Physical modelling techniques

The problems that COFS' researchers are addressing experimentally are becoming more and more complex. The Physical Modelling Techniques research stream attempts to stay abreast of this complexity by developing innovation in actuation control, data measurement systems and model development techniques.

Our most notable achievements during 2012 include improvements to our PIV apparatus, which allows higher image capture rates and real-time 'PIV-image' viewing, the introduction of miniature MEMS and piezo accelerometers for measuring deceleration of dynamically installed 'torpedo anchors' and the use of a combined vertical, horizontal and moment loading actuator.

Next Generation PIV apparatus

During 2012, Sam Stanier and Dave White developed a 'next generation' PIV apparatus for the drum centrifuge. This system (shown in Figure 42) comprises of a small format 5-megapixel resolution camera and lens assembly capable of capturing up to 15 frames per second over a gigabit Local Area Network (LAN). Lighting is provided by two LED light bars controlled via a LAN based control unit, facilitating in-flight control of the brightness of each panel to ensure even exposure in images recorded by the system. Connectivity between the tool table of the centrifuge and the logging computer in the control room is handled by a fibre-optic slip ring assembly that sits on top of the tool table. Custom LabVIEW software has been developed to control both the camera and lighting in-flight, screenshots of which are shown in Figure 43. The capabilities of this new system are a significant upgrade on the previous system, largely due to the superior control and the improved image capture rate. During 2013, it is planned that similar apparatus, based on the same hardware, is developed and added to the repertoire of the beam centrifuge.

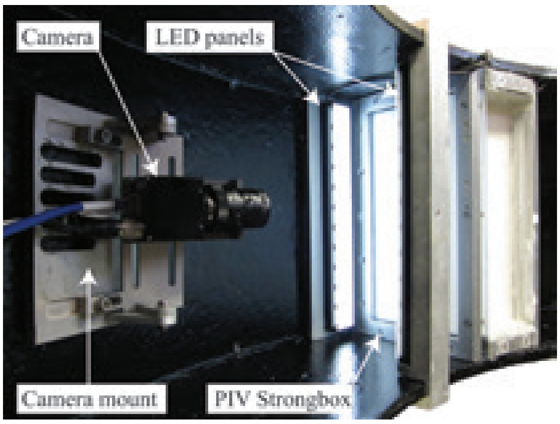


Figure 42: 'Next generation' PIV apparatus installed in the drum centrifuge channel

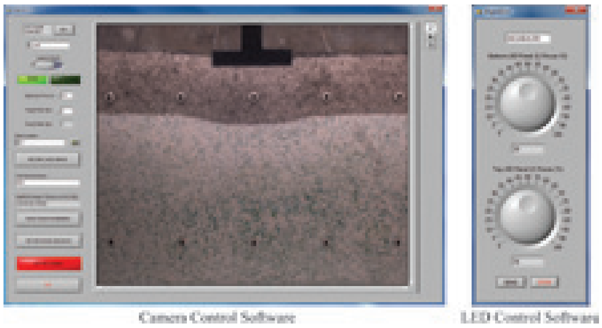


Figure 43: Custom camera and lighting control software, developed in-house at COFS for the new PIV apparatus

Piezo and MEM accelerometers

Measurement of the velocity of dynamically installed 'torpedo anchors' during penetration in soil is important to understand how very high strain rates (up to seven orders of magnitude higher than in standard laboratory element tests) affect the penetration resistance and impacting final burial depth. After failed attempts in the past, COFS had a breakthrough in 2012 with the use of MEMS (Micro-Electro Mechanical System) and piezo accelerometers. An example MEMS acceleration trace captured at 50,000 samples per second is shown in Figure 46a. In this test the anchor was released from 250 mm above the sample surface and after impacting the soil decelerates sharply before coming to rest. Numerical integration of the acceleration data yields velocity (single integration) and depth (double integration), allowing the velocity of the anchor as it penetrates the soil to be determined. Figure 46b shows an example velocity profile together with independent measurements of the velocity during freefall using photo-emitters and photo-receivers. Such velocity profiles are important to allow for the calibration and validation of embedment prediction tools for dynamically installed anchors.

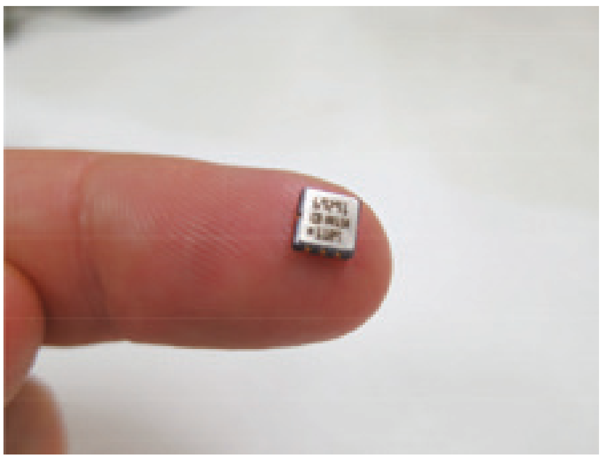


Figure 44: A ± 500 g MEMS accelerometer

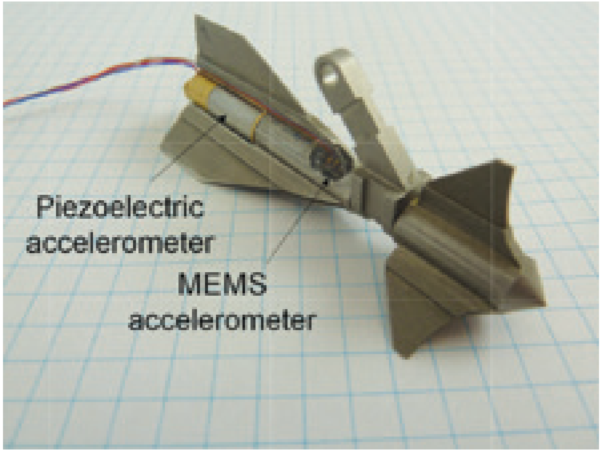
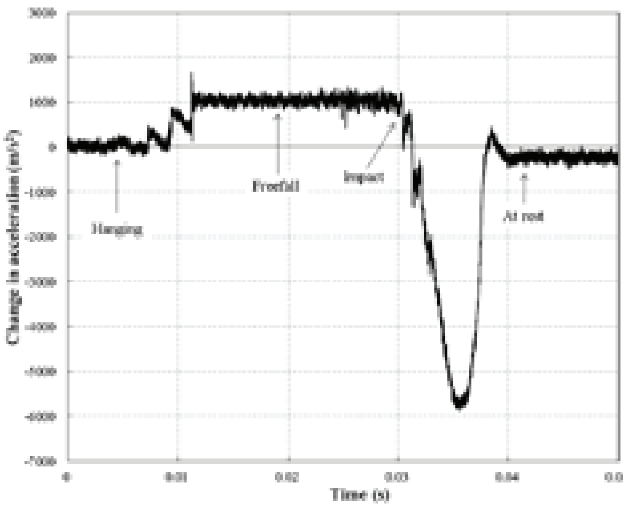


Figure 45: Accelerometers installed in a dynamically installed OMNI-Max anchor

(a)



(b)

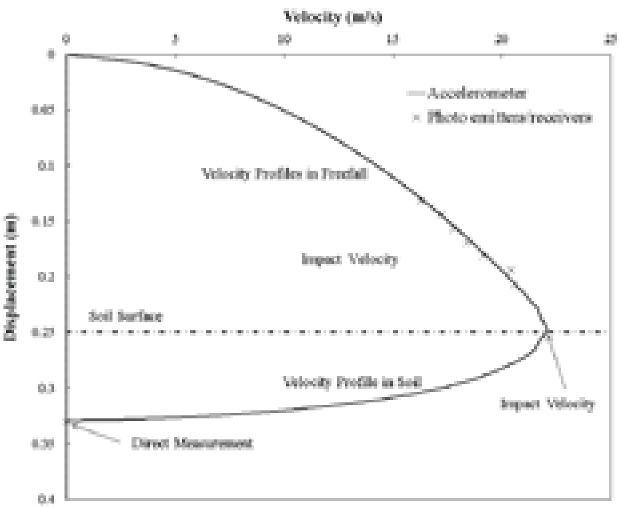


Figure 46: Example data from an anchor drop in the beam centrifuge: (a) acceleration trace, (b) velocity profile

VHM actuator

Work continued on the new vertical, horizontal and moment (VHM) actuator developed for the drum centrifuge by the COFS technical team, Youhu Zhang, Britta Bienen and Mark Cassidy (Figure 47). The VHM actuator permits independent and accurate control of model displacement in vertical, horizontal and rotational directions. Displacement controlled tests known as 'swipe' and 'radial displacement' tests were carried out to investigate the VHM yield surface and plastic flow rule of a spudcan at different embedment depths. PhD student Youhu Zhang utilised the VHM actuator to investigate the combined loading behaviour of spudcan foundations in soft clay. Figure 48 shows a typical set of five swipes against a fitted yield surface performed at a certain embedment depth. Complemented by the theoretical solutions for elastic response and existing method for vertical load-penetration response, the experimental results were used to develop a plasticity foundation model that is appropriate for spudcans in soft clay.

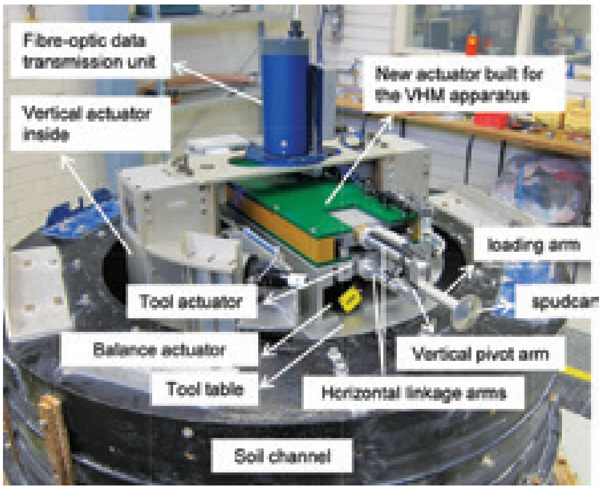


Figure 47: VHM loading apparatus for the UWA Drum Centrifuge

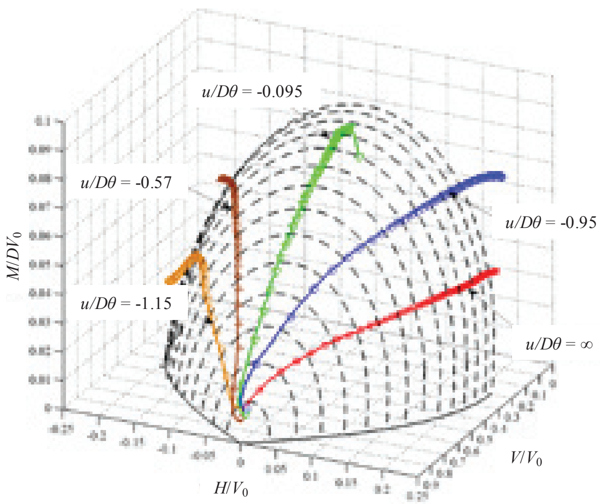


Figure 48: Typical swipe test results