Investigating the installation of innovative suction caisson anchors to support offshore renewable energy structures, a feasibility study

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OUTLINE

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Introduction

- To fulfil UK's commitment to 2050 net zero target, a large portion of renewable energies should come from offshore wind turbines.

- Foundations and mooring systems can be accounted for >20% of total costs of offshore structures including costs of their installation; this cost is likely to increase non-linearly the further we go offshore

INTRODUCTION CONT.

- AMONG VARIOUS AVAILABLE FOUNDATIONS, CAISSON ANCHORS ARE ONE OF THE WELL-ESTABLISHED AND POPULAR SOLUTIONS TO SUPPORT OFFSHORE STRUCTURES AND IN RECENT YEARS THEY HAVE BEEN USED IN OFFSHORE WIND TURBINE PROJECTS.
- THEIR EASE OF TRANSPORTATION, AND INSTALLATION ARE AMONG MANY ADVANTAGES THEY HAVE OVER CONVENTIONAL FOUNDATIONS E.G. PILES .

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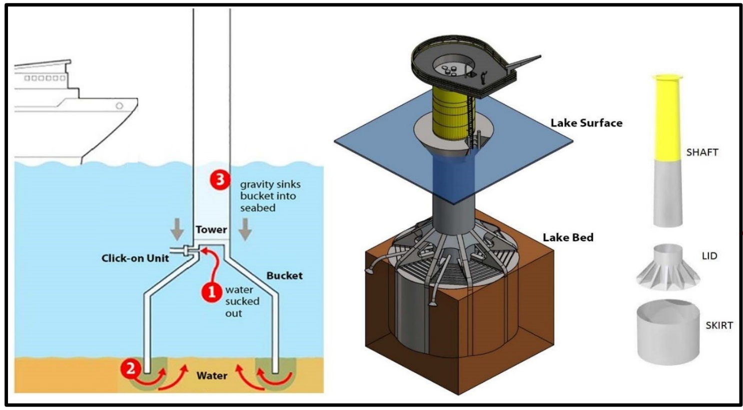
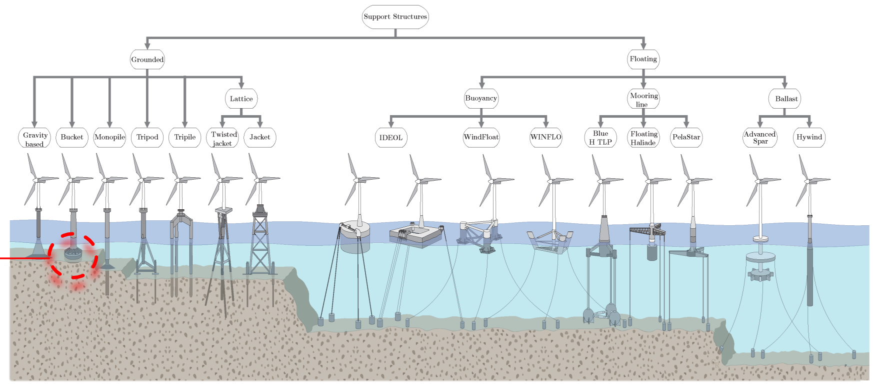


Example of most common grounded and floating turbine support structures [2]



Example of most common grounded and floating turbine support structures [1]

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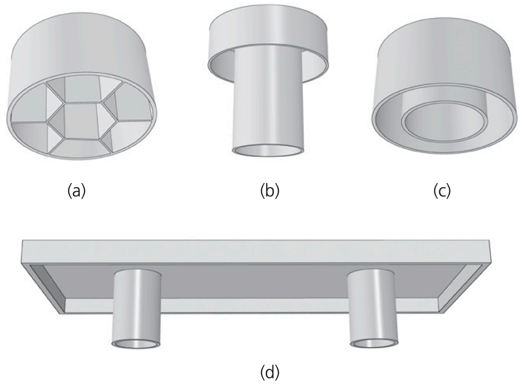
Problem Statement

- In recent years, to enhance the static and dynamic behaviour of offshore wind turbine foundations, a series of novel hybrid systems of skirted/caisson foundations have been proposed based on a combination of two or more types of foundations or inclusion of additional structural elements.
- Despite their promising results in improving the lateral and rotational stiffness, their potential applications in field are hampered by issues related to their construction and/or installation.
- Majority of the proposed hybrid foundations are complex, large and heavy structures. Construction, transportation, and installation of such foundations can be challenging and costly. A few examples of such hybrid foundations are shown in Figure below.



Examples of proposed hybrid foundations concepts in research studies: (a) CBF; (b) MSC; (c) double skirted caisson foundation; (d) skirted mat with caissons [3]

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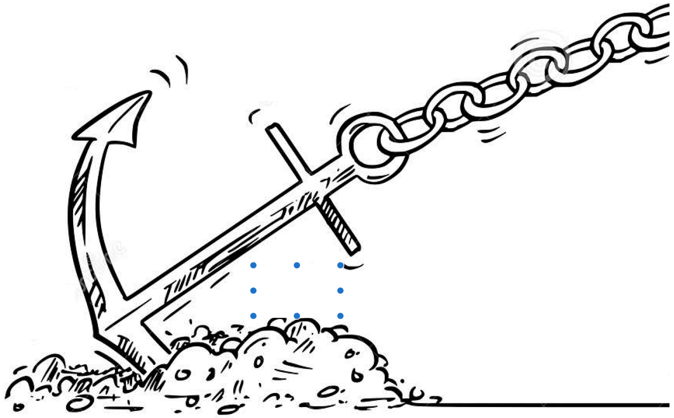
PROJECT AIMS

- THE MAIN AIM OF THIS STUDY IS TO EXAMINE AND UNDERSTAND THE INSTALLATION PROCESS OF A SERIES OF INNOVATIVE SUCTION CAISSON FOUNDATIONS RELATIVE TO THAT OF STANDARD SUCTION CAISSON USING A SERIES OF FINITE ELEMENT (FE) ANALYSIS AND SMALL SCALE EXPERIMENTS.

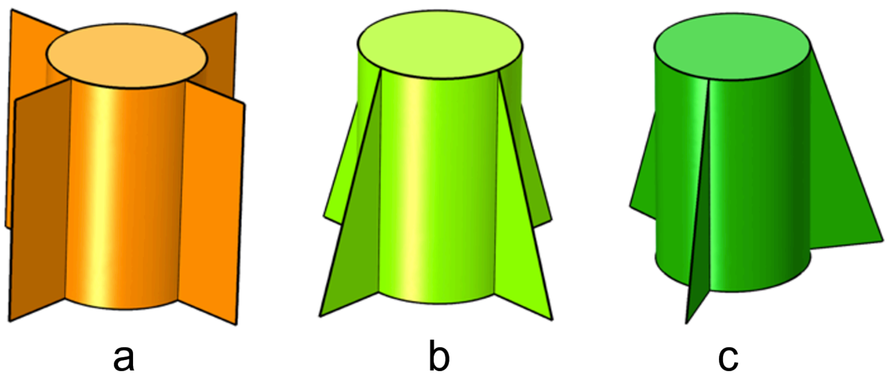
Proposed solutions

- Inspired by the shape of anchors that are used to secure vessels, a number of structurally enhanced anchor designs are proposed with potentially enhanced pull-out and bearing capacity when compared against standard/conventional suction caisson anchors.

- Within this phase of the study, installation of a series of flanged caisson are numerically studied.



Anchors are traditionally used to secure vessels

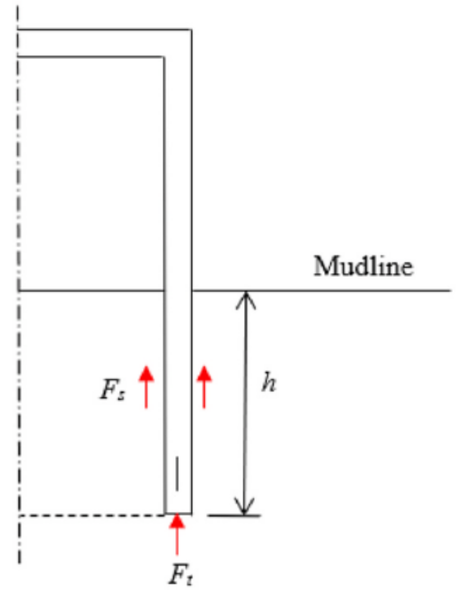


A few examples of flanged anchors

PREDICTING THE REQUIRED SUCTION

- A NOVEL 3D FE MODEL OF THE PROBLEM WAS DEVELOPED TO PREDICT THE AMOUNT OF SUCTION REQUIRED TO INSTALL THE FLANGED CAISSONS AT DIFFERENT PENETRATION DEPTH.
- DARCY LAW IS GOVERNING EQUATION WITHIN THE SOIL MASS AND BELOW ANALYTICAL FORMULATIONS WERE IMPLEMENTED IN COMSOL MULTIPHYSICS TO CALCULATE THE REQUIRED AMOUNT OF SUCTION AT DIFFERENT INSTALLATION DEPTH.

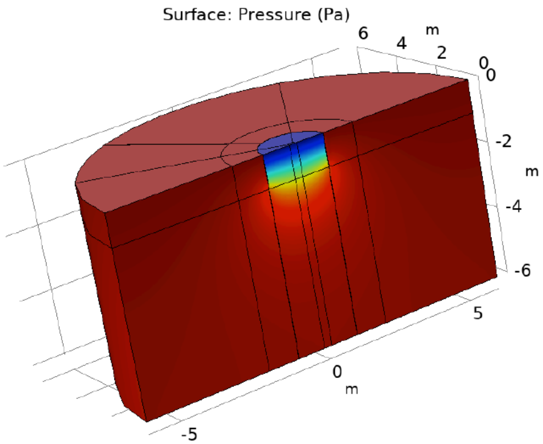
$$S = \frac{F_s + F_t + 3(F_{sf} + F_{tf})}{\pi R_i^2}$$



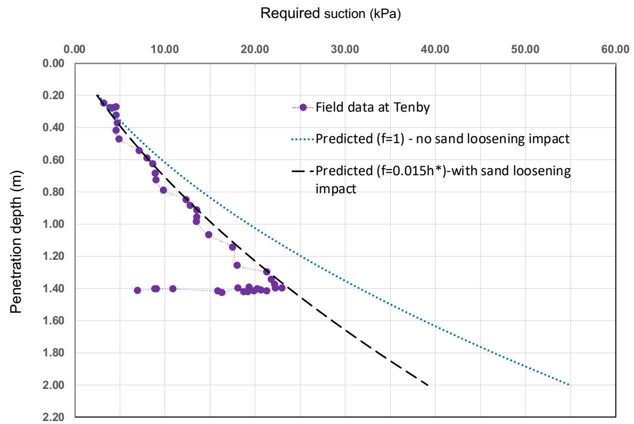
Resisting forces against caisson installation

FINITE ELEMENT MODEL (FEM)

- THE FEM WAS VALIDATED AGAINST PUBLISHED DATA (TENBY FIELD TRIAL).
- A REGION INSIDE THE CAISSON CAVITY SUBJECTED TO PIPING WAS INVESTIGATED AT DIFFERENT STAGE OF THE INSTALLATION.
- THE VALIDATED FE MODEL WAS EXTENDED TO INVESTIGATE THE INSTALLATION PROCESS OF VARIOUS FLANGED CAISSON WITH DIFFERENT FLANGE SIZE AND EXPLORE THE IMPACT OF THE FLANGED BASE SIZE ON THE INSTALLATION RESISTANCES (NEXT SLIDE SHOWS THE RESULTS OF CAISSONS WITH THREE FLANGES).



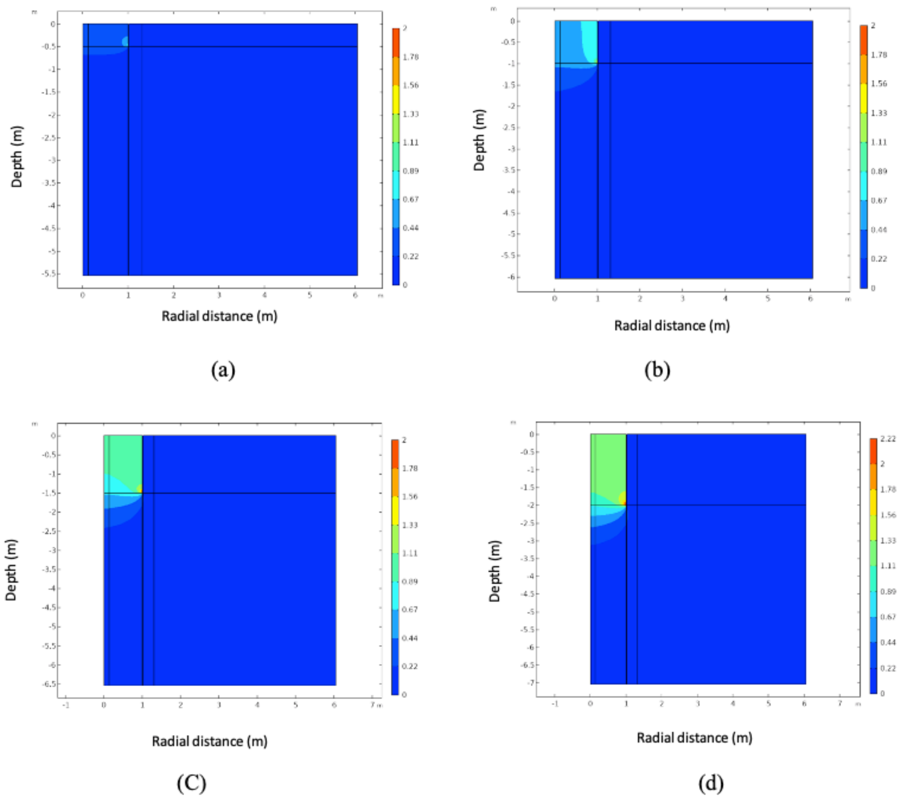
3D FE model of the proposed foundations to simulate their installation



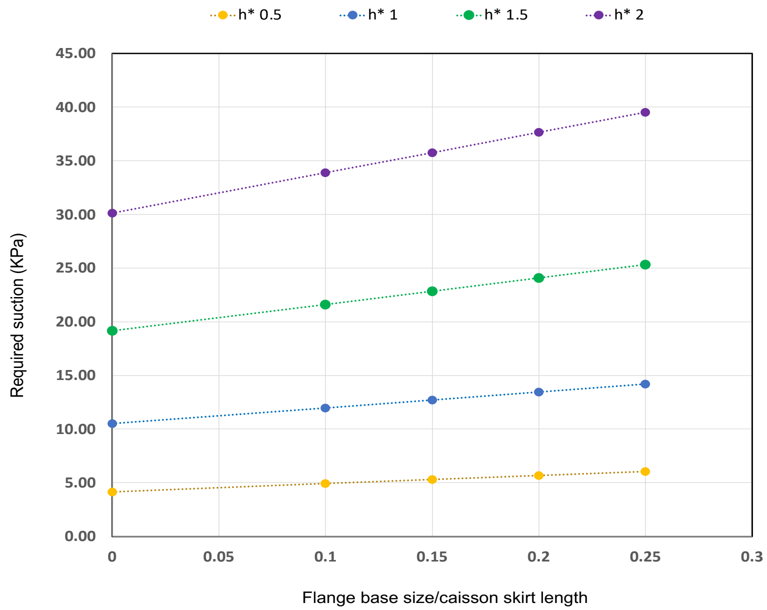
Typical results of the simulations validated against published data

NUMERICAL RESULTS

- FLANGED CAISSON WITH THREE TRIANGULAR FLANGES,



Contours of function μ in flanged caisson with flange base size of 0.15D, at different depths (a) h*=0.5, (b) h* =1, h*=1.5 and h*=2



Impact of flange sizes on installation of caisson anchors ($\phi = 35^{\circ}$ and γ'=9 $^{kN}/_{m^3}$)

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CONCLUSIONS

- A FULL NUMERICAL MODEL FOR SUCTION ASSISTED INSTALLATION OF FLANGED CAISSON INSTALLATION IN SAND HAS BEEN DEVELOPED AND IMPLEMENTED IN COMSOL MULTIPHYSICS.
- THE NUMERICAL MODEL HAS BEEN VALIDATED USING A SIMULATION OF REAL FIELD DATA.
- USING THE FE MODEL OF THE INSTALLATION PROCEDURE, BOTH FEASIBILITY AND SAFETY RELATED TO PIPING CONDITION OF THE INSTALLATION PROCESS OF A SERIES OF FLANGED CAISSONS WERE INVESTIGATED.
- COMPARED TO A STANDARD CAISSON THE FLANGED CAISSONS NEED HIGHER AMOUNT OF SUCTION FOR INSTALLATION AND THE GAP BETWEEN REQUIRED SUCTION FOR INSTALLATION OF THE FLANGED CAISSONS AND THE STANDARD CAISSON INCREASES AS THE INSTALLATION PROCEEDS.
- THE NUMERICAL RESULTS INDICATE THAT MAGNITUDE OF SUCTION TO FULLY INSTALL THE FLANGED CAISSON (H*=2) WITH FLANGE SIZE OF 0.1D, 0.15D, 0.2D AND 0.25D SHOULD BE INCREASED BY ABOUT 12%, 20%, 25% AND 30%, RESPECTIVELY, COMPARED TO THE STANDARD CAISSON.
- CURRENTLY IN THE PROCESS OF SUBMITTING A JOURNAL PAPER BASED ON THE ABOVE RESULTS

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NEXT STEP

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- TO CONDUCT SMALL SCALE LAB EXPERIMENT OF THE INSTALLATION PROCESSES OF A SERIES OF INNOVATIVE FLANGED CAISSONS.

References

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[1] Rodrigues et al. (2016) energies, 9, 216.

[2] LEEDCo - Technical. (2022). Retrieved 11 January 2022, from http://www.leedco.org/index.php/70-resources/156-technical

[3] Faizi et al., (2020), Proceedings of the Institution of Civil Engineers – Geotechnical Engineering 173(5): 448–460.

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