Proceedings of the Tenth (2012) ISOPE Pacific/Asia Offshore Mechanics Symposium **www.isope.org**
Vladivostok, Russia, October 3-5, 2012

ISBN 978–1 880653 93-7: ISSN 1946-004X

Tides Induced Pore Pressure in the Seabed Embedding a Large-Diameter Pipeline*

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ABSTRACT

When tides flow over the ocean floor, they exert dynamic pressure on the porous seabed, and consequently result in oscillatory pore pressure and seepage in the seabed. Stability of the large-diameter pipelines under construction immersed in the seabed may be influenced by the excess pore pressure. In this paper, the authors focus on the tides induced instability of the pipeline in coastal region. A diffusion equation model is setup to verify the response of the pore water. The analytical solution in the semi-infinite space is presented and is used to verify the error in the numerical analysis. An engineering case is presented and a finite elementary method approach is taken to solve the problem.

KEY WORDS: Pore pressure; tide; seepage force; flotation of pipeline

INTRODUCTION

In the latest a few years, a great quantity of undersea infrastructures such as tunnels, pipelines were built in coastal regions, for the necessity of water intake, sewage disposal and so on. Nevertheless, when tides propagate over the seabed, they exert dynamic pressure on the sea floor, which will induce excess pore pressure in the seabed. The shallow buried pipelines with large-diameter are much subject to tides loading during the stage of construction on account of the vast uplifting force. In this paper, the authors gave a practical case to illustrate the affection by tides on the pipe-jacking in the gulf of Xiamen China. For the sake of brevity, we shall simply write the excess pore water pressure as pore pressure in the following sections.

Numerous researches had been focused on the ocean wave induced transient response in the seabed and structures. In his study on the wave induced pore pressure around the pipelines, Spierenburg (1986) gave the uplift force on the pipeline based on the potential theory. Furthermore, a physical experiment was set up to model the breakout of the half buried pipe in sand by Foda et.al (1988). Under the assumption of compressible both pore water and soil skeleton, Mei and Foda (1981); Magda (1992) gave theoretical analysis about the vertical stability of the submarine buried pipes as well as the pore pressure distribution pattern, the seepage force and the uplifting force on the pipe. Then a finite element method approach was set up to analysis the pore pressure around the pipe on the base of Biot' s theory (Magda 1996; 1997; 1999). In view of that waves are usually nonlinear especially in shallow water, Mostafa, Mizutoni (2002) investigated the nonlinear wave force on marine pipe with a coupled FEM-BEM model. On the demand of practical engineering, Kumar, Neelamani and Rao (2005) carried out an experimental study on the uplift force on the pipe embedding in clayey soil. Recently, a three-dimensional FEM approach is presented and verified with the experimental data for simulating wave-induced transient and residual pore pressure responses in seabed around pile foundations (Li et al., 2010; 2011).

The preceding researches present sufficient, multi-perspective and comprehensive knowledge about the response of the structures and the seabed to waves. However, in the near-shore gulf, the main composition of the seabed sediments is sand, silt or shingle, which means that the seepage is principal in seabed. And in coastal gulf region, water wave is not notable. Meanwhile, tides are durable and may influence the shallow buried pipelines. Watkins and Anderson (2000) gave a brief analysis on the design of the immersed pipeline in soil beneath a body of static water. Nevertheless, when taken into account the tide and waves, theory on the stability of the pipeline should be renewed. In this paper, the authors considered the tide induce instability problem.

GOVERNING EQUATIONS FORMULATION

Problem analyzed

The problem considered in this paper is illustrated in Fig. 1. The seepage in the seabed is governed by the mass conservation law. Superposing that the seabed is isotropic and the seepage is linear, the governing equation can be written as

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