KEY ELEMENTS FOR SUCCESSFUL GEOTECHNICAL INVESTIGATIONS

Offshore Innovation and Improvisation

Geotechnical investigations for offshore constructions require continuous technical innovation in order to meet market demands. This is also relevant to the growing offshore wind energy industry, which is itself on a path of constant innovation. The daily costs of offshore operations are high, meaning that honouring a contract satisfactorily and on time is important. To achieve this, improvisational skills are vital to overcome the challenges that may occur while testing and boring at sea.<P>

The world's first offshorewind farm was constructed just off the coast of Vindeby (Denmark, see Figure 2) in 1991, when GEO – the Danish Geotechnical Institute – carried out the geotechnical investigations. The offshore wind energy industry has made vast leaps in progress since then, which have had an impact on the geotechnical services supplied to the industry. As a supplier of geotechnical services, GEO has recognised the need for ongoing technical innovation. Our ability to improvise workable solutions in response to unexpected challenges has been crucial in fulfilling contracts.

Borehole Information

View Larger Map

Much has changed since the first offshore wind farm at Vindeby. Today, the now-giant wind turbines are placed further and further offshore on new types of foundation, demanding more equipment and solutions provided by geoscience companies. As an experienced supplier of offshore geotechnical services, thinking ahead is essential in order to meet the demands of new clients and the challenges offered by deeper waters and different seabed soil types. In the Baltic Sea, the planned offshore wind farm Krieger's Flak is a collaboration between Sweden, Germany and Denmark. GEO has carried out the initial geophysical surveys and geotechnical investigations for the Swedish and German contributions. The geotechnical investigations included a full cone penetration test (CPT) at all wind turbine positions. At selected positions, drilling was conducted to obtain detailed geological and geotechnical information. The information from the boreholes was used to calibrate the CPTs.

DTH System

At most offshore locations, GEO was able to conduct full CPTs using the heavy 20-ton seabed rig, GEOscope. At Krieger's Flak, however, the geology consisted of large areas of hard glacial clay with boulders. These soil conditions proved challenging for GEOscope. We initiated the development of an alternative method to attain full CPTs in dense and stiff soil types. The innovation process resulted in GEOriis (Figure 1), a down-the-hole (DTH) system for sampling and in situ testing in geotechnical boreholes. Using the GEOriis system, the tools are deployed using a wire-line principle – an alternative to the traditional and time-consuming rod-handled systems. The standard DTH method has been used in the offshore industry for many years, and GEOriis has developed several modifications and features. It can be operated in conjunction with different drilling systems and casing dimensions in the range 125–205mm. DTH-CPT is conducted in 2-m strokes with a thrust capacity of 80kN, making it suitable for operation in dense and hard soil types. As well as the possibility of conducting DTH-CPT, the GEOriis can be used for DTH vane testing and intact core sampling. The GEOriis was successfully deployed at Krieger's Flak and later at the offshore wind farms Baltic 1 (Baltic Sea) and Lincs (North Sea).

New Methods

Client requirements can often lead to the development of new methods. At the Rødsand offshore wind farm in the Baltic Sea, the wind farm developer decided to place the turbine foundations directly on the seabed using a gravity-based foundation. This requires meticulous preparation of the seabed before lowering the foundation into place. However, the upper seabed was too soft locally to support the structure at one location; the top 10m of seabed (soft sand and mud) were therefore excavated in order to reach firm ground. A bed of rock fill was then laid and adjusted to the millimetre. Our client requested that GEO verify that the bed of rock fill was sufficiently compact to avoid unexpected settlement of the foundation. On land, this verification is traditionally carried out by plate load tests.

Plate Load Test

GEO had not previously carried out large-scale plate load tests under water. Using the plate load system in order to verify the deformation parameters required adjustments to our equipment used for onshore constructions. In just a few weeks, we designed a method for underwater plate load testing. It consisted of the traditional onshore equipment with the thrust force applied by a hydraulic jack mounted underneath a 205-mm casing pipe from the jack-up platform (Figure 3). The settlement of the steel plate was transmitted through three steel rods inside the casing tube and recorded on top of the jack-up platform using the usual dial gauges. This procedure was performed in 8–10 positions throughout each turbine foundation, and worked perfectly.

Offshore Improvisation

Offshore geotechnical investigations can prove to be very challenging when the soil conditions are discovered to differ significantly from what is expected. Halting an investigation can be very costly and detrimental to the project time schedule. In such cases, the ability to devise new solutions can be crucial in order to complete the investigation. Such an on-site adaptation occurred at an offshore wind farm site in the Irish Sea. The GEO investigation included deep-push CPT using a seabed rig at all planned turbine locations. The seabed conditions showed very soft to soft sediments within the upper 2–4m. Attempting to push deep into the underlying firm sediments failed. The lack of horizontal support to the CPT rod string in the upper soft layer meant that when the push force was increased in order to penetrate the deeper-lying hard layers, the rods became bent and broken.
An immediate solution was required in order to progress. Within a weekend, GEO engineers in Denmark had found the solution: a skirt for the seabed rig, with built-in horizontal support for the CPT rods below the rig, enabling it to withhold a 20-ton push (Figure 4). The skirt was designed and built in Denmark, dispatched to the site and attached to the rig within three days. The following test increased the penetration depth from 5m to 15–25m (the target depth was of the order 20m).

Client Feedback

The role of client dialogue and feedback in offshore operations is important. Campaign adjustments and the improvisation of solutions require a constructive dialogue between the contractor and the client's representative during an offshore operation. We require the understanding of the client if the programme has to be changed, as well as their feedback when searching for workable solutions. A positive approach influences the whole campaign, as described by Centrica's representative after GEO's completion of the geotechnical site investigation at the Lincs offshore wind farm, who said: "During the whole campaign the atmosphere on board was superb, which contributed a lot to the high productivity and quality of the investigation." In all innovations, client dialogue and feedback are necessary in order to keep pace with the ever-advancing offshore wind energy industry. The industry has come a long way since 1991 and, through innovation and improvisation, geotechnical service providers have likewise progressed