

### Developing a two-dimensional penetration model for the GBM Vibro-drill

The energy transition results in large offshore windfarms being installed. The most common support structure for a wind turbine at sea is a monopile. These are currently installed by large hydraulic hammers. However, hammering produces a lot of underwater noise which harms marine life. Therefore the industry is looking for new installation methods that are more environment-friendly. GBM-works aims to be the first to implement such a new installation technique called the Vibro-drill. They introduce a revolutionary new design which is to replace the hammering technique. Vibrations, jetting and liquefaction are used to reduce the soil resistance. This reduction is so powerful that the monopile sinks into the ground under its own weight without producing the harmful underwater noise.

Before each monopile is installed an analysis is made of the factors determining the chance of a successful installation. This process is called a penetration prediction. For the industry to accept the Vibro-drill installation method, penetration predictions are required to prove the applicability of the new technique. The radical changes in the installation process used by this technique make it impossible to use current penetration prediction methods. This means that a new prediction method needs to be developed that takes into account the specific features of the Vibro-drill.

This thesis aims to address this problem by way of providing building blocks for the development of a fully-fledged penetration prediction model that is applicable to the Vibro-drill method. To this end, this thesis will focus on delivering a two dimensional soil model in penetrated by a pile.

The two-dimensional approach which is the basis of this thesis, has of course its limitations as only a part of the pile and soil are included in the model. The assumed point symmetry over the centreline of the monopile leads to only a slice of the pile being modelled.

The soil is captured using a lattice model. A well-known practice for modelling soil in a two-dimensional way. The properties of the lattice are determined using Cone Penetration Test data. As a result the model represents different layers of soil along the depth. The model uses a rigid pile to penetrate the soil. The penetration of the pile causes a reaction force in the soil. This force is used to calculate the friction forces. The reaction force and the friction force are the basis for calculating the penetration speed of the pile. From this it follows that the penetration speed and final installation depth depend on the different soil layers within the soil model.

A first step towards validation is made. The pile/lattice interaction is verified and the results are compared to real life test data. A sensitivity analysis is performed to evaluate the dependence of the lattice size and resolution on the penetration speed of the pile. Subsequently the penetration predictions of the model in its current form are analysed. The results are compared to the real-life outcome of tests with the Vibro-drill.

From this first attempt to validation the conclusion can be drawn that the two-dimensional model, as developed in this thesis, could be a suitable basis for further work on a viable penetration prediction method for the Vibro-drill technique. Finally, recommendations are made for further enhancing the model with a view to its eventual implementation as a fully functional penetration prediction model for the Vibro-drill.

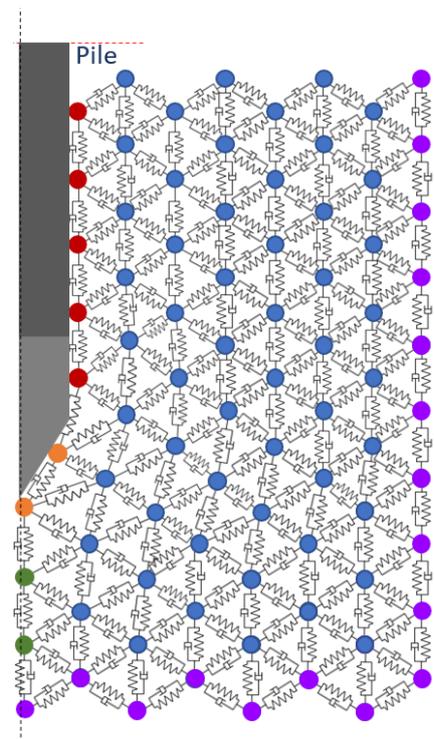


Figure 1: A visual presentation of the pile penetration model