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MASONRY DESIGN FOR LIFE QUALITY AND SEISMIC SAFETY

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ABSTRACT

Here, the use of modern masonry is potentiated as a safe energetic and structural system. Recent evolution of masonry materials is noticed, putting in evidence its functional aspects. The need to design building structures to seismic actions is identified as a requisite to life quality and health in earthquake scenarios. Sustainability of seismic design for masonry buildings requires the consideration of its non-linear capacity, for which performance-based methodologies can be used. Developed tools based in macro-modelling and pushover analysis are available and validated.

MASONRY AND LIFE QUALITY

Historically, the life quality has been associated with the quality of constructions. This fact can early be identified by the use of natural materials as insulation, such as earth material. However, the greater step in the quality of constructions probably was the use of fired clay bricks, which present both constructive and functional advantages relatively to the stone masonry. Since this time, the clay bricks have been continually used, even if its typology and function has changed.

The Industrial Revolution potentiated the mechanized production of ceramic bricks horizontally perforated, whose potentialities allowed a growing development and use of this material. The brick properties were also influenced by the emergent use of reinforced concrete structures, even if the bricks are used as an infill material without significant mechanical requirements.

However, aiming the need of sustainable construction, namely to optimize natural sources instead of the abusive use of artificial climate systems, masonry units have been developed which allow modern masonry structural systems, particularly the plain masonry.

More than the storeys number or the span of constructions, the challenge for construction industry passes for the development of solutions allowing minimal dependence from artificial energetic sources. Then, the use of unreinforced structural masonry in the construction of small buildings is potentiated as a low energy and cost consuming system, which allows saving environmental and economical resources for all.

The industry of masonry units, namely the clay bricks, is particularly developed in countries such as Germany and Spain, where units with high functional and mechanical properties are available to use structural masonry instead of reinforced concrete, with all advantages. For example, the use of a single-leaf wall with the Spanish "Termobrick" (31cm thickness; 0.53W/m2ºK thermal transmittance) alternatively to a double-leaf wall with horizontally perforated bricks (15+11cm leafs + 3cm XPS insulator; 0.54W/m2ºK thermal transmittance; Figure 1) allows an economy of about 25% in the masonry cost; note that in the second case the cost of reinforced concrete piers is added.

Moreover, the structural masonry is a more closed system, which minimizes the loss and compensation of energy, and consequently the impact in the human physical sensations. By this reason, the plain masonry buildings are more comfortable and healthy to inhabit. The use of structural masonry also allows the reduction of accident risk in the construction work.

Figure 1: (a) 1-Leaf Plain and (b) 2-Leaf Infill Masonry

MASONRY AND EARTHQUAKES

Beyond the energetic performance of buildings, its structural safety, particularly the seismic safety, needs also to be verified. The occurrence of recent severe earthquakes, such as the 2010 Haiti and Chile Earthquakes, has putted in evidence the seismic vulnerability of poorly designed buildings (Figure 2).

Figure 2: Buildings Damaged by the 2010 (a) Haiti and (b) Chile Earthquakes

The earthquake resistance of buildings can be considered as a requisite for life quality and health in extreme conditions, since the psychological and physical conditions of persons are affected.

Since the 1970s, as a reaction to some destructive earthquakes in Yugoslavia and Italy, the POR method was introduced for retrofitting and design of masonry buildings. In Italy, this method was extensively used during more than two decades, since it is a simple method which allows an easily implemented storey global analysis, based on the sum of the individual response of walls. However, as a reaction to the 2002 Molise Earthquake the accumulated knowledge until then was spilled in the new Italian code O.P.C.M. 3431/2005 and successive. The new code, which is aligned with the Eurocodes, introduced innovative concepts, particularly the terms for a non-linear static (pushover) analysis. Currently, developed methods are implemented as advanced tools for seismic assessment and design of masonry buildings, such as the commercial softwares ANDILWall/SAM, 3Muri and 3DMacro, and the RAN-inspired method implemented by Marques et al. (2009). All these methods have been evaluated by Marques and Lourenço (2008; 2010).

The referred methods have been implemented with basis in assumptions established from the observation of earthquake-damaged buildings and also from the experimental results of tests on masonry panels. Then, the panels were idealized as macro-elements, which are assembled in 3D models. The safety verification use performance-based methodologies, by controlling the damage and deformation levels of the buildings. The tools need however to be validated in the prediction of the response of buildings, as exemplified in Figure 3 using 3Muri on a building tested by Moon (2004).

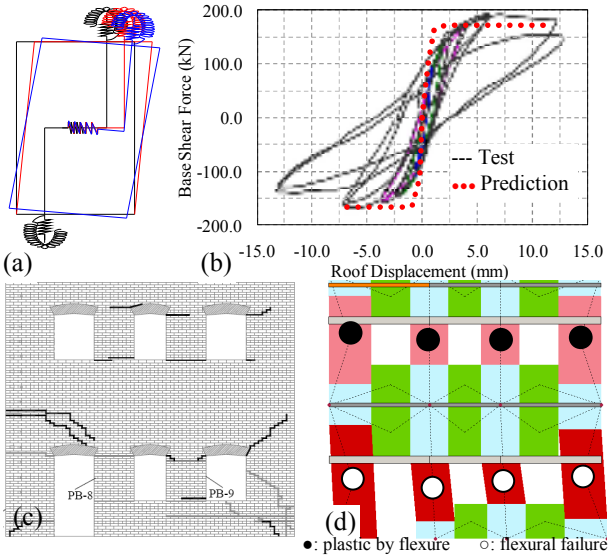

Figure 3: (a) 3Muri Macro-Element; (b) Measured and Predicted Shear Response; Final Crack Patterns from (c) Test (Moon 2004) and (d) Pushover Analysis

Currently, numerical and analytical approaches have been extended to the confined masonry system (Marques and Lourenço 2010b), which has been chosen for example in the rebuilding of Port-au-Prince.

CONCLUSIONS

The current masonry materials are able to optimize functional requirements, which provide better mental and physical conditions for life quality. Sustainability of building construction argues the use of structural masonry in small buildings, for which implemented methods of seismic design are available and validated.

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RUI MARQUES is M.Sc. in Design of Structures and Geotechnics. He currently pursuing the Ph.D. in Civil Engineering at University of Minho, on the analysis and design of masonry structures, granted by FCT.

Rui Marques is a researcher in fields of geotechnics, namely in geomaterial compaction, and of structures, particularly in masonry structures. He has also studied Artificial Intelligence (AI) techniques of Data Mining and Evolutionary Algorithms. He has applied AI techniques to several geotechnical and structural applications, particularly in his M.Sc. study, where he developed a computational prototype to manage the work of geomaterial compaction in transport infrastructures.

Rui Marques has collaborated in several R&D projects, in the fields of transport infrastructures and masonry constructions. He has participated in several studies for design of new masonry buildings, and also one for design of rammed earth constructions. He is author or co-author of about twenty technical and scientific publications in the fields of AI applied to geotechnics and reinforced concrete, and of structural masonry.

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