



Exploration & Production

GENERAL SPECIFICATION

SURVEYS

GS GEO 102

Onshore geotechnical Soil Survey

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1. Scope

The document defines the general requirements for the equipment and procedures applicable to onshore geotechnical soil survey works necessary for designing and constructing foundations for civil-engineering structures and/or earth works.

The document, defining references for obtaining satisfactory and consistent quality in onshore geotechnical soil surveys, applies to:

- The safety of the site operations, and the responsibility of the CONTRACTOR
- The definition of the scope and purpose of the different types of geotechnical survey works
- The equipment and procedures for the performance of the field works, including soil boring or rock coring, trial pits, soil sampling, in-situ testing or measurements, laboratory testing on soil samples or rock cores, etc.
- The procedures for the assessment of all results of the soil investigation tests and measurements, to define the soil characteristics and geotechnical parameters required to design the foundations and/or earth works for the projected structures, as well as the presentation of the results, and the reporting to be provided by the CONTRACTOR.

However, CONTRACTOR is responsible for the suitability of the proposed equipment and procedures to achieve the objectives of the soil investigation.

COMPANY reserves the right to apply further Particular Technical Specifications, should COMPANY consider that any aspects of the geotechnical survey works require more detailed definition.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
ISO 1000	Specification for SI Units and Recommendations for the Use of their Multiples and of Certain Other Units
ISO 9001	Quality Systems – Model for Quality Assurance in Design, Development, Production, Installation and Servicing
ISO 14688-1	Identification and classification of soil
ISO 14689-1	Identification and classification of rock
ISO/TS 22475	Sampling by drilling and excavation methods and groundwater measurements
CEN ENV 1997 Eurocode 7	Geotechnical Design - Part 1: General Rules - Part 2: Laboratory Testing - Part 3: Field Tests
CEN ENV 1998-5 Eurocode 8	Design Provisions for Earthquake Resistance of Structures - Part 5: Foundations, Retaining Structures and Geotechnical Aspects
BS 5930	Code of Practice for Site Investigations
BS 1377, Parts 1 to 9	Methods of Tests for Soils for Civil Engineering Purposes
BS 8004	Code of Practice for Foundations
BS 6349	Code of Practice for Maritime Structures - Part 2: Design of Quay Walls, Jetties and Dolphins
NEN 3650	Requirements for Steel Pipeline Transportation Systems
NS 8000	Geotechnical Testing, Laboratory Methods
NF P 94	Soils: Surveys and Tests
NF P 94-500	Classification of Scope and Purpose of Geotechnical Survey Works
ASTM Standards Volume 04.08	American Society for Testing and Materials - Construction, Soil and Rock; Building Stones

Professional Documents

Reference	Title
API RP 2A	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design & Load and Resistance Factor Design
API RP 2N	Recommended Practice for Planning, Designing and Constructing Pipelines for Arctic Conditions
DTU 11.1	Drilling Foundation Soils
DTU 12	Earth Works for Buildings
DTU 13.11	Surface Foundations
DTU 13.12	Requirements for the Design of Surface Foundations
DTU 13.2	Deep Foundations for Buildings (NF P 11-212-2)
DTU 14.1	Casing String Works (NF P 11-221)
ISRM	International Society for Rock Mechanics - Rock Characterisation Testing and Monitoring - ISRM Suggested Methods (1981)
ISSMGE	International Society For Soil Mechanics and Geotechnical Engineering - International Reference Test Procedure for the Cone Penetration Test (CPT) and the Cone Penetration Test with Pore Pressure (CPTU) - Report of the Technical Committee 16 on Ground Property Characterisation from In-Situ Testing (1999)
USCS	Unified Soil Classification System - Waterways Exp. Station Corps of Engineers, US Army. Technical Memorandum No. 3-357, Vols. 1 to 3 (1953)

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS CIV 101	General Earthworks
GS CIV 500	Special Foundations
GS ENV 111	Baseline Study - Environmental Status of an Onshore Site
GS GEO 301	Offshore Surface Positioning Works
GS STR 431	Installation of Piles for Offshore Steel Structures - Driven Piles

3. Units

Only the ISO international system of units ([ISO 1000](#)) shall be used. However, the standard diameter and wall thickness of steel tubular pipes can also be expressed in inches (1 inch = 25.4 mm). When this is the case, the symbol used for the inch unit (" or in.) shall be clearly indicated.

4. Safety procedures and quality assurance

4.1 Safety and the CONTRACTOR's responsibility

As part of the Project safety plan, a complete hazard identification and risk assessment (HAZID and HIRA) shall be provided by the CONTRACTOR. The procedure for evacuating injured personnel (MEDEVAC/EVASAN procedure) shall be included in this safety plan.

The COMPANY's general safety instructions will be supplied to the CONTRACTOR who shall read them critically, and point out any incompatibility there may be with his own safety plan. When the geotechnical survey works take place at an oil or gas production site operated by the COMPANY, the CONTRACTOR shall report to the COMPANY site manager.

Before commencement of the field works, COMPANY will provide to the CONTRACTOR any specific regulations and/or work permit procedure regarding to the geotechnical survey site.

All questions concerning the safety of all survey personnel present during the field works at the survey site shall be under the CONTRACTOR's responsibility. The CONTRACTOR's responsibility includes informing any SUB-CONTRACTORS on the safety procedures for the different equipment and tasks.

Before commencement of the survey works at the site, a pre-job/kick-off meeting shall be organised by the COMPANY and CONTRACTOR. This meeting shall be attended by the Representatives of the COMPANY, the CONTRACTOR and the SUB-CONTRACTORS, and any other parties involved in the survey works, including the COMPANY site manager and safety manager, and local authority (if required). The purpose of this meeting shall be to review the scope of the geotechnical survey works to be carried out, and to identify any other activities involved at or off the site. Minutes of the meeting shall be drawn up and signed by both the COMPANY and CONTRACTOR Representatives.

In adverse weather conditions, CONTRACTOR may be required to cease geotechnical survey operations at the site, when it is considered that such adverse conditions may affect the safety of survey personnel and equipment, or the quality of the site works. Such adverse conditions

shall be defined in common agreement between the CONTRACTOR and COMPANY Representatives.

4.2 Quality assurance

The documentation supplied by the CONTRACTOR shall allow the quality of the proposed geotechnical survey works and services to be assessed by the COMPANY. The curriculum vitae of all key personnel involved in the soil investigation shall be supplied by the CONTRACTOR, together with a functional organisation chart.

For each phase of the geotechnical survey works, the CONTRACTOR shall establish a quality assurance and quality control procedure. This procedure shall preferably comply with the [ISO 9001](#) quality system, or equivalent.

5. Drilling and soil boring equipment and procedures

5.1 General procedures and documentation

5.1.1 Drilling plant and equipment

Open-hole rotary drilling shall be used to advance the soil borings and shall allow soil sampling and in-situ testing. The drilling equipment shall be compatible with any types of soil conditions likely to be encountered at the site, i.e. soft or stiff to hard clays, silt and more or less dense sands, limestone and rock formations. When necessary, drill casings shall be used to support the soil borings. Rotary diamond core drilling shall be used in cemented rock formations, and the type of drill bit shall be adapted to the rock formations likely to be encountered at the site.

The drilling machine shall meet the following minimum requirements:

- Minimum torque: 250 to 300 m.kg
- Minimum thrust: 2 to 3 tons
- Rotation speed: 0 to 800 rpm
- Mud pump: 30 to 50 bars at a flow rate of 100 l/min.

When drilling at shallow depths and in very soft soils, reduced parameters or characteristics can be used to avoid soil washing or limit soil disturbance.

The rotary drilling machine, including the mud tanks and pumps, shall be set either on an adequate truck or a self-powered caterpillar. In environmental sensitive areas, or for special access reasons, man portability of the drilling equipment can also be considered.

CONTRACTOR shall provide all accessories for drilling, such as casings, drill rods and bits, pumps and compressors, drilling fluid additives, water, and any other materials, supplies and manpower. Drill rods shall be straight and of a large enough diameter to prevent excessive whip, to ensure stability of the drill string, to maintain the up-hole velocity of the drilling fluid, and to allow in-situ testing or soil sampling with the required minimum sample diameter, as mentioned in the Particular Technical Specification. As a basis, the drilling diameter shall not be less than 100 mm (4 inches).

The drilling plant shall be smooth running and mounted in such a way that minimum vibrations or movements are transmitted by the drill string to the drill bit and core barrel for minimising the risk of disturbing the soil to be sampled or tested in-situ. The drilling equipment shall be well

maintained, and the maintenance records shall be available to the COMPANY Representative, upon request.

Continuous and automatic recording of the drilling parameters shall be performed during drilling operations, including the following parameters recorded as a function of penetration depth: drilling rate (i.e. drilling time in minutes per meter, or meters drilled per hour), weight on drill bit, torque on the drill string, mud pressure, and percentage recovery of the drilling fluid. No later than 24 hours after completion of each soil boring, the record of drilling parameters shall be provided to the COMPANY Representative.

The composition of the drilling fluid shall be selected and varied so as to limit soil disturbance, in particular for soft and non-cohesive soils or weakly cemented formations, whilst minimising expense. Spillage of the drilling fluid shall be minimised, and water shall not be allowed to pond on the ground surface. For soil borings which shall be equipped with a piezometer standpipe or PVC strainer, the mud quality shall be especially designed for avoiding the formation of a cake on the boring walls. Any special provisions to respect the site environment, such as recovery and treatment of the drilling mud, for example, shall be specified in the Particular Technical Specification.

Loss of drilling fluid during drilling shall be recorded, as well as any water arrival or loss during drilling. When ground water is first encountered in soil borings, the depth from ground level to point of entry shall be recorded, together with the casing depth. Boring operations shall be suspended for not more than 20 minutes to allow the free static water level to stabilise. If, at the end of this 20-minute period, the water level is still rising, this shall be recorded for another 20-minute period, after which boring operations shall continue. Ground water and drilling fluid levels shall also be recorded at the beginning and end of every shift, and following any significant break in drilling activities.

The CONTRACTOR shall provide complete general technical documentation concerning the drilling and coring equipment and procedures, including the description of the rotary drilling plant (with type and maximum capacities, rotary head, drill string, mud pumps and system for preparing and circulating the drilling fluid, etc.), the equipment and procedures for performing in-situ sampling and testing in the soil borings, and a list of references of works carried out previously with the same equipment.

5.1.2 Completion of soil borings

A boring shall be considered as completed when it has reached the target depth mentioned in the Particular Technical Specification, or as directed by the COMPANY Representative, and all sampling and in-situ testing has been performed satisfactorily.

Borings abandoned before reaching the specified target depth, because of mechanical failure of drilling equipment, negligence of the CONTRACTOR, or other such preventable causes, will be rejected. Any borings so rejected shall be repeated adjacent to the original location at a distance of at least five (5) metres, and the set-up of the drilling equipment at the new location shall be at CONTRACTOR's account.

In soil borings equipped with a piezometer, the water level shall be recorded on a daily basis until the end of the site works. If necessary, flushing the piezometer system of possible drilling contaminant shall be considered. In accordance with the Particular Technical Specification, water samples can be required for geochemical analysis in the laboratory.

Upon completion, the borings shall be filled with a grout slurry made of cement and bentonite pumped to the bottom of the hole (tremie grouting), or between the hole bottom and the base of the piezometer if the boring is equipped with a piezometer. In accordance with the Particular

Technical Specification, COMPANY can request to plug the soil borings with materials obtained locally.

5.2 Site preparation, topographic survey and positioning

5.2.1 Site preparation, logistics and personnel

Unless otherwise mentioned in the Particular Technical Specification, all works required for the access of CONTRACTOR's equipment to the soil investigation site and within the site, i.e. tracks permitting the circulation of all drilling equipment at survey points locations and work platforms, shall be under the responsibility of the CONTRACTOR.

The complete logistics required for the performance of the soil investigation field works, including personnel, drilling machines and all associated equipment, all consumables (including water) and spare parts, site office and laboratory (if required), site containers for temporary storage of core boxes and soil samples, etc., shall be under the responsibility of the CONTRACTOR.

The CONTRACTOR shall ensure that the geotechnical equipment and personnel is sufficient to perform the soil investigation operations in accordance with COMPANY requirements mentioned in the Particular Technical Specification. Prior to commencing the site operations, and as part of the mobilisation, CONTRACTOR shall carry out tests on all equipment to ensure that everything is functioning properly.

The CONTRACTOR shall nominate a Project Manager who shall be in charge of the complete soil investigation work on both technical and administrative grounds. The Project Manager shall be the CONTRACTOR Representative for the whole Project duration. If the Project Manager cannot himself supervise the site works, he shall nominate a Party Chief Engineer, being a qualified geotechnical engineer or engineering geologist, who shall be responsible for the complete soil investigation field works, including drilling, boring and in-situ testing operations, data or measurements acquisition, as well as laboratory testing and interpretation works. During the soil investigation field works, the Party Chief Engineer shall be present at the site on a full time basis.

The geotechnical survey work shall be performed by qualified workers, who shall be in a sufficient number to perform the field operations within the specified time frame. Unless otherwise mentioned in the Particular Technical Specification, the field works at the survey site shall be performed on the basis of 12 hours per day and 7 working days per week.

5.2.2 Topographic survey and positioning

Unless otherwise indicated in the Particular Technical Specification, the initial topographic survey of the work site shall be under the responsibility of the COMPANY, and an accurate drawing will be provided to the CONTRACTOR in charge of the soil investigation work.

In agreement between the CONTRACTOR and COMPANY Representatives, the location and depth of each soil boring, trial pit, or in-situ testing point shall be defined, according to the anticipated local soil conditions, existing facilities and expected projected structures. The agreed location and target depth of soil investigation points shall not be modified without prior approval from the COMPANY Representative.

When a soil boring, trial pit, or in-situ test is to be performed close to existing facilities, hand digging shall be carried out down to one (1) metre depth below ground level, to check that there is no subsurface piping, electric cable, or any other obstruction which may be a hazard to drilling activities.

Each soil investigation point shall be positioned using conventional traverse survey method, or satellite DGPS (Differential Global Positioning System) method. The local geodetic system to be used shall be provided by COMPANY. The depth of borings shall be measured in relation to distance below natural ground surface, with reference to a Chart Datum to be provided by COMPANY.

When CONTRACTOR intends to use DGPS positioning, the equipment and procedures shall comply with the General Specification **GS GEO 301** for surface positioning works. Before the start of site works, the DGPS system shall be verified by comparison with a fixed point with known coordinates (to be provided by COMPANY). At COMPANY's request, or if any doubts remain about the accuracy of the DGPS positioning system, this check shall be repeated after completion of the soil investigation work.

After completion of the geotechnical survey work, the exact coordinates and elevation of all soil borings, trial pits, and in-situ testing points shall be taken by a qualified surveyor, under the responsibility of the CONTRACTOR. A detailed lay-out plan shall be provided to the COMPANY Representative.

6. Soil sampling equipment and procedures

6.1 Trial pits and shallow sampling

The purpose of trial pits is twofold, i.e. to determine shallow subsurface soil conditions by visual identification, and to take samples, generally disturbed, for index testing in the laboratory, in particular for road, landing strip, or pipeline route engineering purposes.

The tentative number and location of trial pits shall be mentioned in the Particular Technical Specification. The exact location and target depth of trial pits shall be defined according to the local site and soil conditions, and in agreement between the CONTRACTOR and COMPANY Representatives.

The trial pits shall be carried out by use of excavators acceptable for the local site and soil conditions, with the following minimum specifications:

- Tracked vehicle
- Backhoes with excavating depth ranging between 3 and 4 metres.

In special circumstances, hand-digging of the trial pits can also be considered, but this shall only be allowed with adequate temporary support or battering.

When ground water is first encountered in trial pits, the depth from ground level to point of entry shall be recorded.

A trial pit shall be considered as completed when it has reached the target depth, or as directed by COMPANY Representative, and when all sampling has been performed satisfactorily.

Depending on the objective of the soil investigation mentioned in the Particular Technical Specification, other types of samplers for shallow penetration can be proposed by the CONTRACTOR, in particular the box corer, and the vibro-driven sampler. In such a case, the CONTRACTOR shall provide a complete technical documentation concerning the proposed equipment and procedures, with the dimensions and main characteristics of the equipment, as well as the list of references of works carried out previously with the same equipment.

6.2 Deep sampling in soil borings

For deep soil sampling and coring carried out inside soil borings, various types of corers can be used, in particular:

- Thin-walled push sampler, for recovering undisturbed samples in clayey soils
- Driven split-barrel sampler, for recovering samples in sands and hard clays
- Rotary coring in more or less hardly cemented strata and rock formations.

The soil sampling and coring equipment and procedures shall be capable of sampling operations in all soil conditions likely to be encountered, including: soft and very soft clays, stiff to hard clays, silts, loose to very dense sands, gravel, weakly to hardly cemented limestone, rock formations, etc.

Unless otherwise mentioned in the Particular Technical Specification, the general procedures for deep sampling in soil borings shall comply with the following requirements:

- a) Push tube sampling: The equipment and procedure shall comply with the [ASTM standard practice D1587](#), regarding in particular the sample diameter, which shall be equal to a minimum of 51 mm (2 inches) and up to 127 mm (5 inches) with a minimum tube length of 0.75 to 0.91 metre, the tube inside clearance ratio, and the corrosion protection of the sampling tubes. In very soft clays, the use of an internal stationary piston is recommended. For improving the sample quality, the drilling operators shall pay attention to clean-out of the soil boring down to sampling elevation, as well as to recording the length of tube advance. The minimum thrust force available shall be mentioned in the technical documentation provided by CONTRACTOR.
- b) Driven split-barrel sampling and SPT testing: The equipment and procedure shall comply with the [ASTM standard practice D1586](#) for split-barrel sampling and SPT testing of soils, regarding in particular the sample diameter which shall be equal to a minimum of 38 mm (1.5 inch), the weight and free-fall height of the striking ram, and the recording of blowcounts (N-values to travel the last 300 mm) to measure the resistance to penetration for estimating the in-situ soil density or strength.
- Note:** The influence of the drill rig set-up and operators on the variability in N-values shall be assessed, and the field SPT blowcounts shall be adjusted for obtaining N-values on the basis of comparative driving energies. Reference can be made to the [ASTM standard practice D4633](#) for stress wave energy measurement for dynamic penetrometer testing systems.
- c) Rotary coring: The equipment and procedure for rotary coring of cemented soils and rock formations shall comply with the [ASTM standard practice D2113](#) for diamond core drilling. Unless otherwise mentioned in the Particular Technical Specification, the coring equipment shall include tungsten carbide or diamond tipped drill bits, as appropriate to the formation to be cored, and double-tube core barrels with retrievable inner-tube assembly used with semi rigid inner plastic liners. The drill rods used with retrievable inner-tube core barrels shall be those manufactured by the core-barrel manufacturer specifically for the core barrel. The minimum core diameter shall be equal to 55 mm (NW/NQ size), except in weak rocks where the minimum core diameter shall be increased to 75 or 85 mm (HQ to PQ size).

In soft to stiff cohesive soils, and loose to medium dense non-cohesive soils, thin-walled push sampling shall be used for recovering relatively undisturbed samples. Driven split-barrel sampling shall be used in very stiff to hard cohesive soils and in non-cohesive soils, when refusal has occurred with thin-walled push sampling.

Typically, the soil sampling interval shall not be greater than 1 metre in the upper formations, down to about 10 metres below the ground level. Below 10 metres of penetration, and particularly in homogeneous or uniform soil strata, the sampling interval can be increased to 1.5 to 2 metres. However, at every change of soil strata, and in heterogeneous soil conditions, the sampling interval shall be equal to 1 metre or less, as agreed between the CONTRACTOR and COMPANY Representatives.

In rock formations, the type of drill bit and the length of core runs shall be adapted to maximise core recovery. In every coring, the initial core run shall be 0.5 metre in length. If the recovery obtained is greater than 80%, the subsequent core run can then be increased in length by 0.5 metre. In all cases, the length of core runs shall be limited to a maximum of 1.5 metre. When recovery falls below 80%, the next core run shall be reduced in length by 0.5 metre.

The CONTRACTOR shall provide complete technical documentation concerning the sampling and coring equipment and procedures, including the dimensions (length, internal and external diameters) and main characteristics of the samplers and corers, the procedure used for extruding and storing the soil samples, and the list of references of works carried out previously with the same equipment, with an estimate of the sample quality and the average rate of progress for various soil conditions.

7. In-situ test equipment and procedures

7.1 Static cone penetration test

7.1.1 Standard cone penetration test

The static cone penetration test with pore pressure (CPTU test) is the reference in-situ test. The cone geometry and test procedure shall comply with the international reference test procedure of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE, 1999).

The cone penetrometer probes shall allow for continuous measurement (that is at least one measurement point per second, or every 20 mm of penetration at the standard rate of penetration) of the cone tip resistance, local sleeve friction, and pore pressure (for CPTU tests).

With respect to the pore pressure measurement in CPTU tests, the location of the porous stone is not standardised, but a position on the cone shoulder immediately behind the tip shall be preferred, in accordance with the recommendations of the ISSMGE. Continuous measurement of the pore pressure shall be possible during penetration into the soil, or while penetration is interrupted for a dissipation test.

The test cones shall be checked at regular intervals, at least twice a year, for signs of wear of the cone tip and friction sleeve, as well as for the general electronics and the sensitivity of the sensors (with respect to accuracy and sensitivity of the measurements). Calibration sheets shall be available with the test cones and shall be supplied upon request of COMPANY.

Additional checks on the sensitivity of the sensors may be required before, during, and/or after the soil investigation field works. The checking procedure used (i.e. test up to maximum sensor capacity or otherwise, test with or without umbilical cable, test with cone in water or not, test with different ambient temperatures, etc.) shall be included in the technical documentation provided by the CONTRACTOR.

For the standard static cone penetration test, the CONTRACTOR shall provide a general technical documentation, including:

- Maximum reaction force or loading capacity available, and maximum possible length of penetration (according to the anticipated soil conditions at the site)
- Main characteristics of the CPT cones, with cone geometry, capacity and sensitivity of the sensors
- System used to transmit the test measurements between the cone probe and surface, and the recording system used
- Availability of a system for monitoring the vertical alignment of the penetrometer rods embedded into the soil, such as inclinometers incorporated in the cone probe, for example
- List of references of previous works performed with the proposed equipment.

7.1.2 Other types of cone penetration tests

Depending on the soil conditions expected at the site, cone types which are different than from the ISSMGE's reference test cone (i.e. 36.5 mm diameter, 10 cm² cross-sectional area and 60 degree cone angle) may be proposed by the CONTRACTOR, in particular:

- Cone with a cross-sectional area of 15 cm² (i.e. 44 mm diameter) or more for very soft clays
- Cone with cross-sectional area of 1 to 5 cm² (i.e. 11 to 25 mm diameter) for light equipment possibly used for shallow subsurface survey, particularly for road and pipeline route surveys.

When such test equipment is proposed, the CONTRACTOR shall provide a complete technical documentation, including the detailed characteristics of the CPT cones, as well as the results of calibration tests showing the correlation, and any necessary corrections, with the results obtained with a reference test cone (i.e. 36.5 mm diameter and 10 cm² cross-sectional area CPT cone).

Depending on the objectives of the geotechnical survey works mentioned in the Technical Particular Specification, the use of special test cones for in-situ measurement of additional parameters can be proposed by the CONTRACTOR, including in particular (non-exhaustive list):

- S and/or P wave velocity (seismic cone)
- Temperature and thermal conductivity
- Electrical conductivity and resistivity
- In place soil density by nuclear method
- Determination of pollution from hydrocarbons or other.

When such equipment is proposed, the CONTRACTOR shall provide complete technical documentation, including the detailed characteristics of the test cones and the operating procedure. A list of references of previous works performed with the proposed equipment shall also be supplied, as well as examples of results obtained with average operating times for various soil conditions.

7.2 Other in-situ tests

Depending on the objectives of the geotechnical survey works mentioned in the Particular Technical Specification, other types of in-situ tests and measurements may be required by COMPANY and/or proposed by CONTRACTOR, in particular (non-exhaustive list):

- Standard Penetration Test SPT (covered in section 7.2 about the driven split-barrel sampler), or other type of dynamic cone penetration test (e.g. “Bevac” type or other)
- Field vane shear test
- Plate load bearing test
- Pressuremeter test
- Dilatometer test
- Hydraulic fracturing test
- Measurement of the in-situ soil or rock density, e.g. by nuclear methods in borings (e.g. gamma-densitometer), sand replacement method in trial pits, or other
- Soil resistivity measurement
- Geophysical borehole logging, e.g. seismic velocity and gamma-gamma logging, including caliper testing of the soil boring diameter
- Seismic measurements, e.g. by seismic refraction or cross-hole method between soil borings
- Other well and/or soil boring tests, such as determination of hydraulic properties by pumping or raising the ground water table, “Lugeon” or “Lefranc” water testing, for example
- Sampling and analysis of gas dissolved in pore water
- Specific tests for frozen soils or contaminated soils.

For any types of in-situ test proposed, the CONTRACTOR shall provide complete technical documentation, including:

- Dimensions and main characteristics of the in-situ testing equipment
- Operating procedure, including the ISSMGE, ASTM, BS, AFNOR or other reference procedure (**Note:** if no reference test procedure exists, a detailed procedure shall be provided, together with examples of test results on similar types of soils)
- Capacity and sensitivity of the sensors, as well as the procedure for calibrating and checking the accuracy of the in-situ measurements
- System used to transmit the measurements between the test probe and surface, and the recording system used
- List of references of previous works performed with the proposed equipment, including the average operating times for various soil conditions.

7.3 Presentation of results

During performance of in-situ tests, the CONTRACTOR shall be able to check in real time the various parameters measured, and the measurements shall be recorded simultaneously on a digital medium.

No later than 24 hours after completion, the results of all in-situ measurements shall be provided by the CONTRACTOR in the daily progress report.

The parameters measured in-situ shall be presented before (i.e. "gross" measurements) and after (i.e. "net" measurements) any corrections, and the correction procedure shall be clearly defined in the final factual report supplied by the CONTRACTOR.

Upon request from COMPANY, all results of the in-situ tests shall be provided by CONTRACTOR on an IBM PC-compatible digital medium, e.g. 3.5" floppy disk or CD-Rom disc.

8. Laboratory test equipment and procedures

8.1 Laboratory tests performed at the site laboratory during fieldwork

8.1.1 Extrusion and conservation of samples

- a) Undisturbed soil samples: Undisturbed soil samples shall be handled with care at all times to avoid damage and disturbance. Immediately after recovery, they shall be tested with hand shear devices, such as pocket penetrometer and hand vane, and then sealed with cool wax at both ends. When possible, undisturbed samples shall be retained in their non-corrodible push sampling tube, and stored in robust containers until arrival at the office laboratory.
- b) Disturbed and bulk soil samples: Disturbed and bulk soil samples shall be stored inside two plastic bags, and collected into robust containers until arrival at the office laboratory.
- c) Rock cores: Cores shall be extruded from their linings or split inner tube using a piston-type extruder, and extrusion shall be in the same direction as the rock core entered the core barrel. The entire length of core shall be supported during this process. Cores shall then be stored in suitable and robust boxes, typically of wooden construction with a hinged lid and up to 1.5 m long. Weak rock samples shall be sealed with cool wax. The sample boxes shall allow minimum movement of cores when full. Wooden spacers shall be used to indicate the start and end of each core run, with the cores placed in their correct natural sequence from upper left to lower right in the box (to be read like a book), and with spacers of appropriate length to indicate zones of no recovery.
- d) Water and soil samples for geochemical analysis: When water or soil samples are taken for geochemical or environmental analysis, the conservation procedure shall include the equipment needed to freeze the samples from the time they are obtained at the fieldwork site until arrival at the agreed office laboratory. Reference shall be made to **GS ENV 111**.

All samples shall be clearly labelled, using strongly adhesive printed labels, for unambiguous identification. The labels shall record in particular the Project and site names, the name of both the COMPANY and CONTRACTOR, the soil boring and sample identifier, the sample depth with both top and bottom of sample depth, and the date of recovery. The containers or boxes containing samples and rock cores shall also be identified in the same way, both outside and inside.

Optimum conditions of storage and conservation of all samples and cores shall be supplied, avoiding in particular excessive heat and temperature variation during daily site operations. Upon completion of each daily activities, all samples shall be removed from the site. Similarly, off-site storage and transportation of the samples from the site to the office laboratory (by road, sea or air freight) shall be performed with caution in order to minimise any risk of soil disturbance.

8.1.2 Schedule of site laboratory tests

Depending on the objectives and scope of work of the geotechnical survey work mentioned in the Particular Technical Specification, the CONTRACTOR can be required to supply a site laboratory to perform a number of tests, including (non exhaustive list):

- Visual description, identification and classification of soil samples
- Geological and structural description, TCR, RQD and SCR, of rock cores
- Photographic record of soil samples from each significant formation and of all rock core boxes (with clear identification of the project, site, and samples or cores)
- Natural water content by weight or wet and dry densities
- Chemical test on ground (organic content, carbonate content, chloride content and PH value)
- Chemical test for groundwater (sulphate content, chloride content, total soluble salts, total dissolved solids, PH value)
- Grain size distribution, and CBR or “Proctor” compaction test, in particular for the construction of backfill or formation layers for road works
- Measurement of the undrained shear strength of clays by pocket penetrometer, miniature vane, laboratory vane, or by correlation with the fall cone test
- Compressibility test
- Unconfined compressive test, or point load index test, for cemented soils and rock cores or fragments
- Geophysical logging and/or X-ray radiography of soil samples or rock cores.

All site laboratory tests shall be carried out based on procedures in accordance with international standards (i.e. ISO, ASTM, BSI, AFNOR, NS, ISRM, or equivalent), performed by experienced personnel and supervised by a qualified geotechnical engineer or engineering geologist.

The laboratory test equipment shall be checked at regular intervals, and the calibration sheets shall be available with the corresponding equipment upon request of the COMPANY Representative.

The schedule of site laboratory tests shall be defined in accordance with the requirements of the Particular Technical Specification, and in agreement between the CONTRACTOR and COMPANY Representatives. No later than 24 hours after completion, the results of all site laboratory tests shall be provided by the CONTRACTOR in the daily progress report.

8.2 Tests performed in the office laboratory

After completion of the field works and site laboratory tests, all remaining samples and cores shall be sent to the office laboratory, as agreed between CONTRACTOR and COMPANY.

The laboratory test schedule shall be defined in agreement between the CONTRACTOR and COMPANY Representatives. It shall depend on the soil conditions encountered at the site and on the objectives of the soil investigation, as mentioned in the Particular Technical Specification. Office laboratory testing shall not start before approval of the proposed schedule has been received from the COMPANY Representative.

All office laboratory tests shall be carried out based on procedures in accordance with international standards (i.e. ISO, ASTM, BSI, AFNOR, NS, ISRM, or equivalent), performed by experienced personnel and supervised by a qualified geotechnical engineer or engineering geologist. The laboratory test equipment shall be checked at regular intervals, and the calibration sheets shall be available with the corresponding equipment upon request of the COMPANY Representative.

When special office laboratory tests are not covered by a recognised standard or procedure, the CONTRACTOR shall provide a complete technical documentation, including a detailed description of the test equipment, the test procedure, and examples of test results on similar types of soils.

After completion of the schedule of office laboratory tests, and unless otherwise mentioned in the Particular Technical Specification, the CONTRACTOR shall store all remaining samples in a wet room for a period of six months after expiry of the Contract. After this period, CONTRACTOR shall obtain a written requirement from COMPANY regarding the final disposition of all remaining samples, i.e. samples to be sent back to COMPANY or to be destroyed.

9. Evaluation and presentation of geotechnical parameters

9.1 Soil conditions and geotechnical parameters

The soil conditions and geotechnical parameters from the soil investigation site shall be defined on the basis of all information obtained, including:

- Regional and local geological conditions at the site, including distribution and interpretation of general material types, evidence of geohazards, such as landsliding, soft soils, erosion, flooding, etc.
- Geotechnical drilling and/or soil boring sections and logs
- Water table level readings during the field works
- Description, identification and classification of all soil and rock samples
- Results of all in-situ tests and measurements
- Results of all laboratory tests and measurements
- Correlations between in-situ tests and laboratory tests and measurements
- Correlations with any results obtained during previous geophysical and/or geotechnical surveys at the reference site (on the basis of reports that can as far as possible be supplied by the COMPANY or CONTRACTOR's files).

The summary and interpretation of all above data must make it possible to define the geotechnical model of the survey site, including:

- Hydro-geotechnical context at the site
- Identification of the different soil layers and geotechnical formations of interest for designing the projected foundations and/or earth works
- Definition of the physical and geomechanical characteristics of each soil layer, as well as the characteristics essential for designing the projected geotechnical works.

The bibliographical references used to justify the choice of correlations to determine geotechnical parameters on the basis of in-situ test results shall be provided by the CONTRACTOR. Application of such correlations, or in-situ test interpretation charts, to the site conditions shall be checked against the actual site data, possibly completed by any specific CONTRACTOR's experience at other sites with similar soil conditions.

Whenever possible, and for each geotechnical formation, an estimate of the uncertainty associated with the geotechnical parameters shall be supplied, giving the mean value, standard deviation and coefficient of variation of each of the parameters considered. The test or measurement results that may be affected by a degree of disturbance of the soil sample shall be clearly identified and shall not be included in the statistical calculations.

For a soil investigation including several borings distributed over the site surveyed, an estimate of the spatial variability of the soil characteristics in the definition of the geotechnical parameters shall be provided in the final engineering report.

9.2 Design studies

The basic geometry of the geotechnical works and/or of the foundations of the intended structures will be provided by the COMPANY in the Particular Technical Specification.

A number of engineering design methods are recognised internationally by the profession, in particular:

- **API RP 2A** for the design of driven or drilled and grouted piled foundations using steel pipe piles
- Eurocodes and **API RP 2A** for the design of shallow and deep foundations for buildings
- **BS 6349** for the design of quay walls, jetties and dolphins
- **NEN 3650** for the design of onshore pipelines
- **API RP 2N** for the design of sub-sea pipelines in arctic conditions.

If the design methods used by the CONTRACTOR differ significantly from the above methods, the basic documentation and bibliographic references justifying the use and application of the method considered for the projected structures shall be included in the final engineering report.

The geotechnical survey report serving as a basis for the design of the projected works and structures, as well as for any installation studies for the foundations of these structures, the conclusions and recommendations shall clearly mention:

- A summary of the site soil conditions, emphasising any possible specific local features or spatial variations revealed by the geotechnical survey results
- Potential problems likely to be encountered during the construction and installation works, in particular regarding any special arrangements which may be required with respect to the ground water table and the risk of settlement close to adjacent works or structures.

10. Reports to be submitted by the CONTRACTOR

10.1 Daily progress report

During the geotechnical survey works, the CONTRACTOR shall provide daily progress reports of his and his SUB-CONTRACTORS activities. This DPR report, to be signed by both the CONTRACTOR and COMPANY Representatives shall include:

- Date and identification of Project and site, as well as COMPANY and CONTRACTOR
- Identification of key personnel at the site, and total number of personnel working per set of equipment and per shift
- Identification of topographic and positioning activities, with the type of equipment used
- Identification of soil borings under progress, with the types of boring and equipment used
- Method of drilling with diameter and depth of casing (if any), or method of coring with type of drill bit and core barrel, with the type of drilling fluid used in both cases
- Soil borings and trial pits where samples or cores were taken, mentioning the depths and recovery
- Soil borings where in-situ tests were performed, mentioning the type of tests
- Soil borings where the level of the ground water table was measured
- Daily and cumulative meterage of drilling, trial pits, and in-situ testing
- Daily and cumulative number of working hours
- Details about non working stand-by hours and reasons for such
- Details about consumables and spare parts used
- List of samples for testing in the site laboratory, with daily and cumulative progress of site laboratory testing
- List of samples packaged for transportation to the office laboratory
- Overall work progress and estimated date for completion of the field works.

Any disagreement that can not be settled at the work site shall be noted and clearly documented in the corresponding daily report.

10.2 Field report

The field report shall be a factual report of the geotechnical survey works actually performed, including:

- Positions of soil borings, trial pits and in-situ testing points, with a lay-out plan giving the UTM coordinates and elevations in the reference system
- Brief description of the field works performed, with the main methods and equipment used, as well as the identification of any discrepancies with the planned scope of work as given in the Particular Technical Specification
- Drilling logs, with the recording of drilling parameters and identification of any problems encountered (e.g. loss of water or drilling fluid, bits falling, low recovery, etc.)

- Level of the ground water table measured in the soil borings, as a function of time where appropriate
- Preliminary geotechnical logs of all soil borings and trial pits, with a description of the different geotechnical formations encountered
- Preliminary results of all in-situ tests and measurements
- Preliminary results of all site laboratory tests
- List of samples sent to the office laboratory, with the schedule of laboratory tests agreed between the CONTRACTOR and COMPANY Representatives
- Results of calibration and verification tests carried out on the positioning system,
- Results of calibration and verification tests carried out on the penetrometer cones and other in-situ test probes
- Copy of the daily progress reports.

Unless otherwise mentioned in the Particular Technical Specification, three copies of the field report shall be provided by the CONTRACTOR within one (1) week after completion of the field works at the geotechnical survey site.

All associated activities, in particular regarding the topographic and positioning survey activities, can be provided in a separate report.

10.3 Final geotechnical survey reports

The final geotechnical survey report shall be in line with the scope and objective of the survey works mentioned in the Particular Technical Specification. It shall be supplied in two separate volumes, i.e. a first factual report containing the summary of the site and soil conditions, and the second report concerning the engineering and dimensioning of the projected geotechnical works and/or foundations for the structures under consideration.

10.3.1 Final factual report

Unless otherwise mentioned in the Particular Technical Specification, the final factual report of the geotechnical survey works shall include at least the following information:

- Purpose and scope of the geotechnical survey works
- Final positions of soil borings, trial pits and in-situ testing points, with a detailed lay-out plan giving the UTM coordinates and elevations in the reference system
- Description of the field works performed, with the main methods and equipment used
- Description of the regional and local geological conditions, as well as the hydro-geotechnical context of the site
- Final geotechnical logs of soil borings and trial pits, with the description, identification and classification of the different geotechnical formations encountered
- Geotechnical cross-sections over the surveyed area
- Level of the ground water table measured in the soil borings, and the results of geochemical analyses on water samples (if any)
- Final results of all in-situ tests and measurements, including the correction procedure applied to obtain the final “net” measurements

- Final results of all laboratory tests
- Photographic records of typical soil samples and rock cores.

Unless otherwise mentioned in the Particular Technical Specification, the draft version of the final factual report shall be provided by the CONTRACTOR within four (4) weeks after completion of the field works at the geotechnical survey site. No later than one (1) week after receiving the COMPANY's comments on the draft report, ten copies of the final version shall be provided by CONTRACTOR, with one unbound copy for reproduction purposes.

Upon request from COMPANY, the final factual report shall be provided on an IBM PC-compatible CD-Rom disc, with text on "Word" or "Adobe Acrobat".PDF and charts in "Autocad" 14.DXF or.DWG format.

10.3.2 Final engineering report

Unless otherwise mentioned in the Particular Technical Specification, the final engineering report of the geotechnical survey works shall include at least the following information:

- Brief recall of the purpose and scope of the survey works, with a list of the type of geotechnical works and structures under consideration
- Lay-out plan giving the positions of soil borings, trial pits and in-situ testing points with respect to the projected structures
- Summary of the final geotechnical logs of soil borings, trial pits and in-situ tests, with cross-sections over the surveyed area
- Summary of the physical and geomechanical characteristics of each identified geotechnical formation
- Comparison of these characteristics with any results obtained at the same site from earlier geophysical or geotechnical surveys (as provided by COMPANY or possibly available in the CONTRACTOR's files)
- Parameters necessary for designing the geotechnical works or foundations for the intended structures
- Results of the engineering studies, in accordance with the conditions set-out in the Particular Technical Specification
- General construction principles, with necessary precautions with respect to potential risks related to the specific site and soil conditions
- Engineering recommendations, with identification of any improvements possibly required, particularly with respect to embedment and bearing capacity for the different types of foundations considered.

Unless otherwise mentioned in the Particular Technical Specification, the draft version of the final engineering report shall be provided by the CONTRACTOR within six (6) weeks after completion of the field works at the geotechnical survey site. No later than one (1) week after receiving the COMPANY's comments on the draft report, ten copies of the final version shall be provided by CONTRACTOR, with one unbound copy for reproduction purposes.

Upon request from COMPANY, the final engineering report shall be provided on an IBM PC-compatible CD-Rom disc, with text on "Word" or "Adobe Acrobat".PDF and charts in "Autocad" 14.DXF or.DWG format.