CASE STUDY: STANDING FIRM IN THE SEA, POWERED BY THE WIND

USERS: SINOTECH ENGINEERING CONSULTANTS INC. & PDE OFFSHORE CORPORATION.

THE FIRST GEOTECHNICAL LABORATORY FOR OFFSHORE SOIL MECHANICS TESTING IN TAIWAN

As global concerns increase about the pace of energy transition in accounting for long-term climate risks, the shift from fossil-based energy production to renewable sources, like wind, has been accelerated. Within Taiwan, the national offshore wind allocation plan has set a target of increasing local production to 20GW by 2035. It anticipates that in the decade ahead, the implementation of offshore wind farms in the Taiwan Strait is expected to grow significantly, with multiple new wind turbines placed into commercial operation.

However, similar to the problems encountered in many countries, restrictions remain on the sites selected for optimal offshore wind farm development. Future development is known to correlate directly with public spending and therefore there is a willingness to invest. In fact, leaving out the influence of variable lateral aerodynamic loads, the greater challenges lie within the highly complex and dynamic coastal environment. A major cost driver for the offshore wind energy industry in Taiwan is the geological uncertainties. Some of the identified risks include: the effect of sloping areas of soft soils, sea-bed motion, complex marine strata, steep topography, obstructions, seismic activity, soil liquefaction and the presence of flammable or toxic gases. These crucial variables are quite often difficult to design for and the information is typically unavailable.

To ensure the whole offshore wind energy conversion system can be installed in a favourable location and to supply a reliable source of energy, a physical design of offshore foundations is the primary focus. This requires an understanding of the mechanical characteristics and dynamic properties of the soil, these include: modulus strength, modulus degradation, damping, stress history and deformation in different locations. Most importantly, accurate test results need to be delivered to the design contractors in a timely manner. This has led to the first geotechnical laboratory for offshore soil mechanics testing being established in Taiwan. It has been made possible by a collaboration between Sinotech Engineering Consultants Inc. and PDE Offshore Corporation.

Sinotech Geotechnical Engineering Research Center (GERC) is known for its expertise in geotechnical engineering for a wide array of civil infrastructure projects. As a pioneer, it always stands on the cutting edge of geotechnical engineering in Taiwan. In accordance with a certification supervised by Taiwan Accreditation Foundation (TAF) on various soil and rock tests, Sinotech has long been involved in numerous large engineering projects for over 50 years within Taiwan.

PDE Offshore Corporation, the joint venture of Pan Formosa Engineering (since 1983), Dragon Prince Hydro-Survey (since 2007), and EGS Asia (since 1974), provides professional onshore and offshore drilling services. PDE has successfully grown its number and diversity of offshore hydraulic fixed platforms, and is one of the largest providers in Asia. It plays an indispensable role in the offshore wind market of Taiwan.

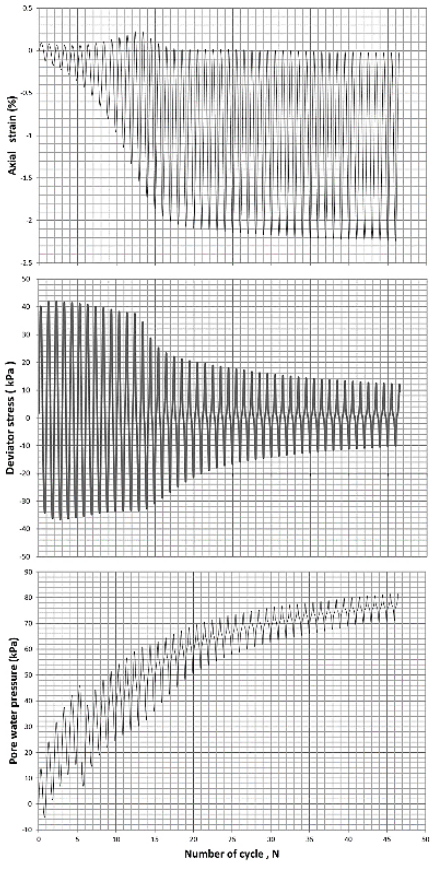
The Sinotech - PDE Offshore joint laboratory was launched in spring of 2021, its aim was to achieve quality control and assurance of testing data. The laboratory has been fully equipped with GDS Instruments (GDS) systems to perform a wide range of soil mechanics testing, including Static and Dynamic Triaxial Testing, Direct Shear Testing, Consolidation Testing, Constant Rate of Strain Oedometer Testing and Resonant Column Testing, all of which, are important for providing critical parameters required for offshore foundation design. The most crucial factor when selecting geotechnical testing systems was to ensure the accuracy and consistency of reported data, hence why GDS were selected. A summary of the equipment purchased to date can be seen in the table below:

GDS SOIL MECHANICS APPARATUS	Quantity
Triaxial Automated System (TAS) with 10, 16 and 25kN load cells	6
Bender Element System (BES)	3
Consolidation Constant Rate of Strain cell (CRS)	2
Automatic Oedometer System (AOS)	10
Enterprise Level Dynamic Triaxial Testing System (ELDYN) (5Hz / 10kN)	5
Advanced Dynamic Triaxial Testing System (DYNTTS) (5Hz / 10kN)	1
Electromechanical Dynamic Cyclic Simple Shear Device (EMDCSS) (5Hz / 10kN)	3
Resonant Column Apparatus (RCA)	3
Ring Shear Apparatus (RSA) (5kN / 200Nm)	1

All the systems can be run consecutively or concurrently. The regular testing methods include (but are not limited to):

- Unconsolidated-Undrained Triaxial Compression Test (UU).
- Consolidated Undrained Triaxial Compression Test (CU).
- Consolidated Drained Triaxial Compression Test (CD).
- Direct Shear Test Under Consolidated.
- Consolidation with Incremental Loading.
- Measurement of Hydraulic Conductivity of Saturated Porous Materials.
- Load Controlled Cyclic Triaxial Strength (CUcyc).
- Determination of the Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus.
- Modulus and Damping of Soils by Fixed-Base Resonant Column Devices.
- Determination of Shear Wave Velocity and Initial Shear Modulus in Soil Specimens ft. Bender Elements.
- Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Fine-Grained Soils.

Thus far, the overall test results are promising and satisfactory. Below is an example of an offshore soil specimen that has been investigated by conducting the load controlled cyclic triaxial test. This test was performed on an undisturbed specimen that classified as fine grained silt with low plasticity. The sample was recovered from a depth of around 8.3 meters below the seabed. The initial water content was 27.5%, the initial dry unit weighed around 1.61 t/m^3. According to the specified testing conditions, with a saturation B Value of 0.95, the consolidation stress was set to 100kPa, the cyclic amplitude and stress ratio (CSR) were set to 40kPa and 0.2. Following the specifications of ASTM D5311, we are able to assess the liquefaction potential of this specimen. As shown, failure occurs at cycle 15 defined by the development of the build-up of excess pore pressure.



THE MILESTONE AND THE VISION

Within the first year of its establishment, Sinotech - PDE Offshore joint laboratory has achieved its preliminary goal of completing a comprehensive set of soil mechanics tests for a specific offshore wind project in Taiwan. More than 15 specialised technicians and researchers have been involved in the project. A huge number of test results have been taken from the cores of more than 30 boreholes to a depth of 100m, each of which, have been transferred for consideration. In the future, the laboratory will become a platform for academic-industry collaboration, not only in Taiwan, but potentially for all of East Asia.

Photo taken showing the set-up of Triaxial Automated System (Right) and Oedometers (Left).

Photo taken showing the set-up of Enterprise Level Dynamic Triaxial Testing System (Left), Resonant Column Apparatus and Advanced Dynamic Triaxial Testing System (Right)

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