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Numerical modeling of suction pile installation in clay with effective stress analysis

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ABSTRACT

This paper is the continuation of a previous study on numerical modeling of suction pile installation in clayey soils, such as those in southern Caspian Sea area. In the previous study, total stress analysis was used for both self-weight penetration and suction penetration, using a FEM. In the present study, an axisymmetric finite difference scheme has been used to simulate the suction pile installation, but with effective stress analysis for clay, in addition to total stress analysis.

Due to low permeability of clay, no apparent seepage is visualized during the suction application, as it is, for example, clearly observed for sands. However, due to upward suction pressure on the top inside plug, a pressure decrease is expected within the interior soil adjacent to the inside side wall of the caisson, significantly affecting the response to penetration due to frictional resistance increases. Therefore, it is essential to consider the pore pressure redistribution within the soil media during suction insertion. There is no general agreement yet, however, on how the applied suction at the top inside pile redistributes the pore pressure response within the clayey soil and also other factors influencing the increase in internal resistance during suction insertion, compared to self-weight insertion.

The suction driving results of Laminaria FPSO in Timor Sea has been used for verification purposes of the model. The results have shown that good agreement can be achieved between predicted and measured suction pressures for insertion, if proper effective strength parameters are selected for the soil and proper coefficient for effective strength calculation at the soil-caisson interface. It is shown that there is a substantial increase in effective stress adjacent to the inside soil wall due to pore pressure reduction during suction insertion, while a cylindrical core of about 2/3 of the suction pile diameter within the pile is experiencing higher pore pressures and hence lower effective stresses during suction insertion. The results are in accordance with the field observations of suction pile insertions in clay in that resistance to insertion increases due to frictional resistance of the soil-caisson wall.

KEYWORDS: *Suction pile; finite difference method; nonlinear numerical analysis; effective stress; installation; clay.*

INTRODUCTION

Suction pile installation is among the challenging operations in offshore engineering. The suction pile installation analysis is usually performed by three methods including limit equilibrium analysis, physical modeling and numerical modeling by different researchers. Huang et al. (2003) proposed analytical solutions for determination of tip resistance, internal and external wall surface resistances during installation, self-weight insertion depth, allowable penetration speed under self-weight penetration, and required and allowable suction pressure for suction pile installation in clay. Olson et al. (2003) conducted experiments on suction pile installation in clay on 17 small-scale models. Soil resistance to installation, pore pressure generation and inside soil plug up-heave during installation were investigated.

Maniar and Tassoulas (2003) developed a numerical model using finite element method for suction pile installation. Mohr-Coulomb model was used for the caisson-soil interface and a new mesh was generated for the gradual installation of the suction pile. They briefly presented the radial and effective stress changes as well as the pore water pressure variations at different consolidation times after installation. Soltanmohammadlou (2004) and Fakharian and Soltanmohammadlou (2005) also presented a finite element method for suction pile installation in Caspian Sea clay. Mohr-Coulomb type behavior was assumed for both soil and soil-caisson surface. With axisymmetric condition for soil and suction pile, total stress condition was assumed for clay throughout the step-by-step installation process and at each step the required suction was estimated. Suction pressure insertions for different aspect ratios with some design charts for suction pile installation in southern zones of Caspian Sea were presented.

The main objective of this paper is suction pile installation numerical modeling with effective stress method. Laminaria floating platform (FPSO) that was launched in 1999 in Timor Sea around Australia is selected for verification of the numerical model, for which 9 suction piles were installed (Ebrich and Hefer, 2002). Well-documented information is available for suction pile installation of Laminaria including mechanical and chemical properties of soil, self-weight and suction insertion lengths, and required insertion suction for different depths. One of the suction piles in South East (SE) group was selected for the verification purposes of the current study.