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The Prediction of Dragging Trajectory of a VLA at Early Stage

Yongshu Jiao, Qingfeng Zhang
School of Mechanical Engineering, Hebei University of Technology
Tianjin, China
Haixiao Liu
School of Civil Engineering, Tianjin University
Tianjin, China

ABSTRACT

The plastic yield locus of a particular anchor expresses the combination of the loads that result in failure of the anchor in clay. It is then used to predict the ultimate holding capacity and dragging trajectory. Since the failure modes are quite different for shallow and deep anchors, the yield loci would be different for an anchor during penetration. It is reasonable to predict the entire penetrating trajectory with the corresponding loci. In this paper, finite element analysis has been utilized to investigate the behavior of a rectangular shallow anchor subjected to combined loadings similar to those experienced during the early stage of dragging. A rigorous numerical study into the ultimate holding capacity of a rectangular shallow VLA has been conducted. Consideration has been given to the effect of embedment depth and anchor inclination. The results are presented in the form of plastic failure loci. The study shows that at different depths and inclinations the values of the force at failure and the shapes of the plastic yield loci of the shallow anchor are quite different. These then would affect the prediction of the dragging trajectory significantly at early dragging stage.

KEY WORDS: Plastic yield locus; vertically loaded anchor; trajectory; finite element method; embedment depth; anchor inclination.

INTRODUCTION

Recently the new trend of offshore developments to move into deep waters has resulted in a greater reliance on anchored floating structures such as FPSOs, FSOs, and CALMs. These structures often require to be anchored in soft, normally consolidated or slightly over-consolidated soils. As a new mooring foundation, the vertically loaded anchor (VLA) is being used to tether more elaborate and substantially larger offshore floating oil and gas facilities. Thus a deeper and more comprehensive understanding of the installation performance of the VLA is needed.

The failure mechanisms of an anchor can be divided into two categories according to the embedment depth. When a shallow anchor fails, the plastic flow of the soil around the anchor extends to the surface. The ultimate holding capacity of the anchor depends strongly on the depth and orientation of the anchor. Whereas for a deep anchor, failure of the soil can be assumed to consist of localized plastic flow just around the anchor. Thus the installation behavior of the anchor will be largely independent of the depth and orientation of the anchor.

The ultimate holding capacity (UHC) of a VLA depends strongly on its final orientation and depth below the seafloor. Hence the prediction of the anchor trajectory during installation is a critical issue in VLA design. Up to now there have been several kinds of methods to predict the kinematic trajectory of anchors.

Based on correlations with observed anchor performance, empirical prediction methods (NCEL 1987, Vryhof Anchors 1999) usually give the anchor depth and capacity according to the anchor weight and the soil shear strength.

Taking into account a more detailed description of the soil and the anchor, the limit equilibrium methods (Stewart Technology Associates 1995, Neubecker & Randolph 1996, Dahlberg 1998) predict the anchor trajectory in an incremental way based on an estimated description of soil force on the anchor faces at failure conditions.

Bransby & O'Neill (1999) proposed a new method to predict the trajectory of a dragging anchor. The method uses a plastic yield locus describing the loads at failure as a plastic potential surface. The yield locus is produced using limit analysis solutions and FEM analyses. Then the locus can be used to predict the dragging anchor kinematics, assuming that the direction of the anchor movement is governed by the normal to the plastic yield locus at the corresponding loading conditions. Supposing that the orientation of the anchor makes no difference to the installation behavior of the anchor, Bransby & O'Neill studied comprehensively the penetration performance of a rectangular and a wedge-shaped deep anchor.

The objective of the current paper is to investigate the failure behavior of a rectangular anchor at the early dragging stage using FEM analyses. Consideration is given to the effect of anchor depth and orientation. The results are presented in the form of plastic yield loci. The study shows that the limiting load values and the shapes of the yield loci depend strongly on the depth and the orientation of the anchor at early dragging stage.

ANCHOR GEOMETRY AND SOIL MODEL