IITK – bmtpc
Earthquake Tip 29
Learning Earthquake Design and Construction

What are the Essential Features of Confined Masonry Houses?

Scope of Construction of Buildings with Confined Masonry

Confined Masonry (CM) system is *suitable* for construction of *low-* and *medium-rise* buildings, and can be implemented with relatively lower engineering inputs and technical supervision. Some countries permit construction of CM houses of up to six storeys tall, supported by *design codes* and *engineering inputs*. CM system is *not intended* for use in the construction of commercial buildings or large span buildings.

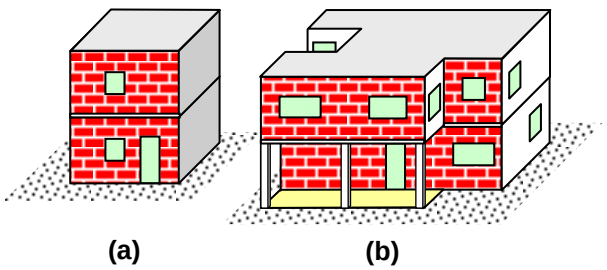
Architectural Guidelines

Architectural configuration critically determines overall earthquake behaviour of CM houses.

(a) Overall Geometry

The overall shape of houses should be regular in both plan and elevation. Best performance is achieved in CM buildings, when, in plan, they (i) are rectangular, (ii) have no significant re-entrant corners and no interior cut-outs, and (iii) have plumb vertical walls along the entire building perimeter (Figure 1a). Buildings with re-entrant corners, cut-outs, vertical offsets and large cantilever overhangs (Figure 1b) perform poorly during earthquakes.

Plan aspect ratio, i.e., ratio of longer and shorter plan dimension (L/B), of a CM house should not exceed 4 (Figure 2); seismic gap can be used in buildings with elongated plan shapes. Typical storey height should not exceed about 3m. Even though buildings up to 6 storeys high have been built in *high seismic regions* in Mexico, Chile and Peru, the recommended maximum number of storeys is 4, 3 and 2 in seismic zones III, IV and V of India, respectively (for now as design codes are unavailable) (Figure 2).



(a) (b)

Figure 1: Overall geometry features – *(a) desirable regular building, and (b) undesirable irregular building*

(b) Wall Configuration

Walls in a CM house should be aligned preferably on a rectangular grid that is symmetrical in plan (Figure 3). Further, all walls must run through from the base of the building to the roof, without being terminated at any intermediate level.

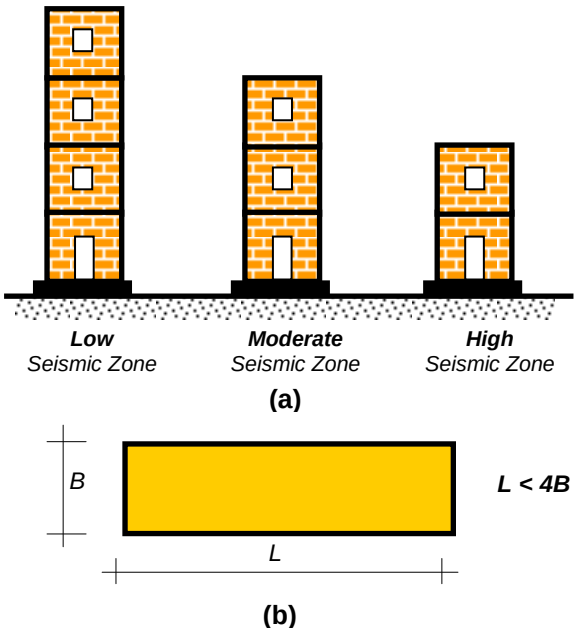


Figure 2: Preferred geometry of CM houses – *(a) maximum height, and (b) plan aspect ratio*

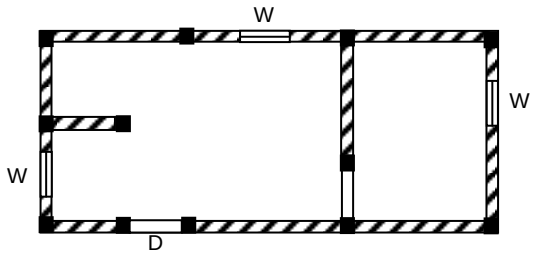


Figure 3: Plan view of CM house showing tie-columns at all wall junctions – *no wall panel is left without a tie-column at each end in plan*

Openings in walls deteriorate earthquake performance of CM buildings. Hence, openings should ideally be kept to a minimum in number and size. Larger openings must be confined by cast-in-situ RC elements all around, otherwise a wall with large openings is considered as unconfined. Openings in all storeys must be positioned at the same location along the height of the building.

Structural Guidelines

Wall thickness required in a building will depend on loads and masonry strength. This should be carefully checked. Masonry walls should be at least *110 mm* thick; their height should not exceed *25 times* thickness. Storey height should not exceed *3 m*, even if thicker walls are used. Ideally, all masonry walls should be *fully-confined* with RC tie-columns on both sides of openings and at wall intersections, and RC tie-

beams above and below it. Earthquake behaviour improves with the number of *fully-confined* masonry walls. For good earthquake behavior, at least a reasonable wall density should be available of *fully confined masonry* (as a percentage of plinth area of the building) in each plan direction of the building; this depends on a number of factors including the expected ground acceleration, number of storeys, and masonry compressive and shear strength. This reasonable wall density varies from 2% to 5%. Minimum depth (height) of RC plinth beams should be *300 mm*.

Many options have been practiced with regard to foundations of CM houses, namely RC tie-column starts from (1) plinth beam (house has no foundation beam), (2) foundation beam (house has plinth beam), and (3) foundation PCC (house has no foundation beam, but plinth beam is used). Option (3) is used commonly (Figure 4).

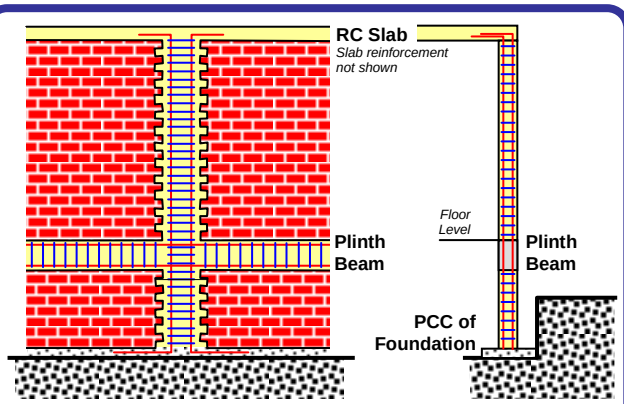


Figure 4: Common Foundation of CM Constructions – *Tie-Column starts from the PCC of the foundation with no foundation beam*

RC tie-columns should be as wide as the thickness of masonry wall, say 230mm in standard burnt clay brick masonry walls in India, although half brick walls are used in many countries, including Mexico and Indonesia. Usually, RC tie-columns provided at wall junctions should be square in cross-section (say *230×230mm*), while RC tie-columns adjacent to openings should be as deep as the wall thickness, but may be less wide in the wall direction (say *115×230 mm*). Proper connections are essential between RC tie-columns and tie-beams, and between tie-beams meeting at wall corners (Figure 5).

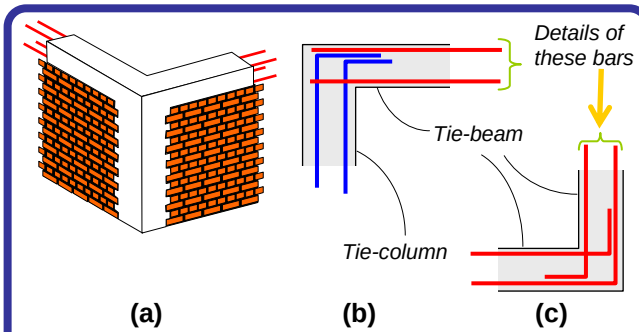


Figure 5: Reinforcement bars in tie-beams and tie-columns – *(a) overview, (b) elevation of tie-column to tie-beam connection, (c) plan view of tie-beam details at a corner*

In tie-columns, at least 4 deformed steel bars of *10 mm* diameter should be provided, and tied with *6 mm* diameter mild steel ties at *200 mm* centers (Figure 6a); closely spaced ties are required in top and bottom portion of a tie-column, with spacing of *100 mm*. Ties should have 135° hook ends. In RC tie-beams, minimum reinforcement to be provided is somewhat similar.

Constructional Guidelines

Using quality materials, *ensuring good workmanship* and *faithfully implementing architectural and structural guidelines* are vital in construction of CM buildings. For improved earthquake performance, the interface between masonry walls and tie-columns should be toothed, *i.e.,* bricks of masonry courses are staggered at the interface with tie-columns (Figure 5a). This ensures that masonry walls are held snugly between tie-columns. Toothing should be such that the minimum gap from bars of tie-column is *25mm* to the nearest brick face and *75mm* to the farthest brick face.

Maximum vertical lift per day of masonry walls should be *1.2 m*. And, concrete for the tie-columns should be poured before the next lift of *1.2 m* of masonry wall is built. This ensures that concrete in tie-columns is reasonably compacted, especially when it is hand compacted.

The formwork is butted against the masonry wall segment for pouring concrete in tie-columns of CM construction. This is the main strength of this construction – snug fit between masonry walls and concrete poured in-situ after the masonry walls are in place. Hence, significant care is required in preparing the formwork (made of wood or steel) and ensuring that gaps are plugged between masonry walls and formwork, before pouring the in-situ concrete of tie-columns.

Related IITK - BMTPC Earthquake Tip

Tip 12: How do Masonry Houses Behave during Earthquakes?
Tip 28: What is confined masonry construction?

Resource Material

Brzev,S.N. (2008), *Earthquake-Resistant Confined Masonry Construction*, NICEE, IIT Kanpur, *www.nicee.org*

Meli,R., *et al*, (2011), *Seismic Design Guide for Low-Rise Confined Masonry Buildings*, EERI and IAEE, *www.confinedmasonry.org*

Blondet,M. (Ed.) (2005), *Construction and Maintenance of Masonry Houses – for Masons and Craftsmen*, Earthquake Engineering Research Institute (USA), Pontificia Universidad Católica del Perú (Peru) and SENCICO, (Peru)

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