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National Standard of the People's Republic of China

GB/T 17503—2009

Replace GB17503-1998

Specifications for offshore platform engineering geology investigation

海上平台场址工程地质勘察规范

（*English Translation*）

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Contents

Foreword

SAC/TC 283 is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This standard replaces the GB 17503-1998 *Specifications for offshore platform engineering geology investigation* in whole.

The main revisions are as followings:

— The terms and definitions of inshore area, shallow sea area and deep sea area have been added as 3.4, 3.5 and 3.6;
— In 4.2 and 4.3, the survey content and procedure have been revised, and in 4.5 and 4.6 the scope, workload and general requirements of survey have been adjusted;
— The contents of organized data for horizontal control survey and vertical control survey, microwave distance measurement and positioning, long and short-line acoustic positioning have been deleted;
— The technical requirements of navigating and positioning for sailing geophysical survey and fixed-point survey have been revised and the 5.3.1.1 and 5.3.1.2 in 1998 edition have now changed to 5.4 and 5.5 in this edition;
— Multi-beam bathymetry has been added as 6.3, and the requirements for performance, implementation on the sea, data acquisition and processing of all involved survey apparatus have been modified, and the 6.2, 6.3, 6.4, 6.5, 6.6 in 1998 edition have changed to 6.2, 6.4, 6.5, 6.6, 6.7 in this edition;
— The title of the Clause of Seabed Sediment Survey in the 1998 edition was changed to Seabed Sediment Sampling in this edition (see Clause 7), and sample packaging and storage have been added as 7.3.3 and 7.3.4, and the sample description has been refined in 7.3.1 in 1998 edition and which has changed to 7.3.2 in this edition;
— Drilling vessels and drilling methods have been added as 8.1.1 and 8.2, and in 8.4.3c the content of lithology description has been refined comparing with 8.3.1a in 1998 edition;
— The contents of seabed in-situ test and geotechnical test in the Clause of Engineering Geological Test in 1998 edition are separately organized into chapters (see Clause 9 in 1998 edition, Clause 9 and Clause 10 in this edition); added standard penetration test and shear wave velocity test (see 9.4, 9.5), added technical requirements of pocket penetrometer test and pocket vane shear test (see 10.1.3 and 10.1.4);
— Corrosive Environmental Parameters Determination has been added as Clause 11;
— Title of the Clause of Seismic Risk Analysis in 1998 edition was changed to Evaluation of Seismic Safety (see Clause12), modified contents and requirements of probability analysis of seismic risk and parameter determination of ground motion in the platform site (see 10.1 and 10.2 in 1998 edition and 12.1, 12.2 in this edition); adjusted contents of evaluation of seismic geological hazards (see 10.3 in 1998 edition and 12.3 in current edition);
— Title of the Clause of Result Charts and Report in 1998 edition was changed to Result Charts and Report Compilation (see Clause 13), and added foundation engineering analysis (see 13.1.2 j), k), l), m) and 13.2.2 h);
— Data Filing has been added as Clause 14;
— A1 and A2 in Annex A have added the contents of classification and designation of soil ;
— Annex C now has added the Drive Ability Analysis of Piles

Annex A and B in this standard are normative and Annex C is informative.

This standard was proposed by the State Oceanic Administration, People's Republic of China.

This standard was prepared by SAC/TC 283 National Technical Committee on Ocean Standardization Administration of China.

The previous edition of GB/T 17503-2009 is as follow:
The first edition was issued in 1998 as GB 17503-1998 *Specifications for offshore platform engineering geology investigation*.

Specifications for offshore platform engineering geology investigation

1 Scope

This standard specifies the contents, methods and technical requirements, report compilation and data filing of offshore platform engineering geology investigation.

This standard is applicable to the engineering geology investigation of pile supported fixed offshore platform, offshore gravity platform, offshore jack-up platform and other offshore fixed structure sites can be used for reference.

2 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments (excluding corrections), or revisions, of any of these publications do not apply to this standard. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

GB 12327-1998 *Specifications for hydrographic survey*
GB/T 12763.6-2007 *Specifications for oceanographic survey- Part 6: Marine biological survey*
GB/T 12763.8-2007 *Specifications for oceanographic survey- Part 8: Marine geological and geophysics survey*
GB/T 17424-1998 *Technical requirements of differential global positioning system*
GB 17501-1998 *Specifications for marine engineering topographic surveying*
GB 17741-2005 *Evaluation of seismic safety for engineering sites*
GB 50021-2001 *Code for investigation of geotechnical engineering*
GB/T 50123-1999 *Standard for soil test method*
GB/T 50269-1997 *Code for measurement method of dynamic properties of subsoil*
SY/T 10030-2004 *Recommended practice for planning designing and constructing fixed offshore platforms-working stress design*
ASTM D2487-2006 *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
ASTM D5778-1995(2000) *Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils*

3 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply.

3.1 Pile supported fixed offshore platform

The offshore platform supported by the pile driven to the seabed
Note: It may be divided into three kinds based on the number and type of the piles: pile group, leg columns

and jacket type.

3.2 Offshore gravity platform

The offshore platform supported by a base (sink pad) consisting of several large cylinders of reinforced concrete or steel structure

Note: It is generally composed of base, leg columns, steel deck and assembly module on the deck

3.3 Offshore jack-up platform

The offshore platform standing on the sea floor supported by its pile legs

Note: It goes up and down by its own hydraulic lifting system to achieve its position or evacuation

3.4 Inshore area

The sea area from the coastline to 20m water depth

3.5 Shallow sea area

The sea area with water depth of 20m to 300m

3.6 Deep sea area

The sea area with water depth more than 300m

4 Generals

4.1 Purpose and task of the survey

4.1.1 The purpose of the survey is to provide basic information for the design, installation of platform foundation and the prevention and control measures for geological hazards.

4.1.2 The task of the survey is to identify the water depth, topography and seabed conditions of platform site, to ascertain the distribution of rock and soil layers and their physical and mechanical properties within the influence range of platform foundation, to identify the hazardous geological factors affecting the stability of foundation and the safety of drilling construction, to conduct engineering geological condition evaluation, etc.

4.2 Contents of the survey

Offshore platform engineering geology survey shall include the following contents:
a) Water depth and seabed topography;
b) Seabed conditions and natural or man-made obstacles;
c) Structural characteristics, spatial distribution, physical and mechanical properties of submarine strata;
d) Hazard geology and seismic factors;
e) Corrosive environment parameters;
f) Marine development activities.

4.3 Procedures of the survey

The survey shall be carried out in accordance with the procedures of preliminary data collection, technical design, marine survey, sample testing and analysis, data interpretation and collation, engineering geological conditions analysis, report compilation, acceptance of results and data filing, etc.

4.4 Methods of the survey

The main survey methods are as follows:
a) Bathymetric sounding;
b) Side scan sonar detection;
c) Stratigraphic profiling;
d) High-resolution multi-channel digital seismic survey;
e) Magnetic detection;
f) Sampling of seabed sediments and bottom water;
g) Engineering geological drilling;
h) In-situ test;
i) Geotechnical test and corrosive environment parameter determination;

4.5 Scope and workload of the survey

4.5.1 Engineering geology survey shall be carried out within a certain range around offshore platform site. According to the importance of project and accumulation of site data in the past, the survey area is generally determined to be 1 km×1 km-4 km ×4 km.

4.5.2 The survey workload depends on the complexity of engineering geological conditions of platform site, the existing survey data and results of previous work. General provisions are as follows:

a) Geophysical survey lines are laid out in grids. The space between survey lines in the edge area of the site is 100 m-250 m, and the center area of the site is 25 m-50 m;
b) The number of seabed sediment sampling station shall not be less than 10;
c) For the offshore fixed platform site, at least one engineering geological sampling drill hole and one in-situ test drill hole shall be arranged. According to engineering requirements, more engineering geological exploration drill holes shall be added.

4.6 General requirements for the survey

4.6.1 The offshore survey vessel shall be able to operate under the sea conditions of class 2 or class 3 of Beaufort scale, and the open sea survey vessel shall be able to operate under the sea conditions of class 4 or class 5 of Beaufort scale. It can maintain the speed of less than 5 kn. and comply with the requirements of navigation, positioning, safety, firefighting and lifesaving, communication, power supply, equipment installation, release and recovery, laboratory, etc.

4.6.2 The technical indicators of survey apparatuses shall comply with the requirements of survey project, and shall be used within validity period of certificate of verification and calibration, and shall be in normal working conditions. Apparatuses which cannot be calibrated indoors shall be compared with traditional apparatuses on the spot to examine their effectiveness. The transportation, installation, distribution, operation and maintenance of

apparatuses shall be carried out according to the provisions of their instructions.

4.6.3 The survey technician shall obtain the qualification certificate issued by the legitimate qualified organization which is in conformity with survey project and is competent for the work.

4.6.4 The person on duty shall abide by the duty and shift system, and make good records. The records shall be unified and standardized. The records shall be completed by person on duty and verified by successor during shift to ensure integrity and reliability of the contents.

4.6.5 The survey chart for site of the platform shall be generally made on the scale of 1:5000. It may also be made on the scale according to the requirements of the entrusting party. Charts for each site shall be made separately and when the sites are very close, the charts for these sites may be merged

4.6.6 When several geophysical survey methods are used for synchronous operation, positioning time and number of survey lines and points shall be unified. If the survey is interrupted or same surveying line is divided, supplementary survey is required to carry out according to same method and at least three positioning points shall be overlapped.

4.6.7 Maritime traffic, fishing and other activities related to platform site survey shall be recorded in time.

4.6.8 All kinds of raw data, records, samples collected and observed at sea shall be given unique identification.

4.6.9 Implementing quality control throughout the whole process, conduct on-site quality inspection and acceptance of samples and raw materials obtained at sea, the survey work that fails to meet the technical requirements shall be supplemented or re-surveyed. Quality inspection shall be carried out on the results of sample analysis, testing and data processing.

5 Navigating and Positioning

5.1 Root mean square error in positioning

The root mean square error in positioning shall comply with the following requirements:
a) When the mapping scale is larger than 1: 5000, the root mean square error in positioning on the sea shall not be larger than 1.5mm on map;
b) When the mapping scale is not larger than 1: 5000, the root mean square error in positioning on the sea shall not be larger than 1.0mm on map.

5.2 Coordinate system and projection

The coordinate system and projection method shall comply with the following requirements:
a) The plane coordinate system adopts WGS-84 geodetic coordinate system or 1954 Beijing coordinate system, or other coordinate systems as required by entrusting party;
b) Use Gauss Kruger projection, other projection methods can also be used according to the requirements of entrusting party.

5.3 Navigating and positioning methods

5.3.1 Navigating and positioning methods shall comply with the following requirements:

a) Meet the requirements concerning error in navigating and positioning operations;
b) Positioning range can cover the operation area;
c) Be able to continuous, stable and reliable operation;
d) Update rate of positioning data is not less than 1 time / sec.

5.3.2 DGPS navigating and positioning shall comply with the requirements as specified in GB/T 17424-1998, Clause 4 and 9, and the error comparison test in positioning shall be carried out before operation. Navigation and positioning shall have differential signals, the number of effective observation satellites shall not be less than 4, satellite angle of elevation shall not be less than 5 degrees, position dilution of precision (PDOP) shall not be more than 6, and difference signal update rate shall not be more than 30 s.

5.3.3 Ultra-short baseline underwater acoustic positioning system is mainly used for the positioning of the geophysical underwater towing probe. The underwater acoustic transponder is installed in the probe, and the probe is positioned according to the position relationship between the positioning equipment of survey ship and underwater acoustic transponder. Before starting work, the installation attitude of positioning system shall be calibrated.

5.4 Navigating and positioning for sailing geophysical survey

Navigating and positioning for sailing geophysical survey shall comply with the following requirements:
a) The survey ship shall be moved ahead and delayed on the extension of survey line. The length of extension line shall be no less than 2 times the length of towing cable when there is a towing body;
b) The surveying speed of ship shall not exceed 5 kn. for the survey of side-scan sonar, sub-bottom profiler and magnetic detection. For the single operation of bathymetric sounding, working speed shall not exceed 10 kn.;
c) The offset between the track and design line shall not be greater than 20% of distance between the lines. When multi-beam bathymetric operation is carried out, the maximum deviation value of survey line shall not be greater than 10% of measured coverage width;
d) The distance between positioning points shall not be greater than 1 cm on the map;
e) The report shall record line number, first and last point number, date and time, quality index of satellite signal, interruption situation and handling opinions in detail;
f) The horizontal position of antenna of positioning instrument on survey ship and probe of survey equipment shall be overlapped as much as possible. When the horizontal distance between antenna and probe of survey equipment exceeds 1 mm on the map, the eccentricity of points shall be corrected.

5.5 Navigating and positioning for fix-point survey

Navigating and positioning for fixed-point survey shall comply with the following requirements:
a) Record the positioning data when sampling or testing devices enter the water. The maximum deviation between actual borehole location and designed borehole location shall be less than

20 m in inshore area and less than 50 m in shallow sea area, and less than 100 m in deep sea area;
b) When sampling, the shipboard of sampling operation should be adjusted to the windward side.

5.6 Collation of positioning data

Data collation shall comply with the following requirements:
a) Field survey data shall be collated in accordance with the requirements given in 9.4.2 of GB 17501-1998;
b) Track chart shall be plotted on the basis of positioning data in accordance with requirements given in 9.8.2 of GB 17501-1998.

6 Engineering Geophysical Survey

6.1 Contents of the survey

Engineering geophysical survey includes bathymetry, side scan sonar detection, sub-bottom profiling and high-resolution multi-channel digital seismic survey. Magnetic detection may be adopted according to the engineering requirements.

6.2 Single beam bathymetric sounding

6.2.1 The sounder selected shall have both analog and digital recording modes, and its main technical indicators shall comply with the requirements given in 6.3.4.of GB12327-1998.

6.2.2 Single beam bathymetric sounding shall comply with the following technical requirements:

a) Root mean square error in bathymetric sounding: in waters with depth less than 20 m, the error is not greater than 0.2 m; in waters with depth more than 20 m, the error is not greater than 1% of the water depth;
b) The tolerance of water depth inconsistency between coincidence points (within 1 mm on the map): In waters with depth less than 20 m, the tolerance is not greater than 0.4 m. In waters with depth greater than 20 m, the tolerance is not greater than 2% of water depth. The number of points exceeding the limit must not exceed 15% of total comparison points;
c) The in-situ measured water level data shall be used in inshore section for water level correction. The root mean square error of water level observation in tide gauge stations shall not be larger than 5 cm. When tidal station along coast or other means cannot control the change of water level in sounding area, forecast water level may be used to correct the water level;
d) When dynamic draft change is greater than 5 cm, dynamic draft correction shall be carried out.

6.2.3 Bathymetric sounding on the sea shall be carried out in accordance with the requirements given in 9.2.6 of GB 17501-1998.

6.2.4 Supplementary measurement or resounding shall be performed in the following situations:

a) Root mean square error in positioning cannot meet the requirements given in 5.1;
b) The deviation of sounding line from design line is more than 50% of the space between designed lines or the missed sounding exceeds 5 mm on the map;
c) Depth error cannot meet the requirements as specified in 6.2.2 a) and 6.2.2 b);
d) Data of water level and sound velocity cannot meet the requirements of depth correction.

6.2.5 Water depth data collation shall comply with the following requirements:

a) Depth value shall be taken according to the requirements given in 9.5.4 of GB 17501-1998;
b) Depth correction shall be in accordance with the requirements given in 9.5.5 of GB 17501-1998,

6.2.6 Compilation of result maps shall be in accordance with the following requirements:

a) Datum level of bathymetric maps and seabed topographic maps shall be the lowest theoretical tidal level, mean sea level or 1985 National Elevation Datum. When other datum levels are used, their relationship with theoretical lowest tidal level, mean sea level or 1985 National Elevation Datum shall be indicated;
b) Basic isobaths interval of bathymetric maps and seabed topographic maps shall be selected according to 0.5 m,1 m,2 m,5 m, and the isobaths are divided into head curves and metering curves;
c) Other requirements for bathymetric map and seabed topographic map shall be in accordance with the provisions given in 9.6 of GB17501-1998.

6.3 Multi-beam bathymetric sounding

6.3.1 Apparatuses

The selection of multi-beam bathymetric system shall take into account the sounding range, accuracy, coverage, renewal rate and other factors. Its main technical indicators shall comply with the following requirements:
a) Root mean square errors of sounding instruments shall comply with the requirements given in 6.2.2 a);
b) Beam angle of transducer shall not be larger than 2 degrees;
c) Measurement accuracy of attitude sensor shall not be less than 0.05 degrees for roll and pitch, 0.05 m for heave and 5% for actual heave, and 0.1 degrees for compass.

6.3.2 Technical requirements

Multi-beam measurement shall comply with the following requirements:
a) Root mean square errors in sounding shall comply with the requirements given in 6.2.2 a);
b) Depth discrepancy for overlapping points (within 1 mm on the map) shall comply with the requirements given in 6.2.2 b);
c) Root mean square error in time delay between depth sounding and positioning shall be no more than 0.1s. and navigation delay shall be retested whenever the navigating and positioning system is changed;
d) The measurement area shall be 100% of the multi-beam measurement coverage, and the adjacent main lines shall ensure a duplicate coverage rate of 20%;
e) In order to correct the sound velocity, the time density of sound velocity profile measurement shall be not less than once a day, and measuring points for sound velocity profiling shall not be less than one in each well site;
f) Draft change of multi-beam transducer shall be measured before and after of each voyage and for a measurement interval of more than 3 days during the survey. Piecewise calculation may be employed to correct the change in draft of transducer, interpolated by time;

g) Observational data of measured water level shall be adopted as reference for the correction of water level in inshore area. Root mean square error in water level observation of tidal station shall be kept within 5 cm. When the coastal tide gauge station or other means cannot control the change of water level in the survey area, the predicted water level may be used to correct the water level.

6.3.3 Marine measurement implementation

Marine measurement shall be carried out in accordance with the following requirements:
a) Stability and navigation test of multi-beam bathymetric system shall be carried out before measurement. The stability test shall be carried out in the flat seabed area. The depth contrast error obtained from repeated bathymetric measurements shall comply with the requirements given in 6.3.2 a) and 6.3.2 b). The navigation test shall select a representative area of sea floor topography, determine the working state of the system at different depths and speeds, and require that the number of beams received by each transmitting pulse shall be greater than 95% of total number of beams, and the dynamic draft of transducer shall be measured at different speeds from static to maximum operating speeds;
b) Observe the displayed system status and beam quality, monitor the settings of system parameters, rolling and longitudinal trim correction, and heading correction of the transducer and beam integrity in the amplitude;
c) Observe the displayed sailing course to monitor for jump or overlapping of adjacent survey lines etc.;
d) When the number of beams received is less than 80% of the number of emitted beams, the sailing speed of survey vessel shall be reduced or the survey line interval shall be adjusted;
e) Observe and record the working conditions and ensure completion of all measurement data;
f) Black areas between survey lines shall be given supplementary survey or be made part of supplementary survey plan;
g) Duty report shall be recorded in great details of starting and ending point of survey lines, number of survey lines, latitude and longitude as well as abnormal conditions etc.

6.3.4 Supplementary measurement or re-measurement

Supplementary measurement or re-measurement shall be carried out in the following situations:
a) Multi-beam measurement coverage cannot meet the requirements given in 6.3.2 d);
b) When situations given in 6.2.4 a), b) ,c) and d) take place.

6.3.5 Data processing

6.3.5.1 Raw data files, sound velocity profile files and other data records shall be backed up.

6.3.5.2 The raw data shall be 100% check-up to delete the mutated wrong data and biased beam data of poor quality. Reading shall be taken from 3 to 5 sounding points in each section to verify their geodetic coordinate, rectangular coordinate and water depth values and determine whether there are blank spaces failing to be measured.

6.3.5.3 Data editing shall be as follows:

a) Delete or correct sudden jump points and abnormal heading points in positioning data, and convert qualified positioning points to the position of system transducer;
b) Delete gross error, spurious signal and unqualified water depth data but shall be careful when dealing with the abnormally shallow points;
c) Depth correction includes transducer draft depth correction, sound velocity correction, water level correction, multi-beam system parameter correction, etc. Water level correction shall be carried out in accordance with the requirements given in 6.3.2;
d) When splicing data of varied errors, low accuracy data shall be leveled to high accuracy data. When data with same accuracy are combined, high density data shall be used or leveled. Then, the difference of water depth before and after leveling is calculated, the arithmetic mean and root mean square error are counted, and root mean square error of water depth splicing is evaluated;
e) Calculate the depth inconsistency and depth root mean square error of the coincidence point and the evaluation shall be performed according to the requirements given in 6.3.2 a) and 6.3.2 b);
f) Forming a digital seabed topographic information file consisting of longitude, latitude and water depth of each beam, i.e. discrete data file;
g) Set up reasonable data grid space to realize data gridding. The minimum grid space shall ensure that there are three water depth points in each grid, and the maximum grid space shall not be larger than the actual distance of 5 mm on the result map.

6.3.6 Result maps

The result maps shall be compiled according to the following requirements:
a) Basic isobaths interval of bathymetric maps and seabed topographic maps shall be selected according to 0.5 m, 1 m, 2 m or 5 m, and the isobaths are divided into head curves and metering curves. Isobaths are divided into intermediate contour and index contour. If basic isobaths are insufficient to display the special topographical characteristics, auxiliary isobaths shall be drawn on the map. Conventional bathymetric maps shall be interpolated and thinned by gridding data. After interpolation and thinning, the distance between water depth points on the map shall not be more than 1 cm. Special water depth points shall be retained, including the deepest, shallowest water depth points and the point of slope change;
b) Other requirements for bathymetric map and seabed topographic map are given in 9.6 of GB 17501-1998.

6.4 Side scan sonar detection

6.4.1 Side scan sonar system shall comply with the following requirements:

a) The operating frequency shall not be less than 100 kHz, the horizontal beam angle shall not be less than 1 degree, and the maximum one-side scanning range shall not be less than 200 m;
b) Shall be able to distinguish seabed objects of 1 m^3 size;
c) Shall have the functions of speed correction and tilt distance correction;
d) Analog and digital recording can be used simultaneously.

6.4.2 Side scan sonar detection shall comply with the following technical requirements:

a) A reasonable range of sonar scanning shall be chosen according to the space between survey lines. It shall cover 100% in corridor zone of route survey, and ensure 100% repetition coverage in adjacent line scanning. When water depth is less than 10 m, the repetition coverage may be reduced appropriately;
b) Height of the tow fish above seabed shall be controlled at 10% to 20% of scanning range. When water depth of surveyed area is shallow or seabed is undulating, the height of tow fish above seabed may be increased appropriately;
c) The image obtained by side scan sonar shall be clear.

6.4.3 Marine detecting shall be carried out according to the following requirements:

a) Before detecting, adjust equipment in operation area or adjacent sea area to determine the best working parameters;
b) After tow fish enters the water, the vessel shall maintain a steady speed (no more than 5 kn.) and course, and avoid parking or backing up;
c) Ultra-short baseline underwater acoustic positioning system can be used to locate the position of tow fish, and manual calculation can also be used to correct the position of tow fish in shallow waters near the shore;
d) Analog recording sonar images shall be labeled, including project name, survey date and time, instrument model, instrument parameters, line number and line starting and ending point number, etc.;
e) The contents of shift report include project name, survey sea area, working vessel, recorder, sea condition, obstacles on the sea surface, emergencies, instrument name and model, date, time, line number, number, vessel speed and course, instrument operating parameters, volume number of recording paper and name of digital recording document, etc.;
f) When a suspicious target is found by preliminary interpretation of the sonar image record, additional lines in different directions shall be laid around the suspicious target for further detection.

6.4.4 Data processing shall comply with the following requirements:

a) Recognize the interference signals and noise on sonar image record;
b) Based on the data of bathymetric sounding and sediment sampling, identify and determine the type and distribution of sediments, hazard geological factors, the location, shape, size and distribution range of seabed objects;
c) Sonar image mosaic and splicing as required.

6.4.5 Result maps include:

a) Seabed conditions map;
b) Sonar images mosaic map in local or whole area.

6.5 Stratigraphic profiling

6.5.1 The performance of stratigraphic profiler shall comply with the following requirements:

a) The sound source of sub-bottom profiler generally adopts electro acoustic or electromagnetic pulse, and the frequency spectrum is 500 Hz-15 kHz;
b) The sound source of medium stratigraphic profiler generally adopts electromagnetic pulse or small electric spark, and the frequency spectrum is 200 Hz-5 kHz;
c) Sound source of deep profiler generally use electric spark, air gun, water gun or combination of gun array with a frequency spectrum of 60 Hz-2 kHz;
d) The transmitter shall have enough power. The receiver shall have enough frequency bandwidth and time-varying gain adjustment function, and can simultaneously carry out analog record profile output and digital acquisition, processing and storage.

6.5.2 Stratigraphic profiling shall comply with the following technical requirements:

a) Stratigraphic profiling includes sub-bottom profiler, medium stratigraphic profiler and deeper stratigraphic profiler detection, which is used for obtaining the acoustic profile record within 200 m under the seabed. According to project needs, three kinds of detection may be carried out simultaneously or sub-bottom and medium stratigraphic profiling detection may be done at the same time or medium stratigraphic and deeper stratigraphic profiler detection may be carried out together;
b) The resolution of sub-bottom profiler shall be better than 0.2 m, that of medium stratigraphic profiler is better than 1 m, and that of deeper stratigraphic profiler is better than 3 m;
c) Record profile images shall be clear, with no strong noise interference and image blurring, discontinuity, etc.

6.5.3 Stratigraphic profiling shall be carried out according to the following requirements:

a) Before profiling, adjust equipment in the operation area or adjacent sea area to determine the best working parameters;
b) Towed sound source and hydrophone array shall be towed in parallel outside the vortex region of the stern. Hydrophone array shall be stably towed under the sea surface of 0.1 m to 0.5 m;
c) The range and delay of recorder shall be timely adjusted when there are great variations with water depth;
d) The methods of swell compensator or digital swell filter shall be used for filter processing;
e) Analog recording images shall be labeled, and its contents include project name, survey date and time, instrument model and parameters, line number, starting and ending point number of line and surveyor, etc.;
f) The contents of shift report shall include project name, survey area, surveyor, instrument name and model, survey date and time, line number, point number, sailing speed and course, instrument operation parameters, record paper number and digital record file name, etc.;
g) When preliminary analysis of field profile images reveals suspicious objects, supplementary survey lines shall be laid to ascertain the nature of those objects.

6.5.4 Data processing shall comply with the following requirements:

a) Identify the interference signal on the stratum section image record;
b) According to the characteristics of reflection structure, amplitude, frequency, coaxial

continuity and contact relationship of reflection wave of profile image, and combined with geological drilling data, the acoustic stratigraphic sequences are divided, the stratigraphic sedimentary textures and structures are explained, and the sedimentary type and engineering geological characteristics are judged. The hazard geological factors are analyzed and their properties, forms and distribution ranges are determined;
c) Time-depth conversion shall be done on the measured sound velocity obtained by means of drilling horizon comparison, acoustic velocity logging or other measurement methods.

6.5.5 The compilation of result maps shall comply with the following requirements:

a) The vertical and horizontal scale of stratigraphic cross-section shall be appropriate. The content includes topographic section line, stratum interface, lithology, hazard geological factors, landmarks, sampling station, borehole location and its column diagram and test results;
b) The contents of the shallow geological feature map mainly include the isopach line or equal buried depth line of the important strata, important topography, geomorphology and shallow geological phenomena, hazard geological factors, landmark, seabed sampling station, drilling hole location, test results, etc. The shallow geological feature map can be combined with the seabed conditions map when it does not contain much content.

6.6 High resolution multi-channel digital seismic survey

6.6.1 Apparatuses

6.6.1.1 Technical performance of master machine shall comply with the following requirements:

a) Pre-amp consistency: amplitude difference is around －2%~2% and phase difference is around (0±1)ms;
b) Noise: when preamplifier gain is at 2^8, the noise is not larger than 0.13 μV; when preamplifier gain is at 2^6, the noise is not larger than 0.19 μV; when preamplifier gain is at 2^4, the noise is not larger than 0.66 μV;
c) Drift: drift of any channel is (0±1μV;
d) Crosstalk: when the main amplifier gain is 1 FP, the crosstalk is not larger than - 78 dB; when the main amplifier gain is 2 FP, the crosstalk is not larger than - 72 dB;
e) Distortion: distortion is not larger than 0.06%;
f) Notch: attenuation of any channel is not smaller than 40 dB;
g) Purity of A/D converter: linearity error is not larger than 0.02%;
h) Dynamic range: dynamic range is larger than 78 dB;
i) Impulse response: amplitude difference is around －2%~2% and phase difference is 2 ms.

6.6.1.2 Technical performance of seismic source shall comply with the following requirements:

a) Use air guns, water guns with small capacity and displacement;
b) Working pressure of the guns is not less than 95% of the rated pressure;
c) Accuracy of gun controller is within ±0.1ms;
d) Frequency band of the source wavelet shall be kept at sufficient width and special attention shall be paid to the fullness of low frequency;

e) Ignition synchronization error of combined air gun shall be controlled within 0.3 ms, the maximum is not more than 0.5 ms, and the number of more than 0.3 ms shall not be more than 20% of the total.

6.6.1.3 Technical performance of the receiving cables shall comply with the following requirement:

a) Insulation resistance of the full cable (before entering the water) shall be larger than 10 MΩ;
b) Crosstalk of the cable shall be larger than 60 dB;
c) Towing noise of the cable shall be lower than 0.1 Pa;
d) Phase difference between the channels shall less than 1 ms;
e) The amplitude change between the channels shall be within 15%;
f) Depth sensor shall be placed at least every 200 m. Controlling range of the cable depth controller shall be from 3 m to 30 m. Sink depth of the cable shall not be deeper than 4 m in general;
g) Cable tail shall be equipped with RGPS tracking and positioning system.

6.6.2 Survey technical requirements

High-resolution multi-channel digital seismic survey shall comply with the following technical requirements:
a) Number of channels shall be no less than 48 and the space between them shall not exceed 12.5 m. Data sampling rate shall not be more than 1 ms and record length shall not be less than 2000 ms;
b) Number of abnormal working channels shall be less than 4% or less than 3 channels. Empty shot or waste shot rate of the survey line shall be less than 5% and no more than 4 continuous empty shot and waste shot guns;
c) Timing line of the monitoring record shall be clear and channel tracks shall be even. Break points of air gun synchronization signal and excitation signal (TB) shall be clear. A set of paper quality monitoring records shall be displayed for the first and last shot and every 40 shots;
d) Survey lines shall be layout with other geophysical survey lines as consistent as possible and try to go through the existing drilling holes. At least two mutually perpendicular survey lines shall pass through the predetermined offshore platform position;
e) Seismometer shall be examined daily and monthly.

6.6.3 Implementation of marine survey

Marine survey shall be implemented in accordance with the following requirements:
a) Horizontal stacking method (common-depth-point) shall be applied and times of coverage and overlapping and array length shall be determined according to actual needs;
b) Equipment shall be debugged prior to the survey near the operation areas to determine the best working parameters by carrying out matching test of sink depth of cable and seismic source;
c) After the source and cable enter the water, the vessel shall maintain a steady speed (no more than 5 kn.) and heading. In order to ensure that the cable is straightened before formal firing, distance to be put on line ahead of time is more than twice the length of rear towing

cable. The bathymetric values of the first gun, end gun and last gun of each recording tape and every 40 guns of each line are marked once on duty record;
d) Feathering angle of the cable shall be recorded on site in duty report at least once for every 40 shots. The feathering angle shall not be larger than 10° ;
e) Replay and examine the monitoring records;
f) Duty report for the first and last shot and every 40 shots of survey lines shall be recorded. Duty report shall keep track of project name, survey sea area, survey vessel, date, survey line number, file number, tape number, shot point number, water depth, sound velocity, water depth of depth sensor, etc. Tags shall be stuck on the tapes, and labeled contents are consistent with duty report.

6.6.4 Data processing

Data processing shall comply with the following requirements:
a) Check debugging data and original record of instrument, requiring data completed and measuring line and points corrected;
b) Seismic data processing includes field band decomposition, single shot and single channel display, bad shot and bad channel editing, pre-stack noise elimination, observation system definition, filtering and amplitude compensation, source wavelet deconvolution, static correction, multiple attenuation and velocity analysis, dynamic correction and stacking, post-stack time migration, time-varying filtering, dynamic balance and result profile generation, etc.;
c) According to the characteristics of reflection structure, amplitude, frequency and continuity of same phase axis of seismic profile, combined with geological borehole data, etc., seismic sequences are divided, and sedimentary textures and stratigraphic structures are interpreted, and hazard geological factors and their feature, shape, distribution are analyzed,;
d) According to velocity analysis, root mean square velocity or average sound velocity and layer velocity are extracted for time-depth conversion.

6.6.5 Result maps

The following maps are compiled on the basis of high resolution multi-channel digital seismic survey, comprehensive stratigraphic profile exploration and geological drilling.
a) Seismic profile interpretation map. Generally, seismic profile interpretation maps of two orthogonal lines shall be drawn up. The maps shall pass through engineering geological boreholes, and one of the sections shall be along the vertical structural line;
b) Geological characteristic map. The map mainly reflects the significance hazard geological factors and their shape, feature, scale, etc.;
c) Stratigraphic isopach map. Choose the main strata with engineering significance to compile;
d) Geotectonic map. It reflects the stratigraphic and tectonic characteristics of about 500 m under the seabed.

6.7 Magnetic detection

6.7.1 The sensitivity of selected magnetometer shall be better than 0.05 nT and the dynamic measuring range shall be at least between 20000 nT and 100000 nT.

6.7.2 Magnetic detection shall comply with the following technical requirements:

a) Mean square error of the measuring difference of intersection point of main survey line and detection line shall not be greater than 2 nT;
b) Layout of the survey lines according to the requirements of geophysical survey line grid given in 4.5.2. Layout of certain survey lines according to actual needs towards the magnetic objects indicated in historical data. The lines shall be perpendicular to extension direction of the objects.

6.7.3 Marine detecting shall be carried out according to the following requirements:

a) Before detecting, adjust equipment in the operation area or adjacent sea area to determine the best working parameters.
b) After the detector enters the water, the vessel shall maintain a steady lower sailing speed and a steady heading, and avoid parking or backing up. The height of the detector above seabed shall be within 10 m, but the height may be increased appropriately in the sea areas where seabed is undulating;
c) Ultra-short baseline underwater acoustic positioning system shall be used to locate the detector, and manual calculation may also be used to correct the position of detector in nearshore and shallow waters;
d) Ensure the integrity of detection records, and make a supplementary survey when records missing or cannot be correctly interpreted;
e) Analog recording shall be labeled, including project name, survey date and time, instrument model and parameters, line number, starting and ending point number of line, surveyor, etc.;
f) The contents of shift report shall include project name, survey sea area, surveyor, instrument name and model, survey date and time, number of line and point, vessel speed and heading, length of tow cable entering the water, and name of digital recording document, etc.;
g) When a suspicious target is found by interpretation of the on-site record, additional lines shall be laid around the suspicious target as required.

6.7.4 Data processing shall comply with the following requirements:

a) The magnetic detection data could be corrected if necessary. The calculation of magnetic anomaly shall be in accordance with the requirements given in 10.4 of GB/T 12763.8-2007;
b) Combined with the results of side scan sonar detection and stratigraphic profiling, the magnetic detection data are interpreted. Then, identify the magnetic objects on the seabed, determine their feature, location and scope, and determine the position and direction of existing submarine cables and pipelines.

6.7.5 Result maps

a) Map of measured magnetic field intensity or magnetic anomaly plane profile. Contour map of magnetic anomaly shall be compiled as required;
b) Distribution map of seabed magnetic objects. The map may be merged into the seabed conditions map, and some of the more important parts may be drawn separately as required.

7 Seabed Sediment Sampling

7.1 Sampling methods

Seabed sediment sampling is divided into surface sediment sampling and core sediment sampling: The former may use grab sampler and box sampler; the latter may use gravity sampler and vibration sampler.

7.2 Technical requirements for sampling

Seabed sediment sampling shall comply with the following technical requirements:
a) Sampling stations shall be laid out in a grid shape with space not more than 400 m. The total number of sampling stations at each site shall not be less than 10, and the number of core sampling stations shall be no less than one third of total sediment sampling stations. According to the results of engineering geophysical survey and interpretation, the station layout shall be adjusted appropriately, and the sampling station shall be added in the complex area of sediment changes;
b) The diameter of core sample shall not be less than 65 mm. The length of cohesive soil core sample shall be longer than 2 m, and that of sandy soil shall be longer than 0.5 m. The surface sediment samples shall not be less than 1 kg;
c) Re-sampling shall be done when the core sample length cannot meet the requirements. If qualified samples still cannot be obtained after two consecutive samplings, grab or box sampler may be used instead;
d) If qualified sample cannot be collected after three consecutive samplings with grab or box sampler, analyze the reason. If it is determined that this situation results from seabed features, sampling may be stopped.

7.3 Catalogue and processing of samples

7.3.1 Sample catalogue

The sample catalogue shall include project name, number and location of sampling station, sampling date, water depth, sampling times, penetration depth, length or weight of soil sample, disturbance degree, etc.

7.3.2 Lithology description

For the lithology description, see 8.4.3 c).

7.3.3 Sample packaging

Sample packaging shall comply with the following requirements:
a) The core sample should be cut in sections, numbered separately, indicated the direction, water depth, sealed with tape and wax, and placed vertically in a special soil sample box;
b) Surface samples or disturbed core samples shall be packaged and sealed with sturdy plastic bags, labeled with station number and sampling depth, and placed in special soil sample boxes;
c) Samples used for geological, biological and chemical tests shall be sampled, packaged and stored according to their special requirements.

7.3.4 Sample storage

All samples shall be stored in sunscreen, freeze-proof and pressure-proof environments. When conditions permitted, they should be stored in laboratories under the control of temperature and humidity.

8 Engineering Geological Drilling

8.1 General requirements

8.1.1 Drilling vessel

The appropriate drilling vessel and drilling equipment shall be selected according to the working site environment and drilling requirements, and appropriate anchor type, anchor cable and mooring cable length shall be selected according to hydro-meteorology and seabed conditions.

8.1.2 Layout of boreholes

Generally, drilling holes shall be layout in the center of platform site. The number of engineering geology boreholes shall be determined according to the data of engineering geophysical survey and type of platform foundation. The number of exploration holes in each platform site shall generally be not less than 2.

8.1.3 Design of drilling depth

The drilling depth for different types of platform sites shall be designed in accordance with the following requirements:

a) Offshore pile-type fixed platform: designed depth of holes shall be the length of pile into the soil plus the width of influence zone of pile foundation (influence zone of pile foundation is generally considered as 10 times the diameter of pile), and the hole depth should not be less than 90 m;

b) Offshore gravity platform: designed depth of holes shall be larger than the maximum width of platform base. The soil layer of this depth shall contain all the soil layers that may be affected by critical shear plane and foundation settlement, and the hole depth should not be less than 30 m;

c) Offshore jack-up platform: designed depth of holes shall be larger than the depth of pile into soil plus the width of influence zone of pile foundation, which equals to 10 times the width of pile diameter, and hole depth should not be less than 40 m;

d) Drilling depth of seismic logging shall not be less than 100 m;

e) Drilling depth of other types of platforms may be designed according to the engineering requirements.

8.2 Drilling methods

The drilling methods shall be in accordance with the requirements given in 9.2 of GB 50021-2001.

8.3 Sampling requirements and methods

8.3.1 Sampling interval

It shall be determined according to the requirements of project and soil conditions. Generally, samples are continuously sampled within 0 m-15 m under seabed, with an interval of 1 m-1.5 m within 15 m-30 m and 3 m deeper than 30 m.

8.3.2 Core collection rate

The core collection rate shall not be less than 50% for sandy soil and shall not be less than 75% for cohesive soil.

8.3.3 Sampling methods

The sampling methods shall be in accordance with the requirements given in 9.4. of GB 50021-2001.

8.4 drilling catalogue

8.4.1 General requirements

Drilling catalogue includes drilling report and geological logging. The records shall be real, timely and according to round-trip of the drill times and successive records.

8.4.2 Drilling shift report

The drilling shift report shall include project name, sea area, number and coordinate position of borehole, rig height, drilling date, type and configurations of drilling rig, drilling patterns, water depth of borehole at the starting and ending, length of round-trip drill pipe, round-trip drilling footage, drill hole depth of per round-trip, core length of per round-trip, core recovery rate per round-trip, sampling mode, sampler type, sampling number, notes (weather, sea condition, equipment failures, bit jumping, wellbore, hole collapse, objects falling to hole bottom), etc.

8.4.3 Geological catalogue

Geological catalogue shall comply with the following requirements:
a) The geological catalogue shall include project name, sea area, borehole number, borehole coordinates, water depth of borehole at the starting, borehole depth of per round-trip, sampling length, lithologic description and stratigraphic division, etc.;
b) Lithology description of the core shall be made by means of observation and hand touching. If necessary, the existing standardized and quantitative methods, such as standard color plate colorimetry, shall be adopted to represent the color of rock and soil with color codes. The state of cohesive soil is represented by the penetration index of pocket penetrometer, and the integrity of core is represented by rock quality index value. Besides, camera can be used to take photos of rock and soil cores;
c) Lithology description shall include the followings:
1) Cohesive soil: color, state, odor, luster, shaking reflection, dry strength, toughness, structure, inclusions, etc.;
2) Silt: color, odor, humidity, density, shaking reflection, dry strength, toughness, inclusions, etc.;
3) Sandy soil: color, mineral composition, particle size distribution, particle shape,

clay content, humidity, compactness, etc.;

4) Crushed stones: particle size distribution, particle shape, particle arrangement, parent rock composition, weathering degree, filling property, filling degree and compactness;

5) Rocks: geological age, weathering degree, color, main minerals, structure and rock quality index, etc.

d) Engineering geological layers shall be classified according to the engineering properties of lithology description.

8.5 Sample handling

Sample handling shall comply with the following requirements:

a) The samples shall be pushed out from sampling tube by bulldozers and stored in core box in the upper and lower order. The cores shall be separated per round-trip with core plate, and starting and ending depth of drilling shall be marked with paint on core plate, and missing parts of the core shall be marked;

b) Geotechnical samples shall be sealed at the scene. Mark the sampling depth, up and down, numbers, and place them vertically in sample box.

8.6 Drilling completion report

The report mainly includes drilling purpose, task, coordinates, elevation and water depth of drilling hole, construction time, drilling and coring methods, abnormal conditions, acceptance certificate of quality, preliminary division of rock and soil strata and drilling hole column diagram, etc.

9 In-situ Test

9.1 General requirements

In-situ test shall comply with the following requirements:

a) In-situ test includes cone penetration test, vane shear test, standard penetration test and shear wave velocity test, etc. In-situ test methods shall be selected according to engineering category, geotechnical and field operation condition, etc.;

b) Hole for in-situ test is generally laid out at the center of platform site. The space between engineering geological sampling hole and in-situ test hole shall be less than 10 m;

c) When analyzing in-situ test data, attention shall be paid to the influence of test conditions, test methods and soil heterogeneity on test results, and abnormal data shall be eliminated.

9.2 Cone penetration test (CPT)

9.2.1 Applicable scope

The cone penetration test is applicable to soft soil, cohesive soil, silt and sandy soil.

9.2.2 Apparatuses

The CPT system shall comply with the following requirements:

a) Seabed CPT or downhole CPT shall be equipped with sensors of cone tip resistance, sidewall

friction resistance, pore water pressure and inclination;
b) The system shall be able to adapt to the harsh working environment such as wave fluctuation and collect in-situ test data safely and steadily;
c) The system shall have experimental data storage and processing system, which can store and process raw data on the spot;
d) Qualified and calibrated probe shall be used.

9.2.3 Field operation

Field operation shall comply with the following requirements:
a) The coordination and cooperation among the maneuvering, navigating and positioning of survey vessel, sounding of borehole depth and cone penetration test shall be guaranteed during the operation on the sea;
b) The nulling correction of cone tip resistance and pore water pressure shall be carried out before starting the test;
c) During the testing, the probe shall be continuously and uniformly pressed into the soil, and the penetration rate shall be kept at 20 mm/s (±5 mm/s);
d) The depth curves of cone tip resistance, sidewall friction, pore water pressure and inclination were obtained by each test. The test results were saved and test records were filled in log sheet;
e) The calibration, debugging and testing steps of instrument shall be carried out in accordance with the requirements given in ASTM D5778-1995.

9.2.4 Data processing and application

9.2.4.1 Correction shall be made to the original recording curve, including initial readings, curve shape and depth, etc.

9.2.4.2 Site test records, diagrams and tables of probe calibration results, curves and charts of various tests shall be submitted.

9.2.4.3 Linear characteristics and test data of various cone penetration curves shall be taken as reference for the classification of soil layers, determination of soil types, estimation of soil properties, bearing capacity of foundation, etc.

9.3 Vane shear test

9.3.1 Applicable scope

Vane shear test is applicable to determine the undrained shear strength and sensitivity of homogeneous saturated cohesive soils. For heterogeneous soil layers, especially soft clay with thin silty-fine sand or silt (there will be more errors in the test) shall be used with caution.

9.3.2 Apparatus

The vane shear test shall comply with the following technical requirements:
a) The shape of cross plate head is rectangular and the ratio of height to diameter (H/D) is 2. The size of cross plate head shall be determined according to Table 1;

b) The insulation resistance of the electrical vane sensor shall not be less than 500 MΩ.

Table 1 Size for In-situ Four-bladed Vane in millimeters

Outer diameter of borehole	Diameter	Height	Vane thickness	Diameter of vane drill pipe
57.2	38.1	76.2	1.6	12.7
73.0	50.8	101.6	1.6	12.7
88.9	63.5	127.0	3.2	12.7
101.3	92.1	184.2	3.2	12.7

9.3.3 Field operation

Field operation shall be carried out according to the following requirements:
a) The depth of four-bladed vane inserted into the bottom of boreholes shall not be less than 5 times of the sleeve or diameter of borehole. Torsion shall not be imposed on the vane drill pipe when it is inserted to ensure that the vane shear test can be carried out in the undisturbed soil;
b) Vertical interval of the test shall be 1m in general. When the soil layer becomes complex with the change of depth, test points shall be laid out in selected representative spots according to the results of cone penetration and engineering needs. Test points shall be increased when encountering a layer change;
c) Shear speed of the vane shall be controlled at 6°/min. Peak intensity shall generally be measured within 2 min to 5 min. If condition permits, torsion value may be recorded every 15 s. When peak value or stable value of torque appears, the data shall be read continuously in 1 min to confirm the peak value and stable value;
d) Undrained shear strength of remoulded soil shall be measured within 1 min after the vane is rotated 10 times rapidly and continuously along the shear torsion direction after the peak value or stable value appears;
e) Friction test between the vane torsion drill pipe and soil shall be carried at least once in each platform site, so as to correct the shear strength.

9.3.4 Data processing and application

9.3.4.1 Calculate the parameters such as undrained shear strength and sensitivity of the soil in test sites.

9.3.4.2 Draw the parameters-with-depth changing curve of the undrained shear strength and sensitivity. The relationship curve between shear strength and torsion angle shall be drawn as required.

9.3.4.3 Correct the measured undrained shear strength by the vane shear test according to the soil conditions and regional experience.

9.3.4.4 Calculate the parameters such as bearing capacity of foundation and bearing capacity

of single pile according to the engineering requirements.

9.4 Standard penetration test

Standard penetration test may be carried out in accordance with the methods and procedures given in 10.5 of GB 50021-2001.

9.5 Shear wave velocity test

Shear wave velocity test shall be carried out when evaluating seismic safety of engineering site. The test method and procedure shall be in accordance with the requirements given in Clause 7, GB/T 50269-1997.

10 Geotechnical Test

10.1 Geotechnical test on shipboard

10.1.1 Test items

The test including water content, density, soil temperature, unconfined compression, pocket vane shear test and pocket penetrometer test, shall be determined according to the engineering requirements, test conditions on board and properties of soil samples.

10.1.2 Test requirements

Shipboard geotechnical tests shall comply with the following technical requirements:
a) The collected samples shall be catalogued and processed in accordance with the requirements given in 7.3;
b) Test for water content, density and unconfined compression shall be carried out according to requirements specified in Clause 4, 5.1 and Clause 17 of GB/T 50123-1999;
c) Pocket vane shear test and pocket penetrometer test shall be carried out at both ends of the sampled core section or in the middle part of original boxed samples;
d) Pocket vane shear test and penetrometer test are suitable for homogeneous cohesive soil. Probes and instruments of different models and measuring ranges shall be selected for the tests on the grounds of hardness of the soil;
e) Soil temperature may be inferred from the relation between water temperature and soil temperature in the seabed. Or it may also be timely measured on the vessel after soil samples are collected.

10.1.3 Pocket penetrometer test

Pocket penetrometer test shall be carried out in accordance with the following requirements:
a) Hard inclusions, wormholes and cracks in the sample shall be avoided during the penetration process;
b) The distance between penetrating point and edge of the sample, the distance between penetrating points in parallel tests shall be no less than 3 times the length of probe diameter;

c) The probe shall be kept perpendicular to the sample surface during the penetration process and shall be penetrated at a constant speed of 1 mm/s. The test shall be stopped once the scribed line of the probes reaches the soil surface. Record test readings;
d) Parallel test shall be carried out at least 3 times per sample so that the average value can be taken as the test result;
e) Soil shall be removed from the probe after each test to ensure the accuracy of test results;
f) A record shall be kept of instrument model, probe specification, number of samples, depth and results of test as well as testers, etc.

10.1.4 Pocket vane shear test

Pocket vane shear test shall be carried out in accordance with the following requirements:
a) The surface of measured soil samples shall be scraped flat with soil cutter before shear plate is vertically inserted into it. Penetration depth shall be the same as the height of shear plate;
b) The pointer shall be zeroed and the shear torsion cylinder shall be rotated at a constant speed of 6°/s until the sample cut off;
c) Parallel test shall be carried out at least 3 times per sample so that the average value can be taken as the test result;
d) The instrument model, probe specification of four-bladed vane, number of samples, depth and results of test as well as testers, etc. shall be recorded.

10.2 Laboratory geotechnical test

10.2.1 Test items include natural density, natural water content, specific gravity, limit water content, particle analysis, permeability, consolidation and shear strength, etc. According to the requirements of platform foundation engineering analysis, geotechnical dynamic parameters test items such as dynamic triaxial shear test shall be added.

10.2.2 Laboratory geotechnical test shall comply with the following requirements:

a) Dynamic triaxial shear test may be carried out according to the requirements specified in Clause 9 of GB/T 50269-1997;
b) Other tests may be carried out in accordance with GB/T 50123-1999. Relevant domestic or international standards may also be referred according to specific engineering requirements.

10.2.3 Test data shall be collated in accordance with the requirements specified in Annex A of GB/T 50123-1999. For soil classification, see Annex A.

11 Corrosive Environmental Parameters Determination

11.1 Bottom water parameter test

11.1.1 The number of bottom water sampling stations is not less than 3 per project. Water samples shall be collected within 1 m above seabed.

11.1.2 The bottom water test parameters shall include pH, Cl^-, SO_4^{2-}, HCO_3^-, CO^{2-} and corrosive CO_2.

11.1.3 Bottom water chemistry testing shall be in accordance with the requirements given in 12.1.3 of GB 50021-2001.

11.2 Seabed soil parameter test

11.2.1 The number of seabed soil sampling stations shall not be less than 3 for each project. Sampling shall usually be carried out in the representative layer and the number of sampling shall not be less than 3 in each station.

11.2.2 The test parameters of seabed soil shall include pH, Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, oxidation-reduction potential and resistivity.

11.2.3 The seabed soil parameters shall be tested according to the requirements given in 12.1.3 of GB 50021-2001.

11.2.4 The measurement of sulfate reducing bacteria in seabed soil shall be carried out in accordance with the requirements specified in Clause 13 of GB/T 12763.6-2007.

11.3 fouling organisms

11.3.1 Fouling organisms include attached organisms and borehole organisms.

11.3.2 Usually, only the historical data of fouling organisms in platform sea area is collated and analyzed, and relevant results provided. In the case of engineering needs, on-site investigation of fouling organisms shall be carried out according to the requirements specified in Clause 13 of GB/T 12763.6-2007.

11.4 Corrosiveness evaluation

Corrosiveness evaluation for the bottom water and seabed soil shall be carried out according to the requirements given in 12.2 of GB 50021-2001.

12 Evaluation of Seismic Safety

12.1 Site seismic risk analysis based on probability method

The probabilistic analysis of site seismic hazards includes regional (extension of offshore platform site not less than 150 km) and near-field (extension of offshore platform site not less than 25 km) seismic activity and seismic tectonic environment evaluation, potential source area division, determination of seismic attenuation relationship, analysis and calculation of seismic hazards, etc. giving the horizontal seismic peak ground acceleration with 50 year exceedance probability of 63%, 10% and 2% and bedrock horizontal seismic peak ground acceleration with recurrence periods of 200, 1000 and 5000 years for offshore platform site.

12.2 Determination of seismic ground-motion parameter for platform design

On the basis of probability analysis of seismic risk of offshore platform site, seismic ground motion response analysis of soil layer shall be carried out according to the results of shear wave velocity measurement of borehole overburdens and dynamic triaxial test of typical borehole

soil layer samples in the site. According to the requirements given in GB17741-2005(no less than 2 controlled drilling holes), the surface of bedrock determined by drilling or top surface of which the shear wave velocity is not less than 500 m/s shall be selected as the seismic input interface. The soil boundary interface where the drilling depth exceeds 100 m and there is an obvious jump in the shear wave velocity or the interface determined by other methods may also be used as the seismic input interface. Seismic ground motion parameters of different probabilities and depths for the offshore platform shall be analyzed and calculated, including the horizontal seismic peak ground acceleration of the seafloor and the depth required under seabed in the site. Response spectrum needs to be calculated according to the time history of seismic ground motion analyzed from the seismic response in the site. The seismic ground motion parameter for platform design shall be synthetically determined based on the above response spectrum.

12.3 Site seismic geological hazard evaluation

12.3.1 Seismic geological hazard evaluation of offshore platform site mainly includes surface faulting, sand liquefaction, seismic subsidence of soft soil, etc.

12.3.2 According to the site engineering geological conditions, types of seismic geological hazards in the site shall be determined and influence degree shall be evaluated.

12.3.3 Evaluate the surface faulting characteristics and its possible impact on the platform site according to the survey results of fault activity.

12.3.4 When saturated sandy soil or silt distributed on the site, the possibility and degree of liquefaction shall be evaluated, and suggestions for anti-liquefaction measures shall be proposed.

12.3.5 When soft soil distributed on the site, the possibility and degree of seismic subsidence of soft soil shall be evaluated, and suggestions for anti-seismic subsidence measures shall be proposed.

13 Result Charts and Report Compilation

13.1 Result charts compilation

13.1.1 Result charts shall be compiled in accordance with the following basic requirements:

a) The engineering geological characteristics and hazard geological factors shall be fully reflected;
b) Complete and accurate data, clear mapping, rich content, legend coordination shall be required;
c) Scale for the charts is 1:5000 in general.

13.1.2 Offshore platform engineering geology survey shall include the following result charts:

a) Track chart: Mark the location of survey lines, number of survey lines, number of survey points, seabed sediment sampling stations, engineering geological boreholes and propose

location for the platform;
b) Bathymetric chart (seabed topography chart): Mark the water depth. Draw contours at intervals of 0.5m, 1m, 2m, 5m, every five contours are thickened. The contents of water depth datum and plane coordinate system shall be marked;
c) Geological structure chart: It is compiled based on the comprehensive analysis of stratigraphic profiling, high-resolution multi-channel digital seismic survey and engineering geological drilling data. It reflects the stratigraphic and the structural characteristics such as ups and downs, folding and fractures within 500m under seabed;
d) Geological feature chart: It is mainly based on the analysis of geophysical survey data, reflecting the geological features and hazard geological factors which impose potential impact on the site selection, design and installation of the platform, such as, the location, shape, nature and burial depth of faults, landslides, collapses, buried ancient valleys, shallow gas enrichment areas, etc.;
e) Geological profile chart: It comprehensively reflects important geological features such as water depth, sedimentary type, stratigraphic texture and structure from cross section. The section line shall generally be through engineering geological boreholes and the direction of tectonic line. Geological profile chart shall be plotted by adopting two orthogonal lines;
f) Seabed sediment type distribution chart: It is drawn mainly according to the data of sediment sampling, side-scan sonar detection and sub-bottom profiling and reflects the spatial distribution features of different sediment types in the seabed;
g) Seabed conditions chart: It is made mainly according to the data of side-scan sonar detection, sub-bottom profiling and sediment sampling and reflects seabed landform, sediments spatial distribution and property, shape and size of the obstacles, etc.;
h) Stratigraphic isopach chart: It is drawn mainly according to the data of stratigraphic profiling, sediment sampling and engineering geological drilling. It reflects the spatial variation feature of upper sedimentary sequence (or acoustic sequence) and state of ups and downs of bottom interface. Isopach chart of layer A, layer (A+B), layer (A+B+.....N) may be made respectively. The interval of the isopach line is 1 m, or it is determined according to the actual situation. If it is impossible to represent the change of stratum thickness continuously by the isopach line, the digital thickness marking can be used locally;
i) Borehole column chart: It reflects stratum lithology, texture, structure, contact relationship, etc. On the left side, it shows engineering geological sequence, age and depth. On the right side, it shows sedimentary environment, geotechnical test and in-situ test data, etc.;
j) For curve of pile into the soil depth analysis of jack-up platform , see Annex B;
k) For bearing capacity curve of the unit pile tip, see Annex B;
l) For ultimate axial bearing capacity of the pile, see Annex B;
m) For the analysis result chart of drive ability of the pile (soil dynamic resistance curve, relationship curve between hammering count and piling resistance, relationship curve between predicted hammering count and pile penetration depth),see Annex C.

13.2 Result report compilation

13.2.1 Result report shall be compiled in accordance with the following requirements:

a) The data and results obtained from the engineering geology survey shall be fully reflected

with prominent key points, full arguments, clear conclusions and elaborations;
b) The platform site engineering geological conditions and hazard geological factors shall be evaluated as key points;
c) Necessary illustration, addendum and photographs shall be attached in addition to the main result charts.

13.2.2 Result report shall include the following contents:

a) Foreword: including source of the task, purpose, schedule, workload, data quality and main results;
b) Overview of the platform site physical geography;
c) Regional geological background;
d) Geophysical survey and interpretation of the data: methods and procedures of the geophysical survey, topography and landform features, seabed conditions and obstacles distribution, stratigraphic sequence and spatial distribution, geological structure features, etc.;
e) Evaluation of engineering geological conditions: seabed sediment survey, engineering geological drilling, engineering geological test, engineering geological unit and its soil characteristics, hazard geological factors and stability of seabed erosion and siltation;
f) Marine activities;
g) Seismic safety evaluation: probability analysis of site seismic risk, determination of site seismic ground-motion parameter and evaluation of site seismic geological hazards;
h) Foundation engineering analysis: bearing capacity analysis, stability analysis, pile foundation design analysis and drive ability analysis;
i) Conclusion and suggestion: site engineering geological conditions, foundation stability, foundation type and suggestions for its bearing stratum, recommended geotechnical parameters;
j) Annex: In-situ test report, geotechnical test result table, T-Z, Q-Z and P-Y data, etc.

14 Data Filing

14.1 Filing scope

The filing scope includes:
a) The task contract and related technical requirements, power of attorney, etc.;
b) Survey plan, implementation plan, etc.;
c) Important original records, raw data, laboratory analysis and test reports and drawings of various carriers;
d) Phased survey results and acceptance records;
e) Final original manuscript of the survey report (electronic manuscript);
f) Report audit and review records, declaration records of achievement award, win award records, and results application records.

14.2 Filing requirements

Filing shall comply with the following requirements:
a) All written records and other materials formed in the course of survey shall be sorted out, examined and signed, After file management departments review and comply with the relevant provisions, archives can be filed;
b) Filing documents shall be unified in format, neat and orderly in handwriting, clear in pattern, firm in binding and complete signature procedures;

c) Filing materials shall be classified according to confidentiality provisions and safekeeping. Important documents, materials, survey plans, original records, raw materials, data compilation, atlas, reports, normative operating documents and retrospective records formed in the course of survey implementation shall be kept permanently;
d) For electronic document materials, the technical environment conditions, relevant software versions, data type formats, operational data, detection data and backup requirements shall be indicated.

Annex A
(Normative)
Unified Classification and Designation of Soil

A.1 General Requirements

Soil shall be classified according to the following indexes:

a) Soil particle composition and characteristics;

b) Plasticity index of soil: liquid limit (ω_L), plasticity limit (ω_P) and plasticity index (I_P);

c) Soil organic matter content.

A.2 Classification and Designation of Soil

A.2.1 Soil may be divided into inorganic soil, organic soil, peat soil and peat according to the content of organic matter. The soil with less than 5% organic content is called inorganic soil. The soil with an organic content of not less than 5%, and not more than 10%, is called organic soil. The soil with an organic content more than 10% and not more than 60% is called peat soil. The soil with an organic matter content of more than 60% is called peat.

A.2.2 According to particle gradation or plasticity index, soil may be divided into detritus stone soil, sandy soil, silt and cohesive soil.

A.2.2.1 Soil with particle size larger than 2 mm comprising more than 50% of total mass shall be designated as detritus stone soil and may be further classified according to Table A.1.

Table A.1 Classification of crushed stone soil

Name	Particle shape	Grain composition
Boulder	mainly circular and sub-circular	Mass of particles larger than 200mm in excess of 50% of total mass
Block stone	mainly angular	
Pebble	mainly circular and sub-circular	Mass of particles larger than 20mm in excess of 50% of total mass
Crushed Stone	mainly angular	
Cobble gravel	mainly circular and sub-circular	Mass of particles larger than 2mm in excess of 50% of total mass
Breccia gravel	mainly angular	

A.2.2.2 Soil with particles larger than 2 mm comprising no more than 50% of the total mass and particles larger than 0.075 mm comprising more than 50% of the total mass shall be designated as sand soil, which may be further classified according to Table A.2.

Table A.2 Classification of sand soil

Name	Grain composition
Gravel	Mass of particles larger than 2 mm comprising 25% to 50% of total mass
Coarse sand	Mass of particles larger than 0.5 mm comprising more than 50% of total mass
Medium sand	Mass of particles larger than 0.25 mm comprising more than 50% of total mass
Fine sand	Mass of particles larger than 0.075 mm comprising more than 85% of total mass
Silt	Mass of particles larger than 0.075 mm comprising more than 50% of total mass

Note 1: Soil shall be designated according to grain composition in the sequence of large to small, with priority given to whichever comes first.
Note 2: Sand soil with particles smaller than 0.005 mm comprising more than 10% of total mass, it shall be referred to as the attribute of cohesive soil, such as coarse sand containing clayey soil.

A.2.2.3 Soil with particles larger than 0.075 mm comprising no more than 50% of total mass and plasticity index of no larger than 10 shall be designated as silt soil, which may be further classified according to Table A.3.

Table A.3 Classification of Silt

Name	Particle size/mm	Content/%	Plasticity index/I_p
Sandy silt soil	> 0.075	< 50	$3 < I_p \leqslant 7$
	< 0.005	< 10	
Clayey silt soil	> 0.075	< 50	$7 < I_p \leqslant 10$
	< 0.005	> 10	

A.2.2.4 Soil with the plasticity index larger than 10 shall be designated as cohesive soil

Cohesive soil may be further classified into silty clay and clay. If the plasticity index falls within the range of 10 to 17, the soil shall be designated as silty clay, but when the plasticity index larger than 17 the soil shall be designated as clay.

A.3 Depending on the actual requirements of marine engineering, soil may also be classified according to requirements specified in ASTM D2487-2006 or other relevant international standards.

A.4 Soil Classification requirements given in ASTM D2487-2006

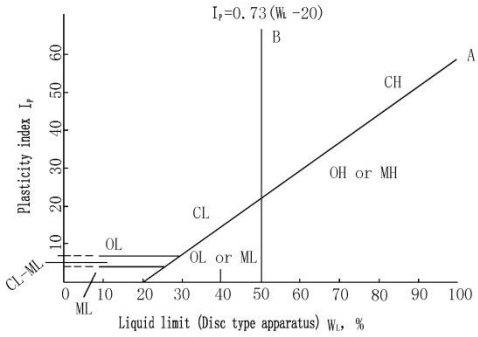
A.4.1 Soil shall be classified into coarse-grained soils and fine-grained soils according to whether the particle content retained on the No 200 American sieve (0.075 mm pore diameter) is more than 50%. Coarse-grained soils may be further classified into gravel and sand based on whether content of particles retained on NO.4 American sieve (4.75 mm pore diameter) is more than 50%. Gravel and sand can be further classified according to sorting situations and content of fine particles. Fine-grained soil may be further classified according to liquid limit, plasticity index and content of organic matters.

A.4.2 Soil classification and designation requirements in ASTM D2487-2006, see Table A.4.

Table A.4 Classification and Designation of Soil

<table>
<tr><th colspan="3">Category</th><th colspan="2">Group Symbol</th><th>Representative soil name</th><th colspan="3">Classification of coarse-grained soil</th></tr>
<tr><td rowspan="7">Coarse-grained soil (more than half of the samples grain size larger than the pore diameter of No. 200 sieve)</td><td rowspan="4">Gravel (more than half of the coarse samples grain size larger than the pore diameter of No. 4 sieve)</td><td rowspan="2">Pure gravel (with no or very little fine-grained soil)</td><td colspan="2">GW</td><td>Well graded gravel or gravel-sand mixture, with little or no fine-grained soil.</td><td rowspan="7">1. Determine the percentage of sand and gravel according to the grain size curve.
2. According to the percentage of fine-grained soil (grain size smaller than No. 200 sieve), coarse-grained soil may be classified as follows:
＜ 5%- GW, GP, SW, SP;
＞ 12%- GM, GC, SM, SC;
5%-12%- marked with double symbols.</td><td>$C_u \geqslant 4$;
$1 \leqslant C_c \leqslant 3$</td><td rowspan="2">Nonuniformity coefficient:
$Cu = \frac{d_{60}}{d_{10}}$
Curvature coefficient:
$C_c = \frac{d_{30}^2}{d_{10} \times d_{60}}$</td></tr>
<tr><td colspan="2">GP</td><td>Poorly graded gravel or gravel-sand mixture, with little or no fine-grained soil.</td><td>Not comply with all grading requirements of GW</td></tr>
<tr><td rowspan="2">Gravel mixed with fine grained soil (quite a bit fine-grained soil)</td><td colspan="2">GM</td><td>Silty gravel or gravel-sand-silt mixture</td><td>Atterberg limit below Line A or I_p＜4</td><td rowspan="2">Soil above Line A and 4 ＜ I_p＜7, marked with double symbols</td></tr>
<tr><td colspan="2">GC</td><td>Clayey gravel or gravel-sand-clay mixture</td><td>Atterberg limit above Line A and I_p ＞7</td></tr>
<tr><td rowspan="3">Sand (more than half of the coarse samples grain size smaller than the pore diameter of No. 4 sieve)</td><td rowspan="2">Pure sand (with no or very little fine-grained soil)</td><td colspan="2">SW</td><td>Well graded sand or gravelly sand, with little or no fine-grained soil</td><td colspan="2">$C_u \geqslant 6$, $1 \leqslant C_c \leqslant 3$</td></tr>
<tr><td colspan="2">SP</td><td>Poorly graded sand or gravelly sand, with little or no fine-grained soil</td><td colspan="2">Not comply all grading requirements of SW.</td></tr>
<tr><td rowspan="2">Sand mixed with fine-grained soil (quite a bit fine-grained soil)</td><td>SM</td><td>d/u</td><td>Silty sand, sand-silt mixture</td><td>Atterberg limit below Line A or I_p ＜4</td><td rowspan="2">Soil above Line A and 4 ＜ I_p ＜ 7, marked with double symbols</td></tr>
<tr><td colspan="2">SC</td><td>Silty sand, sand-clay mixture</td><td>Atterberg limit above Line A and I_p ＞7</td></tr>
</table>

Table A.4 (continued)

<table>
<tr><th colspan="2">Category</th><th>Group Symbol</th><th>Representative soil name</th><th>Classification of fine-grained soil</th></tr>
<tr><td rowspan="6">Fine-grained soil (more than half of the samples grain size larger than the pore diameter of No. 200 sieve)</td><td rowspan="3">(Liquid limit ＜ 50%) Silt and clay</td><td>ML</td><td>Inorganic silt and very fine sand, rock powder, silty or clayey fine sand, or low plasticity clayey silt</td><td rowspan="6"> 

Casagrande plasticity chart
C: Cohesive soil;
M: Silty soil;
O :Organic soil;
H: High plasticity;
L :Low plasticity;
Area above line A for inorganic soil, and below for silty soil and organic soil;
Right side of line B for high-plasticity soil while the left side for low plasticity soil;
Pore diameter of No.200 sieve is 0.075 mm;
Pore diameter of No.4 sieve is 4.75 mm.</td></tr>
<tr><td>CL</td><td>Low-medium plasticity inorganic clay, gravelly clay, sandy clay, silty clay, and lean clay</td></tr>
<tr><td>OL</td><td>Low plasticity organic silt and organic silty clay</td></tr>
<tr><td rowspan="2">(Liquid limit ≥ 50%) silt and clay</td><td>MH</td><td>Inorganic silt, fine sandy soil or silty soil containing mica or diatomite, rubber silty soil.</td></tr>
<tr><td>CH</td><td>High plasticity inorganic clay, fat clay</td></tr>
<tr><td rowspan="2">High organic soil</td><td>OH</td><td>Medium-high plasticity organic clay, organic silt</td></tr>
<tr><td>Pt</td><td>Peat and other high organic soil</td></tr>
</table>

Annex B
(Normative)
Load and Displacement Analysis of Pile-Soil System

For pile supported fixed offshore platform, when designing pile foundation, designed pile depth, vertical load-pile displacement and horizontal load-pile displacement shall be analyzed and calculated in order to make the pile foundation withstand static load, cyclic load and transient load, thus avoiding excessive deformation or vibration.

B.1 Designed Pile Penetrating depth

The designed pile penetrating depth shall enable the pile with sufficient capacity to withstand the maximum calculated vertical load and pull-up resistance with reasonable safety factors at the same time. The ultimate bearing capacity of the pile may be calculated as specified in B.2 and B.3, or calculated according to other computing methods based on massive reliable data. The allowable bearing capacity of the pile is the ultimate bearing capacity divided by the reasonable safety factor. The safety factor shall not be less than the value specified in 6.3.4 of SY/T10030-2004, see Table B.1.

Table B.1 Safety Factor Values under Different Load Conditions

Load Conditions	Safety Factor
Environmental conditions for design with appropriated drilling load	1.5
Operating environmental conditions during drilling operations	2.0
Environmental conditions for design with appropriate oil production load	1.5
Operating environmental conditions during oil production operations	2.0
Environmental conditions for design with minimum load (of the pull-up situation)	1.5

B.2 Axial Bearing Capacity of Pile

B.2.1 Ultimate bearing capacity

Under the static load condition, the ultimate bearing capacity Q_d of pile is determined by the formula specified in 6.4.1-1 of SY/T 10030-2004, see following formula:

$$Q_d = Q_f + Q_p = f \cdot A_s + q \cdot A_p \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (B.1)$$

In the formula:

Q_f —lateral friction of pile (kN);

Q_p— bearing capacity of pile tip (kN);

f —lateral friction of unit pile (kPa);

A_s—lateral surface area of pile (m^2);

q— bearing capacity of unit pile tip (kPa);

A_p—total area of pile tip (m^2);

B.2.2 Lateral friction of pile and bearing capacity of pile tip in cohesive soil

B.2.2.1 For the pipe in cohesive soil, lateral friction at any point along the pile may be

calculated according to the formula specified in 6.4.2-1 of SY / T 10030-2004, see following formula:

$$f = \alpha C_u \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.2)}$$

In the formula:

α — non-dimensional coefficient;

C_u — undrained shear strength of soil of the calculation point (kPa).

Coefficient α can be calculated according to the formula specified in 6.4.2-2 of SY/T 10030-2004, see following formulas:

$$\begin{aligned} &\alpha = 0.5\Psi^{-0.5} \quad \text{当}\Psi \leqslant 1.0 \\ &\alpha = 0.5\Psi^{-0.25} \quad \text{当}\Psi > 1.0 \end{aligned} \quad \cdots\cdots\cdots\cdots\cdots\cdots \text{(B.3)}$$

In the formula:

Ψ — C_u / P_0';

P_0' — effective overlaying soil pressure of the calculation point (kPa).

B.2.2.2 Bearing capacity of unit pile tip q in cohesive soil may be calculated according to the formula specified in 6.4.2-3 of SY/T 10030-2004,, see following formulas:

$$q = 9C_u \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.4)}$$

In the layered cohesive soil, lateral friction of pile f can be calculated according to the formula (B.2). When bearing capacity of pile tip is calculated according to the formula (B.4), if the soil layer adjacent to the cohesive soil layer where the pile tip locates is relatively soft, the distance between the pile tip and surface of the adjacent layer shall not be less than 3 times of the pile diameter. Otherwise, the calculated value shall be adjusted. If there isn't much difference of the soil strength between the adjacent soil layer and calculated soil layer, distance between the pile tip and surface of the adjacent layer may be ignored.

B.2.3 lateral friction of pile and bearing capacity of pile tip in non-cohesive soil

B.2.3.1 In the non-cohesive soil, lateral friction of pipe may be calculated according to the formula specified in 6.4.3-1 of SY/T 10030-2004, see following formulas:

$$f = KP_0 \tan\delta \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.5)}$$

In the formula:

K — pressure coefficient of horizontal foundation;

P_0 — effective overlaying soil pressure of the calculation point (kPa);

δ — friction angle between soil and pile surface (°).

For the driven pile in the opening without soil plug, value of K is assumed as 0.8 no matter it is pressure load or pull-up load. For the pile with a soil plug or a closed end, value of K can be assumed as 1.0. Friction angle δ is selected according to Table B.2. For long piles, the limit value given in Table 6.4.3-1 of SY/T 10030-2004 should be used for f value, see Table

B.2.

B.2.3.2 For pile whose tip is in the non-cohesive soil, bearing capacity of unit pile tip q shall be calculated according to the formula specified in 6.4.3-2 of SY/T10030-2004, see following formulas:

$$q = P_0 N_q \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (B.6)$$

In the formula:

P_0 — effective overlaying soil pressure of the pile tip (kPa);

N_q — bearing capacity coefficient

The parameters listed in Table B.2 are recommended values. Experimental value can be used in the case that experiment data can be obtained. For the soil of which density and type are not listed in Table B.2, special tests or field tests shall be done when design parameters are selected.

Table B.2 Design parameters of non-cohesive siliceous soil

Density	Soil Type	Friction Angle between Soil and Pile (°)	Ultimate Lateral Friction of Pile/ kPa	Bearing Capacity Coefficient	Ultimate Bearing Capacity of Unit Pile tip/ MPa
Extremely loose Loose Medium dense	Sand Sandy silt silt	15	47.8	8	1.9
Loose Medium dense Dense	Sand Sandy silt silt	20	67.0	12	2.9
Medium dense Dense	Sand Sandy silt	25	81.3	20	4.8
Dense Extremely dense	Sand Sandy silt	30	95.7	40	9.6
Dense Extremely dense	Sand gravel Sand	35	114.8	50	12.0
Note: The strength of sandy silt usually increases as the content of sands increasing and reduces as the content of silt increasing.					

B.2.3.3 For the driven pile with diameter less than the borehole diameter in non-cohesive soil, method of soil disturbance caused by construction installation shall be taken into account for the determination of the value of f and q. But it shall not exceed the value of the driven pile. The value of f and q in Table B.2 may also be used for bored grouting pile. But bonding strength between the soil and the grouting interface shall be considered.

B.2.3.4 In the layered non-cohesive soil, value of lateral friction of pile f given in Table

B.2 may be used. When the recommended value for the bearing capacity of pile tip in Table B.2 is used, the distance between the pile tip and surface of the adjacent layer shall not be less than 3 times of the pile diameter if the soil layer adjacent to the non-cohesive soil layer where the pile tip locates is relatively soft. Otherwise, the table data shall be revised. If there isn't much difference of the soil strength between the adjacent soil layer and the non-cohesive soil layer where the pile tip locates, distance between the pile tip and surface of the adjacent layer may be ignored.

B.2.4 Lateral friction and bearing capacity of grouting pile tip in the rock stratum

For the grouting pile in the rock stratum, its unit lateral friction shall not exceed the triaxial shear strength of rock or grouting pile. The value of ultimate lateral fiction may be the ultimate consolidation strength between the steel pile and the grouting pile.
The bearing capacity of pile tip in rock strata shall be determined by its triaxial shear strength and reliable bearing capacity coefficient, and is not permitted excess 9.58 MPa.

B.3 Axial Pull-up Resistance of Pile

Ultimate pull-up resistance of pile shall not be greater than the total lateral friction Q_f. The effective weight of the pile, including hydrostatic buoyancy and weight of the soil plug shall be taken into account when the ultimate pull-up resistance of pile is analyzed. For cohesive soil, value of f shall be the same as the value specified in formula (B.2). For non-cohesive soils, value of f shall be calculated according to the formula (B.5). For the rock, value of f shall be the same as the value specified in B.2.4.
Pull-up resistance of pile shall be the ultimate pull-up resistance divided by the safety factor.

B.4 Axial Load-Pile Displacement Analysis

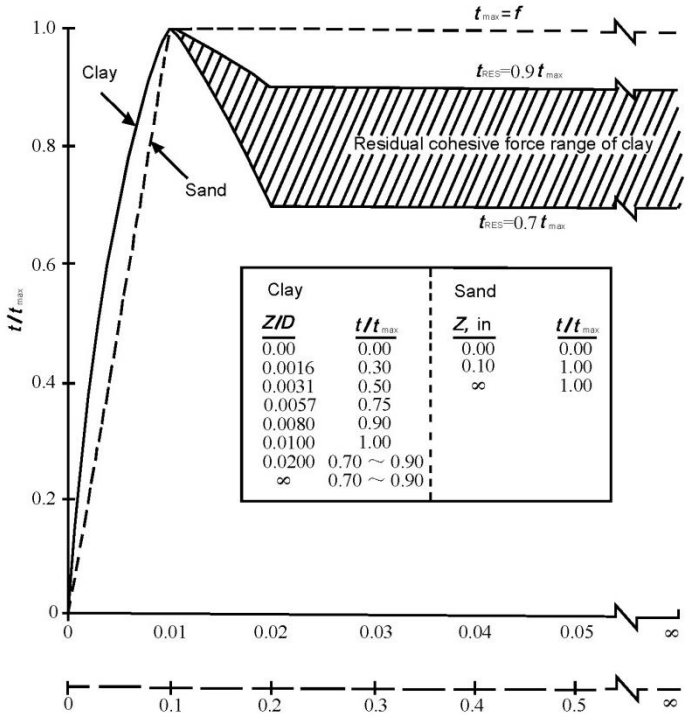
The graphical relationship between the movable shear transfer of the pile-soil and pile local displacement at any depth may be expressed by the t-z curve. Similarly, the movable bearing capacity of pile tip and the vertical displacement of pile tip may be expressed by the Q-z curve.

B.4.1 Vertical load transfer curve (t-z)

The vertical load transfer curve of the pile in clay and sand are specified in Figure 6.7.2-1 of SY/T 10030-2004, see Figure B.1.
The ratio t_{res}/t_{max} of the residual cohesive force at the vertical displacement Z_{res} of the pile is related to the soil stress-strain characteristic, the stress history, installation method of the pile, the loading sequence of the pile and other factors. Range of t_{res}/t_{max} is from 0.70 to 0.90.

B.4.2 Load of pile tip-displacement curve

The bearing capacity of the pile tip is gradually brought into play with the increase of the displacement of pile tip. When the displacement of the pile tip reaches 10% of the pile diameter, bearing capacity of the pile tip in the clay and sand can be completely activated. Curve of load of pile tip and pile displacement in clay and sand (Q-z) is specified in Figure 6.7.3-1 of SY/T 10030-2004, and for the curve and value, see Figure B.2.



Z —local displacement of the pile (mm);

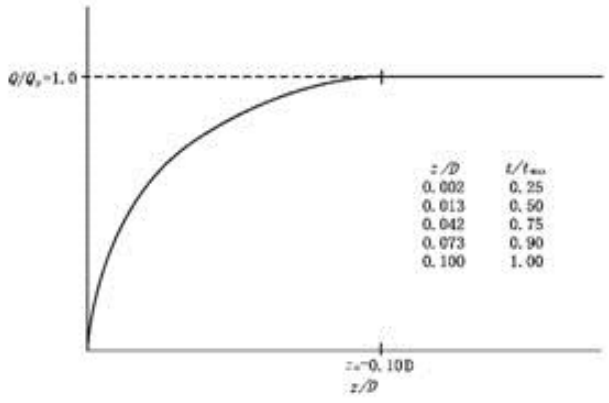
D — pile diameter (mm);

t — movable pile - soil cohesive force (kPa);

t_{max} — maximum cohesive force of the pile-soil or unit lateral friction of pile calculated according to Formula B.2 (kPa).

Note: 1 inch = 25.4mm;

Figure B.1 Typical axial load transfer- displacement (t-z) curve of pile



z — vertical displacement of the pile (mm);

D — pile diameter (mm);

Q —movable bearing capacity of the pile tip (kN);

Q_p— bearing capacity of the pile tip calculated according to this appendix (kN).

Figure B.2 Load of pile tip-displacement (Q-z) curve

B.5 Lateral Load - Pile Displacement Analysis

B.5.1 Lateral bearing capacity of soft clay

The ultimate unit lateral bearing capacity of soft clay P_u varies between $8C_u$ and $12C_u$. Lateral bearing capacity will be lower than the value in static load condition under the cyclic load effect. If there is no more reliable empirical formula, the ultimate unit lateral bearing capacity may be calculated according to the formula specified in 6.8.2-1and 6.8.2-2 of SY/T 10030-2004, see Formula B.7 and B.8:

When X increases from 0 to X_R, P_u shall be increased from $3C_u$ to $9C_u$ according to the following formulas:

$$P_u = 3C_u + \gamma' X + JC_u X / D \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.7)}$$

$$P_u = 9C_u \qquad \text{For } X \geqslant X_R \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.8)}$$

In the formulas:

P_u — ultimate unit horizontal bearing capacity (kN);

C_u — undrained shear strength (kPa);

γ' — soil underwater buoyant unit weight (MN/m^3);

J — non-dimensional empirical constant, varying from 0.25 to 0.5;

D — pile diameter (mm);

X — depth below the mud surface (mm);

X_R — depth of the bottom of soil layer of reduced bearing capacity area from mud surface (mm). If the strength does not vary with depth, formula B.7 and B.8 can be joined to get the value of X_R as below:

$$X_R = \frac{6D}{\gamma' D / C_u + J} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.9)}$$

If the strength varies with the depth, formula B.7 and B.8 can be solved by drawing their curves (P_u to depth). The first intersection of the two curves is X_R. This empirical formula is not applicable to the irregular change in soil strength. In general, the minimum value of X_R is about 2.5 times of the pile diameter.

B.5.2 Load - displacement curve (p-y) of soft clay

The lateral load-displacement relationship of the pile in the soft clay is usually non-linear. *p-y* curve shall adopt the data provided in 6.8.3 of SY/T 10030-2004 under the short-term static load effect.

For the *p-y* curve that has reached equilibrium state under cyclic loading effect, the data given in 6.8.3 of SY / T 10030-2004 shall be used.

B.5.3 Lateral bearing capacity of hard clay

With regard to lateral static load, the ultimate bearing capacity P_u of hard clay (C_u greater than 96 kPa) varies between $8C_u$ and $12C_u$, the same as soft clay. Its strength reduces rapidly under cyclic loading effect. Therefore, design of the ultimate bearing capacity value under

cyclic loading effect shall be lower than that under static loading effect.

B.5.4 Load - displacement (P-Y) curve of hard clay

Hard clay also has a non-linear stress-strain relationship, but with a greater brittleness than soft clay. When the stress-strain curve of hard clay and the *P-Y* curve under cyclic loading effect are made, analysis and judgement shall be done to the rapid degradation of bearing capacity of hard clay under large deformation condition.

B.5.5 Lateral bearing capacity of sandy soil

The ultimate lateral bearing capacity of sand varies between the values determined by Formula 6.8.6-1 and Formula 6.8.6-2 of SY/T10030-2004, see Formula B.10 and B.11 below. The former shows the value in shallow layer while the latter shows the value in deep layer. The formula from which a smaller value can be obtained shall be used for calculation at the given depth.

$$P_{us} = (C_1 H + C_2 D)\gamma' H \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.10)}$$

$$P_{ud} = C_3 D\gamma' H \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.11)}$$

In the formula:

P_u — ultimate bearing capacity, kN, P_u' s subscript *s* means shallow layer, and *d* means deep layer;

C_1, C_2, C_3 — ϕ'' s function value, determined by Figure 6.8.6-1 of SY/T 10030-2004, , see Figure B.3;

ϕ' — internal friction angle of sandy soil (°);

D — average pile diameter from the mud surface to the given depth (m);

γ' — soil underwater buoyant unit weight (kN/m^3);

H — depth (m).

B.5.6 Load - displacement (*P-Y*) curve of sandy soil

The lateral load-displacement (*P-Y*) relationship of the sandy soil is non-linear and the approximate value of any given depth H may be determined according to Formula 6.8.7-1 of SY / T 10030-2004, see Formula B.12:

$$P = AP_u \tanh\left[\frac{kH}{AP_u} y\right] \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(B.12)}$$

In the formula:

A — coefficient of the cyclic load or static load, calculated by the following formula:

A=0.9 for cyclic load

A=[3.0-0.8 (H/D)]≥0.9 for static load

P_u — ultimate bearing capacity at depth H (kN/m);

K — initial modulus of sub-grade reaction (kN/m^3); It is the function of internal friction angle and is determined by Figure 6.8.6-2 of SY/T 10030-2004, see Figure B.4.

H — depth (m);

y — lateral displacement (m).

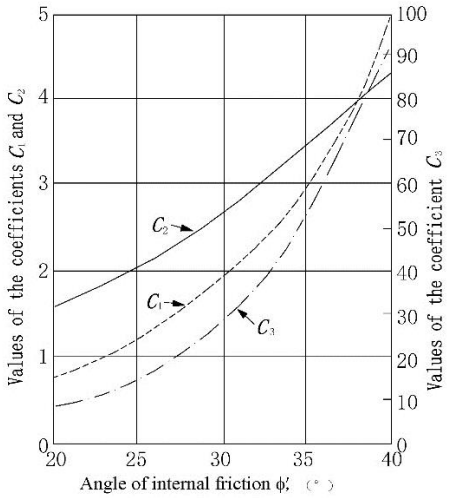


Figure B.3 Function relationship between C and ϕ'

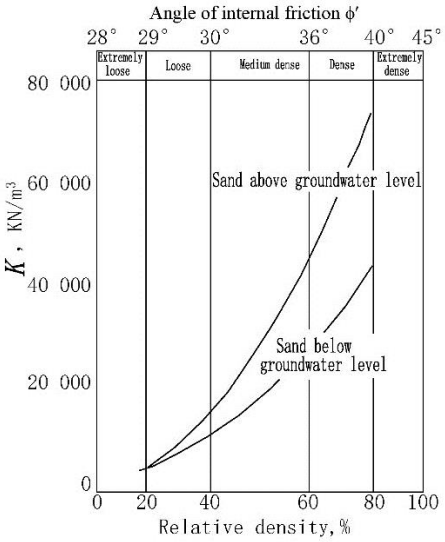


Figure B.4 Function relationship between k and ϕ'

Annex C
(Informative)
Drive Ability Analysis of Piles

Drive ability analysis of piles shall be carried out when designing for pile foundation of the offshore platform.

C.1 Theoretical Basis of Drive ability Analysis of Piles

Assuming the pile is considered as a thin-long elastic rod, the piling is a stress wave propagation process described by a one-dimensional wave equation:

$$\frac{\partial^2 u}{\partial t^2} = C^2 \frac{\partial^2 u}{\partial z^2} \quad \cdots\cdots (C.1)$$

In the formula:

u — displacement along z direction;

t — time;

C — stress wave propagation speed along the rod, obtained by the formula:

$$C = \sqrt{E/\rho} \quad \cdots\cdots (C.2)$$

In the formula:

E — elasticity modulus;

ρ — mass density.

The whole piling system, including hammers, caps, pads and piles, is divided into many units. Each unit is simulated by using a rigid mass block and a massless spring. Soil around the pile is simulated by spring, friction piece and dash pot. Therefore, a hammering process of the hammer to the pile is transformed into the movement problem of a hammer-pile-soil system. According to the finite difference method, the wave equation is converted into an idealized differential equation system of each separate unit of the hammer-pile-soil system.
Get the acceleration of speed change at the next moment in the unit with backward difference method and then substitute it into the unit equilibrium equation. As a result, displacement formula for each unit can be obtained as below:

$$u_{(M,t)} = 2u_{(M,t-\Delta t)} - u_{(M,t-2\Delta t)} + \frac{g\Delta t^2}{W_{(M)}}\left\{K_{(M-1)}\left[u_{(M-1,t-\Delta t)} - u_{(M,t-\Delta t)}\right] - K_{(M)}\left[u_{(M,t-\Delta t)} - u_{(M+1,t-\Delta t)}\right] - R_{(M,t)}\right\} \quad \cdots\cdots (C.3)$$

In the formula:

$u_{(M,\,t-2\Delta t)}$, $u_{(M,\,t-\Delta t)}$, $u_{(M,\,t)}$ — displacement of unit M at the moment $t-2\Delta t$, $t-\Delta t$ and t;

$u_{(M-1,\,t-\Delta t)}$, $u_{(M+1,\,t-\Delta t)}$ — displacement of unit M-1 and M+1 at the moment $t-\Delta t$,

g — acceleration of gravity;

t — time;

Δt — time interval;

$K_{(M-1)}$, $K_{(M)}$ — spring constant of the pile material of unit M-1 and unit M;

$R_{(M,\,t)}$ — lateral resistance of unit M at the moment t;

$W_{(M)}$ — weight of unit M.

And the deformation, stress and speed of each unit can be expressed by the formula C.4, C.5 and C.6:

$$C_{(M,t)} = u_{(M,t)} - u_{(M+1,t)} \quad \cdots\cdots (C.4)$$

$$F_{(M,t)} = C_{(M,t)} K_{(M)} \quad \cdots\cdots (C.5)$$

$$V_{(M,t)} = V_{(M,t-\Delta t)} + \left[F_{(M-1,t)} - F_{(M,t)} - R_{(M,t)}\right] - \frac{g\Delta t}{W_{(M)}} \quad \cdots\cdots (C.6)$$

In the formula:

$C_{(M, t)}$ — deformation of unit M at the moment t;

$F_{(M, t)}$, $F_{(M-1, t)}$ — stress of unit M and Unit M-1 at the moment t;

$V_{(M, t)}$, $V_{(M, t-\Delta t)}$ — speed of unit M at the moment t and $t-\Delta t$.

C.2 Contents of Drive ability Analysis of Piles

Drive ability analysis of pile shall include the follow contents:

a) Verify that the size of the selected pile and the hammering equipment can hit the pile to the desired depth of the design;

b) Determine the tensile and compressive stress values of the pile during the piling process to verify whether the design is safe. Select appropriate pile pad material to ensure the pile sinking capacity and rate;

c) Decide the best design and composition of the pile, fractional length and quantity;

d) Predict the pile depth sinking into the soil under self-weight, namely, the so-called "pile sliding" phenomenon to ensure construction safety.

C.3 Procedures for Drive ability Analysis of Piles

Drive ability analysis of piles shall be carried out according to the following procedures:

a) The soil resistance SRD at different sinking depth of pile shall be estimated under the conditions of soil plug or no soil plug after continuous piling or piling after breaks according to the pile and soil parameters. The relationship between soil resistance and hammering counts under different piling conditions is shown in Figure C.1;

b) Parameters of hammer, pile and soil needed for the analysis of motion wave equation shall be determined. Parameters of hammer include type, maximum energy, weight, length, diameter, drop distance, hammer pad and hammer efficiency. Parameters of pile include length design, diameter of pile, wall thickness. Parameters of soil include the maximum elastic deformation of the pile side QS and of pile tip QP, damping coefficient of pile side JS and of pile tip JP, ultimate soil resistance Ru and resistance ratio of the pile tip;

c) Analysis and calculation of pile sinking capacity shall be based on the wave equation. Maximum tensile and compressive stress of pile, piling resistance, data such as force, speed, displacement and acceleration changing with the time and piling response curve, namely the curve of relationship between piling soil resistance and penetration, can be obtained from the equation;

d) Upper and lower limit curve (see Figure C.2) of the piling resistance with depth is obtained based on the SRD and the piling response curve acquired from the wave equation, thus predict

hammering counts with different depths in piling. If the piling resistance is too large (for example, over 800 blow/m), it is necessary to select new hammer type or change the wall thickness of the pile, to change material and thickness of the pads and then to analyze the piling capacity again;

e) Soil resistance of different sinking depth under self-weight shall be calculated based on block and non-block situation. Its minimum value shall be selected for comparing with the self-weight of the pile in order to estimate the sinking depth into the soil under self-weight effect.

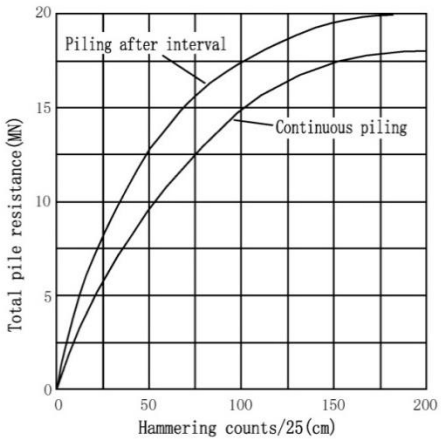


Figure C.1 Sample of SRD curve

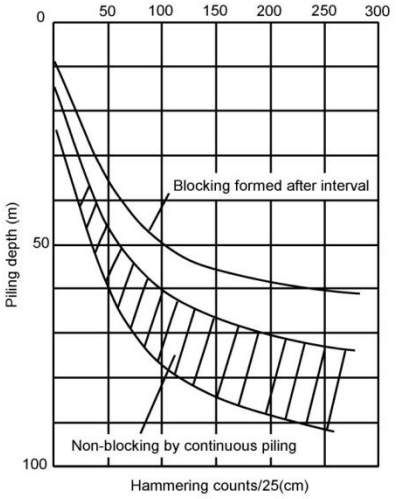


Figure C.2 Sample of curve between predicted hammering counts and depth

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