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Numerical and experimental study on the effect of the installation method on the lateral response of offshore monopiles

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The successful deployment of offshore wind turbines requires the utilization of foundation installation methods that are fast, low-cost, and reliable. Offshore wind turbines foundations are commonly installed by impact driving. The noise generated during the driving process is a major constraint as it impacts marine life [1] and induces high stresses which reduce the fatigue lifetime of the foundation. Vibratory pile driving offers a promising alternative to traditional impact driving for the installation of monopiles [2], the limited data on its effects on the mechanical properties of the soil during installation in offshore conditions and consequently the mechanical response of the structure throughout its lifetime has prevented its adoption. During vibratory driving, the repeated and high intensity vibration can cause an increase in pore pressures and a decrease in both the inter-particle soil friction and the effective stress, which can eventually lead to liquefaction [3, 4].

This research aims at investigating the influence of the installation method on the soil properties around monopiles and how it affects the lateral response of such structures. In order to comprehensively understand the different phenomena involved, this problem is investigated through both numerical modeling and laboratory testing.

A numerical axisymmetric model based on the finite elements method that reflects on an offshore monopile was developed to describe the installation process using fixed boundaries or Perfectly Matched Layers (PML) [5] to realistically simulate the dynamic soil-pile interaction and ensure radiation of waves towards infinity. This model takes into account the reduction in soil strength around the pile shaft during the installation by impact or vibratory driving, along with the dynamic force applied by the vibro-hammer and the pore water evolution. Cyclic triaxial tests have been conducted on a sand extracted from the North Sea. They are used to calibrate the constitutive equations of the model. The results obtained provide insight into the onset and progression of liquefaction, the distribution of pore water pressures, and the resulting deformation of the soil-pile system and how the boundary conditons and the frequency of the imposed load affect those mechanisms.

These numerical results are also compared with 1g reduced scale experiments composed of a large cylindrical box filled with dry and saturated sand, in which a fully instrumented model pile (tube 60mm in diameter) is vertically driven. The impact or vibrations are imposed at the pile head by a scaled vibratory hammer or scaled impact hammer. In addition, the relative density and the homogeneity of the sand is carefully controlled using the pluviation method [6] allowing to test the sand at different controlled densities. After the installation phase, the lateral behavior of the pile is investigated by imposing a horizontal force with a piston. The test results will also be compared to similar tests on large diameter piles (2 meters) than are planned for fall 2023.

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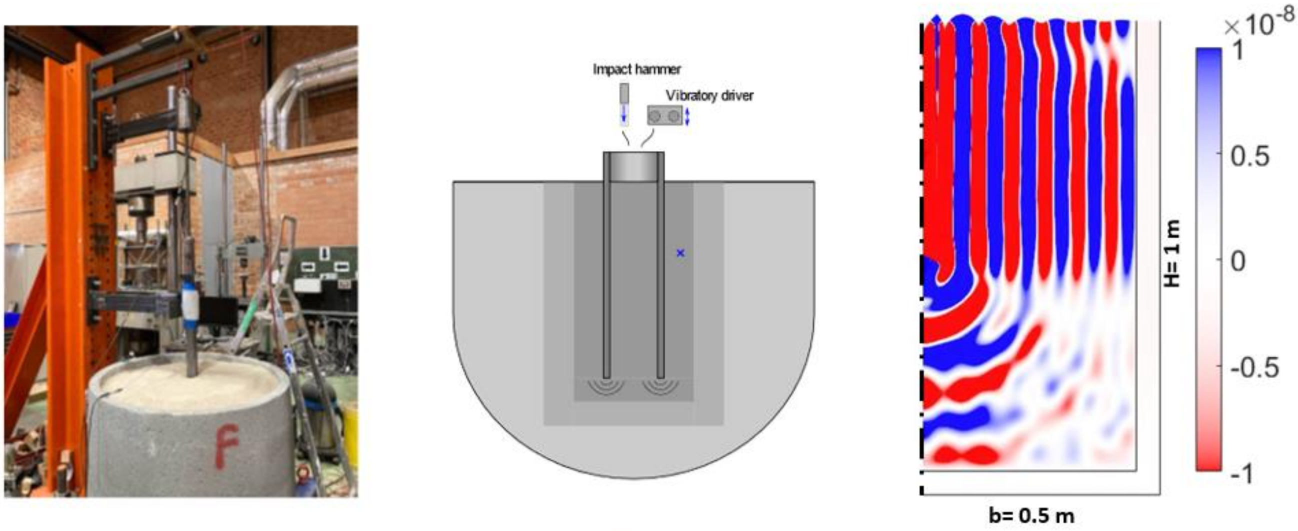

(a) (b) (c)

Figure 1: (a) represents the laboratory setup, (b) represents the schematic representation of the setup in the numerical approach and (c) shows the wave patterns (maximum displacement) generated in the sand box (response of the system) by impact hammering which is a sample of what the model can do (Axisymmetric model).

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