Cyclic Monopile Design at Ørsted

Cyclic design methods and potential improvements informed by pile tests

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Geotechnical lateral load cases: typical 'cyclic MP design'



Cyclic degradation methodology for clay



3 Zhang et. Al. (2016). Monotonic and Cyclic p-y Curves for Clay Based on Soil Performance Observed in Laboratory Element Tests.

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Orsted

0.1 0.3

Load idealisation

What are the major differences?

- Load magnitude and number of 'cycles'
- Ordering

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- Rate of change
- Load direction

What are the effects?

- Much research investigated differences numerically and experimentally
 - i.e. Lab testing (Liu et al. (2024), Skau et al. (2022))
- But is an area which has plenty of scope for further work at monopile scale

The monopile will experience 'pseudo random' loading not well-defined batches in increasing order



Liu et al. (2024). Load history idealisation effects for design of monopiles in clay. Géotechnique. 74. 398-408. Skau, et al. (2022). Response of lightly overconsolidated clay under irregular cyclic loading and comparison with predictions from the strain accumulation procedure. Géotechnique. 73. 1087-1099.

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Comparison of cyclic approach with pile testing: ULS



Pile tests: $R_{M,ULS} \approx R_{M,stat}$



5 Beuckelaers (2017) Numerical modelling of laterally loaded piles for offshore wind turbines

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Comparison of cyclic approach with pile testing: ULS



Byrne (2024) DGF Seminar

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Wahl et al. (2023) Rate effects increasing lateral capacity of monopiles

Beuckelaers (2017) Numerical modelling of laterally loaded piles for offshore wind turbines

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Comparison of cyclic approach with pile testing: SLS



Pile tests: Non-linear unloading following masing rules

7 Beuckelaers (2017) Numerical modelling of laterally loaded piles for offshore wind turbines

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Comparison of cyclic approach with pile testing: SLS



Summary

Medium scale pile tests compared to current design method:

ULS design:

- Capacity does not follow same 'degradation' curve as permanent rotation
- May be increased during the large and fast design loads

SLS design:

- Unloading follows masing rules (non-linear)
- Comparison with more realistic pseudo-random loading is required

PICASO project: will add much more to the body of evidence



Thank-you

