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Recent Results on Masonry Infill Walls

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Abstract The paper summarizes the main research findings on masonry infill walls which were obtained within the framework of a comprehensive NSF-NEESR-SG project directed by Prof. Benson Shing at UC San Diego (Shing et al. 2009). The main focus of this contribution are experimental and computational observations on 2/3 scale unreinforced masonry panels bounded by a reinforced concrete frame which were subjected to cyclic push-over testing at CU Boulder under constant vertical pre-loading. This study included two-wythe masonry panels of 133in x75.5in size (3.378 x1.897m) with and without openings in form of eccentric windows and doors. The background experiments did include a suite of masonry prism tests on rectilinear and slanted masonry prisms providing important insight into the composite behavior of mortar and brick construction. The paper concludes with remarks on the experimental observations when the panels were integrated into infill walls of two-bay width and three-story height with and without retrofits of reinforced ECC layers (engineered cementitious composites) which were attached to one side for quasistatic testing at CU Boulder, and to both sides of the wall for dynamic shake table testing at UC San Diego.

Keywords: Masonry infill wall, reinforced concrete frame, push-over test

Masonry Prism Test

The masonry prism tests in Figs. 1 and 2 were accompanied by two series material property tests on mortar and brick units. The prisms were made of five brick units and four mortar bed joints using half-length bricks because of the size and capacity limitations of the servo-controlled 110 kip MTS material testing system.

Fig. 1 illustrates the basic prism configuration after failure in the form of axial splitting, both in-plane as well as out-of-plane. Fig. 2 demonstrates the effect of mismatch among the brick and mortar properties which introduces triaxial stresses as long as there is no loss of interface bond. Consequently we observe a more than two-fold increase of compressive strength of the composite masonry prism when compared with the strength of the weak mortar layer in uniaxial compression. In fact, it is elementary mismatch of elastic properties and in particular the inelastic mortar properties which introduces triaxial confinement and hence more than doubling of the mortar capacity, and tensile lateral stresses in the brick units leading to axial cracking and splitting of the entire masonry prism, (see (Hilsdorf 1965), and recently (Blackard et al. 2009)). In short, the axial compression test of the masonry prism is effectively a lateral tension test of the brick units similarly to the Brazilian indirect tension test widely used to evaluate the tensile strength of concrete. Another puzzling observation is the brittle appearance of the post-peak response of the masonry prism when compared with the ductile response behavior of both the mortar as well the brick units when tested under stroke control. Whereas the tensile cracking process of the brittle brick units provides an obvious explanation for the axial splitting mode of prism failure, there is another scenario in the form of a snap-back instability. This has to do with the early compression softening in the weak mortar layers which introduce stress reversals and energy release in the form of snap-back instabilities (Willam et al. 2010). Henceforth, there are two explanations for the brittle appearance of prism failure in Fig. 2, (a) either due tensile crack initiation in the brittle brick units, or (b) snap-back instabilities due to localized softening of the mortar bed joints in compression.

Figure 1: Failure of masonry prism as result of compression test

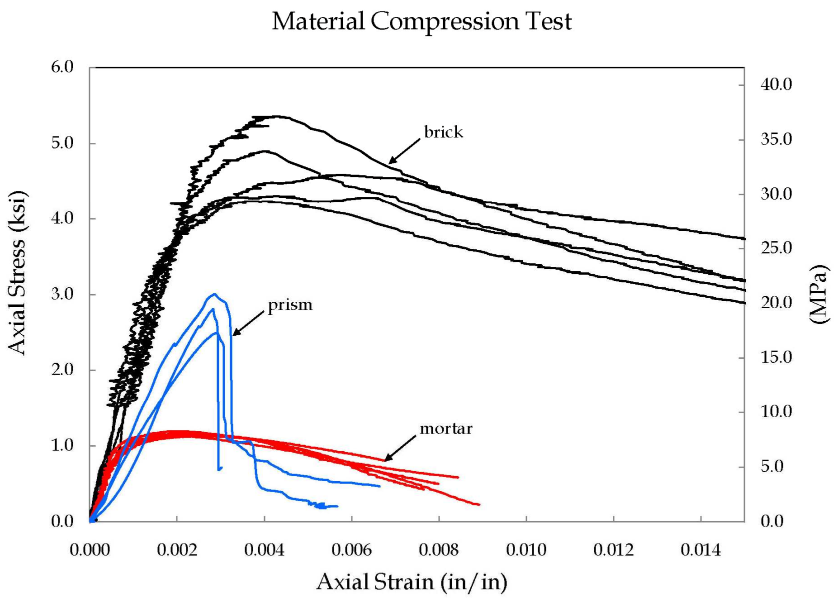

Figure 2: Axial compressive behavior of brick unit, mortar, and masonry prism

Masonry Infill Wall Tests

A representative example of the CU Boulder test series on infill walls with and without opening is illustrated in Fig. 3. It shows the effect of a small eccentric window on the overall behavior of the infill wall. The concomitant Fig. 4 depicts the lateral force-story drift response behavior when the infill wall is subjected to cyclic load reversals by a horizontal 220 kip [979 KN] actuator mounted at the end of the top beam under constant vertical preloading of 2x35 kips [312 KN]. We observe formation of a large inclined crack in the left RC column at the positive load cycle P18 which is associated with a large drop of the shear capacity of the infill wall. In Fig. 4. Moreover we note ovaling of the rectangular window at drift levels of p/m 1.5% while the sustained shear capacity of the infill wall beyond p/m 2% is not shown in the graph for reasons of resolution.

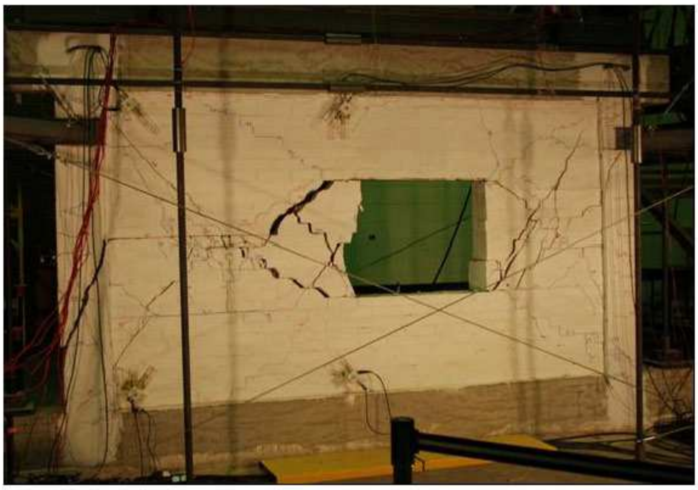

Figure 3: Final crack pattern of infilled frame with eccentric window opening (Blackard et al. 2009)

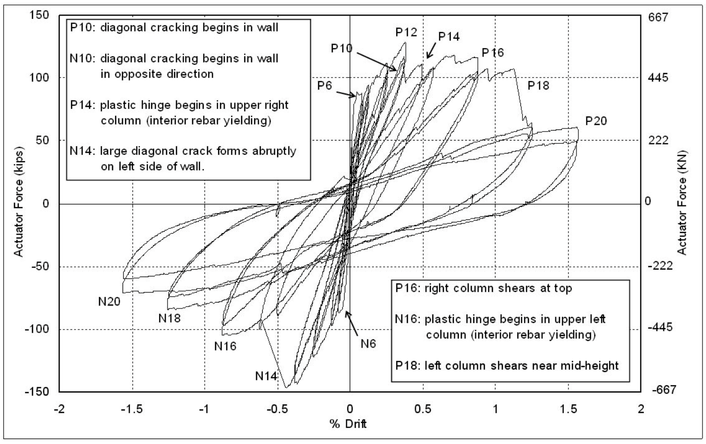

Figure 4: Lateral force vs drift response of infilled frame with eccentric window opening (Blackard et al, 2009)

The test results of the experiments with and without wall openings are summarized in Fig. 5 in the form of envelope curves omitting the details of the cyclic response behavior. The figure illustrates the results of the solid infill wall denoted by S with the envelope characteristics of different openings. Thereby SW stands for a small window, LW for a large window, and D for door all located at the same eccentricity. Note the different wall openings exhibit a moderate decrease of stiffness and strength while the residual shear capacity of more than one third of the maximum shear strength turns out to be quite insensitive with regard to the geometry and size of each opening.

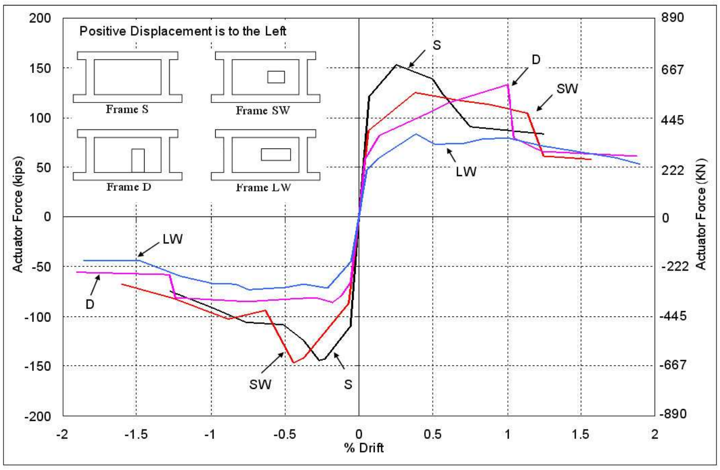

Figure 5: Effect of opening on response envelops [Blackard et al. 2009]

Conclusion

The unreinforced masonry infill walls did exhibit surprising resilience up to drift levels of p/m 2% in spite of the brittle nature of unreinforced masonry and the use of non-ductile bounding RC columns. This was partly die to the confinement of the vertical preloading which plays an important role on the overall performance of masonry infill walls.

Acknowledgement

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