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Research and Application of Comprehensive Survey Technology for Transmission Engineering in Shallow Sea Area

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Abstract: To carry out seabed engineering geological survey is one of the important technical measures to ensure the safety of submarine electric transmission lines. Firstly, the characteristics, principles and application scope of several kinds of geotechnical engineering survey techniques were analyzed. On this basis, a comprehensive survey technique for seabed engineering geology is proposed. By applying the comprehensive survey technology to the engineering geological survey of the submarine transmission line routing area in a certain sea area, the engineering geological characteristics of the area and the unfavorable geology and obstacles affecting the line safety are found out, which provides technical guidance for ensuring the transmission line safety. The rationality and applicability of the comprehensive survey technology are verified by practical examples, which can provide reference for other submarine geotechnical engineering survey and promote the development of marine survey technology in China.

1.Introduction

Submarine engineering geological survey is the premise and basis for the design and construction of submarine transmission engineering, which has extremely important research significance. The purpose of submarine engineering geological survey is to find out the geological conditions of the seabed engineering, analyze the existing geological problems, and make engineering geological evaluation on the routing area of the transmission project. If the survey work is insufficient, the geological problems of bad engineering will not be revealed. Even if the design and construction of the submarine cable reach high quality, it will be damaged. Different types and scales of engineering activities will bring different degrees of impact to the geological environment. On the contrary, different geological conditions will bring different effects to the construction of the project^[1-3]

On the basis of summarizing the existing seabed geotechnical engineering techniques, this paper analyzes the principles and applicability conditions of marine geophysical exploration and drilling technology, and proposes a practical comprehensive survey technology for submarine geotechnical engineering, in order to promote the development of submarine engineering geological exploration technology, and it provides useful guidance for improving the technical level of seabed engineering geological survey in China.



2.Submarine engineering geological comprehensive survey technology

The technical means used in submarine engineering geological survey mainly include seabed geophysical techniques, subsea drilling and sampling techniques, submarine in situ testing techniques, and geotechnical testing techniques for submarine rock layers.

2.1 Submarine Geophysical Technology

The application of geophysical methods in submarine cable engineering mainly includes geological evaluation before sea cable laying (including submarine bottom conditions, adverse geological effects of seabed, etc.) and maintenance of the submarine cable after laying (identifying the position of the submarine cable, burying or floating). Related geophysical techniques include seabed side sweep sonar technology, shallow formation detection technology, magnetic detection technology, and marine seismic exploration^[4-9].

2.1.1 Side Scanning Sonar Technology

The side-scanning sonar is a high-resolution, versatile underwater sound device with a sonar or missile-shaped sonar "tow fish" (with sonar transducer), a data acquisition computer, and a connecting cable. Both sides of the "towing fish" simultaneously emit a certain frequency of sound wave pulses to the seabed. When the sound waves propagate to the seabed or encounter obstacles, they reflect and scatter. The receiving unit receives the sonar signals reflected and scattered to the side-sweeping sound-sucking fish receiving unit. The data processing unit converts into different grayscale pixel images according to the scattering and reflected signal intensity of the seafloor features to present a state of the target to be detected relative to the seabed.

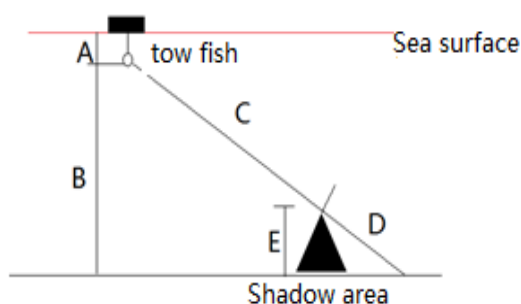


Figure1 Side scan sonar works

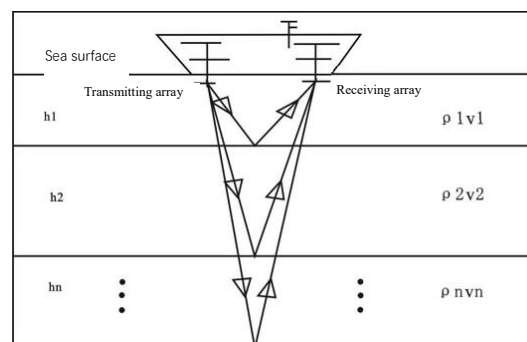


Figure 2 Working principle of shallow stratigraphic section

2.1.2 Shallow formation detection technology

Shallow stratigraphic detection technology mainly determines and interprets and analyzes the acoustic image of the obtained acoustic stratigraphic profile, and divides the acoustic reflection interfaces. Combined with the engineering geological drilling results and regional environmental data, the elevation and burial depth of the interface at the seabed are determined. Infer the soil type and engineering geological characteristics of each unit, classify the possible types of disaster geology, and define the type and distribution range of disaster geology, analyze its type, characteristics and its impact on the project.

2.1.3 Ocean magnetic detection

Magnetic detection has always been a traditional content of marine geophysical surveys. In the past, it was mainly used in the field of marine scientific research, such as delineating rock mass, dividing lithology, and inferring structural morphology and location. In the submarine cable survey project, ocean magnetic detection is mainly used for the detection of existing submarine magnetic pipelines and artificial obstacle detection.

The method of ocean magnetic detection is as shown in the figure below. A pound (8-12Kg) is

added about 10m away from the fish, and the length of the nylon rope is 6m. It is required that during the detection process, the ship should sail at the slowest speed as possible, and the plumb bob should be dragged to the bottom of the sea. Because the air in the cavity the fish will not sink to the bottom and it is assumed that the "fish" can be kept at 4-8m from the sea floor, so the sensitivity is higher and the noise is lower. When the fish crosses the submarine cable, it can ideally detect the magnetic anomaly curve generated by the submarine cable.

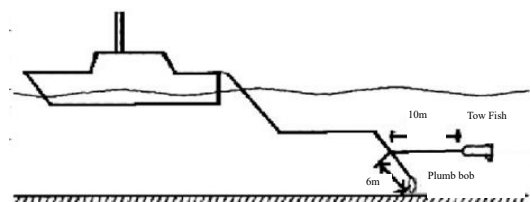


Figure 3 Diagram of Magnetometer Probe Placement in Submarine Optical Cable Routing Survey

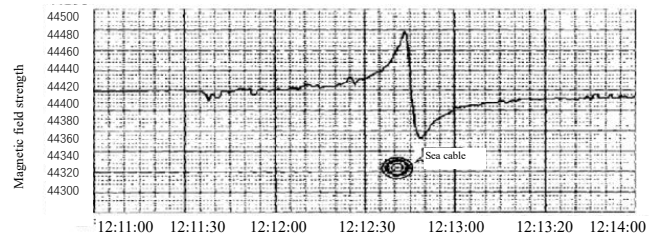


Figure 4 Cable magnetic anomaly detected by magnetometer in cable routing survey

2.2 Subsea formation drilling sampling technology

Engineering geological drilling is mainly based on the Code for Surveying Routes of Submarine Cable Pipelines and Code for Engineering Geological Survey of Offshore Platform Sites, and is mainly based on "Code for Surveying Routes of Submarine Cable Pipelines" [10].

The ship mainly uses barges, cargo ships, water engineering vessels, car ferry ferries, modified landing craft, etc. The working platform is installed on the hull, and 2 or 4 No. 18 I-beam medium channel or thick sleeper is used as the bottom beam of the working platform. The monohull drilling vertical shaft can be installed close to the ship's side, or it can be installed at the bow or tail, while the catamaran is installed in the middle of the catamaran. Under normal circumstances, the main cabin of the ship is properly ballasted with heavy objects, so that the drilling hull maintains a certain draft and the hull is stable.

The small water platform generally adopts a pile-leg fixed platform, that is, the platform legs are inserted into the underwater stable soil layer, and the working platform leaves the water surface. The drilling process is generally the same as on land, with only the lower water jacket to isolate the impact of seawater on the borehole. Due to the ups and downs of the tidal water level, the depth of the drilling hole should be considered in consideration of the water depth. Drilling ships float on the water when drilling, suitable for deep water operations, but are greatly affected by marine natural factors such as sea breeze, waves, tides and currents.

2.3 Submarine formation in situ testing technology

In the geotechnical survey of foreign submarine transmission projects, in-situ testing includes static penetration survey, cross-plate shear survey and standard penetration survey, especially static penetration survey is the main application method.

2.3.1 Submarine Static Penetration Survey

The seabed static probe surveying principle is the same as the onshore static probe survey. It presses the conical probe into the soil at a constant rate to measure its specific penetration resistance or cone tip resistance and sidewall friction resistance. The seabed static penetration survey is applicable to soft soil, general clay soil, silt soil, sand soil and soil layer containing a small amount of gravel. It can be used to divide the soil interface, name the soil, and estimate the soil parameters.

Unlike the land static survey, there is special equipment for the seabed static probe. At present, the seabed static penetration (underwater) equipment is mainly produced in Europe and America, as shown in Figure 5 (the seabed static penetration device ROSON 40kN produced by Vandenberg Machinery Manufacturing Co., Ltd.) and Figure 6 (Geomil, the Netherlands Development of the

Seabed Static Penetration (CPT) System MANTA-200). There are no manufacturers producing related equipment in China.



Figure5 Submarine Static Penetration Equipment ROSON



Figure6 Submarine static penetration testing device MANTA-200

2.3.2 Cross-section shear survey of submarine strata

The Submarine Cross Plate Shearing Survey (FVST) is a test method in which the crosshead of a soft clay is rotated at a certain rate to measure the resistance torque of the soil and then converted into the shear strength of the soil. It is suitable for saturated soft clay soil and can be used to determine the undrained shear strength and sensitivity of homogeneous saturated soft clay. The cross-plate shear test penetration system is the same as the main device of the static test equipment. The test system consists of a penetration system, a torsion device and a measurement system.

- a) penetration system: including probes, main engines, reaction facilities and ancillary tools;
- b) Torque device: including worm gear, shift gear, drill pipe clamp and handle;
- c) Measurement system: including cable, crosshead, torque sensor, test recorder and probe calibration equipment.

2.3.3 Submarine Standard Penetration Survey

The purpose of the standard test is to determine the natural state of the clay and the compactness of the sand by measuring the standard penetration number of the soil layer, and to determine the seismic liquefaction of the silt and sand, and to calculate the foundation. The bearing capacity of the soil layer can also be used to determine the boundary between the residual layer and the weathered rock layer. The Standard Penetration Test (SPT) is mainly applied to sand, silt and general clay, and can also be used for residual soil and full and strong weathered rock. It can be used to evaluate sand, silt, cohesive soil, strong weathered rock or The compactness, state, strength, deformation parameters, foundation bearing capacity of the residual soil, liquefaction potential of sand and silt.

Standard penetration test equipment includes:

- a) Standard penetration: GB12746 standard consisting of a penetration shoe with a cutting edge, a split tube and a penetration cap with drainage;
- b) Drop hammer: consists of a piercing hammer, a hammer pad, a guide rod, and an automatic drop hammer device;
- c) Drill pipe: diameter 42~50mm, tensile strength should be greater than 600MPa, the straightness error of the axis should be less than 0.1%.

3. Application of seabed engineering geology comprehensive survey technology

In order to ensure the stable supply of electricity in China's medium and long-term, China Southern Power Grid Corporation supplemented the submarine power grid interconnection project in a certain sea area of China. Because the submarine cable will be displaced under the influence of the long-term marine environment, and the engineering geological conditions of the newly-connected grid route

submarine stratum are unknown. In order to protect the safety of existing submarine power grid interconnection lines and ensure the smooth laying of new power grid lines, it is necessary to carry out comprehensive engineering geological survey on new loop cable routing.

3.1 Routing area seabed topography

The side scan sonar scanning technology was used to survey the sea area topography of the newly added routing area, and the topographic features of the seabed topography in the routing area were obtained.

The water depth of the routing area gradually increases from the two banks to the center of the strait. In the sea area with a water depth of more than 50 m, an east-west deep trough is distributed. The water depth at the bottom of the trough is between 80 and 110 m. The north slope of the deep trough is slower, the south slope is stepped down, and the local slope is larger. Affected by the strong trend of scouring, the topography of the steep slope and the bottom of the trough is undulating, with secondary scouring grooves and mounds, and there are large areas of fish scale scouring pits and sand waves. The terrain cross section is jagged.

The geomorphological features of the survey area are obvious, mainly distributed with sand waves, sand ridges and gravel, but not many types but widely distributed.

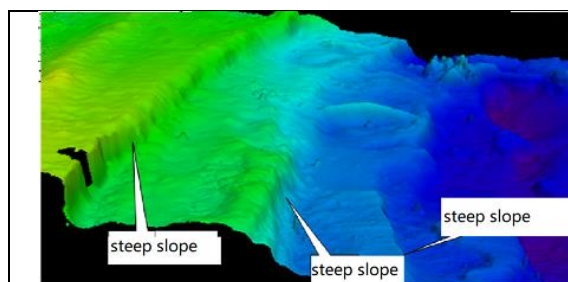


Figure 7 3D map of the seabed topography in the routing area

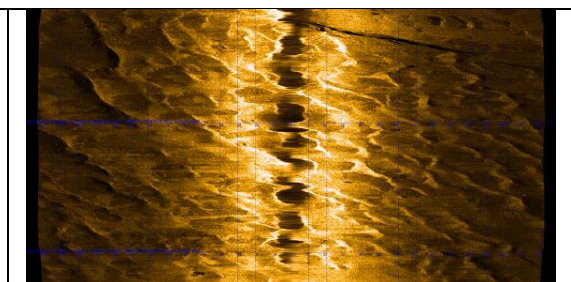


Figure 8 Irregular sand waves on the seabed in the routing area

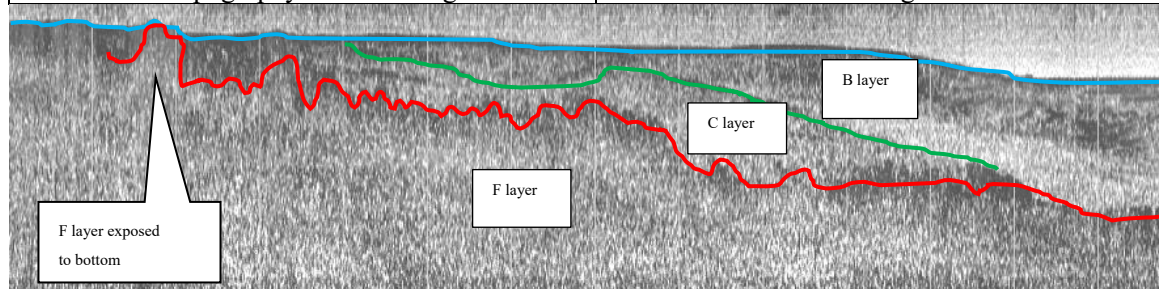


Figure 9 Typical section of the shallow stratum in the routing area Figure 1

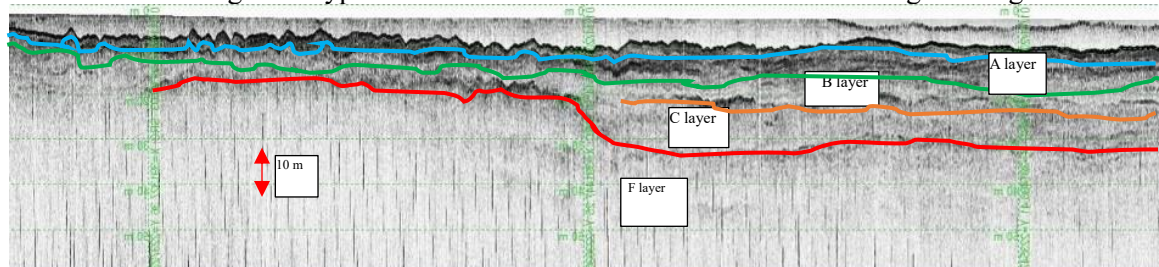


Figure 10 Typical section of the shallow stratum in the routing area Figure 2

3.2 Stratigraphic characteristics of the shallow seabed in the routing area

Using shallow formation detection techniques (see Figure 9-10), geological drilling and CPT test results, combined with the lithology and chronological characteristics of the sea area, the submarine

strata detected in the routing area are divided into six layers from top to bottom.

Layer A, which is a surface sediment, mainly in the north of the route, from plastic to soft plastic silt, silty sand or loose to slightly dense silt, the thickness is more than 2m, the thickest is about 2.5m, under the ground layer is layer B. In the south of the route is loose to slightly dense fine sand or medium coarse sand, the thickness is generally within 2m, and the underlying stratum is layer B.

Layer B: In the northern part of the route, soft-plastic to plastic clay and clay-mixed silt or fine sand, clay, silty clay, muddy clay, silty silt, fine sand, silt, Occasionally medium coarse sand, thickness greater than 5m, underlying formation is layer C and layer F; In the middle of the route, the medium-density sand is slightly dense to medium-density, occasionally fine sand, the thickness is more than 2m, up to 5m in the south of the route, and the layer C, layer D, layer E or layer F in the underlying stratum

Layer C: mainly clay, mainly hard plastic, occasionally plastic, exposed on both sides of the deep trough and on both sides of the southern uplift, with horizontal sedimentary bedding, thickness up to 25m, the top interface erosion marks obvious. The underlying formation is layer D, layer E, which is an unconformity contact.

Layer D: mainly clay, hard plastic shape, the south side of the route is exposed to the sea bottom, the thickness can reach 45m, the top interface erosion mark is obvious, and the underlying stratum is layer E, which is unconformity contact.

Layer E: mainly clay, hard plastic-hard, exposed in the deep groove of the route, the thickness is unknown, and the top interface erosion marks are obvious.

Layer F: is basalt, which is in a strongly weathered or moderately weathered state, and is only distributed in the shallow water section of the north and the southern uplift zone. In the northern section of the route, the depth of the 5m water depth is between 1.5m and 3.0m, and the seabed is partially exposed to 0.6m; The surface of the basalt in the southern uplift has a thin layer of coarse deposits.

3.3 Bad geological evaluation of routing area

For submarine transmission projects, unfavorable geological phenomena refer to geological factors that have some direct or potential hazard to the construction and safety of submarine cables in the submarine and below. The unfavorable geological phenomena that exist on the seabed include sand waves, sand ridges, scouring troughs, scour ridges and mounds, steep slopes, landslides, coral reefs, shallow buried rocks, and weak strata.

There are stepped and irregular sand ridges in the routing area of this survey, which is shown in figure 9 and figure 10.

The terrain of the surveyed sea is relatively narrow, the water area is small, the current is urgent, the sediments in the deep trough and the southern erosion-accumulation area are less, and the erosional terrain such as scouring tanks, scouring ridges and mounds are developed, which makes it difficult to construct and maintain the submarine cable. Laying submarine cables requires sufficient margin

The steep slopes and landslides in the routing area are mainly distributed in the south slope of the central deep trough. The southern slope of the central deep trough descends stepwise and the steep slope develops.

There are coral reefs and shallow buried rocks scattered in the routing area, which are located in the southern uplift zone and the scouring ridges and mounds on the southern slope of the central deep trough. Gravity sampled samples contained fresh coral blocks and growing coral plexus. The shallow buried rock is basalt, which is only distributed in the northern part of the route and has little impact on the route.

The weak stratum of the routing area is stepped north in the sea area. The soft layer of the seabed is thicker, with fine sand and soft clay interlayers. The slope of the terrain becomes larger, and the stratum may slide under the influence of external force.

The sand and silt in the upper stratum of the routing area belong to the liquefied soil layer.

3.4 Comprehensive evaluation of seabed engineering geology in routing area

Combined with the comprehensive survey results of the submarine stratum in the routing area, the submarine engineering geological characteristics of the routing area are:

A. The seabed topography in the middle and south sections of the route varies greatly, and the sand slope and sand ridge are relatively developed, which needs to be fully considered during design.

B. There is gravel distribution near the landing point on the south side of the routing area, and necessary measures must be taken during the construction process.

C. The bottom of the route in the northern and southern sections of the route is a soft plastic-plastic clay or sand layer, which is suitable for cable laying. The middle and south sections of the route are mainly hard plastic clay deposits, with bare mid-weathered basalt in the southern uplift, affecting cable laying.

D. The characteristics of fishery culture in the sea near the landing section in the northern part of the routing area are obvious. There are many pile nets, which affect the laying of submarine cables and need to be cleaned before construction.

4. Conclusion

Conducting comprehensive surveys on seabed rock layers and understanding the engineering geological characteristics of seabed strata is the basis for ensuring the safety of submarine power transmission projects, and is of great significance for submarine power transmission projects. Based on the summary of various submarine engineering geological survey techniques, this paper analyzes the principles and scope of various technologies, and introduces the special engineering equipment for submarine engineering geology. Finally, the seabed engineering geology comprehensive survey method and means are proposed by means of seabed geophysical exploration technology, submarine stratum drilling sampling technology, submarine stratum in situ testing technology and submarine geotechnical test technology.

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