Contact | **Zoe Yin**
Program Coordinator
zoe@eeri.org

EERI Policy White Paper

Earthquake Engineering Research Institute
499 14th Street, Suite 220
Oakland, CA 94612-1934
510-451-0905

EERI Policy Position

International building code writing bodies, academic institutions, and international aid agencies should promote the use of confined masonry as an affordable, earthquake-resistant construction choice for emerging economies in seismically active regions around the world.

Background

Confined masonry is a technology that, if built correctly, performs well in earthquakes. Well-constructed confined masonry buildings have been observed to incur little or no damage when exposed to strong earthquake shaking.

Confined masonry uses the same basic materials of concrete and bricks/blocks that are found in more common construction techniques in areas of high seismic risk around the world, such as unreinforced masonry and reinforced concrete frame construction with masonry infill walls. Because confined masonry uses materials that are commonly available around the world, it can be an affordable and feasible construction choice for low rise buildings (4 stories or less). In contrast, the more commonly used systems have proven to perform poorly in earthquakes as typically constructed.

The key difference between confined masonry and reinforced concrete frame with masonry infill walls is the construction sequence and system. In confined masonry construction, the masonry walls carry the seismic loads while the reinforced concrete confining elements are used to confine individual walls. The confining elements are effective in enhancing the stability and integrity of the masonry walls for in-plane and out-of-plane earthquake loads by confining damaged masonry walls, as well as enhancing the strength and ductility of masonry walls under lateral earthquake loads, hence improving their earthquake performance. This is in contrast to reinforced concrete frame buildings with masonry infill walls where the concrete frames solely carry the loads and infill walls are considered to be nonstructural components. Reinforced concrete buildings with infill walls are much more complex to design and build well, and have proven to perform very poorly in earthquakes, especially when not designed and constructed properly.

Figures 1 and 2. Confined masonry construction in Mexico using multi-perforated clay blocks

Figure 1. *Masonry wall construction*

Figure 2. *Wall intersection showing horizontal steel dowels with 90 degree hooks as an alternative to toothing*

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Confined masonry construction is primarily practiced in countries and regions of high seismic risk. In most of these countries, it has evolved through an informal process based on its satisfactory performance in damaging earthquakes. The first reported use of confined masonry construction was in the reconstruction of buildings destroyed by the 1908 Messina, Italy earthquake (M7.2), which killed over 70,000 people. Later, confined masonry construction was introduced in Mexico City, Mexico in the 1940's to control the wall cracking caused by large differential settlements. Several years later, this system became popular in other areas of high seismic hazard in Mexico due to its excellent performance during earthquakes. This construction technology is now found throughout Southern Europe (Italy, Greece, Slovenia, Serbia, Romania), Latin America (Mexico, Guatemala, Chile, Peru, Argentina, and other countries), the Middle East (Iran), North Africa (Algeria), South Asia (Indonesia), and East Asia (China). Recently, it has also been introduced in India in a first systematic engineered application in the construction of housing on a new university campus in Gandhinagar.

The key components of a confined masonry building are:

1. Reinforced concrete floor and roof slabs transfer gravity and lateral loads to the walls.
2. Confined masonry walls transfer lateral and gravity loads from floor and roof slabs down to the foundations. The masonry walls are enclosed on all sides by horizontal and vertical reinforced concrete confining elements, known as tie-beams and tie-columns; these reinforced concrete elements provide confinement to the masonry walls and protect them from collapse in major earthquakes.
3. A reinforced concrete plinth band transfers the loads from the walls to the foundation system and hence reduces differential settlement; and
4. The foundation transfers the loads to the underlying soil.

Masonry walls in a confined masonry building act integrally with the reinforced concrete confining elements. This integral action is possible due to the unique construction sequence characteristic of confined masonry building technology.

While confined masonry as a building technology is addressed in some countries' building codes (Mexico, Chile, Peru, Argentina, China), as well as by the Eurocodes which are used in the European Union countries, it is more widely treated as an informal technology. This makes it difficult for engineers and architects in countries where its use could be beneficial to use the technology. It is also difficult for international organizations to recommend its use if it is not addressed in codes.

In 2008, the Earthquake Engineering Research Institute (EERI) established the Confined Masonry Network to promote confined masonry construction in seismically prone areas of the world. Confined Masonry Network members have developed guidelines for the design and construction of confined masonry buildings. EERI is committed to continuing this initiative and working with partners to disseminate resources and assist in capacity-building initiatives associated with the application of confined masonry construction.

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Increasing the use of confined masonry is more than a technical problem. In some regions where the technology is needed most, builders may not be literate and require picture-based resources as well as word-of-mouth knowledge transfer. To address this problem, some members of EERI's Confined Masonry Network have worked on materials, through their own organizations, that are primarily pictorial (http://confinedmasonry.org/wp-content/uploads/2015/09/Guide_CCR_EN-A5-XS.pdf) which they have shared with the Network. Such materials have been adapted and used in Haiti, for example, by the Swiss Agency for Development and Cooperation. An even more pictorial guide is under development by the same agency for use in Ecuador. The Swiss Agency for Development and Cooperation also does substantial work in training trainers, who can effectively teach masons and builders in their own communities. There are plans to share these training materials through the Confined Masonry Network.

There is also the perception among some builders and communities in high risk countries that a reinforced concrete frame building is more "modern" and therefore more desirable. Building owners and construction professionals are generally familiar with reinforced concrete frame construction due to its prevalence, but are unaware of its seismic safety concerns and the superior performance of confined masonry. This problem requires education on many different levels, including targeting practicing architects and engineers as well as changes in the engineering curriculum. In many countries the civil engineering curriculum in colleges and universities does not include the structural design of masonry buildings. Training of construction labor is also needed in countries where confined masonry is a new technology. To address this challenge with the masons who were building the first engineered confined masonry buildings on the campus at the Indian Institute of Technology Gandhinagar, training camps for the masons were organized at the construction site.

Needed Action

Multiple groups should promote the use of confined masonry in the following ways:

- Code bodies in various emerging economies should develop code provisions that specifically address confined masonry, based on both the experiences and codes from countries where confined masonry is constructed.
- More training programs and materials are needed for different stakeholders in the construction industry including architects, engineers, builders and construction labor. This also needs to be included in the curriculum in architectural and engineering colleges and universities.
- Aid agencies and international NGOs involved in post-disaster reconstruction work should include training sessions for local masons in the design and construction of confined masonry as integral components to their programs in seismically active areas. Further, by modeling confined masonry construction standards in their own facilities, international agencies would better insure the safety of their employees and guests during earthquakes and improve their ability to use their own facilities, whether owned or rented thereafter.
- EERI's Learning from Earthquakes Program should establish a systematic data collection protocol on the performance of confined masonry after damaging earthquakes. Information was gathered after the 2010 Chile earthquake (http://www.confinedmasonry.org/on-performance-in-2010-chile-earthquake/) but opportunities have been missed to collect data from several more recent earthquakes, in particular in Mexico.

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Partner organizations that can work with EERI to conduct these activities include the International Association for Earthquake Engineering, the Masonry Society, the World Bank, the United Nations Development Program, and the International Code Council.

References and Sources for More Information

Confined Masonry Network (website managed by EERI and IAEE's World Housing Encyclopedia), including resources from countries with codes and standards for confined masonry, construction guidelines and research papers on the performance of confined masonry: www.confinedmasonry.org

Seismic Design Guide for Low-Rise Confined Masonry Buildings (a document prepared by a working group of the Confined Masonry Network): http://www.confinedmasonry.org/wp-content/uploads/2009/09/ConfinedMasonryDesignGuide82011.pdf

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