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Article / Book Information

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Title(English)	Seismic Performance, Soil-Structure Interaction and Effect of Seismic Sequences on Post-Tensioned Hybrid Precast Concrete Walls
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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Post-tensioned hybrid (PH) precast concrete walls have been developed as a self-centering (SC) structural system for the building structures to mitigate the structural damage and the associated financial losses. Although much research attention has been given since the late 90s, the practical adoption of these walls is relatively slow. Therefore, this thesis investigates the seismic performance of PH precast concrete walls as partial infill walls inside the reinforced concrete (RC) moment-resisting frame, provide equations to estimate the inelastic displacement ratio and floor response spectra (FRS) for SC structural systems, investigates the nonlinear soil-structure interaction (SSI) of PH precast concrete walls bearing on a shallow foundation, and develop the aftershock fragility curves for mainshock-damaged walls.

First, the seismic performance and collapse safety of a 4-story PH precast concrete partial infill wall (PIW) and RC partial infill wall (RIW) frames with frame shear ratios $\beta_F = 0$, 0.25, and 0.5 are studied under far-fault ground motions. All the results are obtained from the numerical analysis of finite element models developed in OpenSees. Following the FEMA P695 methodology, fragility curves are generated, the collapse margin ratio (CMR) is determined, and then the adjusted collapse margin ratio $(ACMR)$ of each frame is compared with the acceptable adjusted collapse margin ratio $ACMR_{10\%}$. The results indicate that peak normalized floor displacements, inter-story drifts, and column chord rotation demand of PIW frames are for the most part slightly larger than the corresponding RIW frames but the PIW frames show better seismic performance in reducing the residual inter-story drifts than the RIW frames, under design earthquake (DE) level and risk-targeted maximum considered earthquake $(\mathrm{MCE_R})$ level ground motions. Although a slight decrease in the $ACMR$ is observed with increasing β_F, for both PIW and RIW frames, $ACMR$ exceeds $ACMR_{10\%}$ indicating that the PIW frames show satisfactory collapse performance.

Next, equations to estimate the constant-strength inelastic displacement ratio C_R for SC structural systems are proposed in code-compliant T form and T/T_g form, where T_g is the predominant period of the ground motion. For this purpose, regression analysis has been carried out for the C_R values obtained from the NLRHA for a wide range of flag-shaped single-degree-of-freedom (SDOF) systems with different initial vibration period T, response reduction factor R, post-yield stiffness ratio α, and energy dissipation parameter β under far-fault ground motions. The equations are used to estimate peak roof displacement demand of existing PH precast concrete walls and FRS for the SC structural systems. Estimates showed good accuracy when compared with the peak roof displacement demand of existing PH precast concrete walls under DE and $\mathrm{MCE_R}$ level

ground motions. Further, the ductility demand computed using the proposed equation for C_R accurately captures the spectral plateau of the generated FRS for SC structural systems.

An equation to compute the constant-ductility inelastic displacement ratio C_μ under far-fault ground motions is also proposed for the design of SC structural systems. The influence of parameters $R, \alpha,$ and β is also investigated on C_μ of flag-shaped SDOF systems. The proposed equation showed good accuracy for the estimation of C_μ that could be useful for direct displacement-based design for SC structural systems. The C_μ obtained under near-fault ground motions are larger than far-fault ground motions indicating the necessity of another equation to estimate the displacement demand.

Since the SC structural systems are designed without considering the SSI effect, the seismic performance of PH precast concrete walls bearing on shallow foundation is investigated. The shallow foundations are intentionally underdesigned for an experimented specimen based on a parameter as capacity reduction factor (CRF), defined as the ratio of yield moment of the wall to the ultimate moment capacity of the foundation. A relationship between the CRF and the vertical factor of safety against bearing (FS_v) is also investigated. Further, the obtained results are evaluated with code-designed 2- and 4-story PH precast concrete walls. A feasible range is recommended highlighting the beneficial and detrimental roles of nonlinear SSI on seismic response of PH precast concrete walls. It is observed that when CRF increases up to 1, the seismic force demand decreases, inter-story drift increases, but the performance is within the allowable limit. For $1 < CRF \leq 1.2$, the foundation starts to rock together with the PH precast concrete walls where post-tensioning (PT) tendons and energy dissipation (ED) bars remain ineffective, but results in negligible settlement and tilting. It is determined that the slender walls show better seismic performance if foundations are designed with same CRF.

The reoccupation and restoration activities after post-mainshock may be difficult due to likely strong aftershocks that may cause further damage to structures. Therefore, the collapse capacity of PH precast concrete walls designed with different post-tensioning and energy dissipation are investigated under mainshock-aftershock sequence. Aftershock collapse fragility curves are developed for mainshock-damaged walls considering damage states such as roof drift at which PT tendon yields, ED bar fractures, and near fracturing of PT tendon. It is observed that conventional probabilistic seismic demand model is not appropriate to develop aftershock fragility curves, therefore a bilinear demand model is used for generating aftershock fragility curves. It is found that the residual capacity of walls to resist aftershocks decreases with increase in the amount of damage in walls due to mainshocks, however, PH precast concrete walls showed excellent seismic resilience even for strong aftershocks.

The results presented in this study will be useful to understand the seismic performance, for designing, and assessing the PH precast concrete walls. The outcomes may also lead to propose a seismic design guidelines considering the SSI effect and develop probabilistic aftershock demand model for mainshock-damaged walls.