Study on the Lateral Bearing Capacity of Small-spacing Multi-bucket Foundation in Soft Ground

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ABSTRACT

As a new type of foundation in shallow water, bucket foundation has been developed in recent for its significant advantages over conventional ones. But its bearing capacity and design method can not meet the basic requirements of engineering practice sufficiently. In this paper, the lateral bearing characteristic and the failure mechanism of small-spacing multi-bucket foundation ($B \leq 0.8D$) is studied respectively in no connection, rigid connection and elastic connection between buckets based on three-dimensional finite element method. According to the numerical analysis results, a limit analysis method for evaluating the lateral bearing capacity of small-spacing multi-bucket foundation is proposed.

KEY WORDS: multi-bucket foundation; three-dimensional finite element; limit analysis; soft soil.

INTRODUCTION

As a fixed anchor for offshore facilities, bucket foundation is subjected to various lateral loads caused by wind, wave, current, ice and other factors. Estimating the lateral bearing capacity exactly is much important to the stability of bucket foundation. So, increasing attentions are paid on it now. An upper bound plastic limit approach to lateral load capacity of piles and caissons assuming isotropic soil with undrained strength properties is first proposed by Murff and Hamilton (1993). Their model assumes a collapse mechanism comprised of a surface failure wedge, a plane strain flow-around zone, and a hemispherical failure surface at the pile tip. By optimizing four geometric parameters, a minimum pile lateral load capacity is obtained. Aubeny et al. (2001) give a simplified formulation of the Murff and Hamilton analysis, making it more amenable for use as a design tool. Aubeny et al. (2003) present a plastic limit analysis of the lateral load capacity of suction caissons in an anisotropic, purely cohesive soil assuming conditions of rotational symmetry about the vertical or gravity axis. The formulation utilizes a form of the Hill yield criterion that is modified to allow for different soil strengths in triaxial compression and extension. A new combined three-dimensional failure mechanism of bucket foundation in undrained soft clay under lateral loads is established according to its performance, and based on the upper bound theorem, the limit analysis model of bucket foundation under lateral loads is proposed by Wang et al (2006).

All of the aforementioned formulations are carried out on the base of taking single-bucket foundation as research object. However, multi-bucket foundation is used commonly and widely in practical engineering. It is necessary to develop an improved method that is suit for estimating the lateral bearing capacity of multi-bucket foundation. In this paper, small-spacing multi-bucket foundation under lateral load is analyzed respectively in no connection, rigid connection and elastic connection between buckets as a whole using the general-purpose finite element analysis package ABAQUS. Then, the lateral bearing capacities are compared mutually for the three connection types. Finally, an upper boundary method for evaluating the lateral bearing capacity of small-spacing multi-bucket foundation in soft ground is given based on the failure mechanism of rigid connection.

FINITE ELEMENT METHOD

Modeling

The finite element analyses of small-spacing multi-bucket foundations performed here are small-strain analyses. The planar sketch of a multi-bucket foundation is shown in Figure 1. The soil property is taken as an elastic perfectly plastic using the Hill yield criterion. Poisson’s ratio of the soft clay is taken as $\nu=0.49$ and deformation modulus $E$ is assumed to be 320 times that of $S_u$ based on the existing research experience. Both soil strength isotropy and anisotropy are carried out here. The anisotropy strength is used as the one described by Ladd (1991), that $S_{utc}/S_{ussv}=1.33$, $S_{utc}/S_{ussv}=0.96$ and $S_{utm}/S_{ussv}=1$, where $S_{utc}$, $S_{utm}$, $S_{ussv}$ and $S_{utsv}$ is the shear strength of triaxial compression, triaxial extension, pressuremeter and direct simple respectively. The bucket is modeled as a linear elastic body with a modulus of elasticity $E=210$ GPa, Poisson’s ratio $\nu=0.3$ and the slenderness ratio is selected as $L/D=1.0$ according to actual projects. The unit weight of the bucket is idealized equal to that of the soil to ensure geostatic equilibrium in numerical analyses.

Figure 1 Plane sketch of the multi-bucket foundation