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Lateral Undrained Resistance of Suction Caisson Anchors

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ABSTRACT

A simplified method of analysis for estimating lateral load capacity of suction caisson anchors based on an upper bound plasticity formulation is presented. The simplification restricts the analysis to caissons in uniform and linearly varying undrained strength profiles; nevertheless, its computational efficiency permits quick evaluation of a number of parameters affecting load capacity. The validity and limitations of the simplified formulation are demonstrated through comparisons to more rigorous finite element solutions. A series of sensitivity studies evaluates the effects of various soil conditions and loading parameters.

INTRODUCTION

Suction caissons are large, hollow, cylindrical foundation elements for offshore facilities installed by pressure drawdown within the cylinder, referred to as suction, after partial penetration of the cylinder due to its dead weight. They can have significant advantages over conventional piles and have been used as both fixed foundations and anchors for a variety of offshore structures. Suction caissons avoid a number of drawbacks associated with conventional piles; however, there is a paucity of performance data on suction caisson behavior and our current level of understanding is limited. This paper addresses one aspect of the suction caisson performance: the capacity of the anchor when subjected to short-term lateral loads.

This paper presents the development of an algorithm for estimating lateral capacity using a simplified lateral resistance factor proposed by Murff and Hamilton (1993). The simplified solutions are validated through comparisons with finite element solutions. Finally we present a series of sensitivity studies that systematically detail the effects of soil strength, caisson aspect (depth-to-diameter) ratio, soil-caisson adhesion, soil weight, and suction. While this study was performed primarily with a view toward improving our understanding of laterally loaded suction caisson anchors, the results may also be applicable to other rigid, laterally loaded foundation elements such as caisson foundations and short piles.

BACKGROUND

The ultimate average unit lateral pressure P on an underwater caisson can be expressed as (Matlock, 1970; Reese et al., 1975; Murff and Hamilton, 1993):

$$P = N_p s_u \quad \text{(no gap or a weightless soil)} \tag{1a}$$

$$P = N_p s_u + \sigma'_{v0} \quad \text{(gap)} \tag{1b}$$

where N_p is a dimensionless bearing factor, s_u is the local soil undrained shear strength, and σ'_{v0} is overburden pressure.

For a deeply embedded, laterally loaded circular caisson in perfectly plastic material, the problem can be approximated as a 2-dimensional one with soil flowing horizontally around the caisson. For the cases of perfectly smooth and rough caissons, Randolph and Houlsby (1984) present solutions from plasticity theory to give $N_p = 9.14$ and $N_p = 11.94$, respectively. These flow-around solutions correspond to conditions of no gap formation behind the caisson (Eq. 1a).

The influence of a free surface on ultimate lateral pressure is treated by Murff and Hamilton (1993), who propose an upper bound analysis based on a collapse mechanism comprised of a 3-dimensional wedge mechanism near the free surface and a flow-around failure (Randolph and Houlsby, 1984) at depth. By optimizing 4 parameters characterizing the kinematics of the failure mechanism, they computed a minimum upper bound load capacity F. By successively increasing the length of the caisson by an incremental length ΔL and computing the increase in lateral capacity ΔF for pure translation of the caisson, they computed bearing capacity factors from the relationship:

$$N_p = \frac{\Delta F}{s_u D \Delta L} \tag{2}$$

where s_u is the local undrained shear strength, and D is the caisson diameter.

Using this approach, Murff and Hamilton (1993) conducted several parametric studies. One study comparing predicted lateral resistance profiles for translating and rotating caissons showed virtually identical results: Lateral resistance appears to be relatively independent of caisson rotation. This is consistent with findings by Matlock (1970). Murff and Hamilton compared their N_p values to previous semi-empirical models (Matlock, 1970; Reese et al., 1975) and to centrifuge test data (Hamilton et al., 1991) and found favorable agreement.

By conducting a series of analyses for the special case of a lin-

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