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Evaluation of the Load-Displacement Relationships for Large-Diameter Piles in Sand

S.P.H. Sorensen, K.T. Brodbaek, M. Moller, A.H. Augustesen and L.B. Ibsen
Department of Civil Engineering, Aalborg University, Denmark

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For laterally loaded piles in sand with diameters up to 6m, for example monopiles used as foundations of offshore wind turbines, there is no approved design procedure. The *p-y* curve method, given in offshore design regulations, is usually employed for the design of monopiles. However, this method was developed for slender piles with diameters much less than 6m and it is based on a limited number of tests.

The aim of the present work is to extend the *p-y* curve method to large-diameter non-slender piles by considering the effects of the pile diameter on the soil response. The main focus is the initial stiffness of the *p-y* curves. The evaluation is based on experimental work as well as three-dimensional numerical analyses. The numerical analyses are made by means of the commercial programme FLAC^{3D}. A Mohr-Coulomb material model is employed. The numerical model is calibrated using six small-scale tests conducted on heavily instrumented piles with diameters varying from 60-80 mm subjected to a horizontal load. The tests are carried out in a pressure tank at different effective stress levels in order to simulate realistic effective vertical stresses for a typical monopile. After calibrating the model using small-scale tests the numerical model is extended to full-scale wind turbine foundations. The results are compared with results obtained from a traditional *p-y* curve design based on a Winkler model approach.

Major findings of this paper are:

1. The initial stiffness of the *p-y* curves increases for increasing pile diameter.
2. The initial modulus of subgrade reaction given by the offshore design regulations is overestimated for large diameter non-slender piles.
3. A linear variation of the initial stiffness with depth is a non-conservative estimation at large depths
4. The power function proposed by Lesny and Wiemann [1] describing the variation of initial stiffness with depth provides reasonable results compared with the three-dimensional numerical model.

References

1 K. Lesny, J. Wiemann, "Finite-Element-Modelling of Large Diameter Monopiles for Offshore Wind Energy Converters", Geo Congress 2006, February 26 to March 1, Atlanta, GA, USA, 2006.

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