ABSTRACT

In this paper, the near-trapping effect on the random wave-induced seabed response in the vicinity of the pile array will be investigated. First of all, the model validation will be conducted against the existing experimental data under random wave loading. Afterwards, aiming to analyze the influence of near-trapping, the amplification with respect to the water surface and soil response will be assessed over each pile component and the corresponding pile location. Finally, the fluctuation characteristic of the wave-induced instantaneous seabed liquefaction depth around each pile component will be examined. The parametric study shows that the influence of the near-trapping phenomenon is mainly concentrated on the pile components located in the internal area of the pile array.

KEY WORDS: Wave-Seabed-Structure Interactions (WSSI); RANS; Poro-elastic theory; Random Wave; Mono-pile Arrays; Liquefaction

INTRODUCTION

The foundation of offshore infrastructure (e.g. offshore oil and gas platforms, sea bridges, piers and jetties, etc.), which are generally constructed by means of a group of piles in different arrangements are generally constructed from a set of piles arranged differently to withstand different seismic loads (i.e. earthquake, wave loads, etc). Among this, the decrease in the bearing capacity of the seabed response is one of the leading factors in the failure of monopile foundation under storm surge and strong wave environment (De Groot et al., 2006). Previous studies have shown that the variation of the hydrodynamic process involving the pile array is very different compared to that of a single mono-pile (Bai et al., 2014; Cong et al., 2015). Specifically, the effect of pile group not only alters the outer region near the system but also the near-trapping pile effect has a great influence on the stability of each component. However, such strong nonlinear interactions between random wave-seabed-pile arrays have not been discussed quantitatively.

To date, the rather complex wave-seabed-structure interaction (WSSI) problems involving the pile group have been reported in terms of hydrodynamic wave impact (Zang et al. 2010; Bonakdar et al. 2015; Cao and Wan, 2017), estimation of pile group scour (Bateni and Jeng, 2007; Etemad-Shahidi and Ghaemi, 2011; Yagci et al., 2017; Ahmad et al. 2018), the wave-induced seabed response (Chang and Jeng, 2014; Zhang et al., 2017; Tong et al., 2018) and seabed liquefaction (Lin et al., 2020; Liang and Jeng, 2022). However, previous studies have not considered the dynamic seabed response near the pile foundations under random wave loading. Meanwhile, the analysis of the instantaneous seabed liquefaction of pile arrays under the influence of near-trapping is still rare.

In this study, the combined random wave & current-induced sandy seabed response around the pile array was numerically simulated. The existing numerical model based on Finite Volume Method (FVM) for fluid-seabed-structure interactions was based on olaFlow for wave motion and Biot’s QS theory for the seabed model will be further implanted with the generation of the random wave. To sum up, the workable FVM model, with consideration of random wave generation, is used to investigate the characteristics of instantaneous seabed liquefaction depth that develops around the pile array, and to determine the most critical location of pile component threatened by the soil liquefaction under the influence of near-trapping phenomenon based on several proposed indexes.

THEORETICAL MODEL

Numerical Model: PORO-FSSI-FOAM

Under the finite volume method (FVM) framework on OpenFOAM, an integrated numerical model PORO-FSSI-FOAM (Liang et al., 2020; Liang and Jeng, 2021) composed of two sub-models is proposed to analyse the instantaneous seafloor liquefaction near mono-pile arrays. Thereafter, these two sub-models are described in detail below.

Flow Model

Based on the assumption of an incompressible viscous fluid, the Reynolds Averaged Navier-Stokes (RANS) equations are solved in the flow model. The olaFlow solver (Higuera et al., 2013) is used to generate/absorb water waves and currents in the fluid domain. In addition,