Semana de Engenharia 2010
Guimarães, 11 a 15 de Outubro

INNOVATIVE SOLUTIONS FOR MASONRY INFILLS

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KEYWORDS
Infill, numerical simulation, shaking table.

EXTENDED ABSTRACT

The stresses induced in a structure by a seismic action have a low probability of occurrence and their magnitude is such that the structure is forced beyond the ultimate limit state. The effective standards in Portugal, and the ones that will be effective shortly, consider the possibility of a seismic action in all the territory, fact that has been neglect by designers and authorities in the last years. This new standard, Eurocode 8, Design of structures for earthquake resistance, defines new standards for infill walls, imposing the use of reinforcement but failing to give detailed information besides the type of reinforcement. Furthermore, the structural designer is the responsible for these non-structural elements. Therefore, with the goal of contributing to the creation of simple design rules for these infills, a shaking table test program of reinforced concrete frame buildings with infill walls, reinforced and unreinforced, will be carried out.

Predeceasing these tests, different numerical simulations of the buildings were carried out, with two main objectives: i) understand the behavior of the structure when subjected to a seismic action, in order to more accurately define the experimental program; ii) using different computational programs and numerical elements to perform static non-linear analyses, assess the capability of a commercial Finite Element Method (FEM) software, SAP2000, to simulate infill walls by means of a diagonal strut, comparing it to a more generic and powerful tool, DIANA.

With SAP2000, the analyses were done with and without infills, and these were simulated using diagonal strut bar elements. Their geometry was computed based on previous works (Fardis, 1996; Safina 2002). The reinforced concrete frame was also modeled with bar elements and hinges with concentrated non linear relations (axial force, bending moment or both, depending on the element) were assigned to the beams, columns and diagonal trusses.

With DIANA, the same static non-linear analyses were carried out, using either beam elements, similar to SAP2000, or a plane FEM mesh. In the beam elements model, the geometry of the trusses that simulate the infill is the same of the SAP2000 model, and all other structural elements (beams and columns) were equally simulated with bar elements. As for the second DIANA numerical model, the introduction of a planar FEM mesh, implied that an interface material between the infill and the reinforced concrete frame had to be modeled. A constitutive model based on total strain, referred to as Total Strain Crack Model, was chosen for concrete and masonry. This type of model defines the behavior of the material, in tension and compression, with a stress-strain relation. It was also definite that this stress-strain relation should be evaluated in a fixed coordinate system, adding the Fixed adjective to the name of the model: Total Strain Fixed Crack Model. The Von Mises yield criterion was used for the rebar. As for the interface, a Coulomb Friction behavior was defined.

The mechanical parameters needed to completely compute these constitutive laws of all models (SAP2000 and DIANA) were obtained from CEB-FIP, Model Code 90, for concrete and rebar, as well as Eurocode 6 and Lourenço, P.B. (2009) for masonry. The load cases for the non-linear static analyses were computed following the prescriptions of Eurocode 8.

After analyzing the obtained results, using bar elements on SAP2000 and DIANA led to similar results, regardless to the presence of infill walls simulated as diagonal struts. As for a FEM mesh model, when comparing bare frame structures, the results are coincident with the bar element ones. When the infill is also simulated, the model presents a higher initial stiffness and slightly higher peak load. The failure modes were not affected by the use of different elements to simulate the infill although, to better analyze this phenomenon, a FEM mesh with a constitutive law that more accurately considers the shear failure should be used.

The shaking table experimental program, using the shaking table of the National Laboratory of Civil Engineering (LNEC), in Lisbon, was idealized with three different specimens, sharing the same geometry. This idealization was done regarding the buildings constructed in the last 20 years, in Portugal. Taking into account the limitations of the referred shaking table, the models were reduced to a scale of 1:1.5, using Cauchy's Similarity Law. This Law relates all the key properties of the prototype (1:1) and the model (1:1.5), enabling its correct design using the prescriptions of the design standards.

The different models were obtained by varying both the standard, from which the design of the reinforced concrete structure was done, and the enclosure system. The first model tries to replicate the buildings constructed in the last two decades and it was designed following the two effective standards: Standard for Reinforced and Pre-Stressed Concrete Structures (REBAP); Standard for Security and Actions of Buildings and Bridges (R.S.A.). The enclosure system also reflects the most common solution: a double leaf, unreinforced, clay brick masonry wall, using blocks with horizontal perforation. In addition, C20/25 concrete and S400 rebar materials were chosen.

The other test specimens represent two enclosure systems that could be future constructive solutions, both reinforced, and designed using Eurocodes 1, 2 and 8. Following what could be a simple, not expensive and effective solution, one infill is made of a single leaf, clay brick wall with bed reinforcement. The reinforcement, applied every two bed joints, consists of a simple truss connected to the reinforced concrete columns. The other system consists also of a single leaf, clay brick masonry wall with light wire anchored to the concrete frame. As for the construction materials, a C30/37 concrete and S500 rebar were applied.

The referred reinforced infill solutions, have already been subject of experimental tests, but neither on a shaking table, nor at such a scale (Calvi, 2004).

At the end of the experimental program, and subsequent analyses of the produced data, the goal is to calibrate the numerical models, introducing the reinforcement of the infills. In this way, several possibilities for simple design rules for the infills, in and out-of-plane, can be planned.

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