Reliability Analysis of Offshore Wind Turbine Foundations

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Introduction

This poster provides an overview of the research on the reliability analysis of offshore wind turbine foundations conducted at the Department of Civil and Transport Engineering at Norwegian University of Science and Technology. Reliability analysis of monopile foundations is performed to quantify the inherent variability in soil properties and uncertainties in the wind and wave loading. Reliability-based design is preferred over the standardized factor of safety approach because it provides a physical insight in the likelihood of a failure as a probabilistic measure.

Probabilistic pile-soil model

The studies Depina et al. (2014) and (2015a) considered the effects of spatial variability on the long term response of the monopile foundations in dense sand. The long-term response of a monopile foundation is simulated by a 3D finite element model with the stiffness degradation material soil model. The stiffness degradation material model simulates the pile-soil stress-strain state for a constant loading amplitude and a given number of loading cycles. The reliability analysis was conducted by evaluating the effects of the inherent spatial variability of soil stiffness and friction on the monopile displacements, rotations and bending moments. The spatial variability of soil stiffness and friction angle is modeled by a random field model. The resulting uncertainties in the monopile rotations and the maximum monopile bending moments were used respectively to evaluate the reliability of the monopile with respect to the serviceability and the ultimate limit state.

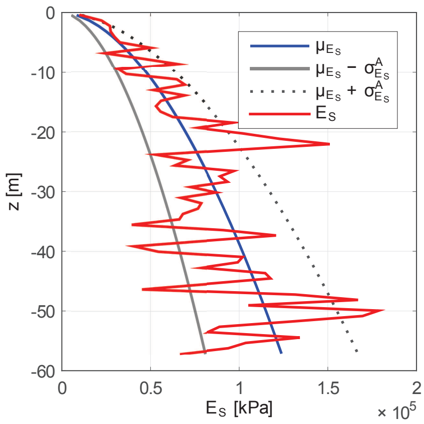

Figure 1: Example random field realization of soil stiffness..

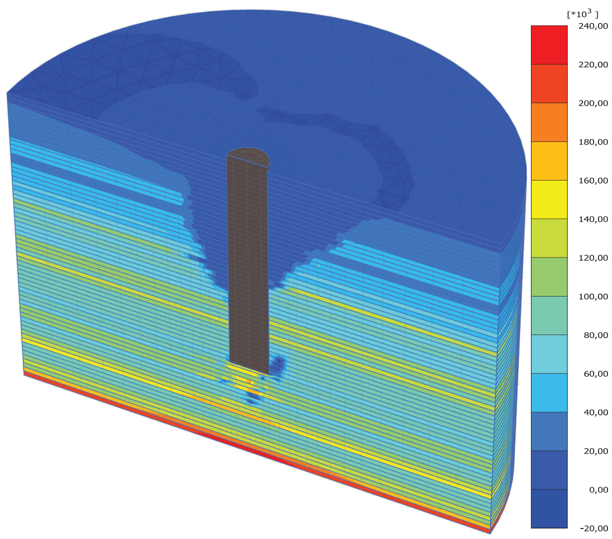

Figure 2: Soil stiffness degradation after 10^4 cycles.

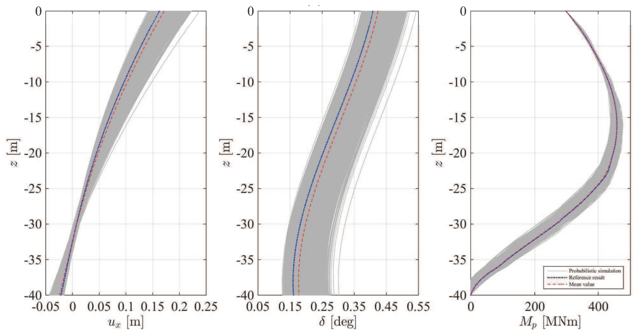

Figure 4: Uncertainty in the monopile displacements, u_x, rotations, δ, and bending moments, M_p.

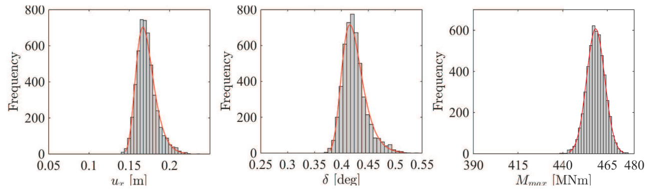

Figure 5: Histograms of the monopile displacements, u_x, rotations, δ, and maxmimum bending moments, M_{max}.

Reliability-based design optimization

The study by Depina and Eiksund (2015b) presented a reliability-based design optimization of a monopile foundation with an objective to minimize the installation and potential failure cost with respect to a reliability constraint. The reliability constraint is defined by limiting the probability of exceeding the ultimate limit state to 10^{-4}. The optimization is conducted by coupling the Simulated Annealing stochastic optimization algorithm and the Subset Simulation reliability method. The probabilistic response of the monopile foundation is simulated by coupling the deterministic p-y beam spring model with random load and random filed model of undrained shear strength.

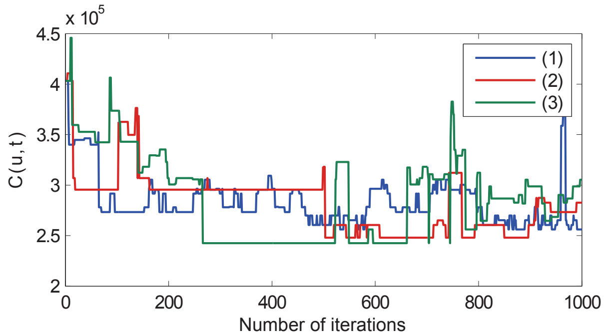

Figure 6: Cost of the monopile with the number of iterations for the three independent optimization procedures.

References

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Depina, Ivan; Eiksund, Gudmund Reidar. (2015b) *Reliability-based design optimization of laterally loaded monopile foundations for offshore wind turbines*. ISFOG 2015, Oslo..