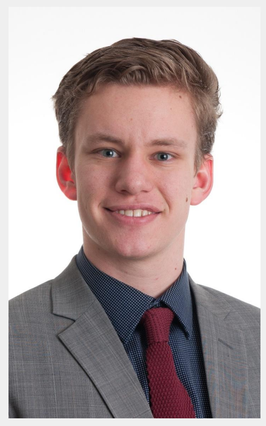
# Design Optimization of Piles for Offshore Wind Turbine Jacket Foundations



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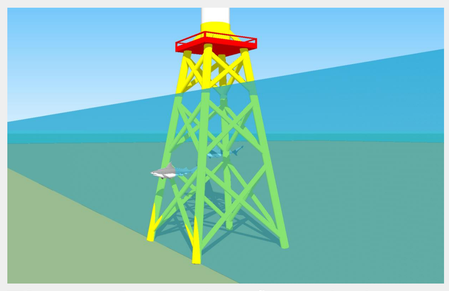

**Figure 1: J**acket foundation.

## Numerical methods can optimize the pile design

The aim of this study is to automatically design optimal piles for offshore wind turbine jacket foundations (Figure 1). Pile mass is minimized with constraints on axial and lateral capacity. Results indicate that accurate knowledge about soil characteristics can translate into significant cost reductions.

## Pile design can be formulated as an optimization problem

Let F and M be the loads on the pile head, and Q(x) the capacity of the pile (Figures 2 & 3). The aim is to minimize the total pile mass while keeping the capacities larger than the loads.

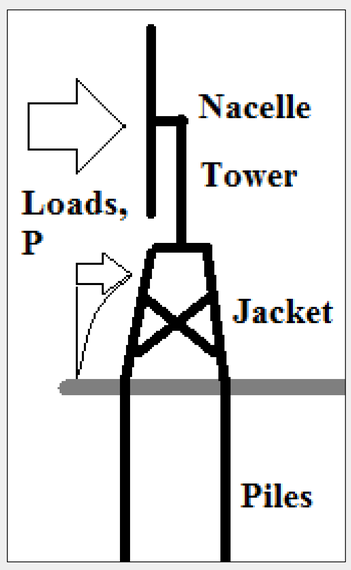


**Figure 2:** Offshore wind turbine and loads.

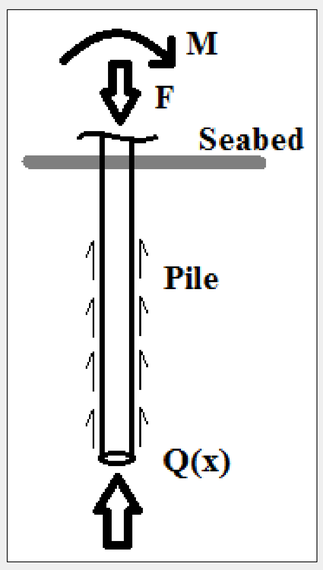


**Figure 3:** Loads and capacity on pile.

$$\underset{\boldsymbol{x}=(d,t,l)\in\mathbb{R}^3}{\text{minimize}} \quad c(\boldsymbol{x}) = \rho\pi(d^2 - d_i^2)l$$

$$\text{subject to} \quad F - Q_F(\boldsymbol{x}) \leq 0$$
$$M - Q_M(\boldsymbol{x}) \leq 0$$
$$d - l/10 \leq 0$$
$$0.0063 + d/100 - t \leq 0$$

**Acknowledgment**

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## Design optimization generates specific pile design

An offshore wind turbine on a jacket is subjected to an extreme thrust force. For a specific choice of soil properties, the optimization problem is solved (Figure 4). Only one soil layer is considered.

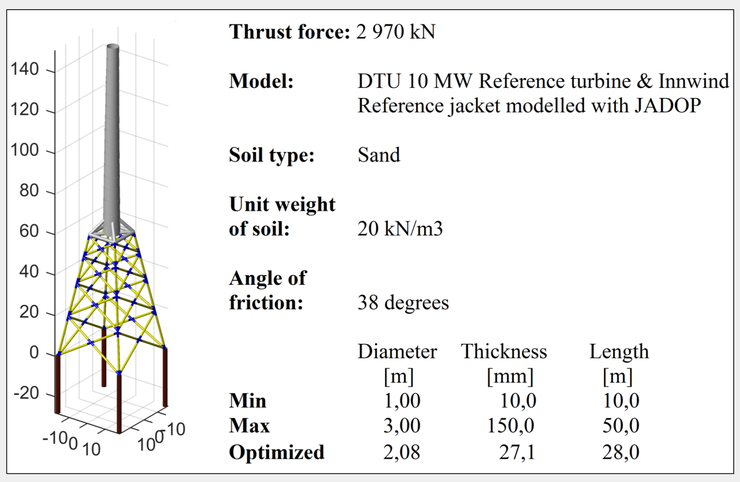


**Figure 4:** Overview of optimization setup. JADOP is a package for jacket optimization developed by the first author and Alexander Verbart.

The optimized piles have a total mass of 153 tons. Thickness does not contribute to capacity, and is therefore minimized. The result is considered realistic, but has not been validated.

## Soil parameters influence the optimal pile design

Pile capacity Q(x) changes with soil conditions. The optimization problem is solved repeatedly for small changes in the soil properties (Figures 5 & 6).

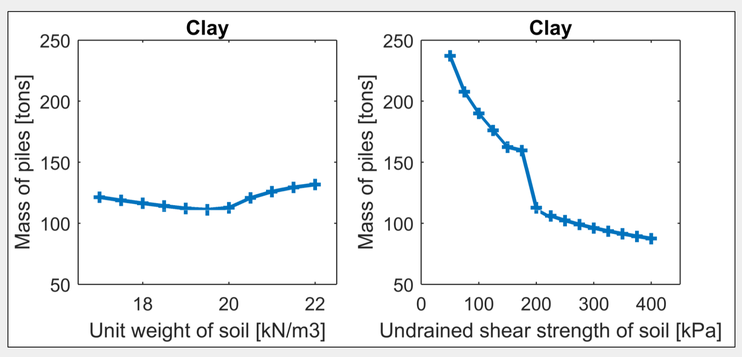


**Figure 5:** Result of parameter study for piles in clay. The shear strength has a large infuence on the pile design.

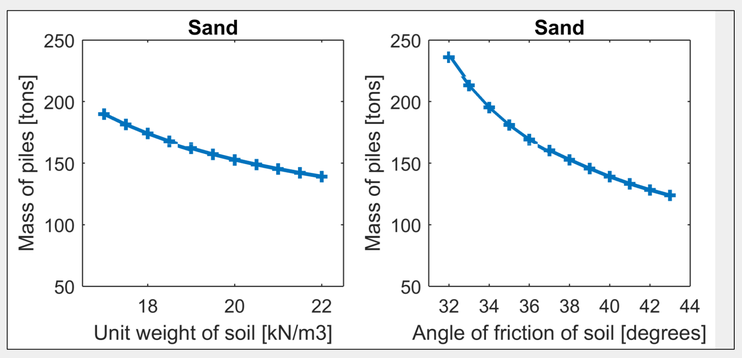


**Figure 6:** Result of parameter study for piles in sand. Both soil weight and angle of friction have a large influence on the pile design.

## Complete soil data and automatic pile design can reduce cost

Automatic preliminary pile design is demonstrated, and it is observed that pile design is very sensitive to selected soil properties. If a wind farm is constructed without full knowledge of soil data, one either runs the risk of non-conservative designs, or the cost of over-conservative designs. Designing piles specifically for each turbine can reduce this expense, and automatic pile design can be a usefull tool.