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Rate Effects for Monopile Foundations: Small-Scale Model Tests

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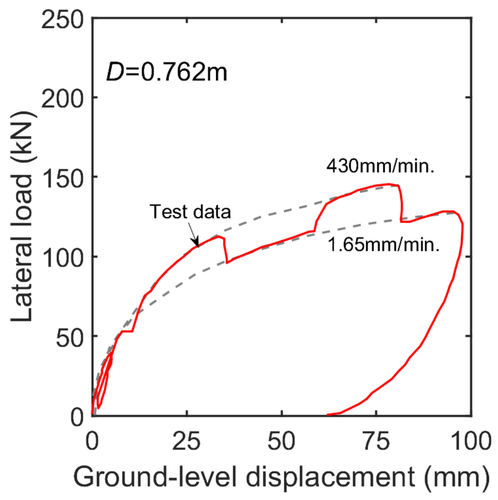
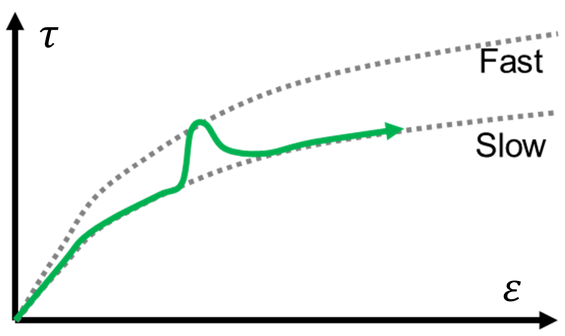
Background

- Monopile foundations for offshore wind turbines are subject to **transient loading** (*e.g.* storms, emergency stop of the turbine).
- Soil strength/stiffness and cyclic behaviour are **rate-dependent**. (see example PISA pile testing)
- Current design practice has yet to include rate effects.
  → **over-conservative?**



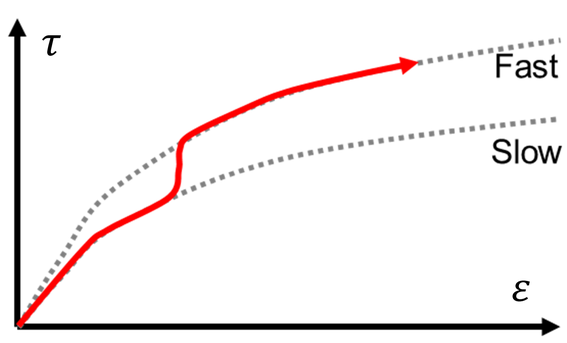
Rate effects in Cowden till in the PISA pile testing (Byrne et al., 2020)

Viscosity types of soils (Tatsuoka et al., 2008)



TESRA type

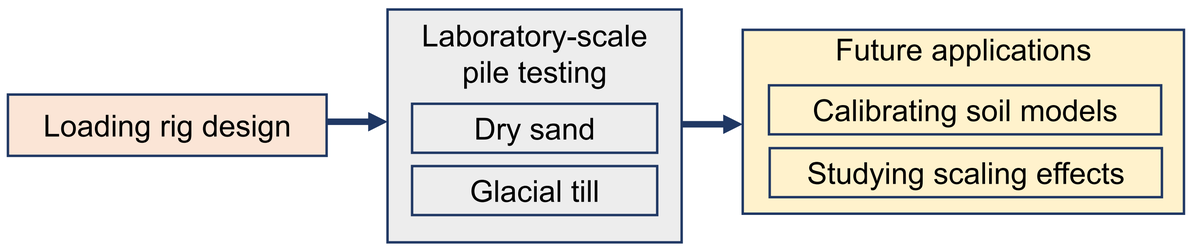
Transient effects of strain rate and strain acceleration (TESRA) (example: dry silica sand)



Isotach type

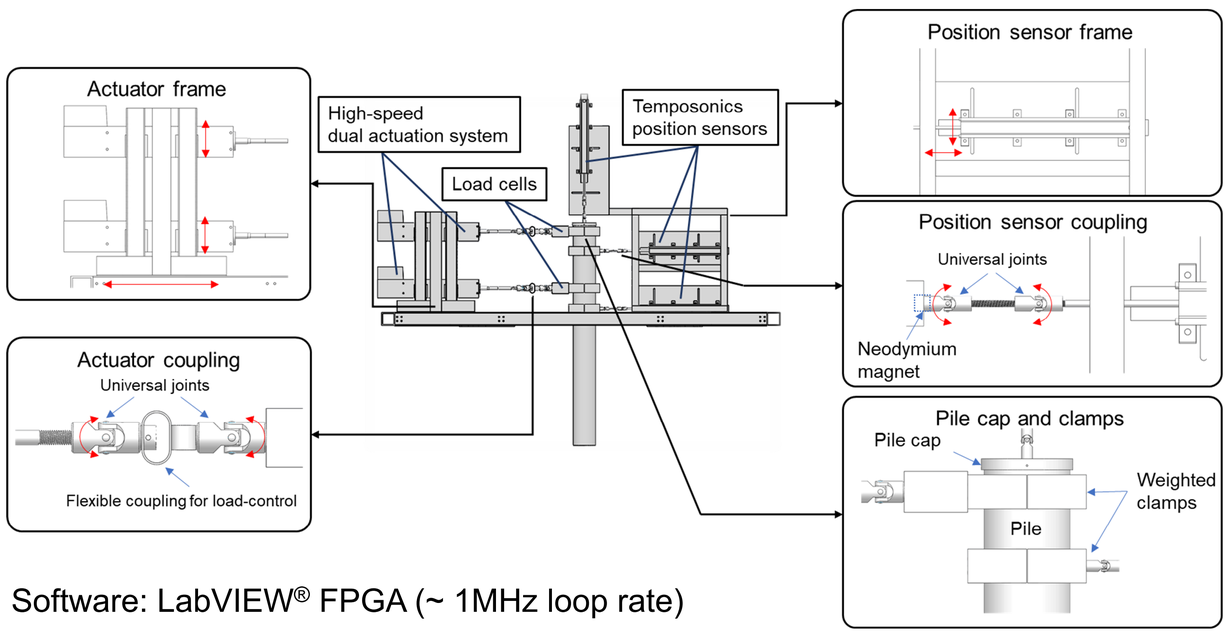
Unique strength-strain-strain rate behaviour (example: clay)

Research structure



Test equipment

Computer-controlled loading rig



Software: LabVIEW® FPGA (~ 1MHz loop rate)

Mobile laboratory for clay tests

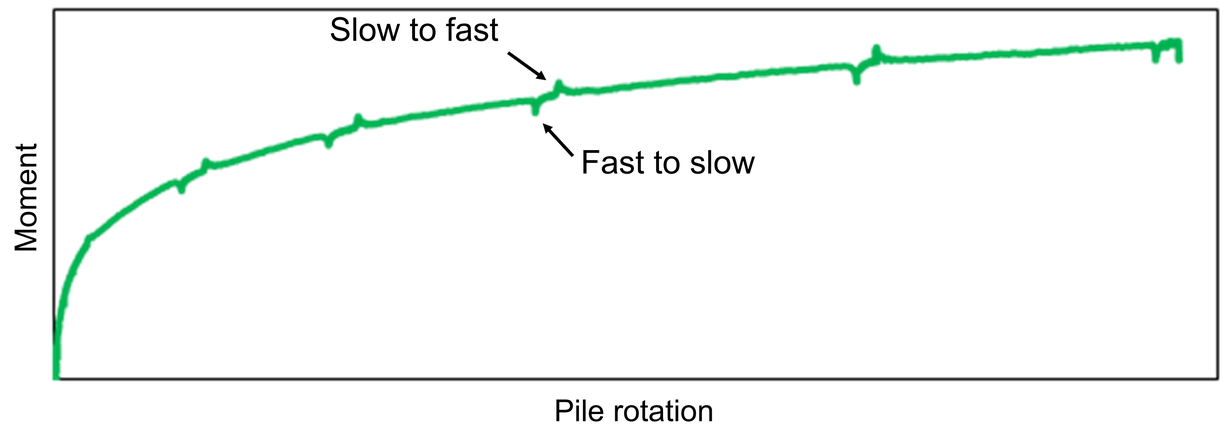
On-site mobile laboratory

Naturally formed glacial till

Pile gapping

- Cowden till s_u> 50 kPa.
- Soil characterisation is in progress.

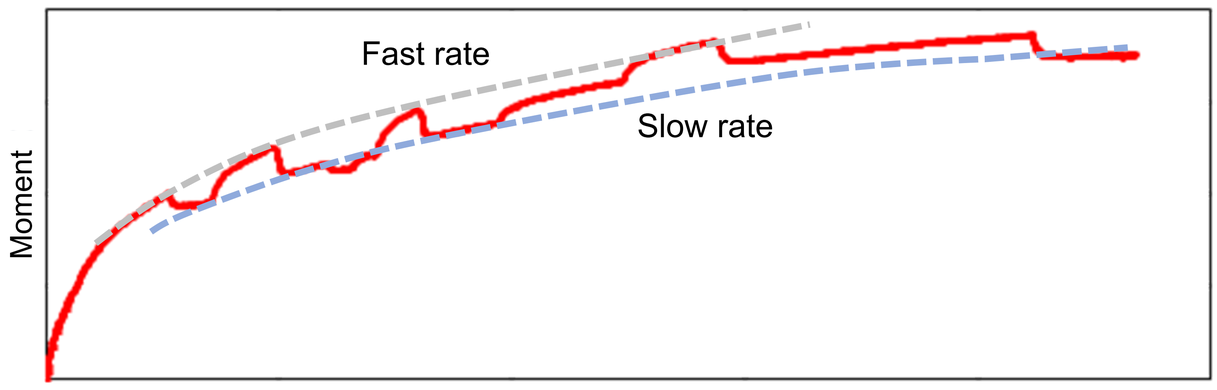
Model testing in dry sand



- 14/25 yellow Leighton Buzzard sand (D_r= 4% - 60%) was used.
- Transient responses are seen when accelerating/decelerating (similar to TESRA type), which may be due to the inertial effects of the actuation system (see Wu et al., 2020).
- The overall behaviour is rate-insensitive.

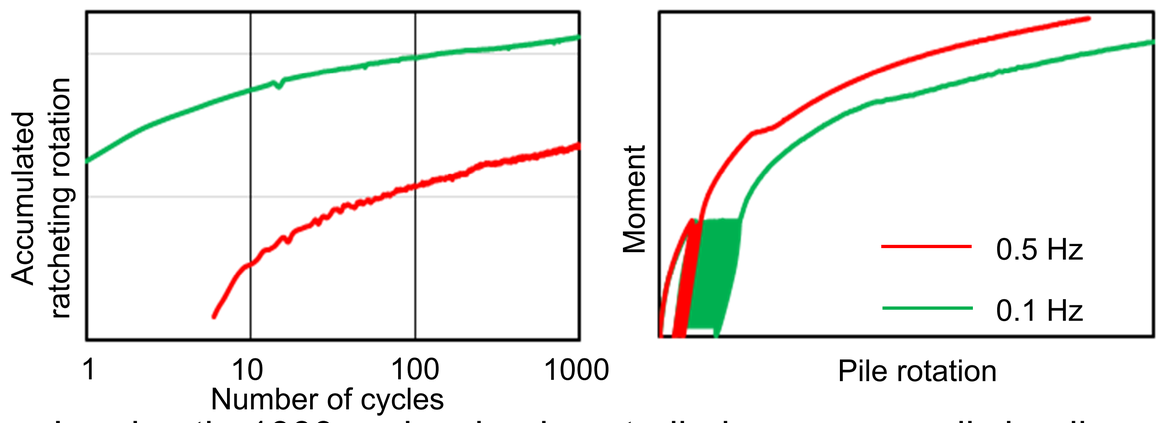
Model testing in clay

Variable rate test



- Result shows rate-dependent responses, in agreement with the PISA testing at Cowden.
- Isotach type behaviour is observed.

Cyclic loading test



- Load path: 1000 cycles, load-controlled one-way cyclic loading.
- Pile stiffness, permanent rotation are rate-dependent.
- Post cyclic loading behaviour varies with the cyclic frequency.

Conclusions

- Transient responses are seen in dry sand, but the overall pile behaviour is rate-independent.
- Rate effects in clay are observed during monotonic loading and cyclic lateral loading.
- Further work on calibrations of soil models and investigating scaling issues will continue to inform design methods.

Reference list

[1] Byrne et al. 2020. Monotonic laterally loaded pile testing in a stiff glacial clay till at Cowden. *Géotechnique*, 70(11): 970-985.
[2] Tatsuoka et al. 2008. Various viscosity types of geomaterials in shear and their mathematical expression. *Soils and Foundations*, 48(1): 41–60.
[3] Wu et al. 2020. Investigations of rate effects for monopile foundations: laboratory-scale model tests. *ISFOG2020*, Texas, USA.

Acknowledgment

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