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Development of an inflight centrifuge screw pile installation & loading system

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Screw piles for offshore wind energy foundations

Aims and objectives

- A novel approach, using screw piles (scale up geometry) for offshore wind turbine foundations.

- Numerical modelling
  - FEA 2D & 3D

- Physical modelling
  - Develop 2D servo actuator.
  - Installation of screw piles models in flight.
  - Axial loading tests in centrifuge (compression & tension).

Installation of onshore screw pile (photo courtesy of Iron Brothers Ltd.)

Screw piles for offshore wind energy foundations

Upscaling onshore screw piles for offshore use

Benefits over driven piles

- Low noise and vibration
- Relatively high capacity as soil-soil shear mobilized (low flange spacing)

Geometry optimisation

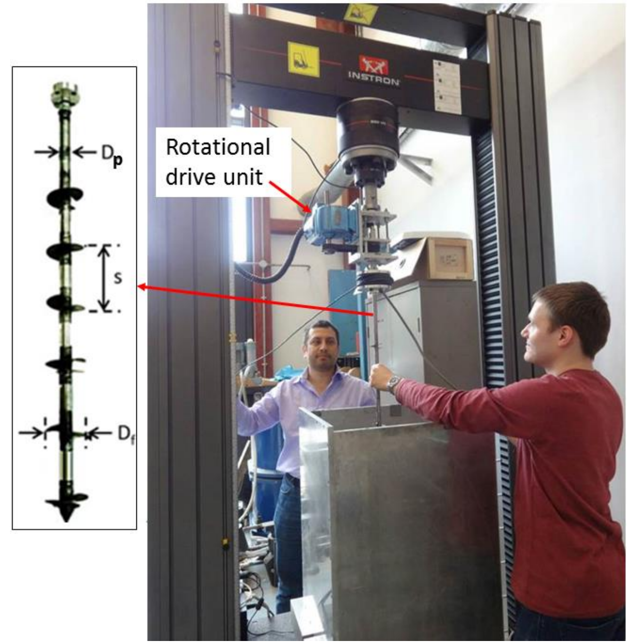
- Uncertainties over upscaling
- Predicting torque requirements for infrastructure investment
- Optimising lateral performance - numerical modelling (Al-Baghdadi et al 2015)

Screw piles for offshore wind energy foundations

Previous studies at the University of Dundee

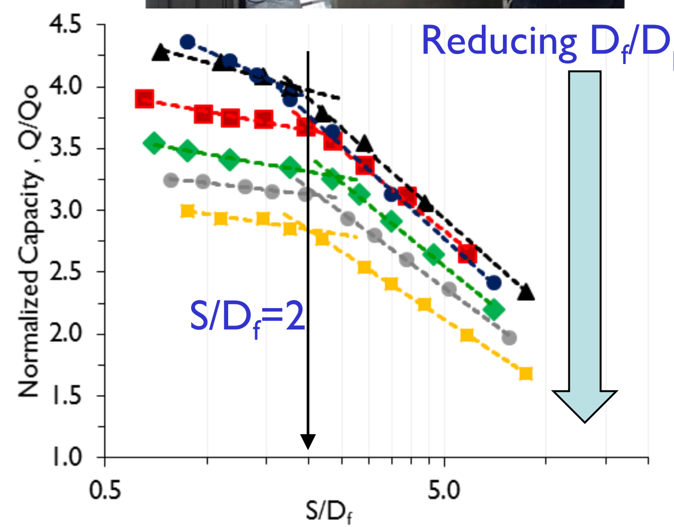
1g lab test (compression)

- Optimization of flanges spacing ratio (S/D_f)
- Screw pile performance under cyclic axial and lateral loading



Numerical Modelling (FEA- 2D Plaxis)

- S/D_f and D_f/D_p ratios optimization
- Reduce in the capacity with reducing D_f/D_p

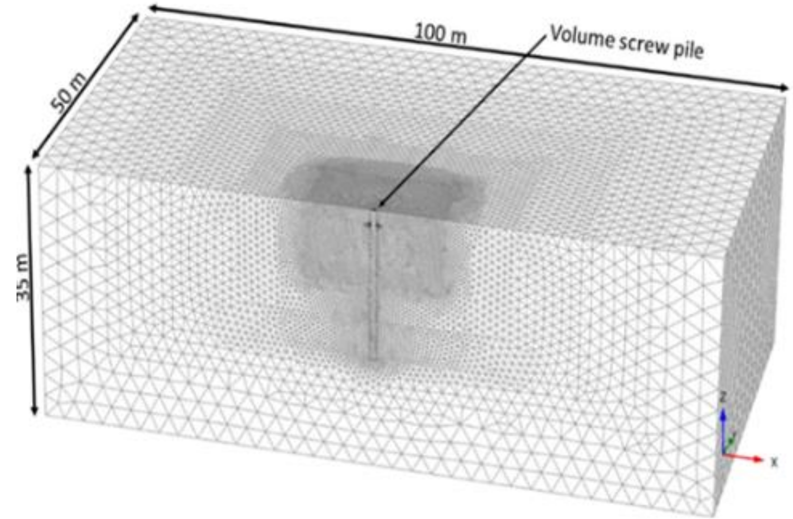


Screw piles for offshore wind energy foundations

Numerical modelling of screw piles

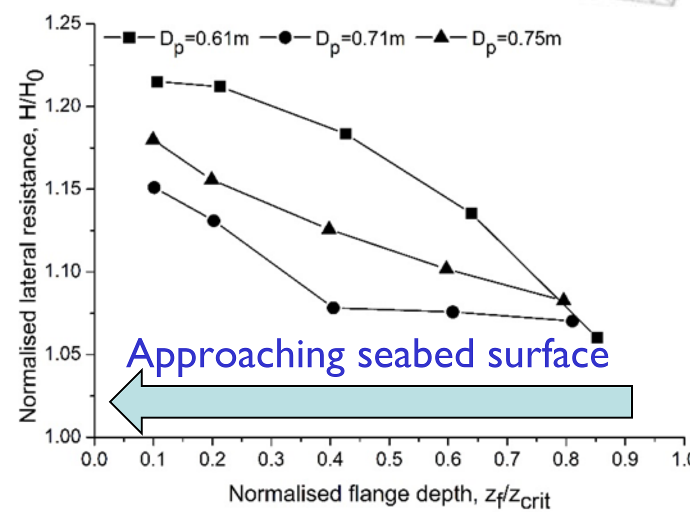
Numerical Modelling (FEA- 3D Plaxis)

- Enhance the lateral capacity
- Near surface flange effect (up to 22% increase)
- V-H combined loading



Problems with 1g and numerical modelling (FEA)

- 1g lab test: scaling problems (low soil stress)
- FEA: screw pile wished in place (installation cannot be modelled)

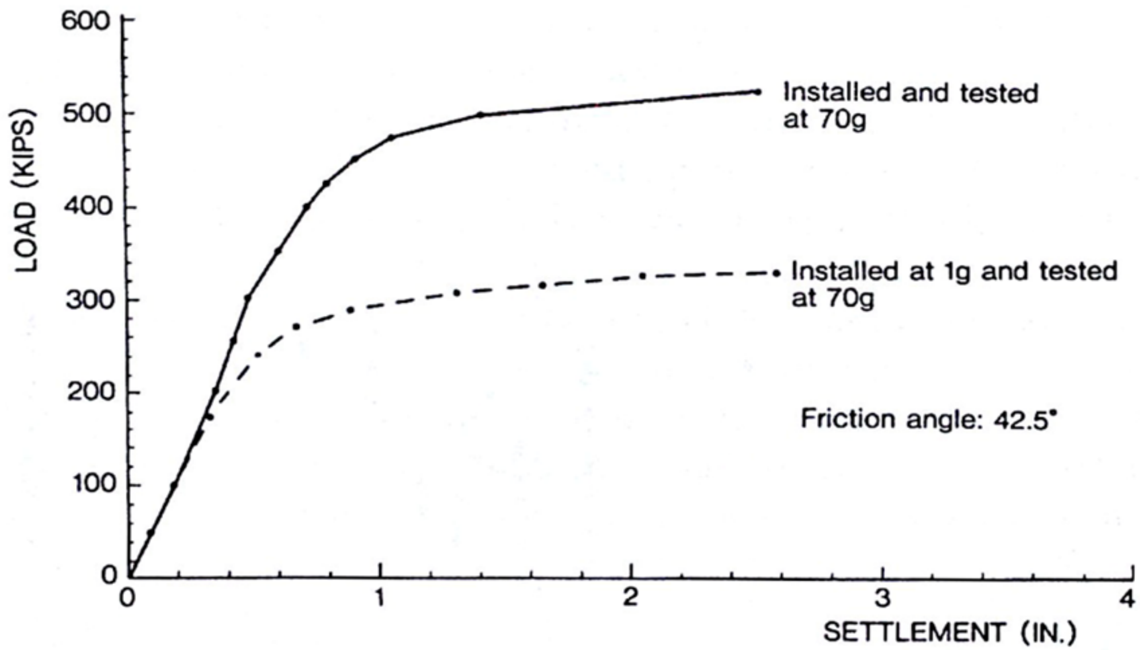


Centrifuge modelling of screw piles

Centrifuge modelling of screw piles with single installation and loading operation

In flight installation

- Predicting realistic installation force and torque
- Previous studies showed that1g installation can reduce the capacity up to 50%



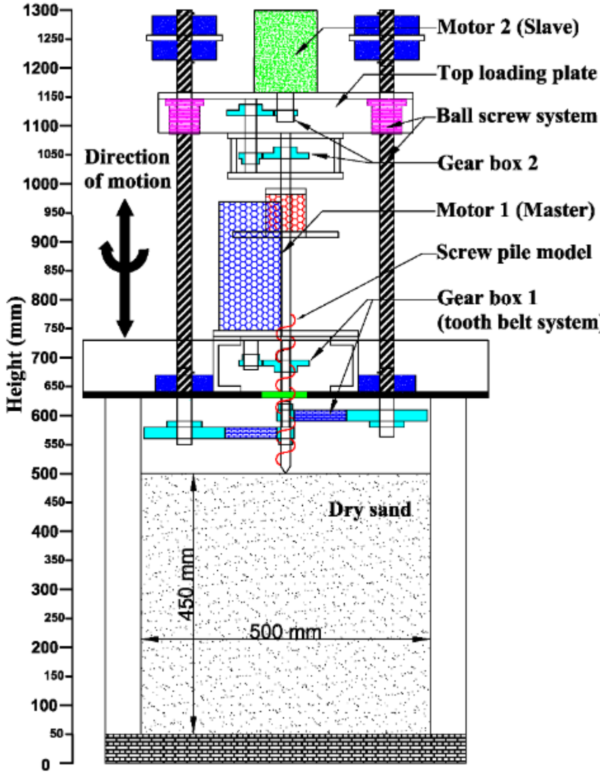
Centrifuge tests results of straight shafted piles installed in dense sand (Ko et al., 1984)

2-D servo-motor actuator system

2D actuator system for centrifuge modelling (Vertical and rotational servo actuator system)

System specification

- Weight 131 kg
- Height 0.8m
- Max. stroke 300 mm
- Max. vertical speed 1.67 mm/s
- Max. torque 30 N.m
- Max. capacity ±10 kN

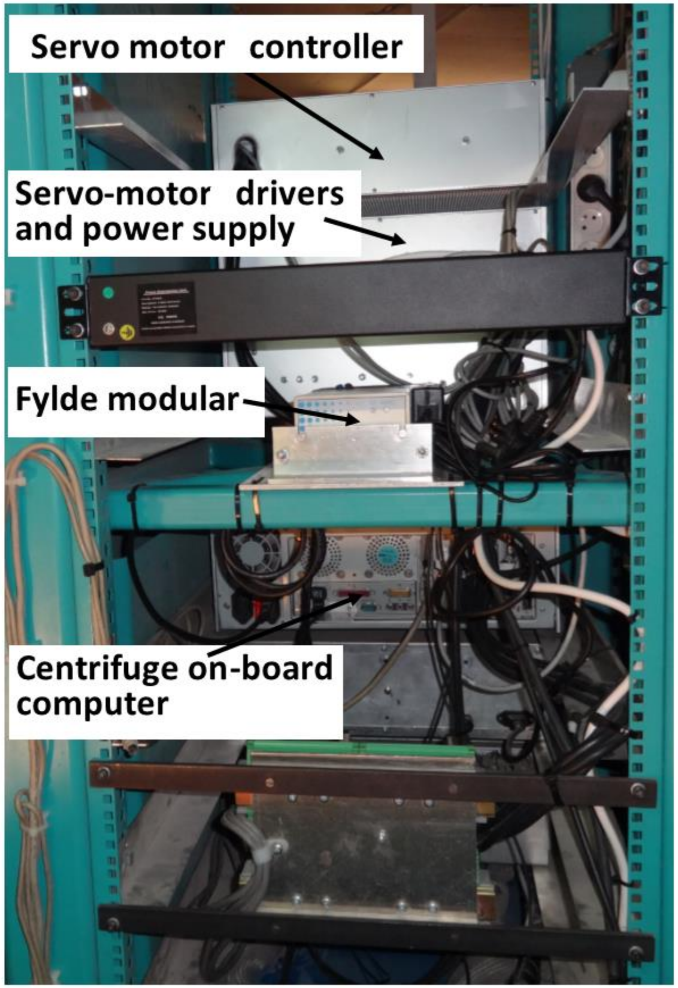


Centrifuge modelling of screw pile

Control system

- Servo control system
  - Servo motor controller (cRIO-9024)
  - AKD servo motor drivers (AKD Drivers)
  - 2 Servo motors (AKM54H & AKM53H)
  - NI Labview software 2013
  - NI-RIO 13.0 and NI soft motion module

- Data acquisition system (DAQ)
  - Fylde micro analog 2 modular instrument (FE-MM8)
  - Up to 8 transducers (2.5V - 10V)
  - Wide rage of single amplifier (1-5000)

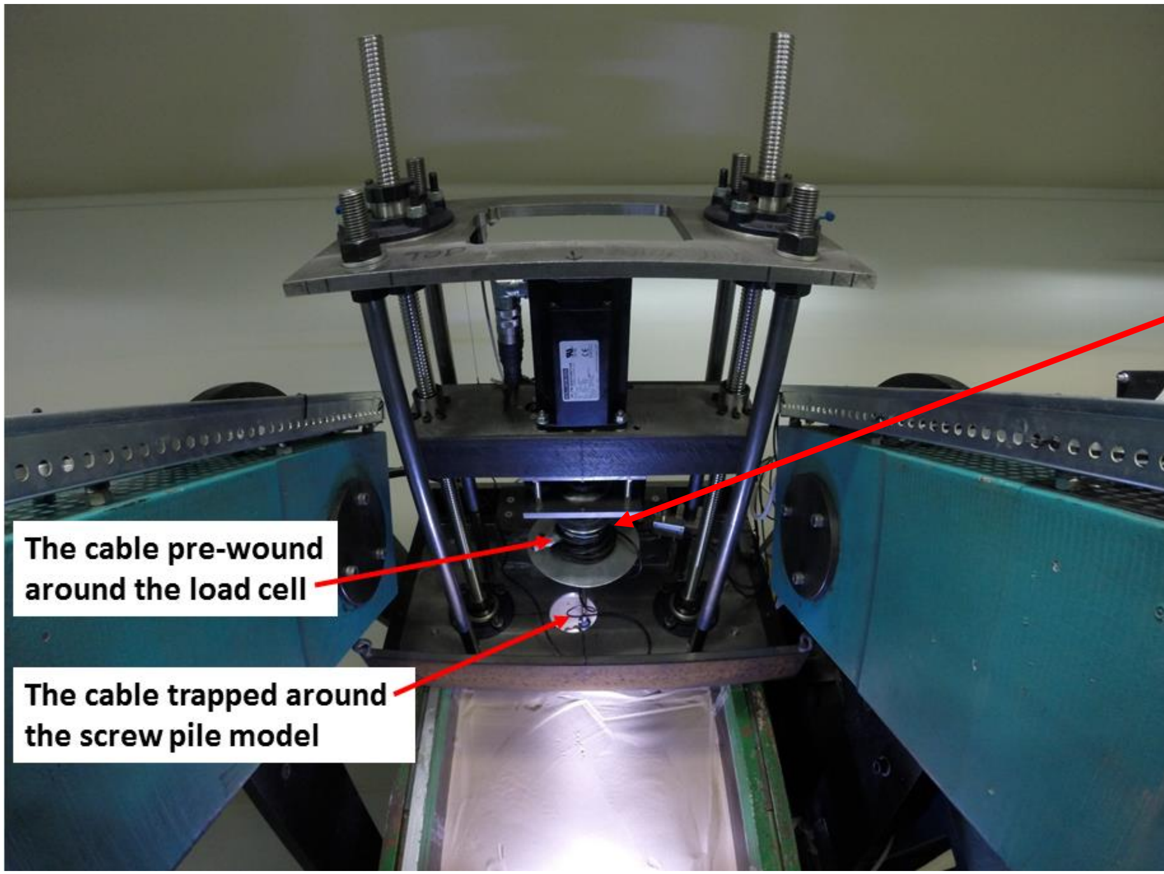


Centrifuge cabin

2-D servo-motor actuator system

Problems with centrifuge modelling with single installation and loading operation

- Cable problem: Centrifuge test at 10 g level



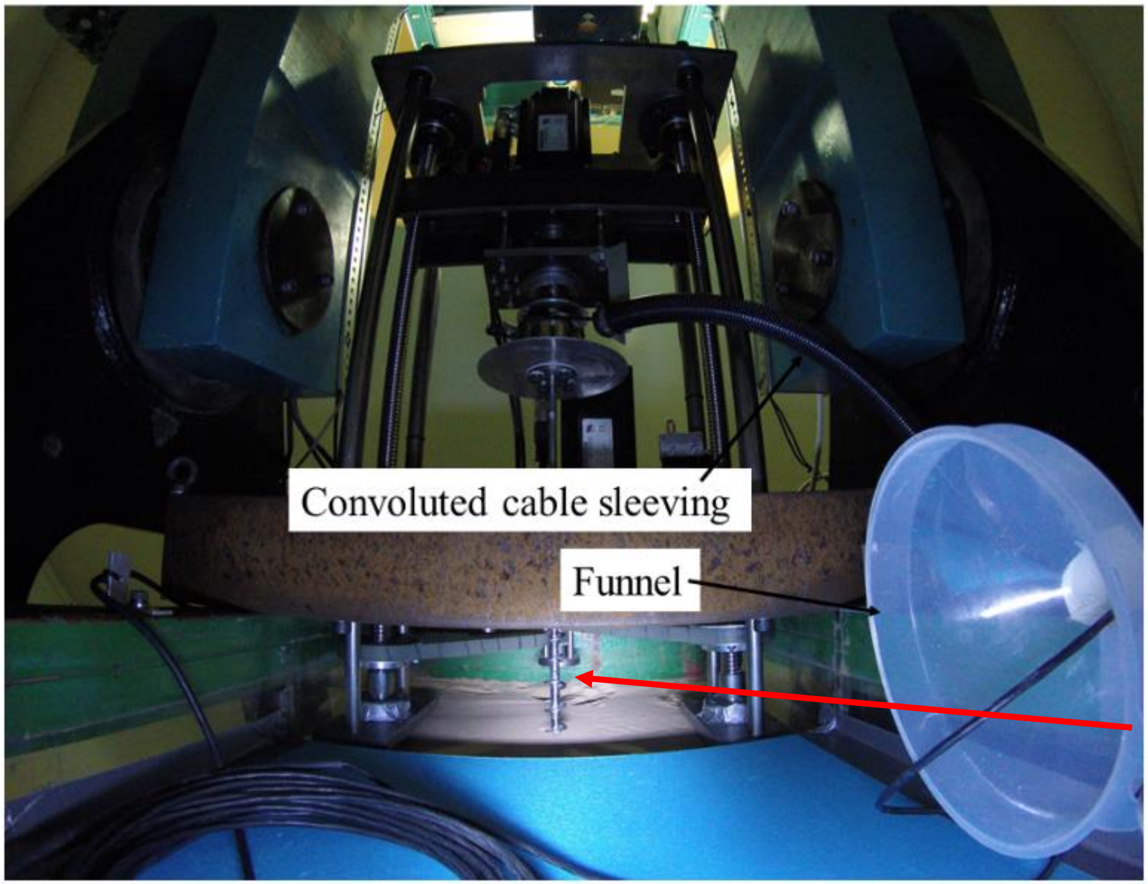
Novatech F310-Z axial force and torque transducer (±20kN & 30Nm)

- Worked during 1-g test trials
- Problem at high g level (cable trapped due to increase cable self weight)

2-D servo-motor actuator system

Problems with centrifuge modelling with single installation and loading operation

- Centrifuge test at 20, 40 & 50 g level



- The cable was pre-coiled
- Using convoluted cable sleeving to guide the cable)
- Developing a new system using a slip-ring (for future centrifuge tests)

Screw pile model

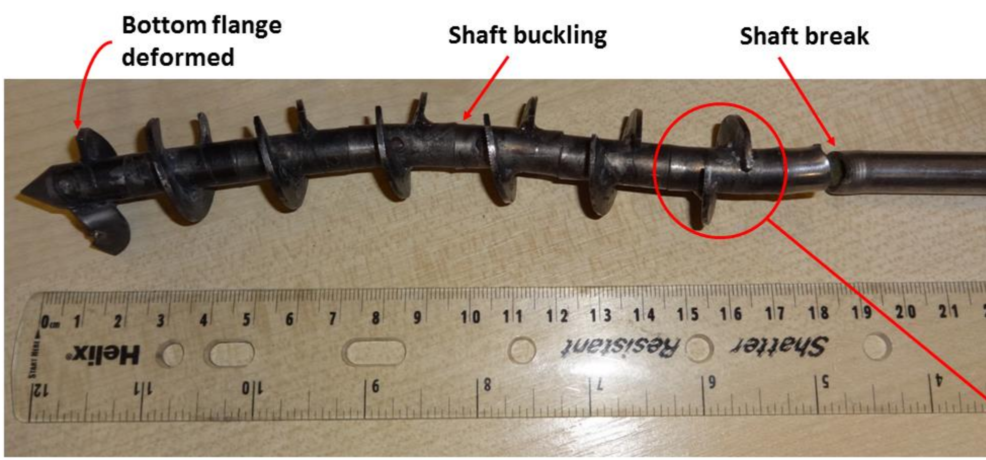
Centrifuge testing of screw piles

Problems with centrifuge modelling with single installation and loading operation

- Screw pile model damage problem:

Screw pile damaged after penetration of 280 mm in dense sand (Dr 85%) at 22g
D_p= (3-6)mm ; D_f= (10-20)mm ; t_f = 0.75 mm
Flanges no. = 3 ; S/D_f=3

(Tsuha et al., 2013)



Screw pile damaged after penetration of 200 mm in dense sand (Dr 73%) at 50g.
D_p=10 mm ; D_f= 25 mm ; t_f = 1.4 mm
Flanges no. = 7 ; S/D_f=1

Centrifuge testing of screw piles

Problems with centrifuge modelling with single installation and loading operation

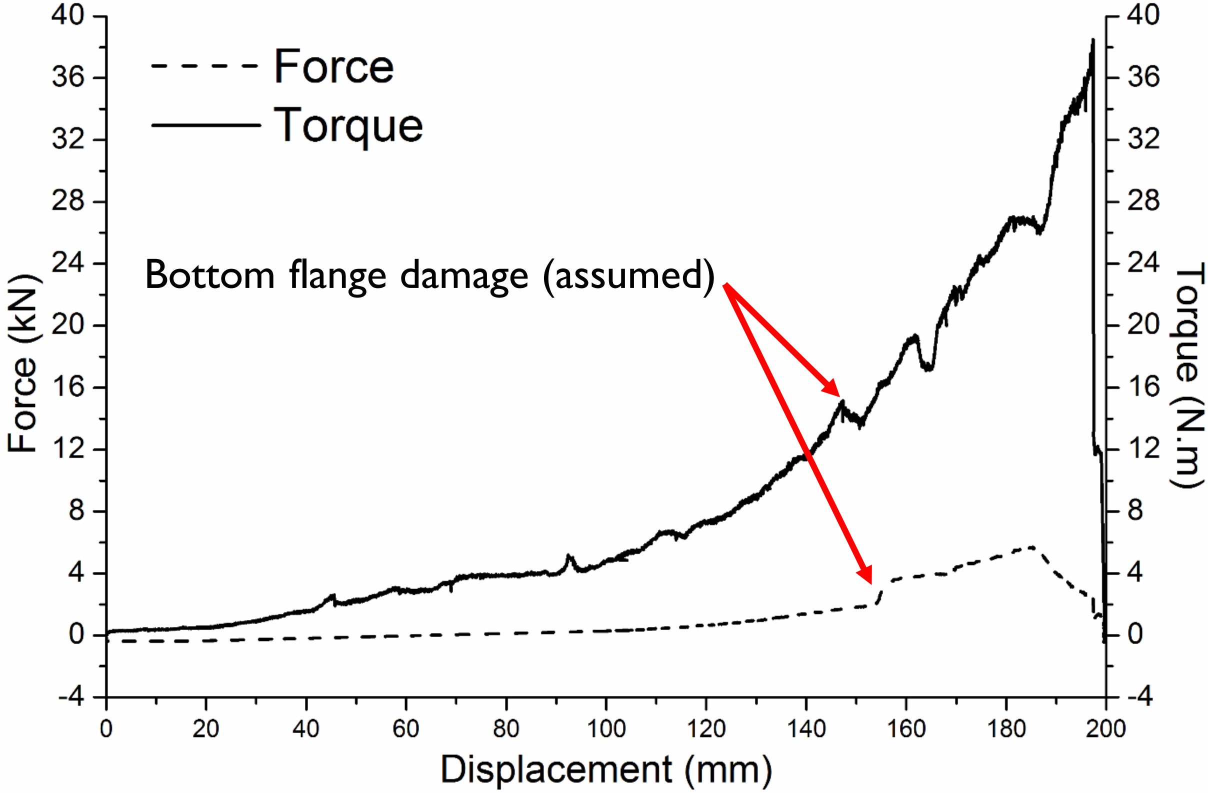
Installation force and torque of screw pile with penetration of 200 mm in dense sand (Dr 73%) at 50g.

D_P=10 mm

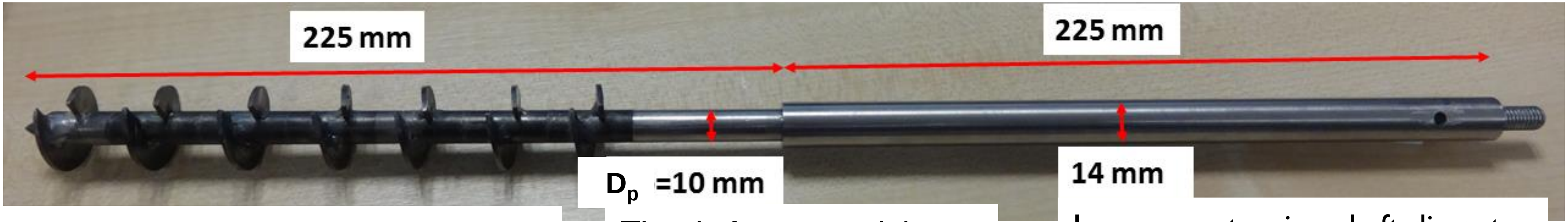
D_f= 25 mm

Embedment depth = 200 mm

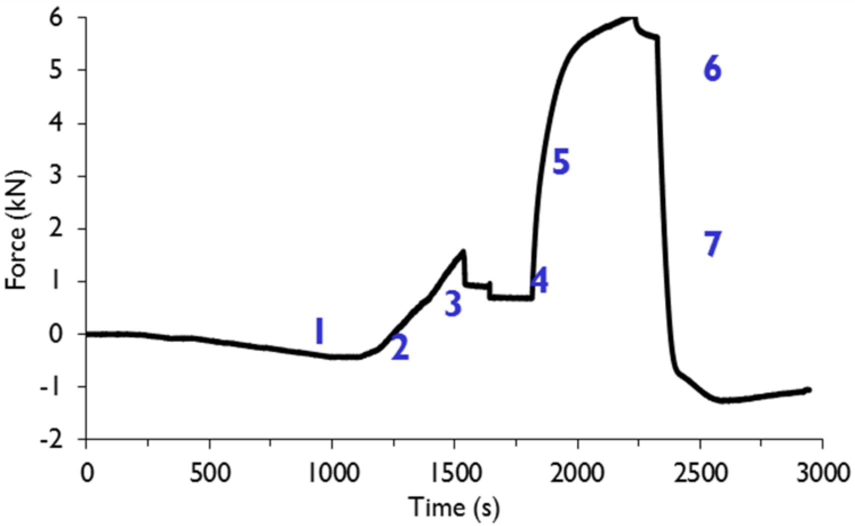
Total length = 400 mm

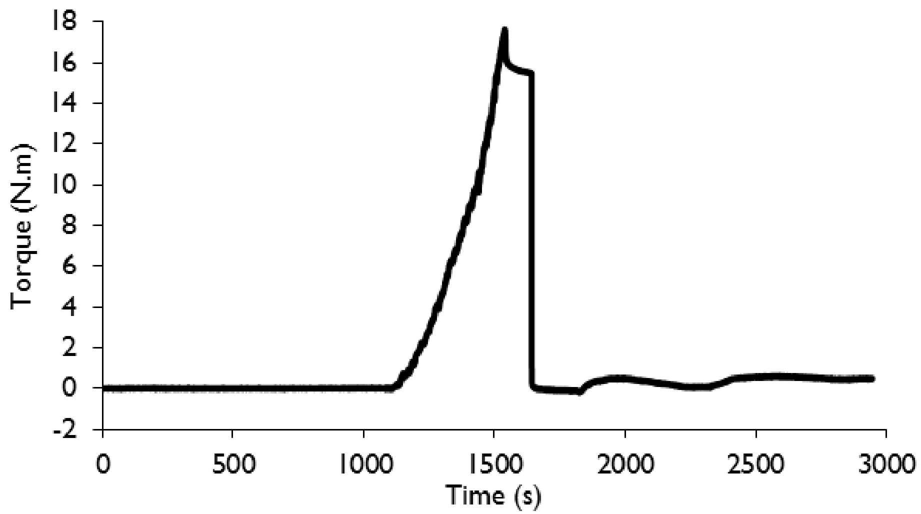


Centrifuge testing of screw piles



Flanges welded carefully with the shaft The shaft is one solid part Increase extension shaft diameter





1. Increasing the g level up to 50g
2. The centrifuge stabilised at 50 g
3. Installation of the screw pile to 200mm
4. Installation ends
5. Start of compression test
6. End of compression test
7. Start of tension test

Centrifuge testing of screw piles

Centrifuge testing of screw piles in dense sand (I_D=73%)

- Empirical factor

$$Q_u = K.T$$

Hoyt & Clemence (1989)

- Field tests of screw piles under compression load (Sakr, 2010)

K_c varied (6.5 - 9.6) m^{-1} with decrease shaft and flange diameter from D_p = 0.508m and D_f =1.016m to D_p = 0.324m and D_f = 0.762m respectively.

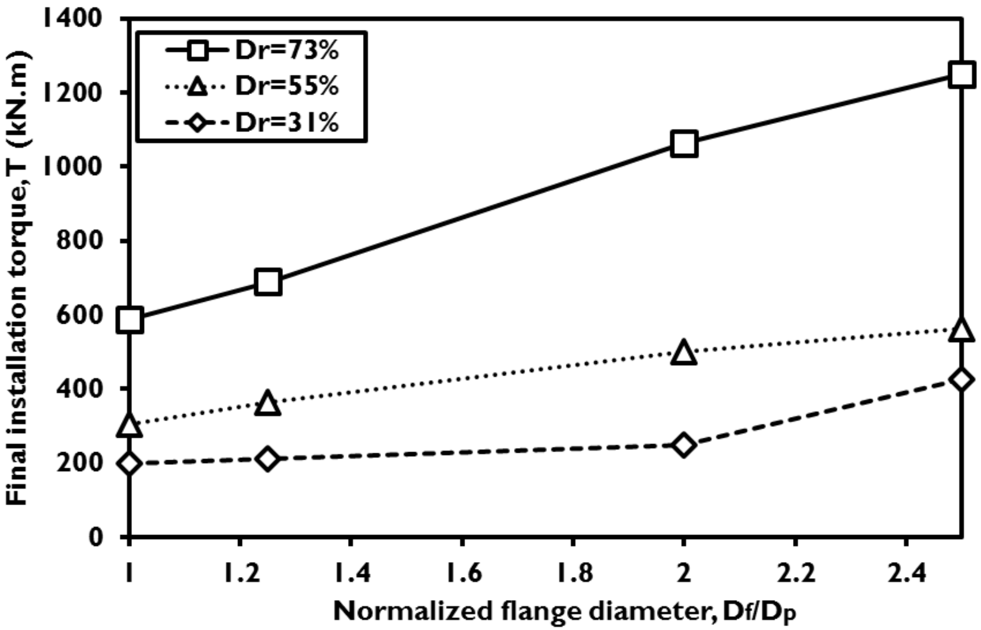
- Screw pile capacities at prototype scale

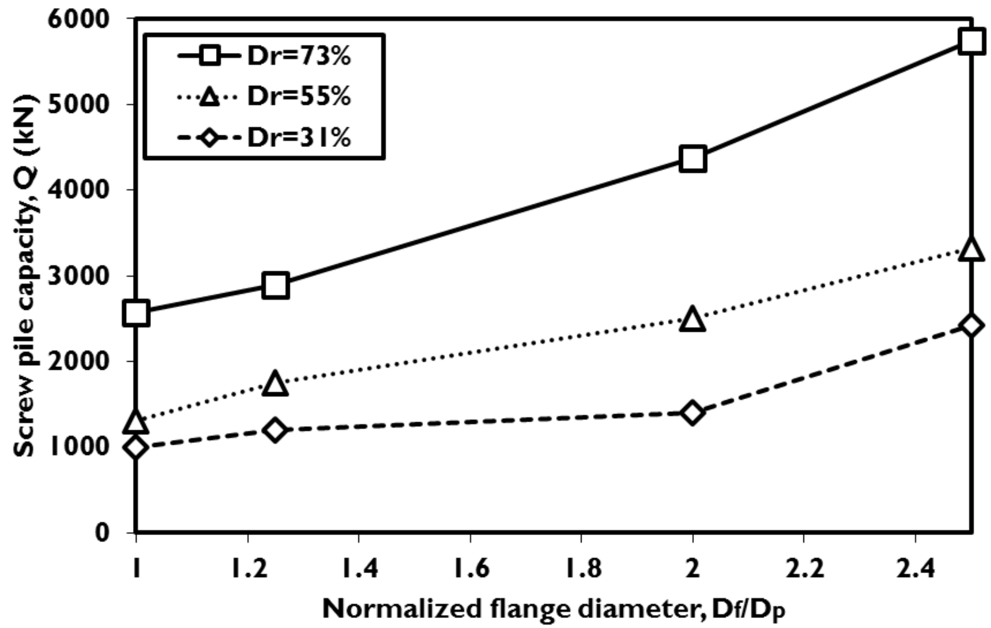
g level	Shaft dia., D_f (m)	Flange dia., D_f (m)	Spacing ratio, S/D_f	Capacity in compression, Q_c (kN)	Installation Torque, T (kN.m)	Empirical factor, K_c m^{-1}
40	0.4	1.0	1.0	5690	788.7	7.2
20	0.2	0.5	1.0	1329	72.5	18.3

Centrifuge testing of screw piles

Effect of flange diameter to screw pile shaft diameter (at 50 g level)

- Single flange at the bottom
- Normalized flange diameter (D_f/D_p)

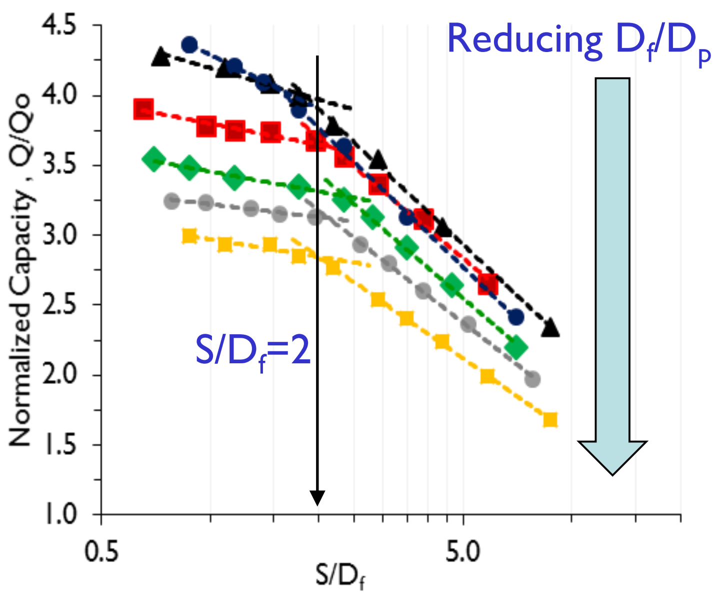


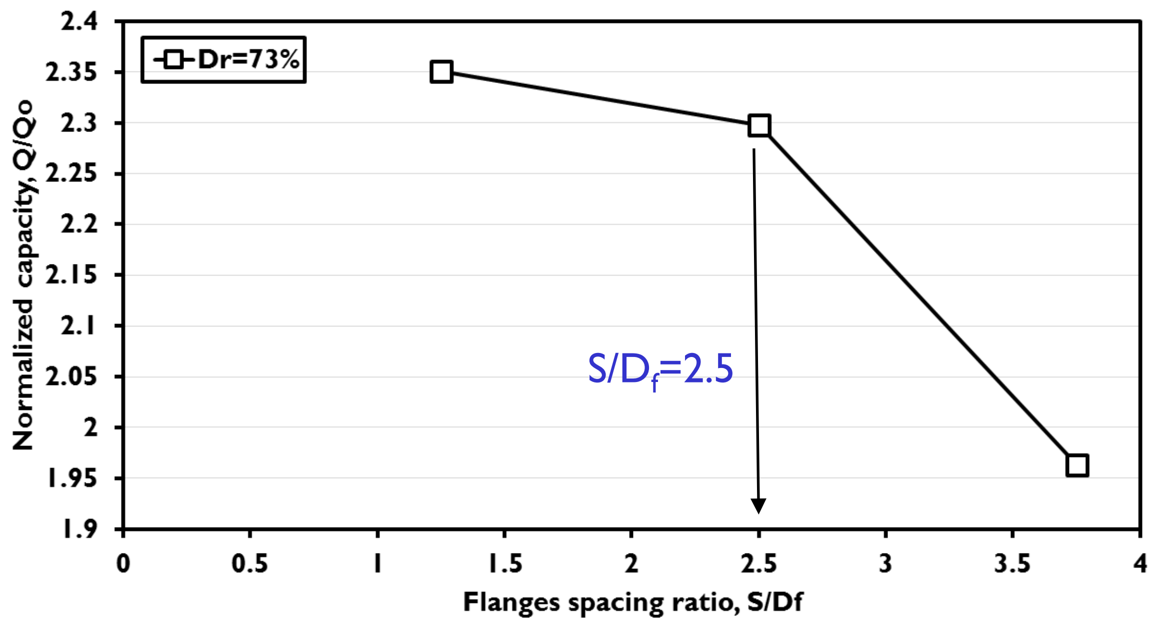


Centrifuge testing of screw piles

Effect of flanges spacing ratio (S/D_f)

- FE 2D Plaxis
- Centrifuge tests (D_r = 73%)
- Flange spacing optimization (S/D_f) ≈ 2.0





Development of an inflight centrifuge screw pile installation & loading system

- **Conclusions:**
  - Develop a new servo control system at the University of Dundee.
  - Carry out centrifuge tests on screw pile models at high g level (50 g) in one single operation.
  - High capacity can be applied (±10 kN & 30 N.m).
  - The empirical factor (Kc) was increased with decreasing the shaft and flange diameter of the screw pile.
  - The optimum flange spacing ratio (S/D_f) was found to be about 2.0 (compression).

Thank you for your attention!

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