Confined masonry

Definition

Confined Masonry is a construction system where the walls are built first, and the columns and beams are poured in afterwards to enclose (confine) the wall.
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Concept

The walls are **tied** down to the foundation.

The ties work like a string around a parcel.

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**Difference with RC frames**

**Confined Masonry**
- Walls first
- Concrete later

**Reinforced Concrete Frame**
- Concrete first
- Walls later
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Difference with RC frames

Confined Masonry
Walls ensure rigidity

Reinforced Concrete Frame
Column – beam connections ensure rigidity

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Difference with RC frames

Confined Masonry
Walls are anchored to the frames through indentation.

Reinforced Concrete Frame
Walls are usually not anchored to the frames and will fall out.

(straightforward transmission of efforts)

(Complicated transmission of efforts)

(Additional re-bars will improve anchoring)

(Later anchoring of walls can be difficult)
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Difference with RC frames

Confined Masonry
Reinforced Concrete Frame

All efforts go through the beam-column connection. If they are badly done, they break.

Concrete goes into the indentation of the brick wall

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Summing up

Confined Masonry
Reinforced Concrete Frame

It’s the walls that do the work.

It’s the columns and beams that do the work.

That’s why they are called load bearing walls.

Walls are only infills.

From here on we’ll talk about load bearing walls made with the confined masonry system.
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Walls

A building needs walls for

1. **Protection against climate, view, intruders, etc.**

2. **Carry the roof and/or upper floor (vertical loads)**

When we talk about *load bearing walls*, they will also

3. **Carry the lateral pushes (horizontal loads)**
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Load bearing walls

• They can be made out of:
  • Bricks
  • Stone
  • Cement blocks
  + cement or cement/lime mortar
  + reinforced concrete confinements

• Most importantly, they must be strong.
  • Water the bricks or blocks before use
  • Fill all joints (horizontal and vertical with mortar)
  • Use the right mixture for the mortar (1 bucket of cement for 5 buckets of clean and rough sand)

• All load bearing walls must be confined.

or

• All confined walls are load bearing.
Earthquake resistance

• When we talk earthquake resistance, we are particularly interested in the capacity of a wall to withstand horizontal loads.

• Confined walls work also for horizontal loads.

In an earthquake the ground moves sideward. That’s like pushing the roof. The walls must help to resist this horizontal load.

A serious earthquake (0.35 g) has the same effect on a house as tilting it at an angle of 20.5 degrees. That’s why walls must be strong.
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Distribution of walls

The earthquake resistance of a house is much better, if least two strong walls without openings (called *shear walls*) are placed in each direction. These *shear walls* must be placed as far away from each other as possible.

Special case with walls in the centre

The *shear walls* must be placed symmetrically and as far away from each other as possible to avoid *rotation.*
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Shear walls

Shear walls cannot have any openings and no slits for pipes!

Shear walls should ideally be as long as they are high. Minimum length should be 2/3 of their height.

Shear walls should not be higher than 8 feet.

If the wall is higher, an intermediate bond beam must be introduced at 8 feet.
The total surface on the ground of all shear walls (L x B) in the same direction must be between 1.0\% and 1.4\% of the roof surface (with 2 floors, add up each floor), according to the soil.

Example:
If your roof surface is 400 sqft, the total shear wall surface touching the ground must be 4 to 5.6 sqft (i.e. all shear walls added up)

<table>
<thead>
<tr>
<th>Type of soil</th>
<th>Description</th>
<th>Min. wall surface on ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard</td>
<td>Rock, Gravel</td>
<td>1.0%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>Hard clayish sand</td>
<td>1.2%</td>
</tr>
<tr>
<td>Soft of loose</td>
<td>Loose sand, soft clay</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

The same calculation must be repeated for the other direction.
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Construction details

Step by step

1. Column reinforcements
2. Foundations
3. Plinth beam
4. Walls
5. Doors and windows
6. Bond beam
7. Roof slab
8. Extensions
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Column reinforcements

General rules

Bend hooks at 45 degrees
Alternate position of hooks
Always use steel bars with ridges (smooth rebars may only be used for stirrups)
All rebars must be covered by at least 1 inch of concrete

Prepare columns reinforcements:

Through plinth and bond beams place stirrups at 4” intervals.

Keep this interval for 2 ½ feet in the lower and upper part of the column.
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Foundations

Place column reinforcement on a 2” bed of concrete on the bottom of the foundation.

Don’t put big stones near to the columns in the foundations. The concrete would not be able to get correctly into the reinforcements.

Place bigger pipes into the foundations to prepare future passages for sewage and water pipes.
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Plinth beam

Prepare the reinforcement of the plinth beam

Don't forget: stirrup ends bent at 45 degrees!

Place plinth beam reinforcement on foundation using ‘distance blocks’ or ‘spacers’. The distance blocks must also be put on both sides to keep the distance to the formwork.

Distance blocks (height 1 ½")
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Plinth beam

Connect beams to columns using straight rebars and 'pins'

Overlapping 50 cm

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Brick walls

Use only bricks with 'frogs' or vertical holes

Water the bricks before use
Brick walls

Use the Flamish rather than the English bond. It has an equal number of joints in each layer, thus ensures more regular mortar joints (i.e. all of the same thickness).

Flamish Bond

English Bond

End walls in zig-zag towards columns

Avoid continuous joints
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Brick walls

All joints (horizontal and vertical) must be between 3/8” and ½”.

Join walls carefully by alternating brick connection.

Don’t build higher than 4 feet per day!

Protect fresh walls in hot climates against drying out.
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Improved wall anchoring

• To improve connection between columns and walls, use “stitches” made of rebar anchors (Ø 1/3” or 8mm).
• Place anchors every 1 ½ foot.
• Place the anchor bars in a bed of concrete the height of a brick layer.
• Anchors must end with a hook.

• Link anchors with small stirrups.

• Add horizontal through bands at sill and lintel level, even if you don’t have a window. These bands will secure the wall against being knocked out during an earthquake.

Seismic band at sill level
Seismic band rebars Ø 3/8”, h = brick course
Seismic band at lintel level

Stitches
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Installations in walls

• Don’t break the wall to place electrical or water pipes.
• Try to keep these pipes outside the wall.
• If they have to be in the wall, place them while mounting the wall, by interrupting the wall in zig-zag and filling in with concrete like you do with the columns.

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Doors and windows

Reinforcement around windows and doors

Add 2 rebars on both sides of any window or door

Rebars are bent on both ends and must be well connected to seismic bands.
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Bond beam

Prepare the reinforcement of the bond beam

Don’t forget: stirrup ends bent at 45 degrees!

Connect bond beams to columns with straight rebars and pins.
Roof slab

For spans up to 11 feet

Example of reinforcement bar distribution for a span of 11 feet.
Roof slab

• A roof pulled over the wall edge is another good method (protects the walls against rain).
• But you still have to place a bond beam over the walls as shown on the previous picture.
• Make sure that the slab rebars go correctly through the bond beam.

Water the slab and keep it wet for one week.
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Column – roof slab connection

- If you want the column rebars to stick out of your roof for future extensions, they must be:
  - Long enough (at least 2 feet).
  - Cast in concrete (to ensure correct anchoring).
- Otherwise it’s better to bend them into the bond beam before casting the slab!

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Roof terrace

If you want to make a roof terrace, the terrace walls must be anchored like all other walls.
Roof terrace

Avoid putting your terrace wall on a cantilevered cornice, as it will fall on your head during an earthquake.

Slope roof

You can use the column reinforcement bars sticking out of the roof slab to anchor the beams of a slope roof.
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Retaining walls

The walls of your house must not be in direct contact with the ground!

- If you build against a slope, you must make retaining walls at least 2.5 feet away from the building.
- Retaining walls keep away the pressure of the slope and of the water.
- If you make retaining walls in dry stone masonry or ‘situ’ they must have an inclination of 1 to 5.

To lead away rain water (including all water that has rained on the slope above your house), make a drainage canal around the house.
Gaps between buildings

To avoid damage among two buildings, or an extension to the original building, a gap of 1/100th of the height is compulsory. This gap must be absolutely empty and clean (no mortar rests).

Example: Height of the building 12 feet (3.6m), the gap must be 1 ½” (36mm).
Take into account any future second floor!

Gaps between buildings

Close gaps with bricks placed in front of them. They will brake away during an earthquake, that’s all.
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Find the error

- No distance blocks or spacers in the roof slab.
- These rebars exposed on the surface will rust quickly and become ineffective.

Find the error

- Stirrups are not bent at a 45 degree angle.
Find the error

• The overlapping length is insufficient

Find the error

• Bond beam must be cast together with the roof slab.
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Find the error

- Bond beam must be cast together with the roof slab.
- Depending on the direction (i.e. in the direction of the shorter span), the horizontal reinforcement bars must end in a hook.

Slab is cast against another house.
- There is no movement joint to protect your house against the hammering of your neighbour’s house during a quake.
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Find the error

• These distance blocks or spacers don’t have a wire to attach them to the rebars. They can move while pouring the concrete.
• You should prepare them as shown below, each block with a wire:

![Image of distance blocks and spacers with wires](image1)

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Find the error

• Concrete has not been vibrated correctly to fill every gap.
• You should use a vibrator when casting concrete, or at least hammer against formwork to make sure that the concrete fills every hole.
• Don’t add more water to the concrete to make it more fluent. It will become weaker.

![Image of a wall with holes and cracks](image2)
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Find the error

- Wall is too high without an intermediate seismic band.
- An opportunity has been missed: for little more money a much stronger wall could have been made.

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Further reading

- City (year n/a), *Confined Masonry Construction*, City University London, [www.staff.city.ac.uk/earthquakes/MasonryBrick/ConfinedBrickMasonryP.htm](http://www.staff.city.ac.uk/earthquakes/MasonryBrick/ConfinedBrickMasonryP.htm)