Build a Safe House with CONFINED MASONRY

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Gujarat State Disaster Management Authority
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Most houses in rural India are masonry houses. The masonry walls are built with burnt clay brick or natural stone masonry. Many choices are made across India for the roof. For instance, a sloping roof with wood truss and burnt clay tile is adopted in Kachchh region of Gujarat (western state of India), and a flat roof with reinforced concrete (RC) slab in Tehri Region of Uttarakhand (northern state of India). These houses are constructed in the conventional manner known to masons. Technically, they are called **Unreinforced Masonry (URM) Houses**; it has plain masonry walls with no steel reinforcement embedded in them to improve their behaviour during earthquakes. Today, of the existing building stock in India, about 45% of houses are made of burnt clay brick and about 10% of natural stone. Thus, over half of India’s population lives in URM houses.
Unreinforced masonry (URM) walls are pushed sideways during a strong earthquake, along their length and thickness directions. When shaken along their thickness, they collapse. And, when shaken along their length, they develop diagonal cracks along their length and/or separate at wall junctions. When walls collapse, they bring down the roof along with them. This is the main reason for large loss of lives during earthquakes that have occurred in different regions of the country.

Shaking along length direction of masonry wall results in diagonal cracking

Shaking along thickness direction of masonry wall can result in collapse
Despite houses collapsing in earthquakes, people still continue to reconstruct their houses in the age old method of unreinforced masonry, thereby making their houses vulnerable to future earthquakes.

In cities, RC buildings are constructed first by making the RC frame, and then by infilling the spaces between beams and columns with masonry walls made of burnt clay bricks or cement blocks, and cement mortar. To build a house this way requires high levels of technical skills, which usually are not available in small towns and villages. But, everyone, whether residing in a town or a village, wants a pucca house - a house with brick walls and RC roof, just like the buildings in larger towns and cities. This is reason enough to improve earthquake safety measures in these houses.
Small, but significant, changes should be made in current method of construction of masonry houses in rural India. This improved method of house construction is called **Confined Masonry Construction**. Loss of life can be reduced considerably in masonry houses during future earthquakes. For this, masonry walls are confined on all four sides with (a) stiffer and stronger vertical elements made in RC, and (b) RC horizontal bands at discrete levels in the masonry walls along the perimeter of all the rooms of the house.

Books providing technical information on confined masonry construction are exhaustive, but largely offer generic details. They have to be adapted for specific conditions at site. Often, this is difficult for a man building his house. An illustrated manual such as this is required, that follows the requirements of Confined Masonry Construction in an easy-to-follow language, and provides guidance on how to build a confined masonry house with specific functional design. Such a manual will enable the individual house owner or a 'practical technician' to build such a house. Also, the manual will help local authorities to construct houses under any social housing scheme sponsored by the Governments.

This book illustrates the step-by-step construction of a **Confined Masonry House** of a specific design. It provides precautions to be taken and amount of material required to construct the house. Also, alternate specific designs are presented.
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The authors remain indebted to their family members for the unconditional support and understanding throughout the of development of the book… This book is dedicated to all the people of India, who lost their kith and kin in masonry house collapses during past earthquakes in the country…
Confined Masonry
What will happen to my house in an earthquake, if masonry is not confined?

**Moderate Shaking**
- Walls crack

**Severe Shaking**
- Walls collapse and slab falls

How do I prevent this?

During an earthquake, when the ground shakes moderately, unconfined walls are pushed sideways and therefore develop cracks. When the ground shakes violently, unconfined masonry walls collapse bringing down the roof, either partly or fully.

By confining masonry walls of the house. This is achieved by using:

1. **(a)** vertical RC elements interlocked with bricks at all wall junctions and door and window openings, and
2. **(b)** horizontal RC bands at plinth, sill and lintel levels.

Masonry confined thus is resistant to earthquakes.
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Masonry confined thus is resistant to earthquakes.
What is Confined Masonry?

Confined masonry (CM) consists of RC confining vertical and horizontal confining elements that are cast in-situ around URM wall segments built in small heights. Concrete in these RC elements is poured after the walls are made. This in-situ concrete fills all gaps and covers vertical bars protruding out from the foundation. On hardening of concrete, the RC elements hold the masonry wall segments snugly without any gap between them. This snug action is created by the toothing left in the masonry walls at wall corners and junctions, and adjoining door, window and ventilator openings.

Small-sized vertical reinforced concrete (RC) confining elements are cast in-situ at all wall junctions and adjoining all openings. Horizontal RC elements (called bands) are cast in-situ above and below all openings and at floor levels. Normally, Plinth, Sill and Lintel Bands are provided; in buildings with pitched roofs, two more bands are provided, namely the Roof and Gable Bands. Longitudinal reinforcement bars in vertical RC elements are anchored into the plinth masonry at the bottom and roof slab (when roof is flat), or into the roof band (when the roof is pitched) at the top. Longitudinal reinforcement bars in horizontal RC bands run through all walls of the house; sill band alone is discontinued at door openings.
Under earthquake shaking, the loads are carried primarily by the composite system of masonry wall and RC elements through load-bearing action. These RC confining elements are small in size and grip the whole width of the wall at door and window openings and wall junctions. They have sufficient stiffness to resist to dilation of masonry wall that otherwise happens during earthquake shaking. Thus, each wall panel bound by the confining RC elements stays as an integral unit without disintegrating into its constituent materials.↑

RC elements holds masonry walls snugly during earthquake shaking
Confined masonry is most suitable and practical method for construction of houses by individual home owners in earthquake areas. The level of engineering required is embedded in empirical rules for planning, design and construction of these houses. Two prominent features of confined masonry construction are:

1. Use of a regular grid of walls in both directions with RC vertical members at all wall junctions and in straight walls of longer lengths, and RC vertical elements (toothed into the masonry wall segments) and RC horizontal bands (resting on the masonry walls of the whole house). These items together confine the wall segments and prevent them from dilating along the length direction of the wall and from falling out-of-plane along the thickness direction of the wall.

2. Sequence of first making the masonry walls and then pouring in-situ the RC vertical elements and horizontal bands. This choice of construction sequence is responsible for enhancing the integrity of the masonry units and mortar in Confined Masonry, which in turn makes Confined Masonry Construction superior to regular RC frame buildings with plain masonry walls as infills.

Earthquake performance is good of confined masonry construction. While confined masonry constructions sustained severe damage during past earthquakes, complete collapse has not been observed in this typology of construction.
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What are the main elements of a Confined Masonry House?

Foundation
All elements of construction from soil level to ground level

Plinth
All elements of construction from ground level to floor level

Wall
Masonry wall, vertical RC elements and horizontal RC bands

Roof
RC slab with all finishes on it in a flat roof, wood/steel truss, clay tiles/sheeting and all finishes on it in a pitched roof

Confining Elements
Vertical RC elements, Horizontal RC bands at plinth, sill and lintel levels in a house with flat roof, and RC eaves and gable bands in a house with pitched roof
Options of Confined Masonry Houses
What are the available options?

Option 1
- Built-up area: 24.67 m
- Carpet area: 18.78 m

Option 2
- Built-up area: 32.03 m
- Carpet area: 20.18 m
What are the available options?

Option 1
Built-up area: 24.67 m²
Carpet area: 18.78 m²

Option 2
Built-up area: 32.03 m²
Carpet area: 20.18 m²
Option 3
Built-up area: 25.54 m²
Carpet area: 18.60 m²

Option 4
Built-up area: 32.47 m²
Carpet area: 19.21 m²

- Main Room
- Toilet
- Bath
- Kitchen
- Access Road
Option 5
Built-up area: 30.53 m²
Carpet area: 18.92 m²

Main Room
Toilet
Bath
Kitchen
Access Road
Option 6
Built-up area: 24.67 m² each house
Carpet area: 18.78 m² each house
Option 7
Built-up area: 30.53 m² each
Carpet area: 18.92 m² each
Option 1

Bath
1.2 m x 1.1 m
(1.32 m²)

Kitchen
1.2 m x 2.31 m
(2.77 m²)

Toilet
1.2 m x 0.9 m
(1.08 m²)

Main Room
2.9 m x 4.69 m
(14.54 m²)
Option 1

Front Elevation

Plan

Brick Masonry Courses

Main Room
2.90m x 4.69m

Kitchen
1.20m x 2.31m

Bath
1.2m x 1.1m

Toilet
1.2m x 0.9m
Option 1

Section A-A

Section B-B
Option 1

Ventilator
with Built-in Steel Grill

Elevation

Section X-X

Plan

Pivoted Window
Closed Position

Pivoted Window
Open Position

Ventilator with Built-in Steel Grill

Round Steel Bars (10mm diameter) along vertical and horizontal directions

Roof Slab

Lintel Band

Vertical RC Elements
Option 1

Pivoted Window
Open Position

Pivoted Window
Closed Position
Option 1

Window Details

Ventilator with MS Grill

12mm thick E Board

RC Roof Slab

Lintel Band

Sill Band

Section W-W
Option 1

Lintel Band
75 mm deep over windows

Primary Timber Frame
75 mm x 25 mm

Secondary Timber Frame
50 mm x 25 mm

Window Shutter
12 mm thick E Board

MS Rods
20 mm diameter

Vertical RC Element
around Opening

Detail Q
Sectional Plan

Detail R
Sectional Elevation
Option 1

Door Details

RC Roof Slab

Lintel Band

Section S-S

T.W. member 100 mm x 36mm

MS Angle 65mm x 65mm x 6mm

I.P.S Threshold 38mm x 100 mm

E Board 12mm thick

T.W. member 100 mm x 36mm

MS Angle 65mm x 65mm x 6mm

E Board 12mm thick

Door Details
Option 1

Detail T
Sectional Plan

- T.W. member: 100 mm x 36 mm
- E Board: 12 mm thick
- I.P.S Threshold: 38 mm x 100 mm
- MS Angle: 65 mm x 65 mm x 6 mm

Detail U
Sectional Elevation

- T.W. member: 100 mm x 36 mm
- E Board: 12 mm thick

Detail V
Sectional Elevation

- E Board: 12 mm thick
- I.P.S Threshold: 38 mm x 100 mm
- MS Angle: 65 mm x 65 mm x 6 mm
- T.W. member: 100 mm x 36 mm
Option 1

House with sloping roof

Plan

Ridge Line

Main Room
2.90m x 4.69m

Kitchen
1.20m x 2.31m

Toilet
1.2m x 0.9m

Bath
1.2m x 1.1m

Backfilled earth
Unexcavated ground
Option 1

Right Elevation

Section C-C
**Option 1 Extended**

**How to extend my house?**

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion.

While extending the house, chip only the concrete from the projected lintel band left for future expansion.
While extending the house, chip only the concrete from the projected lintel band left for future expansion.

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion.

Option 1 Extended

Built-up area: 40.14 m²
Carpet area: 31.77 m²
Option 2

Bath
1.20 m x 1.10 m
(1.32 m²)

Kitchen
1.20 m x 2.31 m
(2.77 m²)

Toilet
1.20 m x 0.90 m
(1.08 m²)

Main Room
3.20 m x 4.69 m
(14.54 m²)
Option 2

Front Elevation

Plan

Main Room 3.20m x 4.69m

Kitchen 1.20m x 2.31m

Bath 1.20m x 1.10m

Toilet 1.20m x 0.90m
Option 2

Back Elevation

Right Elevation
Option 2

Section A-A

Section B-B

Backfilled earth

Unexcavated Ground
Option 2

House with sloping roof

Plan

Main Room
3.20m x 4.69m

Toilet
1.20m x 0.9m

Bath
1.20m x 1.1m

Kitchen
1.20m x 2.31m

Ridge Line
How to extend my house?

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion.

While extending the house, chip only the concrete from the projected lintel band left for future expansion.
Option 2 Extended

Built-up area: 43.85 m²
Carpet area: 29.78 m²

How to extend my house?

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion. While extending the house, chip only the concrete from the projected lintel band left for future expansion.
Option 2 Extended

Plan

- Main Room
- Toilet
- Bath
- Kitchen
- Access Road
- Additional Room

Section D-D

Overlap of Roof Slab done for extension
Option 2 Extended

Overlap of Roof Slab done for extension

Section D-D
Option 3

Bath
1.2 m x 1.1 m
(1.32 m²)

Toilet
1.2 m x 0.9 m
(1.08 m²)

Main Room
3.00 m x 4.76 m
(14.54 m²)

Kitchen
1.10 m x 2.23 m
(2.77 m²)
Option 3

Front Elevation

Plan

Main Room
4.76m x 3.00m

Kitchen
2.30m x 1.10m

Toilet
0.9m x 1.2m

Bath
1.1m x 1.2m

48 49
Option 3

Front Elevation

Right Elevation
Option 3

House with sloping roof

Plan

Main Room
4.76m x 3.00m

Kitchen
2.30m x 1.10m

Toilet
0.9 m x 1.2 m

Bath
1.1m x 1.2m
Option 3

Front Elevation

Section C-C

Backfilled earth
Unexcavated Ground

12
11

3100 mm
975 mm

Option 3

House with sloping roof

C

Kitchen
2.30m x 1.10m

Bath
1.1m x 1.2m

Toilet
0.9 m x 1.2 m

Main Room
4.76m x 3.00m

Plan

Ridge Line

Brick Masonry Courses

450
1000
1050
3650
150
75
925
450
3100 mm
975 mm

Option 3 Extended

How to extend my house?

To extend the house, leave a projection of 600mm from the Lintel Band in the direction of proposed extension.

While extending the house, chip only the concrete from the projected lintel band left for future expansion.
Option 3 Extended

How to extend my house?

To extend the house,
leave a projection of 600mm
from the Lintel Band
in the direction of proposed
extension

While extending the house,
chip only the concrete
from the projected lintel band
left for future expansion

Built-up area: 47.94 m²
Carpet area: 32.20 m²
Option 3 Extended

Plan

Main Room
Toilet
Bath
Kitchen
Access Road
Additional Room
Option 3 Extended

Section D-D
Bath
1.2 m x 1.1 m
(1.32 m²)

Toilet
1.2 m x 0.9 m
(1.08 m²)

Main Room
3.00 m x 4.69 m
(14.54 m²)

Kitchen
1.10 m x 2.23 m
(2.77 m²)
Option 4

Front Elevation

Plan

Main Room
4.69m x 3.00m

Kitchen
1.10m x 2.23m

Bath
1.2m x 1.1m

Toilet
1.2m x 0.9m
Option 4

Left Elevation
Option 4

Section A-A

Section B-B
House with sloping roof

Plan

Option 4

House with sloping roof
Option 4

Front Elevation

Section C-C
Option 4 Extended

How to extend my house?

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion.

While extending the house, chip only the concrete from the projected lintel band left for future expansion.
Option 4 Extended

How to extend my house?

While extending the house, chip only the concrete from the projected lintel band left for future expansion.

To extend the house, leave a 600mm projection from the Lintel Band in the direction of proposed expansion.

Option 4 Extended
Built-up area: 40.38 m²
Carpet area: 26.69 m²
Option 4 Extended

Section D-D
**Option 5**

**Main Room**
4.20 m x 3.00 m
(14.54 m²)

**Kitchen**
1.20 m x 3.00 m
(2.77 m²)

**Bath**
1.2 m x 1.1 m
(1.32 m²)

**Toilet**
1.2 m x 0.9 m
(1.08 m²)
Option 5

Front Elevation

Plan

Main Room 4.20m x 3.00m

Kitchen 1.20 x 3.00m

Bath 1.1m x 1.2m

Toilet 0.9m x 1.2m

Brick Masonry Courses

150, 625, 75, 925, 450

3300, 1000, 2300

7, 12, 11

230, 750, 1200

230, 900, 1660

230, 750, 235

230, 6090, 550

Option 5

625, 75, 925, 450

3300, 1000, 2300

7, 12, 11

230, 750, 1200

230, 900, 1660

230, 750, 235

230, 6090, 550
Option 5

Right Elevation

Left Elevation of Toilet
Option 5

House with sloping roof

Plan

Kitchen
1.20 x 3.00m

Main Room
4.20m x 3.00m

Toilet
0.9m x 1.2m

Bath
1.1m x 1.2m

Ridge Line

Backfilled earth

Unexcavated ground
Option 5 Extended

How to extend my house?

To extend the house, leave a projection of 600mm from the Lintel Band in the direction of proposed extension and while extending the house, chip only the concrete from the projected lintel band left for future expansion.
Option 5 Extended

Built-up area: 40.22 m²
Carpet area: 30.86 m²
Option 5 Extended

Plan

- Main Room
- Toilet
- Bath
- Kitchen
- Access Road
- Additional Room
Option 5 Extended

Section D-D
Basics of Construction
Grade 33 cement is required in foundation and plinth (in plain concrete mat, and flooring), walls (in mortar, RC bands and RC vertical elements) and roof (reinforced concrete).

Well graded clean river sand is required in foundation and plinth (in plain concrete mat, plinth fill, and flooring), walls (in mortar, RC bands and RC vertical elements) and roof (reinforced concrete).

Well graded 20mm down stone aggregate is required in foundation and plinth (in plain concrete mat, and flooring), walls (in RC bands and RC vertical elements) and roof (reinforced concrete).

Steel reinforcing bars of two types are required, namely high yield strength ribbed bars of 10mm diameter and mild steel smooth bars of 6mm diameter. It is required in walls (in RC bands and RC vertical elements) and roof (reinforced concrete).

Masonry units can be burnt clay bricks, natural stone (that is dressed), fly ash bricks or cement blocks. It is required in foundation and plinth (in masonry) and walls (in masonry).

Clean potable water is required for all components of the house, namely foundation and plinth, walls and roof.
What basic materials are required to build my house?

**Cement**

Grade 33 cement is required in foundation and plinth (in plain concrete mat, and flooring), walls (in mortar, RC bands and RC vertical elements) and roof (reinforced concrete).

**Sand**

Well graded clean river sand is required in foundation and plinth (in plain concrete mat, plinth fill, and flooring), walls (in mortar, RC bands and RC vertical elements) and roof (reinforced concrete).

**Aggregate**

Well graded 20mm down stone aggregate is required in foundation and plinth (in plain concrete mat, and flooring), walls (in RC bands and RC vertical elements) and roof (reinforced concrete).

**Steel**

Steel reinforcing bars of two types are required, namely high yield strength ribbed bars of 10mm diameter and mild steel smooth bars of 6mm diameter. It is required in walls (in RC bands and RC vertical elements) and roof (reinforced concrete).

**Masonry Units**

Masonry units can be burnt clay bricks, natural stone (that is dressed), fly ash bricks or cement blocks. It is required in foundation and plinth (in masonry) and walls (in masonry).

**Water**

Clean potable water is required for all components of the house, namely foundation and plinth, walls and roof.
Which masonry units can I use?

Masonry walls/foundation using cement mortar can be built with following materials:

**Burnt Clay Bricks**
Class B or better burnt clay bricks with compressive strength of at least 7-10 MPa. The size of the bricks considered are the standard brick available in India, namely of size 230mm × 115mm × 75mm.

**Fly Ash Bricks**
Fly Ash bricks from nearby Thermal Power Plants with compressive strength of at least 7-10 MPa. The size of these units should be similar to that of the burnt clay bricks, namely 230 mm × 115 mm × 75 mm.

**Sandstone Blocks**
Naturally available sandstone units can be used. Usually, it is relatively light and easy to shape by hand using a steel edge. The compressive strength of such units should be at least 7-10 MPa. The size of such hand-shaped units shall not exceed 300 mm × 150 mm × 100 mm.

**Cement Blocks**
Machine-made cement blocks with 12.5 mm and down aggregated (in 1:3:6 mix of cement, sand and aggregate) can be used. These units should be properly cured to result in a compressive strength of such units of at least 7-10 MPa. The size of such hand-shaped units shall be similar to that of the burnt clay bricks, namely 230 mm × 115 mm × 75 mm.
Should masonry units be watered before I use?

Natural stone with no or little porosity (like granite) need not be soaked before use, but should be cleaned. But, the burnt clay bricks, fly ash bricks, cement blocks and sandstone blocks are porous, and hence should be watered for about 4 hours before laying. This can be done by
(a) Submerging them in a tub, or
(b) Watering them regularly with a hose to keep them wet all through.
What materials are required to build my floor?

- Earth Fill
- Sand Fill
- Plain Concrete
- Flooring

What materials are required to build my roof?

- **Flat Roof**
  - Reinforced Concrete

- **Sloping Roof**
  - Metal Sheet roofing supported on steel angles
What materials are required to build my floor?

- Earth Fill
- Sand Fill
- Plain Concrete Flooring
- Earth Fill

What materials are required to build my roof?

- Flat Roof
- Reinforced Concrete
- Sloping Roof
- Metal Sheet roofing supported on steel angles
How do I measure materials for construction?

Each cement bag has 50 kg of cement

Inner dimensions of the box made of local wood for measuring sand and aggregates
What proportions of materials do I need?

Concrete for roof slab:
- Cement: 1 Box
- Clean Sand: 1 ½ Boxes
- Aggregate: 3 Boxes
- Water: 22 Litres

Concrete for RC vertical element and bands:
- Cement: 1 Box
- Clean Sand: 2 Boxes
- Aggregate: 4 Boxes
- Water: 22 Litres

Concrete for foundation mat and flooring:
- Cement: 1 Box
- Clean Sand: 3 Boxes
- Aggregate: 6 Boxes
- Water: 22 Litres

Each cement bag has 50 kg of cement.

Inner dimensions of the box made of local wood for measuring sand and aggregates.
How do I make confined masonry walls?

Mortar for masonry

- Cement: 1 Box
- Clean Sand: 4 Boxes
- Water: 20 Litres

Build walls in Flemish Bond
How do I make confined masonry walls?

Clean Sand
4 Boxes
Cement
1 Box
Water
20 Litres

Mortar for masonry

Provide 10mm thick cement mortar joints between brick courses

Course 1, 3, 5, ...
Course 2, 4, 6, ...

Do not build walls in English Bond
Provide vertical formwork with supports for pouring concrete of RC vertical elements at brick masonry wall junctions.

Build a maximum of 1.2 m of masonry wall segments in a day.

- **DAY 1**: 1.2 m
- **DAY 2**: 1.2 m
- **DAY 3**: 1.2 m
- **DAY 4**: 1.2 m

Build the walls leaving slots for RC elements.
Provide vertical formwork with supports for pouring concrete of RC vertical elements at brick masonry wall junctions.

Build the walls leaving slots for RC elements.
Vertical and Horizontal confining elements around all openings prevent early cracking at wall corners.

Lintel, Sill and Plinth bands pass through the vertical RC elements. RC bands and elements support the brick masonry at openings.

Vertical RC elements keep brick masonry segments in place at the corners.
Masonry wall segments confined on all sides with RC elements

RC elements prevent masonry form collapsing

Earthquake ground movement

Vertical RC elements and horizontal RC bands hold masonry wall segments together (like a strap holding a package)
How do I make horizontal RC bands?

**Sill and Lintel Bands**

- Two 10 mm longitudinal Bars
- 6 mm diameter ties @ 200mm c/c

**Plinth Band**

- Four 10mm diameter longitudinal bars
- 6 mm diameter ties @ 200mm c/c
How do I make vertical RC elements?

Reinforcement in Vertical RC confining members around door openings (230mm X 115mm)
How do I pass longitudinal bars of horizontal RC bands through vertical RC elements?

T-Junction of Walls
Reinforcement bars will be at two levels, one above the other

L-Junction of Walls
Reinforcement will be at two levels, one above the other
Straight Walls
Reinforcement bars will be at one level

Reinforcement detail at junction of RC element and RC sill band

Window opening

Elevation

Plan

600

Sill Band
Construction of Confined Masonry House - Option 1
Step-wise Procedure

Construction of a Confined Masonry House entails 3 major phases, namely

Foundation and Plinth
Superstructure
Roof

In this section, sequence of construction is elaborated pictorially in a step-wise procedure to recall all salient steps in the making of a Confined Masonry House.

The following colour code is adopted for the above three phases of construction:

How do I build my Confined Masonry House?
How do I build my Confined Masonry House?

Step-wise Procedure

Construction of a Confined Masonry House entails 3 major phases, namely

Foundation and Plinth
Superstructure
Roof

In this section, sequence of construction is elaborated pictorially in a step-wise procedure to recall all salient steps in the making of a Confined Masonry House. The following colour code is adopted for the above three phases of construction:
Foundation and Plinth

Step 1
Dig a pit 900 mm wide and 900mm deep along the wall line of the house.

Step 2
Pour in this pit plain cement concrete (1:3:6 mix of cement, sand and aggregate) of 150 mm thickness
**Step 3**

Prepare reinforcement grill of RC vertical elements. Use steel reinforcement bars of full height till the roof level, up to which RC vertical elements are required. Provide lateral supports to hold these reinforcement grills during construction.
Foundation and Plinth

Step 4
Lay the first three masonry courses with cement mortar (1:4 mix of cement and sand) over the plain concrete mat leaving gaps near steel reinforcement provided for RC vertical elements.
Foundation and Plinth

**Step 5**
Pour concrete (1:2:4 mix of cement, sand and aggregate) in gaps between brick masonry and steel reinforcement bars.

**Step 6**
Place the next four masonry courses with cement mortar (1:4 mix of cement and sand) above the earlier brick masonry wall.
**Foundation and Plinth**

**Step 7**
Pour concrete (1:2:4 mix of cement, sand and aggregate) around steel reinforcement grill up to the top level of masonry course made so far.

**Step 8**
Place the next four masonry courses with cement mortar (1:4 mix of cement and sand)
Step 9
Pour concrete (1:2:4 mix of cement, sand and aggregate) around steel reinforcement grill up to the top level of masonry course made so far.
Step 10
Place steel reinforcement grill for the plinth beam, and pour concrete (1:2:4 mix of cement, sand and aggregates) for plinth band above brick masonry.
Place steel reinforcement grill for the plinth beam, and pour concrete (1:2:4 mix of cement, sand and aggregates) for plinth band above brick masonry.
Foundation and Plinth

For the construction of Foundation and Plinth, the materials required are:

- **Cement**: 36 bags
- **Sand**: 3.6 m³
- **Aggregates**: 3.2 m³ (Nominal) : 3.1 m³
- **Steel**: High Strength Steel : 180 m of 10 mm diameter bars
  Mild Steel : 190 m of 6 mm diameter bars
- **Burnt Clay Bricks**: 3,600

**Step 11**
Fill the plinth with earth up to 225 mm above native ground level.

**Step 12**
Top the earth fill with 150mm thick sand bed.

**Step 13**
Place the plain concrete (1:3:6 mix of cement, sand and aggregate) over the layer of sand.
Foundation and Plinth

For the construction of Foundation and Plinth, the materials required are:

**Cement**
- 36 bags

**Sand**
- 6.8 m³

**Aggregates**
- 20 mm (Nominal) : 3.1 m³

**Steel**
- High Strength Steel : 180 m of 10 mm diameter bars
- Mild Steel : 190 m of 6 mm diameter bars

**Burnt Clay Bricks**
- 3,600

Step 11
Fill the plinth with earth up to 225 mm above native ground level.

Step 12
Top the earth fill with 150mm thick sand bed.

Step 13
Place the plain concrete (1:3:6 mix of cement, sand and aggregate) over the layer of sand.
**Step 14**
Build masonry wall segments till 75 mm below sill level.

**Step 15**
Pour concrete (1:2:4 mix of cement, sand and aggregate) of vertical RC elements around steel reinforcement grill up to the level of top masonry course.

**Step 16**
Place the steel reinforcement cage and pour concrete (1:2:4 mix of cement, sand and aggregate) for Sill Band.
Walls

Step 17
Cure the vertical RC elements and horizontal RC bands for at least 7 days. Two options are available, namely (a) wetting the RC elements with direct water jet every hour, and (b) cover the RC elements with jute sheets and keeping the jute sheets moist throughout.
Step 18
Build masonry wall segments till 75 mm below lintel level.

Step 19
Pour concrete (1:2:4 mix of cement, sand and aggregate) of vertical RC elements around steel reinforcement grill up to the level of top masonry course.

Step 20
Place the steel reinforcement cage and pour concrete (1:2:4 mix of cement, sand and aggregate) for Lintel Band.
Step 21
Build masonry wall segments with cement mortar (1:4 mix of cement and sand) till the soffit of the roof slab.

Step 22
Pour concrete (1:2:4 mix of cement, sand and aggregate) around steel reinforcement cage of vertical RC elements up to the level of top masonry course.
Walls

Step 23
Bend longitudinal bars of vertical RC elements at the ends into the roof slab

Details of A on next page
Walls

How do I bend reinforcement bars into roof slab?

Wall Corner
Detail A

Inside Wall
Detail B

Wall Edge
Detail C
Walls

For the construction of Superstructure till Roof Level, the materials required are:

**Cement**
30 bags

**Sand**
2.5 m³

**Aggregates**
20 mm (Nominal) : 1.5 m³

**Steel**
High Strength Steel : 260 m of 10 mm diameter bars
Mild Steel : 230 m of 6 mm diameter bars

**Burnt Clay Bricks**
4,200
For the construction of Superstructure till Roof Level, the materials required are:

- **Cement**: 30 bags
- **Sand**: 3
- **Aggregates**: 3
  - 20 mm (Nominal): 1.5 m
- **Steel**:
  - High Strength Steel: 260 m of 10 mm diameter bars
  - Mild Steel: 230 m of 6 mm diameter bars
- **Burnt Clay Bricks**: 4,200
How do I Build my house with a Flat roof

Top Layer of Reinforcing Steel
Along X-direction: below
Along Y-direction: above

Extra bars for
(1) Kitchen and Toilet area, and
(2) Cantilever part of Roof Slab

Confined Masonry Walls

Bottom Layer of Reinforcing Steel
Longitudinal reinforcement grid placed at bottom of slab with 25 mm clear cover

Step 24
Place reinforcement cage of RC roof slab
Roof

Reinforcement at Slab Corner Edge

Section A-A

Top Steel grid

Bottom Steel grid
Step 25
Pour concrete (1:1 ½3 mix of cement, sand and aggregates) of RC flat roof. Finish top surface with a gentle slope of 1:100 to drain rain water to the back side of the house.

Cure concrete in flat roof slab after a day of casting. To hold the water, make small bunds of 25mm height to break the large slab into smaller ponds; use 1:8 cement-sand mortar for making these bunds. Water the slab for 28 days.
Step 26
Cure concrete in flat roof slab after a day of casting. To hold the water, make small bunds of 25mm height to break the large slab into smaller ponds; use 1:8 cement-sand mortar for making these bunds. Water the slab for 28 days.
For the construction of Roof, the materials required are:

**Cement**
- 26 bags

**Sand**
- 1.1 m³

**Aggregates**
- 20 mm (Nominal) : 2.1 m³

**Steel**
- High Strength Steel : 500 m of 10 mm diameter bars
- Mild Steel : 60 m of 6 mm diameter bars

**Burnt Clay Bricks**
- None
For the construction of Roof, the materials required are:

- Cement: 26 bags
- Sand: 3.1 m
- Aggregates: 3 m (Nominal) : 2.1 m
- Steel: High Strength Steel: 500 m of 10 mm diameter bars
- Mild Steel: 60 m of 6 mm diameter bars
- Burnt Clay Bricks: None
How do I build my house with a sloping roof

Ridge Beam
Two ISA 65 x 65 x 6 Steel Angles back to back

Ridge Beam
Two ISA 65 x 65 x 6 Steel Angles back to back

Purlin
ISA 65 x 65 x 6 Steel Angle

Wall Runner
ISA 65 x 65 x 6 Steel Angle

Rafters
Two ISA 65 x 65 x 6 Steel Angles
Perspective View

Roof

- Corrugated Metal Roofing Sheets (1 m x 3 m)
- Metal Ridge Flashing
- Ridge Beam
- Wall Runner
- Rafters
- Purlin
- RC Gable Band
For the construction of the entire house, the materials required are:

- **Cement**: 92 bags
- **Sand**: 3 m³ of 10.4 mm (Nominal) : 6.7 m³
- **Aggregates**: 3 m³ of 20 mm (Nominal) : 6.7 m³
- **Steel**: High Strength Steel : 940 m of 10 mm diameter bars
  - Mild Steel : 480 m of 6 mm diameter bars
- **Burnt Clay Bricks**: 7800
- **Water**: ~1,630 liters for mortar and concrete
  - Extra for curing

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**Steel Channel Section**

screwed to wall runner and purlin

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**Purlin**

**Wall Runner**

**Detail at P**
Material required to build the complete house

For the construction of entire house, the materials required are:

**Cement**
92 bags

**Sand**
10.4 m$^3$

**Aggregates**
20 mm (Nominal) : 6.7 m$^3$

**Steel**
High Strength Steel : 940 m of 10 mm diameter bars
Mild Steel : 480 m of 6 mm diameter bars

**Burnt Clay Bricks**
7800

**Water**
~1,630 liters for mortar and concrete
Extra for curing
Confined Masonry House

Burnt clay brick masonry walls
RC vertical elements and horizontal bands
RC flat roof
Walls first, RC elements next