1. Introduction

For offshore wind energy to move into deeper water (>40m), alternative foundation solutions are needed (Fig. 1) which overcome issues with manufacturing and installing existing monopile and straight-shafted pile systems.

Using physical, numerical modelling and field testing, the Universities of Dundee (UoD), Durham (DU) and Southampton (UoS) plus industrial partners are developing screw pile technology which could address these concerns.

Screw (helical) piles have a tubular core (shaft) with one to several helical plates and are installed with continuous torque and vertical force.

Benefits of screw piles include:
- Quick installation
- Low vibration/low noise
- Efficient material use, generating higher axial capacity through soil-soil shearing when helices are optimally spaced (Fig. 2)

Challenges:
- Upscaling current onshore designs
- Optimising geometry (e.g. core diameter and number, position, size of helices) for typical offshore loads
- Uncertainty over performance under cyclic loading
- Predicting installation force and torque
  - Existing analytical and empirical methods may be unreliable
  - In situ CPT (Cone Penetration Test) correlation methods appear more suitable.

Through centrifuge modelling of screw piles, the proposed CPT-torque correlation updates the previously developed formulae to provide accurate predictions of installation torque.

2. Physical Modelling

Two 1/50th scale model screw piles (Fig. 2) were installed into dense, dry sand at 50g acceleration in the centrifuge at the University of Dundee with a specially developed installation rig.

Cone resistance ($q_c$) data from CPT were also acquired for use in the torque prediction method. The $q_c$ data matches well with field data from other studies investigating screw pile installation torque (Fig. 3).  

3. CPT-Torque Correlation

Principle torque resistances on a screw pile act on: the shaft ($T_b$), base of the pile ($T_s$), and the lower surface ($T_{s1}$), outer circumference ($T_{s2}$) and leading edge ($T_{s3}$) of the helix (Fig. 3). Cone resistance ($q_c$) data from CPT is correlated with installation torque using the proposed relationships shown below.

\[
T = T_b + T_s + \sum_{i=1}^{n} T_{s(i)}
\]

\[
T_b = \frac{a}{\tan \delta_{crit}}
\]

\[
T_s = \frac{a}{\tan \delta_{crit}} \frac{\pi}{\Delta x} D_h^2
\]

\[
T_{s1} = a \frac{\pi}{\Delta x} \frac{D_h^2 - d_c^2}{4}
\]

\[
T_{s2} = a \frac{\pi}{\Delta x} \frac{D_h^2 - d_c^2}{4}
\]

\[
T_{s3} = a \frac{\pi}{\Delta x} \frac{D_h^2 - d_c^2}{4}
\]

\[
\theta = \tan^{-1} \left( \frac{D_h - d_c}{\Delta x} \right)
\]

\[
k_0 = 1 - \frac{\sin \phi}{\sin \phi_{crit}}
\]

\[
\delta_{crit} = \frac{1}{15} \phi_{crit}
\]

\[
\phi_{crit} = \tan \theta
\]

\[
\phi_{crit} = \tan \left( \frac{\pi}{4} \right)
\]

The proposed method predicts installation torque well for both centrifuge and field scale studies (Fig. 5), providing improved accuracy over other CPT-torque correlation methods for single and multi-helix designs, while other methods have previously restricted their predictions to single-helix piles only.

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5. References