# Master Thesis

**Topic:**
Investigation of Vibratory Driven Open-Ended Piles using DEM in 2 and 3 Dimensions

**Introduction:**
Open-ended piles are widely used in construction industry as foundation elements for structures ranging from high rise buildings in urban areas to offshore wind turbines far off the coast in marine environments. They are often considered superior to other foundation types as they can be prefabricated, have material properties that are well defined and can be installed within a short amount of time compared to bored piles. One negative aspect of open-ended piles is that they are very often installed by impact driving which leads to noise emissions that are disturbing in urban areas and can be harmful for marine life in the case of offshore applications.

For these cases vibratory driving of open-ended piles is a promising alternative as noise emissions are reduced drastically compared to impact driven piles. However, the performance of open-ended piles that are vibratory driven depends strongly on their installation parameters like frequency, amplitude and mass as well as pile dimensions and ground properties (Fig.1, right).

Open-ended piles have the tendency to either behave in plugged, unplugged or partial plugged mode during installation and subsequent loading of the pile. These different modes are crucial for the evolution of the soil stresses below the pile tip and in radial direction resulting in different magnitudes of the piles load bearing resistance. For unplugged (coring) piles, the inner as well the outer pile shaft and the steel annulus contribute to the load bearing resistance whereas for plugged piles only the outer shaft and the total cross section of the pile contributes to the load bearing resistance (Fig.1, left). For vibratory driven piles this plugged or unplugged state is also complex and depends strongly on the installation parameters that should be investigated within this thesis.

This thesis builds upon the work of a previous Master Thesis that examined different pile installation modes, including driving, jacking, and vibratory driving. The focus of this study is to

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refine and extend the existing DEM codes to model the vibratory driving of open-ended piles in both 2D and 3D, with the goal of improving our understanding of pile-soil interaction and optimizing installation techniques.

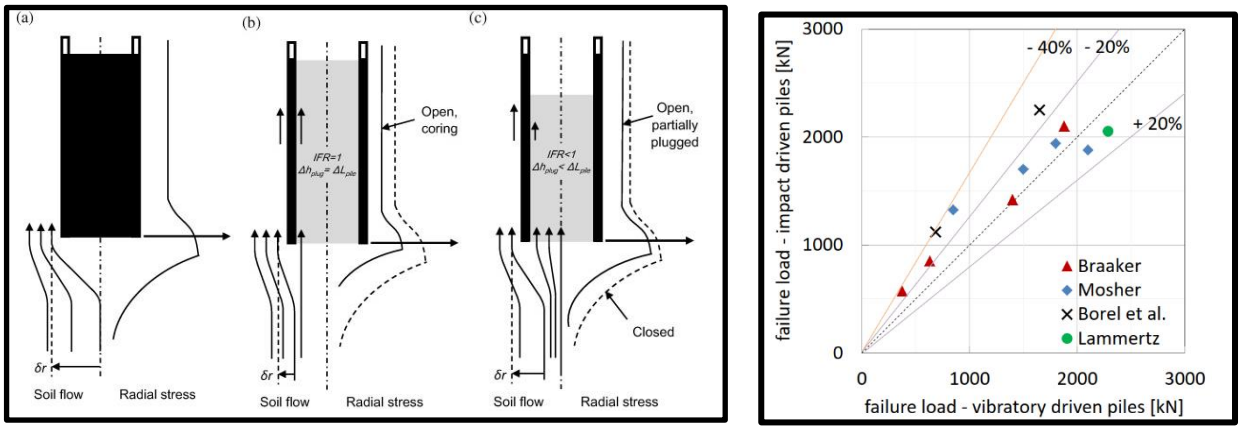


**Figure 1: Radial stress and soil flow – open-ended pile during penetration/loading (White, 2005) left and comparison of pile resistance of impact – vs. vibratory driven piles right (Fischer, 2013)**

## Scope of work:

1. A thorough Literature review covering the fundamentals of Discrete Element Modelling, contact models, fundamentals of vibratory pile installation techniques and their effects on the evolution of soil state and pile plugging shall be conducted.
2. A DEM particle assembly in 2D and 3D shall be created with a stress state and mechanical response of Sengenthaler Sand that is currently installed at TUM-ZGs geotechnical test pit.
3. The DEM models using different piles installation techniques shall be extended, e.g. by using piles made of wall elements according to Sommer (2022).
4. The framework for the dynamic excitation of the wall elements for vibratory driven piles according to Sommer (2022) shall be extended and improved.
5. Then the DEM models shall be run using different installation parameters to gain insight into the influence of the installation effects on the mechanical interactions.
6. The dynamic as well as static penetration resistance shall be evaluated with respect to the different installation techniques.
7. The mechanical response of the pile plug shall be investigated with respect to the different installation techniques.
8. A limited set of simulations shall be repeated in 3D (one simulation per installation technique). The evaluation of the results shall be conducted according to the 2D cases. Recommendations for the conversion from 2D models to 3D models shall be given.

**Prerequisites:**
Interest in numerical simulations.

Issued to:

Date of issue:

**Supervisor:**

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**Literatur:**

White, D., J. Schneider, and B. Lehane. The influence of effective area ratio on shaft friction of displacement piles in sand. Perth: Proceedings of the 1st International Symposium on Frontiers in Offshore Geotechnics, 2005, 741 ff.

Fischer, J.; Sychla, H.; Bakker, J.; Neef, L. de; Stahlmann, J.: A comparison between impact driven and vibratory driven steel piles in the German North Sea. Proceedings of the Conference on Maritime Energy, COME 2013, Hamburg, May 21-22, 2013, Technische Universität Hamburg-Harburg, Institut für Geotechnik und Baubetrieb, Hamburg, 2013, S. 361–380.

Numerical Simulations of the Penetration Process of Open-Ended Piles using DEM in 2 and 3D; Nick Sommer, M.Sc thesis, TUM, 2022

Rainer Massarsch K, Wersäll C and Fellenius BH Vibratory driving of piles and sheet piles – state of practice. Proceedings of the Institution of Civil Engineers – Geotechnical Engineering, https://doi.org/10.1680/jgeen.20.00127

GDG (Gavin and Doherty Geosolutions Ltd) (2015) Comparison of Impact Versus Vibratory Driven Piles: With a Focus on Soil-Structure Interaction. Deep Foundations Institute, Hawthorne, NJ, USA, Research Report CPF-2014-MRNE-1.