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Bucket Foundation Response Under Various Displacement Rates

Evelina Vaitkunaite, Benjaminn N. Nielsen and Lars B. Ibsen
Department of Civil Engineering, Aalborg University
Aalborg, Denmark

The present testing program aims at showing the pore pressure response around a bucket foundation skirt as well as the load and displacement change due to ten different displacement rates. Research findings are useful for a numerical model calibration focusing on the design of the upwind foundation in a multi-bucket foundation system. The foundation model is at a scale of approximately 1:20 prototype foundation size. The tests are performed in a pressure tank with the foundation model installed in dense sand. Based on the data, the conclusion is that the bucket foundation design in a storm case should allow accounting for partial drainage in sand.

INTRODUCTION

If a jacket with several bucket foundations supports a wind turbine (see Fig. 1), the upwind foundation should be able to resist tensile loading in the short or long term. The drained tensile capacity of a bucket foundation corresponds to the self-weight of a structure and the frictional resistance along the inner and outer skirt. If the tensile load is applied rapidly enough, undrained conditions can arise, resulting in high tensile resistance even in sandy soil. Drainage conditions depend on the size of the foundation, soil permeability, and loading intensity. Cavitation pressure limits the pore suction induced by the tensile loading; the cavitation pressure is approximately −100 kPa under atmospheric pressure conditions and at temperatures of about 0°C–35°C.

When the bucket foundation response during a storm loading is estimated, it is important for the foundation to resist the large wave loads. In a jacket case, the horizontal wave loads would be transferred to the dominating tensile and compressive components on the foundations. A well-known case concerning the monster wave in the Draupner E jacket with four bucket foundations proved that the pore pressure dissipation during the large wave (with a wave period of 11.2 s) was very low (Hansteen et al., 2003; Tjelta, 2015). Thus, in a storm loading, the loads on a full-scale bucket foundation would most probably create partial drainage conditions, and the tensile response would be somewhere between the drained and undrained even in sandy soils. Pore suction induced due to rapid loading increases the tensile bucket foundation capacity. The tendencies of the tensile capacity's dependence on the loading rate were also noticed by Bye et al. (1995), Feld et al. (2000), and Kelly et al. (2006). Clearly, a successful numerical model would be preferable for the foundation design. In the best case, a suitable numerical model should be calibrated with a large-scale model test. As the latter is very expensive, laboratory tests can provide useful information.

Iskander et al. (1993) performed tensile loading tests on a model suction pile that had an outer diameter of 0.11 m and a shaft length of 0.19 m. The foundation model was installed in water-saturated dense sand. The authors investigated suction installation and its influence on the frictional resistance. The study included four pull-out tests, each of different type according to the installation method and type of tensile loading. An analytical method predicting the tensile capacity was proposed according to the test data. Feld et al. (2000) and Feld (2001) performed laboratory tests on a small-scale bucket foundation and concluded that a large tensile capacity could be generated by suction. Houlsby et al. (2005) presented an analytical method for evaluating the tensile resistance of a bucket foundation when suction is present. They stated that friction along the skirt reduces vertical stresses and proposed a method to include this reduction in the tensile capacity calculation. Houlsby et al. (2005) validated their analytical method by comparing it to laboratory tests performed in a pressure chamber with a suction caisson installed in water-saturated dense sand. The bucket dimensions were diameter D of 0.28 m and skirt length d of 0.18 m. Houlsby et al. (2006) performed large-scale field testing and remarked that a large tensile capacity at large displacements could be generated during pull-out tests. Kelly et al. (2003, 2004, 2006) performed laboratory tests and concluded that the bucket foundation's tensile capacity should be limited to the self-weight of the structure, frictional resistance, and plug weight (if applicable). Byrne and Houlsby (2006) stated that tension on the upwind foundation should be avoided in order to have a safe structure. To follow such a recommendation, the spacing between

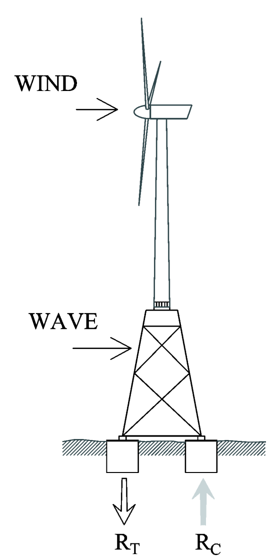

Fig. 1 A wind turbine on a jacket with several bucket foundations with reactions to tensile loading (R_T) and compressive loading (R_C)

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