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Field Validation of Soil Friction Transition During Suction Pile Installation

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ABSTRACT

An analytical solution has been developed to simulate the suction pile installation in sand based on small-scale laboratory model tests. The analytical solution includes the concept of the mobilized effective soil friction angle ratio to describe the reduction in the soil strength and interface friction between pile and soil during the suction pile installation. To validate the analytical solution, 3 suction piles 1.5 m in diameter were tested in the field. During the pile installation, the relationships between the applied suction pressure and the resulting pile penetration were obtained and used for validation.

INTRODUCTION

Based on small-scale laboratory model test results, an analytical solution was developed to help install suction piles successfully in the field (Bang et al., 1999, 2000b). The analytical solution is capable of estimating the correct suction pressure so that the pile can safely penetrate the sandy seafloor without creating any soil instability at a given pile penetration depth. The correct suction pressure value is provided as a range. The lower bound value corresponds to the suction pressure inside the pile that can barely overcome the pile's bearing capacity so that the pile can penetrate the soil. The upper bound suction pressure is the value that initiates the soil instability state, i.e., boiling, at which time the soil becomes unstable and starts to flow into the pile. Eventually the pile inside will be filled with sand, keeping the pile installation from completion.

The analytical solution adopted the concept of the *mobilized effective soil friction angle ratio* to simulate the soil strength reduction due to the water flow caused by the applied suction pressure during installation. The mobilized effective soil friction angle ratio is the ratio between the mobilized effective friction coefficient and the available effective friction coefficient of the soil. The mobilized effective friction coefficient is the soil friction coefficient required so that the pile-soil system is in a balanced state, with a 1.0 safety factor. The available friction coefficient is the maximum friction value of the soil. The relationship of the mobilized effective soil friction angle ratio was expressed as a function of a nondimensional term that includes all pertinent parameters affecting the suction pile installation through the calibration, with the results obtained from a series of laboratory model tests on suction pile installation in sand.

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KEY WORDS: Suction pile, suction pressure, mobilized soil friction angle, field validation.

To validate the relationship between the mobilized effective friction angle ratio and the nondimensional parameter, the U.S. Naval Facilities Engineering Service Center (NFESC) installed 2 medium-size suction piles off the coast of Port Hueneme, California, in January 1999. A third pile was installed in March 1999. Fig. 1 shows a schematic diagram of the installed suction piles.

The details are described below. The suction piles were designed based on the analytical solution previously described by Bang et al. (2000b). During the installation of the suction piles, the applied suction pressure vs. the resulting pile penetration relationships was instrumented.

ANALYTICAL SOLUTION

The analytical solution should be capable of estimating the correct suction pressure necessary for the pile to safely penetrate the sandy seafloor without creating any soil instability at a given pile penetration depth. The correct suction pressure value should be provided as a range. The lower bound value corresponds to the suction pressure inside the pile that can barely overcome the soil resistance so that the pile can penetrate the soil. The upper bound suction pressure is the value that initiates a soil boiling state, at which time the soil becomes unstable and starts to flow into the pile. Described below is how the lower bound value is estimated.

In order for the suction pile to penetrate the seafloor successfully, soil resistance must be overcome. The resistance of the pile is the latter's bearing capacity as it corresponds to the state of the pile penetration. When the total external force, including the weight of the pile, the applied surcharge and the applied suction pressure, exceeds the pile bearing capacity, the pile starts to penetrate until it reaches a depth where its bearing capacity equals the external force. As the suction pressure increases again, the external load also increases, and the pile starts to penetrate the soil until the next equilibrium is reached. This procedure repeats until either the pile installation is completed, or the pile does not penetrate any further. The resulting pile penetration depth at a given applied suction pressure can thus be determined from the equilibrium, which requires that the pile's bearing capacity equals the external forces.