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Analysis of Bearing Capacity of Suction Bucket Foundation Subjected to Horizontal and Moment Loadings

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Abstract: The suction bucket foundation is not only supporting the vertical loading such as the sea platform and weight itself, but also subjecting to horizontal and moment loading due to wind and wave. The response of bucket foundation to combined Horizontal (H) and Moment (M) loading has been studied using 3D finite element analysis Then the proposed method is numerically implemented in the framework of the general-purpose FEM software ABAQUS. Relationship curve between the coefficient of ultimate bearing capacity and displacement is obtained by the application of load-displacement controlled method in homogeneous soft foundation the failure envelope of foundation in the *M-H* is obtained by the application of swipe testing. The behavior is explained using upper bound plasticity mechanisms suggested by the soil deformation mechanisms observed in the finite element analysis. The numerical results computed by the proposed method will be helpful in engineering practices.

Keywords: Bearing capacity, bucket foundation, horizontal loading, 3D finite element method, moment loading

INTRODUCTION

Stability analysis of offshore foundation is not only foundation sedimentation, but also is more emphasizing the plastic theory. Those are being to establish the response problem of offshore foundation under different loadings (Liu, 2002). As one new offshore foundation, bucket foundation is always subjected to horizontal loading and moment loading by storm wind and wave. So, it is one key problem of construction that the bearing capacity of bucket foundation under horizontal and moment loads is effective investigated. To evaluate the bearing capacity of bucket foundation, the failure envelope of foundation subjected to horizontal and moment loadings is drawing. The stability of foundation is evaluated by relationship actual loads and failure envelope (Huang, 1996). The general-purpose finite element analysis package ABAQUS is utilized and numerical analyses are conducted. The displacement controlled method and Swipe method are used to investigate the bearing capacity of bucket foundation under different loadings (Tan, 1990). And the failure envelope is established and mechanics of foundation is analysis, which can be used to evaluate the stability of foundation subjected to actual loads.

NUMERICAL ANALYSIS

An elasto-perfectly plastic constitutive model based on Mohr-Coulomb failure criterion is employed for undrained condition with cohesion of S_u (Zhao *et al*., 2005). The Poisson's ratio is $v = 0.49$ and the Young's modulus is taken as $E = 500\ S_u$. In addition, the bucket foundation is assumed behaving elastically, its Young's modulus is $E = 2.1\times105$ MPa and Poisson's ratio is $v = 0.125$. Three dimensional finite element model is numerically implemented in the general-purpose FEM package ABAQUS. The boundary should be chosen far enough to eliminate the influence of artificial boundary conditions (Pyke and Beikae, 1984). As shown in Fig. 1, a width of 8*D* and a depth of 5*L* are chosen for the example case.

Based on the constitutive model and the computional model, the ultimate bearing capacity of bucket foundation under monotonic loading can be defined by displacement controlled. However, the failure envelope of foundation subjected to horizontal and moment loadings can be established by Swipe test method (Taiebat and Garter, 2000; Bransby and Randolph, 1999).

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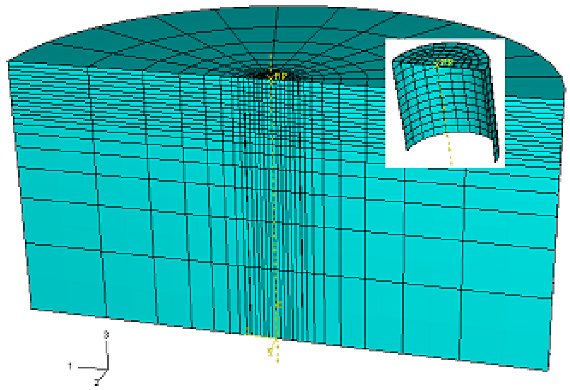
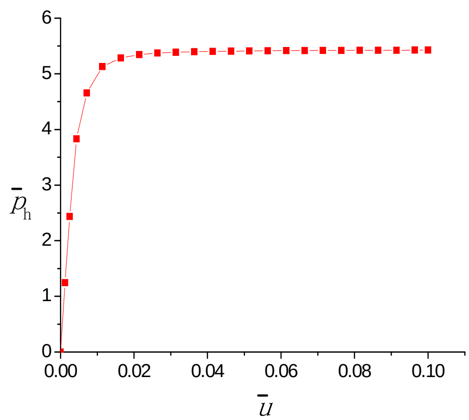
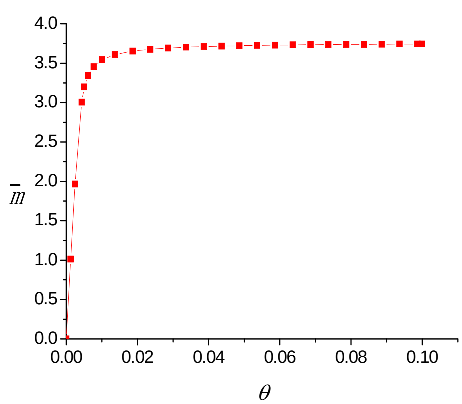


Fig. 1: The finite element model used in analyses

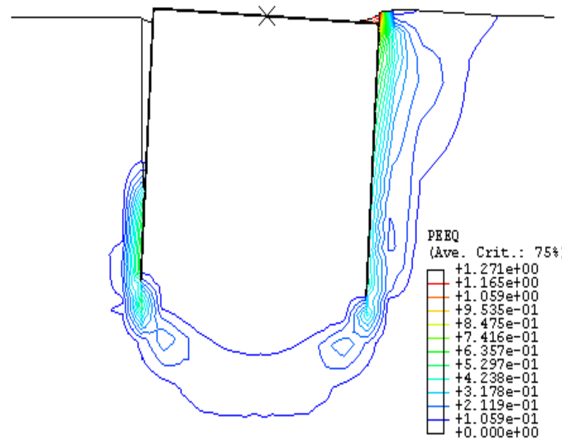


(a) Horizontal loading

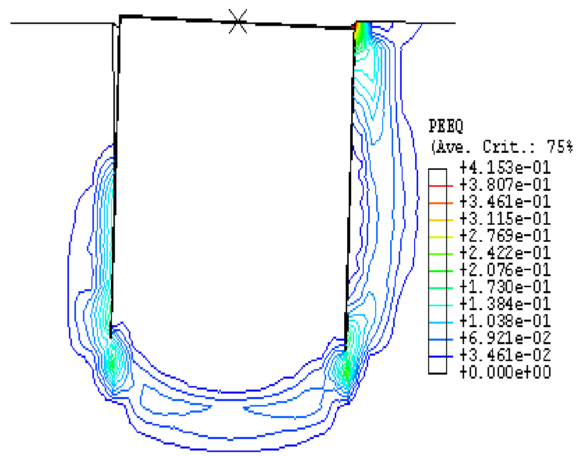


(b) Moment loading

Fig. 2: Relationship between loading and displacement



(a) Horizontal load



(b) Moment load

Fig. 3: The equivalent plastic strain of bucket foundation

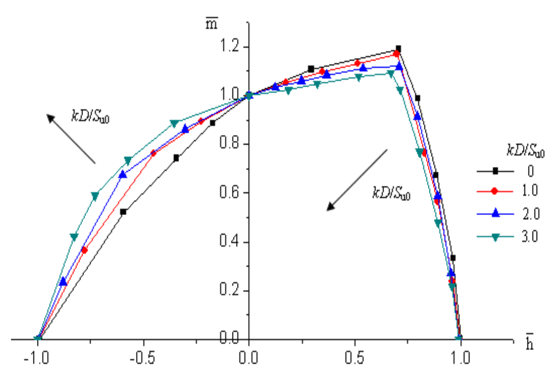
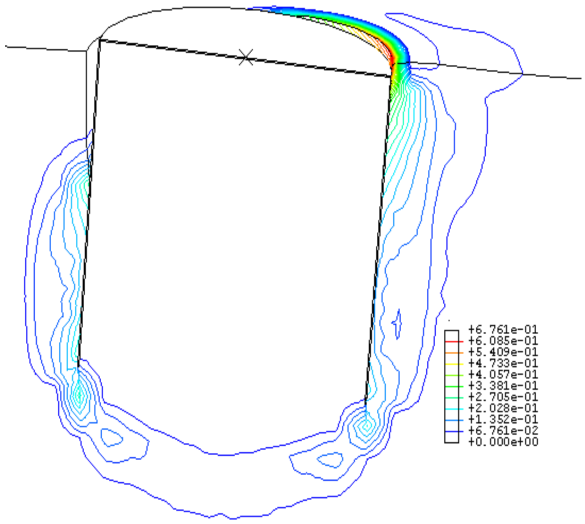


Fig. 4: Failure envelopes in H: M laod plane with normalized load space

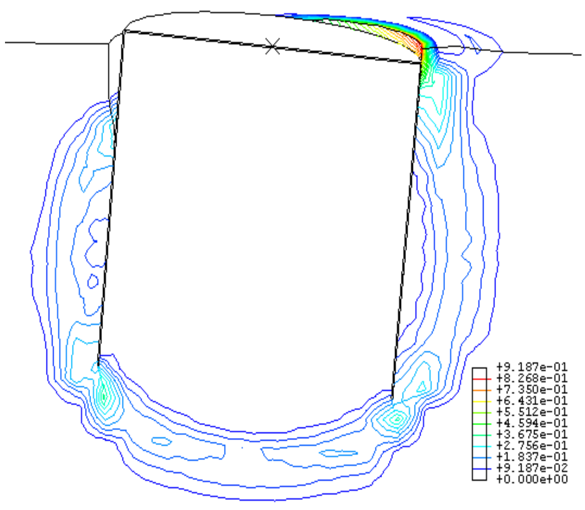
NUMERICAL RESULTS

Ultimate bearing capacity: The relationship between loading and displacement of bucket foundation under monotonic loading is shown in Fig. 2.

It can be observed that under horizontal loading or moment loading, the slope of load-displacement relation computed tends to vanish with increase of displacement and the imposed load sustains in a stabile value. Such a state is thought to be limit-equilibrium condition. Accordingly, the applied load is regarded as ultimate bearing capacity. The factor of horizontal



(a) M = 0.1M_{u1t}



(b) M = 1.0M_{u1t}

Fig. 5: Distribution of εp in foundation under combined loading (V = 0)

ultimate bearing capacity computed is 4.64 and the computed limit state is considered to be achieved at $\bar{u} = 0.02$. Under moment, the computed factor of ultimate moment is 3.66 and the limit state given by numerical analyses is achieved at $\bar{\theta}$0.04.

The equivalent plastic strain of bucket foundation subjected to monotonic loading is shown in Fig. 3. It can be founded that:

- Under horizontal load, the integrated scoop-shaped distribution of strain is initiated at the bottom of bucket foundation. At the same time, a passive wedge is produced in the side of bucket foundation along the loading direction. While in the side of bucket foundation along the direction contrary horizontal loading, a separation is induced in the so-called active area
- Under moment, it seems that the collapse mode is similar to that happens under horizontal loading. In fact, both active and passive zones in limit-equilibrium state depend on moment.

Failure envelop: Failure envelopes in H: M load space with the loads normalized by their respective ultimate values are shown in Fig. 4. It seems that a significant reduction in the overall size of the failure envelopes as the degree of non-homogeneity increase in H: M load space, but the failure envelopes with increase of non-dimensional ratio (kD/S_{u0}) expand markedly.

The equivalent plastic strain of bucket foundation subjected to monotonic loading is shown in Fig. 5. It can be founded that under different moment loads, the integrated scoop-shaped distribution of strain is initiated at the bottom of bucket foundation. At the same time, a passive wedge is produced in the side of bucket foundation along the loading direction. While in the side of bucket foundation along the direction contrary moment loading, a separation is induced in the so-called active area.

CONCLUSION

By integrating the general-purpose FEM analysis package ABAQUS with the Swipe test procedure of loading based on displacement-controlled manner, the failure mechanism and bearing capacity feature of bucket foundation subjected to horizontal and moment loadings are investigated. It is addressed that the slope of load-displacement relation computed tends to vanish with increase of displacement and the imposed load sustains in a stabile value. Through numerical computations and comparative analyses based on FEM, the three-dimensional failure envelope of suction bucket foundation can be established by using the proposed method in order to evaluate the stability of foundation under combined loading. It can be found that a significant reduction in the overall size of the failure envelopes as the degree of non-homogeneity increase in H: M load space, but the failure envelopes with increase of non-dimensional ratio (kD/S_{u0}) expand markedly.

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