The Pullout Capacity of Suction Caisson Foundations for Tension Leg Platforms

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Abstract
The main focus of the “Innovative Foundations for the Deep Ocean” project has been to investigate the behavior of suction caisson foundations for tension leg platforms (TLP) in water depths of 2000 to 3000 m (6000 to 10,000 ft) in the Gulf of Mexico. A set of model caisson foundations was designed, fabricated, and instrumented for testing in the laboratory under simulated TLP loading. The caissons were made with length-to-diameter ratios of 2, 4, 6, and 12 to study the effect of increasing caisson length on penetration resistance and pullout capacity, as well as the feasibility of using suction as the method of installation. The simulated TLP loading was in the form of static and cyclic tension. Measurements of total foundation capacity, displacements, and pore water pressures inside and in the vicinity of the model caissons were made. The pullout capacity of the model caissons was clearly defined under both drained and undrained loading conditions. Results of the experimental program have shown that the rate of pullout loading had a significant influence on the capacity. The long-term pullout capacity represented the upper limit on peak cyclic loading.

Introduction
Traditionally, suction caissons have been built with length-to-diameter (L/D) ratios, or aspect ratios, of approximately 0.5 to 2, e.g., Gullfaks C (Tjelta et al., 1990), Snorre TLP (Fines et al., 1991; Stove and Christophersen, 1992), Europipe (Tjelta, 1994), etc. In the North Sea, the foundation material in the deeper waters is predominantly dense sand and stiff clay. In normally consolidated clay, however, foundation capacity is derived mainly from increased soil shear strength with depth. It was, therefore, deemed necessary to examine the possibility of extending the range of aspect ratios of suction caisson foundations beyond that used in the North Sea.

The objective of our investigation has been the behavior of suction caisson foundations (SCF) for tension leg platforms (TLP) in water depths of 2000 to 3000 m (6000 to 10,000 ft) in the Gulf of Mexico (GoM). At these depths, the foundation material is mainly normally consolidated clay, and loading of the foundation system is composed of static uplift loading due to buoyancy of the TLP, and cyclic vertical and horizontal loading from environmental conditions. The experimental program was designed to test a set of model foundations under simulated static and cyclic loading from TLPs.

The model caissons used in these tests were made with aspect ratios of 2, 4, 6, and 12, hereafter labeled Caissons 2, 4, 6, and 12, respectively, to study the effect of increasing caisson length on penetration resistance and pullout capacity, as well as the feasibility of using suction as the method of installation. Caisson 2 was made of a 125-mm (5.0-in.)-outside diameter Delrin® tube fitted to an acrylic cap. The caisson was double-walled to provide for pore pressure and strain instrumentation in between the walls. Caissons 4 and 6 consisted of a 100-mm (4-in.)-outside diameter acrylic tube fitted to a Delrin® cap. The wall thickness of the tube was 3 mm (0.125 in.) and these caissons were equipped with provisions for pore pressure, load, and displacement measurement. Caisson 12 was 50-mm (2-in.) in outside diameter and was made of a stainless steel tube, with the same wall-thickness-to-diameter (t/D) ratio as for caissons 4 and 6, fitted to a Delrin® cap. Because of space limitation, it was instrumented only with load and displacement transducers. The foundation material used for testing was kaolinite clay consolidated in 0.21-cubic meter (55-gallon) tanks under the effect of self-weight and downward seepage. To assess the pullout capacity of the model foundations for TLP applications, the simulated loading was in the form of static vertical tension, cyclic vertical tension, static inclined tension, cyclic inclined tension, and combined vertical and horizontal cyclic tension. A biaxial linear actuator device provided representation of typical field loading conditions. A high-speed PC-based data acquisition system was used to acquire and process data from nine instrumented channels. Test preparation is described in detail in a companion paper by the writers.