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A Comparison of Different Installation Methods of Monopiles for Wind Power Plants and their Influence on the Bearing Behaviour

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Open steel pipe piles are used for various applications in costal engineering and port structures as well they are getting more and more important for offshore structures. Especially in Europe there are already many offshore wind power parks realized and more are planned. Often a so called monopile is used as foundation for the wind power plant. A monopile is an open steel pipe pile with a diameter of several meters, cf. Figure 1.

Monopiles, or open steel pipe piles in general, can be installed in various ways, e.g. driven or vibrated. During the installation of these open steel pipe piles a plug can form inside the pile. Such a plug formed during the installation has an influence on the installation process of the steel pipe pile as well as on the bearing behaviour and the pile resistance. Forming of the plug depends on different influences, e.g. the pile diameter, the soil conditions and the installation method. The phenomenon of the plug inside open steel pipe piles is not fully investigated yet. To obtain a better understanding of the formation of the plug and its consequences several small-scale tests, field tests and numerical simulations have been carried out, cf. Henke (2013), Lüking (2010).

Figure 1. Monopiles during transportation (Bilfinger Berger 2014)

At the beginning of this paper a structured overview will be provided about the different installation methods of open steel pipe piles. The common installation methods are jacking, vibrating and driving. For offshore applications, such as the installation of monopiles for wind power plants, piles are normally driven. In Figure 2 two installation methods -vibration and driving- can be seen.

One difference of the installation methods is the duration of the installation. While driving of a pile takes a long time, the vibration of a pile can be done in a few minutes. Another difference is the noise level during the installation. If a monopile is driven a so called noise-mitigation shield is needed as there is just a certain noise level allowed during the installation. During the vibration of a pile no further noise protection is needed. The bearing behaviour is another difference which cannot be neglected. There are several analytical approaches as well as national standards to determine the bearing capacity of driven pipe piles, no matter if open or closed. But there are just a few analytical approaches and so far no national standards to determine the bearing capacity of vibrated pipe piles, cf. Lammertz (2008).

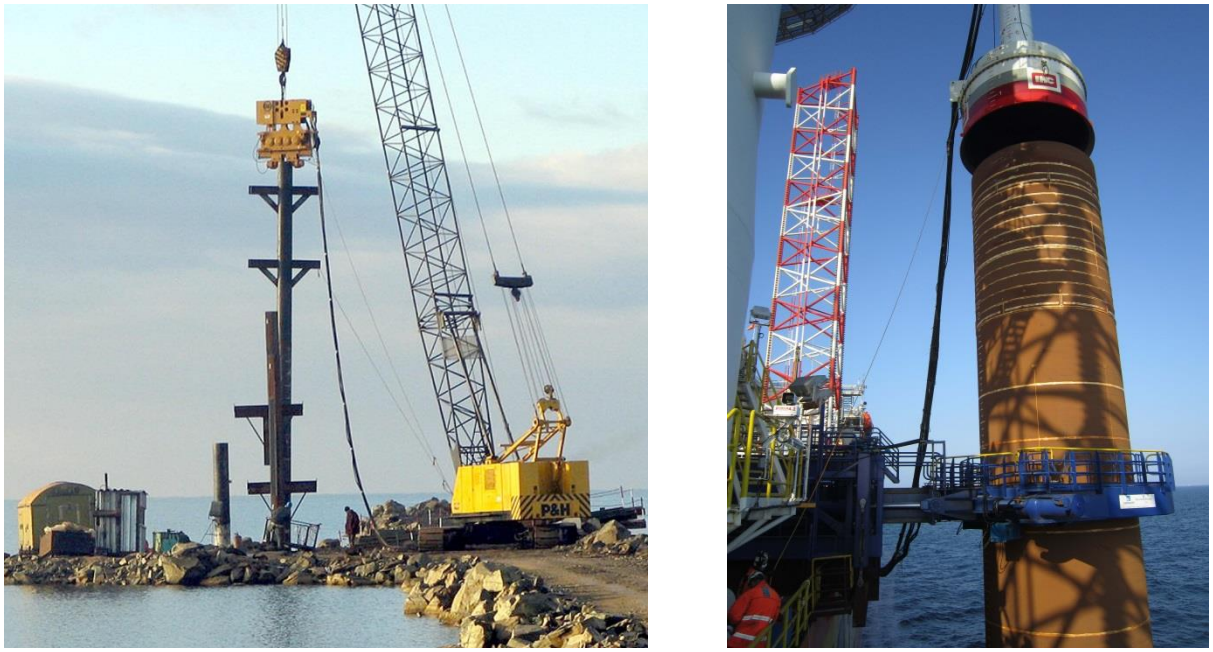

Figure 2. Left: Vibration of an open steel pipe pile (APE 2005). Right: Driving of a Monopile (Vattenfall 2013)

One important difference influencing the bearing behaviour and thus the capacity of open steel pipe piles is the forming of a plug inside the pile during the installation. Such a plug can influence the bearing behaviour of a pipe pile drastically. To determine the bearing behaviour of open steel pipe piles with regard to the effect of plugging, different analytical approaches have been developed, e.g. Randolph et al. (1991, 1994). Recent approaches are the ICP-05 method (Jardine, 2005), UWA-05 method (Lehane, 2005, 2008), UCD-11 method (Igoe et al., 2011) and HKU-12 method (Yu and Yang, 2012). All of these methods have in common that they are not valid for vibrated pipe piles. The so far most promising method to determine the bearing capacity of open steel pipe piles is the UWA-05 method. It is a CPT based method which predicts values for the end bearing and the shaft friction of the pile. It also contains a recommendation for offshore piles. The HKU-12 method is another CPT based method which predicts a value for the base capacity of the pile with a special focus on the capacity of the plug.

The focus of this paper is a comparison of different installation methods of monopiles with regard to the effect of plugging inside the pile. Thus, the advantages and disadvantages of the different installation methods will be shown and the UWA-05 method will be compared with the HKU-12 method. An overview of the different determined bearing capacities with regard to the pile diameter and length will be provided. The result of this paper shall be a guidance to help the engineer selecting a proper method for his individual case.

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