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The Effects of Backfill Soil Properties on Wave-induced Pore Pressures around a Trenched Pipeline

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ABSTRACT

Offshore pipelines are always trenched into seabed to reduce wave-induced forces and thereby to enhance their stability. The trenches are generally backfilled either by in-site sediments or by depositing selected backfill materials over the pipeline from bottom-dump barge. The actual waves in shallow water zone are always characterized as nonlinear. The proper evaluation of the wave-induced pressures upon pipeline is important for coastal geotechnical engineers. However, most previous investigations of the wave–seabed–pipe interaction problem have been concerned only with a single sediment layer and linear wave loading. In this paper, based on Biot's consolidation theory, a two-dimensional finite element model is developed to investigate non-linear wave induced pore pressures around trenched pipeline. The influences of the permeability of backfill soil and the geometry profiles of trenches upon soil responses around pipeline are studied respectively.

KEY WORDS: Submarine pipeline; non-linear wave; excess pore pressure; finite element model.

INTRODUCTION

Wave induced forces upon submarine pipelines have attracted many researchers' attention, for the ever increasing engineering activities in offshore and coastal regions. To reduce wave-induced forces and thereby to enhance their stability, offshore pipelines are always trenched into seabed. The trenches are generally backfilled either by in-site sediment or by pouring selected backfill material over the pipeline from bottom-dump barge. When water waves propagate over a porous seabed, cyclic excess pore pressures can be generated within seabed with accompanying decrease in effective stress, which have been recognized as dominant factors for the instability of a buried pipeline. Thus, the proper evaluation of the wave-induced excess pore pressures around pipeline is important for offshore geotechnical engineers involved with the design of foundations for offshore pipeline.

There have been various analytical investigations of the problem of seabed response to wave loading, based on different assumptions of the rigidity of soil skeleton and compressibility of pore fluid, including Madsen (1978), Yamamoto et al. (1978), Mei and Foda (1981), Jeng (1997). Besides the development of analytical solutions, numerical simulations have been widely applied to examine such a problem in recent years, such as the finite difference method (Zen and Yamazaki, 1990), the finite element method (Thomas, 1989; Gatmiri, 1990; Jeng and Lin, 1996) etc. Most previous investigations of the wave-seabed interaction have been reviewed by Jeng (2003). However, all aforementioned investigations have only examined the soil response under the action of two-dimensional progressive waves, without the presence of a marine structure.

The importance of wave–soil–pipeline interaction phenomenon has ever been addressed in the literature (Clukey et al., 1989). Till now, this problem has not yet been fully understood because of the complicated behavior of soils and geometry of pipeline. Design of marine pipelines regarding their stability is a rather complicated problem. Based on the potential theory, the hydrodynamic uplift forces on the buried pipelines have been studied (MacPherson, 1978; Spierenburg, 1986; MacDougal et al., 1988). However, the potential theory is somewhat far from the realistic conditions of soil as a two-phase medium. Based on Biot's consolidation theory (Biot, 1941), the wave-induced pore pressure around a buried pipeline has been studied through a boundary integral Eq. method (Cheng and Liu, 1986) and a finite element method (Magda, 1997). Among these, Cheng and Liu (1986) considered a buried pipe in a region that are surrounded by two impermeable walls. Magda (1997) considered a similar case with a wider range of the degree of saturation. Jeng (2001) proposed a more rigorous 2-D FEM model to investigate the wave-induced pore pressure, effective stresses along buried pipeline. However, most previous investigations of the wave–seabed–pipe interaction problem have been concerned only with a single sediment layer and linear wave loading. In engineering practice, pipelines are always trenched and covered with coarser materials, especially in shallow water. Wang et al. (2000) have studied the effect of a cover layer on pore pressure around buried pipeline under linear-wave loading. Unlike the trench with vertical walls discussed in by Wang et al. (2000), the trenches in the field have sloping side walls. The trench side slopes and the rate at which the trench may silt up, are dependent upon the nature of seabed sediment, sand or silt transportation due to scouring actions etc. Moreover, the actual waves in shallow water zone are always characterized as nonlinear. Gao et al. (2003) have examined the effects of non-linear component of wave loading upon the soil