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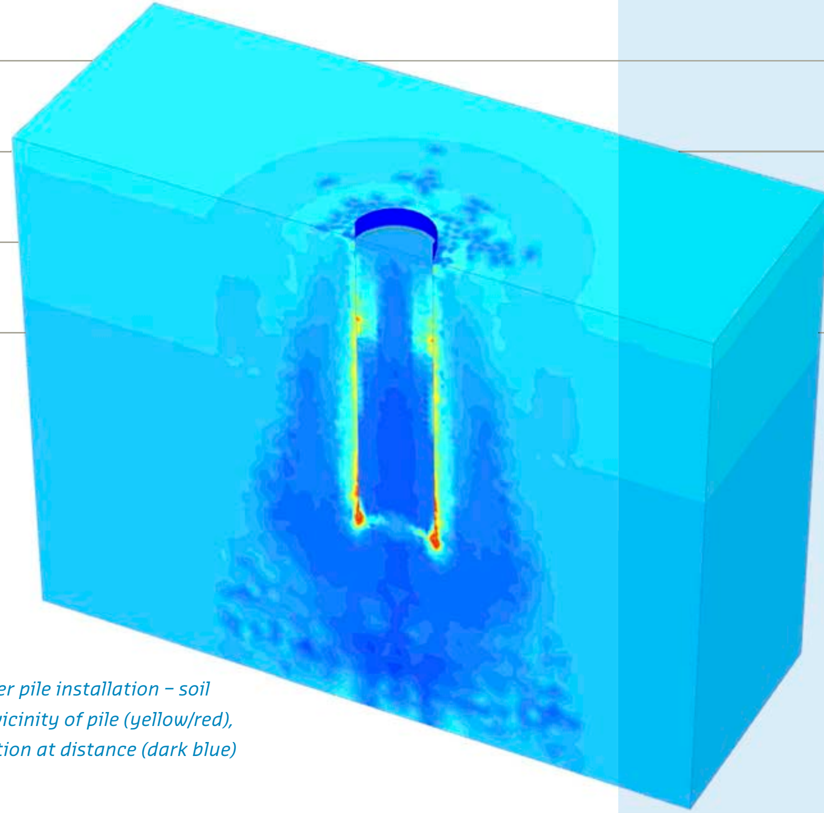
Vibration and impact piling captured numerically



Void ratio after pile installation – soil loosening in vicinity of pile (yellow/red), soil densification at distance (dark blue)

Offshore vibration piling has several advantages compared with the widely-used approach of impact piling. It produces less peak noise and can therefore be used without the need to implement expensive mitigation measures to protect marine wildlife. The piling takes less time, allowing shorter weather windows to be used. Furthermore, vibration piling involves lower peak loads on the monopiles, allowing for design optimisation in the areas of steel use and durability. More vibration piling in wind-farm installation could therefore produce crucial time and cost reductions.

Monopiles must provide accurate vertical alignment of wind turbines during decades of continuous cyclic lateral loading. High lateral system stiffness is therefore required. It is currently not known whether vibration piling meets this requirement in arbitrary soil conditions. Certifying bodies therefore require impact piling, at least during the final stages of piling, and this significantly reduces the benefits of vibration piling.

Finding cost-effective solutions for wind-farm installation that involve the use of both piling techniques requires a good understanding of the mechanical processes involved. An industry-funded field experiment was performed in Germany in 2014 as part of the VIBRO project to learn more about the relationship between the piling techniques and lateral system stiffness. Full-scale monopiles were installed using vibration and impact piling in a sandpit near Cuxhaven and then subjected to lateral loads.

Deltares performed a numerical study of this Cuxhaven field experiment in 2015 as part of the Far and Large Offshore Wind (FLOW) research programme in collaboration with the energy company RWE and Royal IHC. The numerical analysis of vibration and impact piling and the subsequent lateral-load testing is challenging: it involves a relatively complex geometry, the modelling of large deformations in saturated soil and the modelling of the complex soil-monopile interaction. Complexity is significantly increased in the case of vibratory piling because of the cyclic soil loading at high frequencies. In the context of the FLOW project, the Material Point Method (MPM) has been extended to include analyses of this kind. An efficient solution in terms of computation time and the quality of the results was obtained for the numerical study of monopile installation and subsequent lateral load testing. The analysis of the Cuxhaven experiment shows the potential of the MPM for such studies. Numerical investigations of piling in arbitrary soil conditions for the assessment of lateral system stiffness, pile drivability and design optimisations will require the further enhancement of the MPM and subsequent validation.

The potential cost savings are large. The foundations of offshore wind turbines account for about 20% of the total costs. Cost reductions of between 1 and 2% can be achieved if the effects of impact and vibration piling on the soil properties are better understood. Even larger cost savings can in all probability be achieved by optimising the actual monopile structure.

Further reading:

Phuong et al. (2016). Numerical investigation of pile installation effects in sand using material point method, Computer and Geotechnics, **73**, 58-71