Experimental Study on Damping Characteristics of Pipe Vibration in Liquefied Silt

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ABSTRACT

This paper presents an experimental study on the coupled process between pipe vibration and liquefied silt seabed. The results show that once the disturbing force exceeds a certain threshold, the soil rapidly loses its strength and yields a severe deformation. Liquefied soil has obvious dynamic damping effect on pipeline vibration, and the damping effect is related to pipeline burial depth and load amplitude. The natural frequency of the spanning system changed due to soil liquefactions. Meanwhile, this study also indicates that the traditional supporting method may be deficient in preventing pipeline deformation in liquefied seabed.

KEY WORDS: submarine pipelines; silt liquefaction; coupled vibration; damping ratio

INTRODUCTION

As shallow foundation underwater structures, submarine pipelines are usually buried within a limited depth in the recent deposited seabed soil in Quaternary period. Based on the existing pipeline route survey reports, it is found that the type of seabed soil generally is characterized by high water content, high compressibility, low shear strength, and significant regional differences; and thus, the surface unconsolidated sand and silt sediment at seabed is prone to liquefaction or softening under the influence of earthquakes, waves and structures vibrations. Despite mechanical difference, both liquefaction and softening can result in a decline of seabed strength, causing the solid sediment become a plastic or plastic-flow material, consequently effect the instability of offshore structures (Sumer et al., 2001). Besides, submarine pipeline also exerts an influence on the seabed within a certain scope (Foray and Bonjean, 2006), because the buried pipeline serves as a rigid waterproof interface in seabed, which will induce stress concentration under the influence of external loads (Bao and Wen, 2008). Meanwhile, the transformation of the physical or mechanical property of sediment caused by periodic wave loads can lead to the changing of stress state of the pipeline (Damgaard et al., 2006; Teha and Palmer, 2003). Pipeline will easily get into the state of suspended span after exposure, which may experience vortex-induced vibration (VIV) when exposed to currents or other hydrodynamic loading. As a result of the inertia force, such vibration causes a strong disturbance to the seabed at both ends of the pipeline span.

Previous researches usually simplified the seabed to a rigid boundary without considering the changes of soil property under the influence of external disturbance. Consequently, the dynamic properties of pipeline span system (such as its inherent frequency and the bearing capacity) are also considered to be unchanged. So far as the damping effect of the liquefied soil, viscosity coefficient is usually used to represent the damping coefficient. However, viscosity coefficient is only suitable for describing the viscous resistance of Newton-fluid motion, while the liquefied soil is close to viscoelastic body in nature. Therefore, it is irrational to determine the dynamical properties of liquefied soil by constant viscosity coefficient.

This paper focuses on the coupling process between vibrating pipeline and liquefied silt soil through flume experiments. The result indicates that after the seabed liquefaction, arising from the factors such as wave and pipeline vibrations, the silt will reduce or eliminate its supporting and constraining function on pipeline. Besides, the liquefied silt will obviously damp the pipeline vibration, and thus, system damping will rise with the increase of buried depth and soil’s initial capacity. The simulation experiment has achieved the damping ratio between the typical liquefied silt and the pipeline in different burying depths, which has provided a value-finding basis for numerical simulation.

EXPERIMENTAL SETUP

Experiment Design

As shown in Fig. 1, the model pipeline represents a section of prototype buried pipeline, which was supposed to be perfectly rigid body that will not encounter bending deformation and has same displacements in both ends within a certain distance.

Fig. 1 Systematic diagram showing experiment design conceptions