Effect of the soil undrained cohesion profile on the response of a sliding subsea foundation : centrifuge tests

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Abstract

Pipeline end termination (PLET) structures used in subsea deep-water developments are subjected to significant axial expansion forces arising from heating up and cooling down production periods of the incoming pipelines. Resisting these forces with a fixed foundation would lead to excessive foundation sizes when axial expansions are large. Allowing the foundation to slide over the seabed as a whole could lead to a more economical solution. To design this foundation, its displacements and rotations during several cycles of large-amplitude must be precisely characterised. Series of scale model tests (**Figure 1**) in the Ifsttar's geotechnical centrifuge has been performed at 50×g to understand the complex behaviour of this foundation.

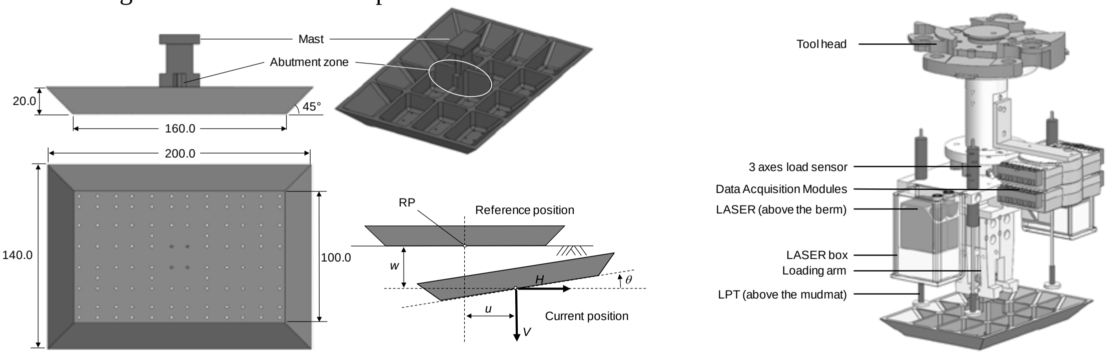

Figure 1. Sliding foundation - model (left) and instrumented tool developed for the robot (right)

This problem is an non standard soil mechanics investigation, as the sliding foundation is installed on deep-water clay, which consolidates under the weight of the foundation, before sliding (when the oil production starts) towards a zone of non consolidated clay. This movement induces the creation of a berm (**Figure 2**), whose shape is quite difficult to predict.

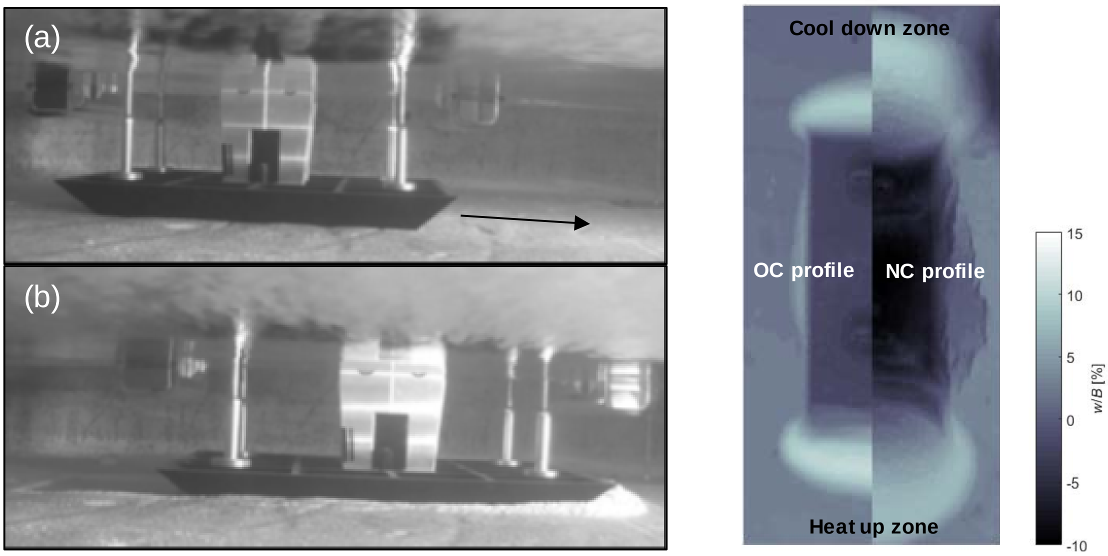

Figure 2. First large-displacement episode observed in flight at 50×g of centrifuge acceleration (left) - (a) before and (b) after; Surface scans of the footprints and berms of the OC and NC tests (right).

These tests focus on the influence of degree of soil consolidation on the sliding foundation response under in-plane loading. The **Figure 2** (right) shows a scanned topography of the footprints after 15 cycles of simulated heating and cooling phases, for both NC and OC clay samples. On the **Figure 3**, detailed results of the effect of the consolidation on the sliding friction and on the settlements.

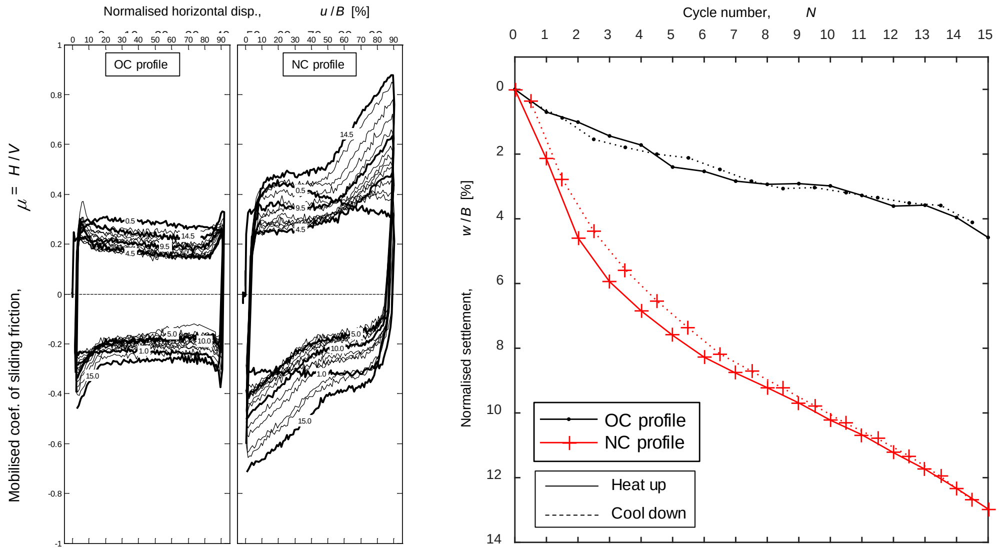

Figure 3. Comparison of the horizontal resistance developed during sliding on OC and NC (left) samples & Accumulated PLET settlements observed during cycles (right).

Conclusions

Pipeline end termination foundations in deep-water developments could benefit from allowing controlled movement of the foundation as a whole during heat-up and cool-down of the associated pipelines. The main challenge in the design of sliding mudmat foundations is the prediction of the foundation trajectory and the forces in the connections throughout the design life of the structure. The reduced-scale (at 1/50) model testing carried out in the Ifsttar's geotechnical centrifuge provided useful insights in the effect of several key parameters on the response of a foundation during large-amplitude sliding.

One of these key parameters is the soil profile (its over-consolidation ratio OCR or yield stress ratio YSR). Over-consolidation of the clay close to the surface leads to reduced settlement during sliding (compared to a normally consolidated case) and the formation of narrower berms. Peaks in horizontal resistance are only observed for the over-consolidated soil profile. Berm collapse is more extensive for the normally consolidated profiles and the PLET will engage the collapsed material earlier.

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