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Innovative seismic isolation of masonry infills using cellular materials at the interface with the surrounding RC frames

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ABSTRACT

In this study an innovative concept is proposed to isolate – at low and moderate storey drifts – infill panels from the surrounding reinforced concrete (RC) frame, using thin layers of cellular materials. The concept is verified experimentally through testing of three fully infilled (i.e. at full height) and two partially infilled (i.e. at reduced height) RC frames with different infill-to-frame interface contact conditions under in-plane cyclic loading. The shear strength, hysteretic behavior, damage evolution and stiffness degradation of conventionally infilled RC frames is compared with the respective properties of frames with isolated infills. The experimental results show that fully infilled test specimens exhibit much more severe damage than the isolated ones, leading to the conclusion that the proposed isolation system significantly preserves the integrity of infill panels at moderate storey drifts and increases shear strength and lateral stiffness of the infilled frames at higher deformations. Additional tests on frames with infills at partial height show that cellular material joints at the sides of infills decrease the adverse effects of the infill-frame interaction. Finally, it is demonstrated that mechanical properties, contact conditions and joint thickness of the cellular material influence the overall hysteretic behavior of the specimens. A simple analytical model is developed, combining single-strut elements for the infills with nonlinear springs for the cellular material joints. The model, implemented in OpenSees, is in good agreement with test results. The concept is demonstrated through parametric analyses in full scale RC structures. Overall, it is concluded that the proposed technique has a high potential in reducing infill-frame interactions – hence damage of the infills – up to moderate drifts, whereas full interaction – hence increased capacity – is still in place when drifts are large.

1. Introduction, background and concept development

In most design codes masonry infill panels are usually considered as non-structural elements, whose only role is to provide an external cladding and partition between different compartments of a building. However, in practice, infills almost unavoidably interact with the surrounding reinforced concrete (RC) frame having great effect on the overall performance of the structure (e.g. [8,20]). Observations made after major earthquakes [e.g. Kobe Japan 1995 (M_w 6.9), Athens Greece 1999 (M_w 5.9), Kocaeli Turkey 1999 (M_w 7.6), L′ Aquila Italy 2009 (M_w 6.3)] have shown that if the contribution of masonry infills to the lateral strength and stiffness of the building is high relative to the strength and stiffness of the structure itself, the infills may affect the control of inelastic response, hence the seismic design of the structure. Due to low tensile strength and brittle behavior of infills, seismic design codes refer to the potential negative influence of infill panels to the structure as follows: (a) the loss of integrity of the infills in the ground storey may produce a "soft" storey and trigger global collapse; (b) the non-uniformly distributed position of infills in plan or in elevation may concentrate inelastic deformation demands in the part of the building which has more sparse infills; and (c) local effects of infills may cause pre-emptive brittle failure of frame members, notably columns. Moreover, recent studies (e.g. [26,9]) have shown that the cost related to the failure of non-structural components in a building (damage at infills and facades, loss of inventory, damage at electrical and mechanical equipment, loss of business etc.) may exceed by far the cost of repair of structural elements. Furthermore, the failure of non-structural components, such as infills, can become a safety hazard or can hamper the safe movement of occupants evacuating buildings, or of rescue workers entering buildings.

A number of techniques for improving the seismic performance of infilled RC frames by isolating the infill panels have been reported in the literature. Some studies in this field deal with the complete separation of the infill panel from the surrounding frame by intentionally creating a construction gap (e.g. [22,11,13]). Other solutions aim at: (a) ensuring a sliding mechanism along predetermined layers of the infill in

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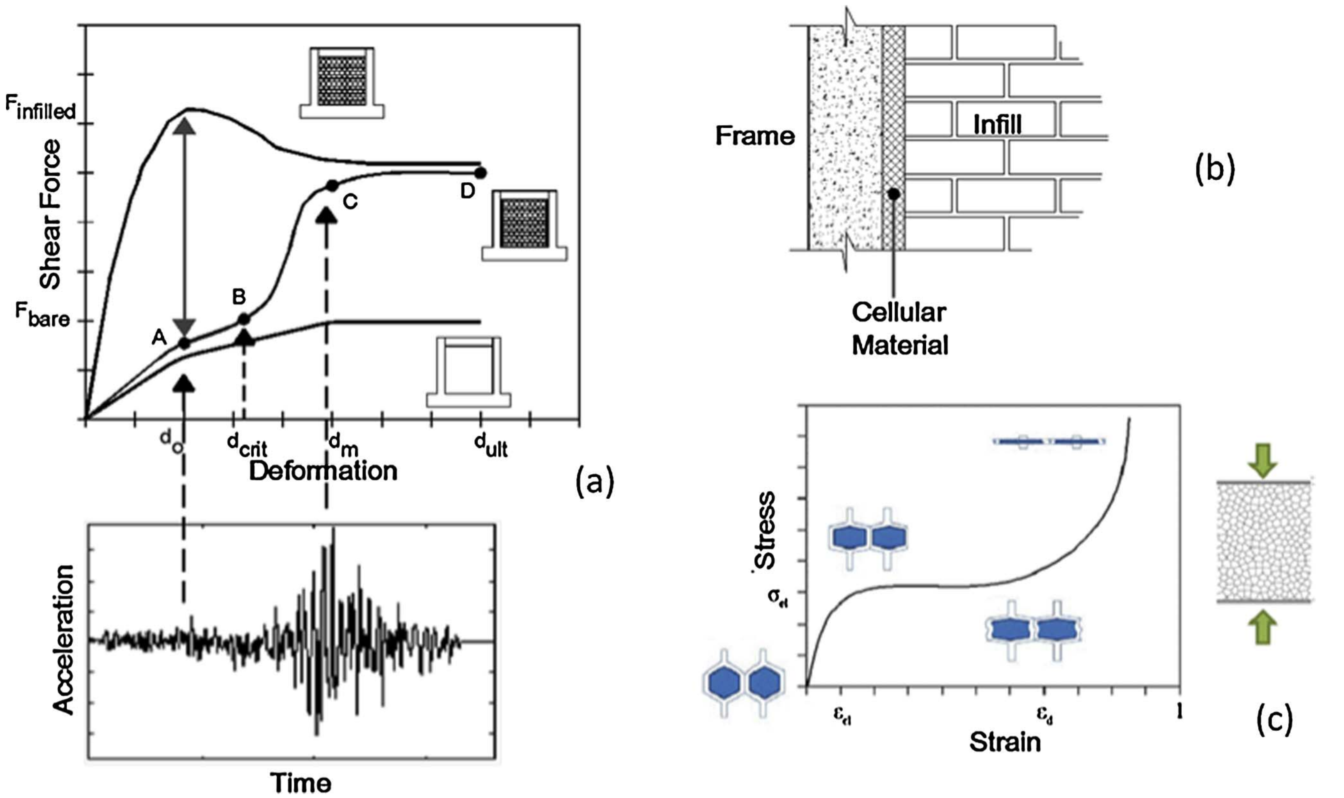

Fig. 1. Schematic illustration of the proposed concept: (a) Response of RC frame with isolation using cellular materials; (b) placement of cellular material at the frame-infill interface; and (c) behavior of cellular materials in uniaxial compression.

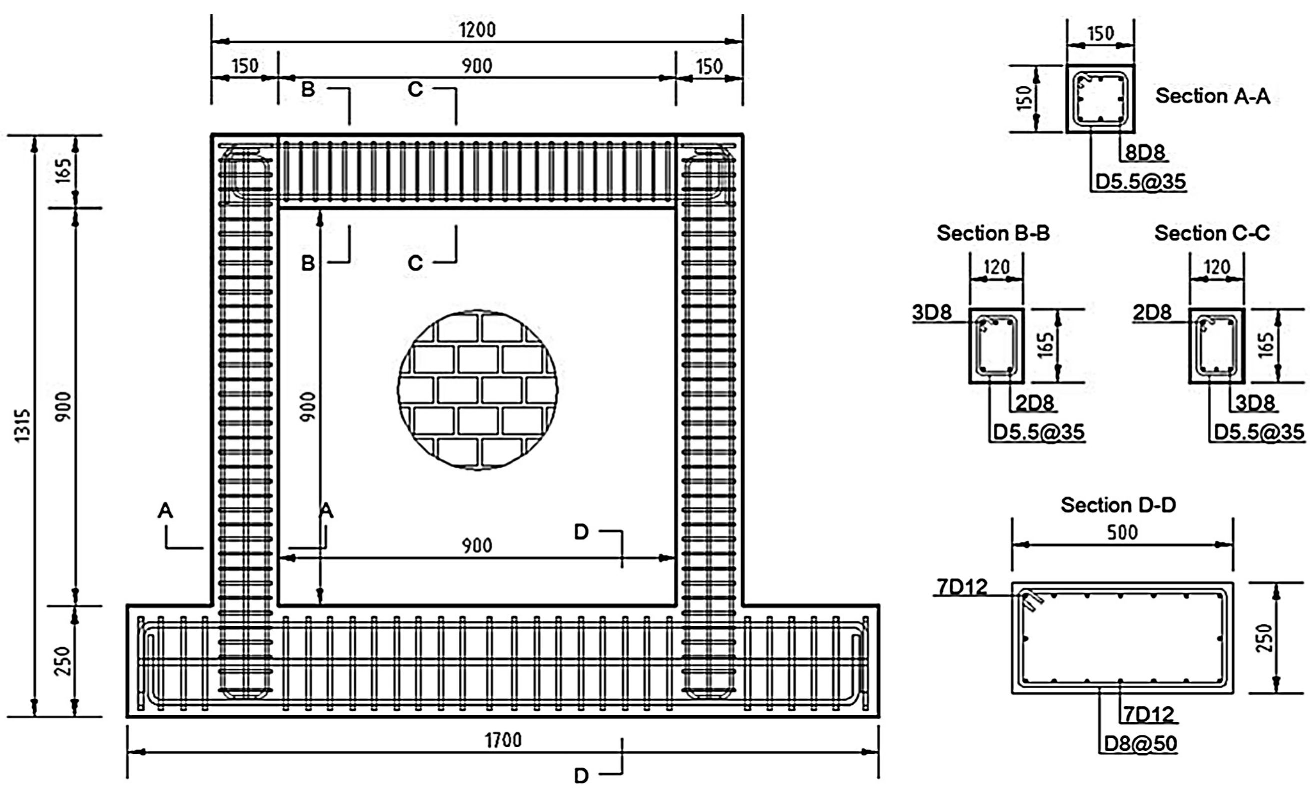

Fig. 2. Geometry and reinforcement of test specimens (dimensions in mm).

order to obtain a ductile response and reduce the in-plane strength and stiffness (e.g. [19,18,21,3]); (b) reducing the damage and the infill stiffness by adopting softer masonry blocks in the infill in contact with the surrounding frame (e.g. [16]); (c) the application of dissipation devices (isolators or fuses) in the perimeter of the infill (e.g. [1,23,14]); and (d) obtaining a more deformable masonry by substituting the