High Resolution Optical Televiewer at work at the Bluestone Dam in West Virginia

Mineral exploration of a zinc resource in the south of the country

Development of the Anderson Road Quarry Site

ROBERTSON GEO®

Unlocking Your GeoData

GeoUnlocked©

GLOBAL GEODATA NEWS

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Nepal

Training group at commissioning of Robertson Geo geophysical logging system, high in the Himalayan foothills of Nepal.

RGEO-EYE® - BOREHOLE CAMERA IS YOUR DOWNHOLE EYE

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EDITORIAL

Borehole camera is your downhole eye

SINCE THE RELEASE of our RGeo-eye® borehole camera system last year, we have seen a resurgence of interest in this new product as international projects regain momentum, and the demand for high quality subsurface imagery has increased.

RGeo-eye®

With RGeo-eye® able to operate to depths of 3,000m, in temperatures of 90°C and pressures up to 5,000psi, this has opened up a number of new applications for this innovative slim hole camera.

The unique capabilities of the camera allow high resolution video images to be generated that are especially useful for inspection and monitoring in deep groundwater, geotechnical, environmental, and mining applications.

The system configuration has enabled many Robertson Geo customers to seamlessly incorporate the borehole camera into their existing borehole logging package, allowing them to increase their own service offering.

We have created an individual website to show off the cameras versatility and examples of downhole video capture, check it out at **www.rgeo-eye.com**

Gavin Rowlands
Global Business Development Manager

If viewing digitally click on downhole video image to view.

AT ROBERTSON GEO we have an ongoing engineering programme to introduce innovative products that enhance geophysical data acquisition for our customers. Follow our regular blog to keep updated on the latest developments www.robertson-geo.com/blog

Get your free copy of GeoUnlocked and our regular direct marketing newsletter to your inbox - subscribe here

A hard climb over two days to get logging equipment up in the HIMALAYAS

Initial training session with the Robertson Geo 500m Winch.

THE ROBERTSON GEO Agent Representative, Aimil, recently commissioned a 500m Winch, High Resolution Acoustic Televiewer (HRAT), High Resolution Optical Televiewer (Hi-OPTV) and Triple Sonic system, supported by the GeoCAD® software, in the foothills of the Himalayas for its client Nepal Electricity Authority (NEA). The trek to the job site involved a 5hr climb over two days and an overnight stop to deliver equipment for the initial training.

As part of the nationwide drive for rural household and irrigation electrification, the logging system will play a key part in the planning and monitoring of new hydropower plants in the region.

The Soil, Rock & Concrete Laboratory (SRCL) of Bhagwwanpaun Swyambhu Nepal carries out extensive geotechnical investigations to assess the sub-surface condition and use an array of techniques including 2D Electrical Resistivity Tomography, Core drilling, SPT & CPT testing, and now Geophysical Logging.

In a region prone to earthquakes, such studies are crucial to the success of the project. The Robertson Geo tools will provide detailed structural and fracture analysis of the formation, as well as an indication of rock strength and elastic properties. With liquefaction previously observed in some areas with earthquake potential of above magnitude 6 (the 2015 earthquake had a magnitude of 7.8 with aftershocks for 7.3), Aimil has also recommended the client considers adding the PS Logger® to its logging arsenal.

United States Army Corps of Engineers commissioned Robertson Geo Client - Coastal Drilling East - for work on the Bluestone Dam

High Resolution Optical Televiewer at work at the Bluestone Dam in WEST VIRGINIA, USA

Robertson Geo 600m Winch in action for the Televiewer application at Bluestone Dam.

THE INSTALLATION OF 278 high-capacity (46-61 strand) post-tension anchors and relocation of the structural work platform mounted to the spillway where the work was performed. Rock anchors were up to 300ft in length.

The constant modification of the platform was completed to allow for the constant flow of work being completed at both platform elevation and below with the work platform supporting 80 ton cranes, drill rigs, and carry deck cranes.

The final row of anchors were drilled and installed from a floating plant located in the spillway and moored to the face of dam. These high-capacity anchors were installed through the concrete dam with embedded steel obstructions at varying depths through the dam down into bedrock consisting of interbedded layers of clay, shale and sandstone.

Project duration was from 2013-2019 and the High Resolution Optical Televiewer (Hi-OPTV) was logged on every anchor borehole prior to inserting the tendons to verify sound bond zone and no obstructions were encountered during drilling.

Mineral exploration of a zinc resource in the south of IRELAND

ROBERTSON GEO HAS recently been contracted to carry out a mineral exploration of an expansive zinc resource in the south of Ireland at Limerick.

Zinc is an important mineral for the offshore industry acting as a sacrificial metal. It is preferentially eroded to others such as iron forming a protective oxide layer. It is also used in the production of batteries, an important consideration as we move towards ever increasing renewable energy dependance.

The Robertson Geo Operational Service logging engineers travelled to Limerick, in the wake of Storm Eunice which proved to be a very windy and shaky journey. With delayed arrival in Dublin, it was decided to stay overnight in the capital before an early start across country to meet the Client. The previous week of storms had left the drill site a quagmire and with a lack of track mats it made driving into location impossible, however the onsite team towed the logging vehicle to the position to facilitate the data acquisition.

The requirement was for a 1.2 km hole surveyed to help identify at what depths bands of the mineral deposits could be found. Holes over 1km in depth are a rare and always interesting project to work on, the Services team ran three tools that can pick up the mineral deposit characteristics that would distinguish it from the surrounding subsurface.

Focussed Electronic (Guardlog):

By inducing the surrounding area with an electric current, we can identify bands of mineral deposits by comparing the returning current to calculate apparent formation resistivity. A large returning signal would indicate a highly conducive area, such as mineral deposits.

Magnetic Susceptibility:

This is a low frequency device specifically designed for mining applications. An oscillating magnetic field in the probe produces a current within a toroidal zone in the surrounding formation. The oscillating current produces a secondary field that is detected by the receiver coils. The 'quadrature' signal is a measure of susceptibility.

Full Waveform Triple Sonic:

This tool can construct the formation velocity of the surrounding subsurface. The probe measures the time of the first arrival at each receiver. The difference in arrival times between the three receiver pairings allows formation velocity to be calculated independent of the borehole fluid path. Different geological bands will be identifiable in processing.

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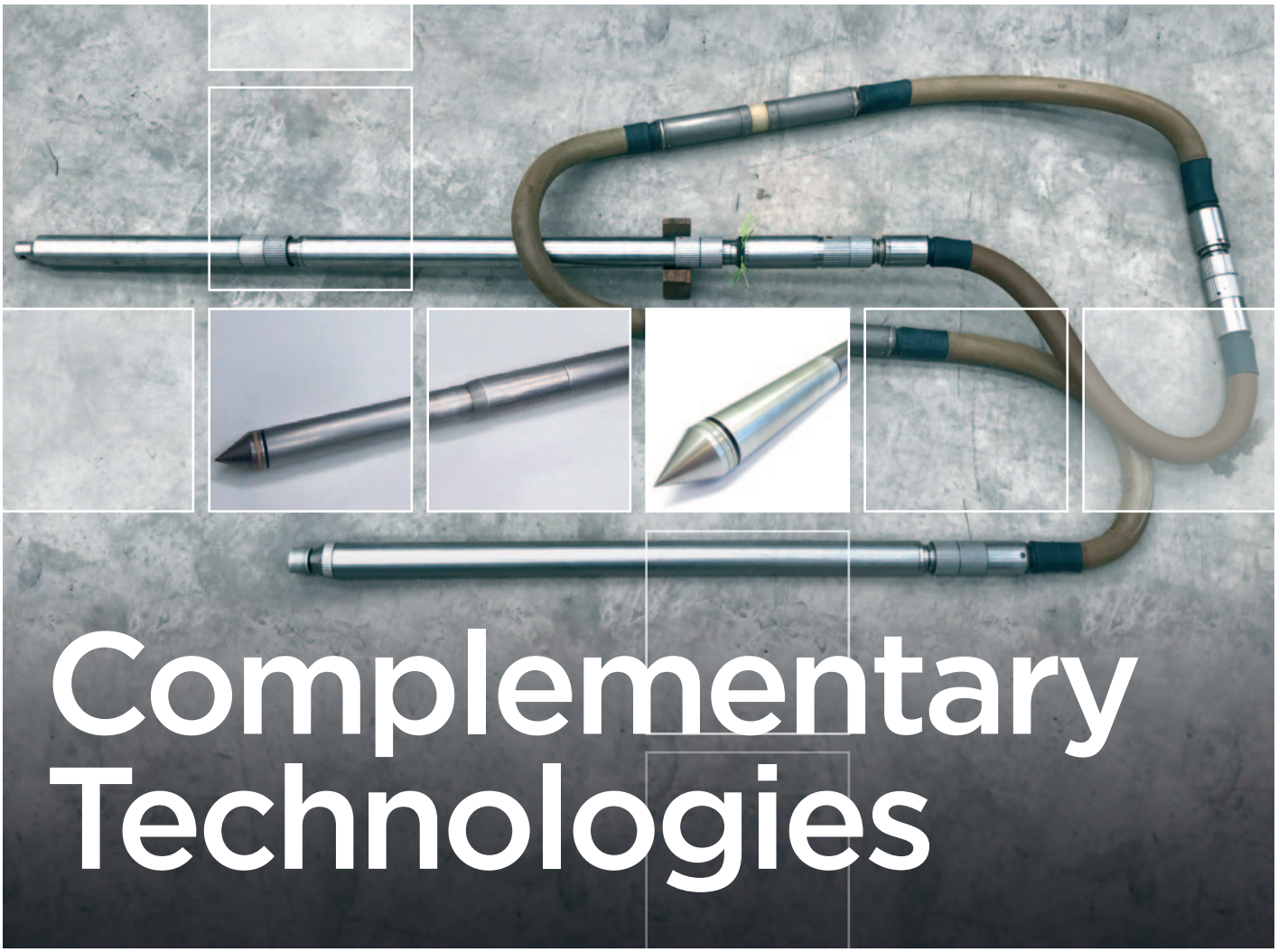


Complementary Technologies

PS Logger®, Seismic CPT and CPT for Ground Investigation

Ground investigation for Offshore Wind Farm (OWF) development routinely employs CPT, Seismic CPT and the PS Logger® in combination to determine in-situ formation stiffness. CPT supplies parameters beyond the linear elastic limit while Seismic CPT and the PS Logger® provide stiffness parameters for very small strain elastic response.

The ongoing development of Cone Penetration Testing (CPT) techniques, now with more measurements, has evolved to the point where CPT now provides a system of testing comparable to that of conventional wireline logging.

The PS Logger® is vital to these investigations as it can provide a continuous stiffness profile through layers where CPT cones cannot penetrate (rocks, pebbles, gravels etc).

Introduction

The characterisation of soils and rocks for the design of supporting structures can involve a myriad of different tests, both in-situ and from laboratory samples. Here we will be focussing on the PS Logger®, Cone Penetration Test (CPT) and Seismic CPT and their application to ground investigation for Offshore Wind Farm (OWF) development.

CPT, which pushes a measuring cone into the formation via a rod, has now become so sophisticated and accepted that it is hard to envisage that any significant civil engineering structures would be constructed without some element of CPT. Seismic CPT (SCPT) and the PS Logger® have emerged as complementary technologies that provide additional parameters relating to the linear elastic response of formations.

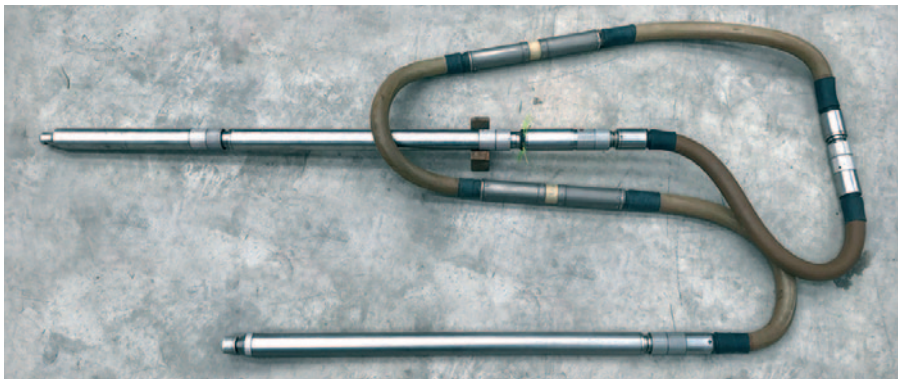
More accurate soil parameters for modelling loading response gives benefits in cost reduction due to better optimised foundation designs.

Example CPT Cone.

History

Before the advent of CPT, the Standard Penetration Test (SPT) appeared, in the early 1900's. This consisted of a tube driven into the soil by a sequence of standard hammer blows, the count of which (N count) gave a measure of penetration resistance which could be used for geotechnical design purposes. Despite concerns over disturbance of samples, the SPT method was adopted worldwide, due to its simplicity, and it remains the most frequently used subsurface exploration drilling test performed.

The CPT method was developed in the 1950's in the Netherlands to provide analogue and subsequently digital data which could be more readily related to soil parameters. Early probes measured the total penetration resistance or bearing capacity of the formation. To separate the resistance of the rod from the tip resistance, a friction sleeve was developed in the 1960's which helped quantify soil cohesive strength. The addition of a transducer to measure pore pressure then allowed for correction of tip friction values. Tip resistance, sleeve friction and pore pressure could now be considered as the standard CPT outputs. Other sensors including those for resistivity, natural gamma, temperature, inclination, video and magnetometry can also be embodied within the cone.



The Robertson Geo PS Logger®.

The addition of one or two geophone arrays in the cone, coupled with an external sound source, saw the emergence of Seismic CPT as an important additional test which can be run concurrently with standard CPT.

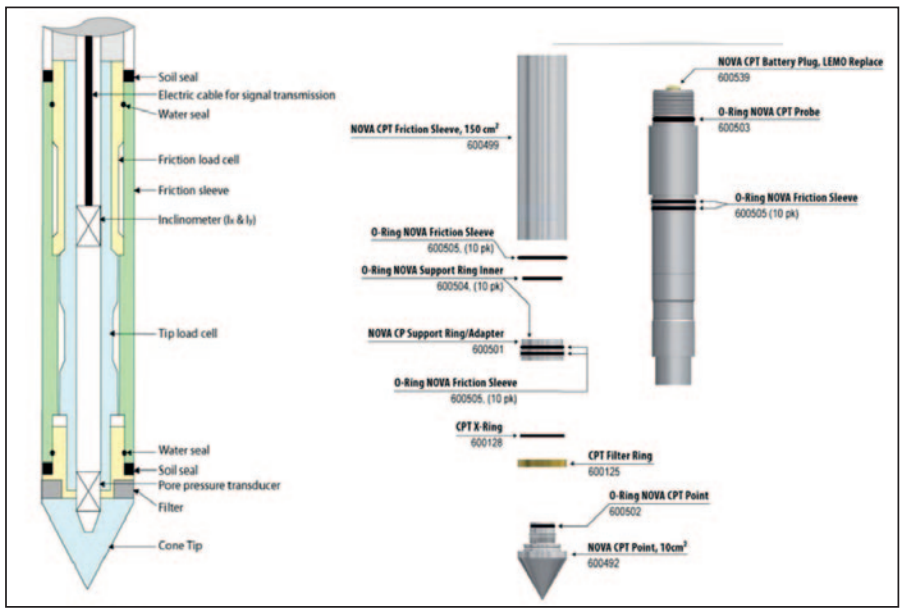
The PS Logger® (a registered Robertson Geo Trade Mark) was originally developed by the OYO Corporation in the 1970's to provide a full waveform tool that would produce reliable P and S wave velocity measurements in unconsolidated materials and rock formations, at depth, from a single borehole. The initial application was for determining earthquake susceptibility, but the probe was soon adopted for geotechnical investigation. Both on land and offshore (mainly for OWFs) the PS Logger® has become a standard means of collecting P and S wave data used for determining small strain moduli, superseding other sonic probes due to its ability to generate shear waves even in unconsolidated sediments.

Deployment

For offshore geotechnical investigation relating to OWFs some testing will be conducted at each turbine location usually with sample boreholes being drilled at a percentage of them. In the early days, where the OWF locations were near shore, jack-up platforms were often used. As the OWFs have gradually expanded to deeper waters (20-50m) boreholes are routinely drilled from heave compensated drill ships. As the commercial development of floating wind farms starts the water depths will increase (up to 500m) which will require different designs and approaches to the ground investigation.

Offshore, CPT testing may use the drilling mode whereby the CPT system is latched into the drill string and the 'push' is provided by a hydraulic umbilical using the drill string as the resistive force. Alternatively, there are dedicated CPT systems which are contained within a seabed frame which is lowered to the seabed under control from the surface where the weight of the frame supplies the reaction mass.

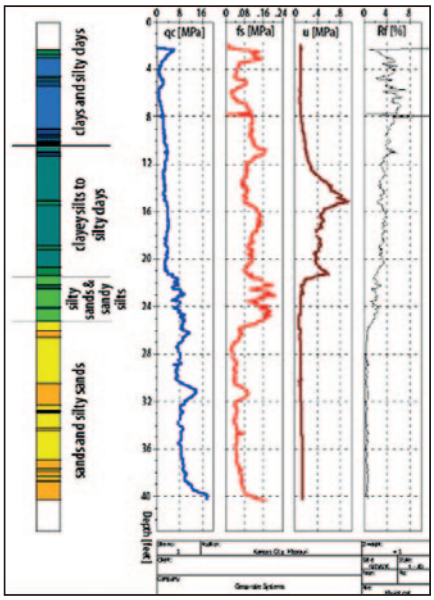
For seismic CPT an additional S wave source generator is required which is lowered into position adjacent to the borehole or may be combined in the dedicated CPT frame. In some cases, the S wave source can also produce P waves but this will usually be on a seabed frame separate from the CPT delivery system.



Cutaway of CPT cone with pore pressure transducer (CPTu).

PS logging requires a borehole to be drilled and once target depth, plus a 5m over-drill, has been reached the borehole is ready to log. The drill string stays in the borehole and is usually withdrawn in stages to expose a section of open borehole. This open section is logged and the probe withdrawn. Then more drill pipes are removed to reveal a further open section. This is logged with an overlap and the process repeats.

For onshore investigation, the CPT is usually delivered from dedicated truck mounted systems. PS logging from drilled boreholes routinely provides deeper data even through hard formations where the CPT 'refuses'.



Sample CPT Data.

Measurements

CPT

The CPT method uses a hydraulic rod fitted with a cone which is pushed vertically into the ground at a controlled speed. The sensors in the cone provide profiles, at centimetre resolution, throughout. As the cone penetrates it forces failure of the soil about 40cm ahead of the tip. The tip resistance is measured by load cells behind the tapered cone and is theoretically related to the undrained shear strength of a saturated cohesive material. Taking measurements from strain gauges, the sleeve friction is theoretically related to the friction of the formation being penetrated. Piezo cones measure pore pressure using a porous plastic insert just behind the tapered head that is made of hydrophilic polypropylene. In dense formations, like sand, pore pressure may drop and in clayey materials high pore pressures may be induced by the driving of the cone head. If pore pressures are measured that appear transient the 'push' may be halted to allow the pressure to equilibrate. The results from CPT combine to supply a soil classification and through theoretical analysis of the data produce further engineering parameters.

Data Outputs

Data	PS Logger®	SCPT single array	SCPT dual array	CPT
Outputs	**Waveforms:** P near P far S left near S left far S right near S right far	**Waveforms:** Sx Sy (+ for P wave source) P	**Waveforms:** Sx near Sy near Sx far Sy far (+ for P wave source) P	Tip resistance Sleeve friction Pore pressure (Inclination) (Resistivity) (Temperature) (Natural gamma)
Derived data	Arrival times P velocity (interval) S velocity (interval) Poisson's ratio	Arrival times S velocity (P velocity) Interval velocities (Poisson's ratio)	Arrival times S velocity (P velocity) S velocity (interval) (P velocity (interval) (Poisson's ratio)	Friction ratio Friction angle Undrained shear strength ++
Additional data	...with bulk density Shear Modulus Bulk Modulus Young's Modulus	...with bulk density (Shear Modulus) (Bulk Modulus) (Young's Modulus)	...with bulk density (Shear Modulus) (Bulk Modulus) (Young's Modulus)	Many other derived parameters

Comparison of PS Logger® versus SCPT for Offshore Ground Investigation

The PS Logger® and the Seismic Cone Penetration Test both measure formation velocities but by completely different means. The PS Logger® is deployed by a conventional wireline arrangement while SCPT usually runs concurrently with standard CPT testing. The table below highlights the significant differences between the two methods.

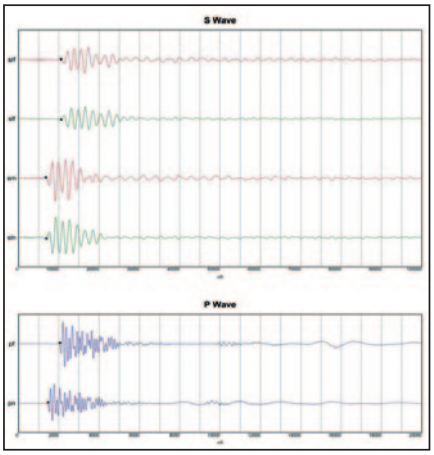
Consideration	PS Logger®	SCPT
Energy source	Bi-directional hammer - integral with probe	Separate generator on seabed frame
Source/receiver alignment	Fixed - 2 x single geophone and hydrophone array	Requires x-y polarised geophones due to uncertainty in cone orientation
Shallow Investigation 5-10m	Often not possible to test due to casing cover/noise	Proximity to source gives good S/N ratio
Deeper investigation	Performs best at depth due to consistent source energy	Below 40m may not be possible as S/N ratio diminishes
Unconsolidated deposits	Requires good borehole condition without washouts	Works well in unconsolidated sediments
Hard/dense soils and rock	Works well in hard/dense formations	May not be able to penetrate
Receiver coupling	Not required for the suspension method	Good
Waves measured	Always P and S	Always S but P waves require a separate source generator
Interval velocities	Measured directly	For single geophone array must be derived from source to receiver arrival times
Depth control	Accurate and consistent	Heave and tides can give problems
Data Formats	Proprietary and SEG Y	Flexible – variety of formats available
Ship borne noise	Can be problematic when probe is near seabed	Generally, quite resilient to ship borne noise
Weather effects	Can be significant when near surface	Mostly unaffected
Set up issues	Winch usually mounted on the 'rooster box' for heave compensation	Requires energy source to be deployed on a seabed frame
Operational issues	5m over-drill is needed to achieve data at target depth	Placement of seabed source can be difficult
Borehole requirements	100-200mm diameter, single borehole preferably with low rugosity and little washout	None – cone is pushed in front of the drill bit

Seismic CPT

Seismic CPT records waveforms at one or two receivers in the cone which are strongly coupled to the formation. The energy source comes from a separate generator placed on the seabed next to the borehole. Readings are taken statically with each receiver station using orthogonally mounted geophones. Data from the best orientation (x or y) are then processed and the arrival times picked. From the source-receiver distance and arrival times, velocities and interval velocities may then be calculated. With the addition of bulk density readings small strain moduli may also be calculated if P waves have been recorded.

PS Logger®

The PS Logger® is run in a borehole with a conventional wireline system and records P and S waveforms at two positions from a powerful integral energy source. Unlike other sonic probes the PS Logger® takes readings statically, usually at 0.5m or 1.0m intervals and at each depth position 3 shots are taken, one for P waves and two for S waves (left and right). The distance between the two receiver stations is fixed at 1.0m and interval velocities are calculated once arrival times are picked. Poisson's Ratio, and with the addition of bulk density data, small strain moduli are then calculated.



PS Logger® Waveforms.

Seismic CPT Cone.

Conclusion

Ground investigation for OWF foundation design has developed over the past decade, now collecting a wealth of data at specific turbine and infrastructure locations. Core sampling and subsequent laboratory analysis provide a multitude of parameters which feed into the design process. In-situ data is also vital, and this is provided mainly through CPT and wireline techniques in drilled boreholes.

While CPT provides a wealth of parameters beyond the linear elastic limit, Seismic CPT and the PS Logger® can provide small strain moduli inside the elastic limit (when combined with a bulk density).

In general, the PS Logger® method is faster than SCPT as the latter requires careful placement of a separate seabed source which can be time consuming and can have an impact on the routine CPT technique. For this reason, the Seismic CPT method is often used only for measuring near surface velocities while the PS Logger® is used for deeper sections (10m+).

Where hard formations, impenetrable to CPT methods, are encountered, only the PS Logger® can provide the required data.

PS Logger®, Seismic CPT and CPT should be seen as complementary technologies which together can supply in-situ stiffness parameters at all depths and in all formations.

Geotechnics and Concrete Engineering (HK.) Ltd. (GCE) is one of the leading companies in providing civil, geotechnical and construction materials engineering in Hong Kong and a long-time user of Robertson Geo technology. One of GCE's latest projects is the 'Development of Anderson Road Quarry Site' (ARQ).

HONG KONG

Development of the Anderson Road Quarry Site

A CIVIL ENGINEERING and Development Department (CEDD) works that includes forming about 40 hectares of land platforms at the Anderson Road Quarry (ARQ) Site. The associated geotechnical works; road works including construction of approximately three kilometre long vehicular roads, footpaths, cycle tracks, and approximately 1.30m long underpass at the southern end and a public transport terminus at the northern end of the ARQ site; provision of and improvement to water supply, drainage, and sewerage systems as well as landscaping works.

The High Resolution Optical Televiewer (Hi-OPTV) has been used to check the formation/fracture regime inside the Anderson Road's landslide. A 100m long horizontal borehole was drilled into the hillside, and GCE fabricated a pushrod system with custom centralisers to push the Hi-OPTV to the end of the borehole. They then used the Robertson Geo Mini Winch to pull the Hi-OPTV out of the borehole whilst acquiring the log data. The set-up proved challenging.

After testing, it was decided to mount the depth wheel on the roof canopy above the borehole, as it helped maintain a more constant speed and improved the log quality.

During the tests, water was observed coming out from the borehole, which caused the image to be a little compromised due to the unwanted water settling at the bottom of the borehole.

It's not unusual for water to be present (even in the dry season) as a confined aquifer is likely to be inside a landslide. There was little rain during the test and the day before the test, therefore, the image got more "water distortion" than expected.

It is recommended doing such a test during the dry season (if possible) as all the water coming from the confined aquifer cannot dry out.

BUSY TIMES OFFSHORE

The expansion of Qatar's North Field

BETWEEN APRIL AND JULY 2021, Robertson Geo Operational Services conducted PS Logging in the Arabian Gulf as part of the geotechnical investigation preceding Qatar's North-Field expansion.

Qatar's North Field is the world's largest non-associated natural gas field; Qatar Gas are increasing extraction here by 43% via the installation of eight wellhead platforms. The locations for seven of these platforms have been investigated by Robertson Geo to advise on their design.

At proposed locations for the wellheads, the PS Logger® extracted data from boreholes up to 160m deep. The geology encountered consisted of intermingling layers of Sands, Clays, Silts, and Limestones, producing Lithologies such as Calcarenite and Calcisilite. This meant data quality became highly variable as depth changed, however a faster sample rate of 10µs for S-wave data ensured greater resolution (and therefore data quality) throughout.

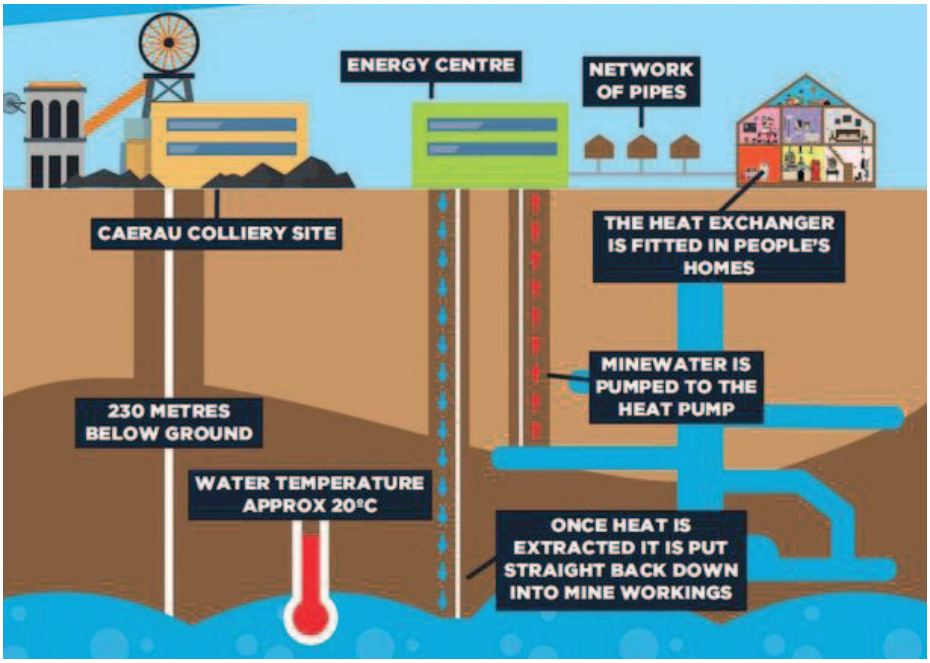
Drilling and testing was conducted onboard the Quest Horizon.

Groundwater investigation for the BGS in **Caerau, Wales**

THE BRITISH GEOLOGICAL SURVEY (BGS) hired Robertson Geo Engineers to provide data on the groundwaters of a disused mine in the town of Caerau which will be converted into a geothermal energy centre.

The data contributes to research by the BGS which aims to locate and categorise similar mines based on their geothermal energy potential, creating a heat map of the UK's geothermal resources.

Such work has attracted a £6.5 million investment by the UK government for repurposing Caeraus mines into a source of geothermal energy using heat pump technology to further heat the warm mine waters. These waters would be passed through heat exchangers to provide heating to the homes of Caerau, creating the largest mine water heating network in the UK. Projects like this have the potential to not only revolutionise green energy in the UK, but also to minimise pollution from mine waters and protect the invaluable ecosystems of these rural communities.



Plan of the proposed heating scheme (Image courtesy of Bridgend county borough council).

A large array of probes saw applications on this job. Data attained by the Temperature Conductivity probe was particularly useful as it provided a continuous log of fluid data down the entire 230m depth of the borehole. Temperature data advised the BGS on the geothermal potential of groundwater at depths where mine workings were located.

Conductivity data can be used to determine the level of solutes in the water which may be deposited in the networks pipes once extraction starts, increasing the maintenance costs. The data collected is therefore crucial to determine the economic viability of this project and contributes to a greater understanding of the UK'S green energy resources.

AIMIL, India is Robertson Geo's exclusive agent for India

LD Mohapatra, heads the geophysical & survey division

I JOINED AIMIL in 2013 with a background in geophysical studies and instrument sales. Aimil was founded in January 1932, and this year (2022) is the 90th anniversary of our company's establishment. We now have over 900 people servicing around 25,000 customers through a network of sixteen offices and fourteen test and calibration labs throughout India.

Our technology objectives are to bring to our region leading edge technologies from the best in the world and our business objectives are to provide the preferred pathway for technology. Characterised by quality, innovation, timeliness, competitive awareness, and ethical business practices with outstanding customer service.

We also strive to cultivate a vibrant, participatory, and rational working environment that nurtures initiative and creativity, values teamwork, shares success and rewards excellence.

We are pleased to have the excellent opportunity to work with Robertson Geo, it has been the leading provider of geophysical logging technology to India for the last 40 years. We are getting tremendous support in terms of technical and commercial aspects. Communication is critical, and I have good access to Robertson Geo 24/7 through its regional base, which promptly provides answers, enabling us to improve our customer service. This has proved particularly important as we consider the impact of the pandemic on global trading.

Throughout this difficult time we persevered with online presentations and direct marketing, we travelled (with the inherent risks) to customers at their place of work, we were noticeably different in attitude to competitors that were mostly silent in work activity due to fear of the pandemic.

We also worked hard to provide the very best customer training and commissioning in person and online.

Robertson Geo worked with us to prepare a dedicated website providing customers with direct access to its technology and we expanded the Aimil portal online presentation.

www.robertson-geo.com/Aimil

Stephen Stroud, our USA sales and operations manager, at the Robertson Geo booth at SAGEEP 2022 (the 34th Symposium on the Application of Geophysics to Engineering and Environmental Problems) in Denver Colorado during March this year.

Sam Harrison during his Offshore Survival Training!

I'M SAM HARRISON, the latest addition to the Operational Services logging team. My journey to Robertson Geo started with a decision to complete my university career at Bangor in North Wales, it was a no-brainer really. From my home in the heart of the Peak District to Snowdonia, was the perfect surroundings to complete a BSc in Geological Oceanography as well as an MSc in Applied Marine Geosciences.

Always keen for a new challenge, I had a few years success as a Technical Sales Executive for one of UK's largest hazardous waste management companies. Here I tackled a variety of unique problems in the waste sector, and it cemented a sense of duty that we should all have to be looking after our environment.

Again, seeking new challenges I contacted Robertson Geo and was delighted to join as a Field Logging Engineer. Shortly after I had my own *'out of the frying pan and into the fire'* moment. Two weeks in and I find myself in Poland aboard a drill ship to complete geophysical surveys of boreholes for an offshore windfarm! As I waved goodbye to land the task ahead did seem very daunting, but with the help and support of the Robertson Geo Services logging team back at base it was a great experience and the data acquired was spot on.

Having been with Robertson Geo four months now, every day adds to my learning curve as I use and experience working with our tools, winches, and software. Overseas travel is part of the job and challenging locations add to the ever-changing days.

Comprehensive suite of logging tools including the **RGeo-eye®** Camera used on location in **Doha**

ROBERTSON GEO'S RGEO-EYE® camera was one of seven tools recently deployed in a hydrogeological project in Doha. The project involved logging a 400m deep-injection and monitoring borehole and a 120m geotechnical borehole to study the aquifer and groundwater system and establish the local stratigraphy.

The aquifer zones were not well delineated in the area. Robertson Geo Client Gulf Labs used a comprehensive suite of logging tools to investigate the stratigraphy and petrological properties of the area. Natural Gamma, Caliper, Resistivity, Fluid Temperature, Conductivity, High Resolution Acoustic Televiewer (HRAT) and High Resolution Optical Televiewer (Hi-OPTV) and the RGeo-eye® Camera were performed in the geotechnical borehole. While Natural Gamma, Caliper, Resistivity, Fluid Temperature & Conductivity and Flowmeter were run in the injection borehole.

RGeo-eye® downhole camera with sinker bar applied to the geotechnical borehole.

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SAFETY IS KEY ©

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