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Centrifuge modeling of load-deformation behavior of rocking shallow foundations

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Abstract

Shallow foundations supporting building structures might be loaded well into their nonlinear range during intense earthquake loading. The nonlinearity of the soil may act as an energy dissipation mechanism, potentially reducing shaking demands exerted on the building. This nonlinearity, however, may result in permanent deformations that also cause damage to the building. Five series of tests on a large centrifuge, including 40 models of shear wall footings, were performed to study the nonlinear load-deformation characteristics during cyclic and earthquake loading. Footing dimensions, depth of embedment, wall weight, initial static vertical factor of safety, soil density, and soil type (dry sand and saturated clay) were systematically varied. The moment capacity was not observed to degrade with cycling, but due to the deformed shape of the footing–soil interface and uplift associated with large rotations, stiffness degradation was observed. Permanent deformations beneath the footing continue to accumulate with the number of cycles of loading, though the rate of accumulation of settlement decreases as the footing embeds itself.

Keywords: Centrifuge modeling; Foundation uplift; Rocking; Shear walls; Settlement; Sliding; Rotation

1. Introduction

Shallow foundations supporting building structures might be loaded well into their nonlinear range during intense earthquake loading. Understanding the nonlinear behavior of shallow building foundations under large amplitude loading is an important aspect of performance-based design. The 1997 Federal Emergency Management Agency NEHRP Guidelines for the seismic retrofit of buildings [1] and the associated Applied Technology Council document (ATC 40) [2] discuss alternative design methods associated with the response of shear walls when subjected to lateral earthquake induced rocking. Geotechnical components of the foundation have a significant effect on the building response to seismic shaking. The nonlinearity of the soil and the interaction between the soil and foundation was shown to influence the building's stiffness and period to change [3]. The nonlinearity of the soil may act as an energy dissipation mechanism, potentially reducing demands exerted on the structural components of the building. This associated nonlinearity, however, may result in permanent deformations (settlement, rotation or sliding) that cause damage to the building.

Many researchers have studied the nonlinear behavior of shallow foundations and the effect of foundation rocking on the behavior of soil–foundation system [3–8]. Foundation rocking and yielding of soil reduce the stiffness of the soil–structure interface, lengthen the structure's natural period, and hence may reduce the force demands imposed on the structure [3]. Rocking of the footing progressively makes the foundation soil curved with a reduction in contact area between the footing and soil and thereby causing nonlinearity in the moment–rotation relationship [8]. With increasing eccentricity and inclination of vertical load, the vertical footing displacements reduce while horizontal

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