Uncouple Nonlinear Modeling of Seismic Soil-Pile-Superstructure Interaction in Soft Clay

S. N. Moghaddas Tafreshi

Received: January 2008; Accepted: June 2008

Abstract: *This paper presents the numerical analysis of seismic soil-pile-superstructure interaction in soft clay using free-field soil analysis and beam on Winkler foundation approach. This model is developed to compute the nonlinear response of single piles under seismic loads, based on one-dimensional finite element formulation. The parameters of the proposed model are calibrated by fitting the experimental data of large-scale seismic soil-pile-structure tests which were conducted on shaking table in UC Berkeley. A comparative evaluation of single piles shows that the results obtained from the proposed procedure are in good agreement with the experimental results.*

Keywords: *Seismic analysis; Soil-pile-superstructure interaction; Winkler side-soil springs; Free field analysis.*

1. Introduction

The coincidence of major pile-supported structures sited on soft soils in areas of earthquake hazard results in significant demands on these deep foundations. Possible resonance effects between longer period soft soil sites, which may amplify ground motions and large structures, can exacerbate the problem. Historically, it has been common practice in seismic design to ignore or simplify the influence of pile foundations on the ground motions applied to the structure. This is generally accepted as a conservative assumption in design for a spectral analysis approach, as the flexible pile foundation results in period lengthening, increased damping, and consequently decreased structural forces related to a fixed base case. It is common to evaluate pile integrity during seismic loading, though it is also accomplished with simplified and non-standardized analysis methods. However, in observations of pile performance during earthquakes, two principal facts emerge: firstly pile foundations do affect the ground motions that the superstructure experiences and secondly the piles can suffer extreme damage and failure under earthquake loading.

Various approaches have been used for the dynamic response analysis of pile-supported structures. In analysis, they are usually characterized by the different ways of treating the soil medium. A 2-D or 3-D finite element analysis is definitely a powerful method, but modeling a soil–pile system and setting numerical parameters for the entire model is indeed laborious and the computational effort can be very time consuming [1–3]. Moreover, direct methods require both soils and structures to be treated with equal rigor and complex variations of soil profile in a 2-D or 3-D space should be provided for the analysis. Hence, there still remains an important place for simple approaches even in these days that highly complex numerical solutions are available for difficult problems. It has been customary in engineering practice to assume that a pile is supported by distinct side-soil springs (Winkler hypothesis) [4–9].

In this paper, a rational seismic design method for soil-pile-superstructure interaction is established based on large shaking table on pile-structure model [10]. Initially, the free field motions are calculated separately through a site response analysis using DYFRA program (developed by the author). Secondly, the motions in the form of displacement time history are used as input boundary conditions for a beam (pile) on nonlinear Winkler model to evaluate the response of the pile. This model is composed of a linear elastic beam-column representing the pile, non-linear p-y springs and linear dashpots representing the surrounding soil. The results are also compared with those of the physical model to confirm that our simulations can predict the behavior of pile with acceptable accuracy.

Associate Professor, Department of civil engineering, K .N. Toosi University of Technology E-mail: nas_moghaddas@kntu.ac.ir