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Wave-Induced Pore Pressure in a Cross-Anisotropic Seabed with Variable Soil Characteristics

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ABSTRACT

Detailed knowledge of the wave-induced pore pressure in a poro-elastic seabed is important for marine geotechnical and coastal engineers involved in the design of offshore installations. To simplify the complicated problem, most previous investigations have only concerned with ocean waves propagating over an isotropic seabed with uniform soil characteristics, ignoring the effects of anisotropic soil behavior and variable soil characteristics. This paper proposes a finite element model to investigate the wave-induced pore pressure in a cross-anisotropic seabed of finite thickness with variable Young's modulus and permeability. The numerical results indicate that the effects of anisotropic soil behavior, variable Young's modulus and soil permeability on the wave-induced pore pressure are significant.

Key Words: pore pressure, cross-anisotropic, Young's modulus, permeability, variable soil characteristics.

INTRODUCTION

The evaluation of the wave-induced pore pressure has been recognized as one of key factors that must be taken into account in the analysis of seabed instability. It has been submitted that gravity waves propagating over the ocean exert significant dynamic pressure on the sea floor in shallow water. These pressure fluctuations further induce variations of excess pore pressure in non-cohesive marine sediments. Once the upward seepage forces generated by excess pore pressure become greater than the self-weight of soils, a sedimentary bed may be liquefied, leading to seabed instability. This is the reason why this problem has attracted more attention from marine geotechnical and coastal engineers in recent years.

In general, marine sedimentary seabeds display some degrees of anisotropy, with different elastic properties in different directions owing to the mode of their deposition, particle shape and stress history. However, most marine sediments show more limited forms of anisotropy. A cross-anisotropic material is one of the examples, which has same properties in all horizontal directions, but different properties in the vertical direction. Unlike an isotropic material, the elastic behavior of a cross-anisotropic material is dominated by five independent elastic parameters (Pickering, 1970). This enhances the difficulty of solving the boundary value problem.

Many variables affect the wave-induced seabed response. Young's modulus and soil permeability are two important ones. However, most theoretical approaches for water-soil interaction in the literature have so far assumed the modulus of soil as *uniform* through the soil matrix. In fact, the rigidity of soil generally increases with buried depth as a consequence of increasing effective overburden pressure in natural seabeds. For consolidation problem, the medium whose modulus increases linearly with soil depth, which is so-called *Gibson Soil*, has been studied (Gibson, 1967). Furthermore, some evidence for the modulus of soils varying with depth has been reported in the literature (Badiey *et al.*, 1990; Suzuki *et al.*, 1991).

The permeability of a soil is a measure of how rapidly fluid is transmitted through the voids between grains. Marine sediments below the water-soil interface undergo consolidation owing to both the overburden soil pressure and the water pressure above the seabed surface. This results in a decrease in permeability of a soil. An example of permeability varying with burial depth was reported for marine sediments in the Gulf of Mexico (Bryant *et al.*, 1974).

Various theoretical investigations of the wave-induced pore pressure have been proposed since 1940s, based on different assumptions of relative rigidity for pore fluid and soil skeleton. Among these, most previous investigations have considered an isotropic seabed with uniform soil characteristics subjected to two-dimensional progressive waves (Yamamoto *et al.*, 1978). Recently, the first author has developed a series of analytical solutions for the wave-induced soil response both isotropic (Jeng and Hsu, 1996; Jeng, 1996; Jeng and Seymour, 1997) and cross-anisotropic seabeds (Jeng, 1997a, b) in the vicinity of a breakwater. Among these, the cross-anisotropic seabed was considered as a uniform medium, i.e., the modulus and soil permeability are constant within the entire soil matrix. Later, a numerical code has also been developed by the authors for the soil response with variable shear modulus and permeability (Jeng and Lin, 1996; 1997). However, to date, the combined effects of the cross-anisotropic soil behavior and variable soil characteristics on the wave-induced soil response have not been investigated. Thus, the objective of this paper is to develop a finite element model to examine the mechanism of the wave-induced pore pressures in a cross-anisotropic seabed with variable soil characteristics.