# 03

# Design Information

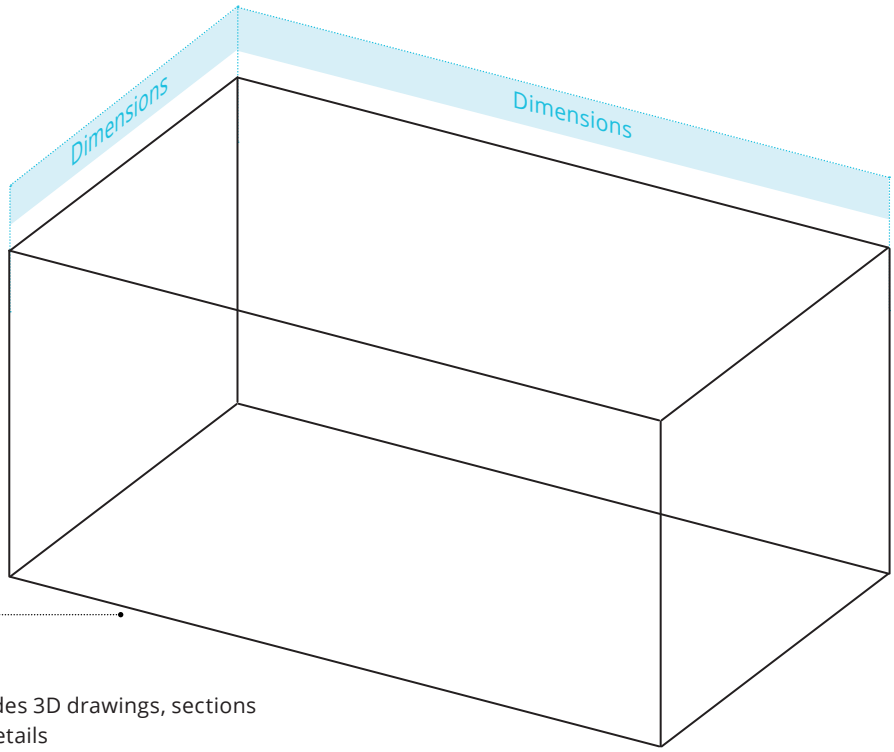
This chapter contains the complete one room shelter designs based on existing local practice and supplemented with the findings of this research project. This information is grouped by outline design components (five foundation types, five wall types, and three roof types) and detailed design variations (ring beams, windows and doors, platforms and plinths). For the interested user, further information is available in chapter four. Due to the relative simplicity of one room shelters, the information provided in this chapter should be sufficient to use for construction. The key design considerations, geometry, materials specification, and construction details are provided to support quality workmanship and assurance on site.

Component type - eg foundation, wall, roof

# Material - eg stabilised blocks, timber

**How to read the design information chapter**

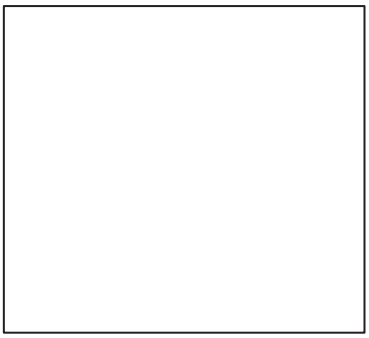
**3D view**




Each design includes 3D drawings, sections and connection details

Annotations are provided on the drawings to label the materials, explain the design features and advise on how to construct the shelter

**3D details**



**3D details**

**SEISMIC CONSIDERATION**
Sindh is a region of moderate to high seismicity. Whilst seismic design outside of the scope of this guide these additional measures would serve to improve seismic performance of the shelter.

**Performance variation**
It may be desirable to change an aspect of the design. The impact on performance (e.g. cost) is highlighted here.

**Maintenance**
Maintenance considerations are highlighted here

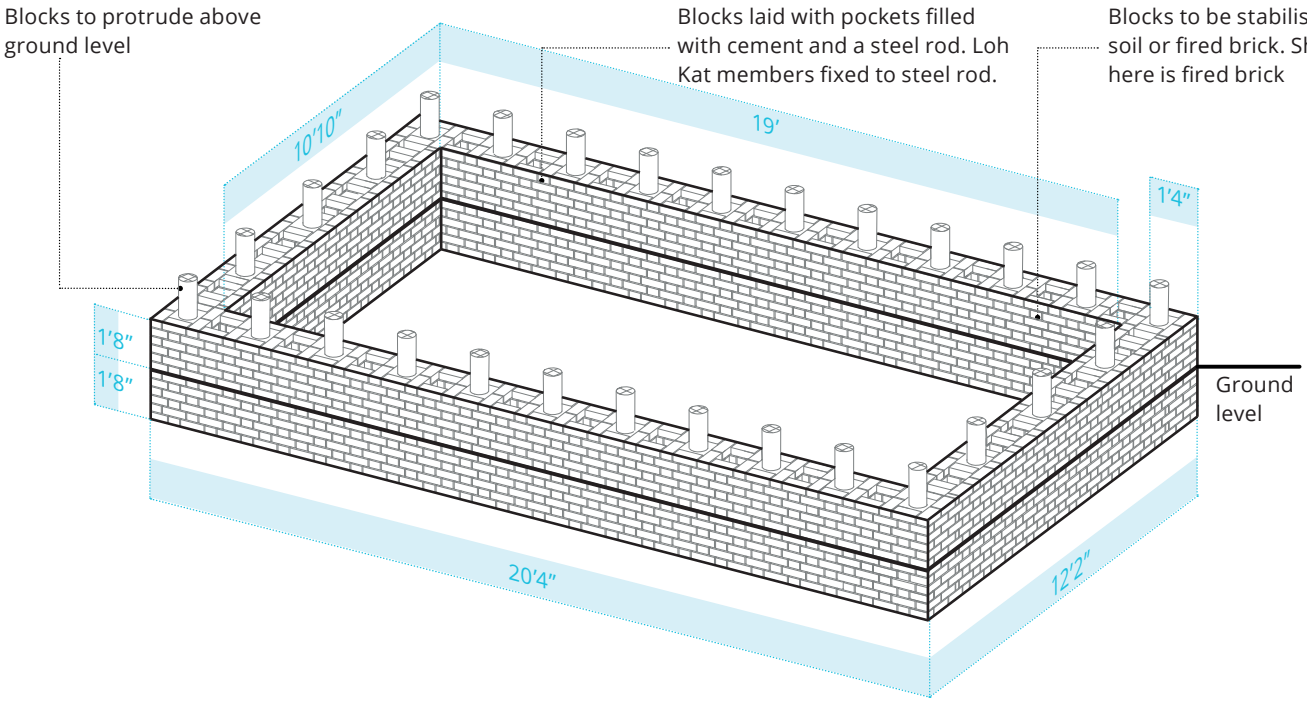
**Health and Safety**
High level site health and safety considerations are provided here

**Specification**
Links to more detailed material specifications in chapter 4 supporting information are listed here

Foundation

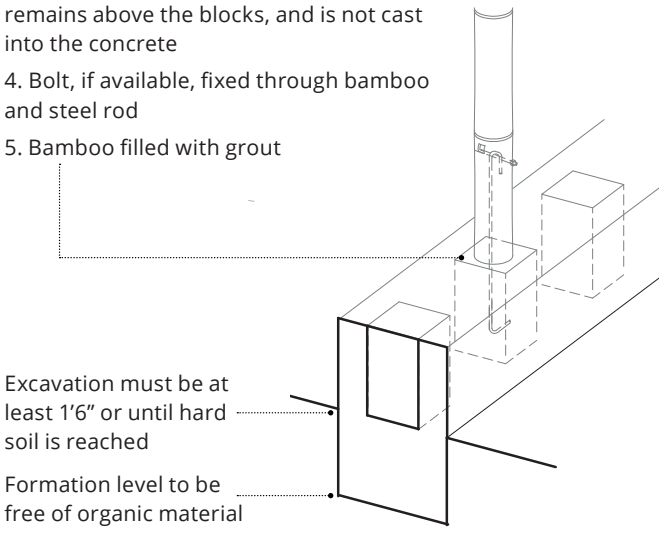
# Loh Kat (improved)

### 3D view



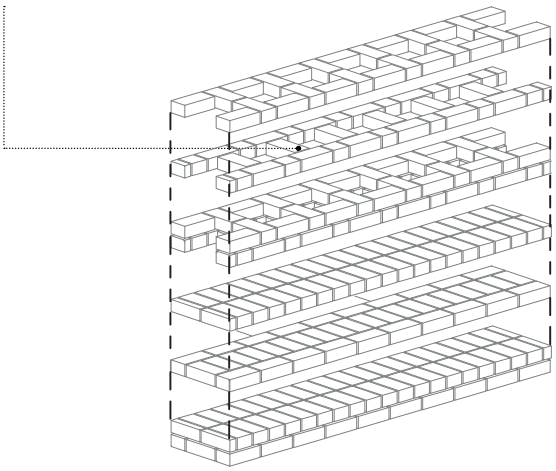

### 3D detail

1. Pockets filled with concrete with cast in steel rod.
2. Grout hole notched into bamboo
3. Bamboo placed over steel rod. Bamboo remains above the blocks, and is not cast into the concrete
4. Bolt, if available, fixed through bamboo and steel rod
5. Bamboo filled with grout




### 3D brick bond detail

Brick bond to allow pockets for filling with concrete and securing loh kat members



**SEISMIC CONSIDERATION**
This foundation is recommended over the 'basic loh kat' foundation for improved seismic performance

**Variation**
Replacing stabilised blocks with burnt bricks will:
+ Buildability
- Sustainability
- Cost

**Maintenance**
Ensure sloped drainage is maintained
Repair render on foundation walls
Repair bricks if damaged

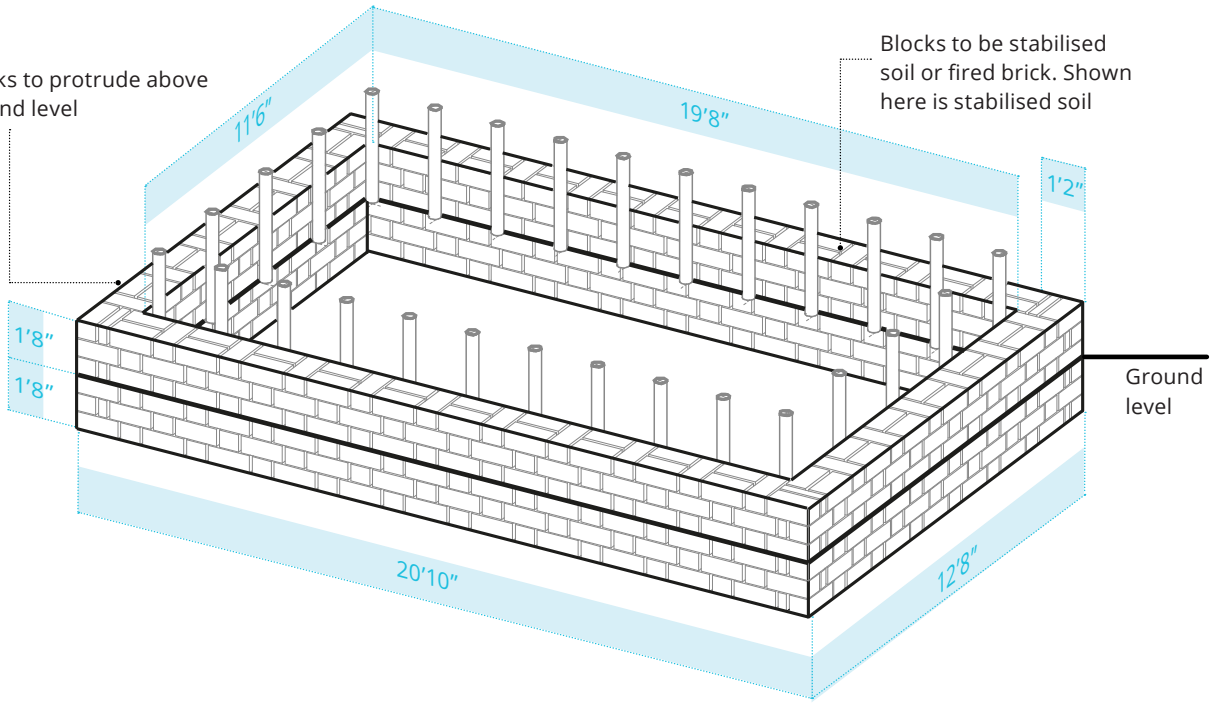
**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.
Blocks are heavy, take care when lifting

**Specification**
Stabilised blocks/Burnt brick
Block laying
Concrete

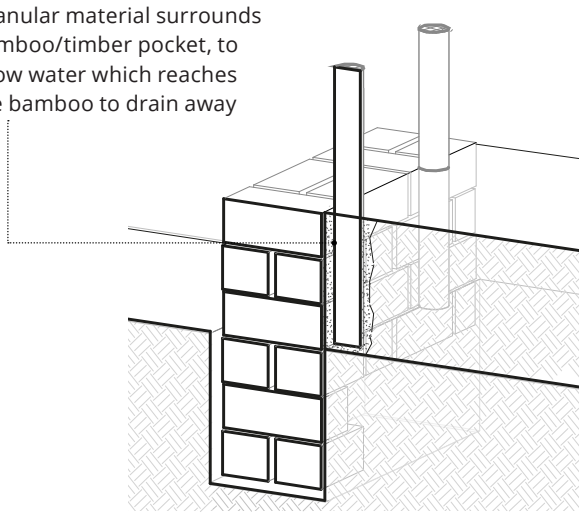
Foundation

# Loh Kat (basic)

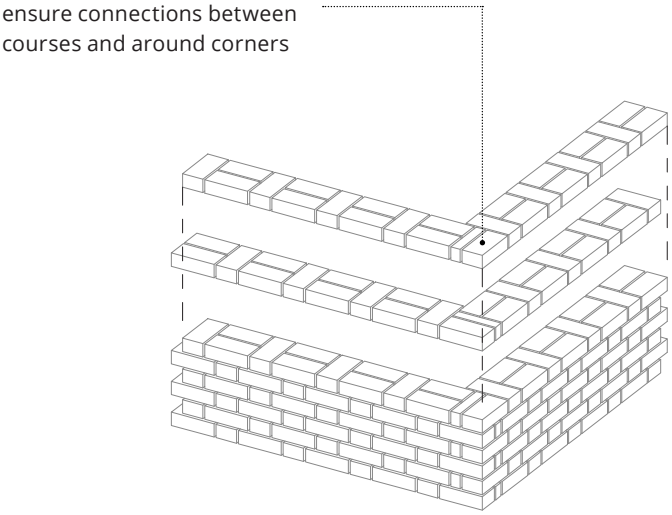
### 3D view




### 3D detail




### 3D brick bond detail




**Variation**
Replacing stabilised blocks with burnt bricks will:
+ Buildability
- Sustainability
- Cost

**Maintenance**
Ensure sloped drainage is maintained
Repair render on foundation walls
Repair bricks if damaged

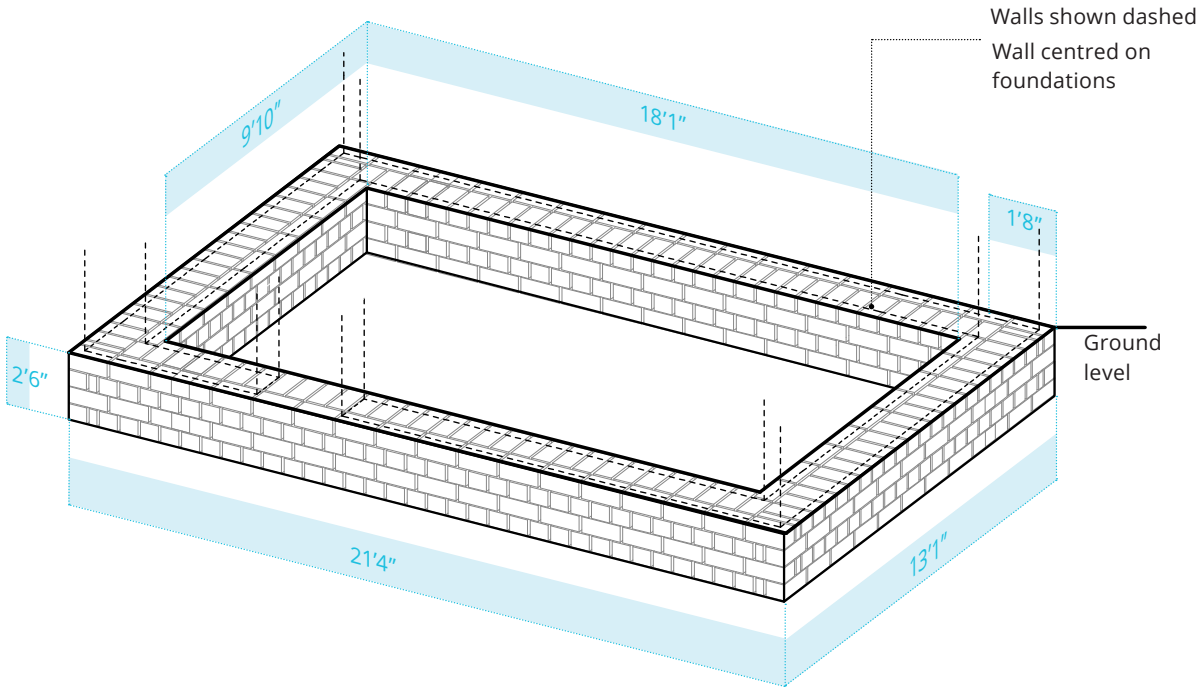
**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.
Blocks are heavy, take care when lifting

**Specification**
Stabilised blocks/Burnt brick
Block laying

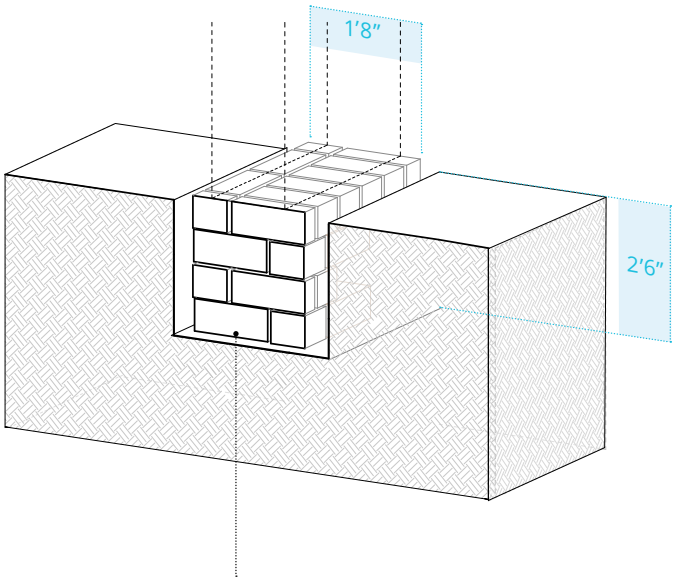
Foundation

# Mud / Adobe

### 3D view



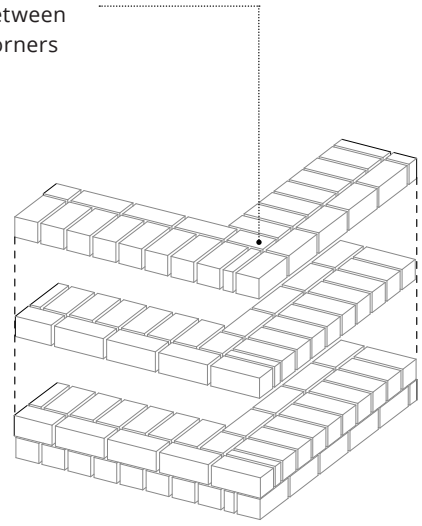

### 3D detail




Excavation must be at least 2'6" or until hard soil is reached Formation level to be free of organic material

### 3D brick bond detail

Brick bonds alternate to ensure connections between courses and around corners



**Variation**
Use of cement for stabilisation:
+ Buildability
- Sustainability
- Cost

**Maintenance**
Ensure sloped drainage is maintained
Repair render on foundation walls
Repair bricks if damaged

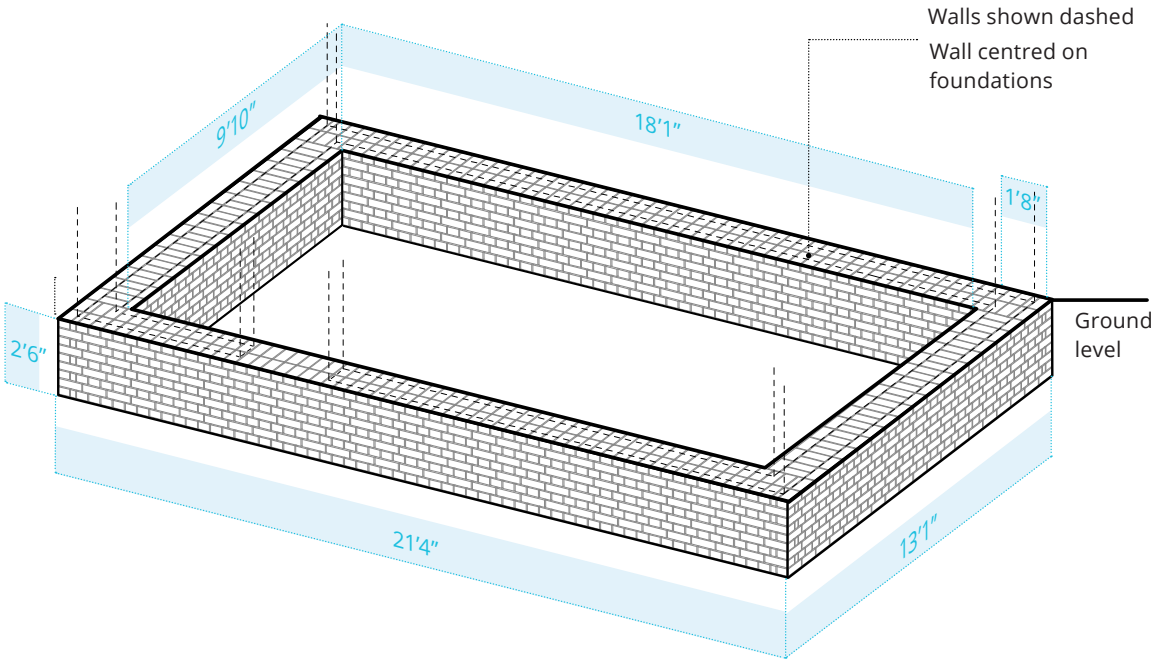
**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.
Blocks are heavy, take care when lifting

**Specification**
Stabilised blocks/earth
Block laying
Damp proof membrane

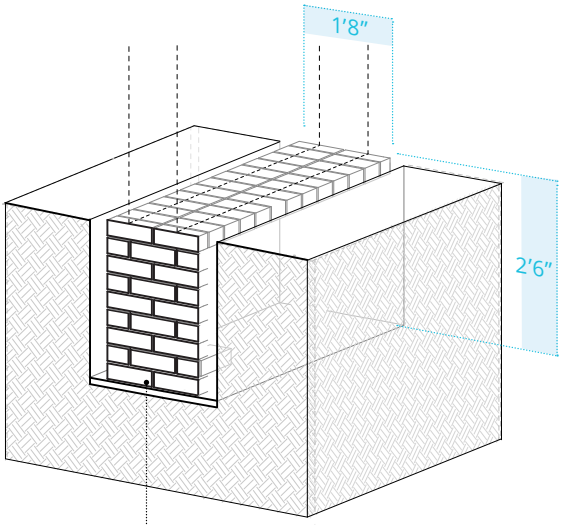
Foundation

# Burnt Brick

### 3D view




### 3D detail

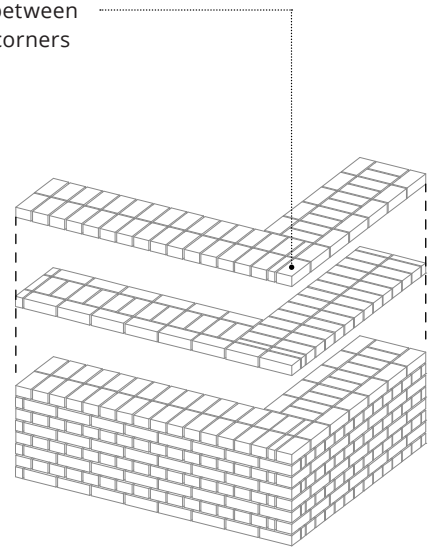



Excavation must be at least 2'6" or until hard soil is reached Formation level to be free of organic material

Concrete blinding at base of excavation

### 3D brick bond detail

Brick bonds alternate to ensure connections between courses and around corners



**Maintenance**
Ensure sloped drainage is maintained
Repair render on foundation walls
Repair bricks if damaged

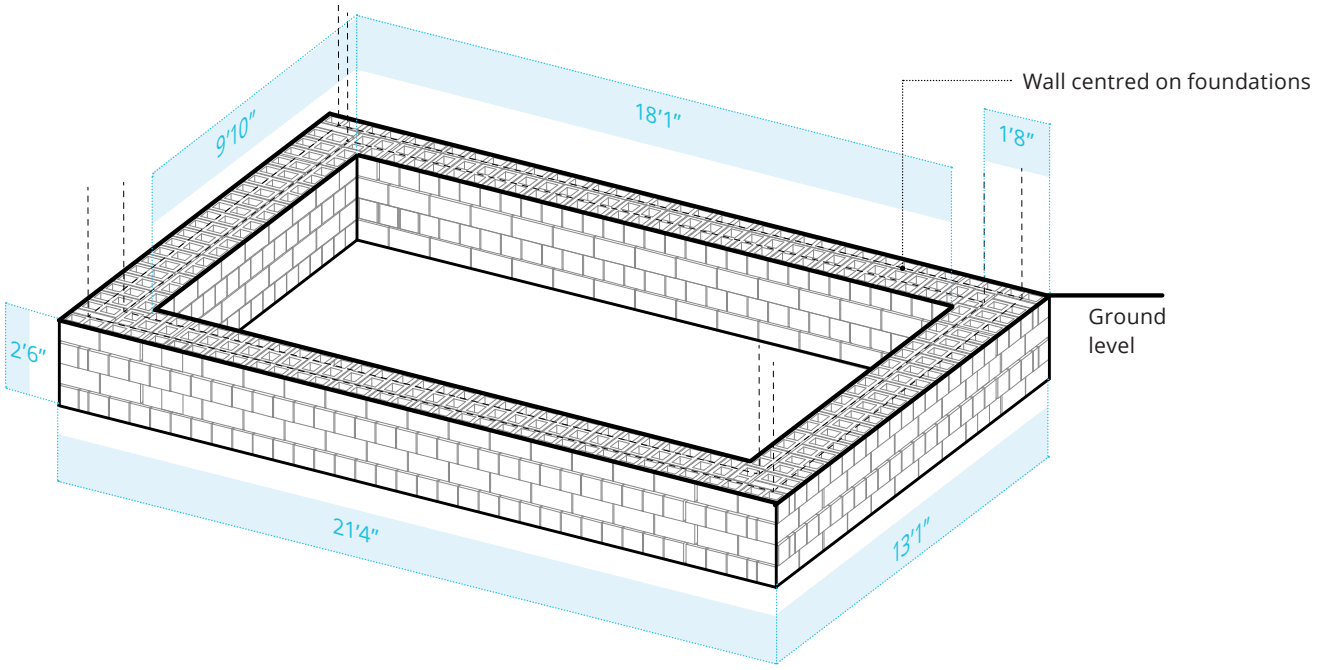
**Health and Safety**
Lime/Cement used in mortar can burn skin. Wear gloves and boots.

**Specification**
Burnt brick
Block laying
Damp proof membrane

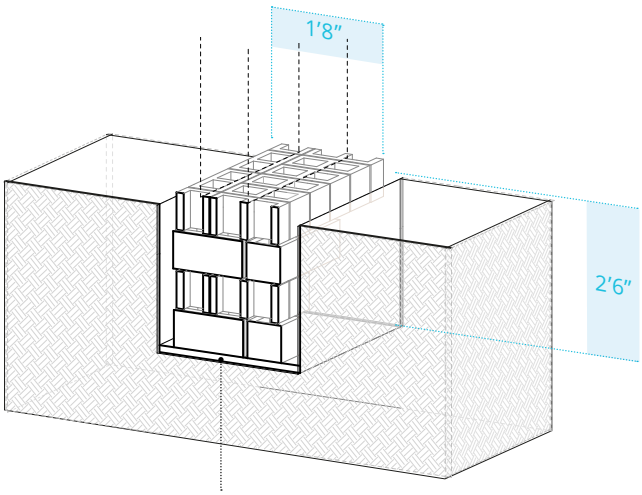
Foundation

# Concrete

### 3D view




### Plan [Not to scale]

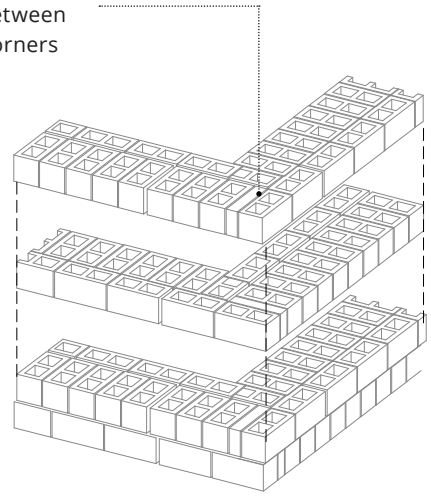



Excavation must be at least 2'6" or until hard soil is reached
Formation level to be free of organic material

Concrete blinding at base of excavation

### 3D brick bond detail

Brick bonds alternate to ensure connections between courses and around corners



**SEISMIC CONSIDERATION**
If walls are to be reinforced for improved seismic performance, it will need to be anchored into the foundations

**Maintenance**
Ensure sloped drainage is maintained
Repair render on foundation walls
Repair bricks if damaged

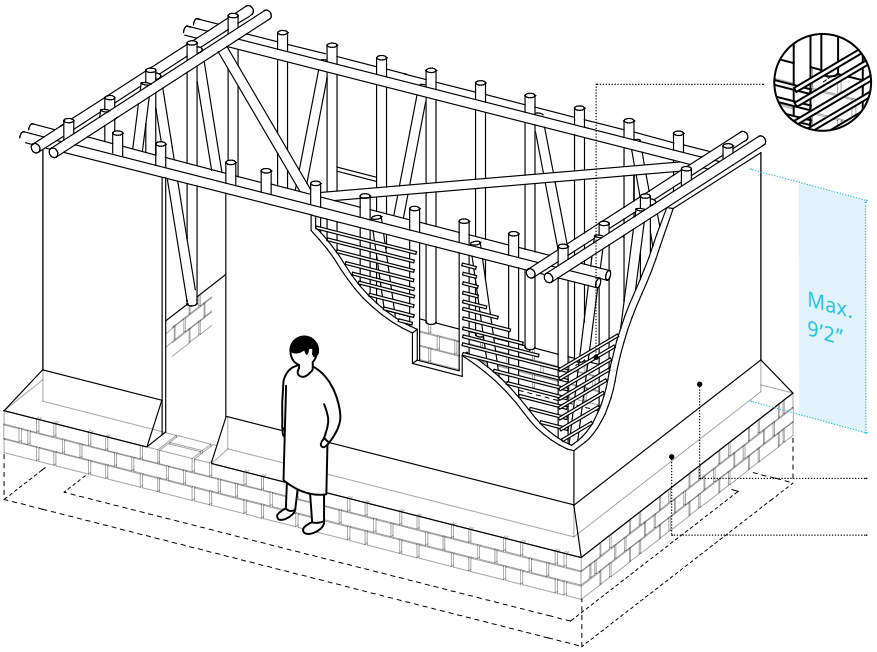
**Health and Safety**
Cement used in blocks and mortar can burn skin. Wear gloves and boots.

**Specification**
Concrete
Block laying
Damp proof membrane

Wall Component

# Loh Kat

### 3D view

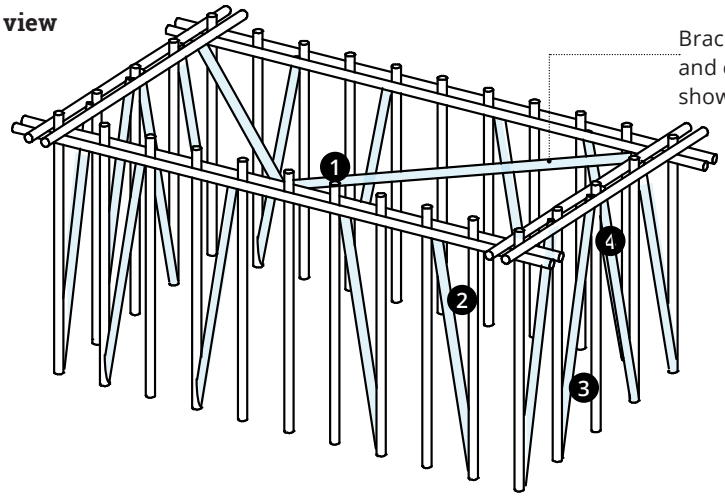



Horizontal members attached to main loh kat frame; split bamboo, cane, small diameter bamboo or timber are all fine. Chicks matting is not ok.

Stabilised render

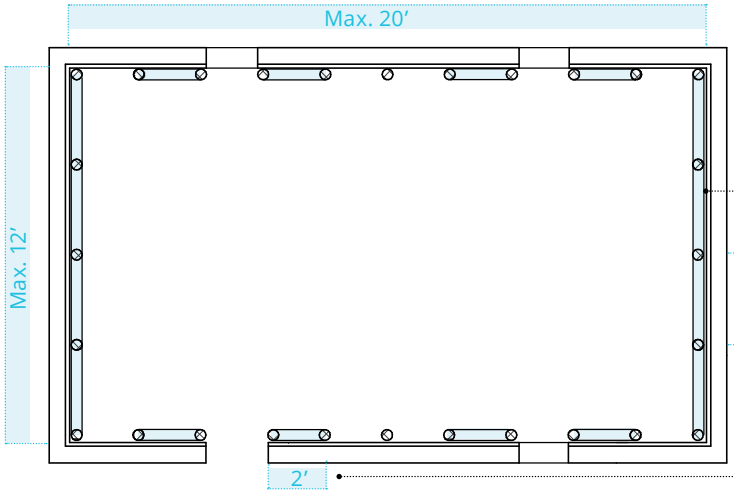
Drainage slope, from stabilised render, at base of wall

### Skeleton 3D view




Bracing on plan and elevation shown in blue

### Plan [Not to scale]

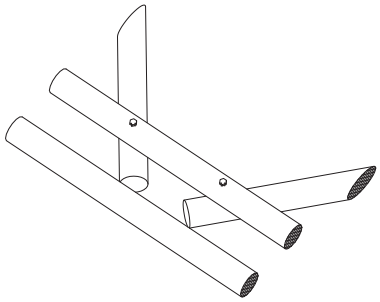



Bracing on elevation shown in blue

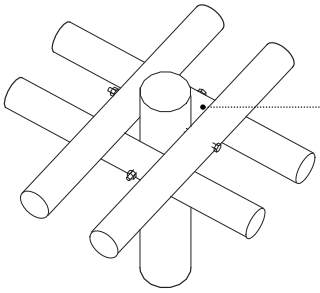
3' spacing of loh kat members on short walls

2' spacing of loh kat members on long walls

**1 3D detail - roof plan bracing connection**

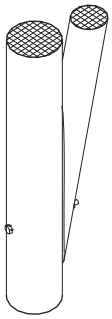


**2 3D detail - Top corner connection**

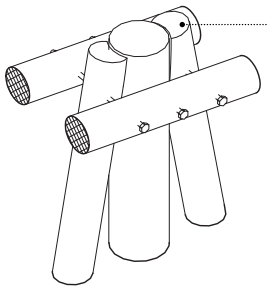


Connections bolted or pegged using pre-drilled holes, or strapped if no bolts/ pegs available

**3 3D detail - Bottom bracing connection on elevation**

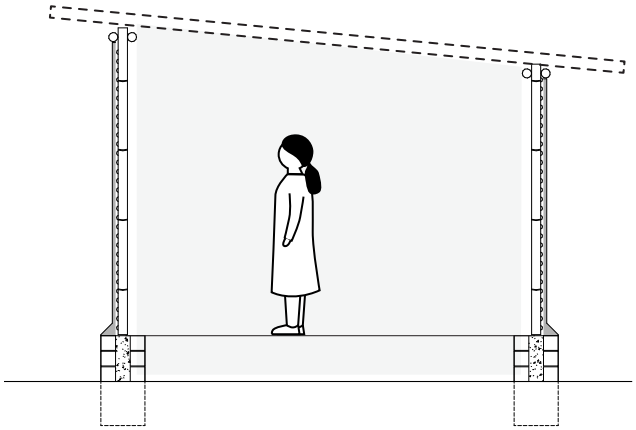


**4 3D detail - Top bracing connection on elevation**

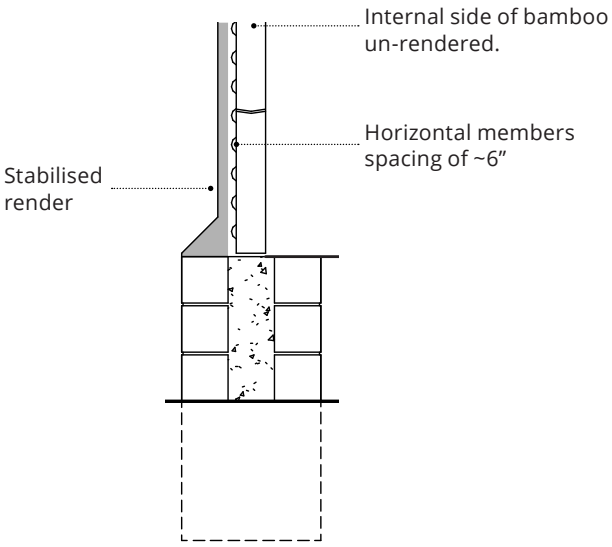


Where possible, extend bamboo further than connection, to provide an 'edge distance' from the connection bolt hole and some resilience against splitting

**Section [not to scale]**



**Detail section [Not to scale]**




**SEISMIC CONSIDERATION**
Lightweight Loh Kat walls will perform well seismically and are preferred to other heavier options in this guide.
- It is recommended to double the amount of roof braces

**Variation**
Replacing lime for cement for stabilisation of render:
+ Buildability
- Sustainability
Replacing bamboo with timber
+ Maintenance

**Maintenance**
Repair render.
Avoid bamboo/timber getting wet.
Remove termite tracks
If bamboo/timber members deteriorate, replace.

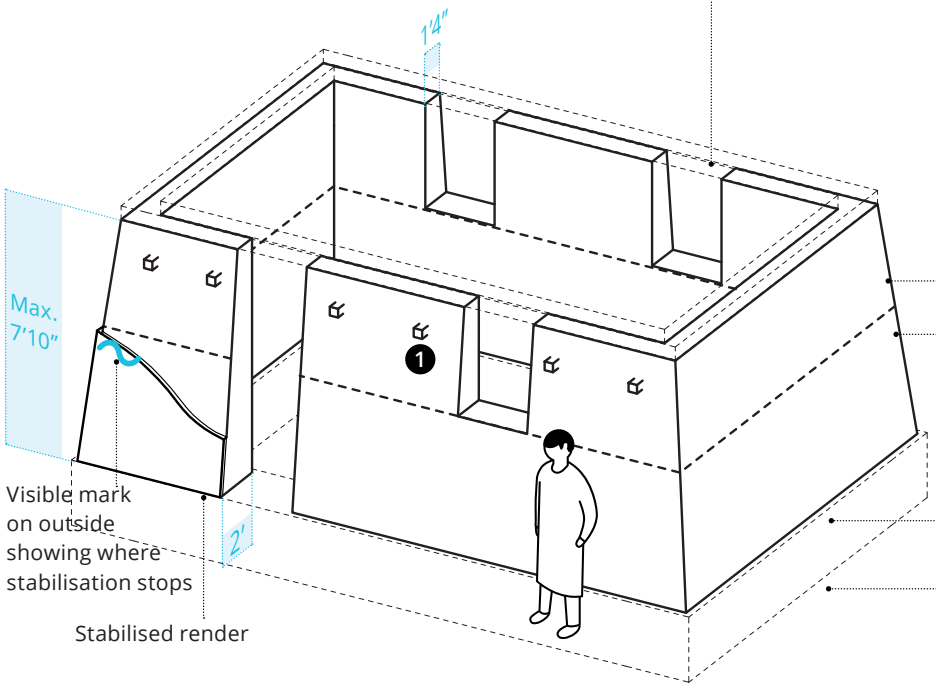
**Health and Safety**
Lime/Cement used in render can burn skin. Wear gloves and boots.

**Specification**
Bamboo/timber
Stabilised render

Wall Component

# Stabilised Layered Mud

**3D view**




Ring beam and foundation shown dashed

Window and door opening extend to the top of the wall. The ring beam acts as a lintel

Timber, bamboo or RC rings beams are compatible with layered mud walls.

Unstabilised earth

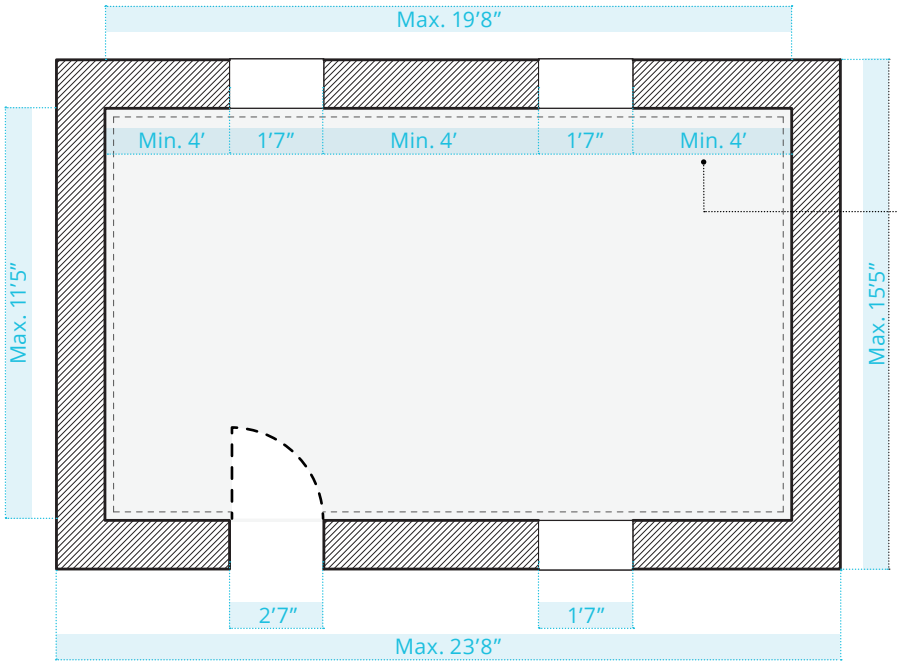
Stabilised earth

Level of stabilisation should be informed by potential future flooding level.

Damp proof membrane between foundation and wall

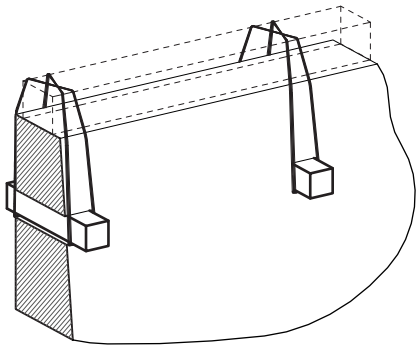
Adobe or burnt brick foundations are compatible with layered mud walls.

**Plan [Not to scale]**

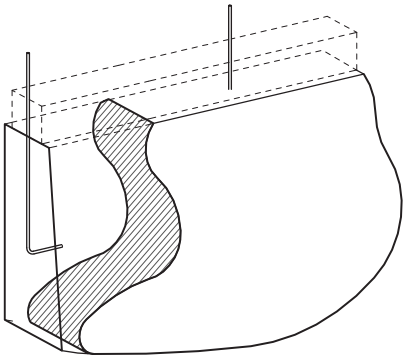



Opening locations can vary providing the distance from two openings or the corner of the wall is a minimum of 4'

1

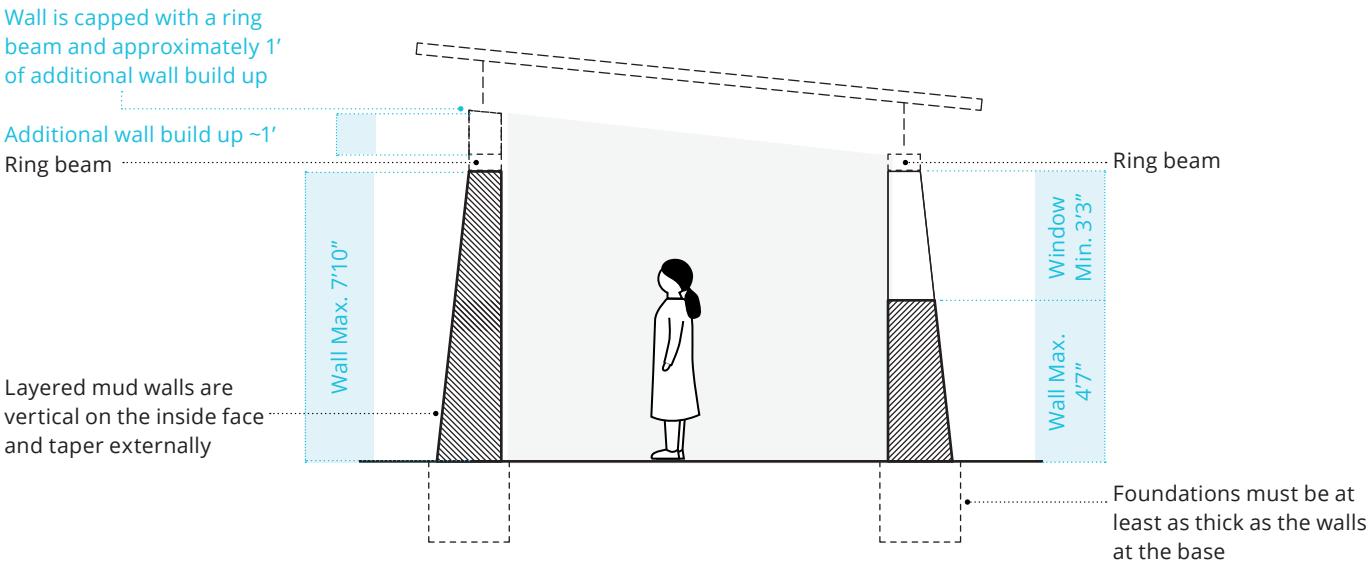


Ⓐ **Tie Connection**
A wooden peg is cast into the wall and wire used to secure the ring beam. This option is easier to build and appropriate for timber and bamboo ring beams.



Ⓑ **Bolt Connection**
A steel rod is cast into the wall and a bolt is used to secure the ring beam. This option is appropriate for timber and RC ring beams.

## Section [not to scale]




**SEISMIC CONSIDERATION**
Layered mud walls are heavy and will perform poorly in an earthquake, therefore avoiding layered mud as a construction method is recommended, though a combination of the following measures will improve seismic performance:

- Use piers at the corners and in the middle of the long wall.
- Use the bolted connection.
- Use a seismically improved timber or bamboo ring beam (see Design Information, Ring Beam)

**Variation**
Replacing lime with Cement for stabilisation:
+ Buildability
- Sustainability
Replacing tie with bolt connection:
+Stability
-Buildability

**Maintenance**
Repair render if damaged.
Replace wire/rope in tied connection if damaged/rusted.

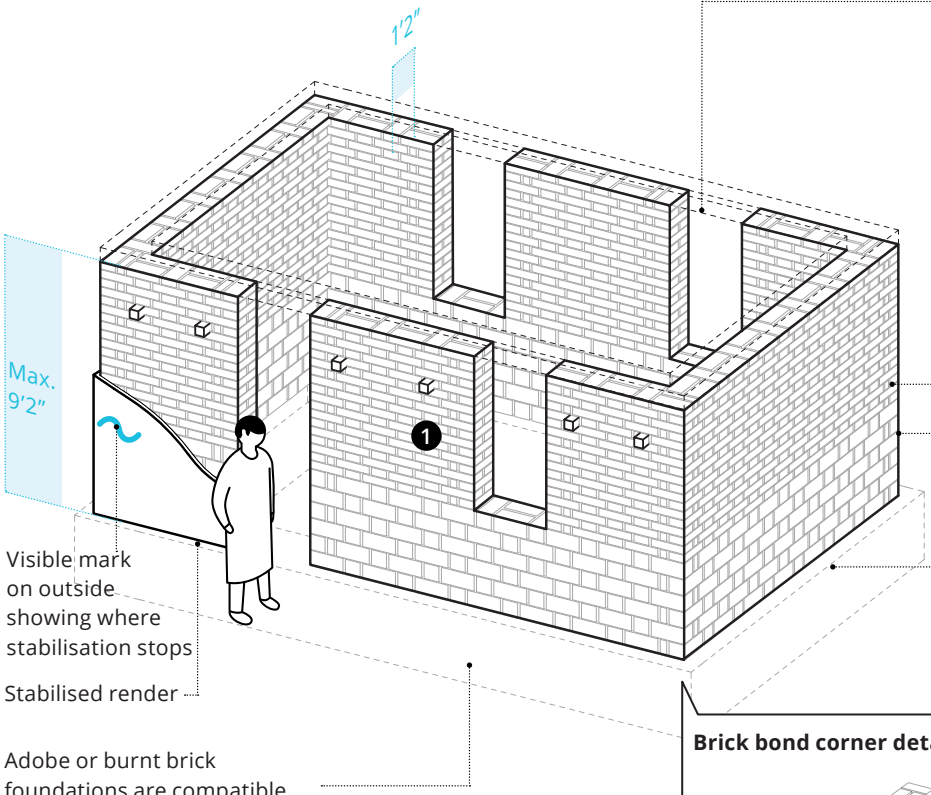
**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.

**Specification**
Stabilised earth
Stabilised render

Wall Component

# Stabilised Adobe

**3D view**




Ring beam and foundation shown dashed

Window and door opening extend to the top of the wall. The ring beam acts as a lintel

Timber, bamboo or RC rings beams are compatible with adobe walls

Stabilised and unstabilised blocks differ in size

Unstabilised earth

Stabilised earth
Level of stabilisation should be informed by potential future flooding level.

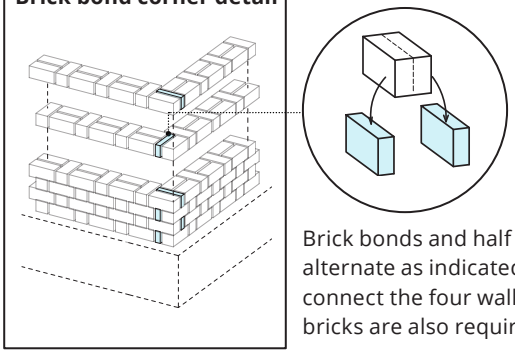
Damp proof membrane between foundation and wall

Visible mark on outside showing where stabilisation stops

Stabilised render

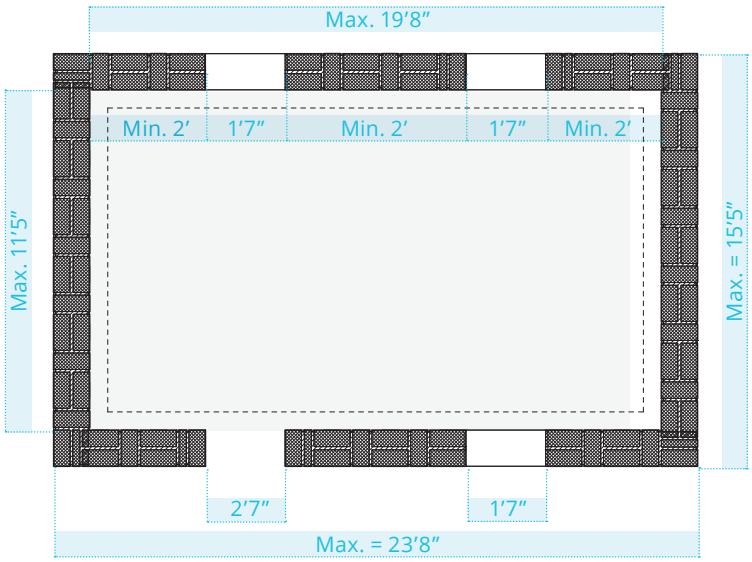
Adobe or burnt brick foundations are compatible with adobe walls.

**Brick bond corner detail**



Brick bonds and half bricks must alternate as indicated in order to connect the four walls together. Half bricks are also required at openings.

**Plan [Not to scale]**



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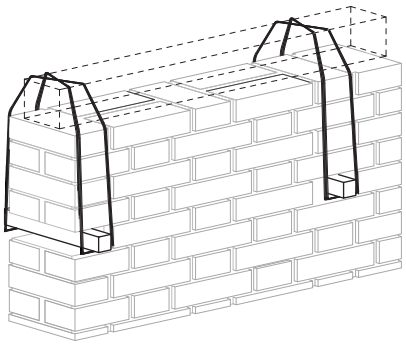
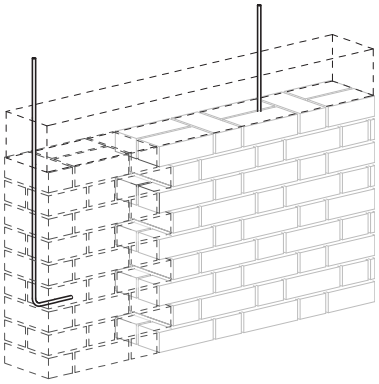
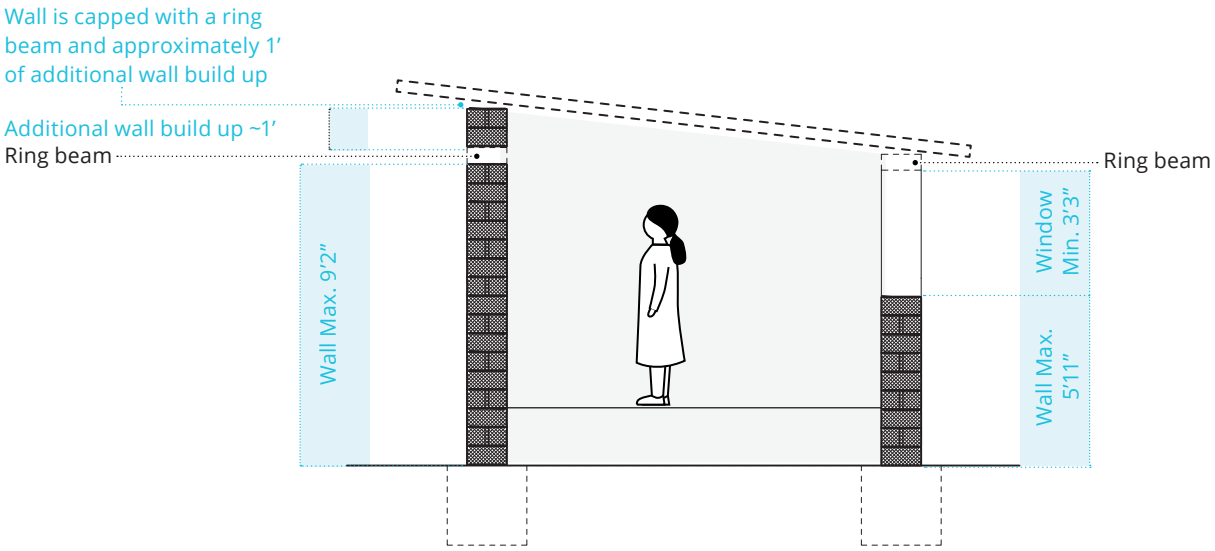


Ⓐ **Tie Connection**: A wooden peg is cast into the wall and wire used to secure the ring beam. This option is easier to build and appropriate for timber and bamboo ring beams.



Ⓑ **Bolt Connection**: A steel rod is cast into the wall and a bolt is used to secure the ring beam. This option is appropriate for timber and RC ring beams

## Section [not to scale]




**SEISMIC CONSIDERATION**
- Limit wall height to 7'10"
- Use piers at the corners and in the middle of the long wall.
- Use the bolted connection.
- Use a seismically improved timber or bamboo ring beam (see Design Information, Ring Beam)

**Variation**
Replacing lime with Cement for stabilisation:
+ Buildability
- Sustainability
Replacing tie with bolt connection:
+Stability
- Buildability

**Maintenance**
Repair render if damaged.
Replace wire/rope in tied connection if damaged/rusted.

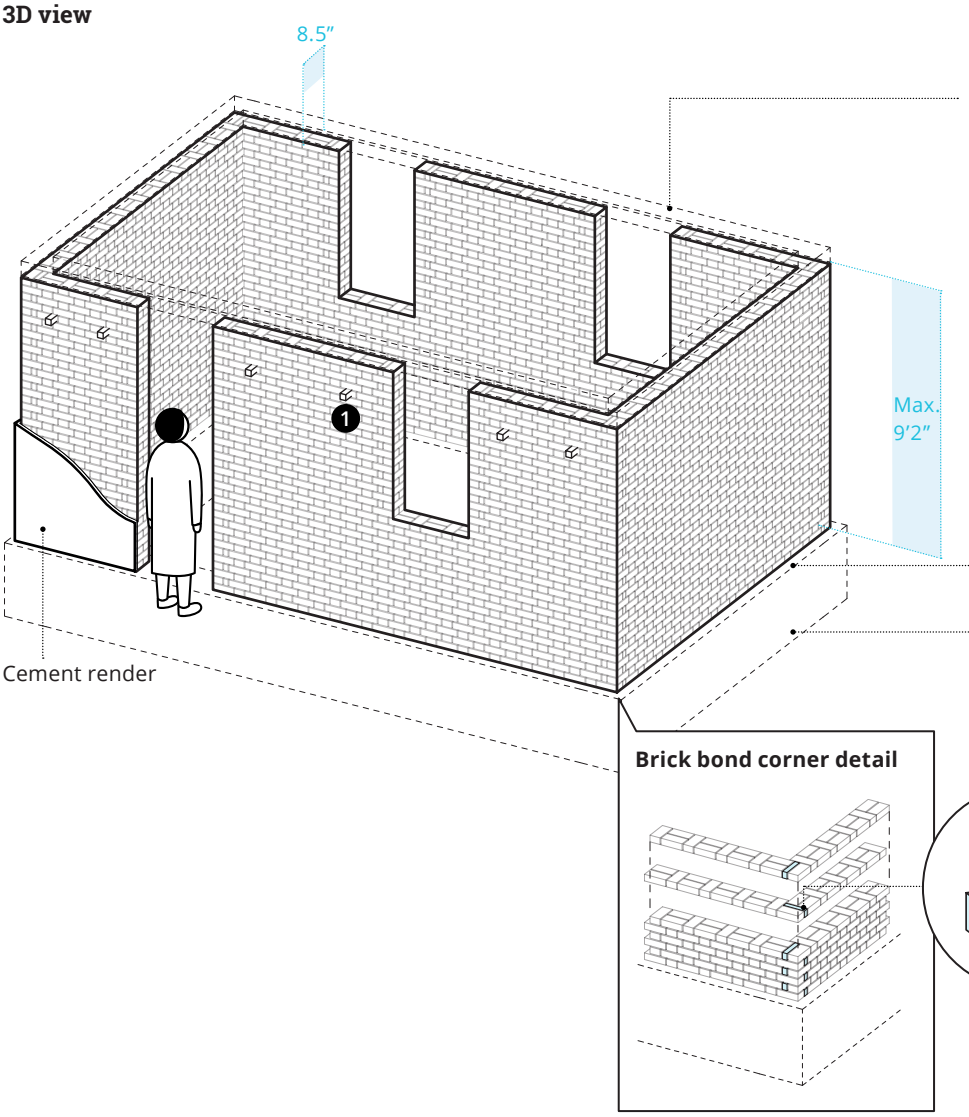
**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.

**Specification**
Stabilised earth
Stabilised render

Wall Component

# Burnt Brick

**3D view**




Ring beam and foundation shown dashed

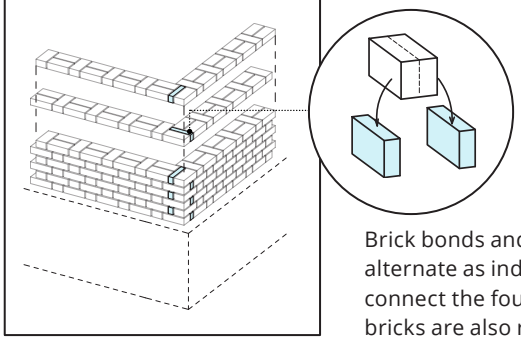
Window and door opening extend to the top of the wall. The ring beam acts as a lintel

Timber or RC rings beams are compatible with burnt brick

Damp proof membrane between foundation and wall

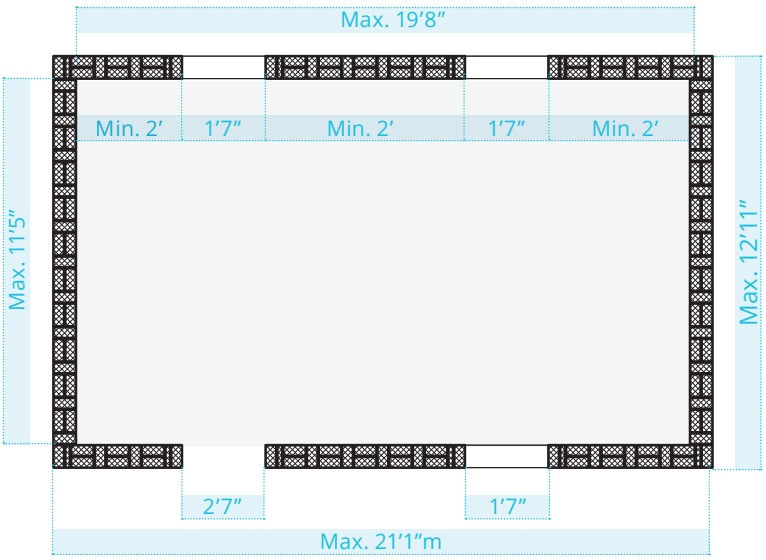
Burnt brick or concrete foundations are compatible

**Brick bond corner detail**



Brick bonds and half bricks must alternate as indicated in order to connect the four walls together. Half bricks are also required at openings

**Plan [Not to scale]**



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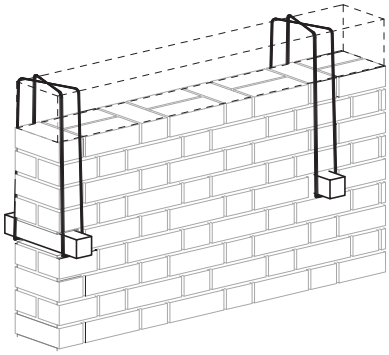
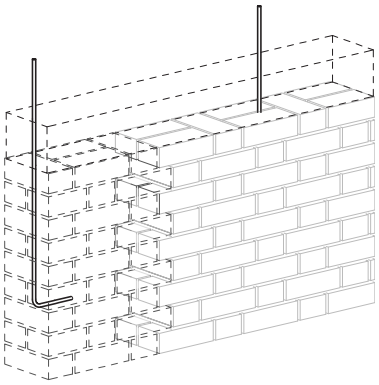
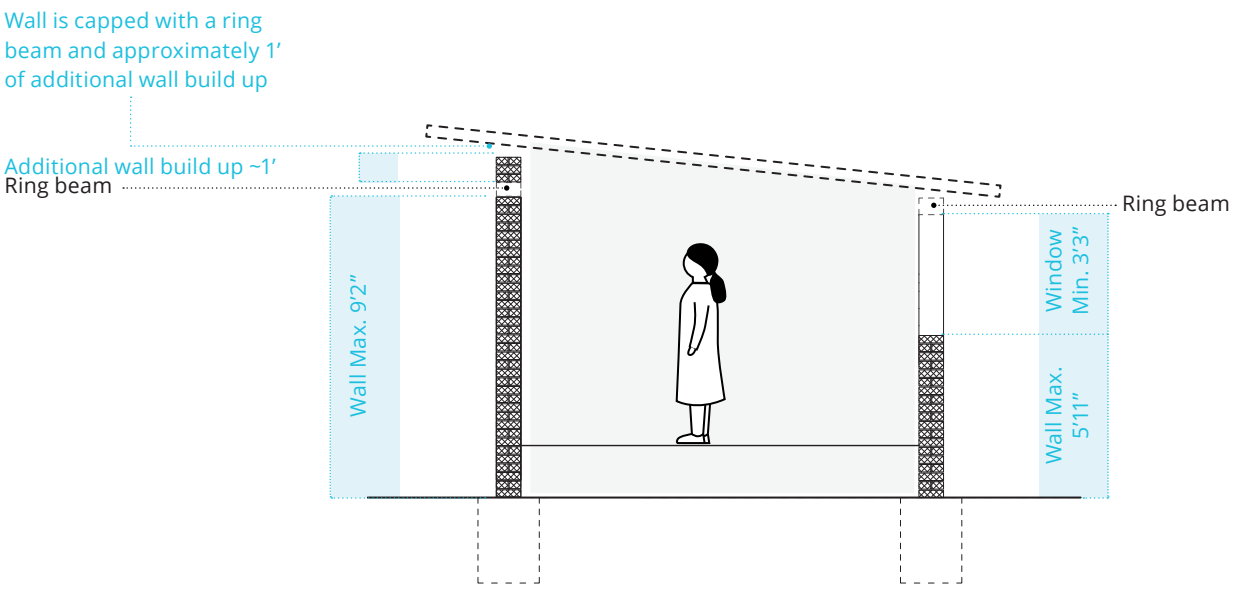


Ⓐ **Tie Connection**: A wooden peg is cast into the wall and wire used to secure the ring beam. This option is easier to build and appropriate for timber and bamboo ring beams.



Ⓑ **Bolt Connection**: A steel rod is cast into the wall and a bolt is used to secure the ring beam. This option is appropriate for timber and RC ring beams

**Section [not to scale]**




**SEISMIC CONSIDERATION**

- Limit wall height to 7'10"
- Use piers at the corners and in the middle of the long wall.
- Use the bolted connection.
- Use the reinforced concrete ring beam

**Variation**
Replacing tie with bolt connection:
+Stability
- Buildability

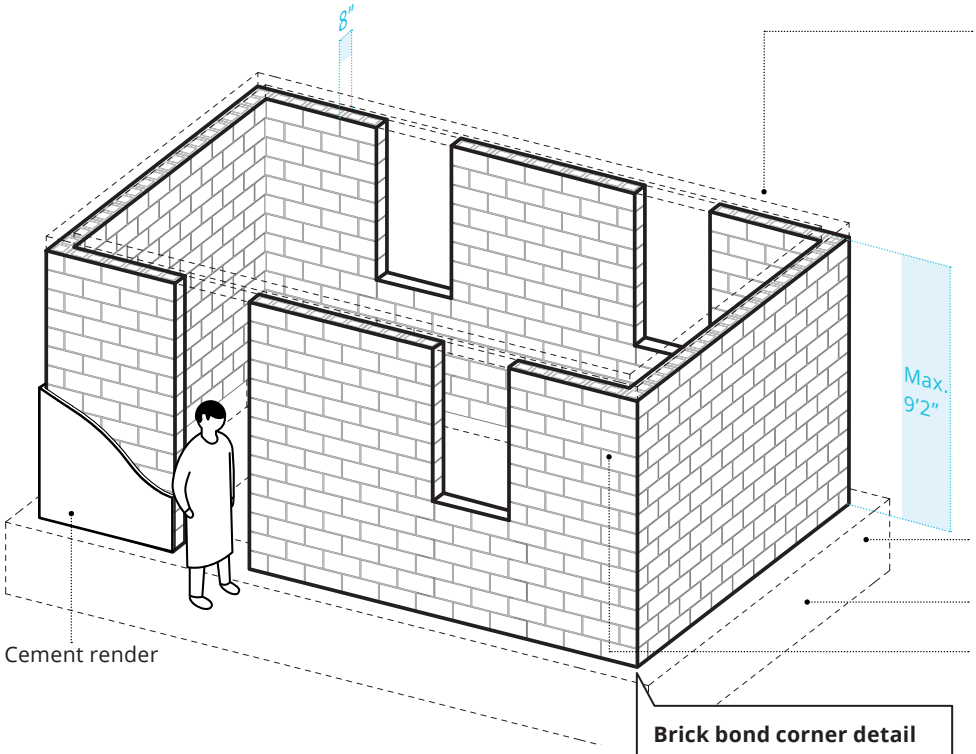
**Maintenance**
Repair render if damaged.
Replace wire/rope in tied connection if damaged/rusted.

**Health and Safety**
Lime/Cement used in mortar and render can burn skin. Wear gloves and boots.

**Specification**
Burnt bricks
Block laying

Wall Component

**3D view**




Ring beam and foundation shown dashed

Window and door opening extend to the top of the wall. The ring beam acts as a lintel

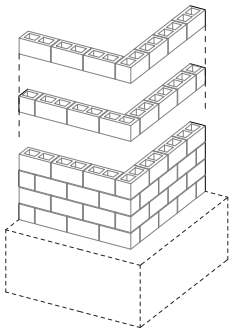
Timber or RC rings beams are compatible with concrete walls.

Damp proof membrane between foundation and wall

Concrete or burnt brick foundations are compatible

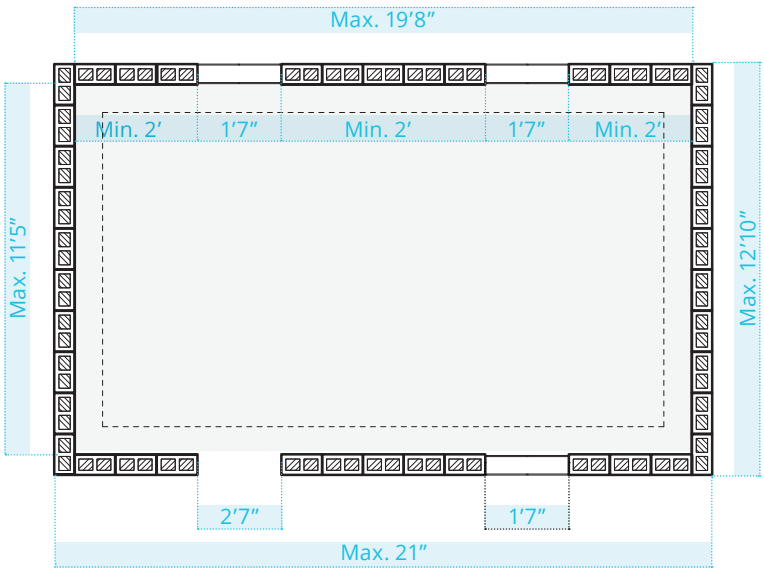
Embedded wooden pegs for future veranda

**Brick bond corner detail**

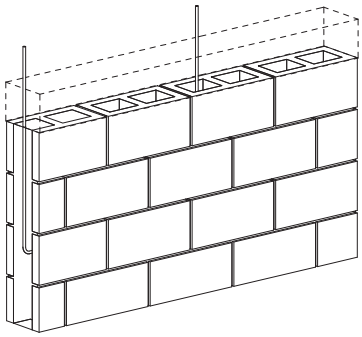


Brick bonds must alternate as indicated in order to connect the four walls together.

**Plan [Not to scale]**

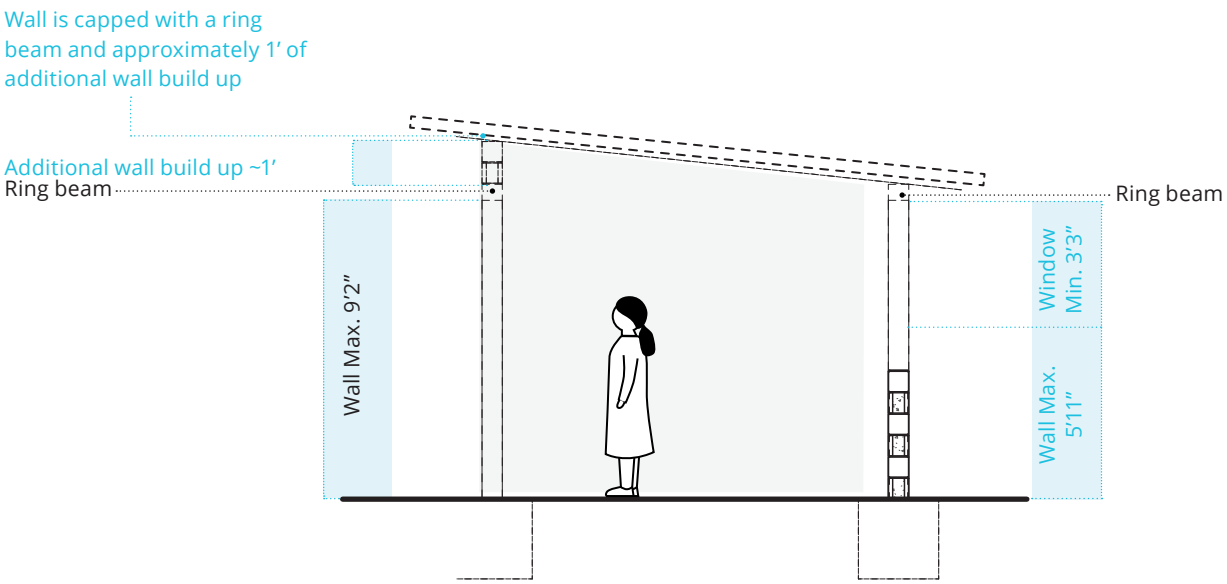


1



**Bolt Connection**: A steel rod is cast into the wall within the block cells if using hollow core blocks, or between the block courses if using solid blocks. If hollow block are used, the block cell with the bolt should be filled with concrete. This option is appropriate for an RC ring beam, where the bolt is cast into the ring beam.

## Section [not to scale]




**SEISMIC CONSIDERATION**
- Limit wall height to 7'10"
- Use an RC ring beam
- Add vertical and horizontal wall reinforcement, 10mm diameter vertical bar every 3 cells + 10mm diameter horizontal bar every 3 courses, with additional 12mm diameter vertical bars in corners and next to openings. Note that adding reinforcement means anchoring to foundation.

**Maintenance**
Repair render if damaged.

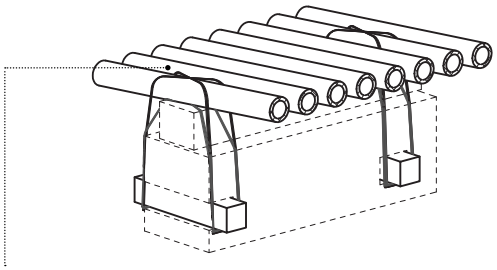
**Health and Safety**
Cement used in blocks, mortar and render can burn skin. Wear gloves and boots.

**Specification**
Concrete
Block laying

Roof Component

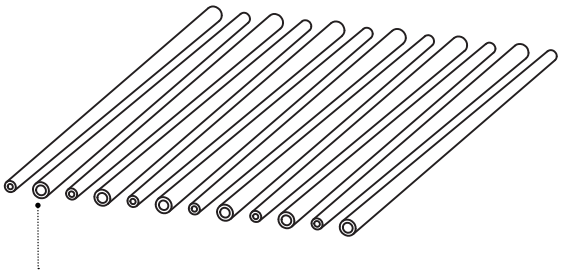
# Bamboo

### Tie Connection



Only this method is suitable for bamboo roofs. Wire/rope/rattan is used to tie the roof structure to the ring beam and wooden pegs cast into the wall

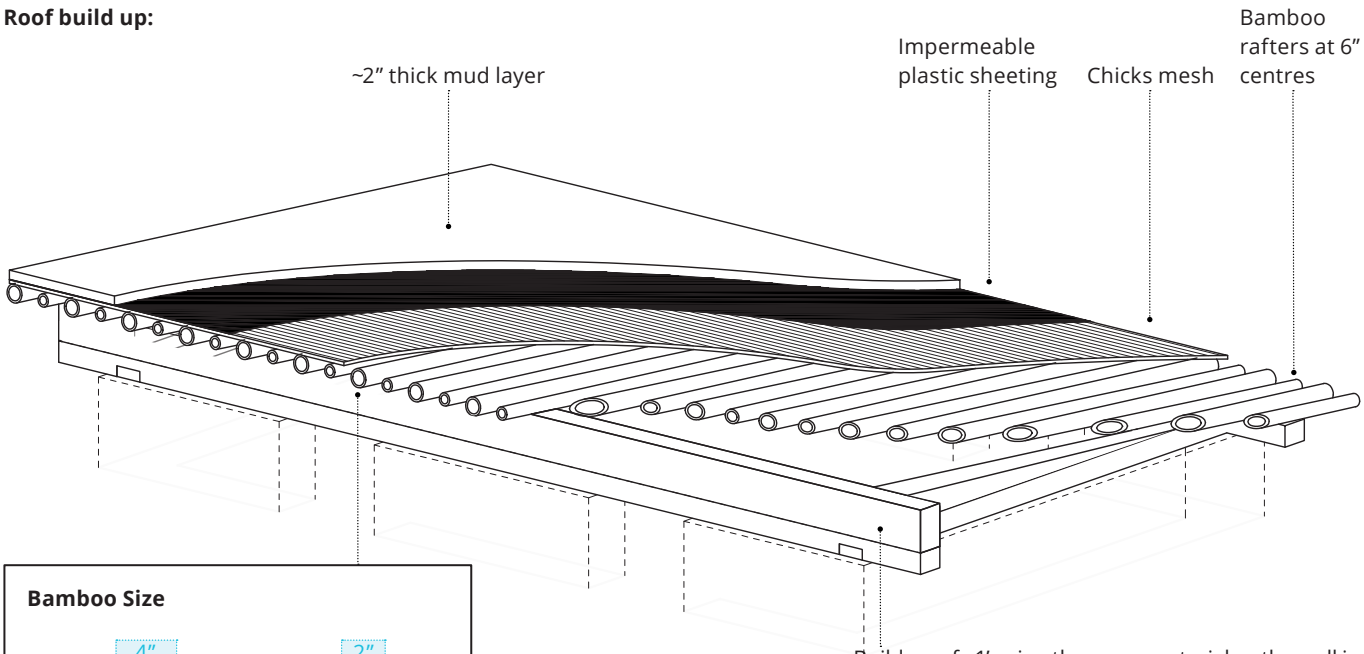
### Bamboo Rafter Orientation



Bamboo lengths to be alternated based on the diameter of each end

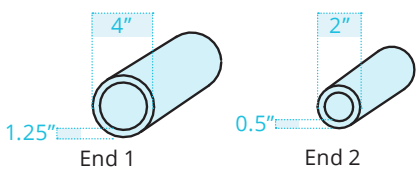
### 3D view

**Roof build up:**




Build up of ~1' using the same material as the wall is used above the ring beam to create the roof pitch.

**Bamboo Size**




**SEISMIC CONSIDERATION**
The following measures will improve performance: Add nails between the ring beam and the roof rafters (nails should be pre-drilled to avoid splitting the bamboo).

**Maintenance**
Ensure sloped drainage is maintained
Remove termite tracks.
Replace deteriorated bamboo members
Repair any leaks

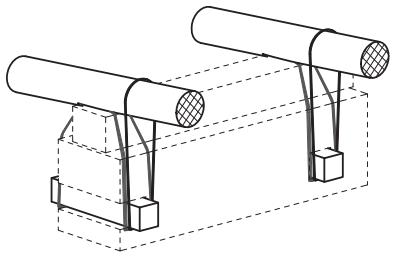
**Health and Safety**
Care required when working at height

**Specification**
Bamboo

Roof Component

# Timber

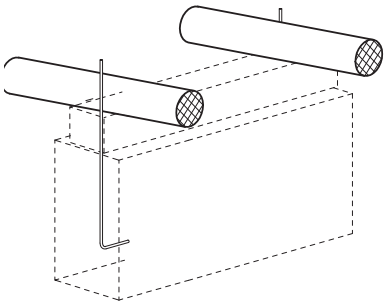
### Tie Connection



Wire/rope/rattan is used to tie the roof structure to the ring beam and wooden pegs cast into the wall. This option is easier to build and deconstruct.

or

### Bolt Connection



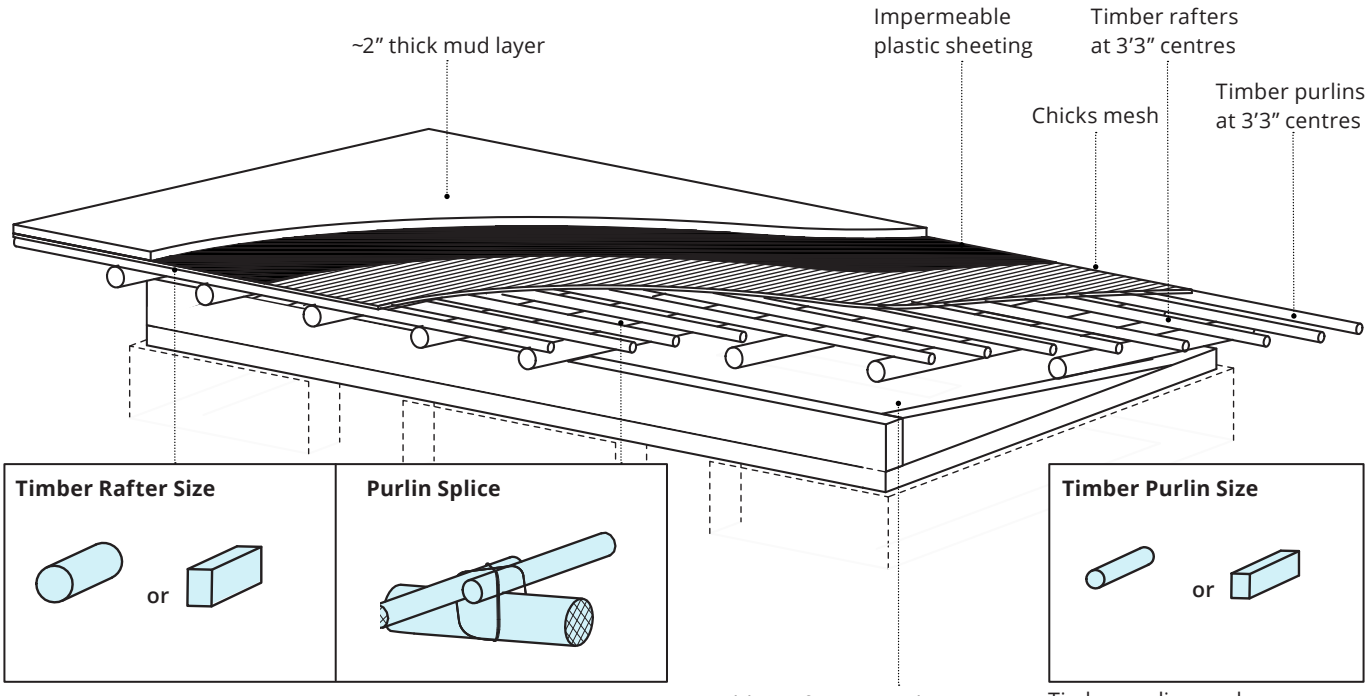
A steel rod is cast into the wall and threaded through holes drilled through the rafter and ring beam. This option appropriate only for timber or concrete ring beams

---

**SEISMIC CONSIDERATION**
The following measures will improve performance:
Use bolted connection
Add nails between the ring beam and the roof rafters.

### 3D view

**Roof build up**:




**Timber Rafter Size**




Timber rafters can be square sawn (6" deep, 4" wide) or circular (6" diameter). If only smaller sections can be sourced, use at a closer spacing.

**Purlin Splice**



If purlins require splicing, lengths to be overlapped and tied as they span the rafters

Build up of ~1' using the same material as the wall is used above the ring beam to create the roof pitch.

**Timber Purlin Size**




Timber purlins can be square sawn (4" deep, 3" wide) or circular (4" diameter). If only smaller sections can be sourced, use at a closer spacing.

---

**Variation**
Replacing tie with bolt connection:
+Stability
- Buildability

**Maintenance**
Ensure sloped drainage is maintained
Remove termite tracks.
Replace deteriorated Timber members
Repair any leaks

**Health and Safety**
Care required when working at height

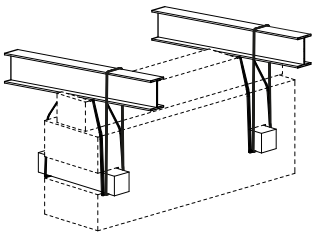
**Specification**
Timber

Roof Component

# Steel

**SEISMIC CONSIDERATION**
As there is no positive connection to the steel beam, this option is not recommended

### Tie Connection

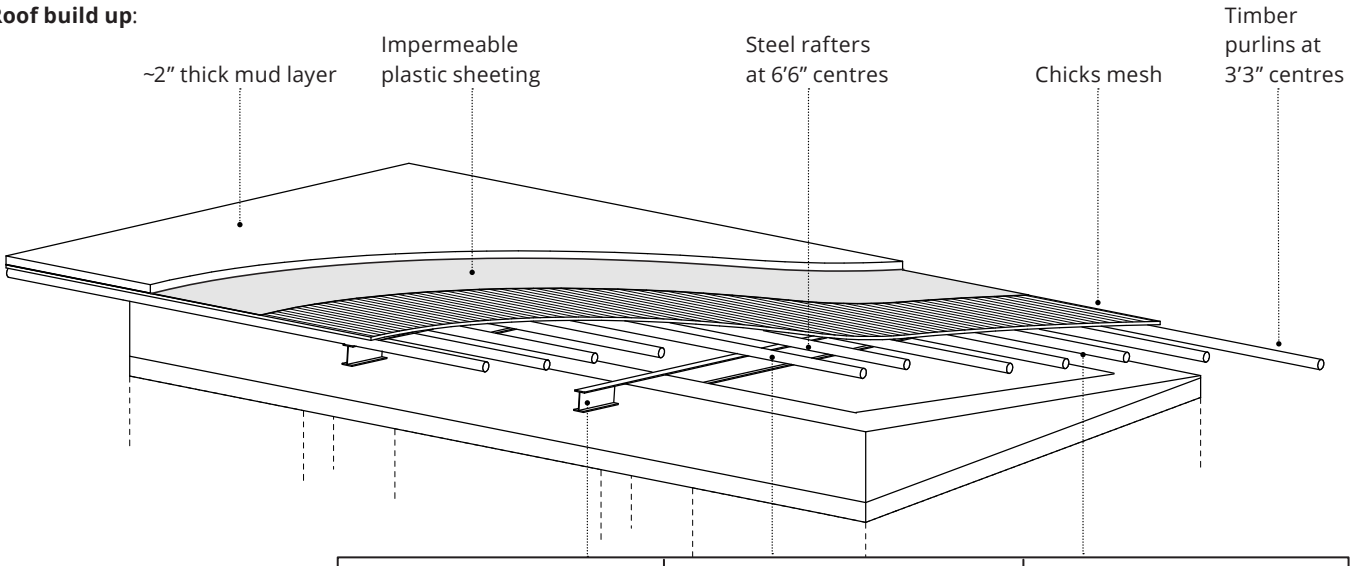


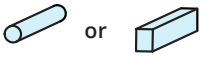
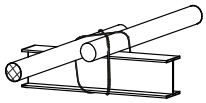
Wire/rope/rattan is used to tie the roof structure to the ring beam and wooden pegs cast into the wall. This option is easier to build and deconstruct.

---

### 3D view

**Roof build up**:




| Steel Rafter Size | Timber Purlin Size | Purin connection |
|---|---|---|
|  |  or |  |
| Steel rafters to have a min. depth of 6", and weight of 3kg/ft | Timber purlins can be square sawn (4.5" deep, 2" wide) or circular (4.5" diameter). If only smaller sections can be sourced, use at a closer spacing. | If purlins require splicing, lengths to be overlapped and tied as they span the rafters |

---

**Maintenance**
Ensure sloped drainage is maintained
Repair any leaks

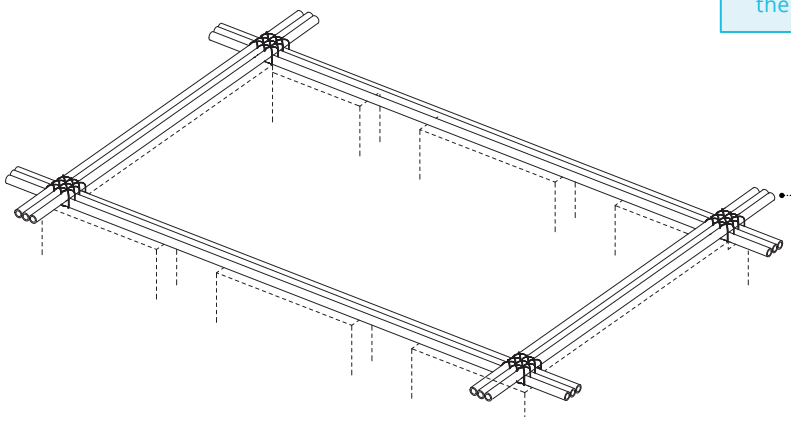
**Health and Safety**
Care required when working at height
Steel beams are heavy, take care when lifting

**Specification**
Steel
Timber/bamboo

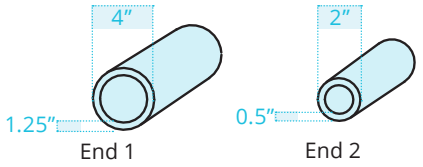
# Ring Beams

**SEISMIC CONSIDERATION**
For bamboo and timber ring beams, add horizontal diagonals in the corner, or horizontal diagonals across the roof plane.

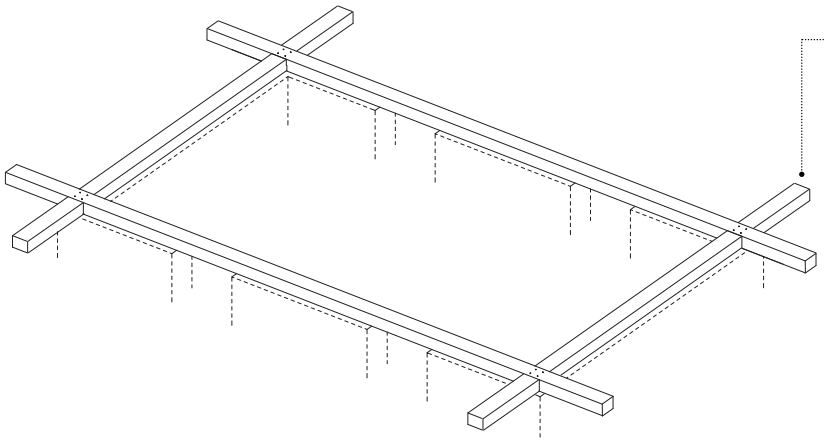
### Bamboo ring beam



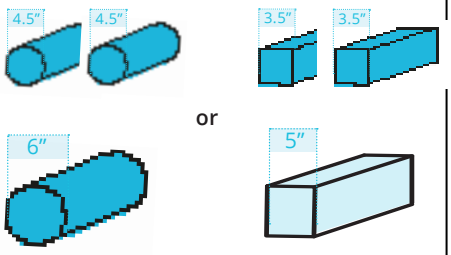
**Bamboo Size**



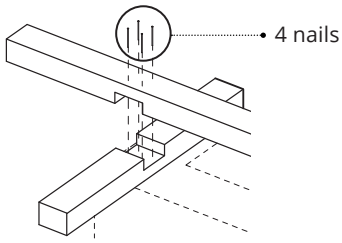

### Timber ring beam



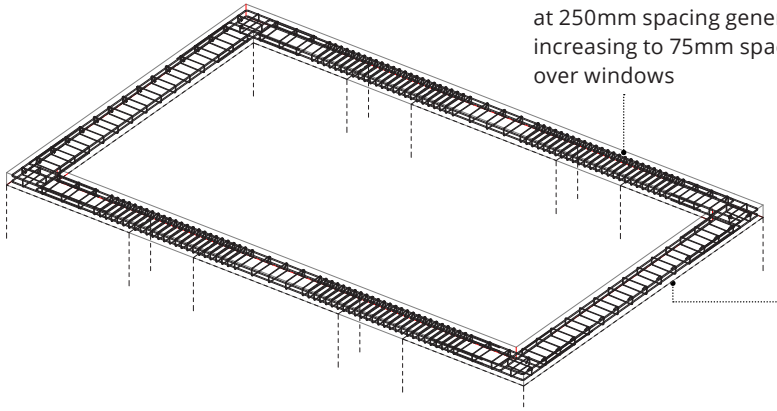
**Timber Size**



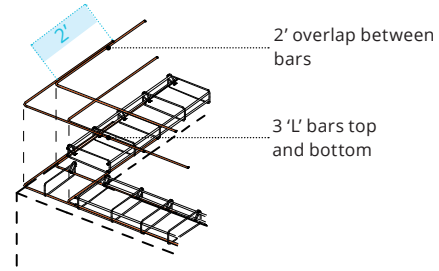

**Ring beam corner connection**

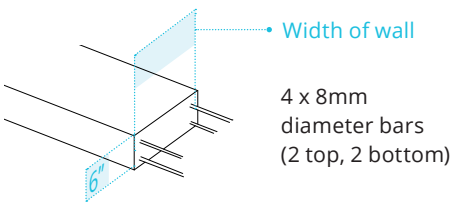



### Reinforced concrete ring beam




**Reinforced concrete corner connection**




**Variation**
Bamboo and Timber options allow easy veranda extension

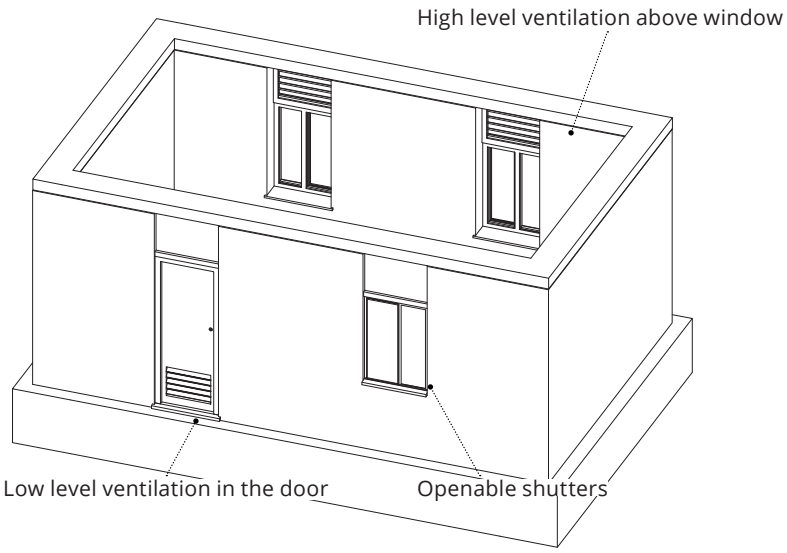
**Maintenance**
Care required when working at height
Cement used in RC ring beam burns. Wear gloves.

**Health and Safety**
Care required when working at height

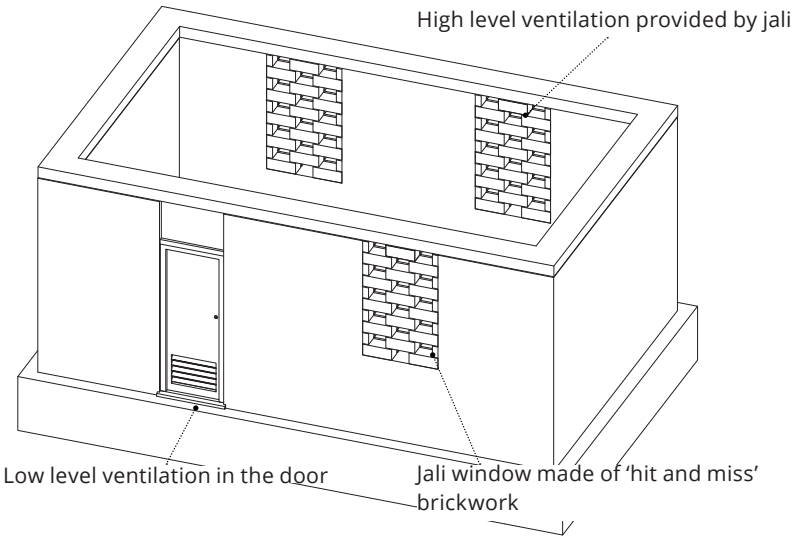
**Specification**
Steel
Concrete
Timber
Bamboo

# Windows and Doors

Openings should be inherently private and secure by design, therefore either shutters or jali windows should be provided. Openings should not be left empty.




**Window shutters**




**Jali Screen**

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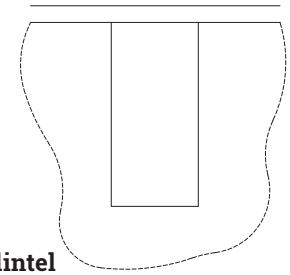
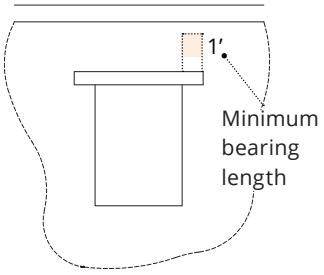
Using the ring beam as a lintel is more efficient structurally but can result in a larger window, which may be more expensive for the window shutter option



**Ring beam as lintel**

or

A more conventional option is to use a separate lintel. Ensure that high level ventilation is still provided in the window shutter option




**Lintel**

---

**Variation**
Windows with shutters
-sustainability
+thermal comfort
Hit and miss brickwork
+sustainability
-thermal comfort

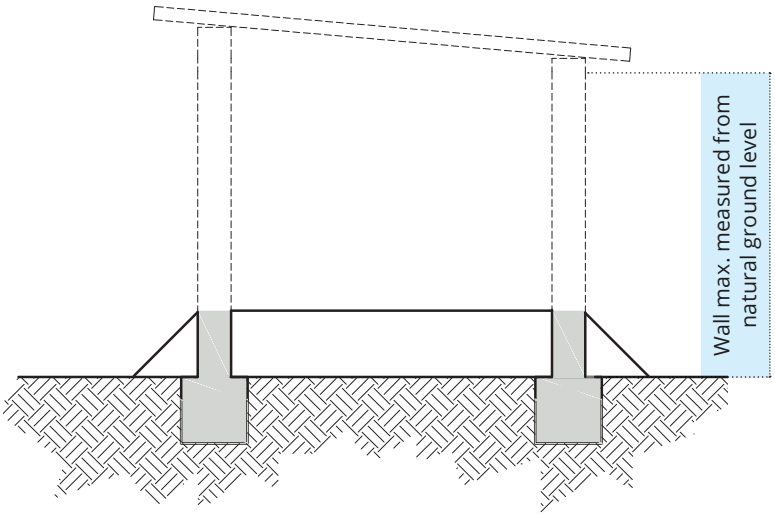
# Platform and Toes

A raised floor is included as standard in all of the designs, to provide protection for people and belongings during a flood.

A toe can be built to encourage drainage away from the shelter, and sacrificial protection of the base, helping with rain resistance.

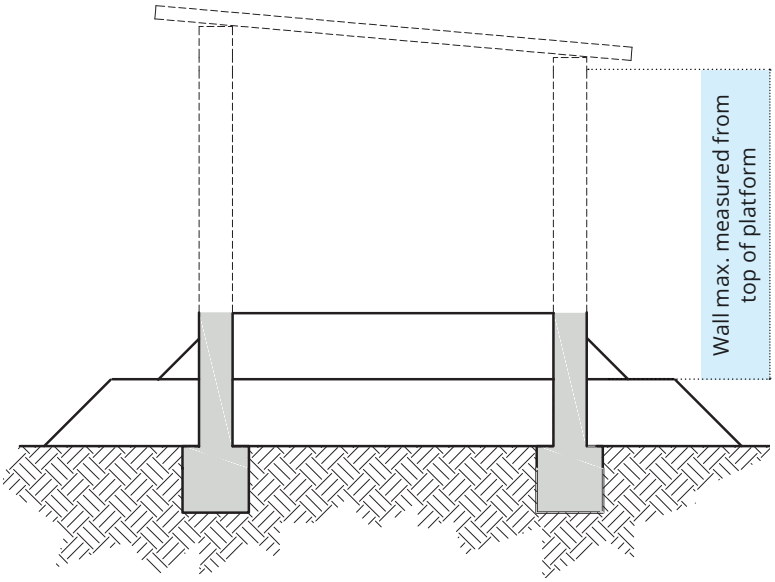
A platform can be used to extend the protected area to outside the building.

It should be noted that these additions do not help the structure of the building during a flood, and shouldn't be used in lieu of correct water resilient material choice and placement.



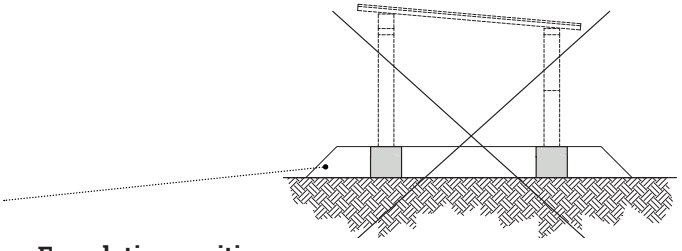

**Toe addition with raised floor**

For the earth construction options, the stabilised material (shown as shaded in grey) should be used, as minimum, to the same level as the raised floor/platform, otherwise the structure will fail before the flood has reached the floor level, and any protection of belongings is undermined.




**Platform addition with raised floor**

Foundations must be placed below natural ground level and not within a plinth



**Foundation position**

**Maintenance**
Repair and replace platforms/toes as they deteriorate

**Health and Safety**
Lime/Cement used in stabilisation can burn skin. Wear gloves and boots.

**Specification**
Stabilised render