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Probabilistic seismic demand analysis of a slender RC shear wall considering soil–structure interaction effects

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ABSTRACT

Reinforced concrete shear walls are often used to resist the lateral loads imposed by earthquakes. Accurate evaluation of the seismic demands on shear walls requires adequate considerations of the nonlinear behavior of structural and foundation elements, the interaction between them, and the uncertainty and variability associated with earthquake ground motions. This paper presents a comprehensive probabilistic seismic demand analysis of a typical mid-rise slender shear wall in western US with a flexible foundation and evaluates the significance of soil–structure interaction (SSI) effects on their damage probability. Utilizing realistic numerical models for the shear wall and its foundation, the nonlinear time history analyses were conducted with a large number of recorded ground motions. Response quantities such as maximum inter-story drift ratio, base shear, foundation displacement and rotation are monitored and related to the intensity measure of ground motions (i.e. the inelastic spectral displacement S_{di}) for the cases with and without considering the SSI effects. Subsequently, the fragility functions of the shear wall are derived and the impact of SSI effects is investigated. It is found that the SSI generally reduces the damage probability of the shear wall, especially when soil nonlinearity is taken into account. The sensitivity of various seismic demands to soil parameters is also discussed. Under strong ground shakings, SSI effects on the maximum inter-story drift are most sensitive to the friction angle of the soil. It is suggested that the damages in foundation and surrounding soil should also be considered in order to systematically evaluate the SSI effects on damage probability of shear wall buildings.

1. Introduction

Reinforced concrete (RC) shear walls are commonly adopted as the primary lateral force-resisting system for mid-rise and high-rise buildings in seismic regions. They possess the necessary lateral strength, stiffness and deformation ductility under seismic shakings and showed good performances in past earthquakes when they were detailed appropriately [1,2]. In the latest 2010 Magnitude M_w8.8 Chile earthquake, the majority of the shear-wall buildings performed very well while there were some shear-wall buildings which suffered severe damage and even complete collapse [3]. The observed failures are related to the lack of confinement in boundary elements, too few and too slender shear walls being used, compounded with building irregularities and pounding due to excessive lateral displacement [3]. In general, the seismic performances of RC shear walls are characterized by the inelastic flexural or coupled shear-flexural responses of the wall itself, the nonlinear behavior of the supporting soil–foundation system and the interaction between them. Further, the responses are also affected by the variability in material properties, structural and foundation details as well as the uncertainty inherent in ground motions.

Soil–structure interaction (SSI) has been observed and identified to affect the seismic responses of structures [4–6]. Under earthquake motions, the foundation that supports a structure can translate and rock, thus altering the foundation input motion to structures (i.e. kinematic interaction effects) and modifying the dynamic characteristics of the overall system owing to the flexibility and damping of the foundation–soil substructure (i.e. inertial interaction effects). In particular, the soil material nonlinearity (yielding and degradation) and the geometric nonlinearity (uplifting, gapping and sliding of the foundation) can greatly complicate the behavior of the foundation–structure system. Although these nonlinearities may act as energy dissipation mechanisms to potentially reduce the structural response, they can result in differential settlement as well as permanent deformation that also affect the overall performance of structures. Additionally, displacement compatibility to accommodate large rocking and settlement may cause overstress of frame elements in shear wall–frame structures.

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