Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Seismic Behaviors of Sandy Soils Confined by Wall-type Underground

C. W. Lu, Y. C. Chou*, Frank, S. Y. Lee***, C. P. Peng****, S. C. Lai*

*Construction Engineering, National Kaohsiung First University of Science and Technology, Taiwan
*** Bureau of Water Resource, Kaoshiung County Government, Taiwan
**** Sixth River Management Office, Water Resources Agency. Ministry of Economic Affairs, TAIWAN, China

ABSTRACT

Dynamic behavior of enclosed sandy soils in a two layered ground is studied in this paper using a numerical analysis of which a cyclic elasto- plastic soil model is employed to reproduce sandy soil behaviors and soils are enclosed by elastic un-porous material. The result shows the excess pore water pressure of enclosed soils decrease with the increasing confinement to a certain level. And also effectively decrease the soil horizontal movement.
Keywords: liquefaction mitigation, seismic behavior of sandy soil, deformation due to liquefaction, 3D FE analysis.

INTRODUCTION

A common consciousness of damage caused by the earthquake is being paid attention day by day in Taiwan after 1999 Chi-Chi earthquake. To reduce possible earthquake induced harm to building, design standard has been revised, of which ground surface acceleration code is greatly increased. This will make a safety factor of liquefaction resistance to many construction sites smaller than 1 easily because regression cycle of maximum earthquake in 2005 years is requested to take into consideration for structure design according to this new design standard. In this condition, any medium dense sand (N<30) could be defined as "liquefiable soils" evaluated by no matter Seed method, JRA method or others. Tremendous extra construction cost for liquefaction mitigation, therefore, requires.

Different mitigation strategies have been applied to reduce and alleviate liquefaction induced damages to a structure, which includes densification, solidification or replacement of the liquefiable soils, gravel, jet grouting, underground piled barrier and cut- off walls. The effect of jet grouting injected into the surrounding soils of a structure and cue- off wall and underground piled barrier constructed close to underground structure is proved to be effective to countermeasure liquefaction [1-5]. Those are thought to be similar to effect of diaphragm wall on the enclosed soils which exists in many excavation procedures. Considering the convenience of construction process and expenditure of the construction cost, this kind of confinement effect is thought to be much better than the extra ground improvement but seldom taken into consideration. Therefore, object in this study is to find the working mechanism of the wall-type underground structure and demonstrate its effect on reducing liquefaction induced deformation horizontally and vertically. A 3-dimensional effective stress analysis is applied to simulate the seismic behaviors of soils different relative densities due to different sizes of confinement under a major earthquake.

NUMERICAL METHODES

In the present study, the governing equations for the coupling problems of soil skeleton and pore water pressure are obtained based on the two-phase mixture theory (Biot [6]), using a u-p (u: displacement of soil; p: pore water pressure) formulation (Zienkiewicz and Bettes [7]). The finite element method (FEM) is used for the spatial discretization of the equilibrium equation, while the finite difference method (FDM) is used for the spatial discretization of the excess pore water pressure in the continuity equation. Oka et al. [8] numerically studied the accuracy through a comparison between the numerical results and the analytical results by Simon et al. [9] for the compressive wave propagation problem. They found that the proposed numerical algorithm has sufficient accuracy.

1. Governing equations

The governing equations for this soil- water- coupled problem are formulated by the following assumptions;

(1) Infinitesimal strain
(2) Smooth distribution of soil porosity
(3) Much smaller relative acceleration between fluid phase to that of solid phase than the acceleration of solid phase
(4) Incompressible soil grain particles

The equilibrium equation for the mixture is derived as following:

$$\rho a_i = S_{ji,j} + \rho b_i \qquad (1)$$

where ρ is density of the total phase, a_i is the acceleration of the solid, S_{ij} is the total stress tensor and b_i is the body force.

The continuity equation is derived as follows:

$$\rho^F \dot{\varepsilon}_{ii} - p_{,ii} - \frac{\gamma_w}{k} \varepsilon_{ii} = 0 \qquad (2)$$

where ρ^F is density of the fluid phase, p is the pore water pressure, γ_w is the unit weight of fluid, k is the permeability coefficient.

2. Constitutive model for sandy soils

Constitutive model law of sands based on finite deformation theory that will be applied in this project is proposed by Oka (1992, 1999). Several features in this cyclic elasto- plastic model are listed as follows:

(1) Non-linear kinematic hardening rule
(2) Non-associated flow
(3) Over-consolidation boundary
(4) Generalized flow rule