

CONFINED MASONRY CONSTRUCTION

Mario Rodriguez, Universidad Nacional Autonoma de Mexico, Mexico

BACKGROUND

Confined masonry construction consists of unreinforced masonry walls confined with reinforced concrete (RC) tie-columns and RC tie-beams. This type of construction is used both in urban and rural areas, either for single-family residential construction or for multifamily construction up to four or five stories in height. In Mexico, in addition to low-rise construction for single-family units, this type of construction is also used for buildings up to seven stories high. In this case, the first two floors are constructed with reinforced concrete structural walls as the lateral load-resisting system; the upper floors are constructed only with confined masonry walls.



Figure 1: Confined masonry housing in Chile (left, WHE Report 7) and Slovenia (right, WHE Report 88)

Confined masonry housing construction is practiced in several countries that are located in regions of high seismic risk. The following countries use confined masonry in housing construction, as reported in the World Housing Encyclopedia (WHE): Slovenia (Report 88), Serbia and Montenegro (Report 69), Iran (Report 27), Mexico, Chile (Reports 7 and 8), Peru (Reports 50 and 51), and Argentina (Reports 1 and 70). Figure 1 shows typical confined masonry housing construction in Chile and Slovenia. The use of this type of construction in these countries is very extensive. For instance, confined masonry accounts for about 40% of the total housing stock in Slovenia, whereas in Mexico, this figure could be higher than 60%. This is a rather modern construction. In most countries, it has been practiced in the last 30 to 35 years. In some countries (such as Slovenia), its wider application is related to the spread of hollow clay blocks in the 1970s. Chile seems to have the longest history related to confined masonry practice dating back to the 1930s. For example, some confined masonry buildings were reportedly affected by the 1939 Chilean earthquake (M 7.8)(WHE Report 7).

The economic level of inhabitants of confined masonry residential construction in the above-listed countries ranges from poor to very rich. With the exception of Slovenia, which has the highest costs for confined masonry housing construction, the construction costs in most countries range from US\$150/m² to \$300/m².

STRUCTURAL FEATURES

Confined masonry construction consists of unreinforced masonry walls confined with reinforced concrete (RC) tie-columns and RC tie-beams. The tie-columns and tie-beams provide confinement in the plane of the walls and also reduce out-of-plane bending effects in the walls. The walls are made of different masonry units, ranging from hollow clay or hollow concrete blocks to solid masonry units of either clay or concrete. Figure 2 shows key structural components of confined masonry construction.

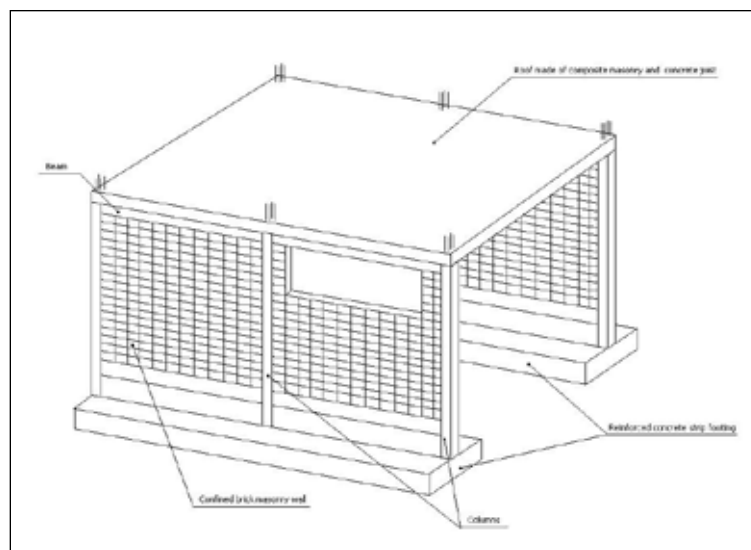


Figure 2: Key structural components in confined masonry construction (Peru, WHE Report 50)

A very important feature of confined masonry is that tie-columns are cast-in-place after the masonry wall construction has been completed. Alternatively, tie-columns are constructed using hollow masonry blocks to allow for placement of vertical reinforcement and cement-based grout. Figure 3 shows an example of the use of both types of tie-columns in residential construction in Slovenia. It can be observed that cast-in-place RC tie-columns are constructed at the first level, whereas hollow-block tie-columns are constructed at the second level. The minimum vertical reinforcement in tie-columns ranges from 4- to 10-mm-diameter bars in Chile and Mexico, to 4- to 14-mm-diameter bars in Slovenia. Both tie-columns and tie-beams have ties that provide confinement to the longitudinal reinforcement and help prevent the buckling of reinforcement. Typically, tie-columns consist of a rectangular section, with cross-sectional dimensions corresponding to the wall thickness, usually within the range of 150 to 200 mm. However, in Slovenia and Serbia, the minimum wall thickness is specified as 190 mm. Figure 4 shows an example of the masonry units used in Slovenia. The spacing of tie-columns is limited to 3 m in Mexico. In Chile, RC structural walls of a minimum 1 m in length are required in buildings in which a plan dimension exceeds 20 m. These walls need to be placed at the building perimeter.

The floor system in confined masonry construction typically consists of composite masonry and concrete joists as shown in Figure 4 or cast-in-place concrete slabs. In some cases, timber roofs are used in combination with tie-beams as shown in Figure 3.



Figure 3: Confined masonry housing during construction in Slovenia (WHE Report 88)

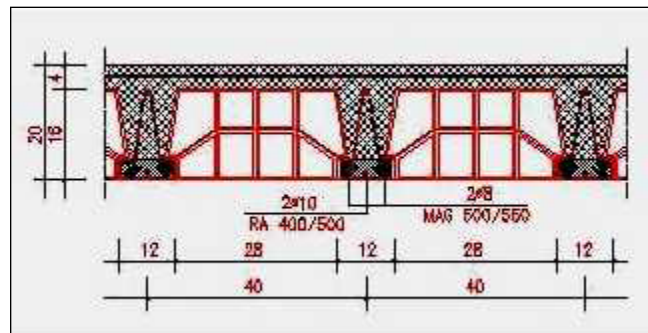


Figure 4: Masonry units used in confined masonry construction (left, Slovenia, WHE Report 88) and a detail of floor construction (right, Serbia and Montenegro, WHE Report 69)

PERFORMANCE IN PAST EARTHQUAKES

If properly constructed, confined masonry construction is expected to show satisfactory performance in earthquakes. The adverse behavior observed in past earthquakes involved houses that were built without tie-columns and/or tie-beams, with inadequate roof-to-wall connection, or with poor-quality materials and construction. Major earthquakes that have affected confined masonry construction include the 1985 Llole, Chile, earthquake (M 7.8) and the 1990 Manjil, Iran, earthquake (M 7.6). Confined masonry buildings suffered light damage in the 1985 Llole earthquake and collapse was not reported. In most of the damaged buildings, tie-columns were missing and the following characteristic damage patterns were observed (see Figure 5):

- Shear cracks in walls that propagate into the tie-columns; most cracks passed through mortar joints. Also, crushing of masonry units has been observed in the middle portion of the walls subjected to maximum stresses.

- Horizontal cracks at the joints between masonry walls and reinforced concrete floors or foundations.
- Cracks in window piers and walls due to out-of-plane action in inadequately confined walls.
- Crushing of concrete at the joints between vertical tie-columns and horizontal tie-beams when the reinforcement was not properly anchored.

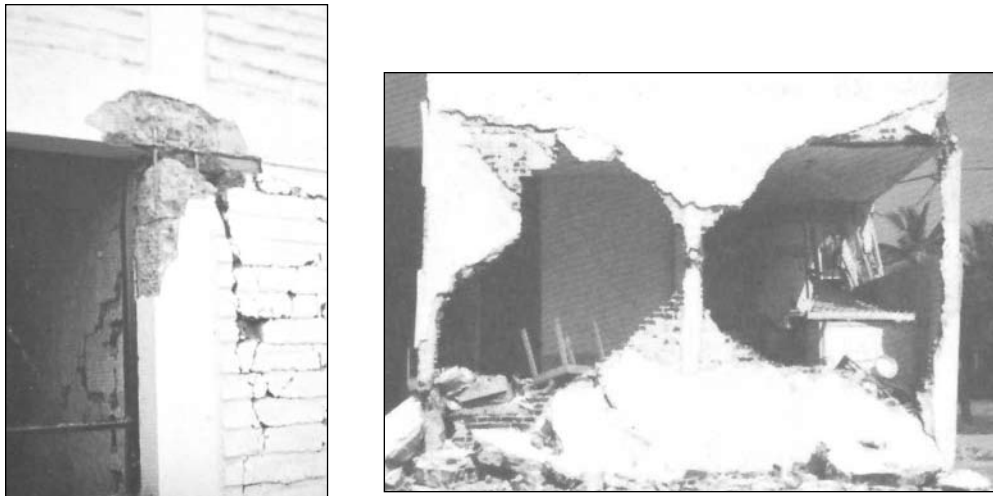


Figure 5: Damage to confined masonry construction in the 1985 Lolleo, Chile, earthquake (Chile, WHE Report 7)

Damage patterns in the 1990 Manjil, Iran, earthquake are similar to the ones reported above (Iran, WHE Report 27), as shown in Figure 6. It seems that the earthquakes of magnitude 6, or smaller, have not caused major damage to confined masonry construction.

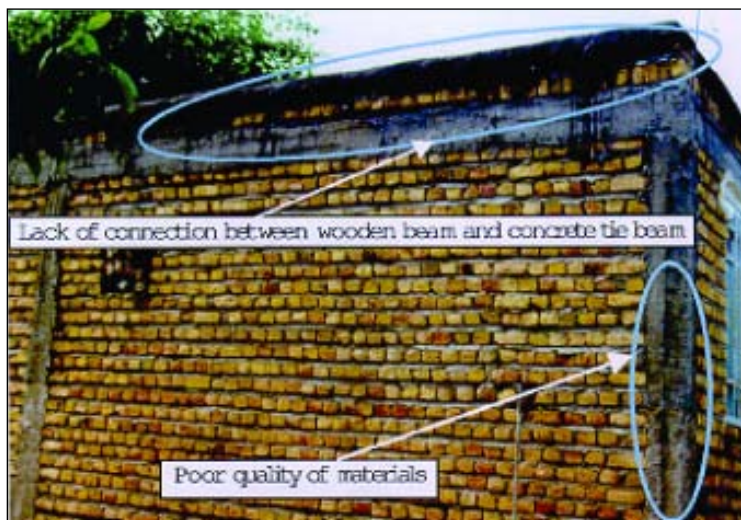


Figure 6: Seismic deficiencies found in confined masonry construction (Iran, WHE Report 27)

