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Calibration of Analytical Solution Using Centrifuge Model Tests on Mooring Lines

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ABSTRACT

Single segmented mooring lines were tested in a geotechnical centrifuge for the purpose of calibrating the analytical solution developed for the analysis and design of various mooring lines associated with underwater drag/permanent anchors. The model mooring lines included steel ball chains and wire cables placed at various depths within the soft clayey seafloor soil. The mooring lines were loaded to preset tensions at the water surface under an elevated acceleration inside the centrifuge to simulate the field stress conditions experienced by the prototype mooring lines. This paper describes the calibration of 2 factors used as part of the input parameters in the analytical solution of mooring lines and considers the effect of chasing wires used in the experiment to determine the locations of the mooring lines.

INTRODUCTION

The U.S. Naval Facilities Engineering Service Center (NFESC) conducted a series of centrifuge model tests (Law et al., 1994) on buried mooring lines in order to validate the analytical model developed by Bang (1996). During the centrifuge model tests a set of chasing wires was attached to the mooring chains and cables. Fig. 1 shows a schematic sketch of the layout of the mooring line and chasing wires. The chasing wires were used to locate the exact geometries of the mooring chains/cable during transition from the initial to the final position due to the applied load.

However, it was found later that the chasing wires had a rather significant effect on the mooring line geometry and tension, particularly on the mooring cable because of its thin cross-section. This paper studies the effect of the chasing wires on the performance of the mooring line and the soil in calibrating the material and geometric parameters necessary for the validation of the analytical model.

CENTRIFUGE MODEL TESTS

The primary objective of the centrifuge model tests was to obtain the detailed load transfer mechanism of the mooring line embedded in a cohesive seafloor. Therefore, the mooring lines were fixed at specific depths. They were tested under a centrifugal acceleration equal to 80 times the gravitational acceleration in order to simulate the nonlinear stress-dependent behavior of the soil. The tests included 3 ball chains and 1 cable embedded at various depths to model the mooring lines in Speswhite kaolin, a white potter's clay (Dunnavant and Kwan, 1993). The model ball chain had a ball diam of 0.48 cm and was loaded to 208.52 N, and the model cable had a diam of 0.48 cm and was loaded to 231.3 N horizontally at the seafloor surface. Note that the corresponding prototype geometric dimensions become model dimensions multiplied by the applied centrifugal acceleration level as a multiple of the gravitational acceleration. However, the corresponding prototype load is obtained by multiplying a square of the applied acceleration level.

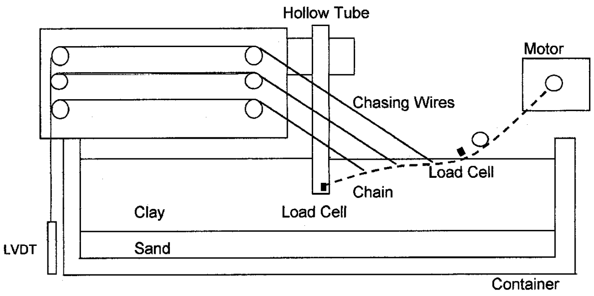

Fig. 1 Centrifuge test layout

A centrifuge at the University of Colorado was used. It has a capacity of 440 g-tons with a capability of accelerating a 2.2-ton payload to a maximum acceleration of 200 g's. It has a radius of 5.49 m from the centrifuge center to the top of the model bucket. The model bucket can be as large as 1.22 m × 1.22 m × 0.91 m.

The soil was first consolidated outside the centrifuge under a constant seepage force and then consolidated further within the centrifuge before the mooring lines were deployed. After the consolidation, the undrained shear strengths of the soil (S_u) were measured in-flight by a miniature vane and correlated with additional data derived from the void ratio versus the shear strength relationship of the test clay (Law et al., 1994). The results indicated that Su remained constant at approximately 3112.2 Pa from the surface to a depth of 3.81 cm and then increased at a rate of 810.57 Pa/cm, indicating higher degrees of overconsolidation near the surface. This corresponds to S_u of 3112.2 Pa from zero to 3.05 m and 1021.06 Pa/m below 3.05 m in the prototype.

After the soil was consolidated, an individual tube with a mooring line attached to its end was inserted vertically into the soil

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KEY WORDS: Mooring line, centrifuge, calibration.