The ROV in Nearshore Site Investigation

Nearshore engineering surveys are undertaken for the purpose of gathering information pertaining to the bathymetry and morphology of the seabed, along with the geotechnical characteristics and geophysical profiles of the sub-stratum. Standard practice tends to involve a low-resolution bathymetric and sub-bottom survey of the approximate area of interest, followed by a higher-resolution, site-specific investigation entailing detailed analysis of the location and form of the materials present.

The traditional survey technique in the nearshore region is to use surface towed equipment and jack-up rigs, with diving teams and ROVs (Remotely Operated Vehicles) acting as support systems, performing very basic investigation tasks.
However, the potential for expanding the capabilities of these supplementary systems is vast, with the possibility of offering them the opportunity to acquire high-resolution survey data in their own right.

Nearshore Survey
A vast range of investigation techniques is employed in the offshore survey environment to acquire data pertaining to the surface bathymetry and morphology and sub-seabed sediment characteristics. Survey in the nearshore or coastal zone, however, presents problems not met in deeper open waters and translation of the current survey techniques is not always straightforward. Restricted access, manoeuvrability, traffic movement and the physical impact of waves and tidal activity define the nearshore environment addressed in this study, and present obstacles to survey.
Although a comprehensive range of survey and testing techniques may be operated in nearshore surveys, some are less adaptable than others. Cone penetration testing and sediment coring are fundamental to geotechnical site investigation and at present the devices used are cumbersome and require large stationary surface vessels for deployment. Sub-bottom profiling using seismic methods may be adapted to meet the restrictions of manoeuvrability but information cannot easily be collected within restricted access areas.
An alternative to surface-based survey techniques is the utilisation of ROVs, which offer the manoeuvrability to penetrate previously inaccessible regions. Unlike large surface vessels, an ROV may survey beneath fixed or floating obstructions and may be fitted with a range of equipment at any one time. As a safer alternative to divers and a more adaptable alternative to AUVs, ROV-based survey is currently an undervalued solution to many nearshore survey problems.
The possibility of creating an integrated ROV survey system should therefore be considered, with particular reference to cone penetration testing, sediment coring and sub-bottom profiling.

Proposed ROV
Given the manoeuvrability restrictions inherent to the nearshore zone, the ROV would need to be small enough to gain access to restricted spaces but large enough to carry and operate equipment independently. The University of Plymouth Deep Ocean Engineering Phantom XTL (Figure 1) is a small and highly manoeuvrable ROV that is most often used as an investigation tool, with limited scope for equipment operation due to the low payload capacity. The Phantom has a video camera and positioning system, which allows the user on the surface to pinpoint its location and to view in â€˜real-timeâ€™ the activities on the seabed or within the water column.
These very basic properties offer the user a great deal of potential when developing an equipment platform. The ability to accurately pinpoint equipment is invaluable, with many current systems relying on layback calculations from a surface vessel. Not only can the equipment be positioned when in situ but it can also be deliberately placed at a specific test site. Large surface-deployed landing frames are lowered to position at the approximate location but cannot adjust position when on the seabed. The added benefit of monitoring equipment activity allows the surface operator to ensure that all systems are running smoothly, aiding quality control. Furthermore the â€˜real-timeâ€™ link to the surface offers the operator the opportunity to â€˜hand-pickâ€™ test locations, with the ROV acting as a reconnaissance tool.
The development of the Phantom as a base for geotechnical and hydrographic investigations in the nearshore zone is limited by one fundamental property: weight. The Phantom is designed to be neutrally buoyant, thus allowing for flexibility in movement. Geotechnical investigations require a stable platform for testing and so require significant down force. With a low weight and limited thruster capabilities, the Phantom is not powerful enough to carry or operate the equipment being developed. Furthermore, limited thrust capacity limits manoeuvrability in the potentially tidally active and wave-dominated nearshore zone.
A simple bottom-crawling tracked ROV is proposed as a solution; a system that may be deployed from the shore or from a surface vessel and can survey the seafloor whilst remaining stable enough to perform in situ testing. A system measuring 1m in length by 0.6m in width with two 0.2m wide tracks is suggested as the base, a size which corresponds well with the Phantom.

Cone Penetration Testing
The ability to acquire in situ strength data is invaluable in the geotechnical industry. Removal of sediment through coring for subsequent laboratory testing imposes disturbance and alters the sediment matrix and strength characteristics. Cone Penetration Testing (CPT) is commonplace in terrestrial and offshore marine surveys and can be undertaken in the nearshore zone with the use of jack-up rigs or landing frames. The access of large vessels to sites in the near-shore zone may, however, restrict testing locations to open channels, limiting the range of data acquired. In order to extend the range of CPT testing, the possibility of using an ROV-mounted system was researched.
Flow-round systems, as developed by Stewart and Randolph (1991), offer the possibility of acquiring high-resolution in situ strength data in material of low, undrained shear strength. The study focused on the T-bar system and an ROV with a weight of 260kgf and assessed the

possibility of acquiring strength data. It was found that a T-bar system measuring 6cm in length and 0.9cm in diametre, with a shaft diametre of 0.8cm, would require a base weight of 175kgf for penetration, increasing to 260kgf with a 50 per cent stability component (Figure 2). If a 1.6kN load cell were used, a resolution of 0.73kPa could be achieved when testing in sediment up to 300kPa undrained shear strength.

Measurements in sediment of higher shear strength could be undertaken using a 1cm2 mini-cone. With a 260kgf ROV, the mini-cone could acquire strength data in sediments with undrained shear strengths of up to 1215kPa. Although this adaptation allows the system to be used in a wide range of sediments the potential error range for a test undertaken in material with an undrained shear strength of 1215kPa is 850kPa (+ 425kPa).

Sediment Coring

The problems associated with in situ testing, such as the ability to acquire data to a high enough resolution given the local conditions, can lead to the requirement for additional laboratory-based investigations. Even without the requirement for comparison with in situ data, laboratory analyses allow for comprehensive ground truthing of data acquired remotely including side-scan sonar and sub-bottom profiler data. Sediment samples may either be collected in an obviously disturbed state through techniques such as grab sampling, or through more contained methods including piston and vibro coring.

Index properties of sediments are those which do not rely on the maintenance of the sediment matrix but are intrinsic to the particles. These form the basis of many laboratory investigations, from particle size analysis to organic matter content. The sediment shear strength is an example of a structural property and is altered by sediment disturbance during sampling and subsequent handling and testing. If sediment coring is to be undertaken for lab testing, it is important not only that the mechanism acquires sufficient sediment but that it is designed to impose the minimum disturbance possible. A sediment corer was designed which would allow samples to be collected from the proposed ROV in areas previously inaccessible, using current sampling techniques.

The sediment corer developed utilised a pneumatic mechanism to drive a core tube into the sediment and also to enable retrieval of the tube (Figures 3 and 4). By using the core tube as the piston, the system was designed to be 0.9m in height, allowing acquisition of samples up to 0.6m in length. Marine-grade stainless steel (316L) core tubes of 38mm internal diametre were utilised to ensure that samples could be used for triaxial testing. A wall thickness of only 1mm limited sample disturbance caused by friction forces at the sides of the tube. Minimal down force was required to maintain ground contact and the system successfully acquired samples in sediment with undrained shear strength of 17kPa. Comparison with in situ shear strength testing and with an â€˜undisturbedâ€™ coring system showed the pneumatic mechanism to inflict negligible disturbance, with some variation in measured shear strength being attributable to changes in moisture content.

To ascertain an absolute value for the level of sediment disturbance caused by the pneumatic coring mechanism, further investigations should be undertaken with laboratory consolidated homogenous clay. The use of a regulated material would remove possible variations recorded in the fieldwork that may be the result of sediment inhomogeneity.

Further Work

In addition to the coring system and the CPT, a resistivity probe was developed for acquiring sub-bottom data. Traditional techniques for acquiring sub-bottom sediment information rely on acoustic systems that use either the reflection or refraction responses of the different acoustic interfaces to provide a profile. By miniaturising the transducer this technique may be operated by either a diver or an ROV to ascertain sub-bottom information in the top few metres. However, alternative techniques are emerging, including Ground Probing Radar (GPR) and electrical resistivity systems. Much of the development of resistivity (the resistance in ohms between the opposite faces of a unit cube of the material)-based methods has evolved around the use of well logging, and borehole investigations have become more numerous in the oil industry.

Resistivity surveying has been severely restricted in marine environs due to inherent issues relating to the high conductivity of seawater; however, penetrating techniques can be used to overcome this problem, creating an alternative solution to nearshore sub-bottom survey methods. Resistivity (ohm m) is measured by briefly introducing an alternating electrical current into the ground via two current electrodes and then recording the voltage (= current x resistance) of the signal using two potential electrodes. Further work is required to provide absolute sediment calibration of the resistivity probe, although initial testing has indicated that it is possible to discern some sediment characteristics, both intrinsic and structural.

Summary

The purpose of this research was to investigate the role of the ROV in the context of integrated geotechnical and hydrographic site investigation. This was undertaken by determining current nearshore site investigation equipment limitations and suggesting alternative equipment through extensive research and development.

It is the authorâ€™s opinion that remotely operated vehicles could potentially play a vital role in nearshore geotechnical and hydrographic investigations. The nearshore zone is a highly dynamic and challenging survey environment and warrants development of techniques specific to requirements.

Further Reading

Stewart, D. and Randolph, M., 1991, A new site investigation tool for the centrifuge, Proceedings International Conference on Centrifuge Modeling - Centrifuge '91, Boulder, Colorado, pp.531-538.

Acknowledgements

The author wishes to express her gratitude to her PhD supervisors, Dr Derek Pilgrim, Dr James Griffiths (University of Plymouth) and Dr Duncan Priestley (Britannia Royal Naval College). In addition, she would also like to thank Professor Mark Randolph (University of Western Australia) for the opportunity to spend time at UWA and for his support on the thesis.