Industry Links

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Keppel Offshore and Marine Technology (KOMtech), Singapore

The link with Keppel Offshore and Marine Technology (KOMtech), Singapore, has been developed through numerous projects and the interaction on the International Standard Organisation's committee on jack-ups. In addition to the longer term research project on hybrid foundation systems detailed in the research reports section, in 2012 Britta Bienen provided expertise on the capacity of skirted spudcans under combined loading based on a numerical study. Christophe Gaudin spent two weeks at Keppel, working with Okky Purwana and Micheal Perry to evaluate the potential of suction caissons to support self-installing platforms in shallow waters.

Development of skirted spudcan for multi layered soils

A series of centrifuge tests performed by Christophe Gaudin and Conleth O'Loughlin explored the feasibility and performance of a novel design of spudcan foundation featuring a peripheral skirt with side openings. The skirted spudcan is designed to be penetrated in particular soil conditions, where a stiff clay layer overlays a loose sand layer. The purpose of the side openings is to enable the clay trapped inside the spudcan skirt to flow outside the skirt, so the skirt can penetrate into the sand layer and develop the required fixities against combined vertical, horizontal and moment loading. It is expected that the spudcan invert would be in direct contact with the sand layer (i.e. all the clay inside the skirt has been expelled) and that the total length of the skirt is embedded into the underlying soil. This assumption is made to ensure, not only maximum fixities, but also resistance against spudcan rocking is provided. Rocking has been identified as a potential issue if clay remains trapped inside the skirt.

Reduced scale models of skirted spudcans, featuring varying skirt lengths, spudcan invert shapes and various configurations of side and top openings were manufactured from stainless steel. A total of eight tests were performed in the UWA beam geotechnical centrifuge under an acceleration of 200g. The model spudcans were penetrated into a soil sample featuring a clay layer 6m thick (in prototype dimensions) with average shear strength of about 15 kPa, overlaying a silica sand layer with relative density of about 40%. During the penetration process, the penetration resistance and the penetration depth of the skirted spudcan were monitored. Live footage and post testing visual examinations also provided insights into the behaviour of the skirted spudcan (Figure 15).

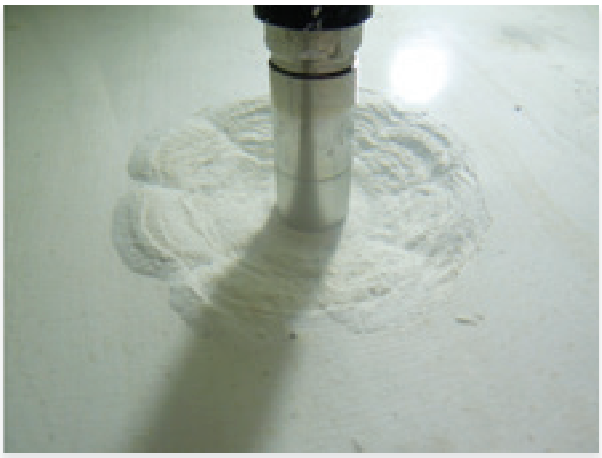

Figure 15: Evidence of soil expulsion through side openings and soil flow around (on top of spudcan)

Delmar Systems, ExxonMobil, Woodside Energy Ltd

Performance of OMNI-Max anchor in calcareous sediments

The OMNI-Max anchor is the latest generation of dynamically penetrating anchor. Its development started in 2004 and it was patented by Delmar in 2006. It is intended to anchor a Mobile Offshore Drilling Unit (MODU), i.e. it is a temporary mooring and as such is designed to be retrieved. The anchor is expected to perform better, in comparisons to standard drag anchors and vertically loaded anchors, or other dynamically penetrating anchors. The OMNI-Max is small, with reduced vessel bollard pull and storage capacity, limited installation time, and a high uplift and out of plane capacity. These latter two advantages result from specific features included in the design of the OMNI-Max anchor; the mooring arm is able to rotate freely about the longitudinal axis of the anchor, resulting in no torsional moment applied on the anchor and no requirement to align the anchor with the pull-out direction during installation. The mooring arm is also strategically located closer to the anchor tip, so the anchor embedment is expected to increase under monotonic pull-out with angle at the padeye lower than 40 degrees. In typical offshore sediments, where the soils strength increases with depth, this type of behaviour implies that anchor capacity is no longer governed by anchor characteristics, but by the tensile capacity of the mooring rope.

A preliminary series of centrifuge testing was performed at UWA in 2010-2011 by Christophe Gaudin, Shazzad Hossain and Mark Randolph to investigate the possibility of modelling the OMNI-max anchor behaviour and performance in a geotechnical centrifuge. Tests were undertaken in kaolin clay and natural silt and demonstrated the feasibility of the modelling and provided information about likely embedment and anchor trajectory in both soils tested.

The success of this preliminary testing campaign triggered the establishment of a Joint Industry Project involving Delmar Systems Inc., ExxonMobil and Woodside Energy Ltd (WEL). The JIP involved testing a new OMNI-Max anchor especially ballasted for the calcareous silt conditions encountered in the North West Shelf of Australia, in soil profiles of interest to ExxonMobil and WEL. This new set of centrifuge tests were the opportunity for Conleth O'Loughlin to develop innovative instrumentation based on piezoelectric and MEMS accelerometer (Figure 16) to measure the anchor acceleration during free fall, deceleration during penetration, and anchor trajectory. A total of five anchors (Figure 17) were tested in four different soils, including one featuring a crust at the top. A new soil reconstitution technique was used to create the crust, for which calcareous sediments were mixed with plaster. Different crust strengths were achieved, depending on the ratio plaster sediment used.

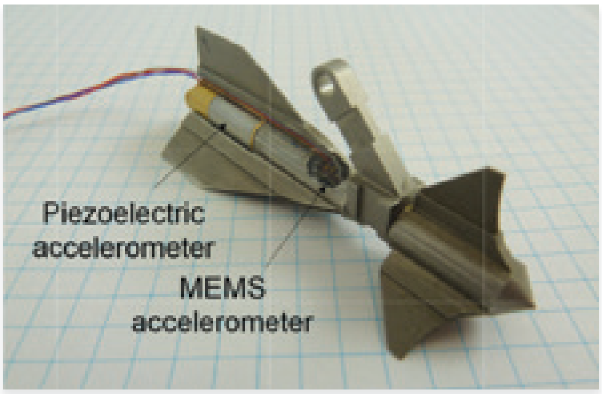

Figure 16: The Model OMNI-Max anchor featuring innovative accelerometer systems to measure both the deceleration of the anchor in the soil and its trajectory during pulling out

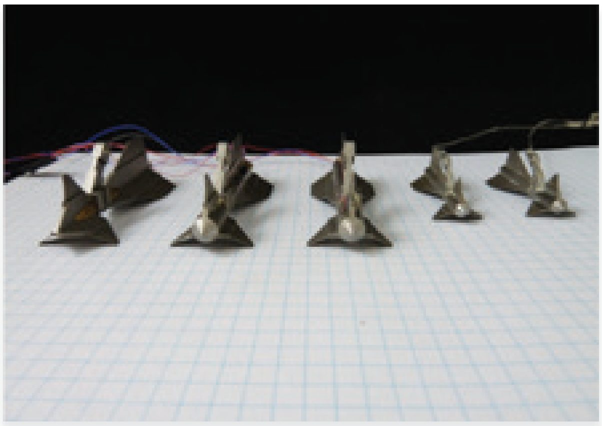

Figure 17: The five OMNI-Max model anchor featuring various amount of ballast and instrumentation

Woodside Energy Ltd, Advanced Geomechanics

Pipe-Soil interaction

Fraser Bransby from Advanced Geomechanics has been collaborating with Conleth O'Loughlin and Christophe Gaudin to provide a set of model test data to assist AG in the developing suitable pipe-soil interaction models for a Woodside project. Following an initial centrifuge modelling program in 2011, a second series of tests were undertaken during June and July 2012 that focused on partially drained and undrained conditions in calcareous silty sand. A highly instrumented model pipeline featuring 6 pore pressure transducers located around the pipe surface was used to assess the pore pressure response. The experimental program included 20 tests, featuring different installation sequences, followed by lateral movements representing buckling or hydrodynamic stability events. In some tests, random storms were modelled by imposing a time history of drag and lift forces on the model pipe.

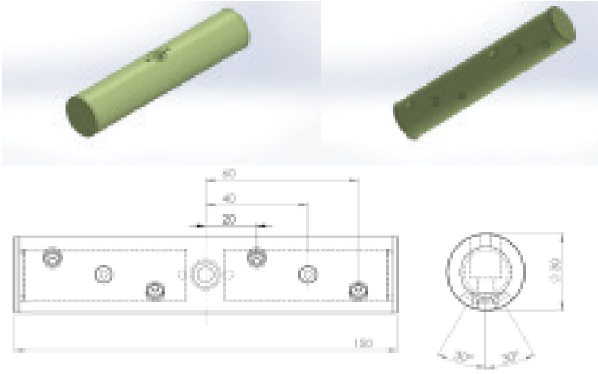

Figure 18: Sketch of the model pipe and the pore pressure transducers

Industry-funded Skirted Foundation Project

Christophe Gaudin, Conleth O'Loughlin, Susan Gourvenec and Steve Neubecker from AG have been collaborating to assist the design of a skirted foundation for a project offshore Australia. The foundation design consists of a skirted foundation with internal compartments. The model was heavily instrumented to monitor pore and total pressures along the skirts and at the foundation invert, and the foundation displacement and rotation about the X, Y and Z axes. A series of 6 centrifuge tests were performed, which aimed to investigate the foundation response under monotonic and cyclic loading in vertical, horizontal and inclined directions. The centrifuge soil samples were reconstituted from silt taken from bulk samples retrieved offshore and exhibited strength characteristics similar to those measured in-situ.

Gapping along the foundation skirt-soil interface was studied and the cyclic loading sequences mimicked 10-year, 100-year and 10,000-year cyclonic storms relevant to the project. Cyclic conditions with mean compression and mean tension were simulated. The results demonstrated the level of suction generated during cyclic uplift loading, the effect on the overall foundation capacity, and provided information regarding gapping at the skirt interface.

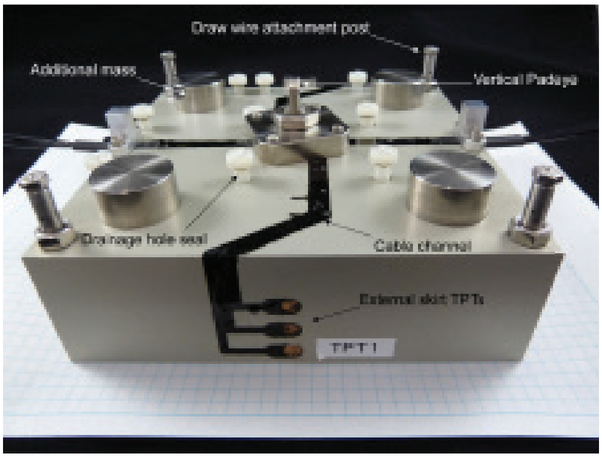

Figure 19: The model skirted foundation with its instrumentation

Subsea7

Subsea mudmat optimisation under 6 degrees of freedom loading

A collaboration led by Susan Gourvenec, Mark Randolph and Xiaowei Feng at COFS and Regis Wallerand at Subsea 7 focused on development of a design methodology for subsea mudmat foundations under 6 degree-of-freedom loading continued throughout 2012.

The design methodology is calibrated for rectangular mudmats with aspect ratio B/L = 0.5, embedment ratios d/B from 0 - 0.2 in soils with a range of linearly increasing shear strength with depth (Figure 20). Subsea 7's publication Deep7 reported that the design method has resulted in the potential to reduce the size of subsea mudmats by up to 20%, or the potential for a mudmat of specified size to withstand larger jumper loads.

The design methodology is being extended to incorporate a new 'hybrid subsea foundation' (HSF), that involves a mudmat augmented with corner pinned piles.

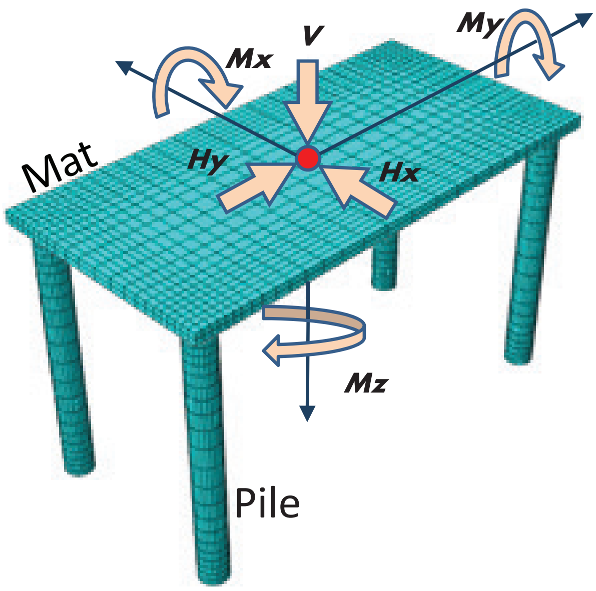

Figure 20: Configuration and loading conditions for hybrid subsea foundation (HSF)

ROV-Mounted measurement

Sam Stanier, Santiram Chatterjee and Dave White have been working collaboratively with Paul Brunning of Subsea7 on the development of an ROV-mounted device to measure the resistance between the seabed and infrastructure such as pipes and chains. The concept is that these tools are laid onto the seabed before being dragged axially by a custom-designed ROV tool, whilst the tow force is monitored.

Data is logged during the tests using the DigiDAQ data acquisition system previously developed at COFS. In this study, DigiDAQ is making its debut offshore. The system is housed in a sealed enclosure able to withstand submersion offshore, with Subconn waterproof connectors providing live data and power connectivity to the ROV. Tests can be monitored by the ROV pilot from the surface vessel and data is transmitted in real time. Figure 21 shows Sam Stanier performing preliminary tests with the device on dry land at a COFS test site, while Figure 22 is a close up of a flat plate tool during a drag test. The device is currently being prepared for deployment offshore. This field data will extend two previous studies performed for Subsea7 investigating seabed friction in previous phases of our collaboration.

Figure 21: Preliminary testing of the device on 'dry land'.

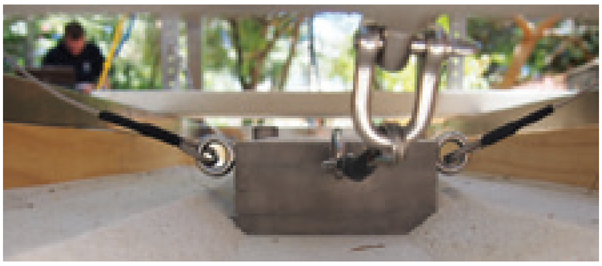

Figure 22: Close up of flat plate tool during a drag test.

Woodside Energy Ltd: Pipe-soil fluid interaction

The O-Tube research team completed their input to Woodside's life extension study of the first trunkline to the North Rankin A platform. This work, reported in the Journal of Pipeline Engineering, showed how O-Tube data was used to validate numerical modelling of the trunkline. This demonstrated that the pipeline was sufficiently stable, despite conventional code checks indicating otherwise. This work led to Liang Cheng, David White, Hongwei An and Chengcai Luo receiving recognition through multiple industry awards during 2012, along with their industry colleagues for the 1TL work by Eric Jas and Dermot O'Brien at Atteris.

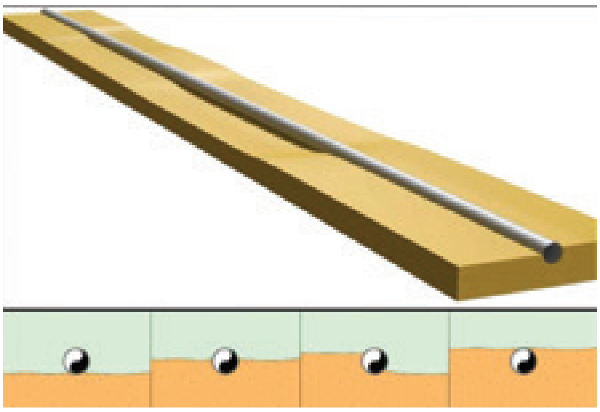

Figure 23: A reconstruction of the burial state of the 1TL pipeline (Jas et al. 2013)

STABLEPIPE JIP

COFS and UWA's School of Civil and Resource Engineering continued to participate in the STABLEPIPE Joint Industry Project. This JIP, operated by Woodside in collaboration with Chevron and J P Kenny, is developing new techniques for the stability design of pipelines. Experimental studies using the large and small O-Tubes provide evidence to support new procedures that treat seabed mobility as a key behavioural mechanism controlling pipeline stability. The first two phases of the JIP are now complete and a third phase is planned for 2013 and beyond. UWA's contributions are led by Liang Cheng, and supported by David White, Scott Draper and Hongwei An. The STABLEPIPE activity was showcased to industry in a one-day workshop held at UWA during November 2012. The outcomes to date were presented to thirty participants from local Operators and consultants and a future research plan was developed.

SAFEBUCK JIP

COFS continued to contribute to the SAFEBUCK JIP through continuing studies into the pipe-seabed interaction modelling, with David White working in collaboration with Chris Martin and Byron Byrne of Oxford University. A revision of the SAFEBUCK Guideline has recently been issued, with COFS contributions including improved design methodologies for assessing pipe-soil interaction parameters for buckling and walking design.