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CONFINED MASONRY: A CASE OF SUCCESS FOR REDUCING SEISMIC RISK

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ABSTRACT

Confined masonry, CM, is one of the most popular masonry construction systems used in several countries in the Americas, Europe and Asia. One of the first known applications of CM is dated in Italy at the beginning of the 20th century, and was aimed at improving the seismic performance of masonry structures. Since then, CM has also become popular as a method for controlling wall cracking due to differential settlements that typically occur in soft soil areas. Also, because of its ease of construction, CM is very often used as a self-construction method.

Over the years, earthquakes have provided evidence of the high vulnerability, and thus, high rate of damage and casualties caused by masonry structures. However, such lesson is often extended and applied to all kinds of masonry systems, while it should be mostly related to plain or unreinforced masonry structures. In effect, lessons have been learned, and reaffirmed over and over, about the excellent performance of well-constructed CM structures. Because of its good performance, design and construction professionals have adopted CM throughout the world. Moreover, in many countries, codes include design and construction requirements which are permanently under improvement and clarification.

Confined masonry walls are confined vertically and horizontally with tie-columns (TCs) and bond beams (BBs), respectively. In some countries, such elements have very small cross-sectional dimensions. In many countries, width of TCs and BBs is typically equal to the wall thickness. Confining elements are intended to tie structural walls and floor/roof systems together, and to improve wall energy dissipation and deformation capacities. When properly designed and detailed, a significant increase in lateral strength can be quantified.

However, one important role of TCs, typically overlooked or ignored, is their contribution to the overall stability of the building. Experimental data has shown that during seismic-induced forces, inclined masonry cracking causes a continuous reduction of axial stiffness and strength of masonry. This phenomenon is similar to that recorded for cracked concrete subjected to compressive loads. With the reduction in axial stiffness and strength, vertical load acting on the load-bearing wall (i.e. masonry panel and TCs) shifts to the TCs because of their

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relative larger stiffness as compared to that of cracked masonry. As long as TCs remain uncracked, or with minor damage, they will behave as short columns. Even though a TC has small cross-sectional dimensions, and as a isolated member they may be considered as a slender (or very slender) member, shear transfer mechanisms with the masonry panel along their height prevents them from buckling, thus behaving as short columns. If TCs are properly reinforced and protected against premature penetration of inclined cracking from masonry with closely spaced hoops, TCs' vertical load carrying capacity would be maintained, thus preserving the overall stability of the building.

Although masonry units vary a lot from one country to another, in terms of geometry and materials, units display similar performance based on whether they are solid or hollow. Definitions of a "hollow" unit are related to the amount of material (excluding voids) in a gross section. Although percentages are also different from one country to another, a typical value of 50% may be regarded as a limit for hollow; i.e. minimum net area of 50% of gross area. Under earthquakes, hollow units exhibit brittle behavior, which causes a sudden, and seldom large, reduction in stiffness and lateral load-carrying capacity. This is the reason behind lower "ductility" or "seismic-reduction" factors for CM made of hollow units.

As expected from a system that was actually developed at the construction site and not through a rational process of testing and research, most design and detailing requirements are empirical. Aimed at clarifying and providing a more rational framework for CM requirements, a considerable amount of research efforts have been carried out over the past years in several countries. As expected, differences exist in material-related properties, as well as on design philosophy. Nevertheless, when properly designed and constructed, its seismic performance has been superior to most other masonry construction systems.

In effect, most codes require an abundant amount of walls, well distributed over the building plan and height, as well as along the perimeter. Also, codes specify minimum spacing and detailing requirements for TCs and BBs. Typically, TC and BB spacing is such that wall panels are nearly square.

As indicated, due to its simplicity for construction, CM is a preferred method by self-builders. Self-builders are often layman who, due to lack of economic resources or of technical support, are not able to get advice of knowledgeable professionals (engineers and architects) on CM code requirements. This phenomenon leads to CM construction not complying with code requirements, thus considerably increasing the building vulnerability and risk. To counteract such increase in risk, efforts in many countries have concentrated on the development of risk reduction programs, based on training and production of manuals and leaflets aimed at self-builders. Results of such programs vary a lot; however, most successful ones have been those is which the following recommendations have been met:

- Encourage the participation of housing owners (beneficiaries) as stakeholders in different stages of the vulnerability-reduction program, with emphasis on the construction process itself.
- Promote the use of structural solutions akin to the local practice, but with superior performance based on their improved layout, materials and structural features.
- Develop training and educational programs for masons at the local level, and encourage the participation of local universities and professional associations.
- Take advantage of periods of hyper-receptivity immediately following severe earthquakes.
- Develop pilot studies at small-scale, where conditions and results can be used as feedback.
- Disseminate to potential beneficiaries of this program, case studies of success attained in similar areas and conditions.
- Implement economic incentives, mostly related to supplying suitable materials at reduced prices and to temporary employment programs for masons, tied to organized educational programs intended to improve quality and construction knowledge.
- Link vulnerability-reduction efforts to other efforts aimed at improving housing habitability and durability, and at reducing poverty. In all cases, it is important to remember that safety is an ethereal concept, not easily understood and even more difficult to "sell" to a population with serious unmet needs in their everyday lives. Nevertheless, it can be better "sold" if it is accompanied by tangible daily benefits.

CM is a success story for reducing seismic risk in developing countries.