Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Numerical Study of the Mechanics of Inflatable Anchors in Clay

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ABSTRACT

This paper describes an investigation into the performance and pullout capacity of an inflatable anchor system embedded in soft clay soil. A series of scaled physical model tests have been used to study anchor performance and pullout capacity. The anchor behaviour during pullout has been interpreted using finite element analysis that accounts for the non-linear soil behaviour with different undrained shear strengths, inflation pressures and anchor-soil interaction. The scaled model tests and interpretations indicate that the soil strength, inflation pressure and the degree of consolidation were the dominant mechanisms affecting the pullout capacity of the inflatable anchor system in soft clay. The results of back calculation obtained from the finite element analysis indicate that local drainage occurred during placement of the anchors and subsequent inflation (cavity expansion) leading to increase of the undrained shear strength of the soft clay.

KEY WORDS: Soft clay, inflatable anchor, undrained, pullout capacity, finite element analysis.

INTRODUCTION

Anchor systems can be advantageous when used with remotely operated offshore vehicles (ROV). Significant reaction loads are sometimes required to prevent movement and/or to assist with controlling the vehicle. Previous attempts to employ 'classical' anchor systems, such as helical screws, duckbill or plate anchors, have had variable success and an alternative form of inflatable anchor has been developed.

This paper describes an investigation into the performance and pullout capacity of this inflatable anchor system embedded in soft clay. The anchor system comprises of a hydraulically inflated rubber membrane or packer that may be bored or jetted into place and inflated to provide pullout resistance. A series of scaled physical model tests have been used to study anchor performance and pullout capacity (Newson and Brunning, 2001). The model tests were done in a calibration chamber using an artificial soft clayey soil with various undrained shear strengths. The finite element program PLAXIS has been used to analyze the anchor behaviour during pullout. The non-linear soil behaviour response, variation of different undrained shear strengths, inflation pressures and anchor-soil interaction were considered in this finite element analysis. Back calculation obtained from this finite element analysis indicated that local drainage occurred during the cavity expansion phase and lead to the increase of the undrained shear strength of the soft clay. The results of the scaled model tests and interpretations indicate that the soil strength, inflation pressure and the degree of consolidation that occurred during the tests were the dominant mechanisms affecting the pullout capacity of the inflatable anchor system in soft clay.

EXPERIMENTAL STUDY

Equipment

Small scale physical model testing was previously carried out in a large cylindrical steel test chamber of 700mm internal diameter and 1200mm height and is reported elsewhere (Gallacher, 2000 and Newson et al., 2001). Fig. 1 shows the test setup. The inflatable anchor system consisted of a 35mm diameter cylindrical steel tube with two layers of 1.5 mm thick rubber tubing fixed to the rod using mechanical clips. Fluid or air can be pumped into the annular space between the rod and the membrane. Tests were done using sand roughened outer membranes to improve its interface strength. Two different forms of experiment involving constant pressure and constant anchor volume testing can be performed. Values for the pullout loads and displacements, inflation pressures and volume change, etc. were recorded during each experiment.

Materials and Properties

The anchor tests were conducted on an artificial clayey soil, which was a blend of Speswhite kaolin and Congleton silica sand to represent the typical offshore deposit (Gallacher, 2000 and Newson et. al., 2001). Congleton silica sand has a uniform gradation with D_{50}=0.3mm, and a specific gravity, G_s, of 2.65. The constant volume friction angle, ϕ'_{cv}, is in the range of 32-34^o. The Speswhite kaolin clay was a commercially produced kaolin clay with G_s=2.68, I_L=65% and I_p=30%. The effective angle of friction, ϕ', is about 22^o.