Georisk techniques

Through the Lloyd's Register Foundation Chair and the new GeoRisk theme in the ARC Centre of Excellence for Geotechnical Science and Engineering we are building up research projects within geotechnical risk and reliability. We have been fortunate to have Dr Marco Uzielli of GeoRisk (Florence, Italy) as our frequent guest in Perth, and together we are conducting research using the Random Finite Element Method, Bayesian statistics analysis of spudcan punch-through events and in transformation modelling.

Yinghui Tian, Mark Cassidy and Marco Uzielli combined the soil random field generation and Finite Element simulation (using ABAQUS) to produce a Random Finite Element Method (RFEM) package. They employed this package to study the combined loading (V, H and M) envelope of offshore foundations in a probabilistic framework. 1000 realisation of random fields of the soil with spatially varying heterogeneous undrained shear strength were generated. A Monte Carlo framework has allowed the size and shape of VHM failure envelopes to be defined for distinct levels of their probability of occurrence. These provide guidance for the reliable design of strip footings on clays in heterogeneous soil conditions, and have particular application offshore where horizontal and moment loads can be proportionally large. Figure 49 shows the failure mechanisms under pure uniaxial loading V, H and M.

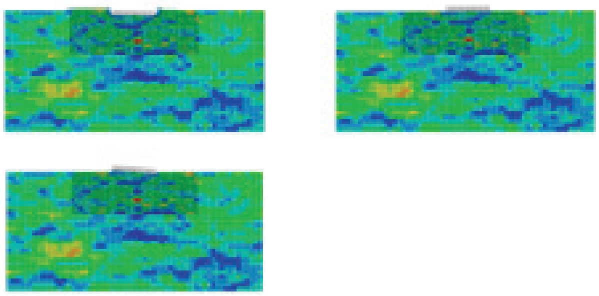

Figure 49: the failure mechanisms under pure uniaxial loading V, H and M

In another application we have concentrated on the probabilistic assessment of the resistance factor for bearing capacity for a strip footing on a stiff-over-soft clay profile. Again, analyses were performed by applying the Random Finite Element Method, which combines finite element simulation, spatial variability analysis and Monte Carlo simulation. Undrained strength values were assigned to the finite element meshes on the basis of quantitative estimates of the vertical and horizontal spatial variability and the probabilistically modelled scatter of undrained strength itself. The stochastic implementation of the numerical analyses resulted in samples of bearing capacity factors which, when normalised by a deterministic bearing capacity factor, provide a set of tabulated factors calibrated to user-defined target reliability levels. These results have application for the prediction of foundation punch-through, where the footing pushes the upper strong layer of soil into the softer clay beneath, and will be presented at the ISSMGE conference in Paris 2013. Further cases of differing spatial variability are currently being investigated.

A collaboration between Marco Uzielli, Paul Mayne (Georgia Tech) and Mark Cassidy has called for a simple design code format for assigning design values of effective friction angle of clean sands from in-situ tests incorporating all sources of geotechnical uncertainty, including model uncertainty. The new transformation models used a high-quality database of undisturbed sands (provided by Georgia Tech). The quantitative characterisation of uncertainty was pursued using a Bayesian hybrid Markov Chain Monte Carlo simulation framework and design factors were calibrated using the posterior distributions output by the Bayesian framework. In a paper published in a special issue of *Advances in Soil Mechanics and Geotechnical Engineering* we discussed the effects of the aleatory and epistemic components of geotechnical uncertainty and assessed it quantitatively. We also demonstrated how to apply the results practically in geotechnical design.

Figure 50: Mud, glorious mud: Marco and Mark taking some advice on geotechnics in Tuscany

A project seeing the participation of Marco Uzielli and Mark Cassidy is underway to provide prior and in-operation estimates of the probability of punch-through of spudcans in stiff-over-soft clay stratigraphies using a Bayesian framework. "Prior" probabilities of occurrence of punch-through (i.e., before installation) will be assigned spatially for couples of depth-load values. Subsequently, during installation, monitoring data will be used to update probability values on the basis of presumable load-displacement curves. Uncertainties in geometric and geotechnical parameters are addressed explicitly, parameterised probabilistically and propagated in analytical models for estimating punch-through depth and load using

Monte Carlo simulation. Models used in the algorithm rely on LDFE numerical analyses performed by Shazzad Hossain. Figure 51 shows an example of application of the method.

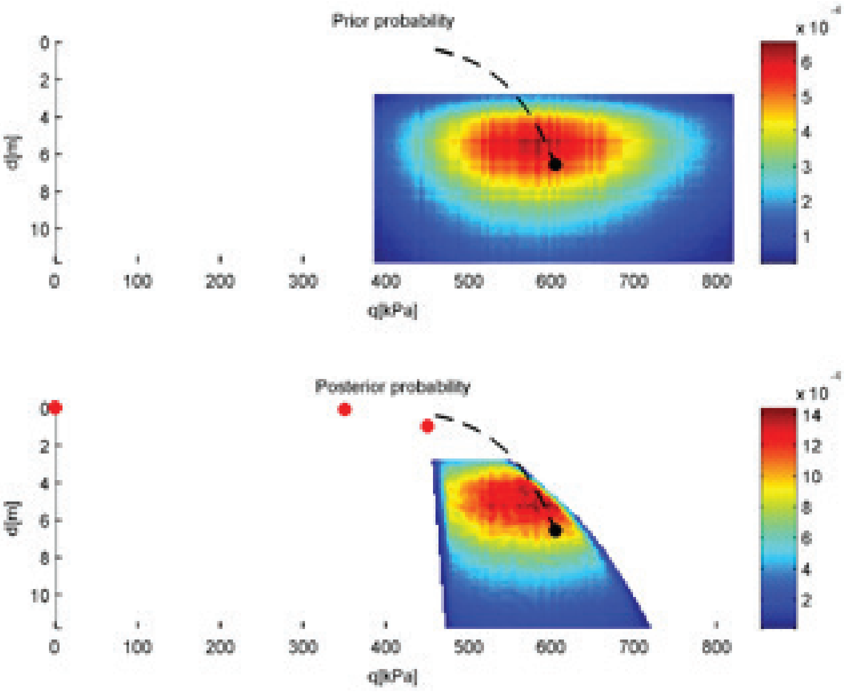

Figure 51: An example of an application on LDFE numerical analyses

Probabilistic models for dynamic collapse of jack-up platforms under extreme waves

PhD student Jalal Mirzadehniasar continued his studies in probabilistic response of jack-up platforms subjected to extreme dynamic wave loads. The aim of this study is to investigate the ultimate strength and failure mechanisms of jack-ups exposed to extreme waves, considering soil-structure interaction effects.

Using USFOS software, a series of dynamic time history analyses were carried out on an example jack-up platform subjected to randomly generated CNWs (Constrained NewWaves) as well as three hour random waves. USFOS models used in this study were able to capture structural nonlinear behaviour and spudcan-soil interaction models as recommended by SNAME code. Figure 52 and Figure 53 show schematic views of a typical structural collapse and VHM yielding and bounding surface of a jack-up foundation respectively. The code developed by Jalal, was used to generate Constrained NewWaves and random wave profiles based on a given wave spectrum.

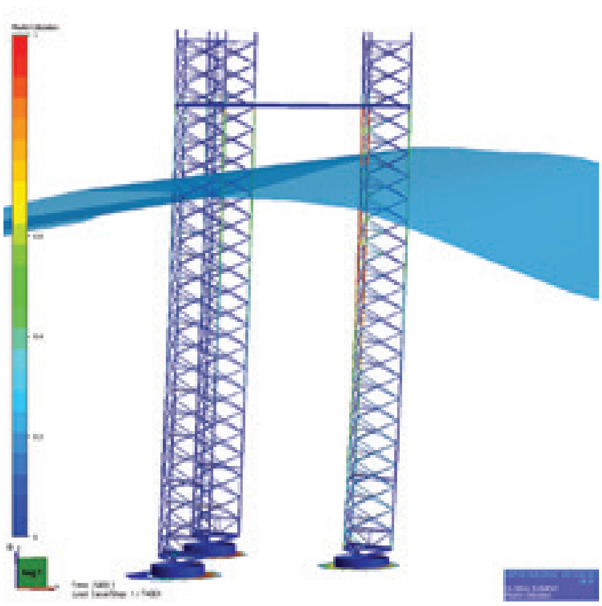

Figure 52: Typical structural collapse of a sample jack-up platform

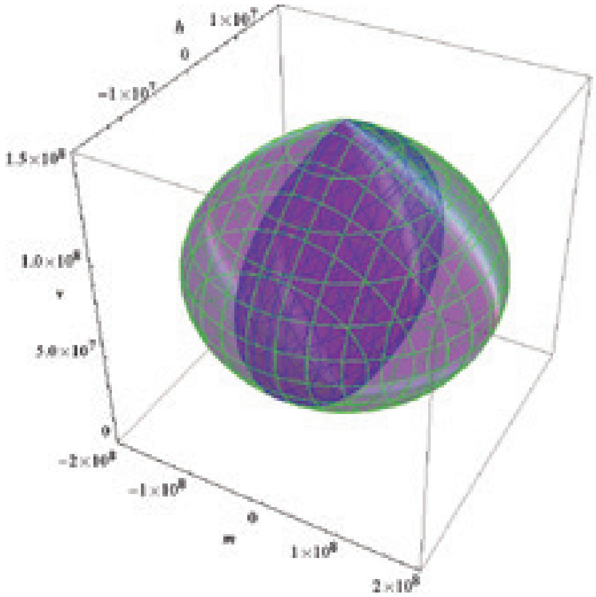

Figure 53: VHM yielding and bounding surfaces of a sample Jack-up foundation

A detailed study has been carried out on the dynamic response and on failure mechanisms of the whole system. For this aim, a series of wave crest heights with an even distribution have been selected to cover a wide range of probable crest heights in the given sea state. For each crest height, 100 CNWs were generated and the structural response (maximum deck displacement here) under these waves was assessed. Then probability distribution of the response of structure for different crest height and consequently the probability distribution function of structural response were estimated. In addition, based on the failure cases observed for each crest height, a limit state in the maximum deck displacement has been assumed as the failure threshold, therefore the structural failure surface as a function of the crest height has been generated.

Numerous three hour random waves were also generated and the maximum crest height distribution was estimated. Using PROBAN software and Monte Carlo simulation, structural response and structural failure distributions were assessed and then the probability of overall failure for the given sea state was calculated. For example, for an extreme wave with Hs=20.6m and Tz=12.6s, the probability of the overall failure of the studied platform was 1.26%. Statistical characteristics of the structural response distribution, as shown in Figure 54, were also evaluated.

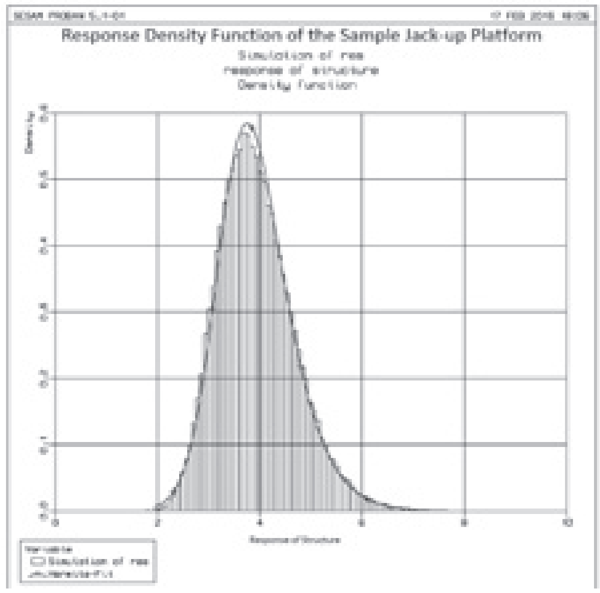

Figure 54: Response density function of a sample Jack-up platform