DEVELOPMENT OF AN INTEGRATED ANCHOR MODEL VIA INDUSTRY ENGAGEMENT

A Career-Development Research Project with the Norwegian Geotechnical Institute (NGI)

The offshore renewable energy industry requires efficient anchoring systems to support floating offshore wind turbines as well as floating wave energy and tidal turbine devices. This project extended my recent work on the 'whole-life' time-dependent capacity of anchoring systems – which has revealed potentially significant 'hidden' anchor capacity – by opening a collaboration with the Norwegian Geotechnical Institute (NGI) on 'whole-life' seabed-anchor effects. This collaboration explored new methods to capture long term anchor behaviour for design through three activities: (i) collaboration on efficient computational models to integrate the anchor into a floating system model, (ii) data mining into NGI's extensive database of and (iii) a program of new soil element tests involving realistic 'whole-life' loading. These activities were facilitated via working remotely with NGI, and led to both conventional research outcomes[1] and also industry-aimed outputs (i.e. ongoing integration into mooring software numerical analysis packages (NAPs) – such as *Bifurc*[2] and in the future, *Riflex*[3]– within the Norwegian SFI BLUES project[4]).

This project resulted in a numerical computational 'macro-model,' which captured 'hidden' anchor capacity enhancements in soft-soil type seabeds from (i) 'whole-life' changing soil strength, (ii) viscous effects on soil strength and (iii) added soil mass effects, which are usually absent in geotechnical foundation design soft soils. The model enabled integration of the soil-anchor interactions into mooring analyses in a simple and practical way, while unlocking the full potential anchor capacity provided by these mechanisms. This was achieved by using 'smart' mechanical analogue parameters (MAPs), including spring-slider, dashpots and added mass elements to represent the different soil-anchor interactions that evolve through the facility life (Figure 1). The components were calibrated from existing published field and laboratory direct simple shear test data.

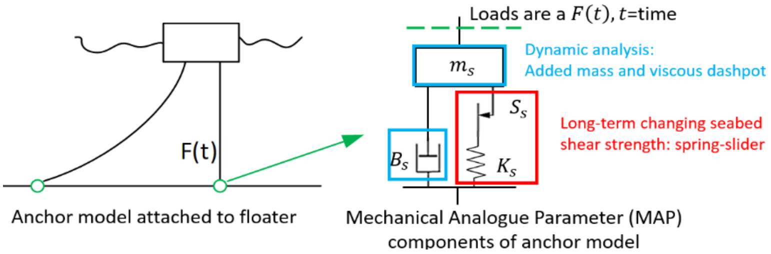

Figure 1: *Schematic of anchorage, consisting mechanical analogue parameter (MAP) components connected to floating ORE facility*

The model was connected and benchmarked with existing mooring software NAPs and the results from applying the coupled NAP-MAP model to example cases demonstrated how the coupled model efficiently predicted changes in anchor capacity over a multiscale hierarchy of time processes, from wave period loads (10^0 to 10^1 s) through to geotechnical consolidation durations (10^6 s) through to full facility life (10^{12} s) (Figure 2). It provides a new basis for assessing the through-life changes in geotechnical anchor capacity, enabling a better understanding of the fully coupled soil-anchoring mooring behaviour of ORE infrastructure over its operational lifetime.

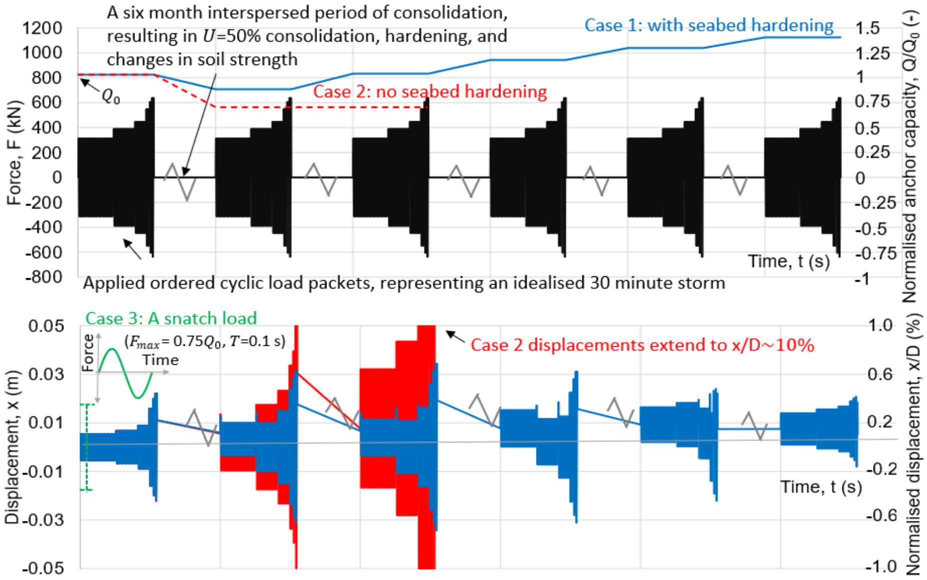

Figure 2: *Whole-life (a) force response of macro model allowing for consolidation and (b) the resulting displacements during cyclic loading (Cases 1 and 2) or a single snatch load (Case 3)*

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[1] Kwa et al. (2022) A numerical macro model to simulate the whole life response of anchors for floating offshore renewable energy systems, OMAE 2022. ; Kwa et al. (2022) Report to NGI: A Whole-life anchor macro model for floating offshore systems (*UoS GEO: 21010*), [2]Jostad H. P., (1993). Report: Geotechnical properties of clay-shales. Description of BIFURC- a finite element program for bifurcation analysis of boreholes. [3]https://www.sintef.no/globalassets/upload/marintek/pdf-filer/factsheets/riflex.pdf, [4]https://sfiblues.no/wp7-mooring-and-anchors/