Centrifuge modelling of drained lateral pile - soil response - DTU Orbit (27/10/2019)

Centrifuge modelling of drained lateral pile - soil response: Application for offshore wind turbine support structures

The installation and foundation cost of offshore wind turbines is substantial, and today energy from offshore wind is not competitive with energy from more classical energy production methods. The goal of this research project has been to develop simple engineering tools, which can be used in the design of a technical optimal and cost beneficial solution for an offshore wind turbine foundation and thereby reduce the price of energy from offshore wind turbines. The methodologies developed in this thesis hopefully contribute to a better understanding within this field.

Monopiles are one of the most popular foundation methods today for offshore wind turbines. These piles are often installed in dense sand at water depths ranging from 10-30 meters. A monopile is a single, large diameter tubular steel pile. The current design methodology originates from tests on long slender piles but is also used for monopiles today. Therefore it appears that the methodology for monopiles lacks scientific justification and a better understanding of rigid piles is needed.

More than 70 centrifuge tests on laterally loaded rigid model piles have been carried out in connection with this thesis to get a better understanding of rigid piles. The tests have been performed in homogeneously dense dry or saturated Fontainebleau sand in order to mimic simplified drained offshore soil conditions. Approximately half of the tests have been carried out to investigate the centrifuge procedure in order to create a methodology of testing that enables the transformation of result from tests in model scale to prototype scale. The grain size to pile diameter ratio, the non-linear stress distribution and the pile installation was identified from this investigation as important parameters in reliable scaling of centrifuge results.

The remaining tests were used to investigate the pile - soil interaction to gain a better in-sight into the complex problem. A monotonic test series was carried out initially and then pile - soil interaction curves were deduced from these tests and compared with methodologies used today. The results indicate that the current methodologies can be improved and a modification to the methodology has been proposed. Secondly, a cyclic test series was carried out. The accumulation of displacement and the change in secant stiffness of the total response of these tests were evaluated. A simple mathematical model was proposed to predict the accumulation of displacement and change in secant stiffness using the observations seen in the centrifuge.

With the centrifuge test observation as basis, a cyclic pile - soil interaction element was developed. The element can be used in Winkler type analysis where the soil is modelled as spring elements and the rest of the structure as beam elements. The model was calibrated against monotonic and cyclic centrifuge tests. The element predicts the hysteresis seen on element level in an acceptable way, but does not predict the accumulation of displacements and change in secant stiffness as seen in the experiments. The element used in a dynamic analysis gives an estimate of the frictional soil damping. The capabilities of the element were demonstrated by a series of free decay simulations where the logarithmic decrement could be calculated afterwards.

Altogether, the methodologies developed in this thesis can be directly used in the design of offshore monopiles, with a scientific justification based on centrifuge model scale tests.

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