Numerical Analysis on the Sliding Failure of Suction Pile

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ABSTRACT

This paper presents the pullout behavior of suction pile using finite difference method; and the commercial software, FLAC3D, was employed for the numerical analyses. The conventional equation for predicting ultimate pullout capacity for sliding failure was compared with the numerical analysis results. The pile diameter, pile length, and the undrained shear strength of the clay were varied to investigate the effect of the parameters. Based on 3-D analyses of total 32 cases, it was concluded that the conventional equation for sliding failure could be adopted reasonably if the interface coefficient is reasonably provided. The interface coefficients were found to vary depending on the undrained shear strength, pile length-diameter ratio. This paper presents interface coefficients which could be used to the internal and external side friction of suction pile.

KEY WORDS: pullout capacity; sliding failure; suction pile; finite difference method

INTRODUCTION

Recently, attentions are paid on the offshore construction as the demands in offshore and deepwater development gradually increase; and it is expected that a number of offshore structures will be constructed in the near future. Because of the severe construction condition, a few foundation systems are economically feasible for the offshore foundations, one of which is the suction pile.

In order to estimate the pullout capacity of suction pile, three failure mechanisms were generally considered depending on the venting condition during pullout: 1) sliding failure, 2) tensile failure, and 3) reverse end bearing failure. If the suction pile is pulled out with a vent open or if the suction pile is pulled out for sufficient time, the suction pile would fail in sliding manner. This case could be considered as drained condition. Because the suction piles are being used offshore, the sliding failure will be due to ventilation, not due to the drained condition of surrounding soils. If the suction pile is pulled out without ventilation at the pile top, the end bearing capacity would fully develop.

This case could be considered as fully undrained condition.

Many researchers have been investigating the pullout behavior of suction piles using laboratory model tests, field tests, and numerical analyses (Finn and Byrne, 1972; Bye et al., 1995; Randolph and House, 2002). Deng and Carter (2002) divided failure mechanisms into three, which are generally accepted in design nowadays, and deepened the understanding of each failure. They theoretically derived the solutions for estimation of pullout capacity of suction piles through finite element methods and validated the results using field tests and model tests. Bang and Cho (2002) studied the inclined pullout capacity of suction piles, and suggested the failure envelopes providing the ultimate pullout capacity under lateral loading condition. Supachawarote et al. (2004) carried out a parametric study to find out the optimum padeye location for inclined load with varying diameter-length ratio of suction piles in normally consolidated clay.

This paper focuses on the sliding failure and the conventional equation to estimate the pullout capacity of the case. Fig. 1 illustrates how to come up with the pullout capacity in sliding failure. The capacity is the sum of submerged weight of a suction pile and external and internal side resistance. The capacity could be calculated by following equation:

\[ V_u = W + Q_v + Q_e = W + \alpha_i S_{uav} A_p + \alpha_e S_{eav} A_p \]

where, \( V_u \): net pullout force, \( \alpha_i \): internal interface friction ratio, \( \alpha_e \): external interface friction ratio, \( A_p \): internal perimeter area, \( A_{p,ext} \): external perimeter area, \( S_{uav} \): average undrained shear strength over the pile length.

The key factors determining the accuracy of the equation are the internal and external interface coefficients. In this paper, the interface coefficients were provided for different undrained shear strength and length-diameter ratio. The commercial software, FLAC3D, was employed, and total 32 simulations were performed out to conclude the interface coefficients.