Can Buckling In Monopiles Be Verified Analytically?

Motivation

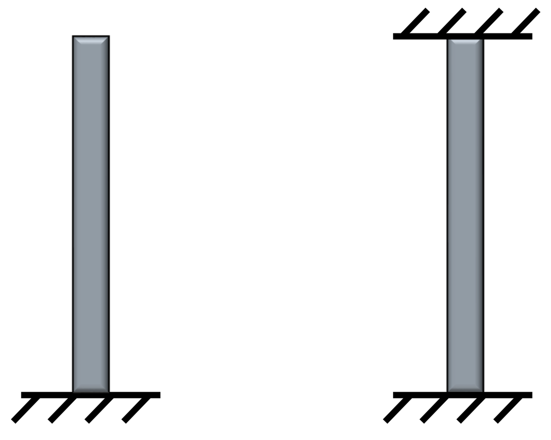
The offshore wind energy sector has undergone significant development over the past decades, and the work still continues. However, there is a notion in the wind industry that analytical buckling verification methods used nowadays might be overly conservative for wind turbine supporting structures, such as monopiles.

Problem statement

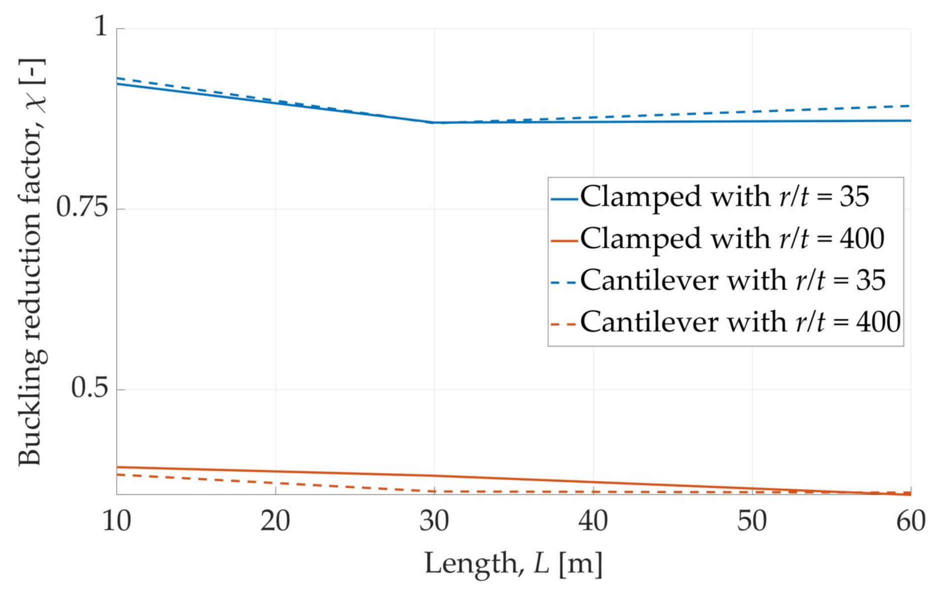
How well do the analytical methods in EN 1993-1-6 fit to a typical monopile and how can the expressions be optimized regarding boundary conditions, geometry and geometric imperfections observed in a monopile using a series of finite element analyses?

Static system

Simplified, a **monopile** behaves as a **cantilever** beam-column. In contrast, the analytical buckling verification method in **EN 1993-1-6** assumes **clamped** supports at each end.

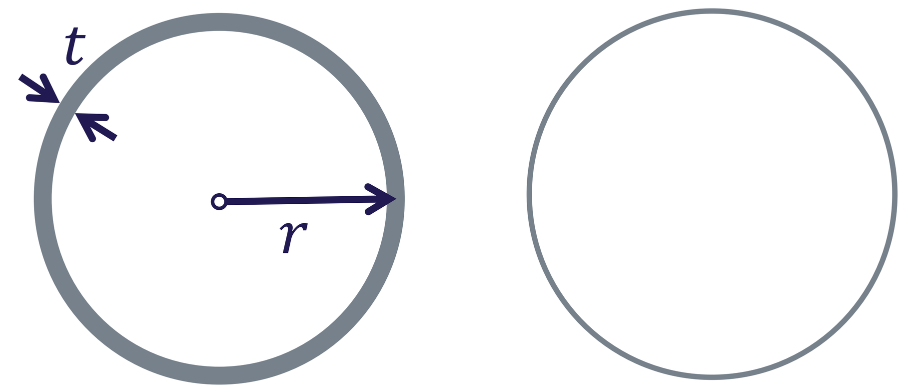


Based on a brief study, it appears that the static system has a **limited effect** on the buckling resistance. There is **no obvious correlation** between the buckling resistance and the geometric parameters, such as the length or the radius-to-thickness ratio.

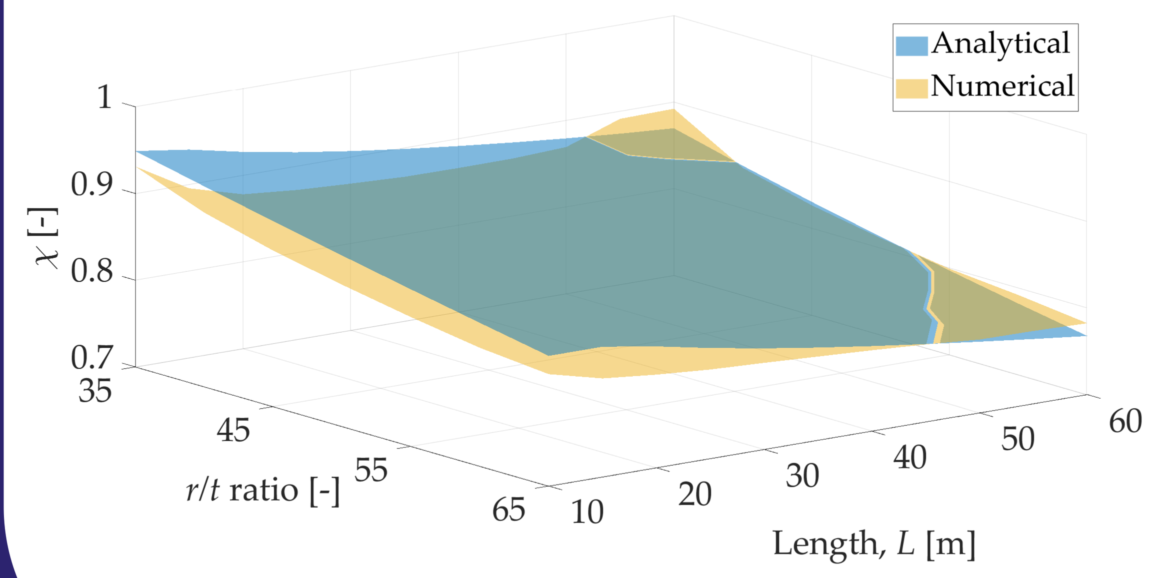


r/t ratio

A **monopile** supporting an offshore wind turbine typically has an r/t ratio **between 35 and 65**. However, the analytical method in **EN 1993-1-6** is **valid** for r/t ratios **between 50 and 2 000.**

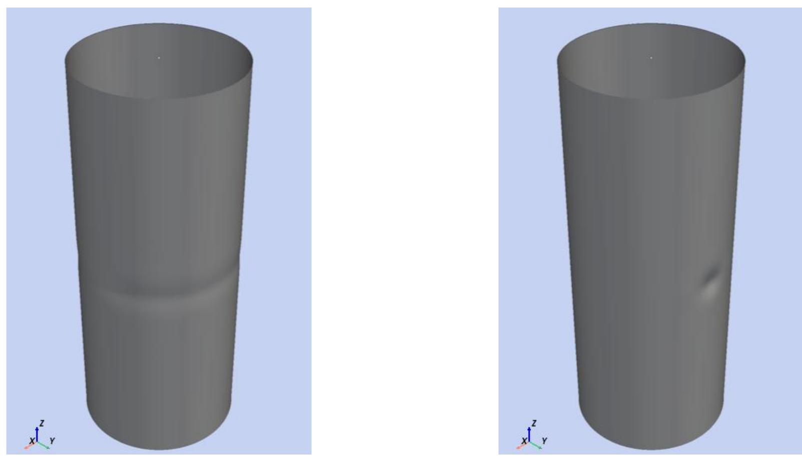


The numerical results show that the analytical method provides **unconservative results** for many of the investigated geometries with r/t ratios below 50.

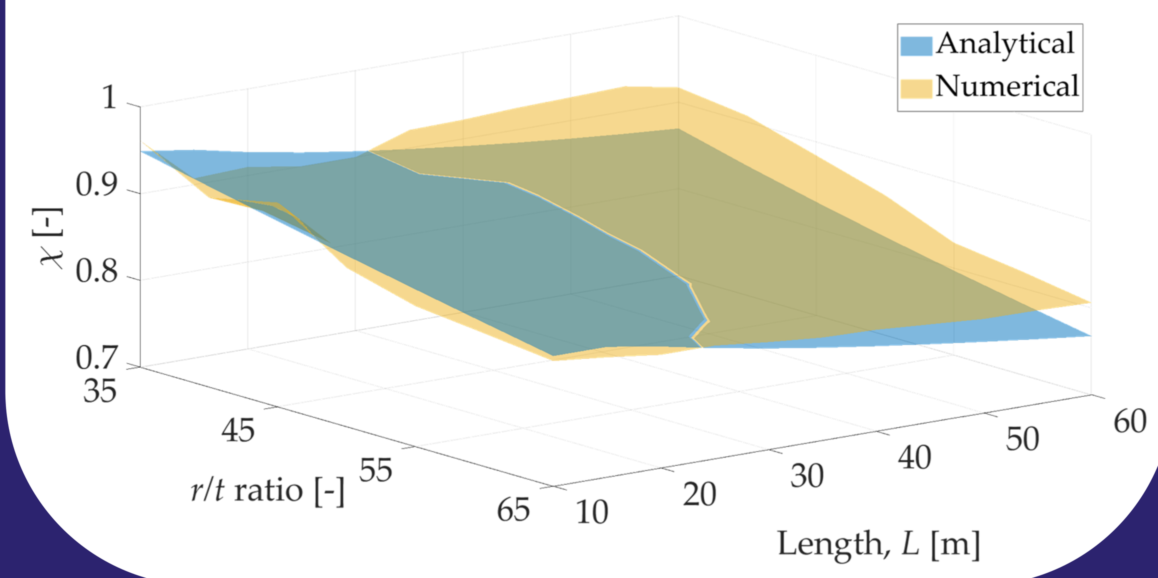


Imperfection form

The analytical buckling verification method in **EN 1993-1-6** assumes a **full-circumferential dimple** at midspan, even though the **rules** in the standard do not **allow** a dimple to have a larger extent circumferentially than along the cylinder, i.e. like the **limited dimple** below. This can give the impression of **conservatism** in the methods.

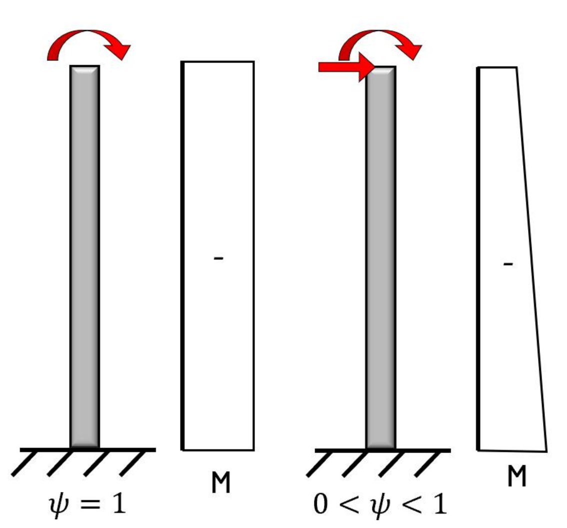


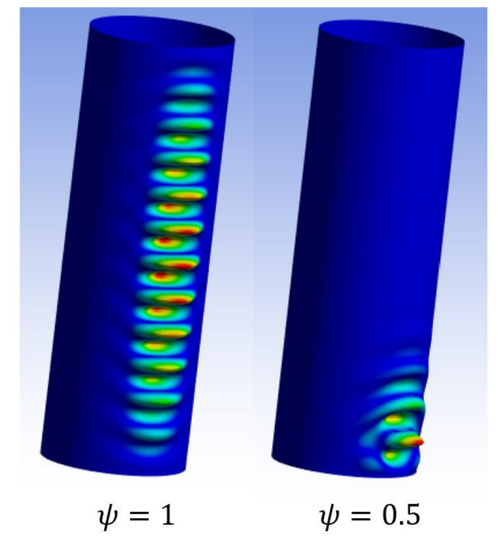
Limiting the circumferential **extent of a dimple** has a **considerable effect** on the buckling resistance. However, the analytical method still provides **unconservative** results in many cases as seen in the plot below.



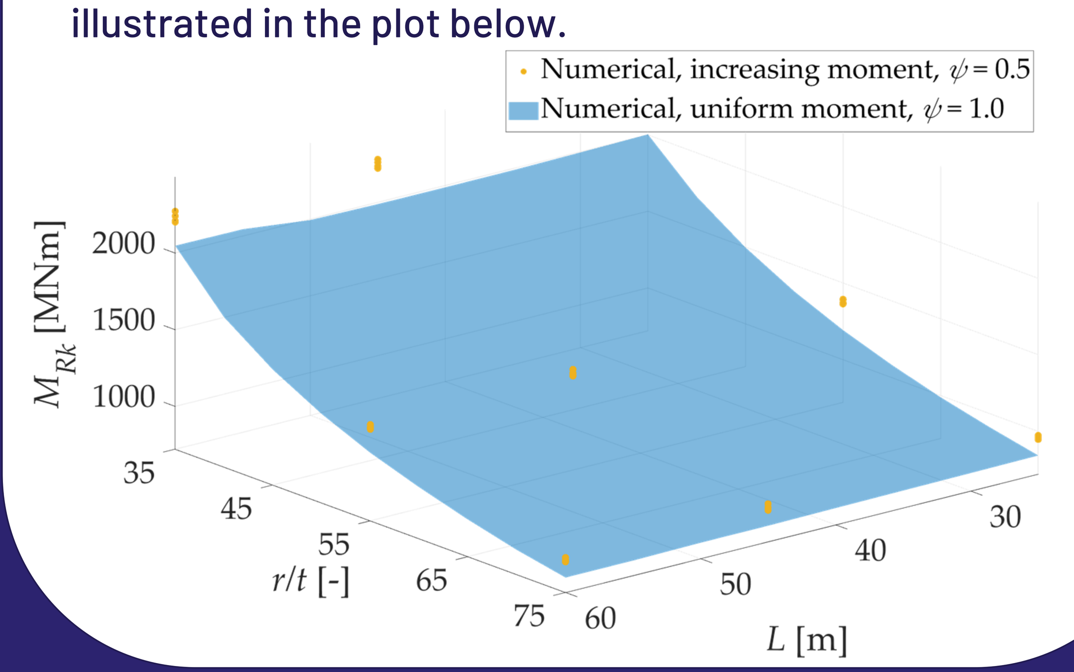
Moment distribution

The analytical buckling verification method in **EN 1993-1-6** assumes a **uniform bending moment** distribution. In contrast, **monopiles** typically experience a **bending moment increasing** from top to bottom.





A simplified **linearly increasing bending moment** distribution in the cylinder instead of a uniform one **leads to** a significant **increase in the buckling moment resistance** as illustrated in the plot below.



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The results show that the analytical methods are in many cases unconservative when only considering typical monopile geometries, support conditions and geometric imperfections. On the other hand, they become rather conservative when taking more realistic bending moment distributions into account. Comparing the simplified case of linearly increasing bending moment with that of uniform bending moment reveals an underestimation of capacity of at least 7%. Improved analytical formulations are presented in the thesis, but the topic is far from being exhausted.

Conclusion


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