University of Tabriz

Journal of Civil and Environmental Engineering
Volume 53 (2023), Issue 1 (Spring), 31-41

EXTENDED ABSTRACT

3-D Simulation of Bucket Foundations Used For Offshore Wind Turbines under Monotonic Loading Conditions

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Received: 30 October 2019; **Accepted:** 17 August 2021

Keywords:
Offshore wind turbine, Numerical simulation, Monopod bucket foundation, Finite Element Method.

1. Introduction

Bucket foundation is a new foundation concept developed in the last decade for offshore wind turbines. Due to easy and faster installation with significantly lower expenses compared to the conventional foundations such as gravity bases and mono piles, suction caissons foundations are reliable and alternative foundation solutions. In this study push-over analysis was utilized to investigate the response of a typical monopod offshore wind turbine foundation under monotonic loading condition. Finite Element Method was used to define and analyze different scenarios.

2. Methodology

2.1. Numerical modeling

A 3D finite element model of suction caissons with different geometries were simulated to assess the bucket behavior under various loading conditions. The finite element program PLAXIS 3D (Brinkgreve et al., 2012) software was used for simulation modeling. Displacements in all directions of the model boundaries (the bottom, all directions of periphery plus normal direction on the symmetry) were fixed. The displacement-controlled method was employed to model the horizontal loads.

2.2. Validation of the model

Two field test studies for suction bucket foundation at Frederikshavn (Houlsby et al., 2005) and Sandy Haven (Houlsby and Byrne, 2000) were analyzed by the above model to validate the numerical modeling adopted in this study. To verify the capability of the bucket foundation used for a 3 MW wind turbine, large-scale experiments were conducted at Denmark. The second study consisted of large-scale field tests at Sandy Haven on the south coast of Wales. Displacement and rotation of the bucket were captured for increasingly applied horizontal load.

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3. Results and discussion

3.1. Ultimate load, moment capacities

Numerical simulation was performed on a typical model of bucket foundation installed in dense and medium dense sand. A vertical dead load V, $10000\ kN$, which is a conventional load for a 5 MW offshore wind turbine was applied on the center of bucket lid. Buckets with the diameters of $10m\ and\ 12m$, and three embedment ratios, $L/D = 0.5, 0.75\ and\ 1$ installed into two different soil densities were considered in this study. Push-over analysis was employed for a broad range of load eccentricities ($h = 0m, 5m, 10m, 20m, 40m, 70m, 100m$).

The load eccentricity has a significant effect on both the ultimate horizontal load and moment capacities. For example, in the case of bucket with the diameter of 12 m and skirt length of 9 m, there can be seen almost 14 and 2 times increases in ultimate horizontal load and overturning moment capacities when with the height of applied load increased from 0 to 100 m. The highest ultimate horizontal loading capacity occurred with no load eccentricity $h = 0m$.

3.2. Normalized diagram curves

To get more practical diagram curves, dimensionless horizontal load and moment variables were sought and presented in Equations 1 and 2.

$$\overline{H}_u = \frac{H_u}{\gamma' L^2 D} \tag{1}$$

$$\overline{M}_u = \frac{M_u}{\gamma' L^3 D} \tag{2}$$

Where $\overline{H}_u$ is a non-dimensional ultimate horizontal load, H_u is an ultimate horizontal load, $\overline{M}_u$ is non-dimensional ultimate overturning moment, M_u is an ultimate overturning moment, γ' is the effective unit weight of soil, D is a bucket diameter, and L is a bucket skirt length. It should be noted that the effect of bucket geometry on the load and moment capacity was investigated, and both bucket diameter and skirt length with different weights were taken into account to define dimensionless variables. Fig. 1 illustrates the ultimate horizontal load-moment interaction diagrams in a normalized form. The given curves may be employed for the preliminary design to estimate the failure load in addition to finding suitable bucket geometry.

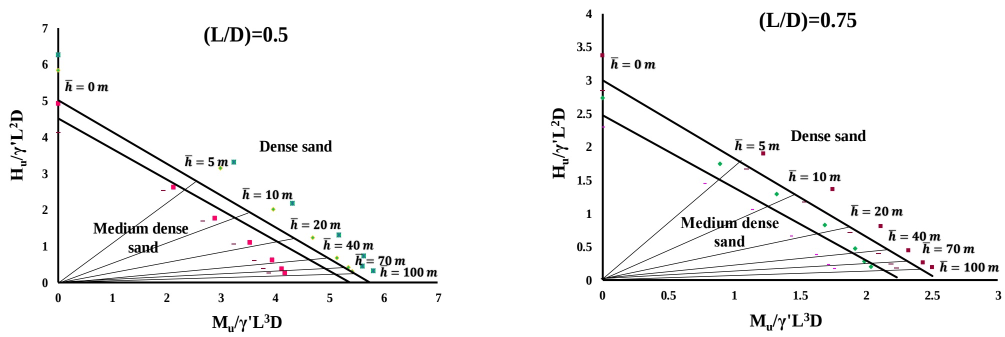

Fig. 1. Normalized ultimate horizontal load-overturning moment diagrams (Embedment ratio=0.5; up left, Embedment ratio=0.75; up right, Embedment ratio=1; down).

4. Conclusions

3D analyses were conducted for suction caissons used for offshore wind turbines to evaluate the bucket response under various loading conditions. The numerical analysis results show that the displacement and rotation of the bucket foundation are highly dependent on the embedment ratio. There is strong correlation of ultimate horizontal load and overturning moment capacities with bucket geometry and soil density. By presenting the normalized diagram curves, the dependency of the bucket load and moment capacity with skirt length and diameter were found. The normalized curves and equations can be used for the preliminary design of suction bucket foundations used for offshore wind turbines.

5. References

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