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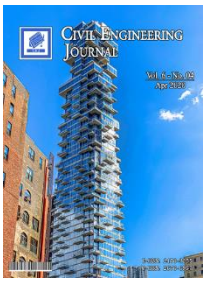

A Macro-element for Modeling the Non-linear Interaction of Soil-shallow Foundation under Seismic Loading

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Abstract

This paper presents a macro-element for simulating the seismic behavior of the soil- shallow foundation interaction. The overall behavior in the soil and at the interface is replaced by a macro-element located at the base of the superstructure. The element reproduces the irreversible elastoplastic soil behavior (material non-linearity) and the foundation uplift (geometric non-linearity) at the soil- foundation interface. This new macro-element model with three degrees-of-freedom describes the force-displacement behavior of the footing center. The single element is restrained by the system of equivalent springs and dashpots. The footing is considered as a rigid body. It is solved by a suitable Newmark time integration scheme and implemented in Matlab to simulate the nonlinear behavior of soil-shallow foundation interaction under seismic loading. A reduce scaled soil-foundation system has been tested on a shaking table at the University of Transport and Communications, Hanoi, Vietnam. Five series of earthquake motions were used with maximum acceleration increased from 0.5 m/s^2 to 2.5 m/s^2. The comparison of numerical results obtained from the simulation and experimentations shows the satisfactory agreement of the model. The proposed macro-element can be used to predict the seismic behavior of a wider variety of configurations.

Keywords: Macro-element; Soil–foundation Interaction; Non-linearity; Seismic Loading.

1. Introduction

In structural design, soil–foundation interaction (SFI) is an important phenomenon that should be taken into account. However, simulating SFI often needs complex models for the soil and the foundation with a great number of degrees-of-freedom (DOF) which requires significant computational costs. That is why various simplified modeling strategies have been recently developed. The macro-element concept consists in condensing all nonlinearities into a finite domain and works with generalized variables (forces and displacements). The macro-element model replaces the soil-foundation system with a single element that allows simulating the behavior of foundations in a simplified way. This approach helps to reproduce the non-linear behavior of foundations considering material and geometric non-linearity. The macro-element reduces the computational effort significantly while preserving the essential dynamic responses of system.

The term “macro-element” was initially introduced by Nova and Montrasio for studying the settlements of shallow foundations on sand [1]. After that, they proposed an elastic-plastic macro-element for strip and circular footings under quasi-static monotonic loading [2]. Based on this model, Paolucci proposed a numerical tool for studying the response of simple structures under seismic loading. Paolucci’s work took into account the coupling between the non-linear response of SFI and the response of superstructures [3]. Cremer et al. [4] developed the first application of the

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