ShenZhong Passage (Island-Tunnel) Project – Refined Exploration Technology and Management

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Abstract. For Shen-zhong Link project with two islands and a tunnel, the survey process is in full compliance with international standards. The large-scale survey equipment with international advanced level (offshore power head drilling platform, support drilling platform) is used to carry out survey operations and tests in accordance with international standards, so as to minimize the disturbance to the undisturbed samples. Various in-situ test and indoor test methods are used to carry out all-round and multiple means for rock and soil layers. The results of the investigation are better than that of the conventional investigation and have been verified in the implementation of the island and tunnel project. Experience of this survey is helpful to promote the fine geological survey in China.

1. Introduction
The Shenzhenhong Passage is a challenging and magnificent project after the HongKong-Zhuhai-Macao Bridge. The project is connected to Shenzhen Qianhai in the east, Guangzhou Nansha and Zhuhai Hengqin in the west. It is a world-level super-large cross-sea project integrating “tunnel, island, bridge and underground intercommunication” with complex construction conditions and technical difficulties. The island and tunnel in sea is a key controlling project for the entire passage. It consists of three parts: the immersed tunnel and the east / west artificial islands. This is a two-way eight-lane extra-long submarine highway immersed tunnel without precedent.

The immersed tunnel is deeply embedded, and the engineering properties of the soil layers at the bottom of the tunnel vary greatly. During the construction phase, the foundation soils will undergo excavation and unloading, tunnel placement, backfilling and reloading; there will be a large amount of additional stress caused by the artificial island filling, and foundation pit dewatering is required.

In order to meet the design requirements of the construction plans of the island and tunnel project, ensure the accuracy of the exploration results, and ensure the quality of the project, the project owner proposed to implement refined geology exploration on the cofferdam of the west / east artificial islands, the west slope section of the tunnel and the tunnel building section, in order to achieve various geotechnical parameters reflecting the actual conditions with high precision. Therefore, specific requirements have been made based on exploration evidence / basis, equipment, and exploration implementation.

2. Exploration evidence / basis
The exploration is based on the relevant domestic standards, and is following the international standards which is stricter:
BS5930:1999; BS1377:1990 Part 1 to 9; International Society of Geomechanics and Geotechnical Engineering ISSMGE Test Procedures (1999), etc. The application of the above international standards supplement the insufficiency of the domestic standards in the following areas:

1. Soil classification. The BS includes the analysis of the main components of the soil as well as the domestic standards, and it also focuses on the secondary components, providing a standard for refined stratification.

2. In-situ testing. The international standards supplement the statical cone penetration test measuring the pore water pressure which is not included in the domestic standard, and provides more effective in-situ data for the statical cone penetration test to eliminate the influence of pore water pressure. Meanwhile, the international standards have included the hammer energy correction in accordance with the standard penetration principle while the domestic standards include only rod length correction for the standard penetration test, which provide a reliable guarantee for the in-situ data acquisition of the standard penetration test.

3. Laboratory testing. The undrained shear test was performed by using the anisotropic undrained consolidated triaxial shear test methodology which is not commonly used in the domestic standards, in order to obtain the in-situ undrained shear strength by simulating the in-situ stress state. Meanwhile, based on the actual excavation and backfilling scheme, the consolidation loading procedures are established to obtain the consolidation index during construction and working period.

3. Exploration equipment

The Island-Tunnel project has high requirements for soil stratum division and refinement of geological parameters. The advanced equipment and methodology are used to carry out refined exploration in order to obtain the in-situ data with little disturbance. The ship-machine equipment, soil sampling equipment, in-situ testing equipment and laboratory testing equipment used in this exploration are in line with the international standards which are very different from the conventional domestic marine exploration.

3.1 Drilling platform

The HD-300 marine power-head drill rig platform (see Figure 1) and the bracket type stationary drilling platform (see Figure 2) are mainly used in this exploration.
HD-300 marine power-head drill rig is a new type of full hydraulic drill rig designed and developed for engineering geological exploration and construction in non-land areas such as oceans and rivers. The advantage is that the vertical movement of the rotary axis and the drill rod is completely separated from the vertical movement of the ship, so that the driving drill rig, the rotary axis and the drill rod are no longer affected by wave undulations, which can significantly improve the quality of the drilling and sampling, and achieve the purpose of refined exploration.

The bracket type drilling platform is equipped with XY-150 engineering drill rig. It can be directly anchored into the seabed, and the upper part is stabilized by ship to eliminate the influence of wave fluctuations, significantly improve the quality of drilling and sampling, and achieve refined exploration. It can be operated within water body of 15m deep.

3.2 Soil sampling equipment

3.2.1 undisturbed sampling
In order to improve the quality of soil sampling in this exploration, we improve the drilling equipment, sampling equipment, storage and transportation. The length of the undisturbed cohesive soil sample is between 0.5m and 1.0m, and the sample is packed in thin-walled seamless steel pipe and PVC pipe. Use the following soil sampling equipment:

(1) Fixed piston thin-walled soil sampler (see Figure 3), is equipped with seamless thin-walled steel pipe (1.0m long, diameter 76mm or 100mm). It can take the Class-1 soil sample as per the continuous static pressure method, which is mainly suitable for the flow-plastic or soft-plastic cohesive soil.

Figure 3 Fixed piston thin-walled soil sampler

(2) Open thin-walled soil sampler (i.e. Shelby Tube soil sample) (see Figure 4), is equipped with seamless thin-walled steel pipe (0.5m long, diameter 76mm). It can take the Class-1 soil sample as per the continuous static pressure method, which is mainly suitable for the plastic or hard-plastic cohesive soil.

Figure 4 Open thin-walled soil sampler

(3) Rotary soil sampler (i.e. Mazier soil sampler) (see Figure 5), is equipped with PVC pipe (1m long, diameter 72mm). It can take the Class-1 soil sample as per the rotary drilling method, which is mainly suitable for hard plastic or hard cohesive soil.

Figure 5 Rotary soil sampler
The undisturbed cohesive soil sample is kept in the seamless steel pipe. The both ends of the seamless steel pipe are sealed with wax, covered with plastic cover, and then sealed with tape, and placed vertically in a special shockproof soil sample box (see Figure 6).

![Figure 6 Undisturbed soil sample storage-transportation box](image)

3.2.2 Disturbed sampling

(1) Standard penetration test sample (SPT sample)

Significantly disturbed samples of cohesive soil and sand are taken using a standard penetration sampler. The disturbed soil samples are kept in the plastic film or sample box and sealed with tape.

(2) Minor disturbed sample

After the rock core tube is drilled through the sand layer to obtain the core, a representative sample selected from the core is placed in a steel sample box of about 0.2 m long, the top and bottom are covered and wrapped with tape, and it can be used for particle analysis test as level 4 sample.

3.3 In-situ testing

3.3.1 Seabed Statical Cone Penetration Test (CPTU)

To ensure the quality of the CPT operation, the seabed CPTU equipment (see Figure 7) is mainly used to ensure that the required penetrated depth even if in the case of dense coarse sand.

![Figure 7 Seabed CPTU test](image)

The seabed CPTU equipment has four turning wheel that clamp the probe and casing tightly. When the wheel is rotated under hydraulic power, it can power the probe and casing to penetrate downwards. This CPTU test uses a three-bridge electrical probe with a cross-sectional area of 10 cm² or 15 cm². The end resistance, the side friction resistance, and the pore water pressure caused by the probe can be measured simultaneously. The test is carried out at a speed of about 20 mm/sec. The data is collected every 20 mm, and the frequency of data acquisition meet the requirements of international standards, in order to obtain large amount of refined stratum in-situ data.
3.3.2 Standard penetration test
Adopting standard penetration test equipment in line with international standards, the equipment is different from the domestic standard penetration test equipment: (1) Hammer, weigh 15-20kg, and the domestic hammer is about 3kg; (2) A galvanized inner liner is added to the penetrator.

3.3.3 Vane test
The offshore vane test is performed by a fixed platform. The engineering geological drill rig is used to install the guiding casing, the pilot hole and the protective wall. Based on each work site condition, the vane test use the electric vane. The plate head is rectangular, 100×50×2mm, the diameter-to-height ratio is 1:2, the probe diameter is 38mm; the penetration device is 2Y-20C statical cone penetrator, the penetration pressure is 20T.

3.3.4 Laboratory test
Set up the on-site geotechnical laboratory at the construction site (see Figure 8). In addition to the conventional test equipment, the stress path test required for the tunnel design is performed by using a triaxial cell to obtain the strength index under true stress state, so that we can establish reliable correlation with CPTU data.

![Figure 8 Field Laboratory](image)

4. Exploration implementation

4.1 weight workload requirements
The workload has been detailed in the bidding documents on the following aspects to ensure the quality of the exploration, such as, engineering geological drilling (including drill hole purpose, coring, borehole measurement and calibration, stratum division, borehole sampling, borehole grouting, etc.), in-situ testing (including standard penetration test, wave velocity test, vane shear test, side pressure test, pore pressure statical cone penetration test (CPTU), sampling, etc.) and laboratory test (including general physical property test, strength test, consolidation test, chemical test, main geotechnical parameters required, etc.).

4.2 Field exploration

4.2.1 Quality of the field exploration
The field exploration shall be performed strictly in accordance with the specifications, operating procedures and work outlines (which shall be approved after review) to ensure the quality. The original records shall be detailed, complete, correct and reliable, and signed by the geological personnel.

4.2.2 Acceptance of field exploration
The tenderer’s quality inspection on the filed exploration work shall be allowed at any time. After the field work is completed, it shall be inspected by the tenderer. The drilling equipment and vessels may be evacuated only after the tenderer accept and agree exiting.
5. Summary of refined exploration technology

(1) High Standard. Execute the most advanced current international exploration standards, and make detailed provisions on the technical requirements and workload of relevant exploration implementation in the bidding documents.

To ensure the reliability, authenticity, rationality and advancement of the final product of the engineering exploration, i.e. the engineering exploration documents, the following shall be carried out.

Select the experienced exploration consulting company in open bidding. Perform all-weather, all-round, full-process on-site consultation for the necessary engineering geophysical exploration, such as drilling, pore pressure statical cone penetration test, vane shear test, pumping test and side pressure test; Control the exploration personnel, machinery, equipment, methods and environment effectively; Consulting on laboratory testing and data collation.

(2) High quality equipment. The use of large-scale drilling platforms such as the HD-300 marine power-head drill rig platform and the bracket-type stationary drilling platform can effectively reduce the impact of waves on drilling, to obtain high-quality original samples and reliable in-situ test data. In order to improve the quality of soil sampling, requirements have been made for soil sampling equipment, storage and transportation. The seabed CPTU equipment is used to ensure that the exploration requirements are met.

(3) Multiple means. A variety of in-situ and laboratory tests are performed on the soil stratum from all aspects and with multiple means, including seabed CPTU, electrical VST, international standard penetration test (SPT), wave speed test and other in-situ tests and laboratory tests, in order to obtain a variety of in-situ test data of the mechanical properties of soil stratum for comparative analysis, to provide a variety of reliable geotechnical design parameters for optimal design.

(4) Detailed process. First, the exploration process is closely linked and strictly implemented in accordance with international standards; secondly, a detailed special laboratory test plan is formulated according to the deformation characteristics and geological characteristics of the proposed structure, and the full course is supervised by the consulting company; finally, based on the CPTU test results, analyze the physical and mechanical indexes of each soil layer by thickness per meter or even per centimeter, and verify each other through various test results.

6. Conclusion

Select high-quality technical and management personnel to form an exploration team, conduct full-personnel management, full-process management and comprehensive coordination in order to provide international-level exploration results report is the core of refined exploration and the key to improving exploration quality.

The refined management of engineering projects will become the mainstream gradually, and the refined exploration is the foundation and quality assurance. Therefore, refined exploration will become an inevitable trend in domestic and international large and super large projects.

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