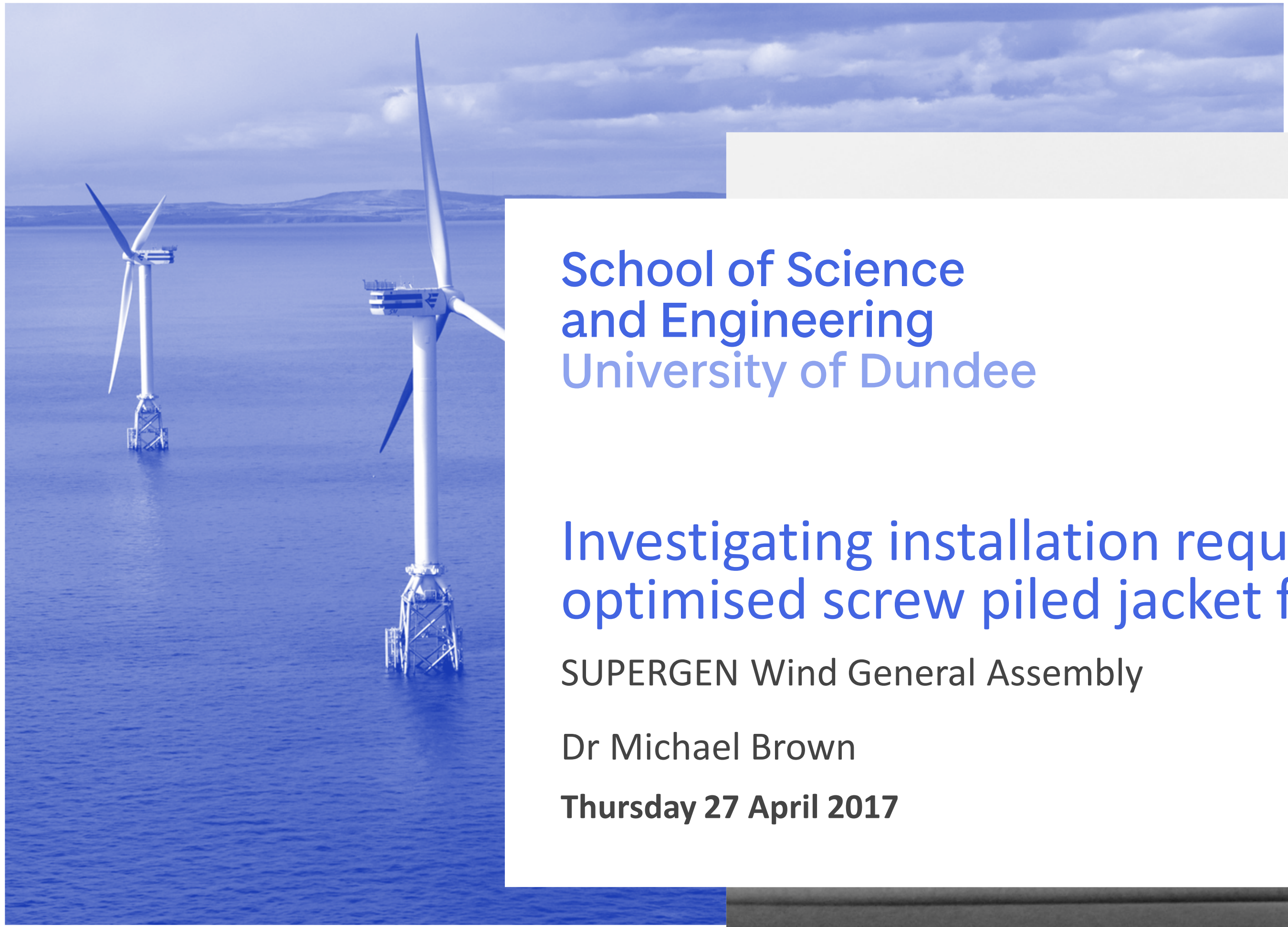

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Investigating installation requirements for optimised screw piled jacket foundations

SUPERGEN Wind General Assembly

Dr Michael Brown

Thursday 27 April 2017

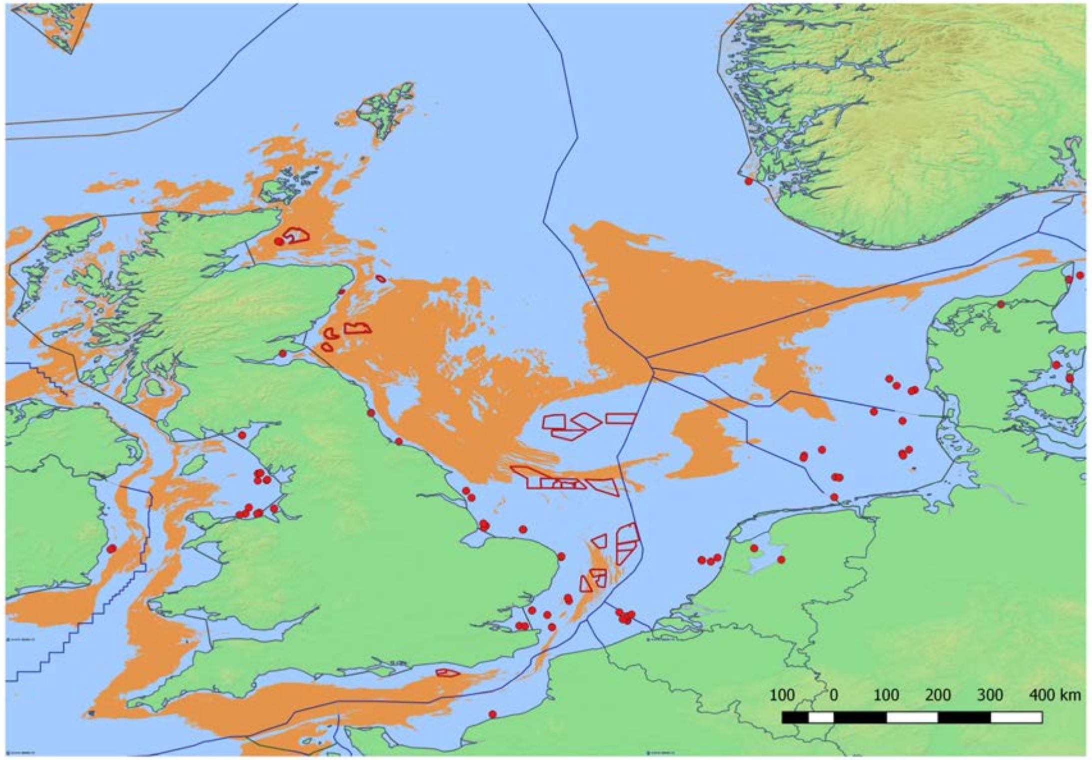
Overview

- → Background to screw piles and the deployment challenge
- → Current screw pile design elements and performance
- → Progress in Physical Modelling
- → New design methods and Optimisation
- → Numerical Modelling progress
- → Field testing to verify our work
- → Outputs and opportunities

Lego Mindstorm public engagement

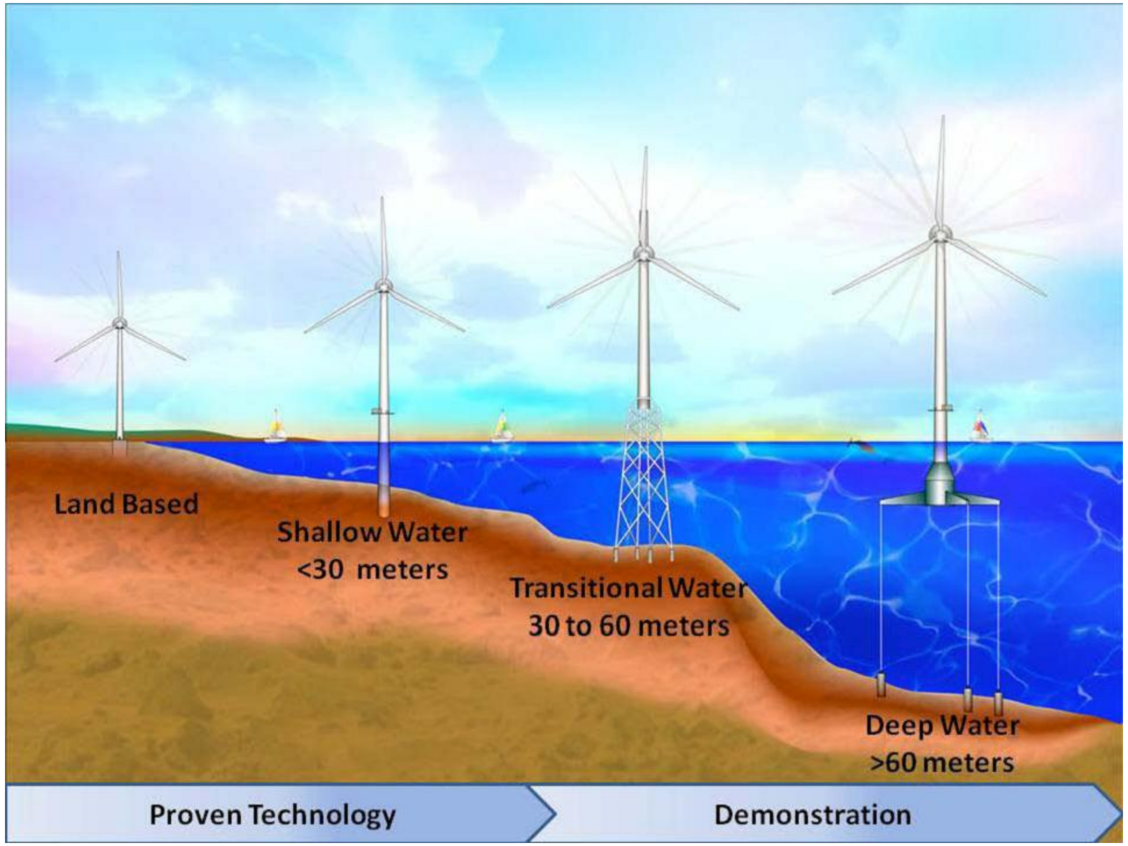
Screw piles for wind energy foundation systems: Deployment challenge

→ Offshore wind is advancing in to deeper water



45-80m depth
Existing wind farm
Round 3 licences
EEZ

→ Foundation system required for intermediate depths between monopile and floating

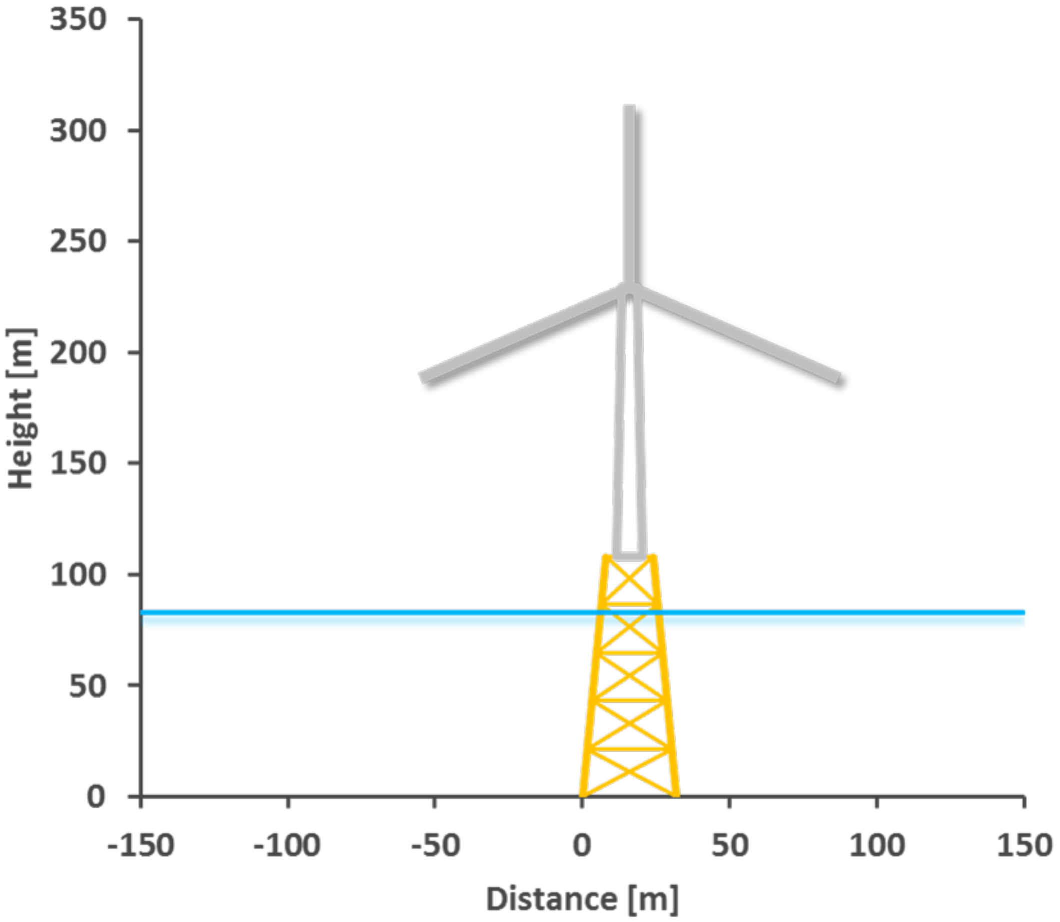


By Jplourde umaine - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=49937716

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

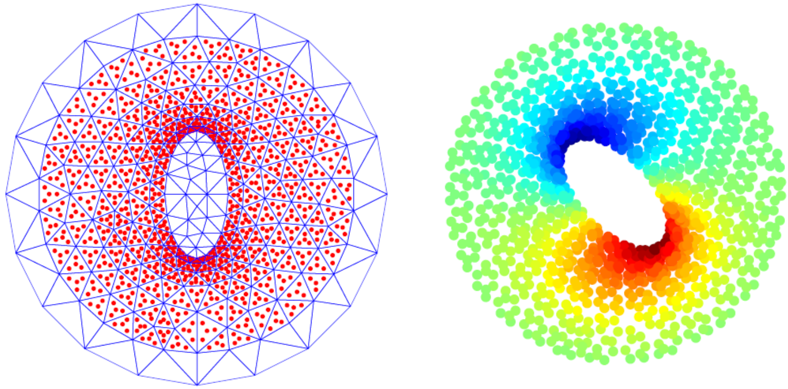
European Union
The Scottish Government
EUROPE & SCOTLAND
European Regional Development Fund
Investing in a Smart, Sustainable and Inclusive Future

EPSRC
Engineering and Physical Sciences Research Council

Cathie Associates

Roger Bullivant

SMD



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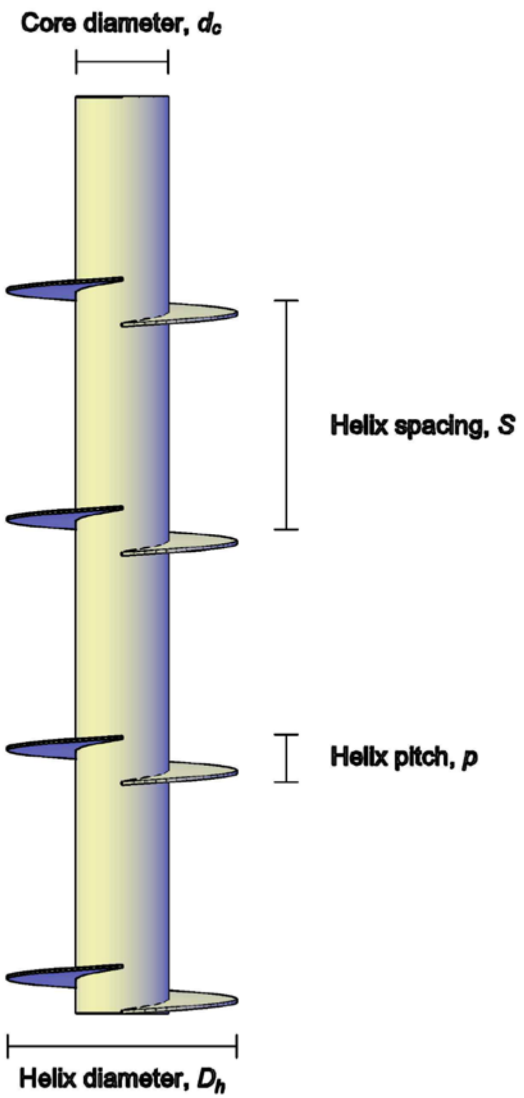
Introduction to Screw Piles

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



fendermarine.com/helical-pile-driving-foundation-support.html

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

- Up-scale screw piles from typical onshore designs to manage offshore loads / BMs
- Principle influential factors include:
  - Loading
    - Wind / waves / water depth / turbine / ….
  - Soil properties
  - Screw pile geometry (upscaled)
- Challenge to meet installation torque requirements (or predict)

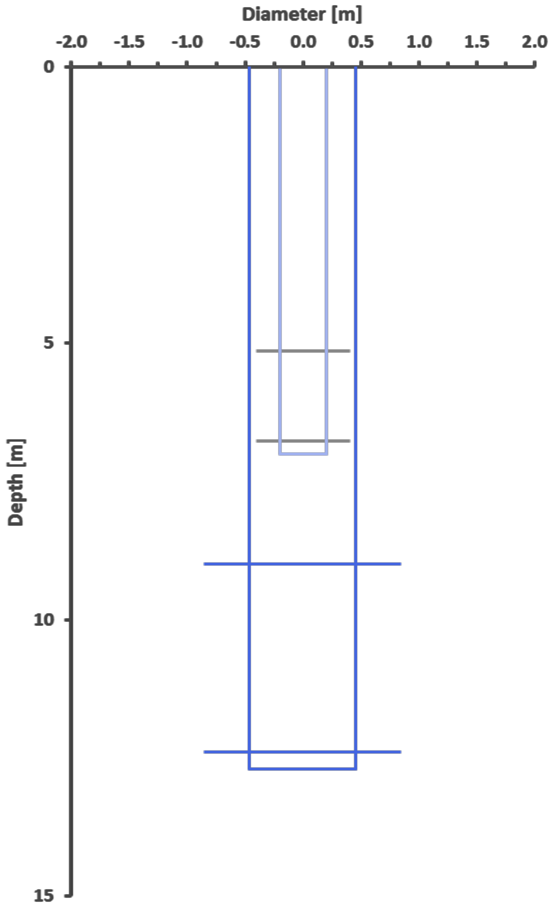
Typical onshore use

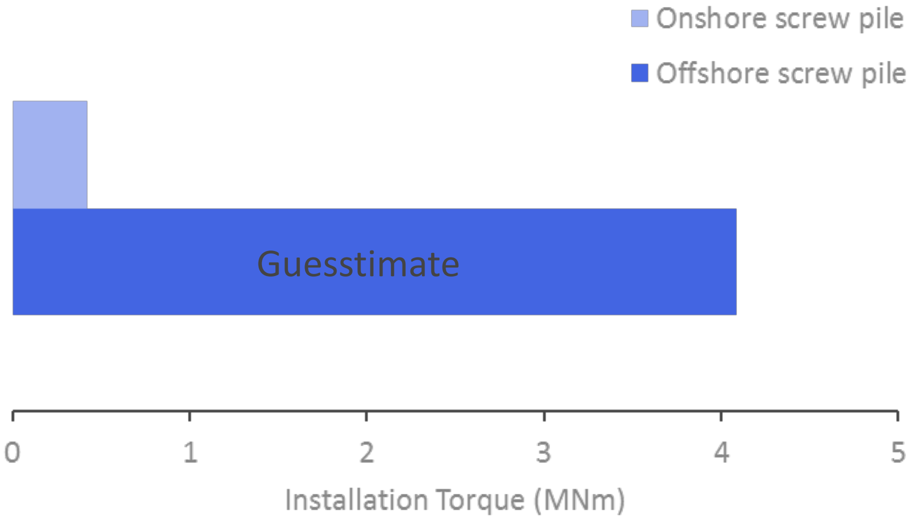
https://flic.kr/p/8sTShp

Offshore jacket installation (driven piling)

slpconsult.com/news.html?newsId=20

Installation Torque required for offshore deployment?



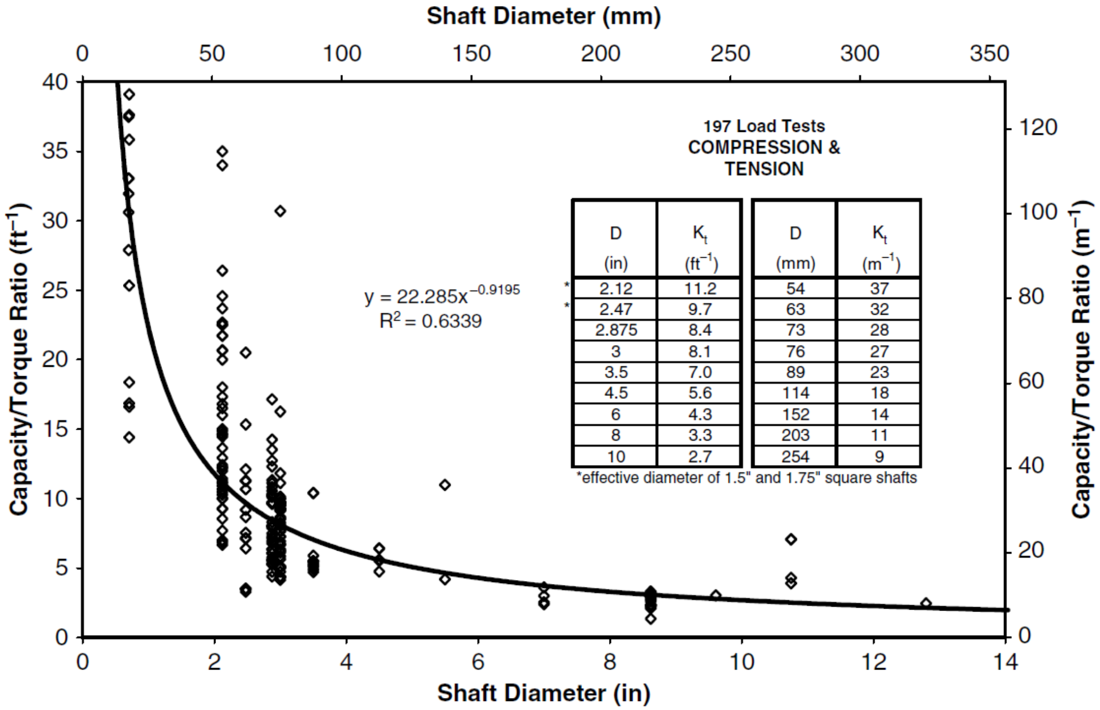


http://www.terratorque.com/helical_piling_-screw_piles

https://www.bumace.com/kor/projects/projects_cr.html

Existing screw pile design methods: Capacity & Torque

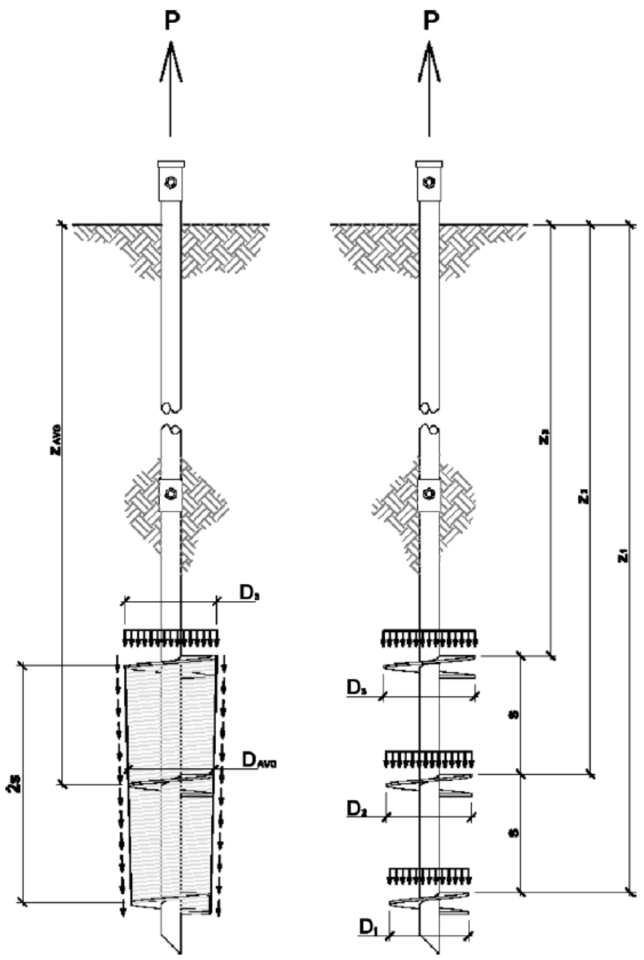
- → Empirical methods
  - → Hoyt and Clemence (1989), Perko (2009)
  - → Correlates installation torque to axial capacity
  - → Based on database of “small” onshore piles
- → Problems?
  - → Correlating torque and capacity reliant on control (how big are the crowding forces?)
  - → Torque used to verify installed capacity not predict torque
  - → Effect of changing geometry not clear for capacity and torque.



PERKO, H. A. (2009) Helical piles: a practical guide to design and installation, Hoboken, New Jersey, John Wiley & Sons.

Existing screw pile design methods: Capacity

- → Empirical methods
  - → Hoyt and Clemence (1989), Perko (2009)
  - → Correlates installation torque to axial capacity
  - → Based on database of "small" onshore piles
- → Analytical methods (semi-empirical)
  - → Analyses shear and bearing resistances
  - → Assumes individual plates or trapped sand column (soil-soil shear)
- → Problems
  - → When does mechanism change (S/D_h, D_h/D_c, D_r)?



PERKO, H. A. (2009) *Helical piles: a practical guide to design and installation*, Hoboken, New Jersey, John Wiley & Sons.

Existing screw pile design methods: in service capacity

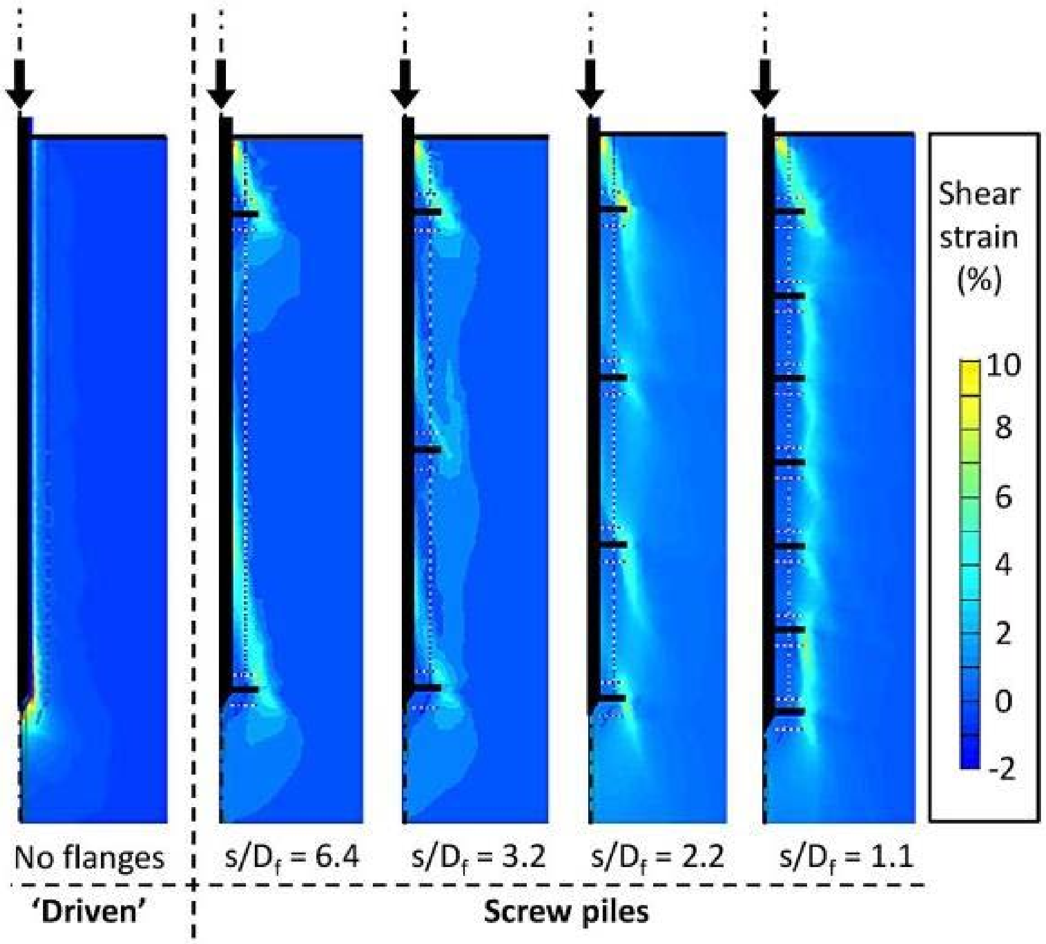
- Empirical methods
  - Hoyt and Clemence (1989), Perko (2009)
  - Correlates installation torque to axial capacity
  - Based on database of “small” onshore piles
- Analytical methods (semi-empirical)
  - Analyses shear and bearing resistances
- CPT Common Site Investigation tool
  - Relates screw pile capacity to CPT cone and shaft resistances
- Problems
  - Highly empirical (alpha x q_c)
  - Onshore small pile experience


http://www.gouda-geo.com/

https://www.fugro.com/

Existing screw pile design methods: in service capacity

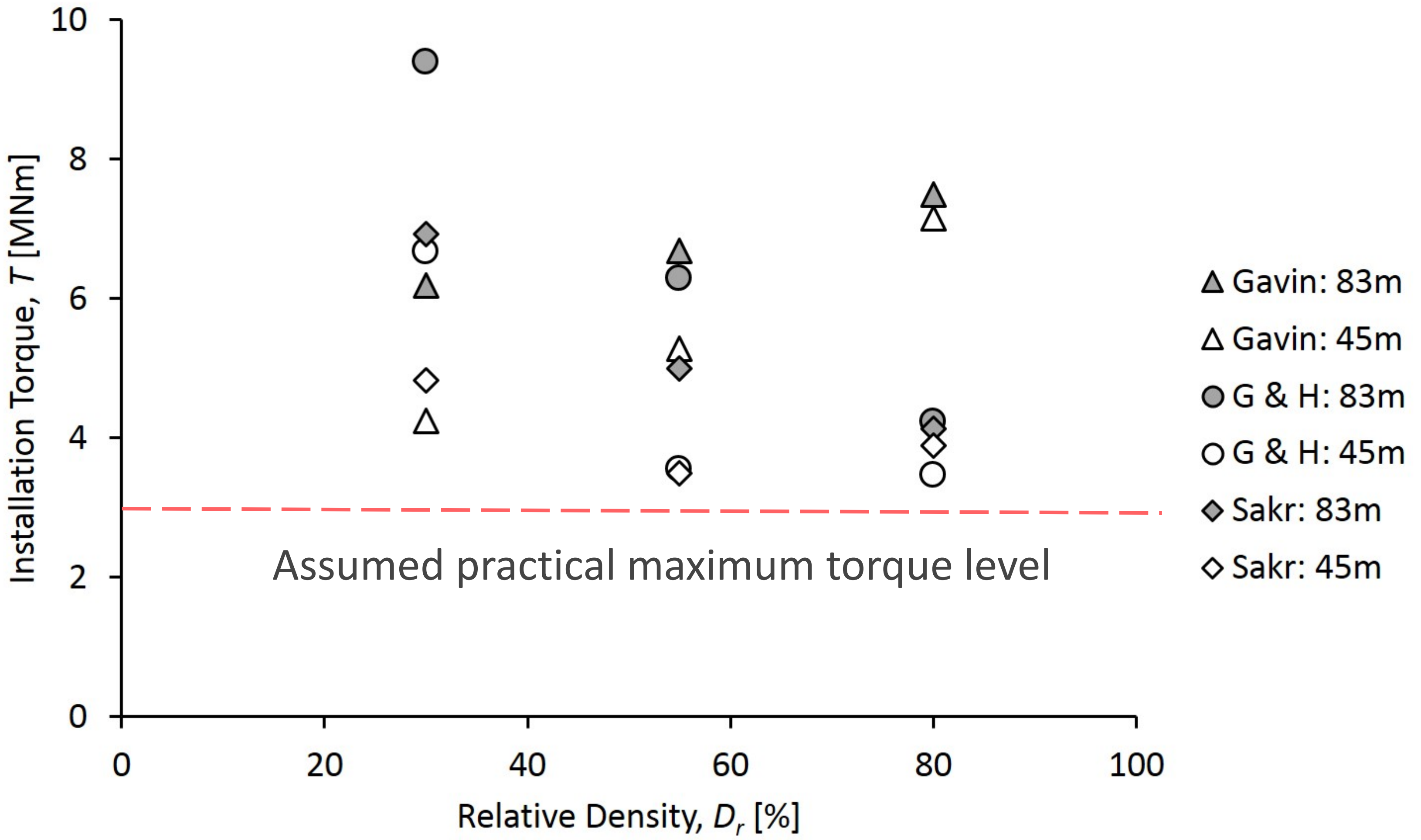
- Empirical methods
  - Hoyt and Clemence (1989), Perko (2009)
  - Correlates installation torque to axial capacity
  - Based on database of “small” onshore piles
- Analytical methods (semi-empirical)
  - Analyses shear and bearing resistances
- CPT Common Site Investigation tool
  - Relates screw pile capacity to CPT cone and shaft resistances
- Standard Numerical modelling (S/D_h, D_h/D_c)
- Problems
  - Generally unable to model installation effects
  - Needs model or field verification



Knappett et al (2014)

Existing screw pile design methods: Existing installation torque prediction?

- Torque prediction methods
  - Empirical
  - Analytical
  - CPT

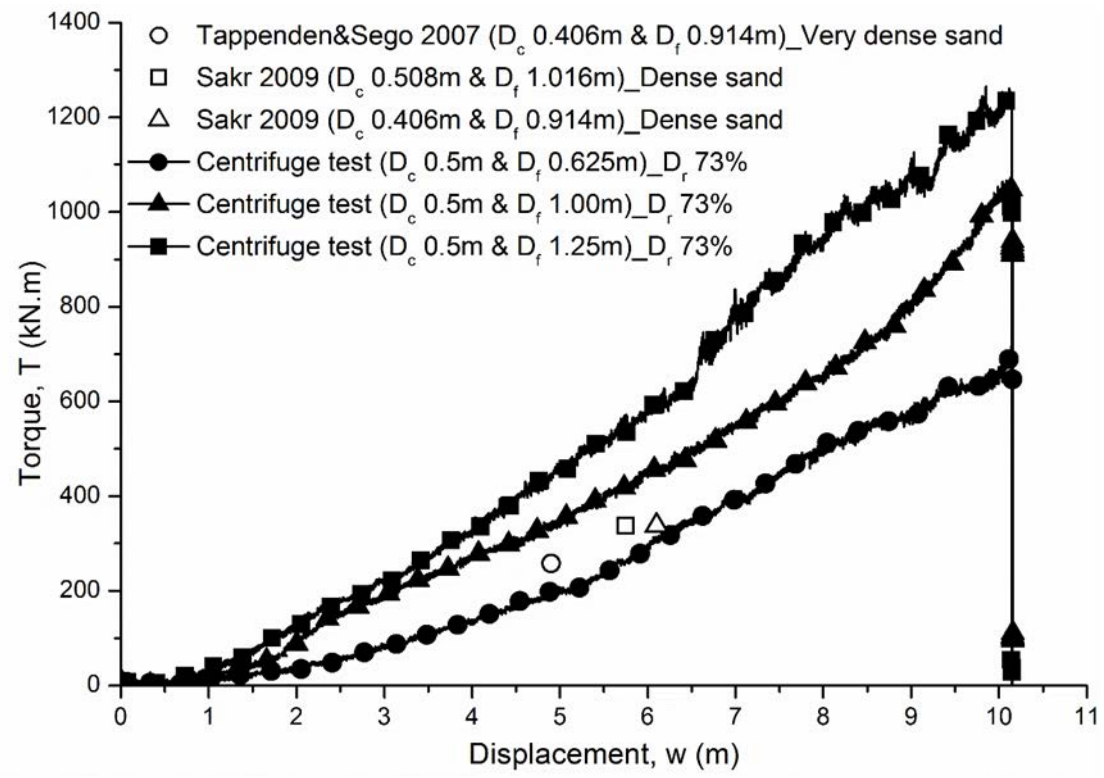


Development of centrifuge test equipment at UoD

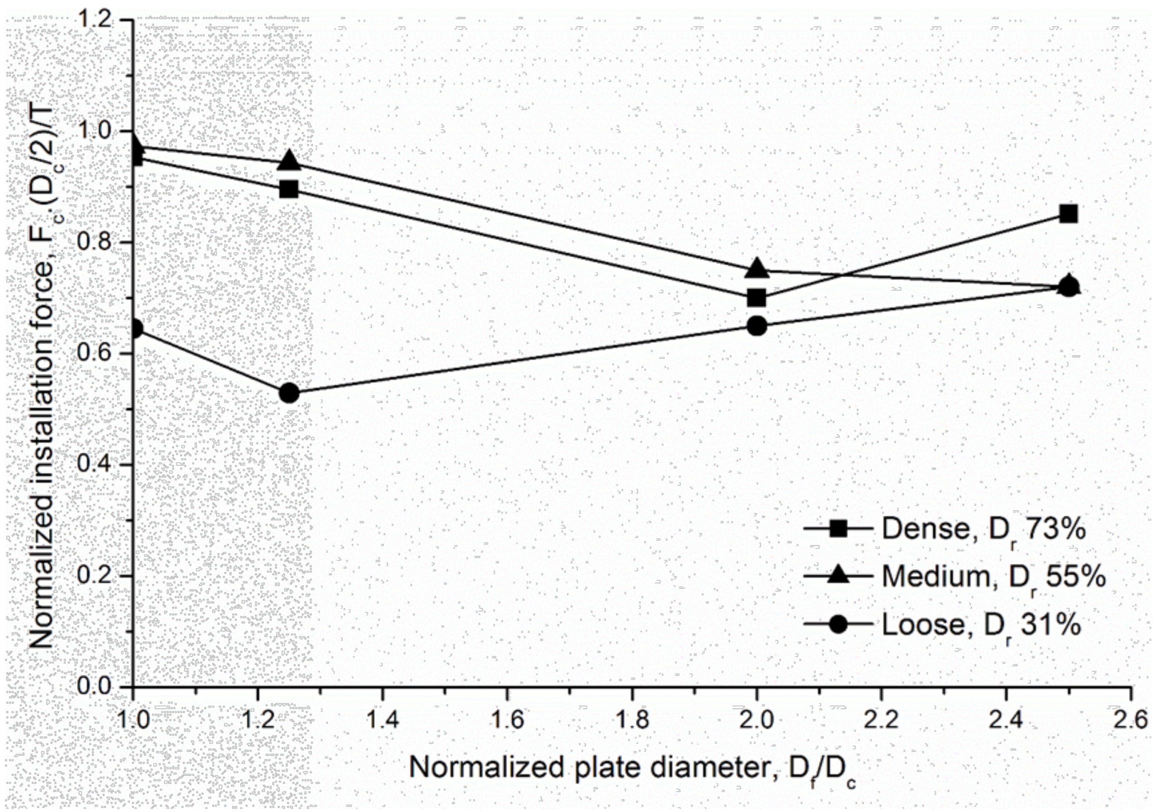
- → 2D actuator system for centrifuge modelling (Vertical and rotational servo actuator system)
- → Allows installation and testing in single in-flight operation (50th scale or 50g)

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

Preliminary centrifuge test results: Insights into installation requirements



Model testing predicts full scale behavior well



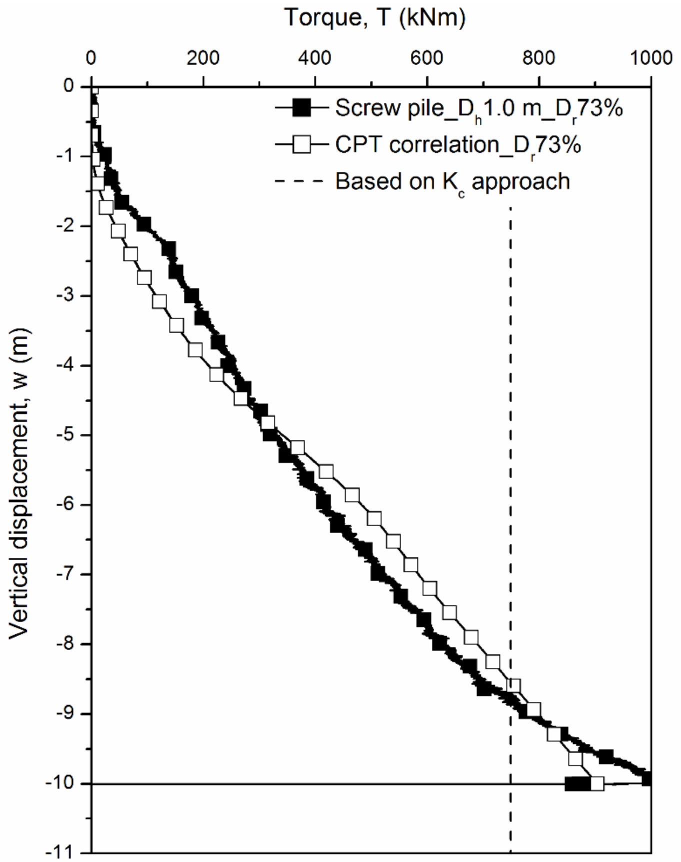
Predicting vertical load needs

Increased accuracy and confidence: Improved CPT method

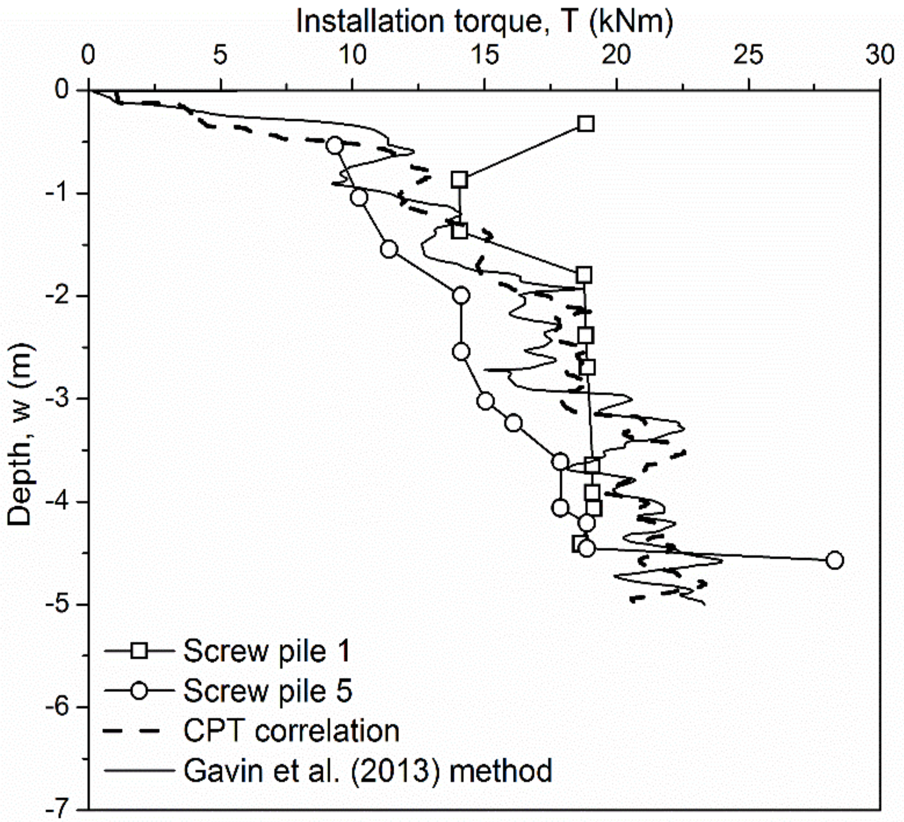
→ Increase confidence of prediction methods for installation requirements

→ CPT method developed (T & V_c)

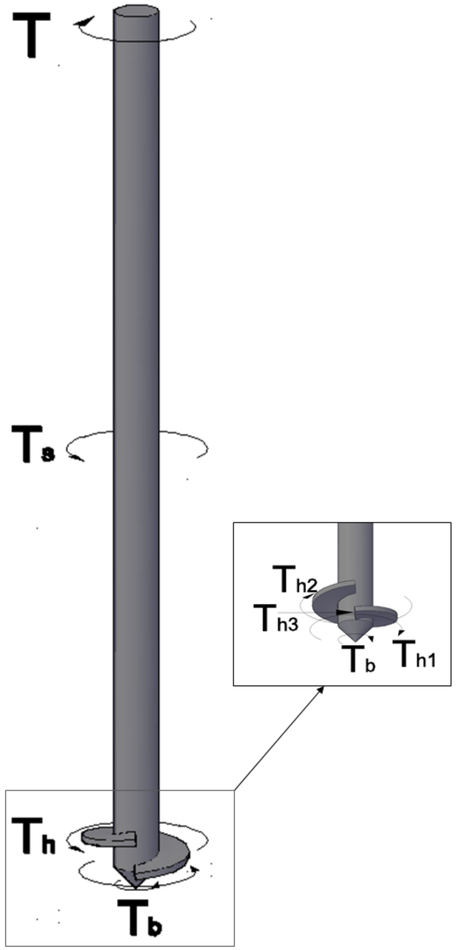
→ Analytical method developed and testing (T & Vc)



Model testing



CPT method captures full scale behavior well



Optimised design

- Optimised designs required to reduce installation requirements
  - Reduce dimensions where possible
    - Helix diameter
    - Core diameter
- Investigate with centrifuge tests
  - Check prediction methods
  - Check capacity as anticipated
  - Check sensitivity of torque reduction to geometry change

Durham University

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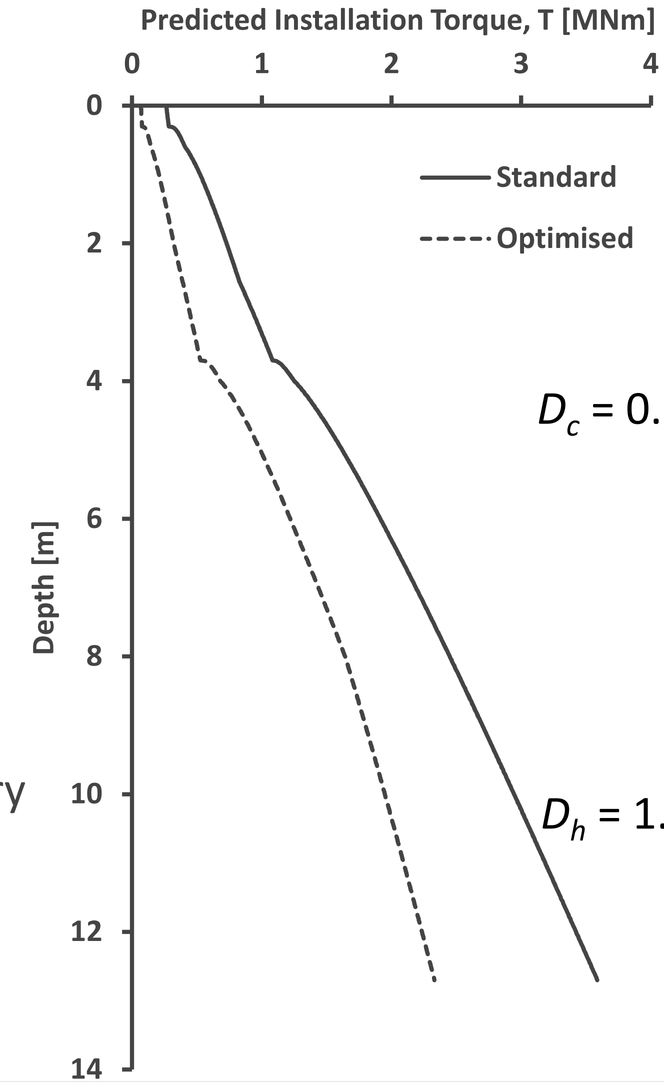
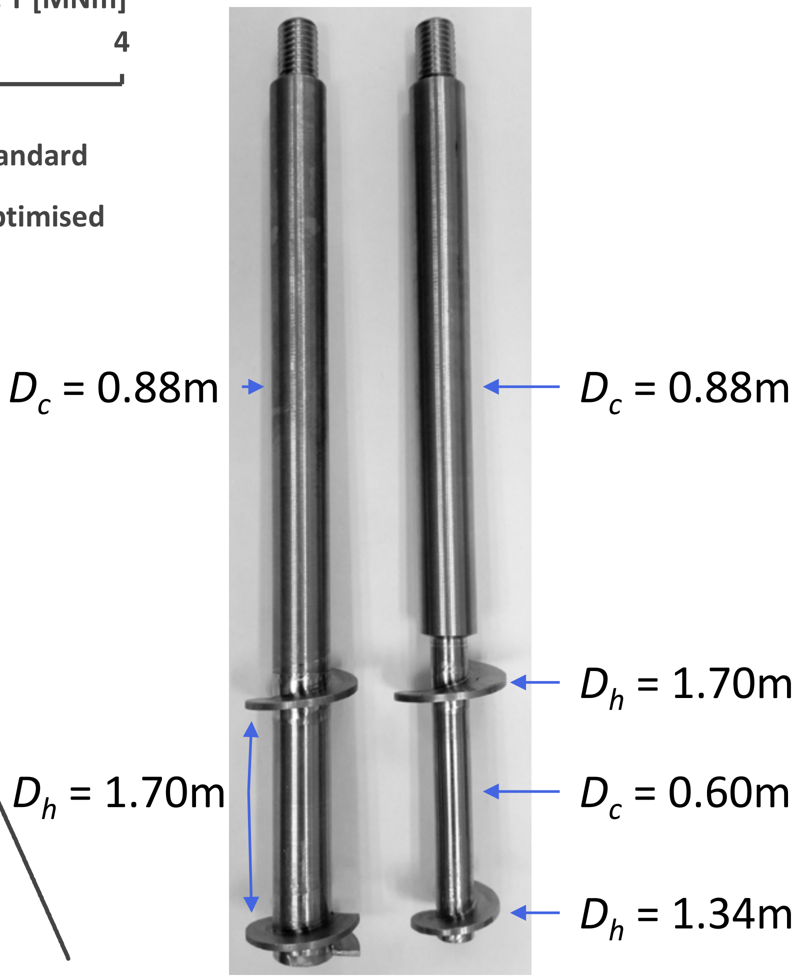


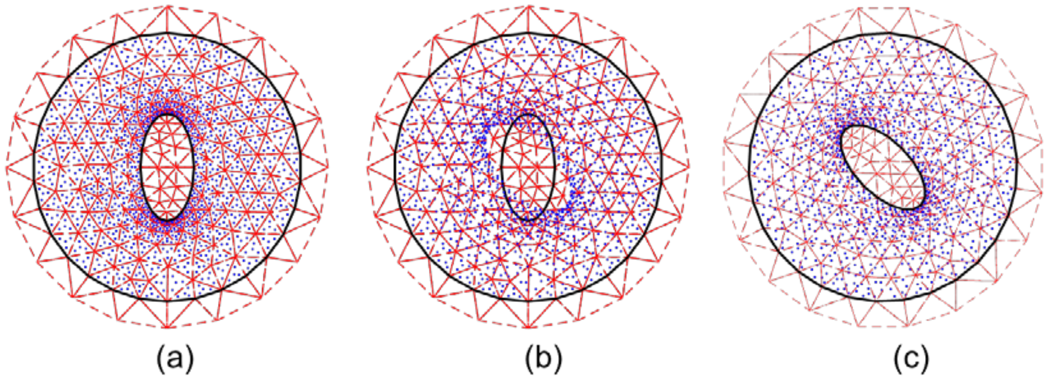


80th Scale, 80m water depth, Very dense sand

Numerical modelling

- Finite Element Analysis (FEA) cannot model large scale deformation (Screw piles). 10-20m?
- Numerical modelling advantages in predicting effects of geometry changes/efficient (S/D_f)
- 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.

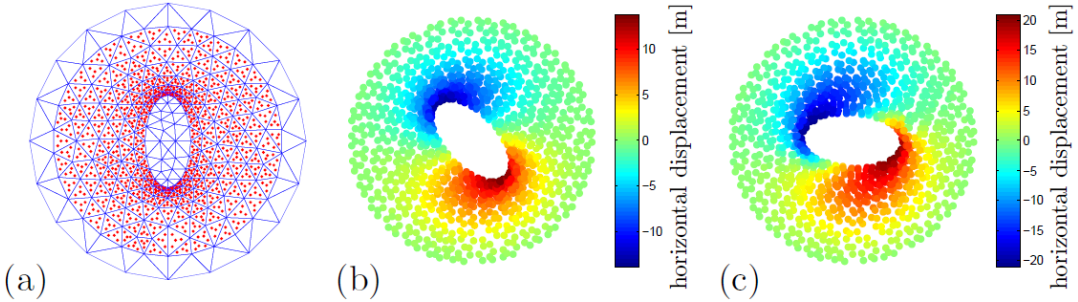


(a) Initial computational mesh and material points, (b) material point after twist 45° without moving mesh, (c) material point with moving mesh

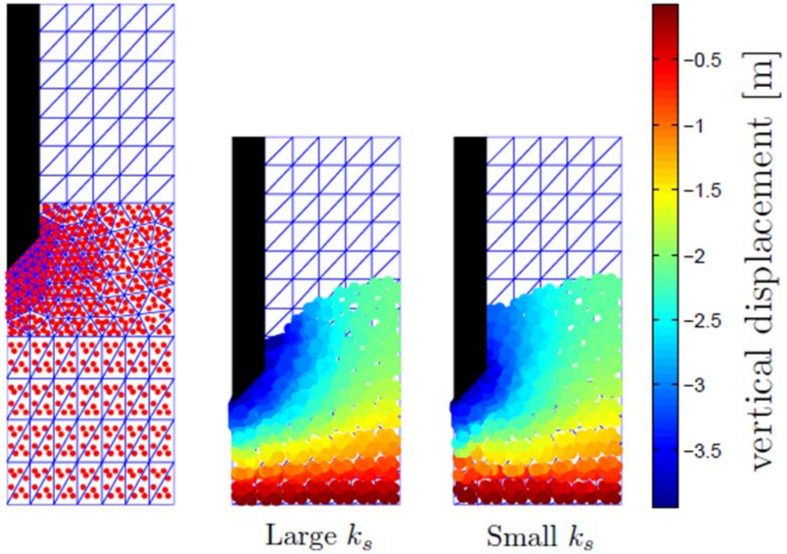
Screw pile twists and penetrates over large distances

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



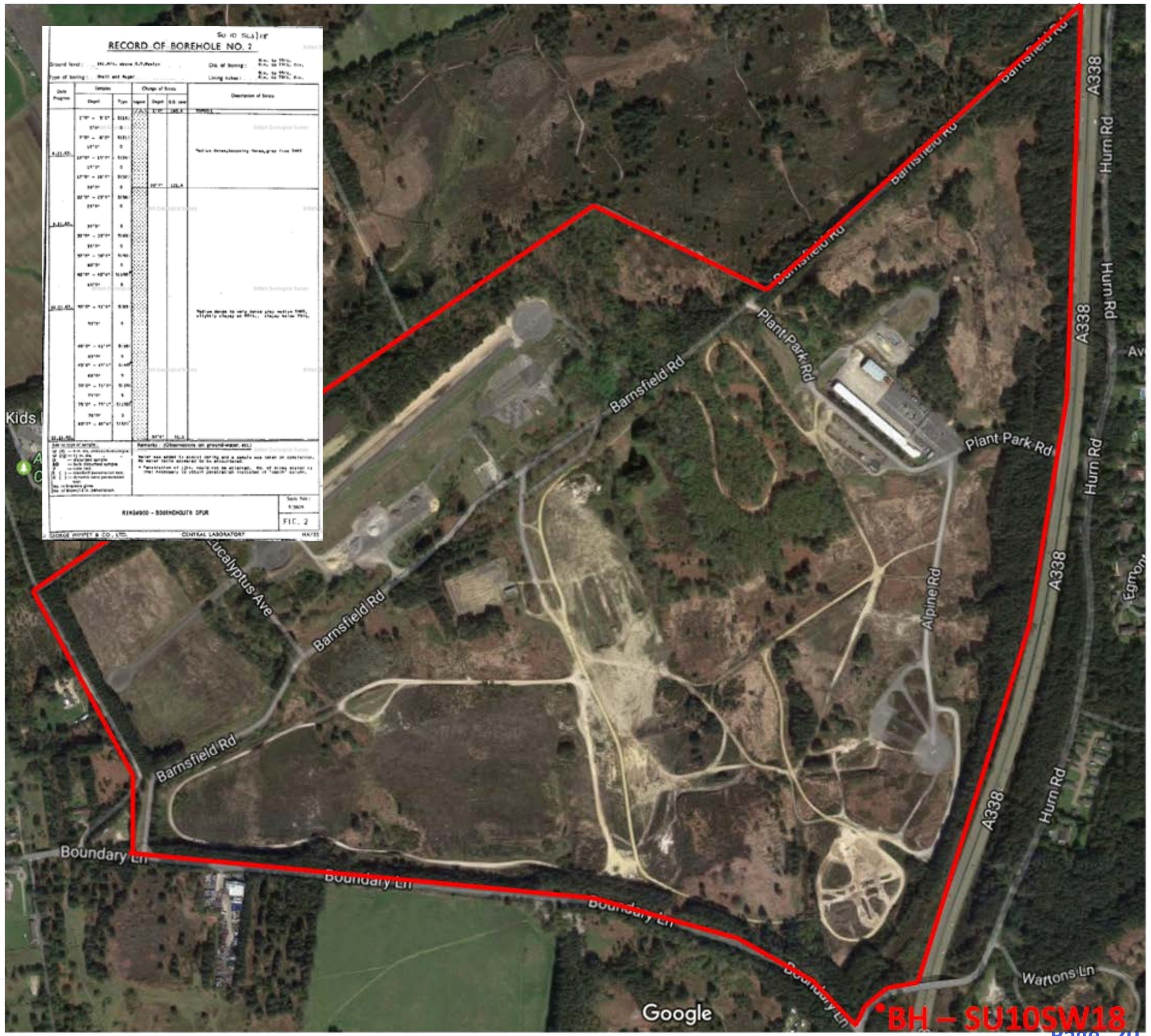
Twist or rotation



Vertical translation

Field testing: Identifying field study test sites.

- 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.

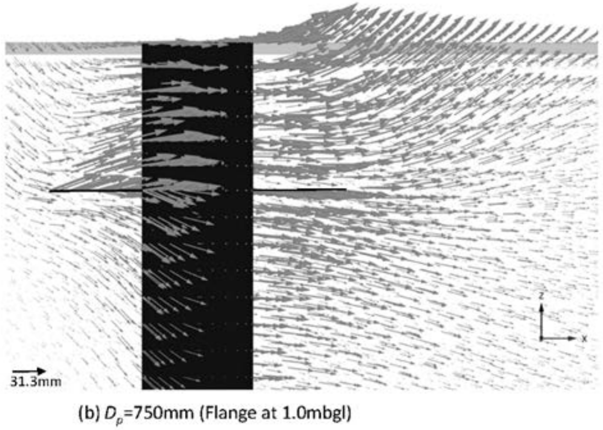
Some questions to tackle as the project progresses

→ Expanding the prediction of installation behaviour to in service performance

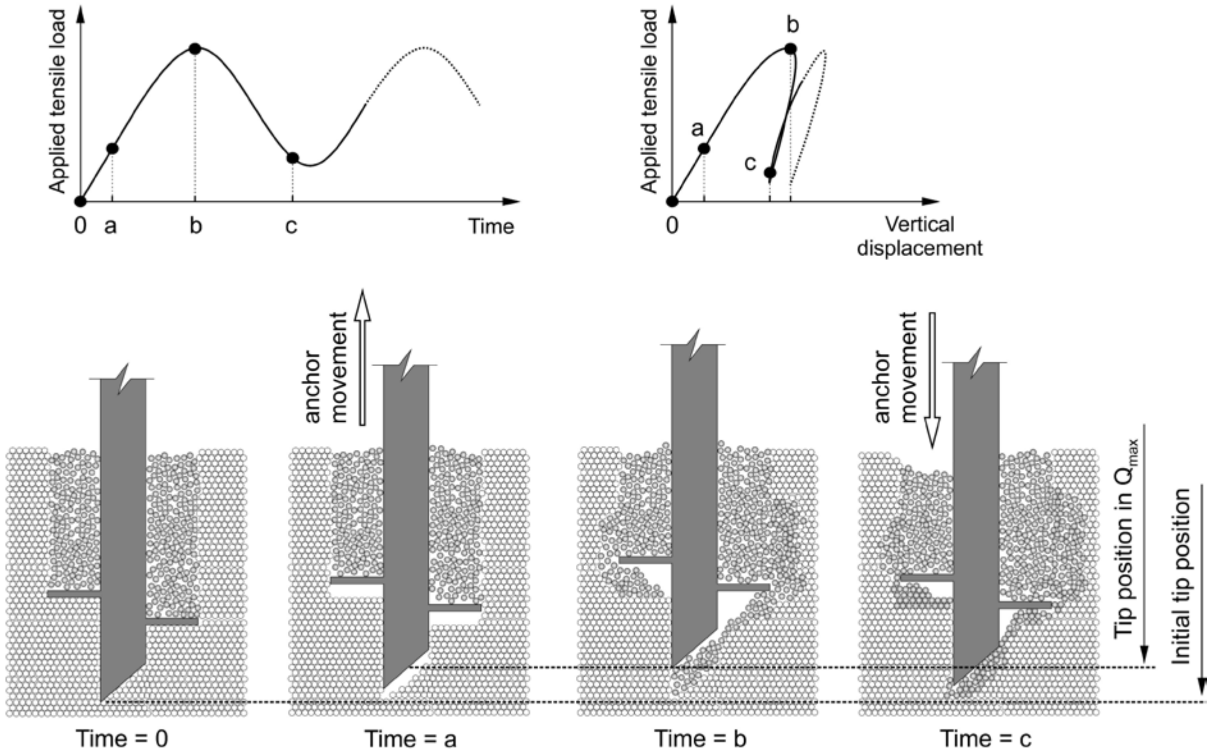
→ Cyclic performance

→ Behaviour in other soil types

→ Lateral screw pile behaviour and performance



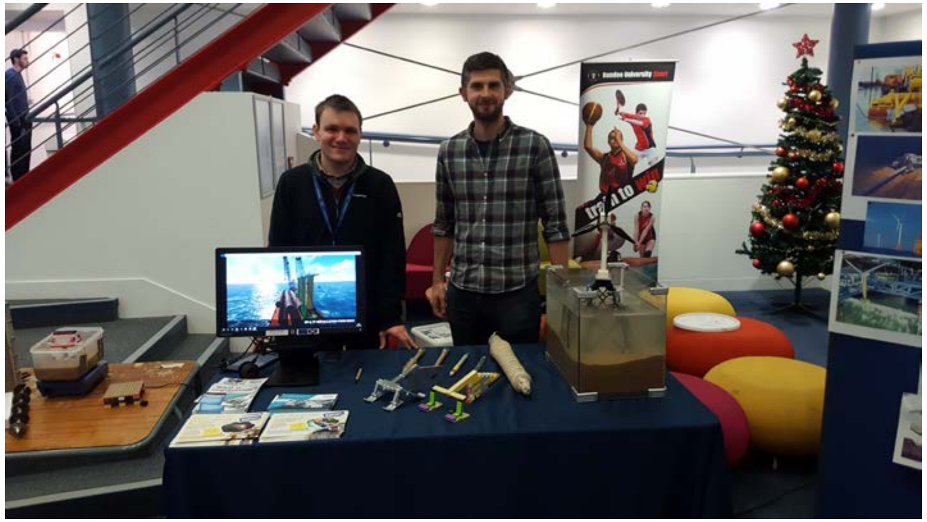
FE Modelling of a laterally loaded screw pile (Al Baghadadi et al 2015)



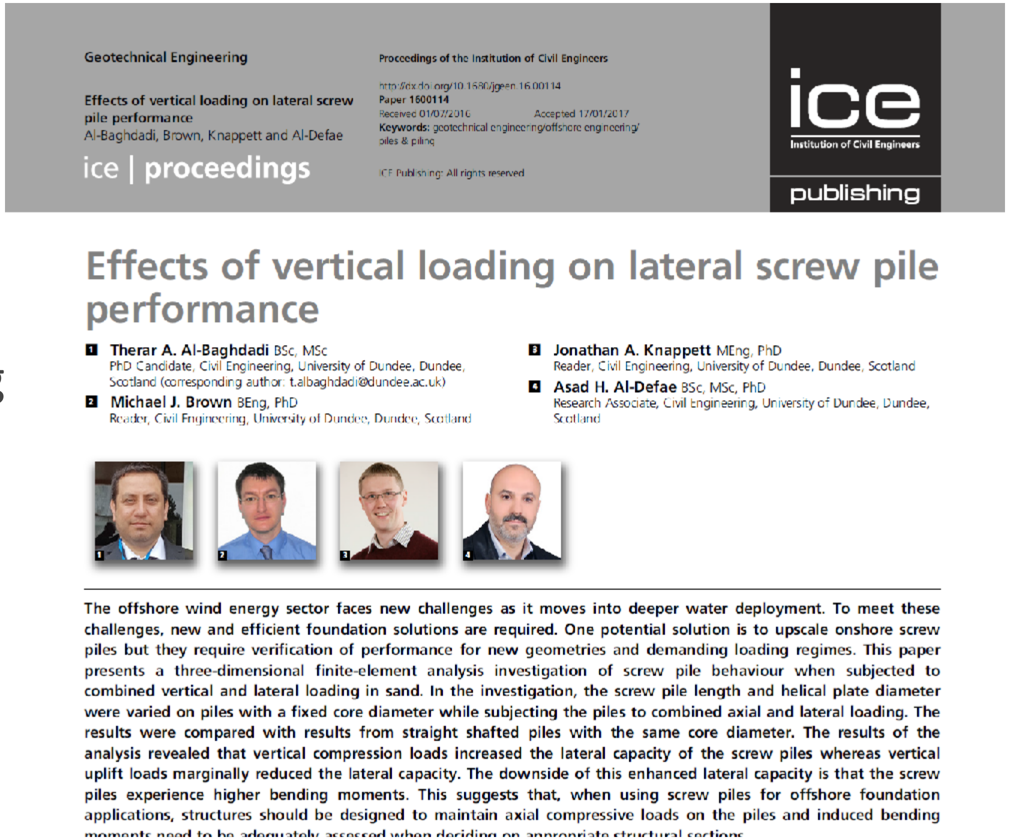
Tensile cyclic loading of a single plate screw pile (Schiavon et al 2017)

Some outputs and Opportunities

- 2017- Euro 195k H2020 Fellowship: Screw anchors for floating ORE (2 year fellowship), UoD.
- 2017- £1.25M EPSRC WindAfrica, DU
- EPSRC ORE China bid submitted, DU & UoD + BGS
- 2017- £220k Forthwind Demonstration Project. 2B Energ



Screw piles engage with school children at Lego Mindstorm



Geotechnical Engineering

Effects of vertical loading on lateral screw pile performance
Al-Baghdadi, Brown, Knappett and Al-Defae

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Proceedings of the Institution of Civil Engineers

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ice Institution of Civil Engineers publishing

Effects of vertical loading on lateral screw pile performance

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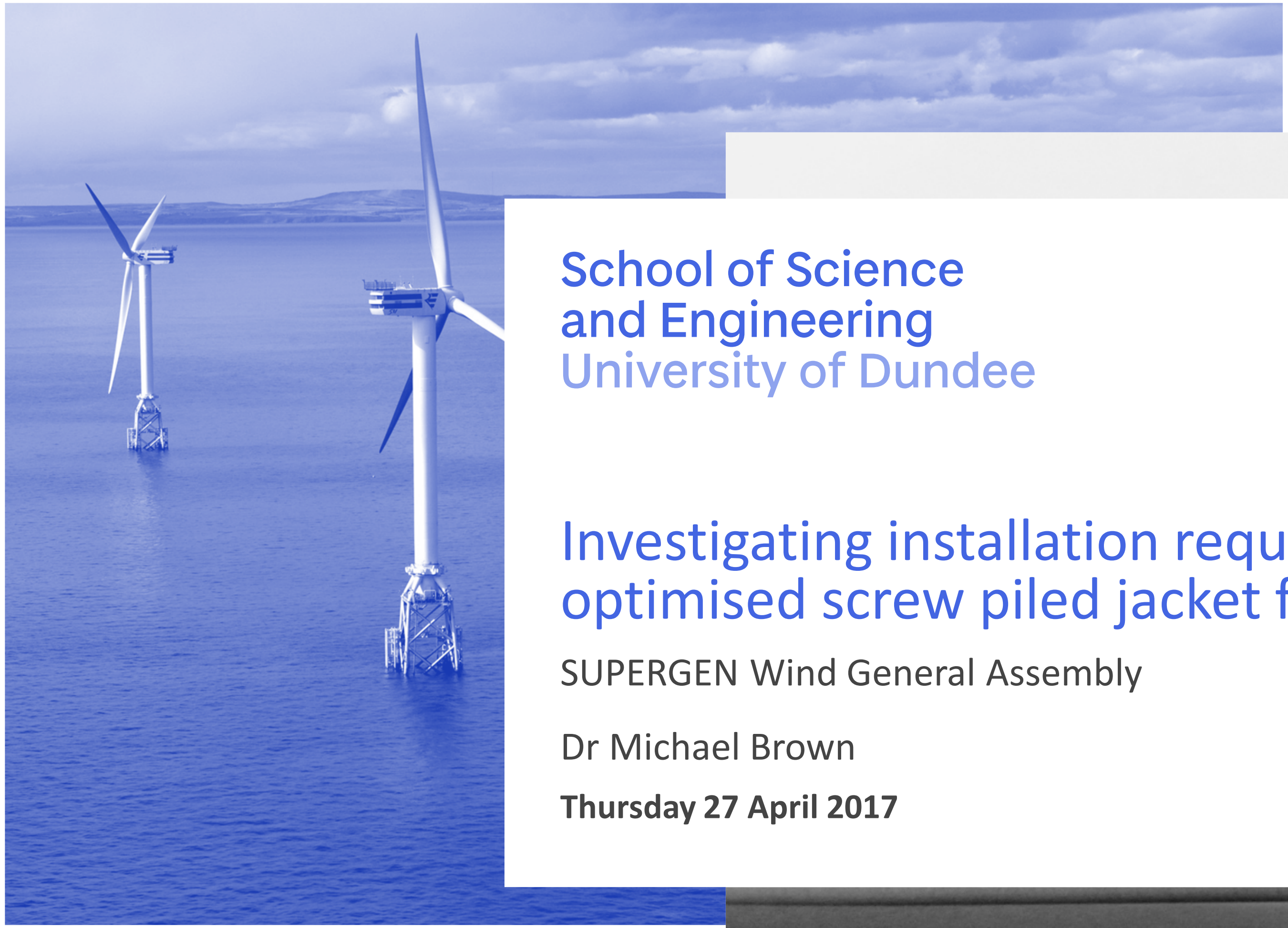
The offshore wind energy sector faces new challenges as it moves into deeper water deployment. To meet these challenges, new and efficient foundation solutions are required. One potential solution is to upscale onshore screw piles but they require verification of performance for new geometries and demanding loading regimes. This paper presents a three-dimensional finite-element analysis investigation of screw pile behaviour when subjected to combined vertical and lateral loading in sand. In the investigation, the screw pile length and helical plate diameter were varied on piles with a fixed core diameter while subjecting the piles to combined axial and lateral loading. The results were compared with results from straight shafted piles with the same core diameter. The results of the analysis revealed that vertical compression loads increased the lateral capacity of the screw piles whereas vertical uplift loads marginally reduced the lateral capacity. The downside of this enhanced lateral capacity is that the screw piles experience higher bending moments. This suggests that, when using screw piles for offshore foundation applications, structures should be designed to maintain axial compressive loads on the piles and induced bending

First journal paper published



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