

An aerial photograph of an offshore wind turbine installation site. In the foreground, a large red and white supply vessel is positioned next to a yellow crane that is lifting a white wind turbine tower section into the water. The turbine's three blades are visible, extending upwards. In the background, another yellow crane is visible on the water, and further out, a small yellow buoy or marker is visible. The sea is a deep blue, and the sky is a pale, hazy blue.

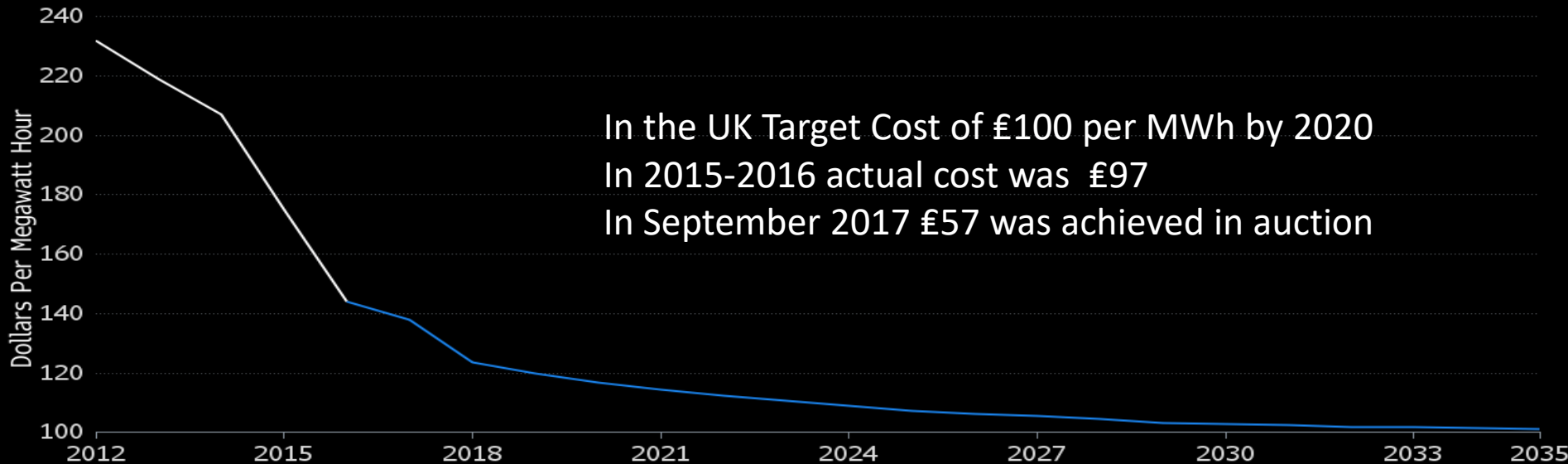
Foundations for Offshore Wind Turbines Key Geotechnical and Geological Uncertainties

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Offshore Wind Costs Falling Steeply

Prices have declined and are set to drop further

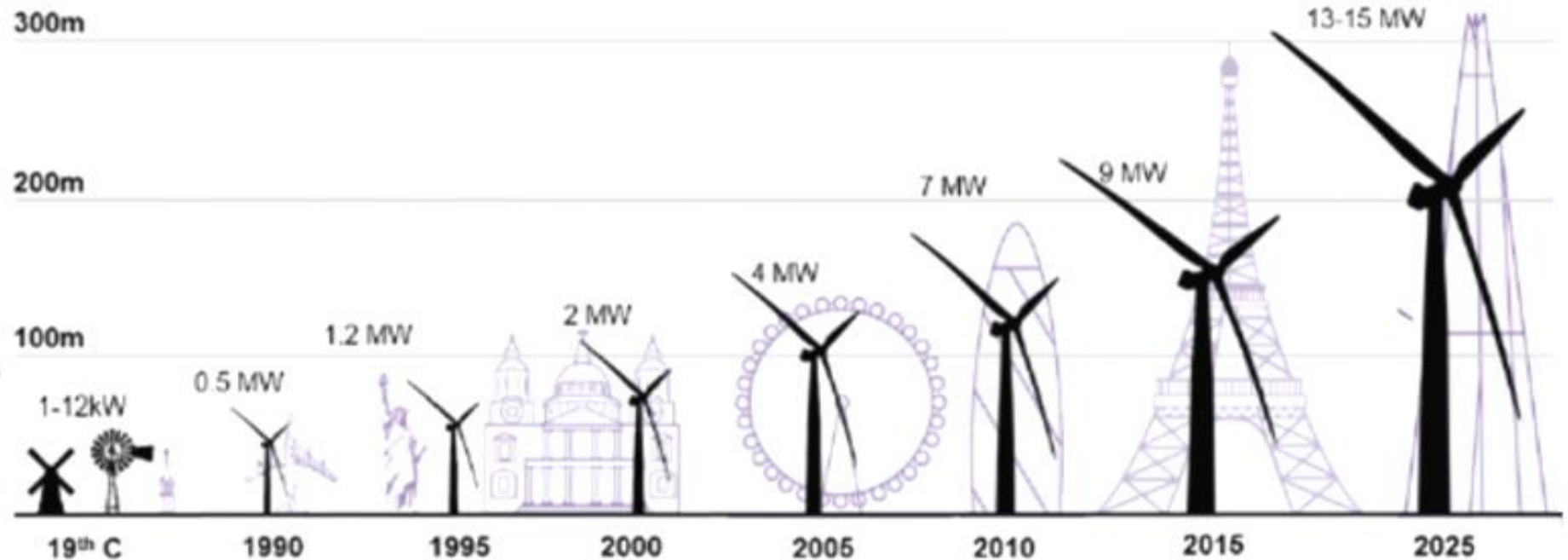
■ Historical price ■ Forecast



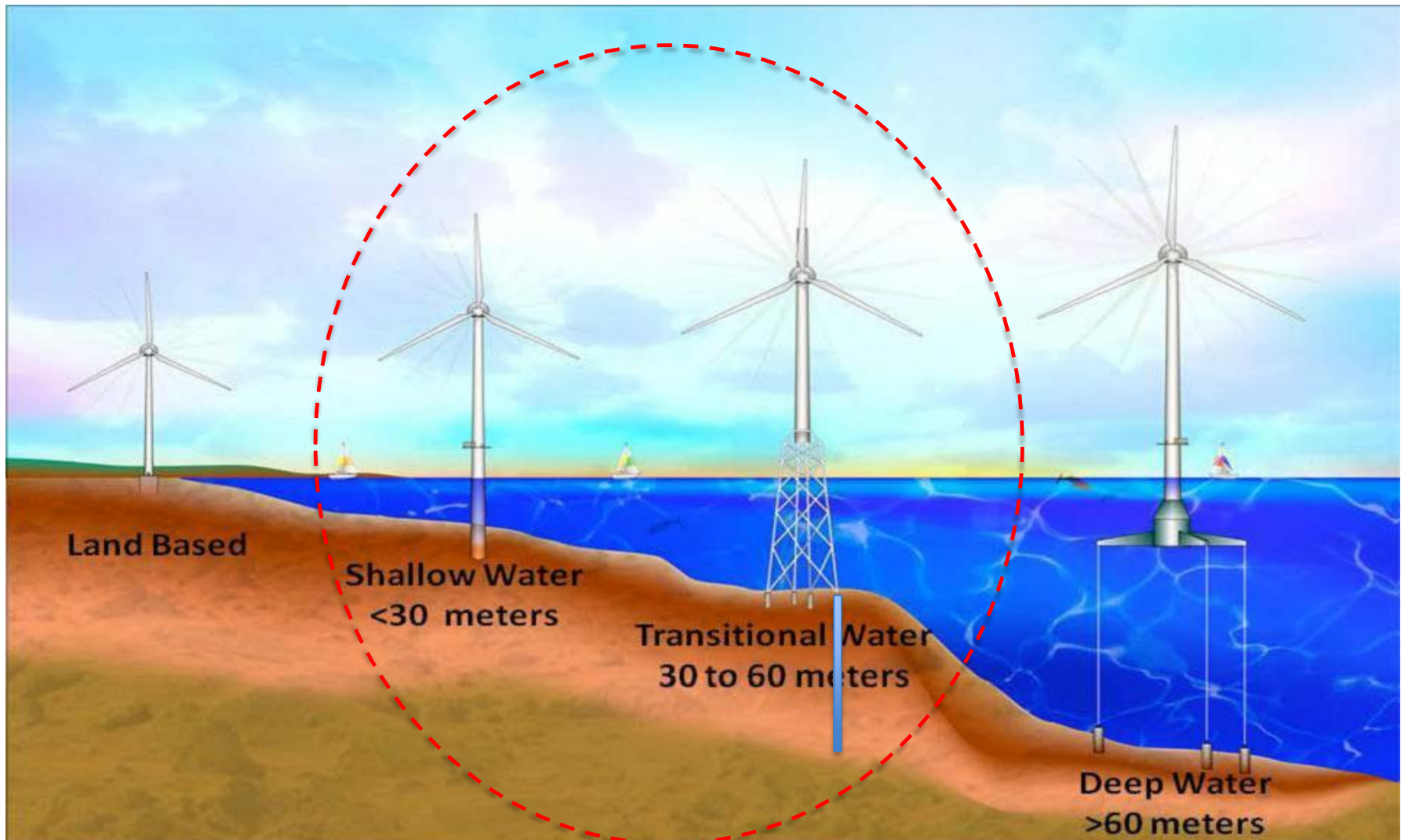
Source: Bloomberg New Energy Finance

Bloomberg

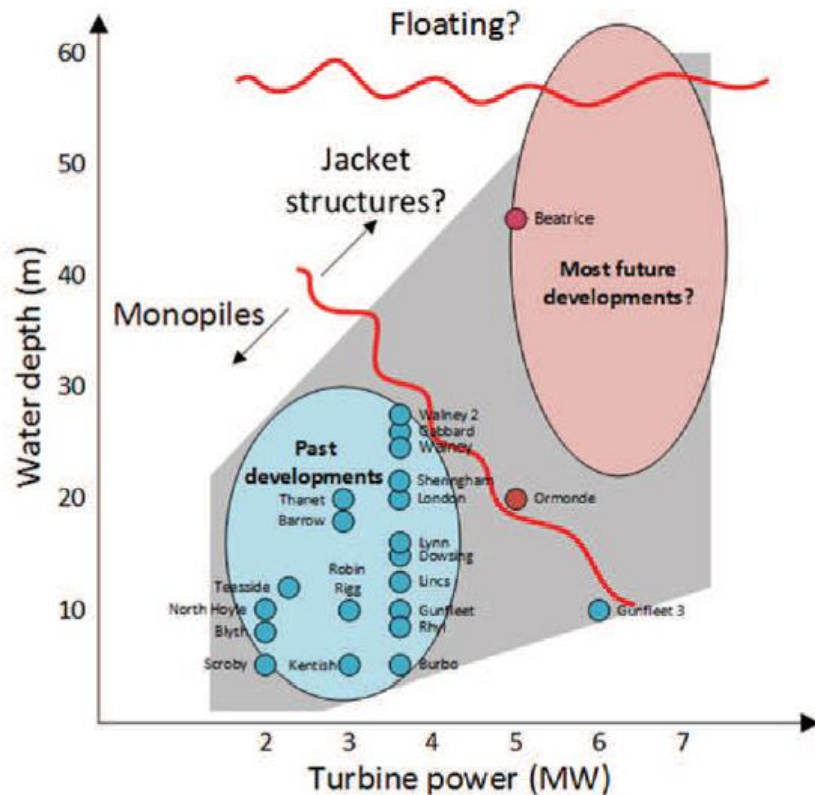
Advances in turbine capacity and size



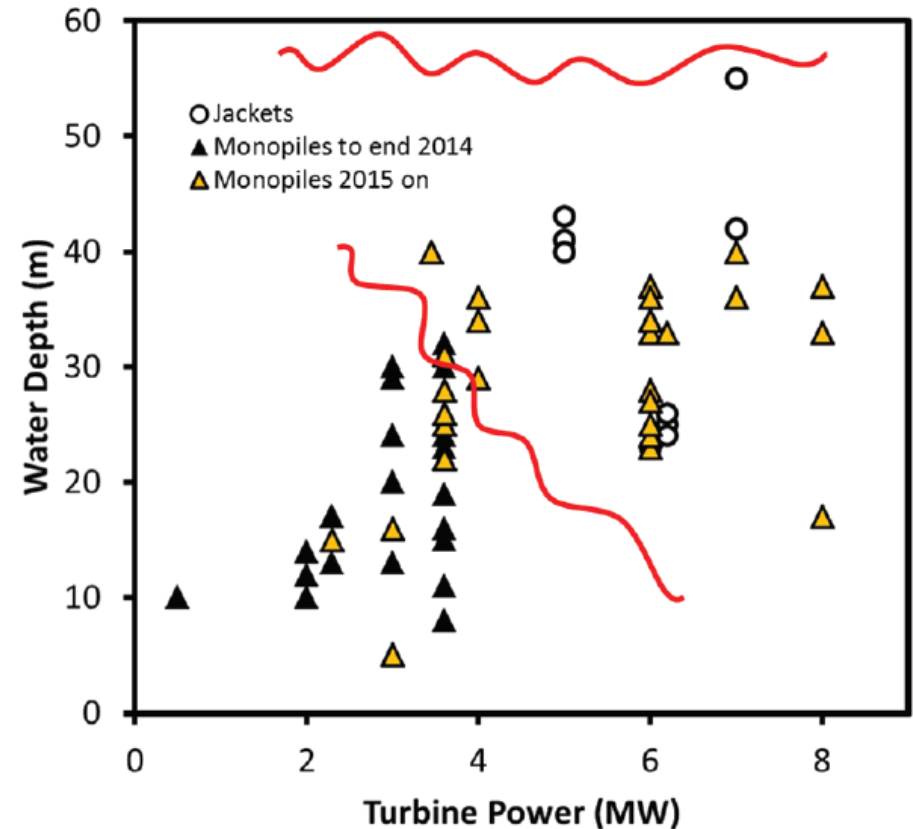
Foundation Types Depend on Water Depth



Fixed Bottom Foundations – Monopiles

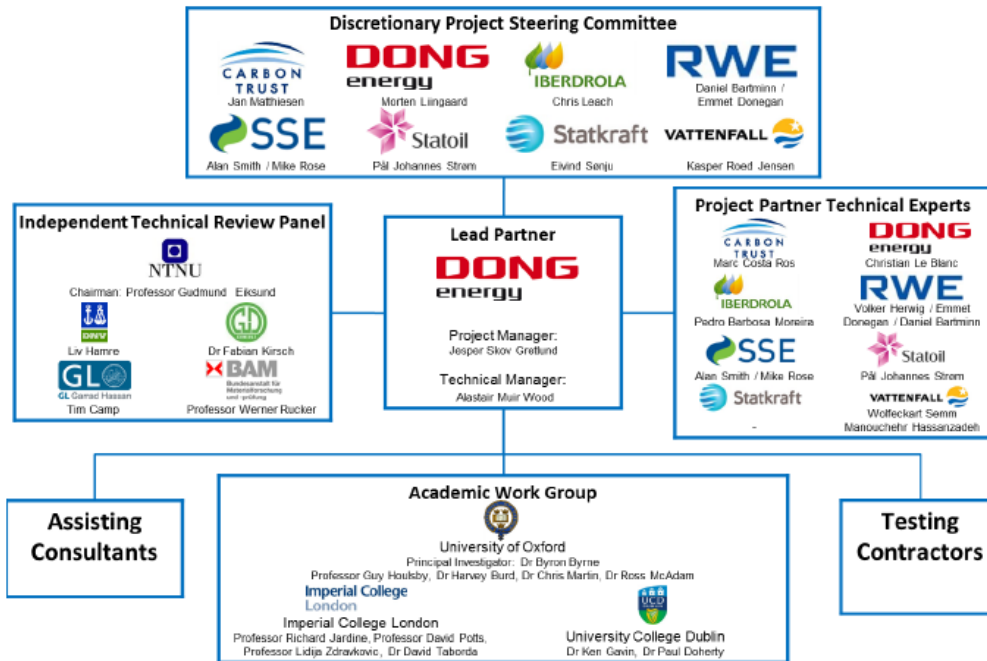


From Guy Houlby
2014 Rankine Lecture

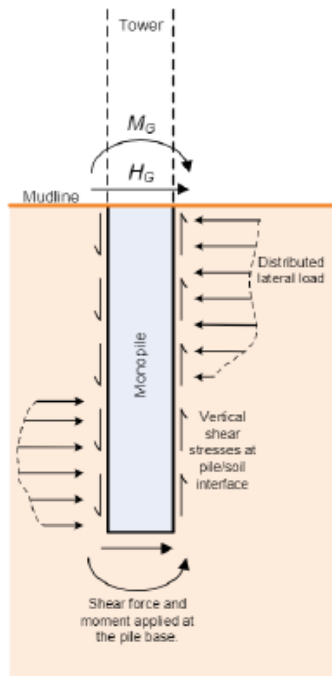


With thanks to David Maloney
DNV-GL

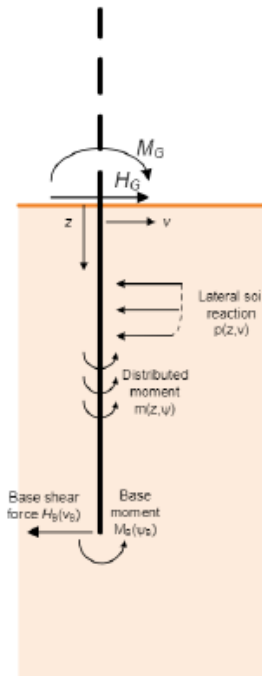
PISA Project



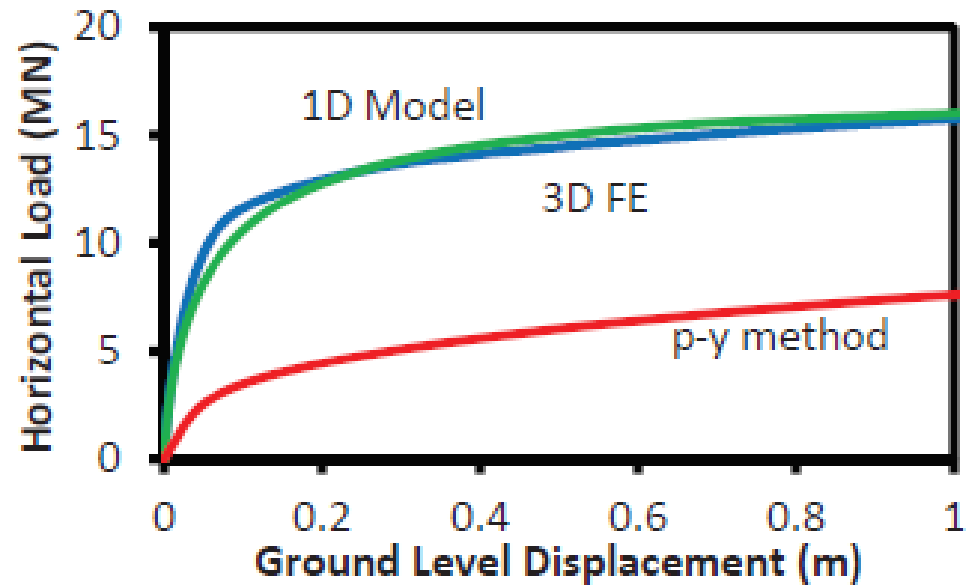
Move from Industry Standard p-y



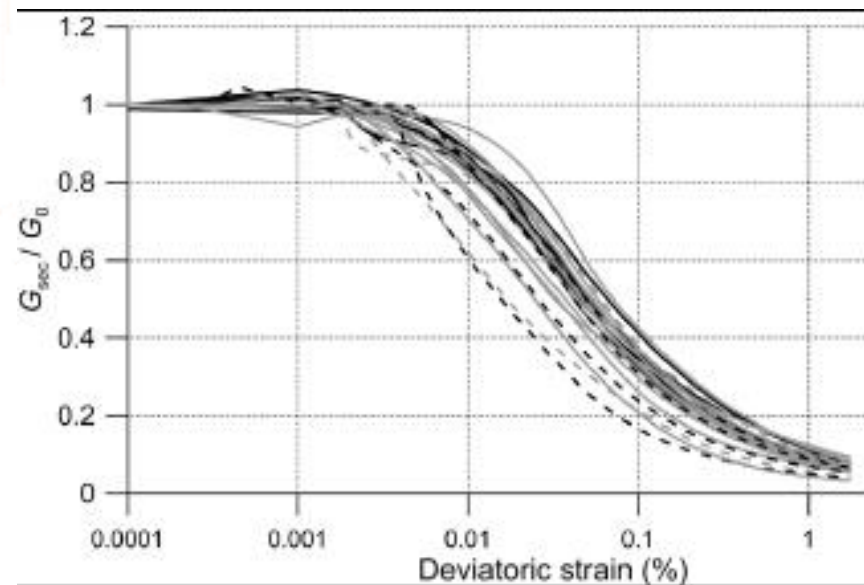
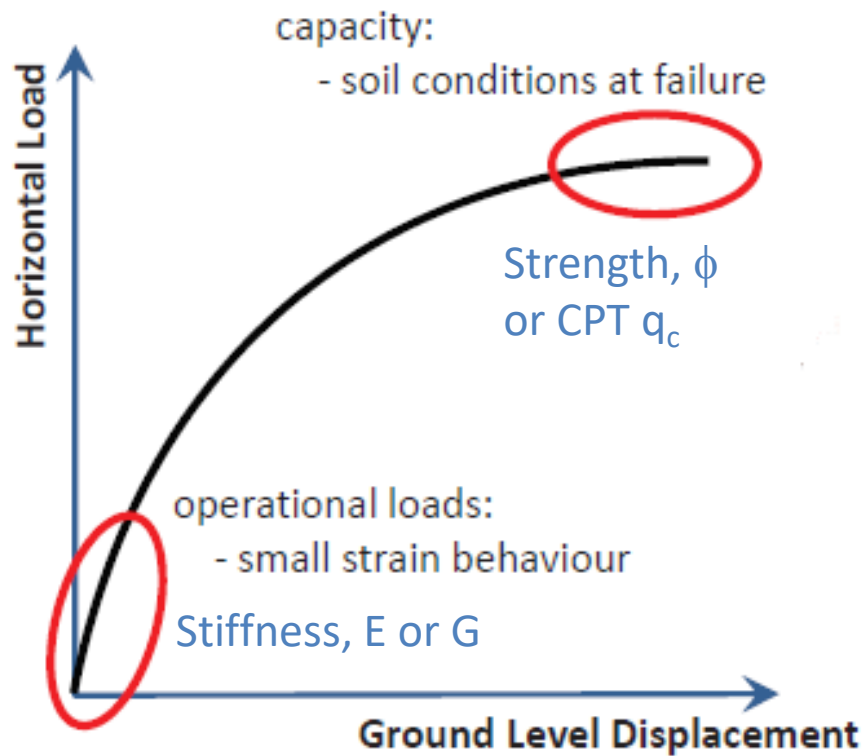
(a) Assumed soil reactions acting on a monopile



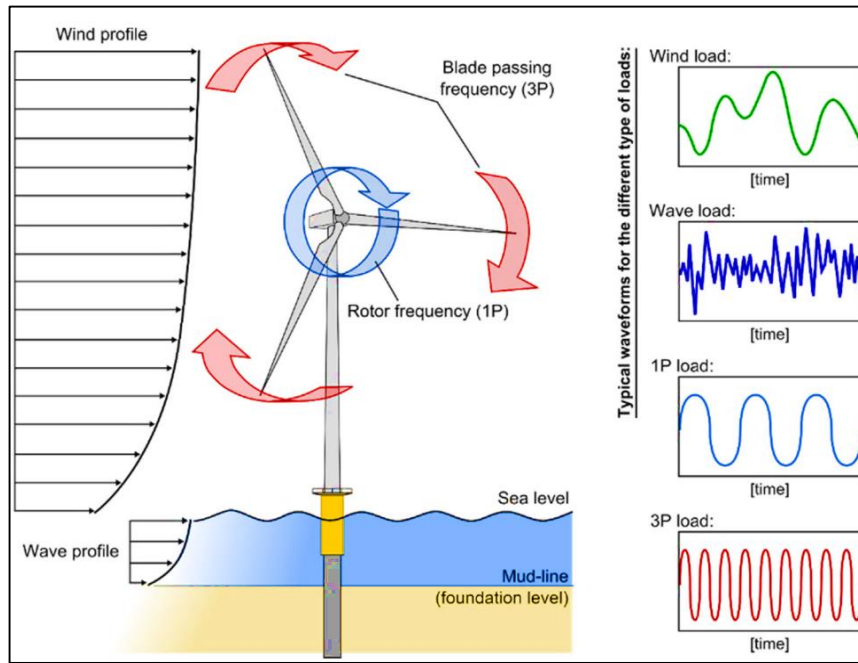
(b) Analysis model



Ultimate vs In-Service Response

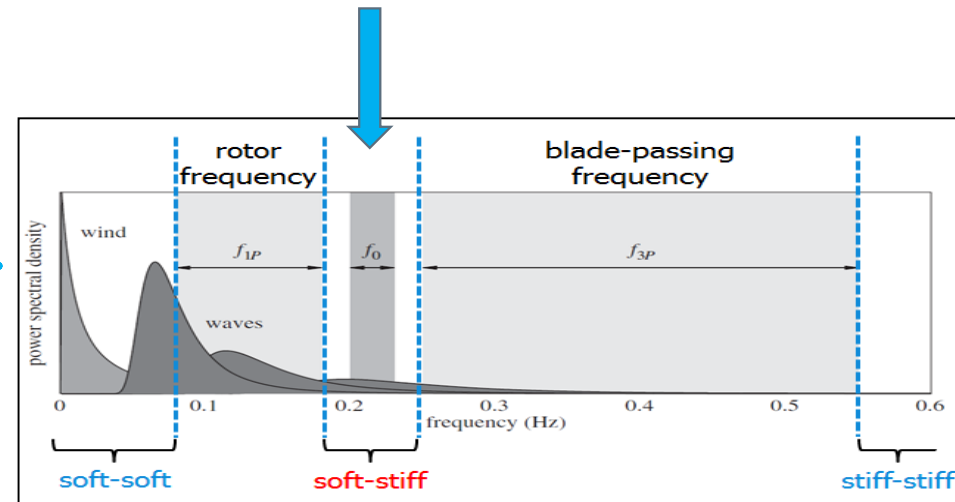


Dynamics and Natural Frequency



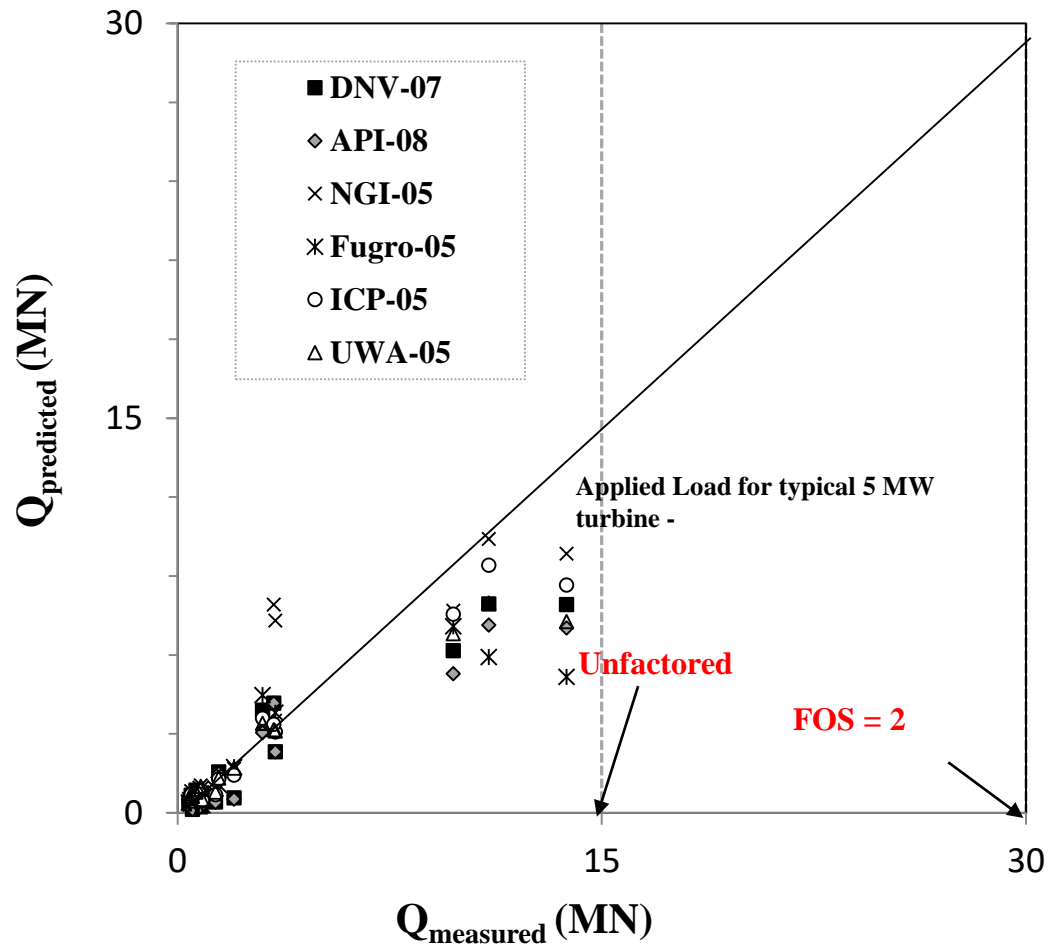
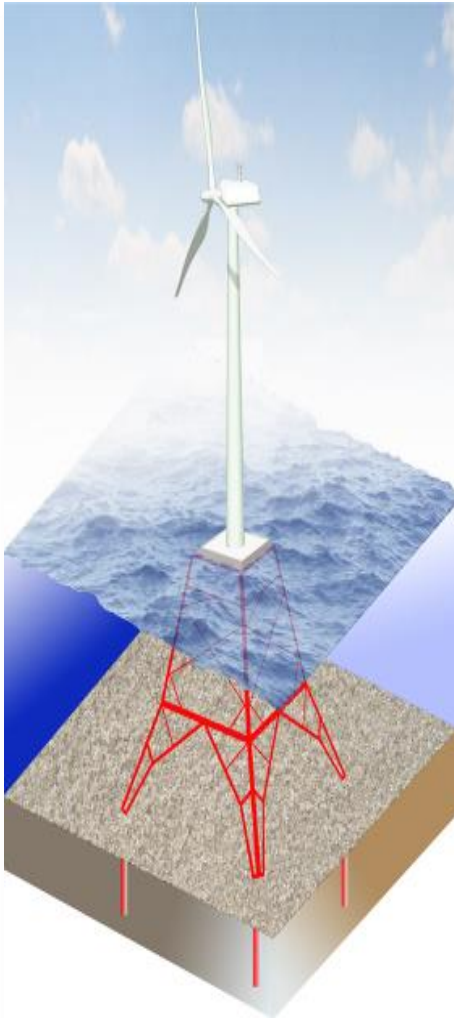
adapted from Nikitas et al.(2016)

Target Frequency Range



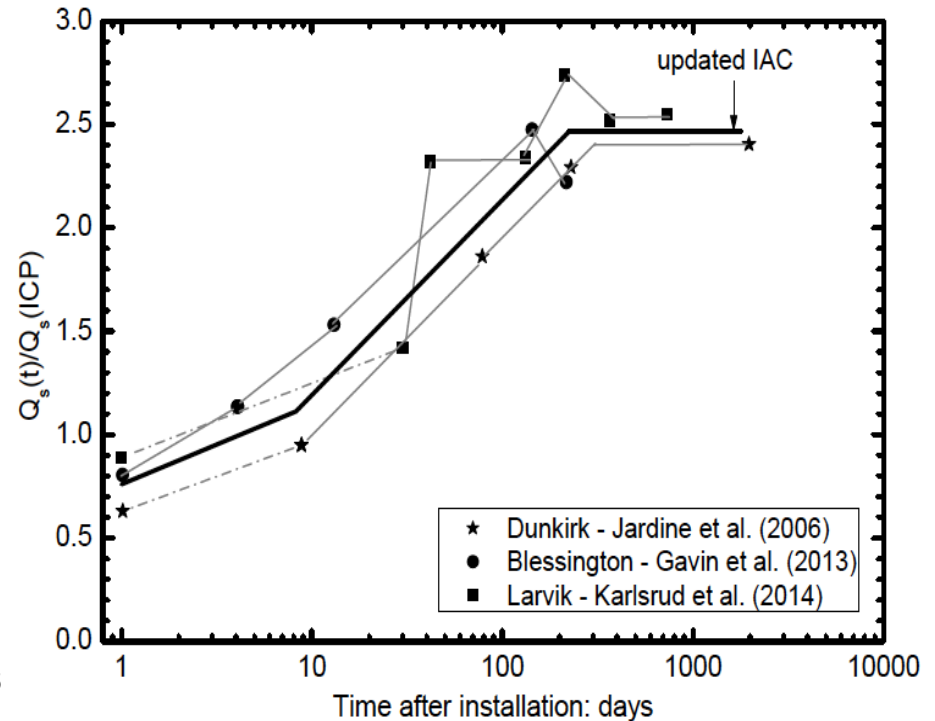
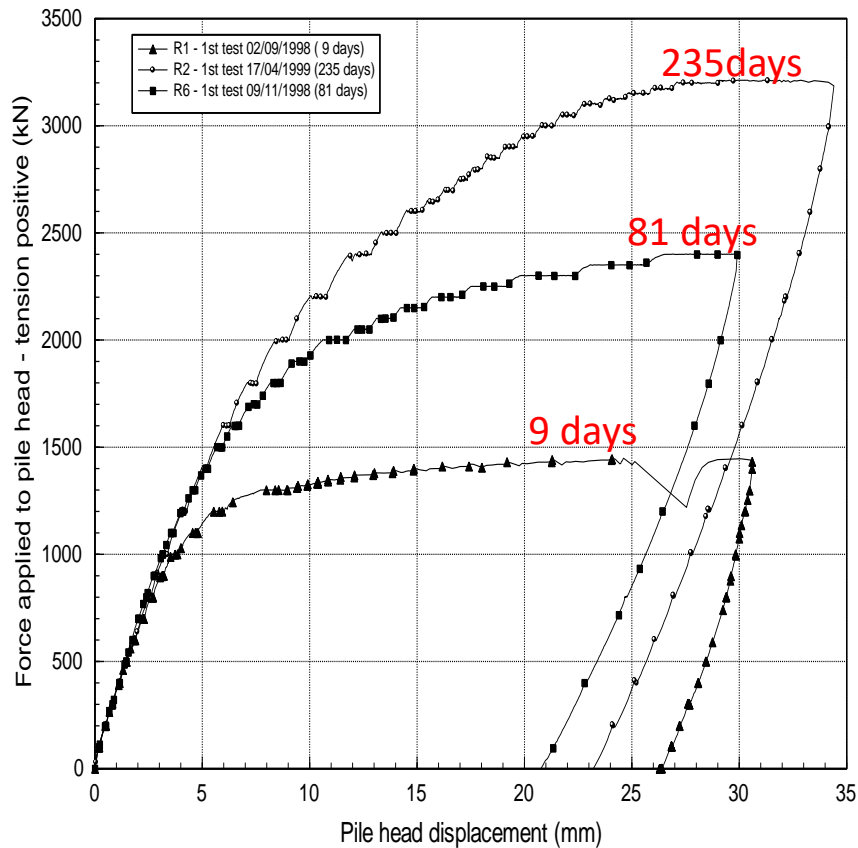
adapted from Kallehave et al. (2015)

Axially Loaded Piles for Jacket Structures

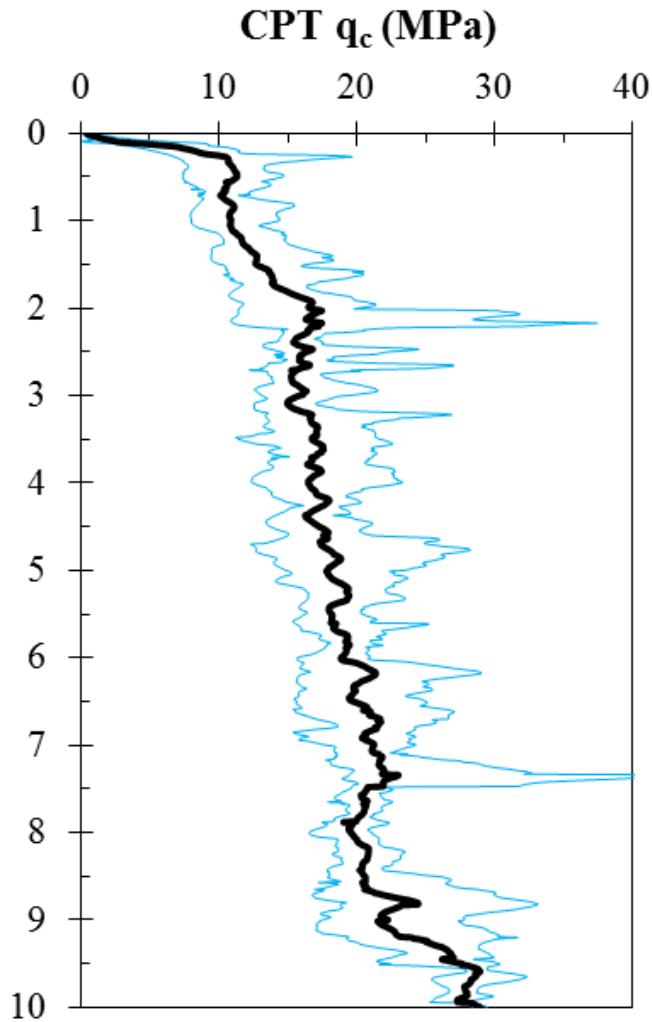


Open-ended piles Gavin et al. (2011)

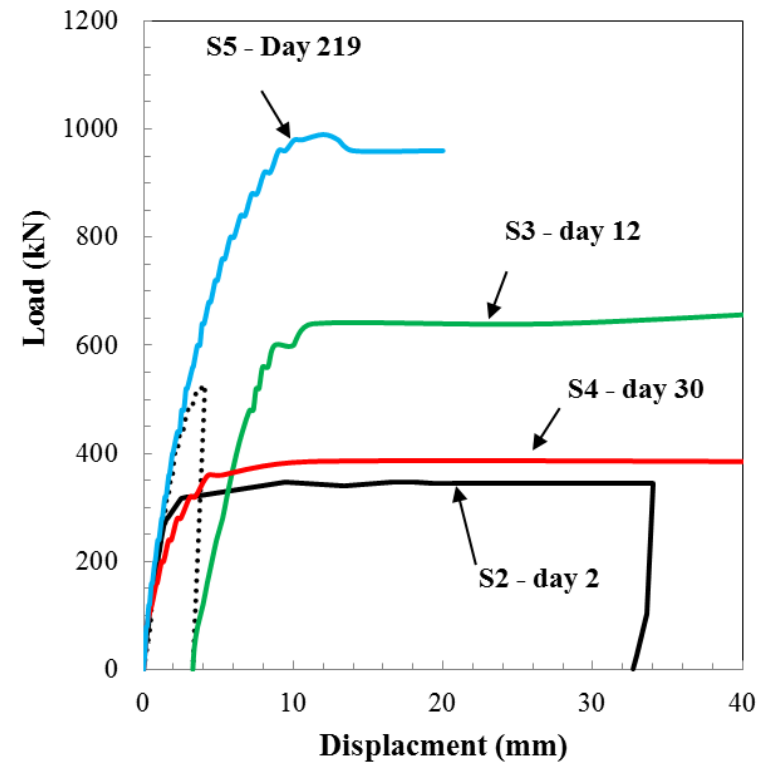
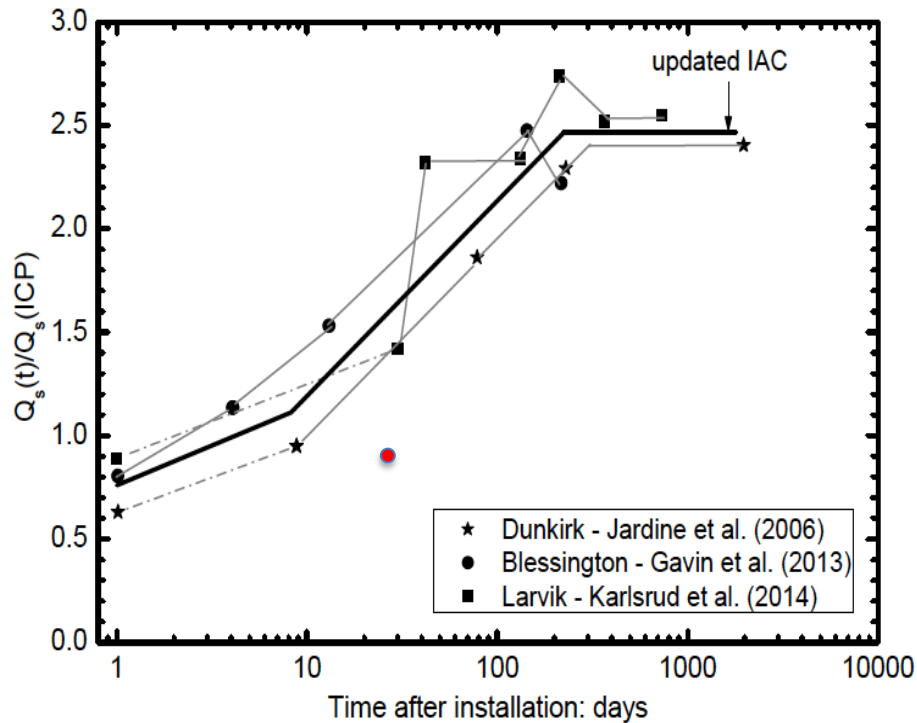
Field Tests on Ageing (Jardine et al. 2006)



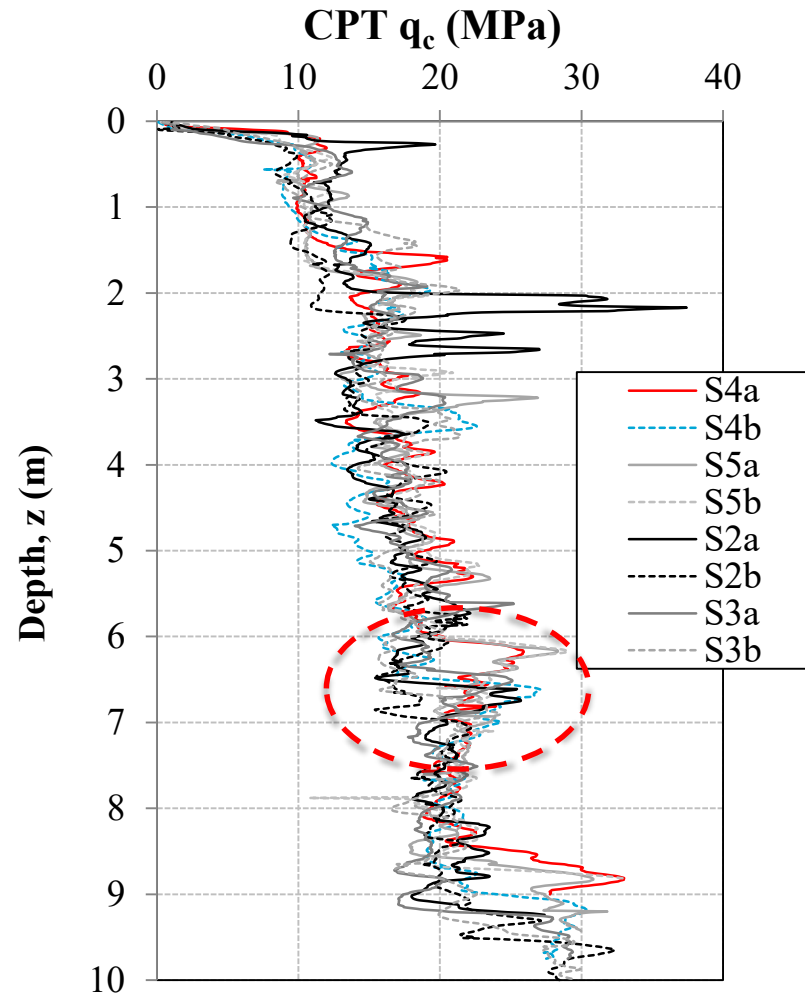
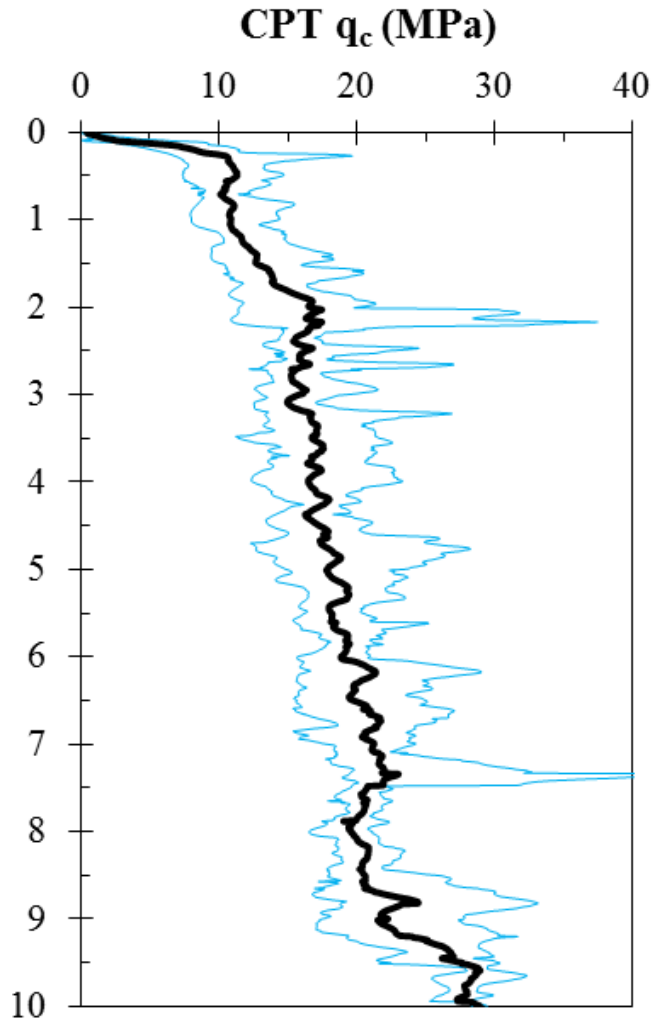
Axial Loading - Aging Tests



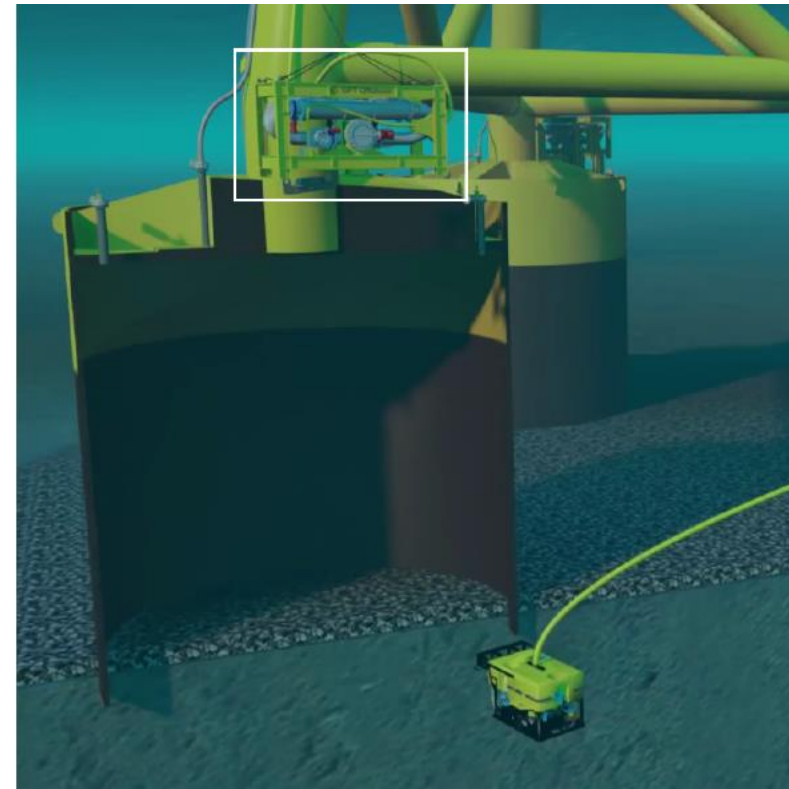
Normalised ageing trends; Rimoy et al. (2015)



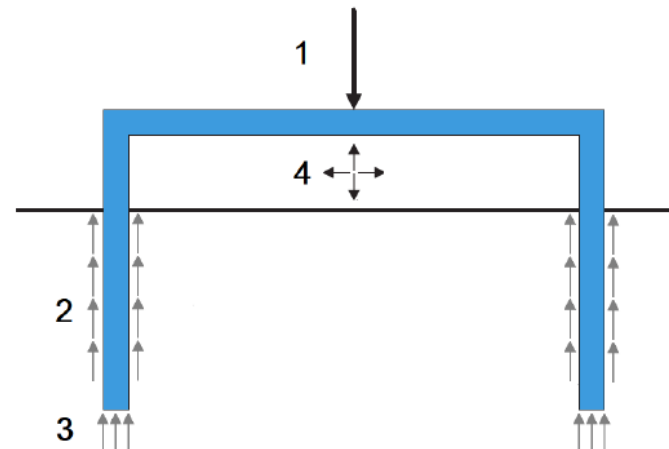
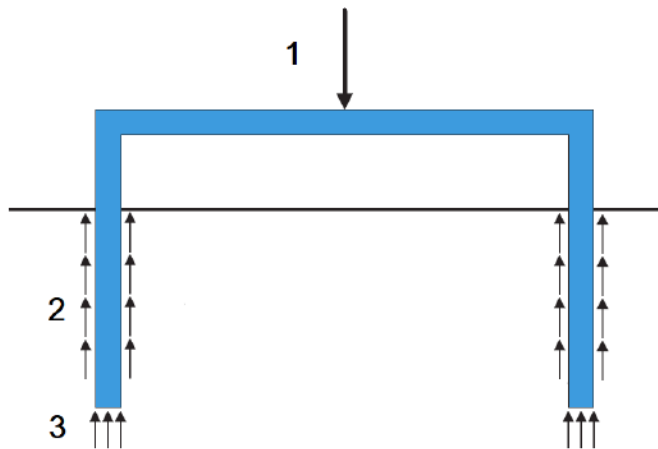
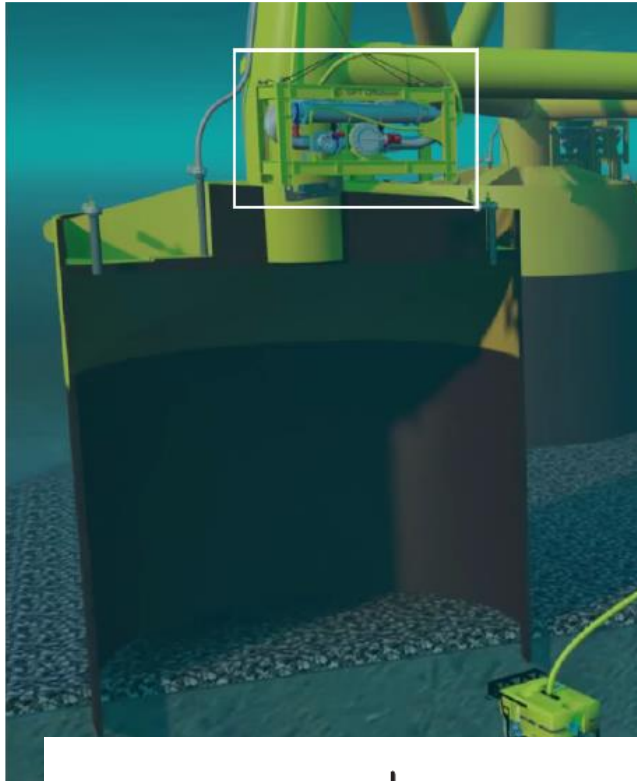
Site Conditions



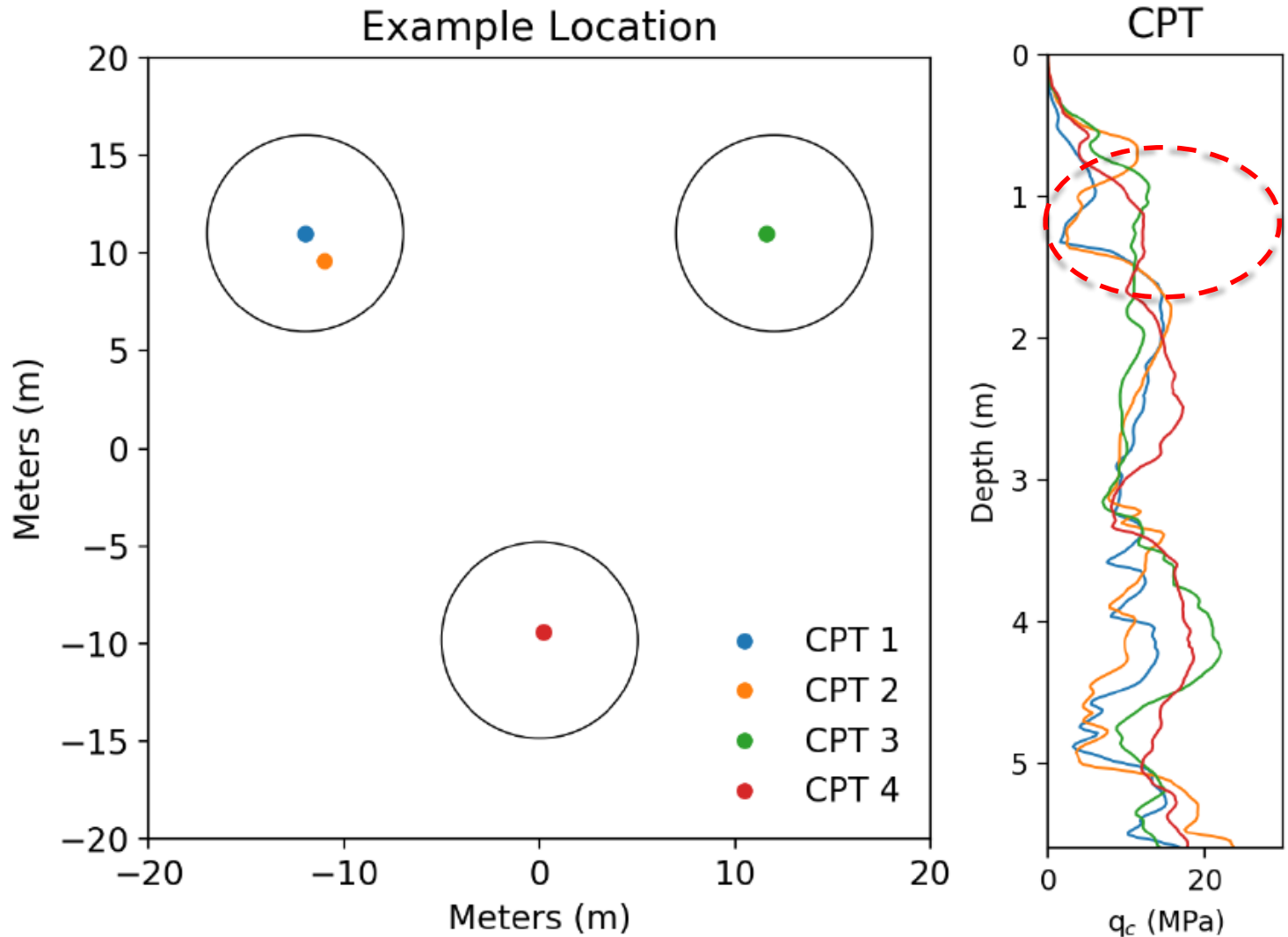
Suction Caissons



Installation Process

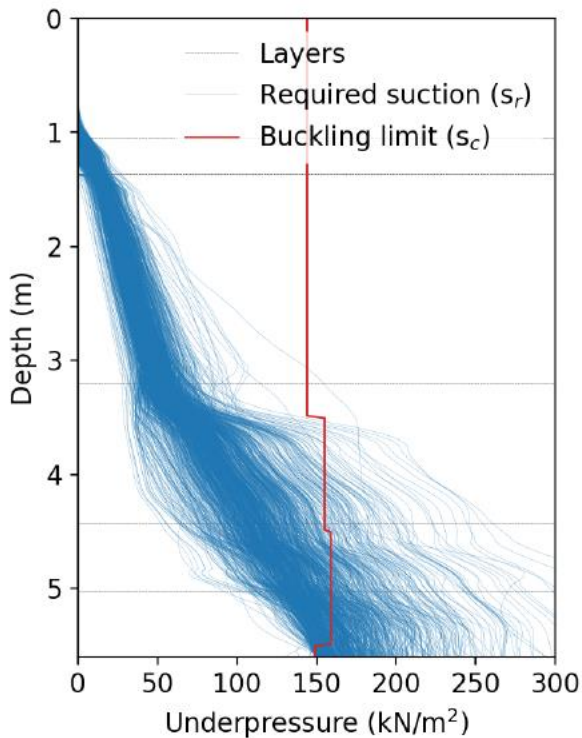


Typical Soil Variability

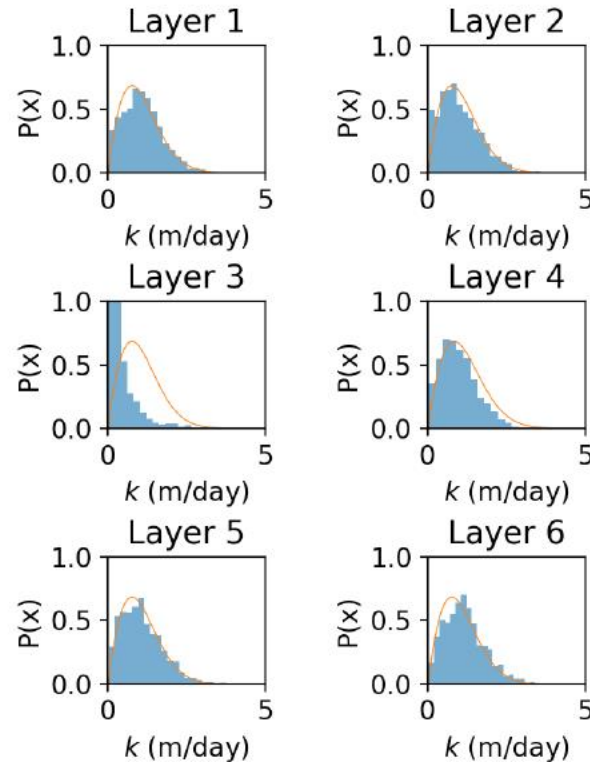


Effect of Permeability

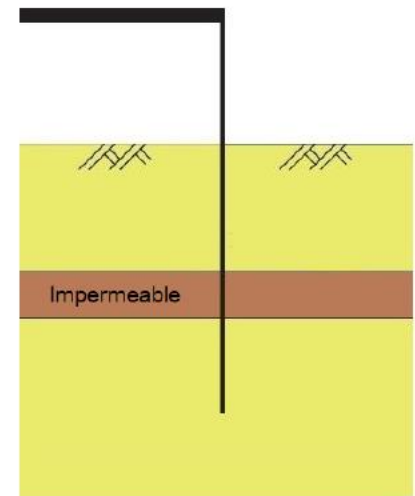
Failure states simulated ($Z < 0$)



Sampled permeabilities



Governing mechanism:



Seepage blocking

Conclusions

1. Overview of the type of foundation systems
2. Monopile design methods have improved significantly still work to do on cyclic loading, load-interaction effects and dynamics, the most important parameters relate to small strain stiffness
3. For jackets still uncertainty about axial capacity – aging provides reserve capacity but sensitive to local variations in CPT.
4. For suction caisson knowledge of the presence of obstructions and low-permeability layers is critical – also obstructions such as cobbles and boulder.

Thanks

