ABSTRACT

Composite plate shear walls – concrete-filled (C-PSW/CF) are a new innovative lateral force resisting system intended for high-rise buildings. The walls consist of parallel steel faceplates connected with tie bars and filled with concrete. This dissertation introduces the C-PSW/CF system and coupled C-PSW/CFs consisting of C-PSW/CF walls and composite coupling beams. Three studies are presented herein covering seismic design parameters for C-PSW/CFs, non-linear modeling techniques for composite coupling beams, and the design philosophy for coupled C-PSW/CFs.

The first study summarizes the results of a recent FEMA P695 study completed to verify seismic design parameters for uncoupled C-PSW/CFs with rectangular flange plate boundary elements. Seven archetype structures were: (i) designed, (ii) modeled using a benchmarked fiber-based finite element analysis approach, (iii) subjected to nonlinear pushover analysis, (iv) subjected to incremental nonlinear dynamic analysis to failure for 22-sets of scaled ground motions, and (v) the results were statistically analyzed to assess performance. These structures ranged from three (3) to twenty-two (22) stories and included both planar and C-shaped wall configurations. As part of this design process, recommendations for stiffness approximations for linear analysis of C-PSW/CFs were developed. Additionally, these nonlinear incremental dynamic analysis results were post-processed to determine the rotation and strain demands at the base of these structures at the design basis, maximum considered, and failure level earthquakes. These results showed that the rotation and strain demand at failure level earthquakes were comparable regardless of the ground motion. Ultimately, this FEMA P695 approach verified the R factor of 6.5, C_d factor of 5.5, and Ω_0 of 2.5 for C-PSW/CFs with boundary elements.

The second study proposes modeling approaches for composite coupling beams used in combination with C-PSW/CFs. Capturing the behavior of these components is critical to understanding the system behavior of coupled C-PSW/CFs, as the coupling beam components undergo yielding, plastification, and fracture prior to collapse of coupled C-PSW/CF walls. Although steel-concrete composite walls have been a known structural system for decades, only

recently have coupled C-PSW/CF systems been investigated and implemented as a seismic force resisting system. As the interest in coupled C-PSW/CF systems increases, the necessity of reliable nonlinear modeling techniques for pushover, cyclic, and seismic analysis has become apparent. This paper presents fiber-based options for modeling composite coupling beam components of coupled C-PSW/CF walls for use in nonlinear and seismic response analyses. Recommendations include effective steel and concrete stress-strain curves, modeling parameters for fiber-based materials, and concentrated plasticity options for additional computational efficiency. These recommendations are then implemented for a full-scale coupling beam section.

In the final study, a capacity design principle is used to establish a basis for the seismic design of coupled composite plate shear walls – concrete filled (CC-PSW/CF) systems. This design philosophy implements a strong wall-weak coupling beam approach, where flexural yielding in coupling beams occurs before flexural yielding at the base of walls. The coupling beams are sized to resist the calculated seismic lateral force level. The walls are sized to resist an amplified seismic lateral force corresponding to the overall plastic mechanism for the structure, while accounting for the capacity-limited forces from the coupling beams and the coupling action between the walls. Based on this philosophy, recommendations and requirements for appropriate sizing of coupling beams and C-PSW/CFs are presented. These recommendations are used to design four example (8-22 story) structures and evaluate their seismic behavior. The structures were modeled using 2D finite element models and fiber-based models subjected to monotonic and time history analysis. The nonlinear inelastic behavior and seismic responses of the example structures were in accordance with the capacity limited design philosophy (strong wall-weak beam), thus confirming the philosophy's efficacy.