ABSTRACT

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Degree Received: May 2018
Title: Multi-Hazard In-plane Response of SC Walls: Out-of-plane and Accident Thermal Loadings
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Steel-plate composite (SC) walls have been used for the third generation of nuclear power plants, and are being considered for small modular reactors of the future. Modular SC walls are also being considered for commercial applications, owing to their structural efficiency and construction economy. Walls in important structures may be subjected to combination of demands due to cascading hazards. Experimental and numerical studies were conducted to evaluate the in-plane response of SC walls (with boundary elements) and wall piers (without boundary elements) subjected to out-of-plane and accident thermal loadings.

First series of experiments comprised of four SC wall pier specimens. One control specimen was subjected to in-plane loading (no out-of-plane loading). Three specimens were subjected to different magnitudes of out-of-plane loading in combination with in-plane loading. Experimental results indicate that the in-plane response of wall piers with aspect ratios greater than or equal to 0.6 is flexure dominated. Introducing an out-of-plane force results in out-of-plane shear and moment in the wall piers. Wall piers subjected to out-of-plane shear equal to their nominal shear strength (per US codes) develop flexural yielding and failure due to interaction between the in-plane and out-of-plane moment. Shear failure does not occur for these wall piers. The wall pier specimen subjected to out-

of-plane shear force that is 2.5 times the nominal shear strength (per US codes) was forced into a shear failure mode by the interaction of in-plane shear and out-of-plane shear.

Second series of experiments involved subjecting one SC wall and one SC wall pier specimen to different magnitudes and durations of accident temperatures in combination with in-plane loading. Experimental results indicate that typical accident temperatures (up to 232˚C) do not result in significant reduction in in-plane strength of walls and wall piers. The strength for accident temperatures can be estimated using existing strength equations (per US codes). However, accident thermal loads result in a significant reduction in the stiffness of wall and wall piers. The reduction is primarily due to concrete cracking, and depends on the magnitude of accident temperature. Stiffness reductions of up to 40% of the ambient stiffness were observed.

Three-dimensional finite element models were developed for the two sets of experiments. Additionally, a fiber based model was developed to evaluate biaxial moment interaction for SC wall piers. The fiber model was then updated to include axial force-moment interaction and vector shear failure. Results from the numerical models compare favorably with experimental observations, and provide additional insights into the behavior of the specimens.

Experimental and numerical results formed the basis of strength and stiffness recommendations for SC walls and wall piers subjected to combined in-plane and accident thermal loading. The results were also employed to recommend an interaction surface for in-plane and out-of-plane moments. The recommendations are intended to help designers consider the simultaneous presence of multiple demands due to cascading hazards.