Interaction between Seabed Soil and Offshore Wind Turbine Foundations

Today, monopiles are widely used as foundation to support offshore wind turbines (OWT) in shallow waters. The stiffness of monopiles is one of the important design aspects. Field observations show that some monopiles, already installed in the field, behave more stiff than predicted by the current design recommendations. The present study addresses the pile/seabed interaction problem, related to the stiffness of the monopile by means of a numerical model and experimental investigations. The numerical model is a 3D model. COMSOL Multiphysics, a finiteelement software, is used to calculate the soil response. The model is based on the Biot consolidation theory which involves a set of four equations, the first three equations describing the equilibrium conditions for a stress field, and the fourth one, the so-called storage equation, describing the conservation of mass of pore water with the seepage velocity given by Darcy's law (Sumer and Fredsøe, 2002, chap. 10). The constitutive equation for the soil considered in the model is the familiar stress-strain relationship for linear poro-elastic soils. The so-called no-slip boundary condition is adopted on the surface of the rocking pile. The numerical model is validated against the laboratory experiments. The experimental setup includes a container (a circular tank with a diameter of 2 m and a height of 2.5 m), and a stainless steel model pile (with a diameter of 20 cm). Coarse sand \(d_{50} = 0.64 \text{ mm}\) is used in the experiments. Pore-water pressures, pile displacements and forces on the pile are measured in the experiments. The pore-water pressure is measured at 12 points over a mesh extending 0.75 m in the vertical and 0.10 m in the radial direction (the measurement points closest to the pile being at 2 cm from the edge of the pile), using Honeywell pressure transducers. The pile displacement is measured, using a conventional potentiometer, while the force is measured with a tension/compression S-Beam load cell. The model, validated and tested, is used to calculate the soil response for a set of conditions, normally encountered in the field. The results are presented in terms of non-dimensional \(p-y\) curves, obtained from the numerical simulations. A parametric study is undertaken to observe the influence of various parameters on the latter. The parametric study shows that, for a given displacement, \(y\), the soil resistance \(p\), increases with increasing \(S\), a non-dimensional parameter responsible for generation and further dissipation of the pore-water pressure. The parametric study also shows that, again for a given \(y\), the soil resistance increases with decreasing bending stiffness of the pile, expressed in terms of a non-dimensional quantity \(s\). Finally, the soil resistance increases, when the non-dimensional foundation depth decreases.