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Thesis Outline

Seismic Design and Higher-Mode Effects of Post-Tensioned Hybrid Precast Wall-Frame Buildings

H. A. D. Samith Buddika

This thesis presents a comprehensive study of post-tensioned hybrid precast concrete wall-frame (PWF) buildings under design and beyond-design level ground motions.

The study is first focused on developing refined numerical analysis tools to accurately simulate the behavior of PWF buildings under lateral loads. Applicability of alternative modeling techniques viz. lumped plasticity model, fiber model, and three-dimensional (3D) macro model to simulate the behavior of post-tensioned hybrid (PH) precast concrete walls are investigated in this study by comparing with the experimental results available in the literature. Improvements to the existing modeling techniques are introduced where necessary.

Previous studies on PWF buildings have been performed by assuming the frame shear ratio $\beta_F = 0$. The effects of wall-to-frame interaction are investigated by evaluating the multi-level seismic performance of code-designed 4-, and 8-story PWF and SWF buildings, with frame shear ratios $\beta_F =$ 0, 0.25, and 0.5 using three-dimensional finite element (FE) models. Scaled earthquakes records (with or without the vertical component of earthquake motion) are employed to represent both the design (DE) level and the risk-targeted maximum considered earthquake (MCE_R) level hazards. The roof drifts of PWF and SWF buildings with similar height increase as the β_F increases. It is determined that, the seismic performance of PWF buildings is superior to SWF buildings in terms of limiting structural damage, despite the relatively larger roof drifts observed in the PWF buildings, however, nonstructural damage due to floor accelerations is more pronounced in the PWF buildings. Moreover, the inclusion of the vertical component of earthquake motion does not significantly affect the peak response indicators of the PWF and SWF buildings considered in this study.

Rocking motion at the base can reduce the contribution of the first mode shear and increase the relative contribution of higher modes compared to their monolithic counter parts. The PH precast concrete walls, post-tensioned rocking (PR) precast concrete walls (which have no ED devices), and RC shear walls, rely on the formation of a mechanism at the base of the wall to limit the first-mode response. However, a widely accepted method to calculate wall shear forces in PH precast concrete walls is not available. First the existing shear design procedures for PR precast walls, PH precast walls and RC shear walls are examined and their limitations discussed. Then, a rigorous nonlinear response history analysis of 4-, 8-, 10-, and 12-story PH precast concrete walls, designed with a ED steel moment ratio $\kappa_d = 0.5$ and 0.8, is carried out under DE and MCE_R ground motion hazard levels using a suite of 40 ground motions. Regarding the base shear force, existing methods developed for PR precast concrete walls and RC shear walls are found to fairly predict the base shear force under DE-level ground motions. Regarding the wall shear force along the height of the wall, existing methods for RC shear walls is found to provide good estimations. Therefore, (i) an equation for calculation of peak base shear force and (ii) a multi-linear shear design envelope to calculate wall shear demands along the height are proposed under MCE_R-level ground motions.

Seismic performance of PWF buildings have been mainly studied in the past by considering the effects of far-fault (FF) ground motions. In this part of the study, rigorous nonlinear response history analysis is carried out using 3D FE models of code-compliant 4- and 8-story PWF buildings, designed with frame shear ratios $\beta_F =$ 0, 0.25, and 0.5. The response of the PWF buildings is evaluated separately for NF forward-directivity, NF fling-step, and FF ground motions scaled to represent DE-level and MCE_R-level ground motions. Moreover, the use of

supplemental viscous dampers to enhance the seismic performance for NF pulse-like ground motions is also investigated. It is found that NF forward-directivity ground motions are more damaging than NF fling-step and FF ground motions. Although NF fling-step ground motions imposed larger displacement demands on PWF buildings when compared to FF motions, the potential for nonstructural damage to buildings is higher for FF ground motions. In addition, it is also determined that PWF buildings with supplemental viscous dampers is effective in reducing the peak roof displacements and peak floor accelerations without compromising the self-centering behavior.

The seismic pounding of PWF buildings with adjacent buildings is carried out for the first time. In particular, seismic pounding analysis of (i) PWF building with a moment-resisting frame (MRF) building and (ii) SWF building with MRF building are studied. A modified Kelvin-Voigt impact force model is used to calculate pounding force between impacting nodes. The structural performance of buildings is evaluated considering various separation distances under both DE-level and MCE_R-level ground motions. It is determined that, PWF buildings are effective in reducing pounding induced damages compared to SWF buildings.