Offshore engineering science

In this research stream theoretical models advanced geotechnical models and new numerical techniques were used in applied offshore engineering topics such as loading, design and response of offshore oil and gas platforms and risers, together with work on marine renewable energy and scour around subsea infrastructure.

In this section we present some specific design projects which were advanced during 2012, and group them into work on submarine risers, jack-up platforms, scour and sediment transport around subsea infrastructure and marine renewable energies. Other progress is reported separately in the O-Tube facility report on page.

Risers

Fatigue design of steel catenary risers in the Touch Down Zone

PhD student Lucile Quéau, continued her numerical studies aiming to quantify the dynamic response of steel catenary risers (SCRs) in the Touch Down Zone (TDZ) relative to the static response by defining a dimensionless factor: the dynamic amplification factor (DAF). Her research focused most recently on developing a simple and accurate analytical framework to predict the static response of SCRs, which is a pre-requisite to the DAF approach. She extended an existing analytical model to accommodate the displacement of the upper end of SCRs in order to assess the static stress range along the entire length of the riser. This model uses a boundary layer solution in the vicinity of the Touchdown Point (TDP, where the riser first touches the seabed) and a Winkler type soil model in the riser-soil contact area. Numerical simulations in OrcaFlex software were performed to validate the results. This analytical framework, namely ETFM (Extended Three Field model), was developed further for lazy wave catenary riser (LWRs) applications to broaden the scope of the DAF approach. LWRs are SCRs with a buoyant section that improves fatigue performance of the TDZ. Figure 109 presents two different base cases (BC1 and BC2) used to validate the ETFM. Normalised stress range distributions evaluated in OrcaFlex and through the EFTM are compared in Figure 110. Despite the local discontinuities at both ends of the buoyancy catenary that are inherent to the type of equations used in EFTM, a good agreement between OrcaFlex and ETFM is observed overall and in the TDZ in particular. Results of this study will be presented by Lucile at the upcoming OMAE conference in 2013.

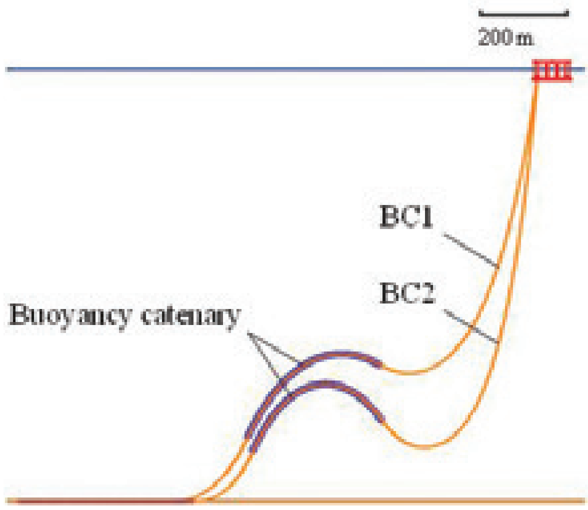

Figure 109: Illustration of the LWR configurations (superimposed view)

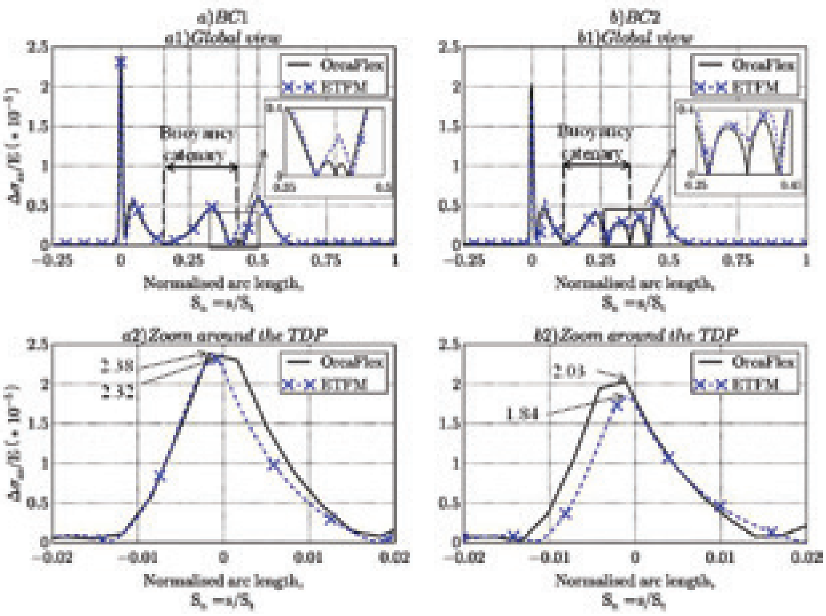

Figure 110: Comparison of the normalised stress range distributions on a global and a local scale in the vicinity of the TDP

Lucile has also developed numerical tools to automate the simulations performed by OrcaFlex software and link OrcaFlex with optimisation software to assist her future sensitivity studies, enableing evaluations of DAF values.

Masters student Rasoul Hejazi completed his work on ‘replacement of the complex nonlinear riser-soil interaction with equivalent soil stiffness for fatigue design purposes’. Rasoul, Quéau and Mehrdad Kimiaei worked on contributions of some selected key input parameters for evaluation of the equivalent linear soil stiffness. A good match for stress range results between nonlinear and equivalent linear soil models for an example case is shown in Figure 111.

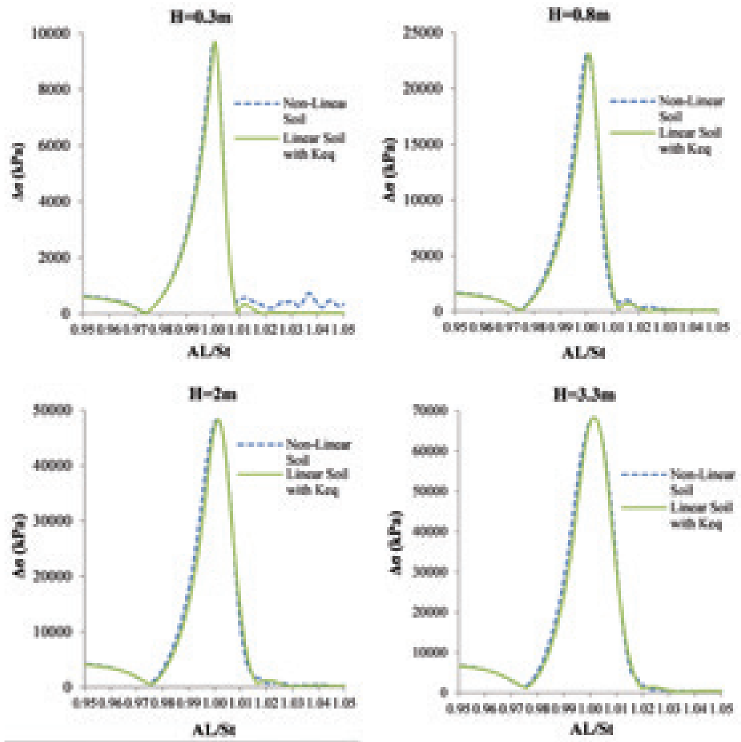

Figure 111: Comparison of the stress range distributions around TDP between nonlinear and equivalent linear soil models

Fluid-soil-riser interaction at Touch Down Zone

A SCR laid on the sea floor and connected to a floating vessel at the sea surface is continuously subjected to cyclic loads due to displacement of the floating vessel and direct fluid forcing on the riser. In the Touch Down Zone (TDZ), this can result in a complex interaction between three different domains: the riser section, seawater around the riser, and the sea bed soil underneath the riser.

Ehssan Zargar, started his PhD studies on Fluid-Riser-Soil Interaction in June 2012,primarily focusing on better understanding interactions between riser and the surrounding media (soil and fluid) in the TDZ. The main areas for this study are: riser-soil interaction, riser-fluid interaction and fluid-soil interaction. FVM (Finite Volume Method) is the main technique for the planned numerical studies in this research. All simulations will be carried out using FLUENT software combined with UDFs (User Define Functions) for different parts of simulations.

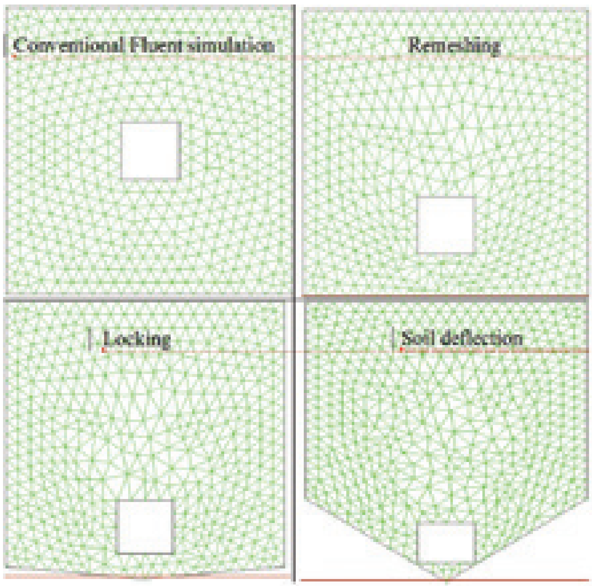

Figure 112: Schematic views for FLUENT simulation in FSR interaction

Ehssan has developed a series of UDFs in: remeshing seawater (when the riser moves towards seabed), boundaries locking (when riser gets very close to seabed) and seabed deflection (when the riser physically touches the seabed). Figure 112 shows main steps of FLUENT simulation in a fluid-riser-soil interaction problem. He is currently working on a new hysteretic soil model which eventually would be able to model trench formation and degradation in the soil properties during penetration and uplift cycles. In completion of this model, he will develop a UDF for seabed boundaries which simulates the soil deformation for each penetration-uplift cycle of the riser motion. Advection and induced vortices around the risers (due to current profile passing over the riser and/or oscillations of the riser), as typically shown in Figure 113,

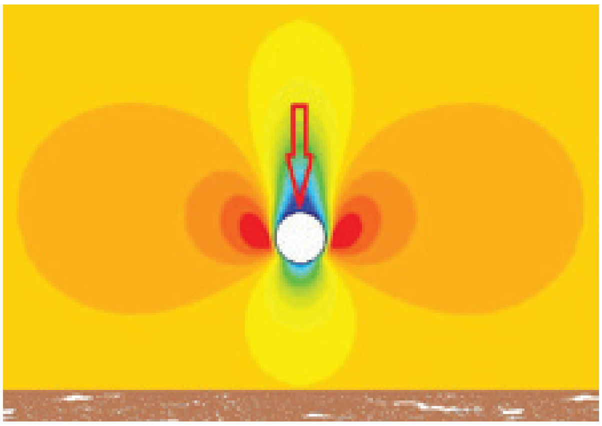

Figure 113: Contours of water particle velocities around an oscillating riser

impose extra shear stress on the soil at the sea floor. If this shear stress is significant, it can initiate erosion in the soil domain and sediment transportation in the fluid domain. Another UDF will be developed here to solve sediment transportation equations to model scouring underneath the riser. As shown in Figure 114, Ehssan will merge these two major UDFs (soil deflection as a result of riser–soil interaction and soil erosion as a result of fluid-soil interaction) in the main FLUENT module to model the whole phenomena.

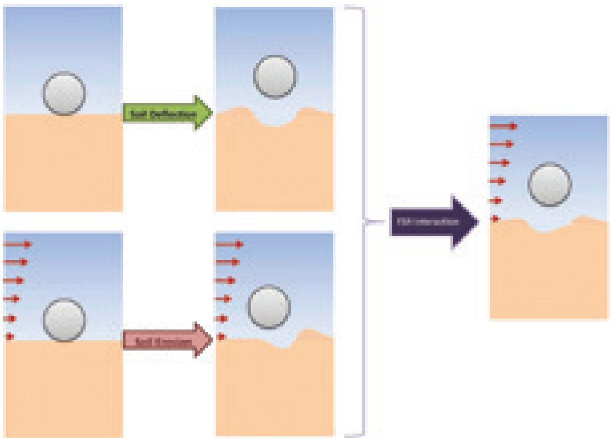

Figure 114: Merging soil deflection and soil erosion UDFs in FSR interaction

Marine renewable energies

Laboratory scale experiments and preliminary modelling to investigate basin scale tidal stream energy extraction

Scott Draper completed collaborative work conducted through the Energy Technology Institute, UK which involved a set of model scale laboratory experiments to investigate tidal stream energy extraction in a tidal channel and close to a coastal headland. The experiments were the first ever conducted at such a large scale, and provided insight into the 'blockage' effect that tidal stream devices can use to extract power more efficiently in a confined channel. The experiments also provided clear insight into the effect of the energy extraction on natural tidal currents, which is of significant importance to properly assess environmental effects. The project also made comparisons, for the first time, between experimental results and depth-averaged numerical simulations (which are commonly used to predict the effect of tidal stream devices in coastal locations). The results suggest that depth-averaged models well represent the drag offered by tidal devices, but fail to completely capture the velocity deficit (and the wider flow field) behind the devices, where vertical and horizontal mixing is important.

Renewable energy from tidal stream energy devices in the Pentland Firth (a.k.a. the 'Saudi Arabia' of tidal stream energy)

The Pentland Firth, a strait of water separating the UK mainland from the Orkney Islands, (see Figure 115) is arguably the most well-known tidal stream energy site in the world. Recent research at COFS has produced the first theoretically correct estimate of the tidal stream energy resource of the Pentland Firth. The work was undertaken by Scott Draper in collaboration with Thomas Adcock from the University of Oxford, UK. Their research highlighted the variability in the energy resource of the Pentland Firth and, for the first time, has shown and explained the interaction in energy extraction that would be expected between isolated deployments of tidal stream devices within a complex tidal channel. This explanation is of significant importance given the UK Crown Estate's present plans to lease separate sites to different tidal stream device developers within the Pentland Firth.

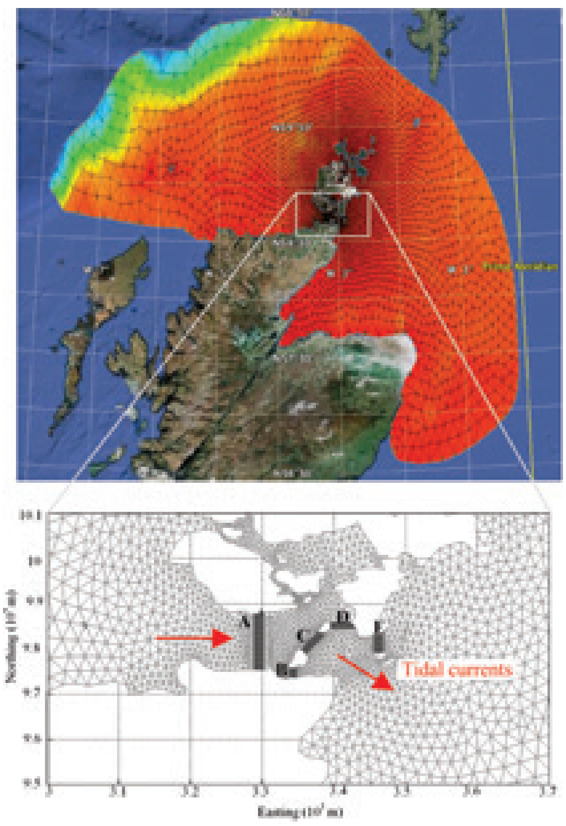

Figure 115: Map of the Pentland Firth, UK. Colour shading at top indicates bathymetry (i.e. water depth). Below, sections A through E indicate locations where tidal energy extraction has been modelled

The work involved the construction of a numerical model of tidal currents around the North of the UK (Figure 115) together with the development of analytical models to capture the fundamental physics and interpret the numerical model.