Evaluation of a Sprayable, Ductile Cement-based Composite for the Seismic Retrofit of Unreinforced Masonry Infills

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The research to be presented in this paper and presentation is on a sprayable, ductile cement-based composite that is being investigated to retrofit unreinforced masonry infills in non-ductile reinforced concrete frame structures. Retrofitting such structures is challenging. Many retrofit techniques being used or proposed enhance the strength of the masonry infill which can be desirable for certain structures (e.g. steel frames) but not for others (e.g. non-ductile reinforced concrete frames).

The proposed retrofit technique uses a thin layer of sprayable, ductile fiber-reinforced mortar material referred to as Engineered Cementitious Composites, or ECC. ECC uses 2% by volume of polymeric fibers and can carry direct tension up to roughly 3% strain (Figure 1) and does not spall in compression. When reinforced with steel or wire mesh, the ECC and steel yield and deform compatibly with no bond deterioration. In the proposed retrofit, the ECC is applied to one side of the wall, preserving the aesthetics on the other side, and at less than 50mm thick, adds minimal weight to the existing structure. The aim of the retrofit is to improve the seismic performance of non-ductile frame-infill systems by holding the masonry wall together, delaying strength degradation and enhancing system ductility. The research is a collaboration between Stanford University, The University of Colorado at Boulder and the University of California at San Diego, and covers the experimental performance ranging from quasi-static to large-scale shake table testing of unreinforced masonry infills in nonductile concrete frames with and without openings as well as with ECC retrofits. An additional goal of the collaborative research is to develop reliable and simple analysis tools to predict the response of these retrofitted structures ranging from detailed finite element modeling to simple strut models. The research team is advised by a panel of practicing professionals with expertise in masonry performance in seismic regions.

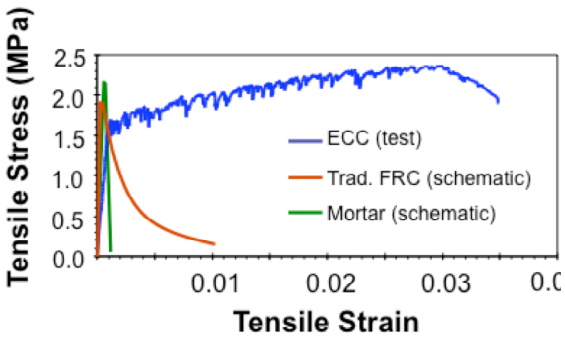

Figure 1. Uniaxial tensile response of ECC

This paper and presentation will describe the research findings, both experimental and analytical, focused on the ECC retrofit evaluation. Proof-of-concept experiments on retrofitted masonry prisms and beams will be presented wherein large increases in strength and ductility were identified. These experiments are being used to develop finite element modeling approaches for system predictions. Highlights of the quasi-static cyclic testing of small-scale frames with masonry infills including 3 retrofit designs will be presented. An increase in ductility of 10x was achieved in the final design relative to the unretrofitted system tested (Figure 2). These results were then used to design a retrofit for larger-scale tests conducted at The University of Colorado at Boulder using a simple strut & tie modeling approach. The design and correlation with the larger-scale test results will also be presented. Finally, preliminary

work on developing modeling techniques to predict the performance of ECC-retrofitted unreinforced masonry infills will be reviewed including sequential linear analysis for predicting nonlinear behavior of large-scale structures.

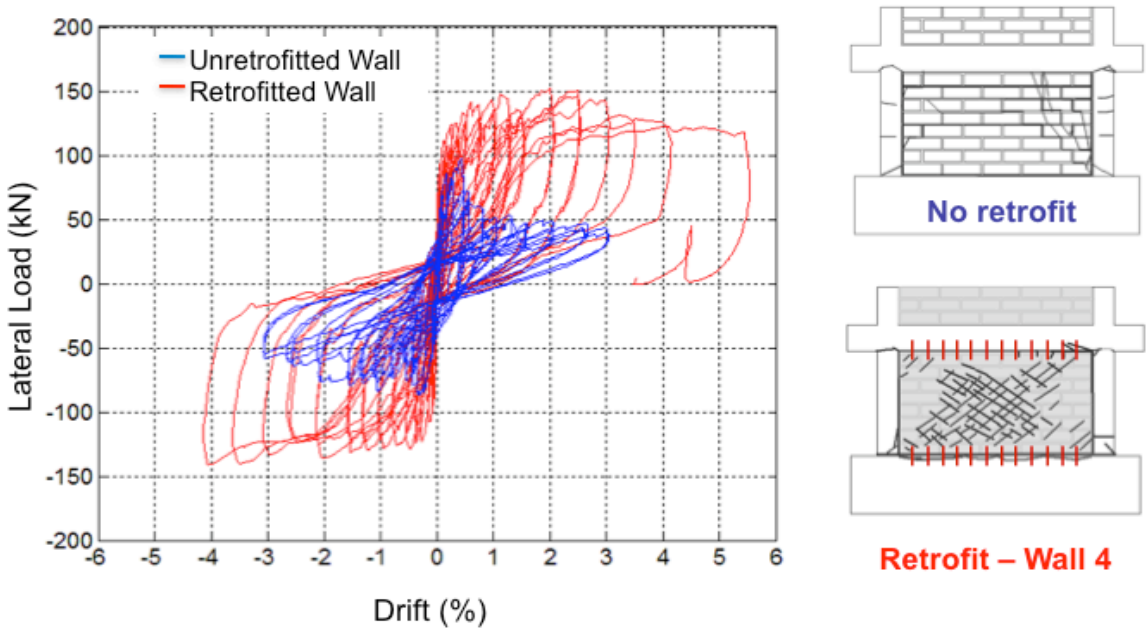

Figure 2. Hysteretic response of the unretrofitted wall and the final retrofitted wall