Axial Cyclic Loading Tests on Pile Segments in Sand

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This paper presents one-way cyclic tension tests on a pile segment installed in dense sand in a laboratory test setup. The test setup allowed application of surcharges to increase the vertical effective stress. The open-ended pipe pile segment was 0.5 m in diameter and 1 m in length. The test results showed that cyclic loading with small amplitudes can increase the shaft capacity, but increase of the cyclic amplitude can result in large accumulated displacements and decreased cyclic reloading stiffness. The test results are compared to an existing interaction diagram.

INTRODUCTION

Undesirable permanent tilt of offshore wind turbines on jacket foundations can occur as a result of accumulated upward displacements of foundation piles loaded in tension during a storm. To prevent this from happening and to avoid load cases resulting in large accumulated displacements of the foundation piles in the future, it is necessary to analyze the effect of cyclic loading on the shaft capacity.

Field tests and small-scale tests with idealized data series of one-way (OW) or two-way (TW) cyclic loading have been carried out (Chan and Hanna, 1980; Al-Douri and Poulos, 1994; Chin and Poulos, 1996; Le Kouby et al., 2004; Tsuha et al., 2012; Silva et al., 2013). These tests analyze the effects of mean load levels and cyclic amplitudes on the pile capacity (Tsuha et al., 2012; Jardine et al., 2006; Le Kouby et al., 2004). Moreover, researchers analyzed the local stress paths in the soil adjacent to the pile (Tsuha et al., 2012) as well as the behavior in the pile–soil interface (e.g., Tsuha et al., 2012; Prai-ai, 2013; Mortara et al., 2007).

Field tests are expensive and researchers often conduct laboratory tests instead, although this incurs the disadvantage of small-diameter pile specimens with an incorrectly modeled pile–soil interface. The OW cyclic tension tests presented in this paper are conducted in a laboratory test setup but with an open-ended pile segment with a diameter of 0.5 m and a length of 1 m. By increasing the vertical effective stresses in the sand by means of a surcharge, different soil depths are simulated, and the test results provide the capacity of a 1 m pile segment at a given soil depth.

This paper will provide a short description of the test setup and present the chosen test program. The test program is based on the aim of analyzing the effect of OW cyclic tests with the mean load in tension and on the interaction diagram by Jardine and Standing (2012). This paper will also include analysis of the effects of the chosen mean load level and cyclic load amplitude on the accumulated displacement and postcyclic capacity.

METHODOLOGY

To minimize the scaling effects in the laboratory tests, the objective was to model the pile–soil interface correctly. Therefore, it was desired to have a pile diameter approximating full-scale pile diameters and to make the pile specimen of steel to obtain the lightly rusted surface seen for full-scale piles. The test facilities at Aalborg University Geotechnical Laboratory could not accommodate a full-scale pile, so an open-ended 1 m long pile segment with a diameter of 0.5 m was selected. The tests were conducted in a sandbox with the possibility of increasing the effective vertical stresses in the sand. Thus, 1 m pile segments at different soil depths could be simulated in the tests. Thomassen (2016) provide a detailed description of the test setup while the following sections provide a short description.

Sandbox

Figure 1 shows the test setup that consisted of a large circular box with a diameter of 2.5 m and a height of 1.5 m. The vertical boundaries and the bottom boundary were rigid. A drainage system at the bottom of the sandbox made it possible to saturate and loosen the sand by means of a hydraulic gradient. The sand layer was 1.2 m thick and consisted of Aalborg University Sand No. 1 with the properties given in Table 1.

Hydraulic load systems were used to install and load the pile. The hydraulic piston to the right was used when installing the pile.