Centrifuge Model Tests on Suction Piles in Sand Under Inclined Loading

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ABSTRACT

A series of centrifuge model tests on suction piles embedded in sand have been conducted to determine the horizontal, vertical and inclined loading capacities. The centrifuge model tests include as main variables the load inclination angle and the loading point. Test results indicate that the loading capacity of a suction pile with small load inclination angles in sand increases, reaches its peak, and then starts to decrease slightly as the point of load application moves downward. For larger load inclination angles, the loading capacity slightly but continuously increases as the mooring point moves downward. The maximum and minimum loading capacities occur when the applied loading is horizontal and vertical, respectively.

KEY WORDS: centrifuge model tests; suction piles; loading capacity; load inclination angle; loading point.

INTRODUCTION

An innovative underwater permanent foundation system utilizing suction piles was introduced in the offshore industry in 1982 (Sempere and Auvergne, 1982). Since then, this new foundation system has been successfully used on numerous occasions for a variety of offshore structures in a wide range of environments due to its low cost, simplicity, efficiency, and reliability (Clukey and Morrison, 1996; Cottrill, 1992; Larsen, 1989).

Suction piles have numerous advantages over conventional underwater foundation systems. The most significant advantages are: easy installation, large bearing capacity, and retrievability. Suction piles are installed through the application of reduced water pressure inside the pile. A suction pump attached at the top of the pile can accomplish the entire pile driving operation. Because of this efficient operation, very large suction piles can be driven into the soft seafloor, which eliminates the use of large numbers of small piles.

As part of a study on the determination of the suction pile inclined loading capacity, a large number of centrifuge model tests have been conducted on a model suction pile embedded in sand. The primary factors influencing the loading capacity of a suction pile include the inclination angle of the mooring line attached to the suction pile that can vary from horizontal to vertical and the point of the mooring line attachment that can vary from the top to the bottom of the model suction pile in addition to the soil type and the embedment depth (Bang and Cho, 1999a; Bang and Cho, 1999b; Cho and Bang, 2002; Bang, et al., 2000). This study was therefore focused on examining the effects of the first two parameters, i.e., the pullout load inclination angle and the loading point, through centrifuge model tests. The type of soil and the suction pile dimensions remained same for all model tests.

The centrifuge acceleration selected for the tests was 100 g’s. The tests were conducted with locally available sand. A total of 80 tests were conducted. They include five different loading points and five different load inclination angles. This paper describes the details of the centrifuge model test procedures, instrumentation, test results, and discussion of the test results.

DESCRIPTION OF CENTRIFUGE MODEL TESTS

DICT Geotechnical Centrifuge

The DICT centrifuge that was used for the model tests has a single arm with the nominal radius of 2.7 meters and the platform radius of 3.0 meters. The acceleration at the maximum payload of 1,200 kilograms is 100 g’s. The acceleration range is from 10 to 230 g’s and the speed range is from 25 to 265 rpm. Figs. 1 and 2 show the layout of the centrifuge facility and a photo of the centrifuge.

Model Test Container

The box-type container used for the model tests has dimensions of 0.2 x 0.8 x 0.5 meters in width, length, and height. Three sidewalls and the bottom of the container are made of high strength stainless steel plates to protect against possible corrosion and to reduce the friction between the soil and the container surface. The front wall of the container is made of a 40 millimeter thick Plexiglas plate. The model container was used to test one model suction pile per container.