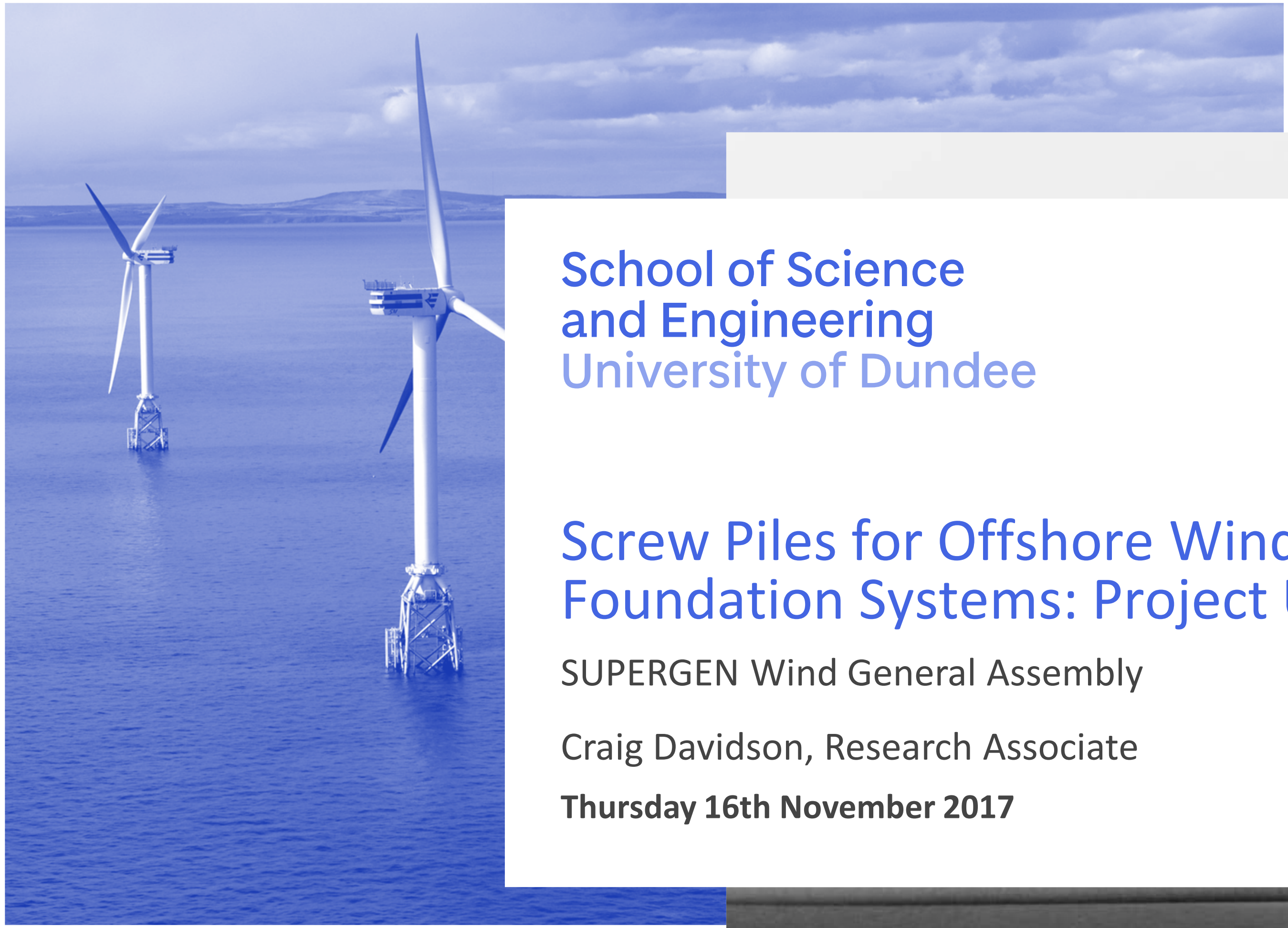


School of Science
and Engineering
University of Dundee

Screw Piles for Offshore Wind Energy Foundation Systems: Project Update

SUPERGEN Wind General Assembly

Craig Davidson, Research Associate

Thursday 16th November 2017

Overview

- → Project background
- → Progress in Physical Modelling
- → Benefits from Numerical Modelling
- → Field testing to verify our work
- → Outputs and opportunities

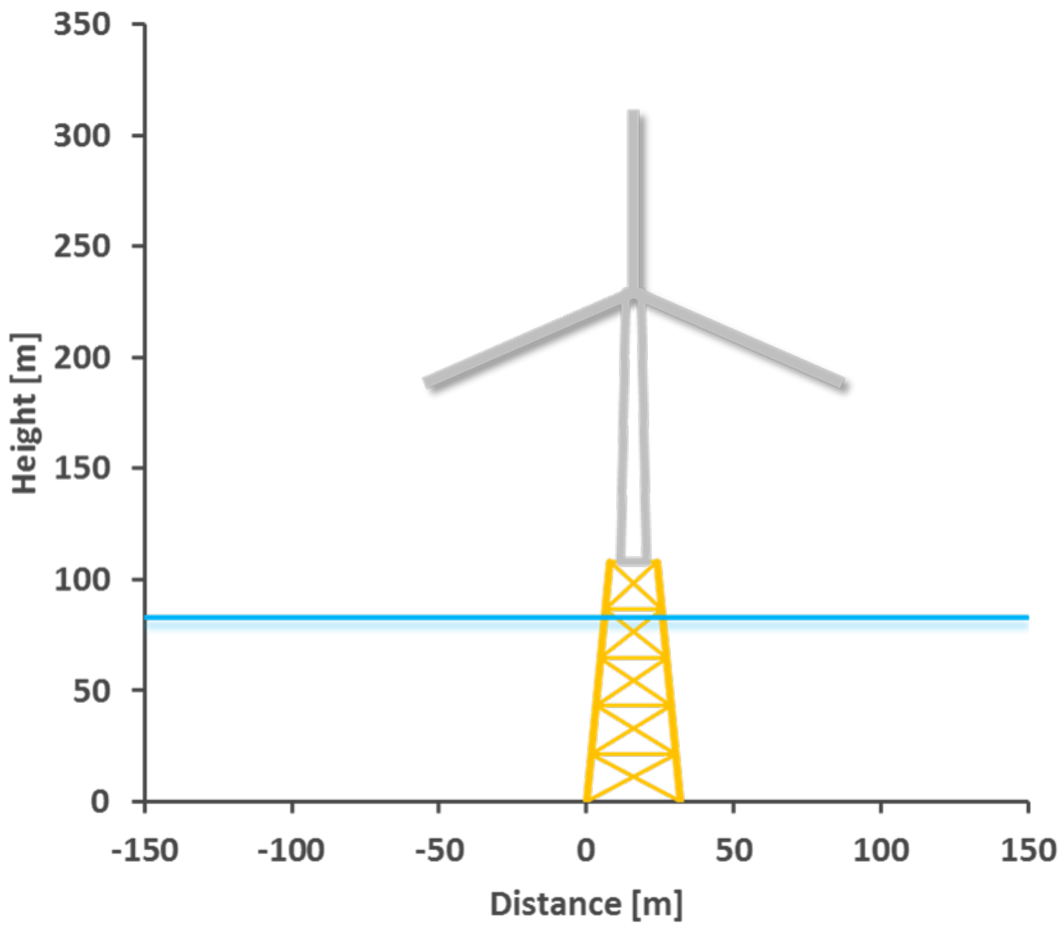
@UoD_Geotechnics

Beatrice jackets & ORE Catapult 8MW turbine at Methil, Fife

Screw piles for wind energy foundation systems: Deployment challenge

- → Offshore wind is advancing in to deeper water
- → Foundation/support systems required for intermediate depths between monopile and floating
- → Systems may create increased foundation operation events (4 piles per jacket)
- → Concern/regulations associated with noise from piling (continuous long term installation events)
- → Cost effective solution required (20-30% cost)

- → Jacket structures supported on screw piles?



Visual output from foundation optimisation spreadsheet (80m water depth)

Screw piles for wind energy foundation systems

- Physical modelling, numerical modelling, field scale testing
- Investigate optimised design solutions
- Improved design methods for future implementation

European Union
The Scottish Government
Riaghaltas na h-Alba
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European Regional Development Fund
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EPSRC
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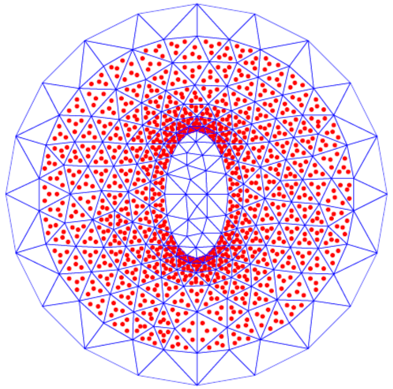
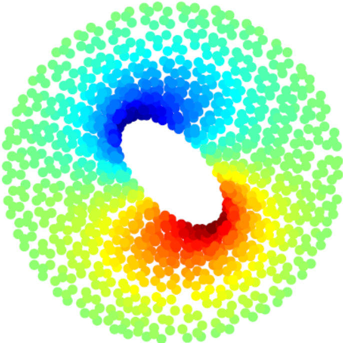
IN SITU SITE INVESTIGATION

SMD

PRO-DIG
Reliability Under Pressure





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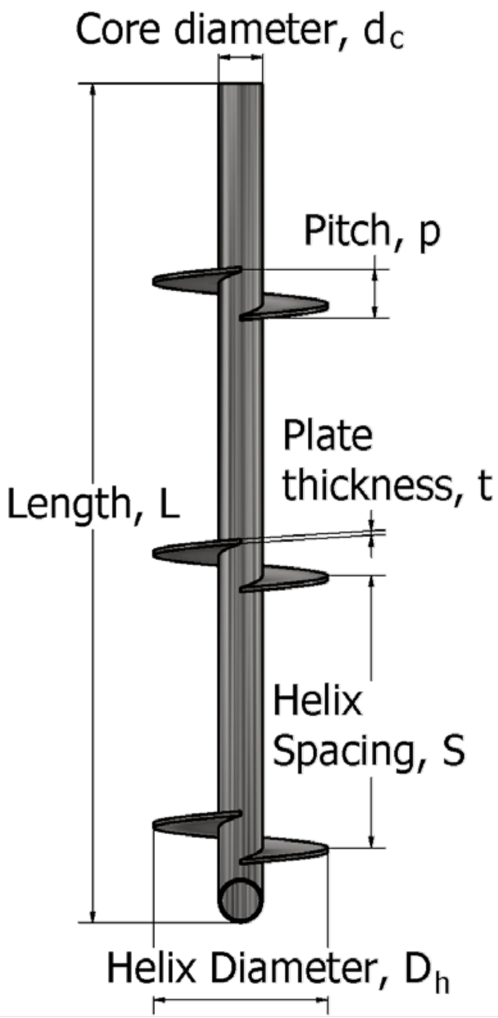
Screw pile introduction

- → Tubular steel core/shaft
- → Single/multiple helical plates
- → Helices regularly spaced
- → Nomenclature
- → Many uses:
  - → Started offshore: Maplin Sands Lighthouse (1838)
  - → Contemporary use typically onshore
  - → Pylons, guy lines, underpinning…
- → Benefits over straight-shafted pile:
  - → Improved axial capacity
  - → Lower installation noise



https://flic.kr/p/8sTShp

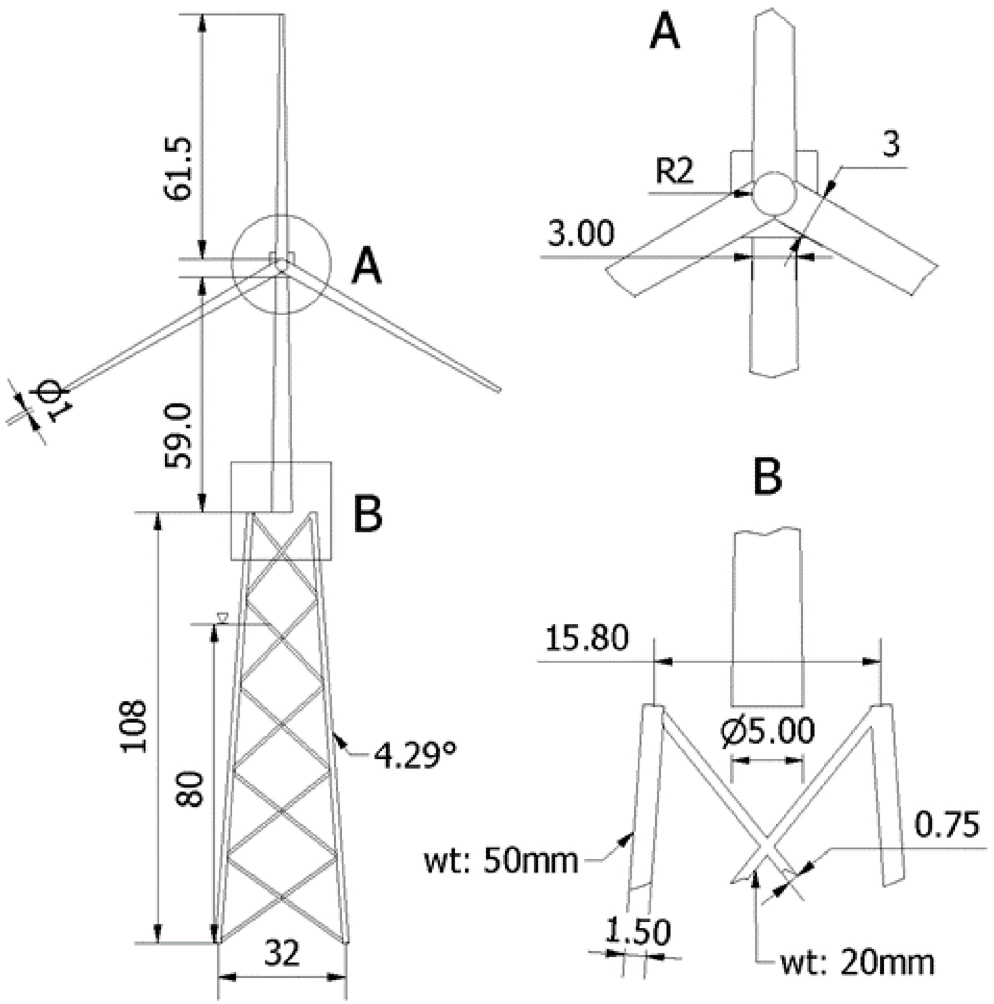
Screw pile design considerations: How big is an offshore screw pile?

How big are our loads in 80m water depth?

Table 1. Loads acting on screw pile (negative value indicates tensile load)

Load Direction	Upwind	Downwind
Horizontal (MN)	6.28	6.28
Vertical (MN)	-26.14	34.85

FOS = 1.35 (1.5 minimum in API RP2A-WSD)



Dims in m unless stated otherwise

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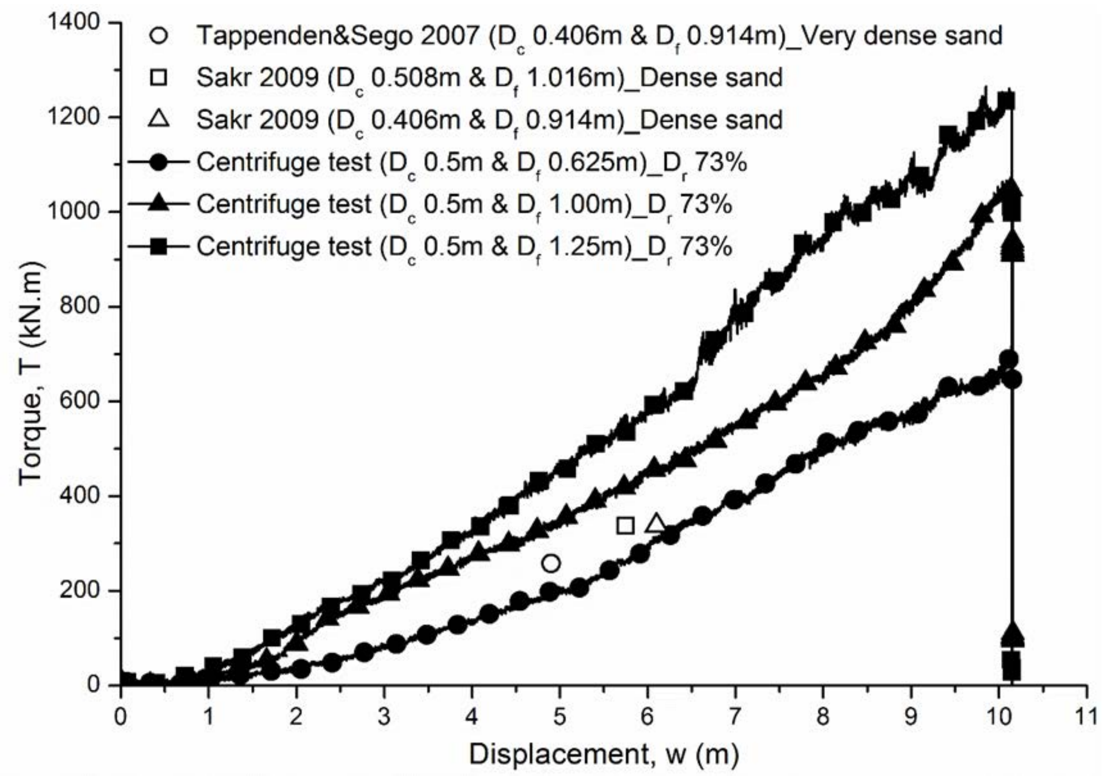
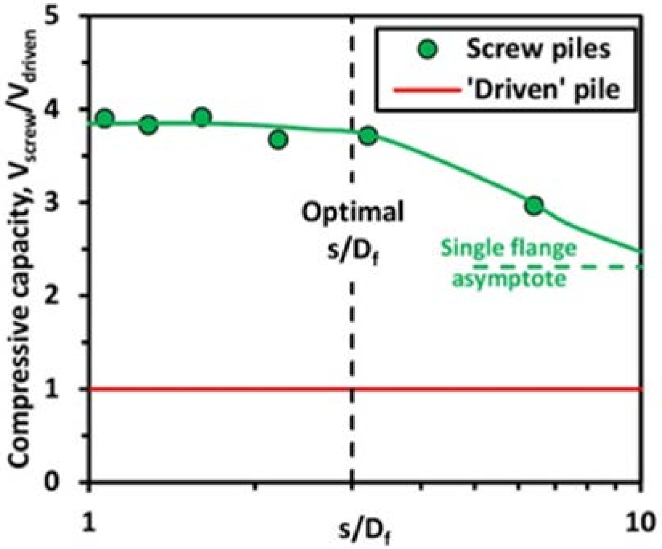
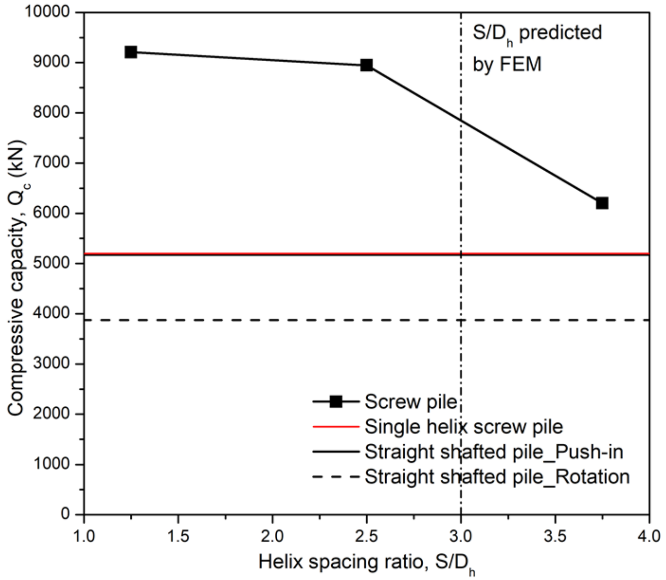
Centrifuge testing at UoD: Scaled up but non-optimised geometry

Centrifuge test results: Validation against field and FEA



Model testing replicates full field scale behavior well

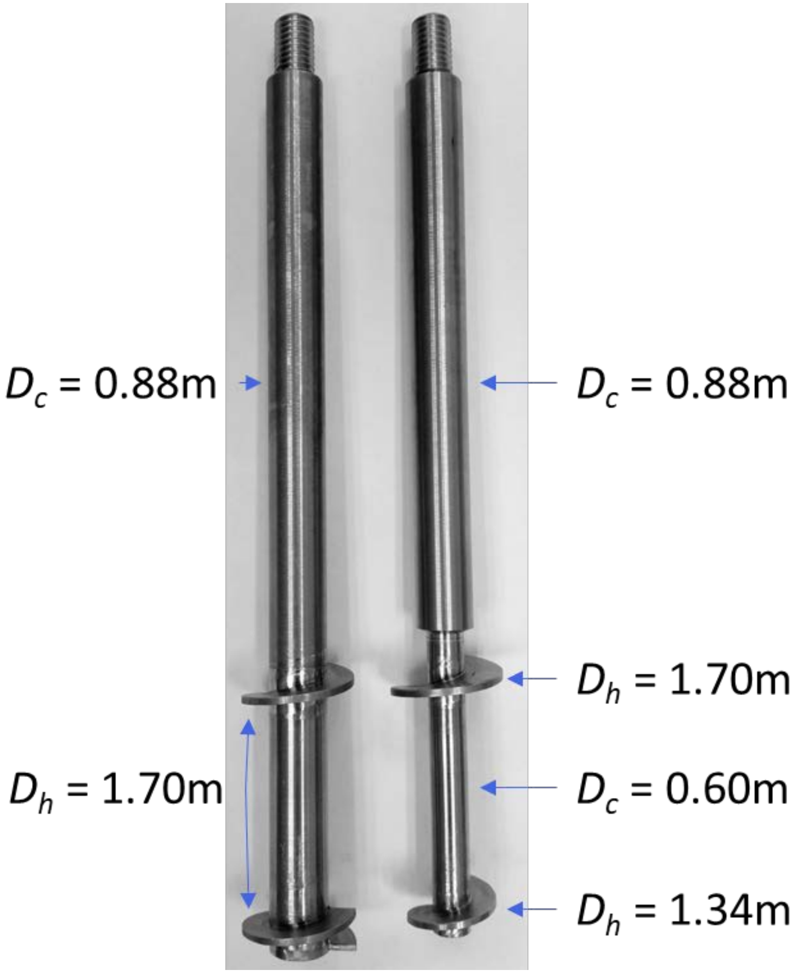




FEA Wished in place

Centrifuge

Centrifuge testing : Installation torque and vertical force requirements



80th Scale, 80m water depth,
Very dense sand

Information redacted

Centrifuge testing : Post installation performance

Information redacted

Centrifuge testing: Post installation performance

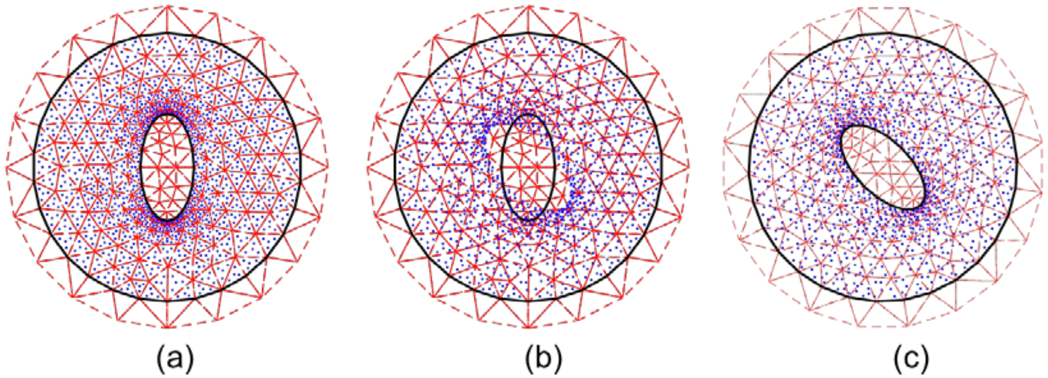
- Why the poor performance?
  - Geometry outside of range of experience?
  - D_h/D_c too low (1.9-2.83), Minimum 2.5-3?
  - Uplift factor calculated based upon Das & Shukla (2013) = N_q = 80 (assuming a shallow failure)
  - Back figured N_q = 25!!
  - Perko N_q' = 336 but resistance limited to that at $2D_h$
  - Existing approaches based upon deep and shallow mechanisms H/Dh may not be valid for large Dc and low D_h/D_c

Information redacted

Numerical modelling

- Numerical modelling advantages in predicting effects of geometry changes/efficient (S/D_f)
- Finite Element Analysis (FEA) cannot model large scale deformation (Screw piles). 10-20m?
- Material Point Method (MPM) can model effects of screw pile installation on soil body
- Key components of DU approach
  - Moving mesh for displacement boundary conditions
  - elasto-plastic material models for both soil and interface
- Plan to map changes on soil from MPM on to standard FE as starting point. MPM to captures installation phase.

Moving mesh: a mesh always conforming with the boundary of the deformed body.

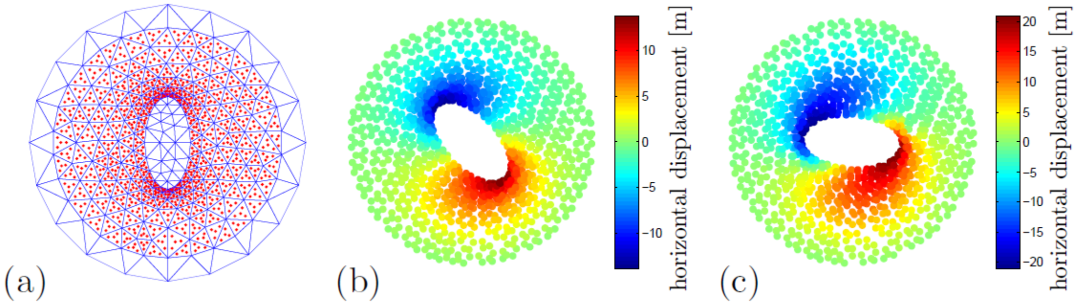


(a) Initial computational mesh and material points, (b) material point after twist 45° without moving mesh, (c) material point with moving mesh

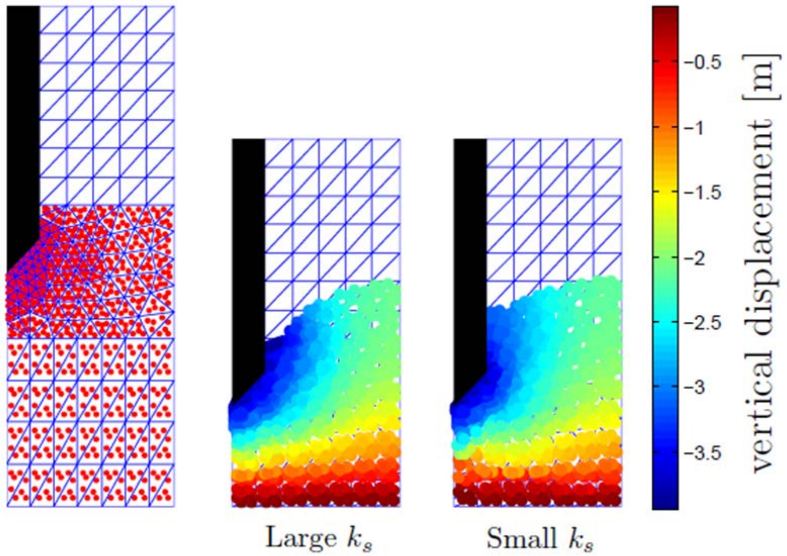
Screw pile twists and penetrates over large distances

Numerical modelling: Progress to date

- Decomposed the to rotation and translation, and developed codes for 2D modelling of motions
- The standard MPM and several advanced extensions investigated to identify optimal for modelling strategy
- Strategies for accuracy and stability determined:
  - non-uniform triangular mesh
  - implicit implementation
  - convected particle domain interpolation
  - finite-volume particle domains for quadrature
- Next step: Combine methods used in 2D models to develop the 3D model



Twist or rotation



Vertical translation

Field testing: Identifying field study test sites.

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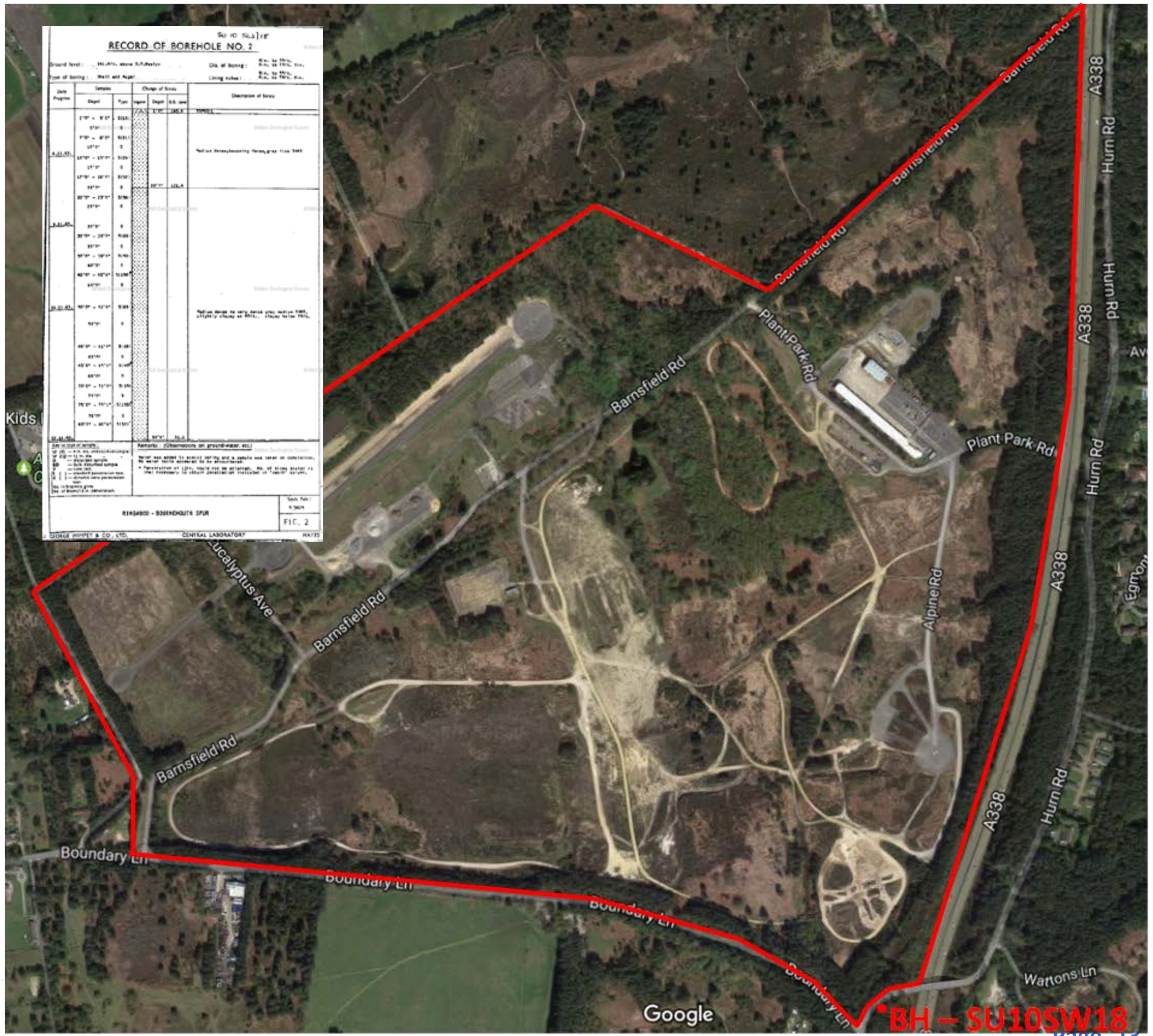
- → Working with Roger Bullivant (RBL) to identify suitable test sites and design field tests.
- → Desk study carried out on the feasibility of two sites proposed by RBL - Sommerford Keynes and Warmell Quarry.
  - → Sites ruled out due to unsuitable ground conditions
- → QinetiQ's Hurn proving ground identified as a possible sand test site
  - → Military vehicle test site (25km from UoS)
  - → Substantial supporting facilities
  - → Promising ground conditions
  - → Potential to become a national sand field study resource?
  - → In discussions with with QinetiQ and In Situ SI

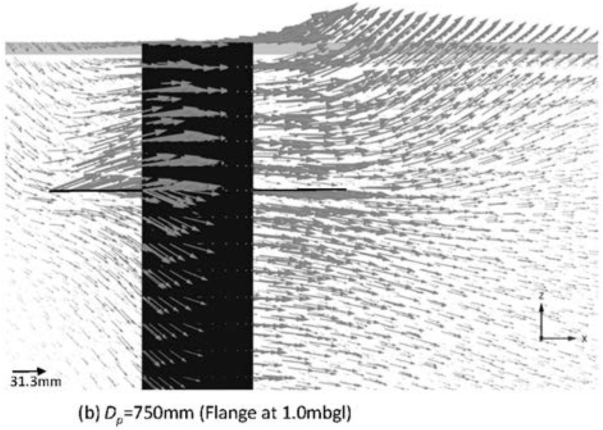


Field testing: Designing equipment & Field tests

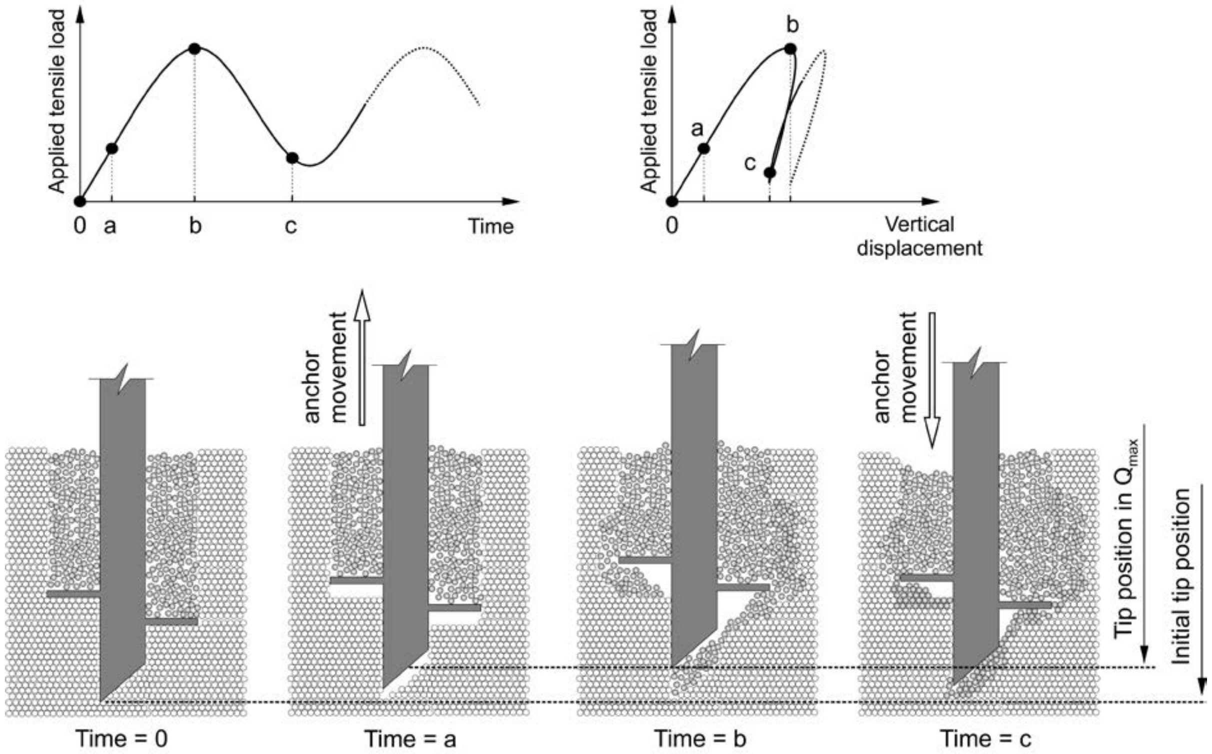
- Field test design and model testing has identified need for specialist instrumentation
  - UoD work feeding into design of a bespoke wireless combined torque-load cell
  - RBL interested in potential for existing CFA piling rig fleet in UK
- UoS to design field piles and installation equipment based upon coming UoD testing
  - Access to site required to characterise soil (CPT)
  - Ordering and fabrication of piles based upon UoD findings and suggestions.

Some questions to tackle as the project progresses

- Expanding the prediction of installation behaviour to in service performance
- Cyclic performance
- Behaviour in other soil types
- Uplift factors
- Lateral screw pile behaviour and performance



FE Modelling of a laterally loaded screw pile
(Al Baghadadi et al 2015)



Tensile cyclic loading of a single plate screw pile
(Schiavon et al 2017)

Summary

- → Screw piles have potential as new foundation type for deep water offshore wind energy
- → Current screw pile designs are inadequate for imposed loads
- → Required upscaling of designs leads to large installation force and torque
- → Current design methods for axial capacity are questionable
- → Centrifuge & numerical modelling with field verification will address the design issues