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Supergen Offshore Renewable Energy

ALPHA: NUMERICAL ANALYSIS OF LATERALLY LOADED PILES DRIVEN IN CHALK

Research team: Dr Giuseppe Pedone (RA), Dr Stavroula Kontoe (PI), Prof Lidija Zdravkovic (CI) & Prof Richard Jardine (CI)

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BACKGROUND

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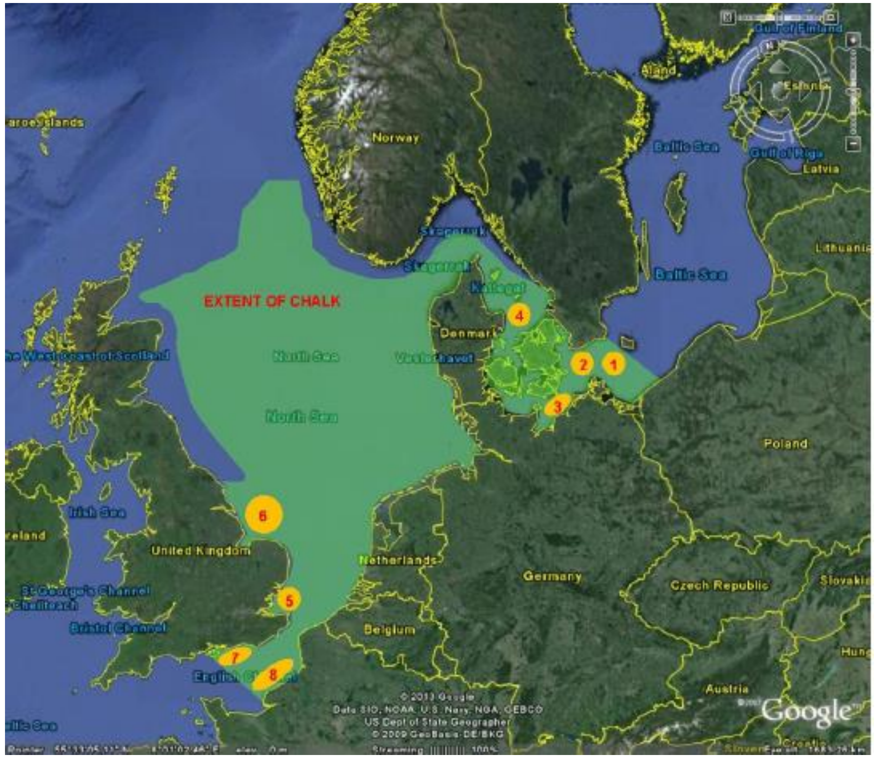
- Chalk is widespread under N. Europe & often encountered at foundation depths
- Several planned or completed offshore wind projects are founded in chalk
- Basic mechanisms of driven pile behaviour poorly understood in chalk; poor design method reliability

Related recent projects:

- PISA (2013-2018) JIP (Ørsted, ICL, OU, 9 developers) delivered new PISA-numerical & PISA-1D design methods for lateral capacity in sands and clays
- UK Innovate JIP (2014-2017) (Iberdrola, ICL, GCG) delivered preliminary design for axial capacity in chalk
- ALPACA & ALPACA Plus JIP (2017-2021) (ICL, OU, several industrial sponsors), extended scope to cover lateral field tests & intensive laboratory testing of chalk



Broad extent of Chalk in NW Europe and selected planned or completed offshore wind projects

ALPHA:
NUMERICAL ANALYSIS OF LATERALLY LOADED PILES DRIVEN IN CHALK

ALPHA aimed to develop a reliable lateral design method for large diameter offshore wind turbine piles in chalk, through application of PISA-numerical design approach:

1. Synthesis of in-situ testing characterisation data with advanced triaxial, oedometer, ring shear & other experiments to develop a theoretical framework for chalk behaviour

2. Numerical modelling with the bespoke finite element code ICFEP:
   - Versatile constitutive model developed for calcarenites (Lagioia & Potts 1999)
   - Non-local regularisation to facilitate rigorous modelling of chalk's marked softening behaviour (Summersgill et al. 2017)
   - 3D FE model for the ALPACA near-scale instrumented lateral pile tests, allowing for application at other chalk sites and practical design application

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Steering Committee: Dr Róisín Buckley, Oxford University
Dr Angeliki Grammatikopoulou & Dr Felix Schroder, GCG
Paul Knight & Alastair Muir Wood, Wood Thilsted Partners Ltd
Sebastien Manceau, SNC-Lavalin Atkins

Funding: £100k from Supergen ORE Flexible fund @ 80% FEC

Duration: 9 months, Nov 2019 – August 2020, + 3 months unfunded extension due to COVID -19

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MODELLED ALPACA PILE TESTS

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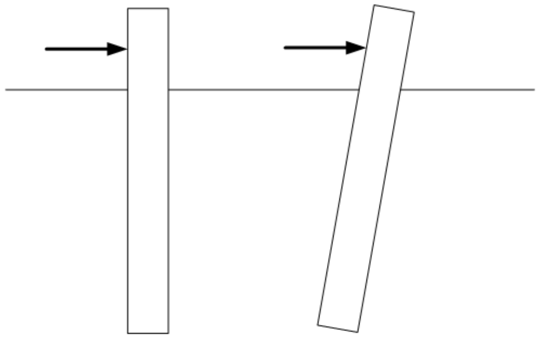
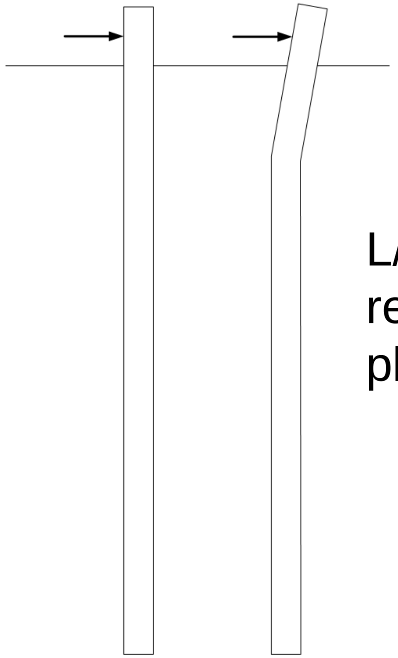
Monotonic lateral loading tests at:

- 2 by 508mm diameter by 3m long piles (L/D=6)
- 2 by 508mm diameter by 10m long piles (L/D=20)



L/D=6: failure mechanism involves a rigid body rotation



L/D = 20: flexible pile response, failure forming plastic hinge in the pile.

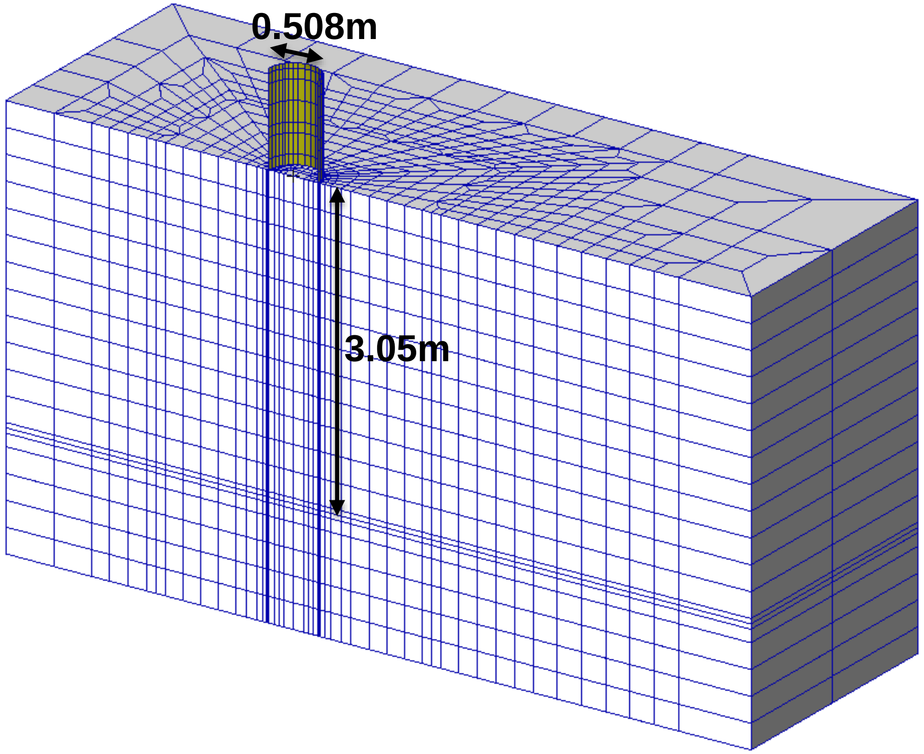
Driving of 508mm OD piles, ALPACA site November 2017

Jardine et al. (2019)

Numerical modelling

Key features of the developed numerical models:

- Simulation of 3 geotechnical units (chalk putty, fractured chalk, intact chalk) to account for the impact of pile driving
- Model calibration accounting for stiffness anisotropy
- Constitutive models accounting for intensely pressure dependant chalk behaviour, ranging from very brittle at in-situ stresses to gradually becoming ductile under high stresses
- Extensive sensitivity studies to investigate the impact of the putty chalk, effect of prior axial loading, pile-chalk interface conditions



Example FE model for the L/D=6 piles

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Modelling strain-softening of intact chalk

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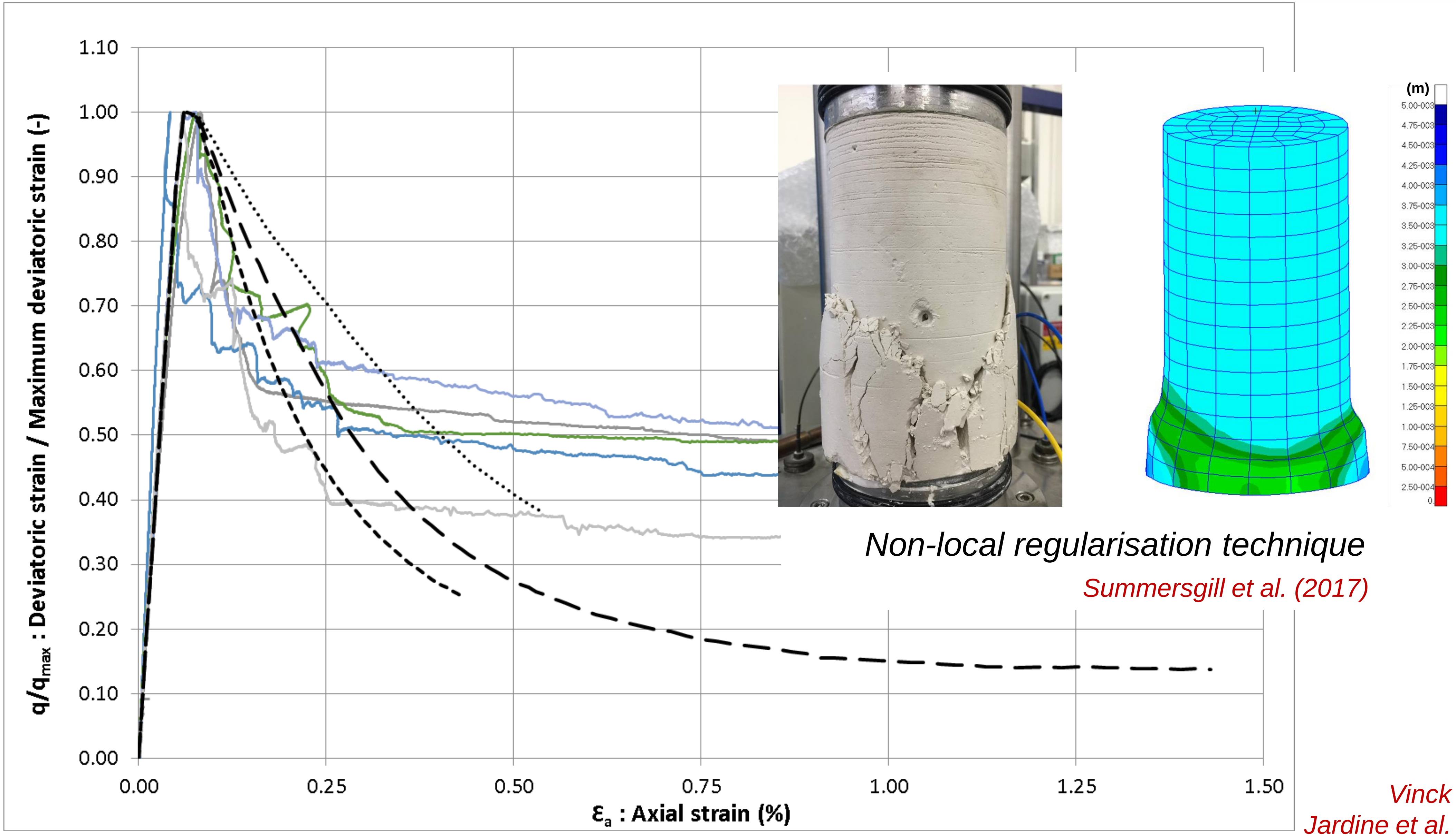


Non-local regularisation technique

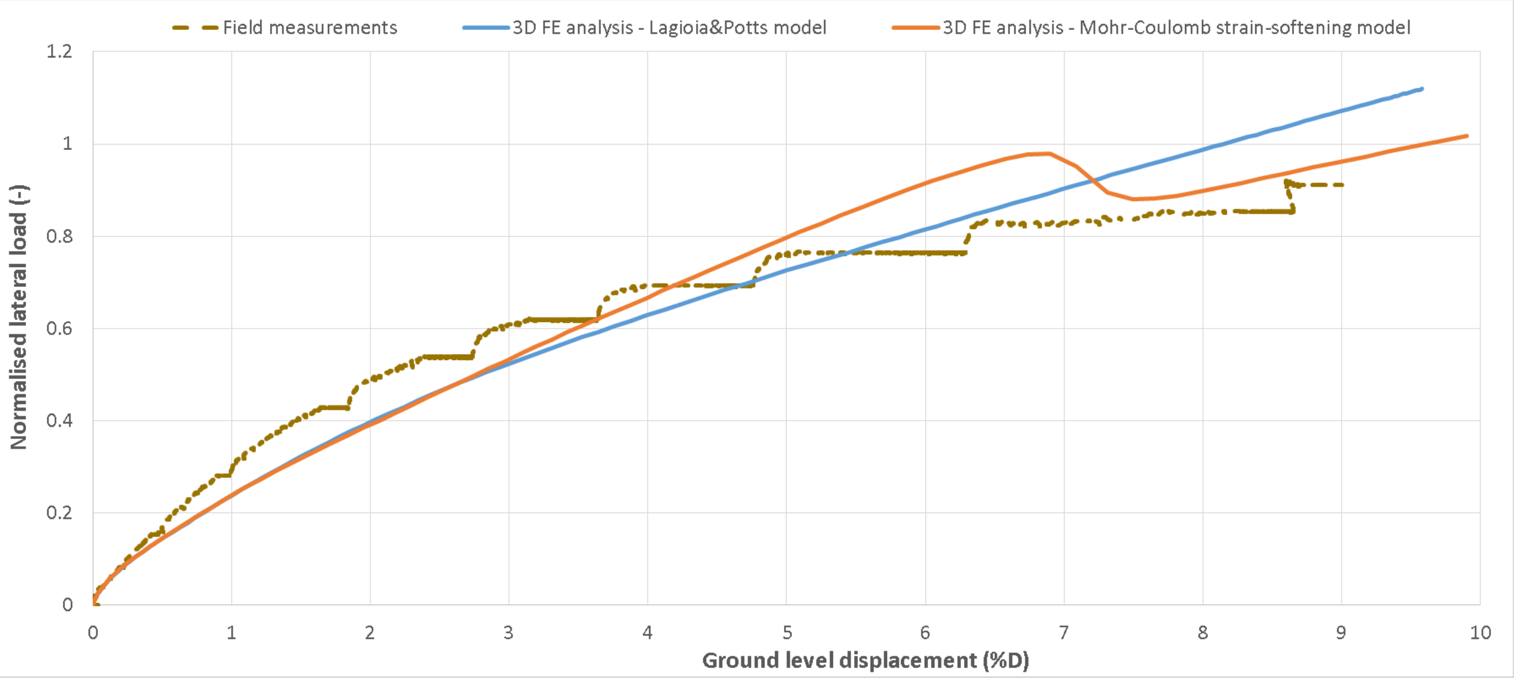
Summersgill et al. (2017)

Vinck (2021)

Jardine et al. (2019)

ALPHA PROJECT FINDINGS

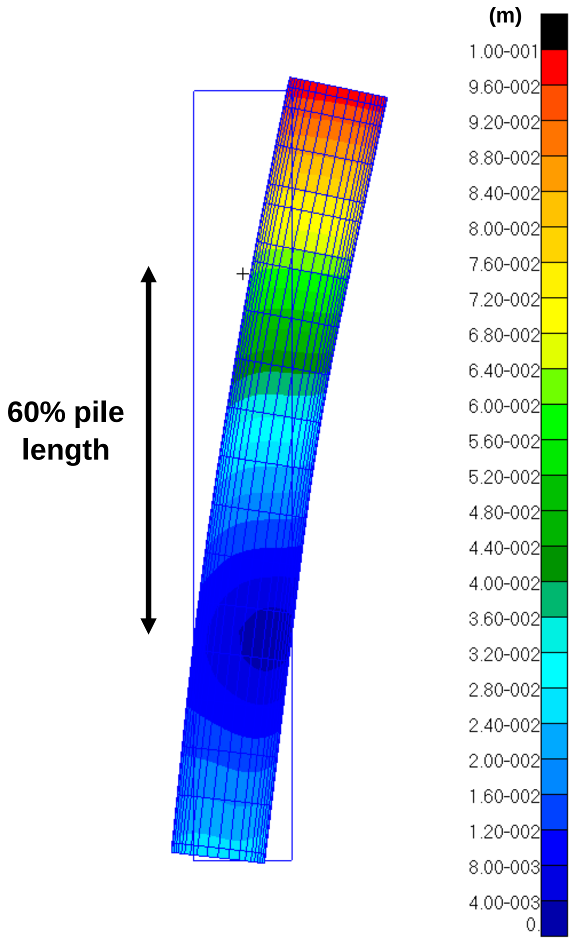
- The ALPHA project successfully synthesised a wealth of field & laboratory characterisation data
- A systematic numerical approach was developed which accounts for the chalk de-structuration due to pile driving
- Advanced 3D FE analyses successfully simulated laterally loaded piles (L/D=6 & 20) driven in low- to medium-density B2-B3 chalk



Numerical predictions vs field measurements in terms of load-displacement response for an L/D=6 pile

ALPHA PROJECT FINDINGS

- ALPHA highlighted the need for advanced laboratory characterisation & rigorous numerical modelling in order to capture the response of piles driven in a challenging geo-material
- ALPHA also provides insights on how simpler constitutive models can be used to provide reasonable predictions
- Additional ALPACA Plus field tests, planned for spring 2021, will provide a further independent dataset to verify the modelling approach developed within ALPHA



Depicted failure mechanism for L/D=6 piles

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