = A* fc=	3.81	KN	>3.51 OK

Design of Verandah Post:

Induced tensile force =	2.51	KN	
Induced Compressive force =	11.08	KN	
Modulus of elasticity E =	9400	Mpa	
Allowable tensile strength (ft)=	6.9	Mpa	
Allowable Compressive Strength (fc)=	5.5	Mpa	
Allowable Shear Strength (fs)=	0.6	Mpa	
Use 100 X 100 mm Size of Verandah post element			
Length of Member (L)=	3	m	(Leff =2.4)
Width of Member (B) =	0.1	m	
Depth of Member (D) =	0.1	m	
Length / Width ratio (L/B) =	30		(<50 OK)
Sectional area of Bracing (A) =	0.0100	m2	
Check for tension			
Tensile Capacity of Member = A* ft =	69	KN	>2.51 OK
Check for compression			
K8 = Constant = 0.702 E / fc =	12.37		
Since L/B ration is greater than K8 , Design as long Column			
Permissible Compression Stress = $0.329*E/(L/d)^2$ =	3.44	Mpa	
Compression Capacity = A* fc=	34.36	KN	>11.08 OK

Design of Connection

Connection of Post and Wall Plate

Tensile Force on the post =	12.74	KN	
Compression Force on the post =	14.46	KN	
Yield Strength of Steel plate (fy)=	250	Mpa	
Strength of Plate in tearing (ft)=	150	Mpa	
Shear Strength of bolt (tb) =	100	Mpa	
Use 12 mm dia bolt			
Diameter of the Bolt (d) =	12	mm	
Shear Area of Bolt in Single Shear =	113.1	mm2	
Capacity of one bolt in Single Shear =	11.31	KN	
	1.1264		
Number of Bolt required =	6		
Use 2-12 mm Bolt			
Check for tearing of Plate			
Thickness of plate =	4	mm	
Effective length (l-n*d0) =	126	mm	
			>12.74O
Tearing Capacity =	75.6	KN	K

Connection of Bracing, Post and Wall plate

Tensile force of the post =	12.74	KN	
Compression Force on the post =	16.76	KN	
Tensile force on the Bracing =	19.64	KN	
Angle of Bracing =	64	deg	
Compression force on the Bracing =	23.42	KN	
Net vertical Force in Connection =	37.81	KN	
Net Horizontal Force in Connection =	8.61	KN	
Yield Strength of Steel plate (fy)=	250	Mpa	
Strength of Plate in tearing (ft)=	150	Mpa	
Shear Strength of bolt (tb) =	100	Mpa	
Use 12 mm dia bolt			
Diameter of the Bolt (d) =	12	mm	
Shear Area of Bolt in Single Shear =	113.1	mm2	
Capacity of one bolt in Single Shear =	11.31	KN	
	1.7365		
Number of Bolt required in Bracing =	6	Nos	
	1.1264		
Number of Bolt required in Post =	6	Nos	
	3.3431		
Number of Bolt in wall Plate =	2	nos	
Use 2-12 mm dia @ bracing and post and 4-12 mm dia bolt in Wall plate			
Check for tearing of Plate			
Thickness of plate =	4	mm	
Effective length (l-n*d0) =	76	mm	
Tearing Capacity =	45.6	KN	>37.87 OK

Connection of Rafter and Wall plate

Tensile Force on the Rafter =	24.13	KN	
Compression Force on the Rafter =	37.56	KN	
Yield Strength of Steel plate (fy)=	250	Mpa	
Strength of Plate in tearing (ft)=	150	Mpa	
Shear Strength of bolt (tb) =	100	Mpa	
Use 12 mm dia bolt			
Diameter of the Bolt (d) =	12	mm	
Shear Area of Bolt in double Shear =	226.2	mm2	
Capacity of one bolt in double Shear =	22.62	KN	
Number of Bolt required =	1.06678		
Use 1-12 mm Bolt			
Check for tearing of Plate			
Thickness of plate =	4	mm	
Effective length (l-n*d0) =	48	mm	
Tearing Capacity =	28.8	KN	>24.13OK

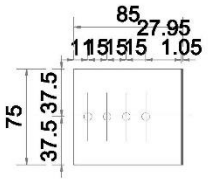
Connection of Horizontal Batten and post

Tensile Force on the post =	3.21	KN	
Compression Force on the post =	3.51	KN	
Yield Strength of Steel plate (fy)=	250	Mpa	
Strength of Plate in tearing (ft)=	150	Mpa	
Shear Strength of bolt (tb) =	100	Mpa	
Use 12 mm dia bolt			
Diameter of the Bolt (d) =	12	mm	
Shear Area of Bolt in Single Shear =	113.1	mm2	
Capacity of one bolt in Single Shear =	11.31	KN	
	0.2838		
Number of Bolt required =	3		
Use 1-12 mm Bolt			
Check for tearing of Plate			
Thickness of plate =	4	mm	
Effective length (l-n*d0) =	63	mm	
Tearing Capacity =	37.8	KN	>3.21OK

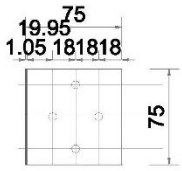
Connection of Wall plate and Masonry wall

Maximum Uplift force on Wind =	141.906	KN	
At least 4 vertical post will be there and 8 nail at each vertical			
Number of Nails =	32		
Diameter of Nail =	3.55	mm	
Shear Strength =	100	Mpa	
Shear Area of each nail =	9.90	mm2	
Shear Capacity of each nail =	0.99	KN	
Total Capacity =	31.7	KN	
Residual Uplift Force =	110.23	KN	
Use Gabion wire , of 3.25 mm dia			
Diameter of gabion =	3.25	mm	
Section Area of gabion wire =	16.59	mm2	
Tensile Strength of the Gabion =	140	Mpa	
Capacity at Each level =	2.323	KN	
Number of Gabion Required =	47.46	Nos	
Total Length of Wall =	21.6	m	
Spacing required for Gabion =	455.2	mm	

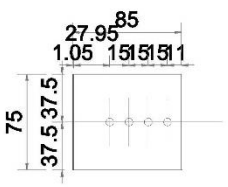
Provide gabion of 3.25 mm (10 Gauge) at the spacing of 450 mm C/C throughout the wall



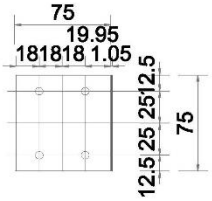
VIEW -1A



VIEW -2A

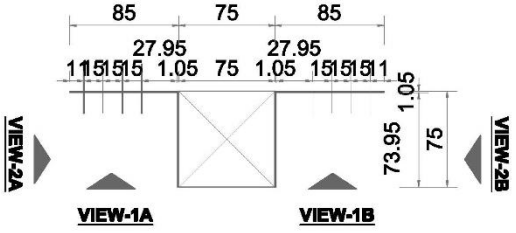


VIEW -1B



VIEW -2B

VIEWS FROM DIFFERENT SIDES

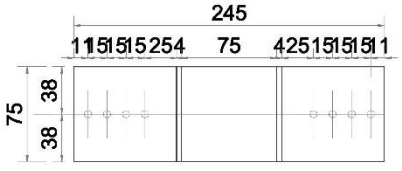


PLAN VIEW

CGI SHEET DETAIL

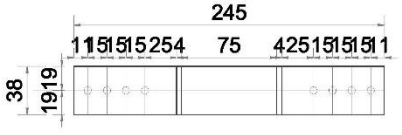
(ALTERNATE OPTION FOR METAL STRIP)

SCALE = 1:5



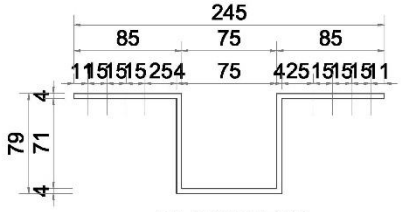
FRONT VIEW -1

(TO BE USED FOR FLOOR AND ROOF BANDAGE)



FRONT VIEW-2

(TO BE USED FOR SILL/LINTEL BANDAGE AND CORNER STITCH)



PLAN VIEW

METAL STRIP DETAIL

SCALE = 1:5

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