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ITALY - INNOVATIVE EARTHQUAKE-RESISTANT SYSTEMS FOR CLAY MASONRY INFILL WALLS:

- **enclosure wall with "deformable bed-joints".** *INSYSME partners:* ***ANDIL – UNIPD***
- **enclosure wall with "sliding bed-joints".** *INSYSME partners:* ***ANDIL - UNIPV - RUREDIL***

There is still a year to go on the INSYSME research project, co-funded by European Commission under FP7, which is expected to benefit SMEs and create new opportunities for the European clay masonry industry and construction sector. The innovative systems conceived and developed in Italy have produced excellent results and are now in the final phase of experimental validation and practical demonstration.

Under the framework of INSYSME, a European research project aimed at developing advanced earthquake-resistant infill walls, teams of Italian researchers developed two innovative systems. The researchers from the Universities of Pavia-UNIPV and Padua-UNIPD (*WP3 – Product and construction technology development*) assessed the systems' performance through parallel numerical studies (*WP4 – Modelling of seismic response),* experimental campaigns *(WP5 – Multi-scale experimental testing)* and also by building of applicative prototypes *(WP6 – Demonstration of constructability).* The systems and the materials were designed to guarantee the required performance for infill walls. These systems can be used both in new buildings and in existing buildings when infill walls have to be substituted.

UNIPD system board & video of the practical demonstration of wall specimen laboratory construction
UNIPV system board & video of the practical demonstration of wall specimen laboratory construction

The principal objective of the project is to identify and develop optimised masonry enclosure solutions for enhanced earthquake resistance, respecting local materials and construction practice, and to provide clear design rules so that the proposed systems can be used effectively. The publication of design, detailing and construction guidelines for masonry infill walls and veneers, as well as accompanying software for design, is aimed to constitute helpful additional tools to promote the new systems (*WP7 – Guidelines for optimised design*). The future transposition of the design rules and procedures implemented in the more technical codes will enable the most crucial goal of INSYSME project, namely complementing and adding value to research results. In accordance with the aforementioned project objectives, Italian association ANDIL submitted two application patents as applicant holder (*WP2 – Dissemination, training and exploitation*).

UNIPD (Inventors*: C. Modena, F. da Porto, Giovanni Guidi and Nicolò Verlato*) and ANDIL proposed a system named DRES "Damage Reduction Enclosure System", which is a single-leaf clay masonry enclosure to be employed for low to medium height residential or commercial reinforced concrete (RC) frame buildings in regions prone to medium to high intensity earthquakes. The system uses thick vertically perforated clay blocks and introduces special horizontal rubber joints in the infill wall. The units must guarantee the robustness to sustain the in-plane and out-of-plane design loads; and thanks to the rubber joints, the new construction system allows the masonry infill walls to absorb the movements imposed by the frame, when this is subject to significant seismic action, thereby minimizing damage to the wall. In addition, the system has two rubber joints between the masonry infill wall and the RC columns characterized by a low compression stiffness in order to reduce displacement requirements for the infill and avoid stress concentrations that may damage the frame columns and the masonry infill wall itself. Understanding the combined in- and out-of-plane behaviour of new system, the experimental tests have been carried out on one-bay, one-story frames, filled with masonry walls. The preliminary results of in-plane cyclic tests showed that the *inter-storey drift* (relative lateral displacement between two consecutive floors in a building, expressed as percentage of the storey height)

reached 2.4% (6.9 cm for the lateral displacement of the top beam of the specimen) and small to medium cracks were found mainly along the interface infill wall/frame and secondly within the masonry bands. Moreover no clay blocks were crushed and the RC frame was unharmed following interaction with the infill wall. As a demonstration activity within the project, prototypes of UNIPD construction system were built for the final Ediltrophy competition, a building race organised by Formedil and ANDIL, in the context of the SAIE fair (International Building Exhibition). The final competition took place on 17 October 2015 at SAIE in Bologna with 20 senior worker teams from all over Italy who were presented with the challenge of building an innovative and technological construction that meets the requirements of the INSYSME project.

UNIPV (Inventors*: G. Magenes, P. Morandi and R. Milanesi)* developed the innovative masonry infill system with "sliding joints", together with ANDIL and RUREDIL. The seismic solution aims to reduce the in-plane interaction between the masonry infill wall and the RC frame. The solution divides the clay masonry panel into four horizontal bands that are able to slide over each other through properly conformed sliding joints composed of a ribbed profile in plastic-type material bedded in the mortar joints. Between the masonry and the RC members there are thick joints filled with a specific small stiffness cement-based mortar to keep the adherence between the masonry infill wall and the RC frame. The masonry is made up by robust in-plane and strong clay units and general purpose mortar. The out-of-plane stability is guaranteed by suitably designed shear keys attached to the columns; the units at the edges of the infill adjacent to the columns and to the openings are shaped with a recess in order to accommodate the shear keys. The energy dissipated through the sliding joints should also provide additional damping to the structure. Through a combined use of the sliding joints included in the clay masonry and deformable joints at the wall-frame interface, it will be possible to limit the in-plane damage of the masonry infill wall even at significant level of drift demand and to reduce the local effects on the RC member. In-plane cyclic tests were carried out on single bay and single storey RC frame infilled with the innovative solution, followed by dynamic tests on shaking table for the application of out-of-plane action on the panels. With the in-plane cyclic pseudo-static test of RC frame infilled without openings, the *inter-storey drift* reached 3.0% – or a lateral displacement inter-story equal to 9.4 cm. This resulted in the RC structural elements showing plastic hinges at the base of the pillars and at the end of the beams; while, for the enclosure wall, the cracks remained substantially localised in the layer of plaster and in areas close to the sliding joints without any significant damage to the clay masonry parts. In addition, in November 2015 a **full scale two-storey RC building infilled** with the proposed system was dynamically tested **on the shaking table** at Eucentre laboratory of Pavia. The seismic input applied to the INSYSME building refers to a natural accelerogram – recorded in "Ulcinj, Albatros Hotel" during the earthquake of Montenegro of 04/15/1979 (Mw 6.9) – scaled from acceleration (PGA) low (0.1g) to increase up to very high values (1.2g), corresponding to particularly violent and potentially very destructive earthquakes. With the last accelerogram at high intensity, the first storey experienced a significant shift of about 10 cm (more than 3% of inter-drift) without the infill walls suffering damage that would compromise the safety of its inhabitants.

The design and construction methods for each innovative enclosure wall systems will be implemented on the basis of the experimental and numerical results obtained. This will also enable the review of national and European Codes to make engineering design easier and more reliable.
ANDIL, and the other SME Association partner of INSYSME, will collect information and contributions from the RTD performers on the progress of the implementation of design recommendations. ANDIL will also relay useful feedback on possible regulatory improvements to TBE members and specific standard committees (e.g. CEN TC 125 and CEN TC 250).