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Experimental Study of Wave Motion and Pore Pressure Around a Submerged Impermeable Breakwater in a Sandy Seabed

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Wave–seabed–structure interaction has become one of the main concerns of coastal engineers and researchers, as it may largely affect seabed instability and structure safety. In this study, a series of experiments has been carried out in a wave flume to investigate wave motion and wave-induced pore pressure around a submerged impermeable breakwater as well as in conditions without a breakwater. Pore pressure within the sandy bed and water surface elevation are measured simultaneously in the experiments, which are used to investigate the effects of wave height, wave period, and breakwater structure on the wave–seabed–structure interactions at different water depths. Comparison of the experimental results of two different constraint conditions (around a submerged impermeable breakwater as well as in conditions without a breakwater) shows that the interaction of water waves and a submerged breakwater causes a significant change of wave motion and wave-induced pore pressure within the sandy bed. Meanwhile, it is found that the values of pore pressure along both the wave propagation direction and vertical seabed depth are largely dependent on water depth.

INTRODUCTION

With the rapid development of coastal management strategies in the last few decades, offshore structures such as breakwaters are commonly constructed to protect the coastal environment. Meanwhile, offshore breakwaters are becoming common features of deepwater ports. Like other marine structures, the stability of submerged impermeable breakwaters may be largely affected by the strong interaction with the waves and seabed. Damage to offshore structures includes two general failure modes, namely the structural failure caused by wave forces acting on the structure and foundation failure in the vicinity of the structure (Jeng et al., 2004). Owing to seepage flow and pore pressures within the sandy bed induced by progressive water waves, many breakwaters have reportedly been damaged in past years (Smith and Gordon, 1983; Lundgren et al., 1989).

Because of its practical importance, wave–seabed interaction has been extensively studied by using theoretical and experimental methods. For example, Yamamoto (1977) proposed a semi-analytical solution for wave–seabed interaction based on Biot's poroelastic theory (Biot, 1941) and verified the results with the data of the Mississippi Delta. Thomas (1989) utilized the finite element method (FEM) to study the relationships between wave-induced pore pressures and soil stiffness. Sleath (1970) carried out water flume experiments to measure pore pressures and found that there is a phase lag between pore water pressures and wave profile. Sassa and Sekiguchi (1999) focused on wave-induced seabed liquefaction in a centrifuge, and they had enough data to draw the new conclusion that liquefaction emerged first on the surface of the homogeneous seabed. In addition to the laboratory experiments, field measurements of pore pressures and wave pressure were made by Okusa and Uchida (1980). The measurement data indicated that, compared with that of a short period wave, attenuation of the long period wave could be ignored.

To effectively protect marine structures, researchers and engineers have carried out analyses to study the complicated mechanics of wave–seabed–structure interaction. Among those, an analytical solution for wave-induced soil response in front of a vertical wall was proposed by Hsu and Jeng (1994). Mynett and Mei (1982) investigated the dynamic stress within the saturated seabed around rectangular caissons, suggesting that the stress in the seabed was induced by the motion of the waves and the caisson, and obtained the analytical solution with the boundary layer approximation method. Jeng et al. (2001) and Jeng and Cha (2003) analyzed the seabed response of transverse anisotropy through elastic FEM and studied pore water pressure evolution in the anisotropic seabed around caissons. Zen et al. (1985) explored the damage of breakwaters and found that one of the causes is

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