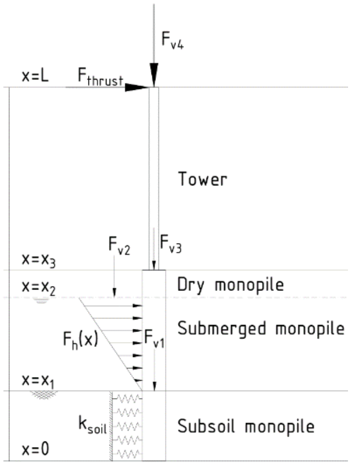
Offshore & Dredging Engineering

Technische Universiteit Delft

Buckling monopiles: stability of a monopile based offshore wind turbine

Offshore wind turbines are being placed all over the world. The increased popularity of these structures comes with a boost to the development of wind turbines in general, resulting in larger and higher constructions. To ensure the support structures of the turbines are able to withstand the extreme loads and environmental conditions, it is subjected to a series of tests and checks, prescribed by codes and standards. This thesis focuses on buckling checks, with global buckling in particular.

Several codes and standards define buckling checks, differing in approach. For example, the global buckling check is based on global buckling (compromised stability due to an axial force), but also takes eccentricities into account. How these parameters and safety factors are incorporated is analyzed for the Eurocode and the DNVGL, which are considered the most relevant design standards regarding offshore wind turbines around the Netherlands. Difference between both global buckling checks are analyzed using a monopile based reference wind turbine.



Looking to the more mechanical term of global buckling (also called Euler buckling), one finds an expression for the buckling load, based on the flexural stiffness and the buckling length of the structure. However, both parameters vary over the height of the support structure: the monopile has one relevant buckling value, where the flexural stiffness varies with its geometry. Therefore the buckling length cannot be constant for the structure. To tell something about this buckling length, the support structure is modeled with Euler beams as visualized in the figure. Subsequently the buckling force is analyzed, a constant value for the flexural stiffness is derived and the buckling length is calculated. Finally, the influence of the soil conditions on the buckling length of the structure is analyzed.

To determine whether a second order analysis is required to calculate the buckling force of the support structure, a comparison is made. Two Euler-Bernoulli beam models are introduced, one with a second order term, one without. The influence of the term on the bending, rotation, moment and shear force is analyzed, as well as the influence of the Euler buckling force. Subsequently an incremental load factor is introduced to incorporate the second order effect in the more simplified beam model.

Finally, the relevance of global buckling is considered. How relevant is the global buckling check for the currently installed wind turbines, and how relevant will it be for the larger support structures that are to be expected? To answer these questions, comparisons are made between the buckling checks and how far from failing the checks are. Subsequently, the local buckling is introduced to compare the global buckling check to the local buckling check regarding relevance.

The most important results and conclusions are summarized:
The buckling check of the DNVGL and the Eurocode differ for result. However, the unity check is a factor 20 lower than critical.
A buckling length of more than twice the length of the structure (from the seabed to the top) should be used for Euler buckling analysis.
The second order term affects the total displacement- and moment distribution minimally: approximately 5% of the total moment (and displacement) is contributed by the second order term.
Local buckling and global buckling are equally important, regarding the Eurocode. Both unity checks result in approximately the same values, which is a factor 20 away from being critical.

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