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Modeling the Effects of Short- and Long-Term Loading on Suction Caissons Using 2D- and 3D-Finite Elements Methods

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ABSTRACT

In this paper a numerical study of the effects of the initial and the long-term loadings of suction caissons is presented. 2D and 3D simulations were done. The soil considered was a soft normally consolidated clay with a shear strength increasing with depth, corresponding to deep sea sediments. The clay was simulated in Plaxis* with a Mohr-Coulomb and a Soft-Soil model. A hyperbolic relationship was obtained for the load-displacement curves, which permitted the extrapolation of the 2D to 3D results. A comparison of the typical yield failure envelope is also presented. The dissipation of the initial excess pore pressure was studied.

KEY WORDS: Suction caissons; deepwater; soft soils; effective stress; numerical modeling.

INTRODUCTION

Caissons foundations (Fig. 1) are widely used in marine environments for many types of offshore structures TLPs, SPARs, FPUs and FPSOs for the oil and gas industry. They have been used extensively for deep water (e.g. Colliat et al., 1996) and recently they have been considered as solutions for the foundations of offshore wind turbines (e.g. Houlsby et al., 2005). Design issues for suction caissons can be divided into those associated with installation and with operational conditions (Randolph et al. 2005).

During the installation of the caisson, the friction resistance of the lateral walls is considered first during the penetration under its self-weight, then during the pumping stage in order to reach the final penetration depth. In the design for operational conditions, short-term pullout resistance and displacements under permanent lateral tensile load are generally considered. However the caissons are also subjected to temporally fluctuating loadings due to storms and surface or deep currents. Therefore, it can be important to consider the effect of cyclic loads on the behaviour of the anchor (Andersen et al. 1988).

Analytical models are generally used in the preliminary design of the suction caisson. Assumptions are taken for the different failure mechanisms trough limit analysis and limit equilibrium in order to determine the pullout capacity. Such analytical methods have been developed by Deng and Carter (2000); Bureau Veritas; Cho and Bang (2002); Aubeny et al., (2003), among others. Practical design of suction caissons is also generally completed by using the finite element analyses FEM. In this paper a numerical simulation of the behaviour of caisson using the FEM code Plaxis* is presented. The objectives of the study were i) compare the mechanisms and the results between analytical and numerical solutions, ii) evaluate how the 3D pullout resistance can be estimated from a simpler 2D numerical analysis and iii) study the effects of sustained long term loads.

The methodology followed was: firstly a parametric study was carried out in axi-symmetric, 2D and 3D conditions using the Plaxis* code. The applied loads were a pullout vertical load and a pullout lateral load. Then an analysis was performed with a permanent load in undrained conditions and in drained conditions. Finally a low initial loading was applied in undrained conditions and was followed by a consolidation under sustained loading in order to estimate the long-term behaviour of the anchor. The effect of the dissipation of the initial excess pore pressures was studied.

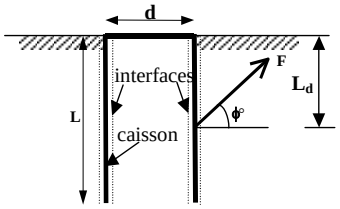

Figure 1 Scheme of suction caisson with a lateral load

FINITE ELEMENT SIMULATION (FEM)

The simulation in Plaxis* in the axi-symmetric (AXI), 2D, and 3D conditions for the material parameters, shaft friction and the mesh was done as follows.

Material Parameters

The soil simulated was a clay with the characteristics of deep sea