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Lateral response of vibratory installed monopiles: A scaled lab investigation

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ABSTRACT

The installation of monopiles for offshore wind turbines via vibratory methods presents an alternative to conventional impact-hammering, offering reduced noise emissions. However, understanding the influence of vibratory installation on e.g. lateral pile response remains largely unknown compared to impact-driving. This talk presents findings from laboratory-scale tests investigating the lateral behavior of monopiles subjected to various installation parameters, focusing on sand density and installation methods. The results provide insights into the differences in lateral response between vibratory and impact-driven installations.

1. INTRODUCTION

In recent years, there's been a big increase in the demand for renewable energy, mainly because of goals to reduce carbon emissions (International Energy Agency, 2023). Offshore wind power is growing quickly as a major renewable energy source. However, this growth comes with technical challenges, especially in installing foundations. Most offshore wind turbines use bottom-fixed foundations, with the monopile being the top choice for shallower to mid-level water depths (Musial et al., 2023). The usual way to install monopiles is by using impact hammers, which is effective but raises concerns about the loud underwater noise it makes and how it affects marine life (Merchant, 2019). To deal with this problem, there's a growing interest in alternative, eco-friendly ways to install piles. More research projects are looking into methods that can reduce the environmental impact of building offshore wind farms. The growing size of monopiles has exacerbated noise concerns, prompting exploration of quieter vibratory installation methods. Offshore wind turbine foundations are uniquely subjected to cyclic horizontal loads due to wave and wind action, necessitating consideration of lateral stiffness in design. Prior research indicates varying lateral behavior between vibratory and impact-driven piles in different soil densities. However, understanding the effects of vibratory installation settings on lateral stiffness remains limited.

2. Experimental Setup:

Laboratory tests were conducted at Deltares, Netherlands, utilizing a Water-Soil Flume tank filled with saturated sand. The experimental program involved scaled piles installed via impact and vibratory methods, subjected to monotonic and cyclic lateral loading regimes. Instrumentation included accelerometers, load cells, and sensors to measure soil response during installation and loading.

3. Soil Characteristics:

Tests utilized saturated Sibelco S90 sand with defined particle characteristics, ensuring consistency across experiments.

4. Pile Properties:

Steel piles of scaled dimensions were employed, representing typical offshore monopiles.

5. Installation Equipment:

Both impact and vibratory hammers were used for pile installation, with variations in parameters such as frequency and lowering speed.

6. Lateral Loading Device:

A custom lateral loading device applied horizontal loading to the piles during testing.

7. Results and Discussion:

The initial monotonic loading tests revealed differences in lateral stiffness between impact-driven and vibratory-installed piles. Crane-controlled vibratory installations exhibited behavior akin to impact- driven piles, while free-hanging vibratory installations showed softer lateral response, potentially due to installation mode differences.

Cyclic loading tests indicated changes in lateral stiffness over cycles, with vibratory-installed piles exhibiting greater stiffness gains compared to impact-driven piles.

8. Conclusions:

The study highlights the influence of installation method and parameters on monopile lateral behavior. Crane-controlled vibratory installations exhibited stiffness akin to impact-driven piles, while free-hanging installations displayed softer response. In medium-dense sand, lowering speed during vibratory installation significantly impacted lateral behavior. Insights gained from laboratory tests will inform larger-scale field testing, enhancing understanding and guiding future offshore wind turbine foundation practices.

9. Next Steps: Large-scale Field Tests:

Results from scaled laboratory testing will inform forthcoming large-scale field tests, providing further insights into monopile behavior under varied installation methods and conditions.

10. Acknowledgement:

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