CIVIL ENGINEERING

Screw pile foundations for offshore wind turbines: WP3 Experimental Physical Modelling

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1- What are screw piles?

Screw piles, also known as Helical piles or anchors consist of a central steel pipe (core) with one or more steel screw flights/flanges welded near the toe of pipe and sometimes at intervals along the shaft.

2- Why screw piles?

- Quick, easy installation (Fig.1)
- Easily field modified or adapted to suit varying soil conditions
- No vibration/low noise
- No Spoil to Remove
- High capacity/weight ratio (i.e. high efficiency) by achieving optimal flange spacing:

Fig.1: Screw pile installation for offshore

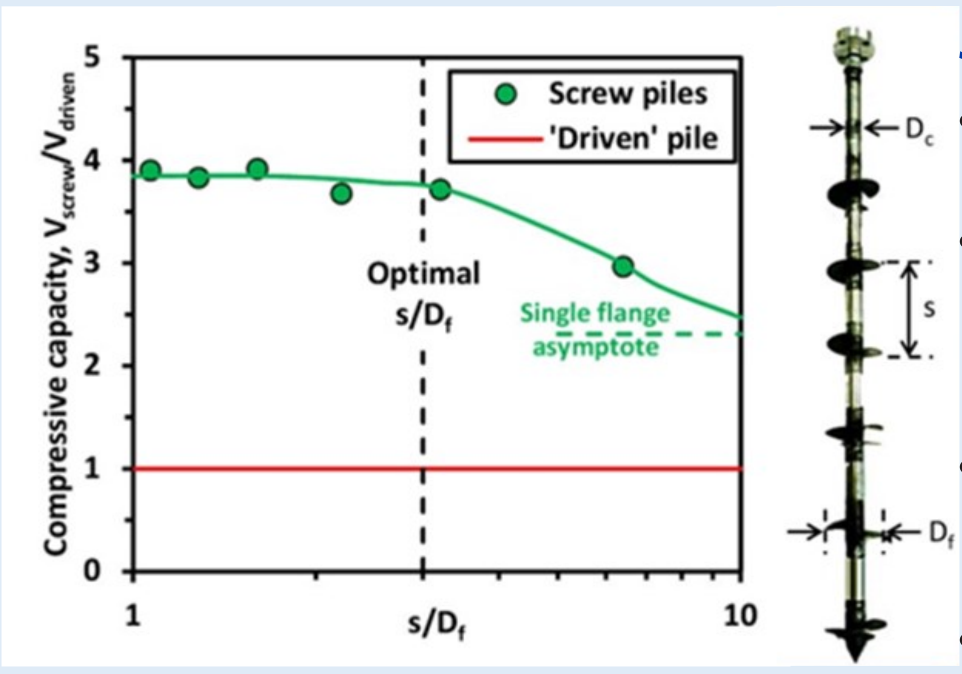

Fig.2: Spacing ratio optimisation (S/D$_f$)

3- What are their barriers to use?

- Piles need to be made much larger than their current onshore sizes
- Optimal geometry (e.g. number and position of flanges, size of flanges and core, etc.) for typical offshore loadings is not clear (Fig. 2)
- Required installation forces and torques need to be understood to design installation equipment
- Uncertainty over performance under cyclic loading (Fig. 3)

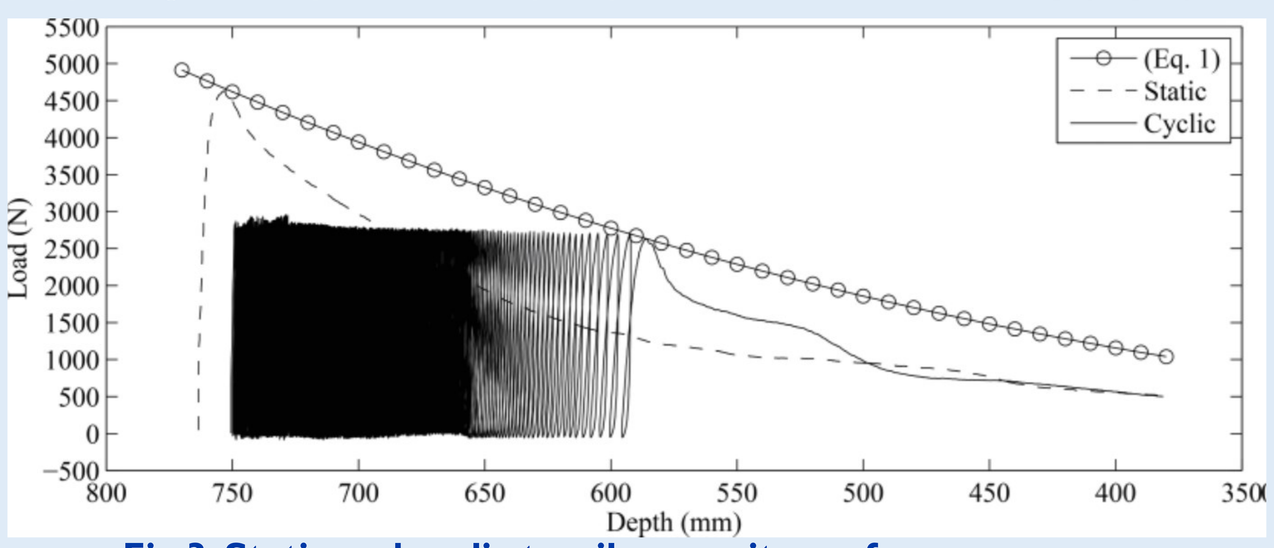

Fig.3: Static and cyclic tensile capacity performance

Newgard et al., 2015

4- Preliminary numerical studies

- Flange spacing (S/D$_f$) optimised for monotonic loading (various flange/core diameter
- ratios), Fig.4a.
- Axial monotonic capacity can be increased 3-4x compared to core alone (conventional pile)
- Lateral resistance can be increased up to 20% with near surface flange (Fig. 4b)

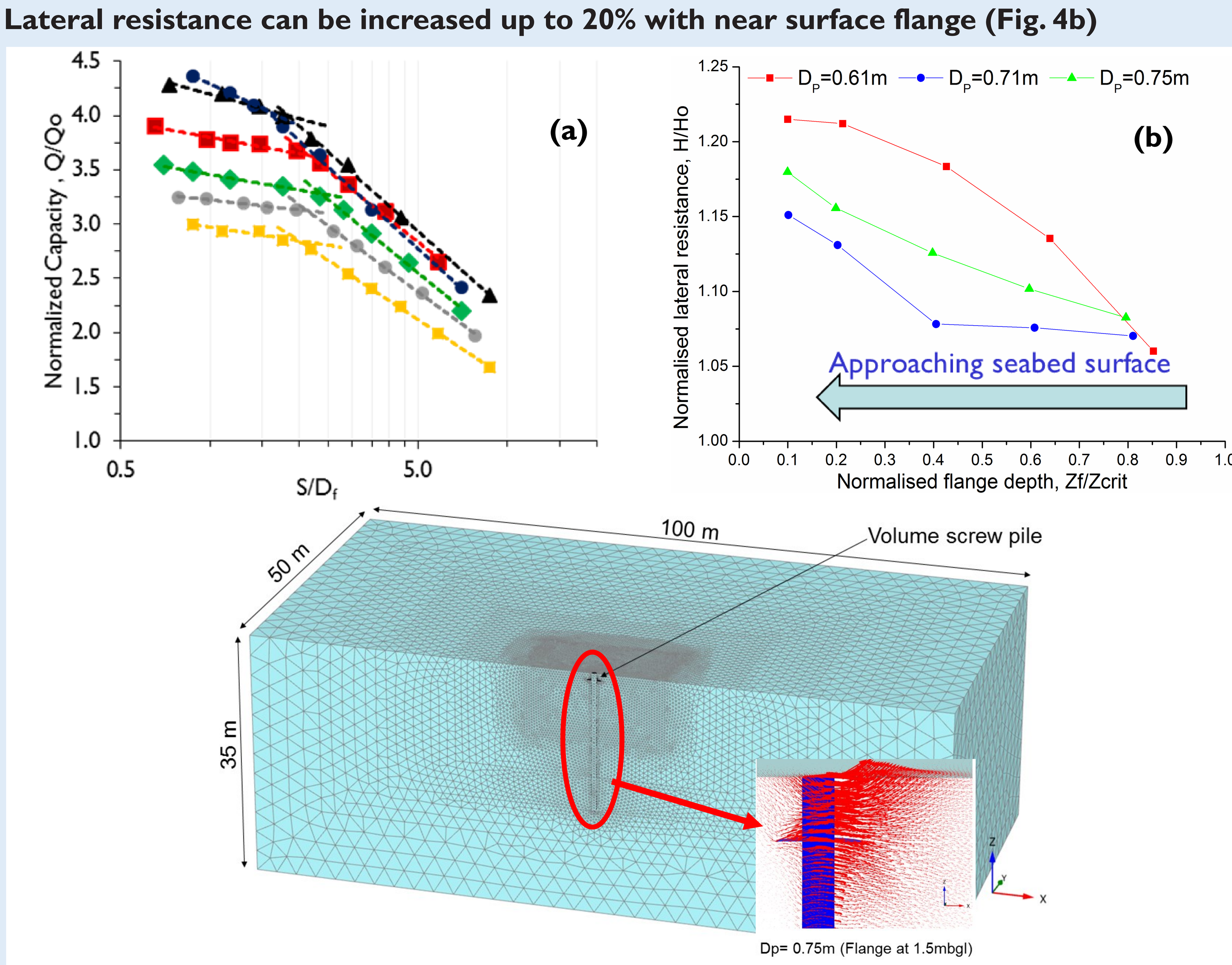

Fig.4: 3-D FE analyses (axial compression and lateral load test)

5- SUPERGEN project

Aims and objectives

- Conduct centrifuge modelling to physically simulate installation of screw piles in flight using a recently commissioned actuator (Fig.5)
- Determine the maximum torque and force requirements for installation of large diameter screw piles and geometry optimisation.
- Conduct in-flight monotonic and cyclic load testing under loads typical of offshore facilities at various life stages
- Assemble a database of high quality load test data for validating numerical models of:
  - Installation (using Material Point Modelling, at Durham University)
  - Peak cyclic load performance (using PLAXIS)

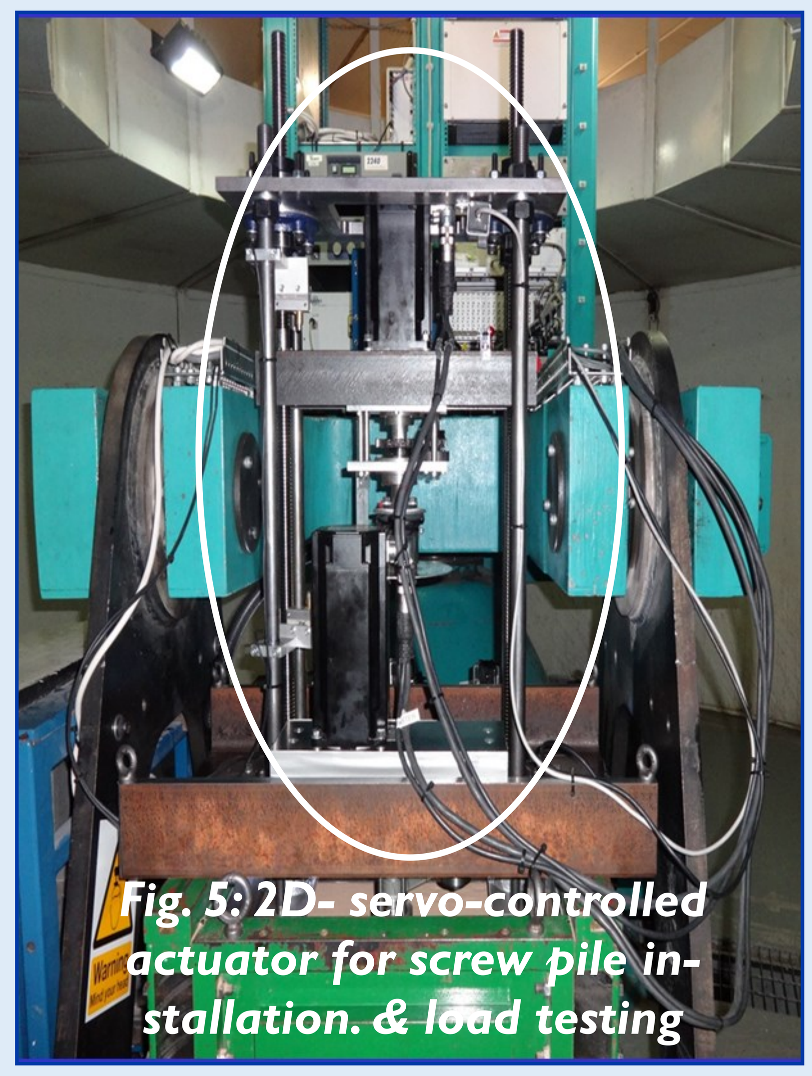

Fig. 5: 2D- servo-controlled actuator for screw pile installation. & load testing

6- Centrifuge modelling with single installation and loading operation

- The effective confining stress and stress history effects the mechanical properties of the soil and the response to installation and in service loading (Fig. 6).
- The centrifuge is used to provide appropriate scaled insitu stress levels
- Problems with previous studies due to 1g installation. (Fig. 7)

Fig.6: Screw pile damaged after penetration of 200 mm in the dense sand (Dr 73%) at 50g.

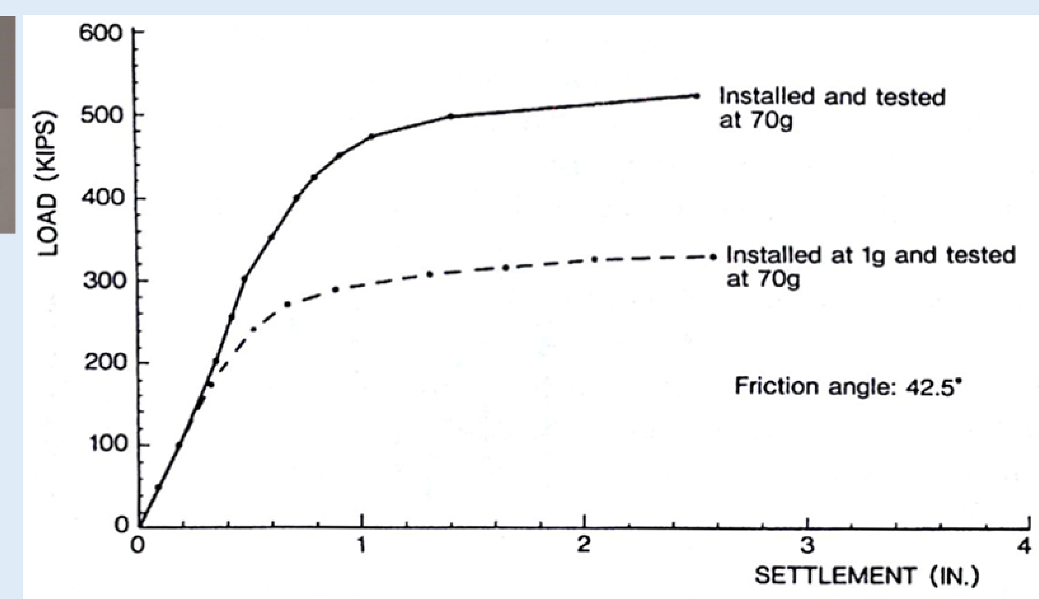

Fig. 7: Pile installation of straight shafted piles pushed into dense sand

7- Installation / loading rig

- A 2-D servo actuator has been manufactured in the UoD having ±10kN capacity, maximum speed 3.1mm/s and up to 300mm stroke (Fig. 8).
- Two servo motors are used, one (master) to translate the rotary motion into a linear motion for vertical displacement via screw ball system and the other (slave) is used for screw pile installation.
- Gears were used on both axes to increase the torque supplied by the servo motors.
- A Combined torque and load cell transducer is used to measure both parameters during installation in-flight.

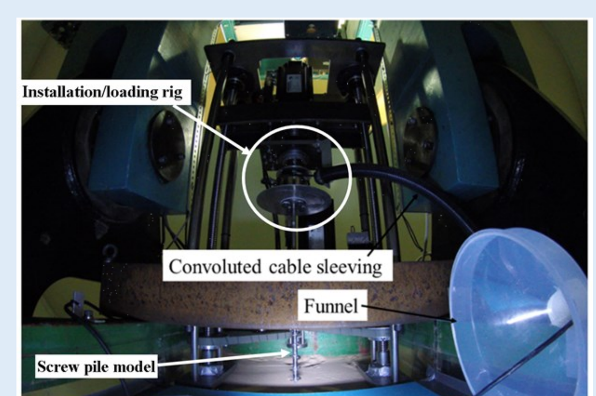

Fig.8: Installation/loading rig

8- Geometry effects and general observations for a singe flange only

- Wing ratio, D$_f$/D$_p$=1 is the no flange case.
- Reduction in torque and capacity for low diameter flanges (Fig. 9 and 10)
- Single flange at the bottom of the screw pile interests to industry (low cost) but may not give the required capacity enhancement anticipated from multiple flanges.

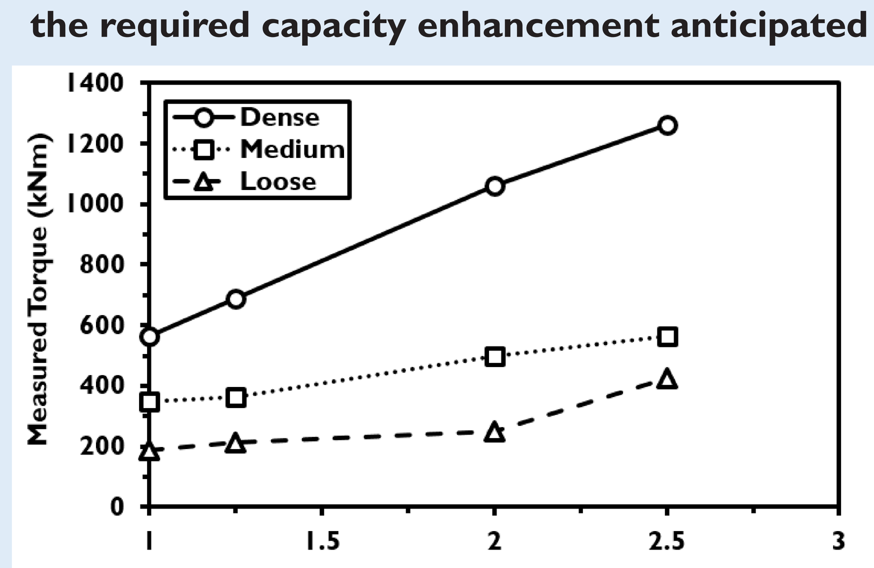

Fig.9: Effect of wing ratio on installation torque

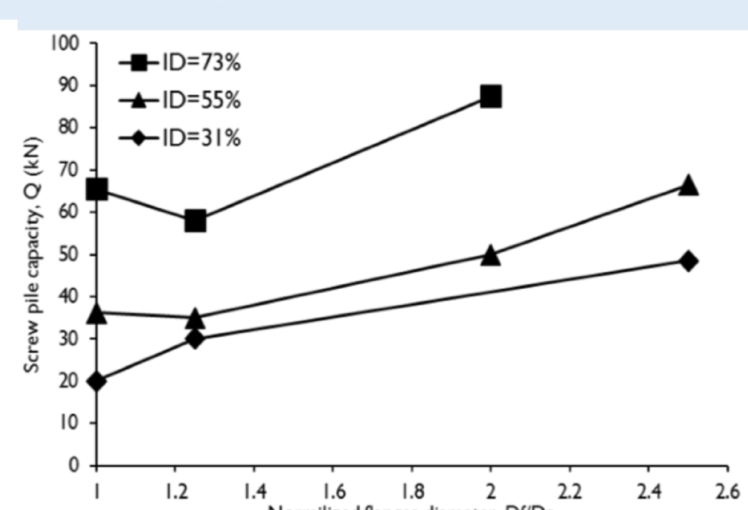

Fig. 10: Effect of wing ratio on compressive capacity

8- Conclusion

- Upscaling onshore screw piles for offshore use is the next challenge.
- Screw piles capacity may ne 2 to 3 time that of conventional piles (i.e. driven piles)
- Screw piles installation in-flight (N-g) is more realistic than 1-g installation (required centrifuge).
- The measured torque and the capacity are influenced by the screw piles geometry which requires further investigation for optimised pile geometries.

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EPSRC
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References

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