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A Multi-Facetted Design Concept for Offshore Foundations

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Abstract

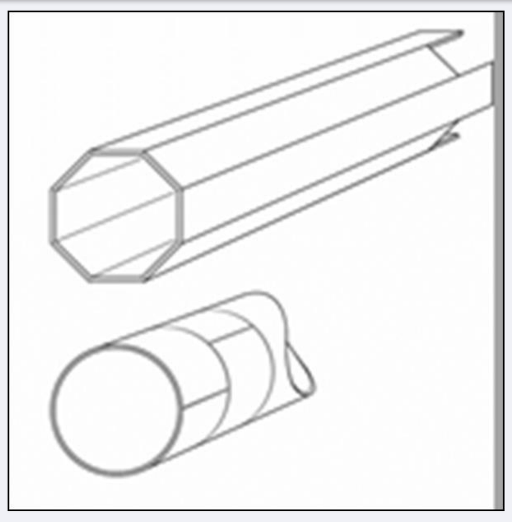
It is anticipated that the market for offshore wind turbine foundations will significantly outstrip the current manufacturing capacity. This work examines an innovative fabrication process for foundations which has the potential to offer design flexibility and allow the necessary production capacity to be met. The novel multi-facetted foundation investigated in this work is fabricated from long strips of flat plate welded together longitudinally. This allows sub-assemblies of greater than 10m in length to be manufactured, reducing the number of circumferential welds necessary in the foundation. The approach is enabled through the use of rapid welding for the longitudinal seams.

This work examines the geotechnical and structural aspects of the multi-facetted design concept. The entire production route is examined in terms of performance, logistics and economics, in order to determine the viability of the approach. A 1:5 scale model has been fabricated and pile-driven to demonstrate potential.

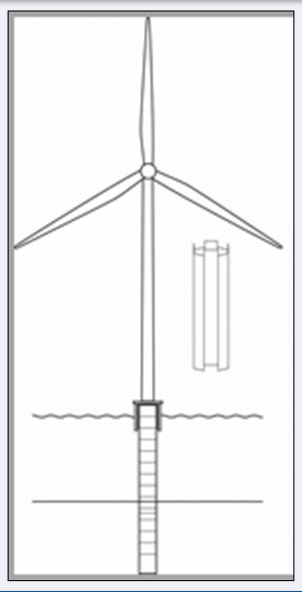
Objectives

To assess the feasibility of an innovative multi-facetted foundation design concept and demonstrate advantage over conventional monopiles in terms of:

- Geotechnical requirements
- Structural performance
- Fabrication route
- Production capability and associated costs
- Design flexibility

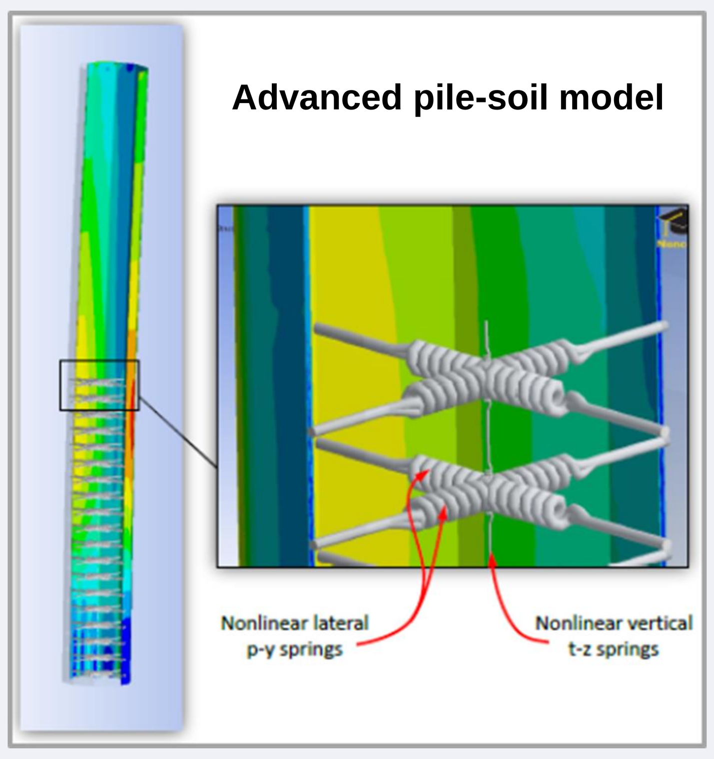


The multi-facetted design concept



Methods and Results

Modelling of design and installation

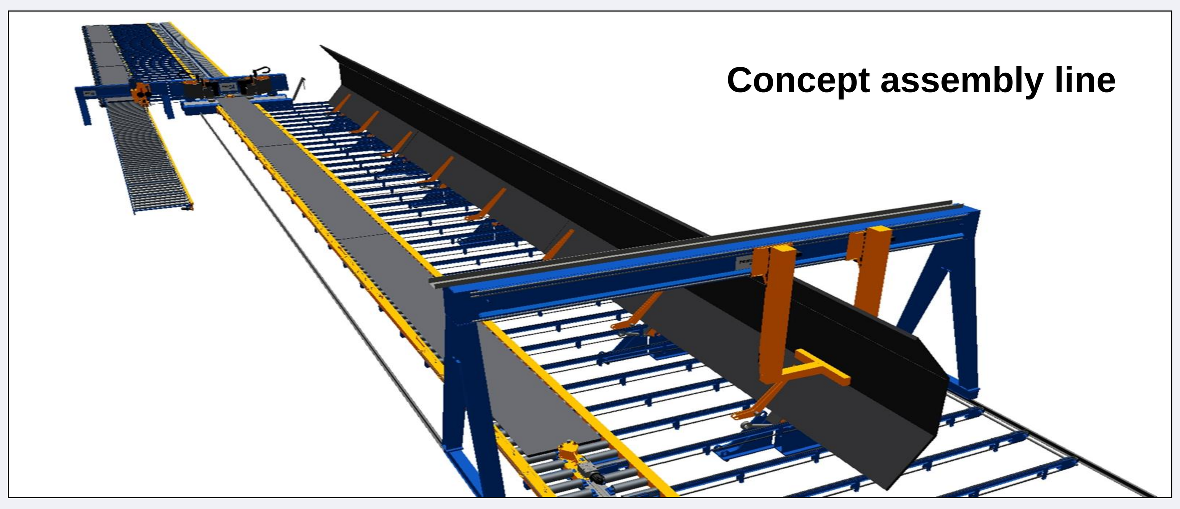


An advanced pile-soil model was developed, allowing many permutations of soil condition, monopile geometry and loading condition to be simulated, resulting in an optimised design specification for a 10-sided foundation.

Calculations have shown satisfactory performance in the Ultimate Limit State (ULS) and Serviceability Limit State (SLS). The multi-faceted design was found to have a higher fatigue damage resistance than a round (reference) design as the girth welds could be located further from the point of maximum stress.

Modelling of production facilities

Attention has been given to the industrial feasibility of fabricating the multi-facetted foundation system. Proposed production facilities have been modelled and equipment considered. As a result, the process was determined to be viable.



Fabrication of scale model, piling trials and testing

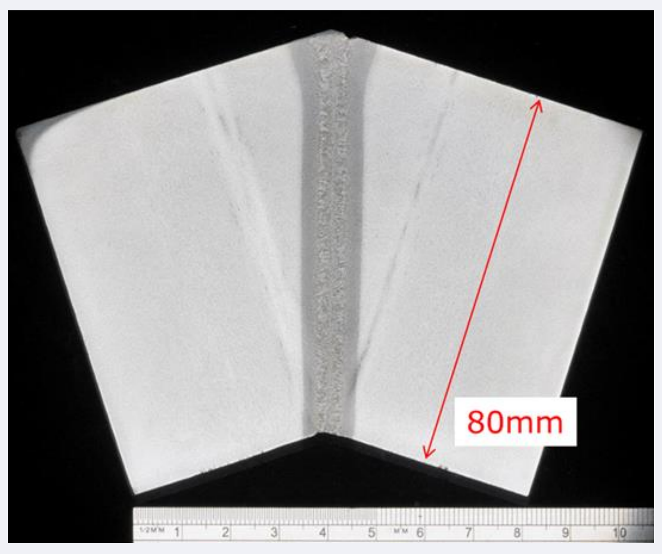
A 1:5 scale model was constructed to demonstrate the potential of the fabrication route and to assess the behaviour of the multi-facetted design under piling. The scale model was instrumented and performance data was collected as the model foundation was driven into the ground.

Piling loads used in the trial were based on actual piling log data provided by Scottish Power Renewables, corrected for the smaller cross-sectional area of the scale model. No visible damage of the longitudinal welds was observed as a result of piling.

Fabrication of multi-facetted piles

Electron beam (EB) welding is a fast process, producing single pass, high integrity welds in thick section material and hence is an ideal joining process for wind turbine foundations. Local vacuum EB welding with a mobile sliding seal (to provide a local vacuum atmosphere for the beam) has been developed. This process has been successfully demonstrated on corner welds in C-Mn steel (with a thickness similar to that of a full-scale foundation).

Section of an EB corner weld in 80mm thick steel:
- **single pass**
- **125mm/min**



Application of novel foundation designs

Potential applicability of the multi-facetted concept to monopile, multi-piled and universal foundations has been identified, both for the fabrication of structures and the connection of secondary steel elements to flat faces. Benefits and limitations of the multi-faceted approach have also been identified.

Benefits of the multi-facetted pile design include:
- Reduced number of circumferential welds
- Strategic positioning of circumferential welds
- Potential to reduce net steel mass
- Versatility for a range of geometrical structures
- Reduced welding time
- Absence of rolling/re-rolling
- Flat surfaces for welding of secondary structures
- Easy storage, handling and transport.

Conclusions

A multi-facetted design for the fabrication of structural steel is showing promise for a range of applications in the next generation of offshore structures. A 10-sided foundation design has been developed and detailed calculations have shown satisfactory performance in the ULS and SLS and a suitable fatigue performance. The feasibility of the fabrication route has been demonstrated by making a 1:5 scale model and successfully piling it into the ground. A route for the fabrication of full-scale piles has been outlined; this involves local vacuum EB welding which has been demonstrated to effectively produce welds of the required thickness and geometry. This fabrication route addresses the anticipated shortfall in capacity for the future market of offshore wind turbines and offers a number of product advantages including a significant reduction in the number of circumferential welds required, allowing weld placement further away from points of maximum stress.

Acknowledgements

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