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Random Wave Induced Pore-Pressure Build-Up in Marine Sediments

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ABSTRACT

Evaluation of wave-induced residual pore pressure in marine sediments is a key factor in prediction of wave-induced liquefaction around coastal structures. Conventional models for wave-induced soil response have focused on regular wave loading. In this paper, we present a semi-analytical approximation for random wave-induced residual pore pressure. Two spectra, JONSWAP and B-M, will be used for simulations of random wave generation. Numerical results demonstrate significant influence of wave randomness on wave-induced residual pore pressure.

KEY WORDS: pore pressure; seabed response; random waves; Biot's consolidation; poro-elasticity

INTRODUCTION

Recently, considerable efforts have been devoted to WSSI (Wave-Seabed-Structure Interaction) problem due to growing offshore and coastal activities. Foundation failure around coastal structures has been reported in literature (Christian et al., 1974; Miyamoto et al., 1989). Wave-induced pore pressure and resultant liquefaction in a porous seabed has been recognized as a key factor for foundation failure.

In general, mechanisms of the wave-induced seabed response may be classified into two categories, depending upon how the excess pore pressure is generated (Nago et al., 1993). One is caused by the residual or progressive nature of the excess pore pressure, which appears in the initial stage of cyclic loading. This type of soil response is similar to that induced by earthquakes, caused by the build-up of the excess pore pressure. The other, generated by the transient or oscillatory excess pore pressures, accompanied by the damping of amplitude and phase lag in the pore pressure, appears periodic response to each wave. In this study, both mechanisms will be considered.

Numerous investigations for the wave-induced soil response have been carried out since the 1970s. These include analytical approximations (Yamamoto et al., 1978; Jeng and Hsu, 1996), numerical modeling (Mostafa et al., 1999; Dunn et al., 2006) and physical modeling (Zen and Yamazaki, 1990; Sassa and Sekiguchi, 1999; Sumer, 2006; 2007). The contributions and limitation of most aforementioned work have been reviewed in Jeng (2003). However, all aforementioned investigations have been limited to regular wave-induced seabed response.

In this study, we establish a semi-analytical model for random wave-induced residual pore pressure in a porous seabed. We further extend the analytical solution for regular wave-induced pore pressure build-up in marine sediment (Jeng et al., 2007) to random wave loading. A parametric study will be conducted to examine the effects of wave and soil characteristics on wave-induced residual pore pressure in marine sediments

RANDOM WAVE SIMULATIONS

The profile of random sea waves can be regarded as a stationarity stochastic process, which follows the Gaussian (normal) distribution. Such process satisfies the property of ergodicity. When we consider the profile of random sea waves, following the mathematical representations of Longuet-Higgins (1952), the wave profile or the water surface elevation $\eta(x,t)$ can be represented by

$$\begin{aligned}\eta(x,t) &= \sum_{i=1}^{\infty} a_i \cos\left(k_i x - 2\pi \tilde{f}_i t + \varepsilon_i\right) \\ &\approx \sum_{i=1}^{M} a_i \cos\left(k_i x - 2\pi \tilde{f}_i t + \varepsilon_i\right)\end{aligned}, \qquad (1)$$

with M being a sufficiently large number. In (1), a_i denotes the amplitude of the component wave in the *i*-th frequency, $\tilde{f}_i$ is the *i*-th representative frequency, which is evenly distributed in the range of (f_{i-1}, f_i), and ε_i is a random initial phase angle and equally distributed in the range of (0, 2π). In this equation, wave number of the *i*-th component (k_i) can be determined from the dispersion relationship after knowing the corresponding representative frequency $\tilde{f}_i$ and water depth d