

Marine soil investigations

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

Introduction

Revision 2 of this NORSOK standard is mainly an updated version to take into account the developments in the Offshore Soil Investigation Industry that have taken place since Revision 1 was issued in 1996.

According to the "Petroleum Activities Act" (1996), marine soil investigations are petroleum activities. The "Petroleum Activities Act" (1996) itself and the health, environment and safety (HES) regulations issued by the Petroleum Safety Authority (PSA) are therefore applicable for planning, documentation and execution of marine soil investigations. The HES regulations includes a number of requirements which have to be applied and documented before a marine soil investigation can commence, especially if a drilling vessel is used.

Type of soil investigation equipment to be used, extent of an investigation, laboratory testing programme and reporting requirements will be agreed as part of each contract. This will depend on type of structures involved (e.g. fixed platform, subsea structure, pipeline etc.), type of soil conditions and if it is a regional, site specific, preliminary or final soil investigation.

Use of this NORSOK standard will result in equal quality from the various soil investigations.

This NORSOK standard is published without marking of changes, compared to Rev. 1, as the modifications are considerable.

1 Scope

This NORSOK standard includes guidelines and requirements for equipment, testing procedures, interpretation and evaluation of test results and reporting for marine soil investigations. This NORSOK standard covers the most common equipment available today for sampling, in situ testing and laboratory testing.

This NORSOK standard is applicable both for marine soil investigations performed by specialised drilling vessels (drilling mode investigation with down-hole sampling and in situ testing) and for investigations performed by standard survey vessels (surface mode investigation). The detailed requirements in this NORSOK standard are only applicable for the equipment and methods specified by the user (client) in the scope of work for the actual field work.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

2.1 Normative references

API RP 2A-LRFD,	Planning, Designing and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design. 1 st Edition, July 1, 1993.
API RP 2A-WSD,	Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design. 21 st Edition, December 2000.
ASTM D422-63,	Standard Test Method for Particle-Size Analysis of Soils.
ASTM D854-02,	Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer.
ASTM D2166-00,	Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.
ASTM D2216-98,	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
ASTM D2435-03,	Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
ASTM D2573-01,	Standard Test Method for Field Vane Shear Test in Cohesive Soil.
ASTM D4015-92,	Standard Test Methods for Modulus and Damping of Soils by the Resonant-Column Method.
ASTM D4318-00,	Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
ASTM D4452-85,	Standard Test Methods for X-Ray Radiography of Soil Samples.
ASTM D4648-00,	Standard Test Method for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil.
ASTM D5334-00,	Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure.
ASTM D6528-00,	Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils.
BS 1377-1:1990,	Methods of test for soil for civil engineering purposes. General requirements and sample preparation.
BS 1377-2:1990,	Methods of test for soil for civil engineering purposes. Classification tests.
BS 1377-3:1990,	Methods of test for soil for civil engineering purposes. Chemical and electro-chemical tests.
BS 1377-4:1990,	Methods of test for soil for civil engineering purposes. Compaction-related tests.
BS 1377-5:1990,	Methods of test for soil for civil engineering purposes. Compressibility, permeability and durability tests.
BS 1377-6:1990,	Methods of test for soil for civil engineering purposes. Consolidation and permeability tests in hydraulic cells and with pore pressure measurement.
BS 1377-7:1990,	Methods of test for soil for civil engineering purposes. Shear strength tests (total stress).

BS 1377-8:1990,	Methods of test for soil for civil engineering purposes. Shear strength tests (effective stress).
BS 1377-9:1990,	Methods of test for soil for civil engineering purposes. In-situ tests.
BS 5930:1999,	Code of practice for site investigations.
DNV Classification Note 30.4,	Foundations
IRTP (1999),	ISSMGE International Society of Soil Mechanics and Geotechnical Engineering (1999) International Reference Test Procedure for the Cone Penetration Test (CPT) and the Cone Penetration Test with Pore Pressure (CPTU). Report of the ISSMGE Technical Committee 16 on Ground Property Characterisation from In-situ Testing, Proceedings of the Twelfth European Conference on Soil Mechanics and Geotechnical Engineering, Amsterdam, Edited by Barends et al., Vol. 3, pp. 2195-2222. Balkema.
ISO 19901-4,	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations.
ISO/DIS 19902,	Petroleum and natural gas industries - Fixed steel offshore structures
NS 3481	Soil investigations and geotechnical design of marine structures.
NS 8001,	Geotechnical testing - Laboratory methods - Percussion liquid limit.
NS 8002,	Geotechnical testing - Laboratory methods - Fall cone liquid limit.
NS 8003,	Geotechnical testing - Laboratory methods - Plastic limit.
NS 8005,	Geotechnical testing - Laboratory methods - Grain-size analysis of soil samples.
NS 8011,	Geotechnical testing - Laboratory methods - Density.
NS 8012,	Geotechnical testing - Laboratory methods - Density of solid particles.
NS 8013,	Geotechnical testing - Laboratory methods - Water content.
NS 8015,	Geotechnical testing - Laboratory methods - Determination of undrained shear strength by fall-cone testing.
NS 8016,	Geotechnical testing - Laboratory method - Determination of undrained shear strength by unconfined pressure testing.
NS 8017,	Geotechnical testing - Laboratory methods - Determination of one-dimensional consolidation properties by oedometer testing - Method using incremental loading.
NS 8018,	Geotechnical testing - Laboratory methods - Determination of one-dimensional consolidation properties by oedometer testing - Method using continuous loading.
Petroleum Activities Act (1996),	Lov om petroleumsaktivitet. LOV 1996-11-29, sist endret LOV-2003-06-27-68. English translation: Act 29 November 1996 No. 72 relating to petroleum activities.

2.2 Informative references

ASTM D2487-00,	Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).
ASTM D4253-00,	Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
ASTM D4254-00,	Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.
ASTM D2850-03a,	Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils.
ASTM D6467-99,	Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils.
Bishop et al. (1971),	Bishop, A. W., G. E. Green, V. K. Garga, A. Andresen and J. D. Brown (1971): A new ring shear apparatus and its application to the measurement of residual strength. Geotechnique 21, 273-328.
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- NS 4737, Determination of sulphide content of waste water - Colorimetric method.
- Pettijohn, F.J. (1957), Sedimentary rocks. 2nd ed. New York, Harper & Brothers XVI, 718 pp.
- Rad, N.S. and T. Lunne (1994), Gas in Soils: Detection and η -profiling. Journal of Geotechnical Engineering, Vol. 120, No. 4, April, pp. 697-715.
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- Ramsey et al. (1998), Ramsey, N., R. Jardine, B. Lehane and A. Ridley (1998) "A Review of Soil-Steel Interface Testing with the Ring Shear Apparatus", Proceedings SUT International Conference, Offshore Site Investigation and Geotechnics, London, November 1998.

Randolph et al. (1998),	Randolph, M.F., Hefer, P.A., Geise, J.M. and Watson, P.G. (1998) Improved seabed strength profiling using T-bar penetrometer. Proceedings of the SUT International Conference, Offshore Site Investigation and Foundation Behaviour 'New Frontiers', London 1998. Pp. 221-235.
SFT (1991),	Veiledning for miljøtekniske grunnundersøkelser. SFT-veiledning nr 91:01. Translated to English by NGI: "Guide to environmental soil investigation". NGI Report No. 537000-1, December 1992.
SUT-OSIG (2004),	"Guidance Notes on Geotechnical Investigations for Marine Pipelines", OSIG-Rev 03, 17 September 2004. Prepared by the Pipeline Working Group of the Offshore Soil Investigation Forum, OSIG. Updated 2004 by the Society for Underwater Technology.
Taylor, Donald W. (1948),	"Fundamentals of Soil Mechanics", New York, John Wiley & Sons Inc.
The Unified Soil Classification System (1953),	Waterways Exp. Station. Corps of Engineers, U.S. Army, Technical Memorandum No. 3-357, Vols. 1 to 3. Vicksburg, 1953.

3 Terms, definitions and abbreviations

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

3.1 Terms and definitions

3.1.1

shall

verbal form used to indicate requirements strictly to be followed in order to conform to this NORSOK standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.2

should

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.1.3

may

verbal form used to indicate a course of action permissible within the limits of this NORSOK standard

3.1.4

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.2 Abbreviations

BAT	commercial name of a gas sampler
CCV	consolidated constant volume
CPT	cone penetration test
CPTU	piezocone
CRS	constant rate of strain
CU	consolidated undrained
DGP	deepwater gas probe
DSS	direct simple shear
IRTP	International Reference Test Procedure
ISO	International Organization for Standardization
NGF	Norsk Geoteknisk Forening (Norwegian Geotechnical Society)
NGI	Norwegian Geotechnical Institute
NS	Norwegian Standard
OCR	overconsolidation ratio
RPM	rotations per minute

OSIG	Offshore Site Investigation and Geotechnical Committee
SFT	Statens Forurensningstilsyn (The Norwegian Pollution Control Authority)
SHANSEP	stress history and normalized soil engineering properties
SRB	sulphate reducing bacteria
SUT	The Society of Underwater Technology
UCT	unconfined compression test
UU	unconsolidated-undrained

4 General objectives of investigations and need for planning

The requirements given in ISO/DIS 19902, ISO 19901-4, NS 3481 and DNV Classification Note 3.4 shall be mandatory, unless otherwise documented. These standards are the basis for this NORSOK standard regarding planning and execution of marine soil investigations.

The level and extent of a soil investigation should be a function of several factors including, but not limited to, geology of the area, local soil conditions, project requirements, availability of previous investigations, accessibility, environmental conditions and any limitations related to budget and time available.

The detailed plans and specifications for the investigation should be based on a consideration of the following factors:

- type of investigation, regional or site specific;
- expected soil conditions, bathymetry and seabed features;
- active geological processes and possible geohazards;
- type of problem, soil structure interaction, slope stability etc.;
- required soil parameters;
- previous knowledge from the area, geological, geophysical and geotechnical;
- equipment that can be used;
- budgetary restraints;
- time schedules.

5 General requirements to execution of work

The requirements given in ISO/DIS 19902, ISO 19901-4, NS 3481 and DNV Classification Note 3.4 shall be mandatory, unless otherwise documented. These standards are the basis for this NORSOK standard regarding planning and execution of marine soil investigations.

Major equipment used during field work should as a minimum have a documentation consisting of the following:

- description with schematic drawings showing all significant dimensions (size and weight);
- operational procedures including safe job analyses;
- interface of various drilling and geotechnical tools;
- interface requirements to auxiliary equipment, power supply etc.;
- calibration charts for documentation of prescribed accuracy.

All lifting equipment including shackles and pad eyes shall be certified.

Sufficient number or amount of equipment and associated required consumables to perform the work shall be available on board.

The operators of the equipment shall have proper training and experience in the use of the equipment. Established routines shall be used for fault finding. This shall include personnel, equipment and spare parts to maintain and repair testing equipment breaking down during mobilisation or operation.

Soil borings shall be carried out in such a way that there is a minimum disturbance to the soil to be sampled or tested.

Continuous observations of the drilling progress shall be performed and checked against expected soil conditions, sample quality and results of in situ tests.

A continuous evaluation of results as the work proceeds shall be carried out. The investigation programme can thus be immediately revised in order to meet the objectives of the investigation.

The requirements regarding marine soil investigations shall be in accordance with ISO 19901-4.

6 Drilling and logging

The quality of down-hole samples and in situ tests depends very much on the equipment and procedures used for the drilling. Also performance rate and coverage of sampling and in situ testing depends on the drilling process. The drilling procedures should therefore be based on the aims of the project as detailed in Annex A. Attention should be given to drill bits, bit load, flow rate and mud type and their application to different soil types.

In many cases useful information can be obtained from the drilling parameters and these shall be logged as outlined in Annex A.

In some cases rotary core drilling may be the best solution, and if required this can be done according to Annex A.

7 Sampling

Basically sampling can be carried out in the following two modes:

- from the seabed without drilling (seabed mode);
- inside the drill string in the bottom of a borehole (drilling mode).

In most cases sampling and sample handling should be done in such a way as to cause minimum disturbance to the sample. In some cases it is most important to get as complete a coverage of the soil profile as possible or to get a large sample volume. In such cases other types of equipment may have to be used.

The choice of sampling equipment should be based on consideration of actual soil conditions, and the type of testing the soil samples are to be subjected to. A range of equipment is therefore normally required.

Generally the type of equipment to be used for sampling in drilling mode should be considered in the following priority:

- piston sampler, thin walled;
- push sampler, thin walled;
- push sampler, thick walled;
- hammer sampler;
- rotary core sampler.

In some cases, especially in very stiff or hard clays the use of rotary coring may give the best quality samples.

Further details are given in Annex B.

8 In situ testing

All in situ test equipment systems prescribed shall be checked for functionality during mobilisation of equipment on board the survey vessel. Such functionality checks shall include, but not be limited to

- signal response of sensors,
- data acquisition system,
- wet test of essential subsea equipment.

The in situ equipment with electronic transmission shall be designed to sustain the water pressures expected in the field.

During testing, zero readings of all sensors shall be recorded before and after each test.

The specifications for in situ test equipment and procedures in Annex C are made for the most used tests. For other in situ testing, equipment specifications and procedures shall be established prior to mobilisation.

Records of experience with the use of the equipment, routines and procedures for interpretation of measurements for assessment of soil parameters shall be documented and be made available on request.

9 Laboratory testing

Laboratory tests shall be carried out according to recognised standards or codes.

Detailed requirements to tests are given in Annex D, either as sole reference to standards and codes, or with additional guidance.

The laboratory should provide documentation upon sound working procedures and show that the relevant tests can be carried out as specified in Annex D.

Prior to the commencement of the testing the codes to be used and forms of presentation such as figures and plots should be agreed upon.

10 Evaluation of data and reporting

10.1 Evaluation of data

An evaluation of all test results shall be carried out. Commonly there will be some results less representative than others. These shall be identified and given less weight when establishing characteristic soil parameters.

The characteristic values shall in general be selected as conservative assessed mean values where the actual material property shall be selected so as to be on the conservative side.

The actual soil design parameters recommended shall depend on at least the following factors:

- soil investigation coverage;
- quality of data
- soil behaviour at failure (plastic, brittle, etc.);
- consequence of failure;
- spatial variability of material property within soil volume of interest;
- possibility of progressive failure.

10.2 Reporting of data

A standardised reporting structure will improve the access to the data and reduce laborious work. It is therefore required that reports are structured in levels and organised as outlined in Annex E.

The organization of the report shall depend on the type and extent of the investigation.

The reported data shall also be submitted in such a format that they can electronically be transformed to a geotechnical data base.

All reporting shall be in SI units.

Annex A

(Normative)

Drilling and logging

A.1 Introduction

The aim of this annex is to set focus on drilling procedures and how they may influence sample quality, performance rate and recovery. What the individual projects will focus on, will depend on the purpose of the investigation. For geotechnical work, sample quality will in most cases be most important. For geological investigations, sample coverage (recovery) may be more important than quality and for some projects (for instance hard layer detection) fast penetration in order to cover as large area as possible within the limit of the budget may be the most important. For some projects geophysical borehole logging may be a valuable supplement to sampling and in situ testing.

A.2 Drilling spread

The description shall, as a minimum, include

- weight capacity of drilling system under the power swivel (i.e. maximum weight of drill string including drill collars and BHA),
- description of system and procedures for depth accuracy (for instance hard-tie system),
- maximum stroke on heave compensation system and weather/current limitations,
- mud capacity including mixing capacity, number and volume of mud tanks and maximum pumping rate,
- drill string handling,
- geotechnical equipment handling,
- description of drill bits available onboard,
- crane and A-frame capacities,
- available free deck space for geotechnical equipment,
- laboratory facilities,
- office facilities.

A.3 Choice of drilling procedures depending on soil type

The drilling procedures shall be designed based on the aim of the project, i.e. sample quality, recovery or fast penetration. Emphasis shall be on sample disturbance minimisation, borehole stability, drill cutting removal and penetration rate.

Equipment and procedures to use in the following soil types shall be available:

- very soft to soft clays;
- stiff to hard clays;
- loose silty sand;
- dense sand;
- dense gravel;
- hard boulder clay with stones;
- soft rock (chalk).

For the various soil types and seabed conditions, the following variables shall be considered:

- type of drill bit;
- criteria for change of drill bit;
- type of mud and additives;
- mud pressure;
- mud flow rate;
- RPM;
- bit load;
- torque.

A.4 Logging of drilling parameters

Drilling parameters are useful for

- interpolation/extrapolation of soil data,
- to explain possible sample disturbance,
- detection of layering,
- rough assessment of soil conditions,
- assessment of drilling resistance for later wells and conductor setting,

If required by the client the following data should be logged in real time with a frequency of maximum 10 s and stored electronically:

- time;
- penetration;
- penetration rate;
- mud pressure;
- mud flow rate;
- RPM;
- bit load;
- torque.

A.5 Rotary core drilling

In some soil types and for certain purposes rotary drilling may be the best solution. In soft rock this is the case, but by experience rotary drilling may be a good alternative in hard boulder clay, especially if recovery is more important than sample quality. Standard geotechnical sample tools such as push and piston systems tend not to penetrate far in such soils. There are different systems in use. The most common are Christensen coring, various types of fast rotating piggyback diamond coring systems and Geobor S.

For hard boulder clay and soft rock the following variables shall be considered:

- type of drill bit;
- criteria for change of drill bit;
- type of mud and additives;
- mud pressure;
- mud flow rate;
- RPM;
- bit load.

A.6 Geophysical borehole logging

For some projects where enhanced geological and engineering details are required geophysical wireline logging can be considered. A number of tools are available, some for in-pipe measurements and some for open hole measurements as outlined by Digby, A. (2002). These tools include

- calliper tool,
Measures borehole diameter by a mechanical calliper.
- natural gamma radiation,
Measures concentration of radioactive isotopes. Gives information on soil type and variation in particle size distribution.
- neutron tool,
Uses a radioactive source to provide the porosity of the formation. Can also measure natural gamma radiation and formation resistivity.
- sonic tool,
Measures sound velocity. Gives indications on soil type and change of soil character.
- density tool.
Uses a radioactive source to measure the soil density. Can also measure natural gamma radiation and formation resistivity.

Operation of tools with radioactive sources shall comply with Norwegian safety requirements. A qualified "Radiation Protection Supervisor" shall on board, and procedures for use of the logging equipment, risk evaluation and contingency procedures have to be established.

A.7 Shallow gas

In areas with potential shallow gas, special procedures shall be available. Such shallow gas procedures shall evaluate and consider to include, but not be limited to, the following elements:

General precautions

- No hot work or smoking on deck.
- Heavy mud available.
- Gas detectors in the moon pool and in the derrick.
- Wind meter.
- Current meter.

In areas with risk of shallow gas

Consider to drill a dedicated pilot hole with a non-return valve in the lower part of the drill string and no running of down hole tools. When no shallow gas is encountered, a second boring close to pilot hole can be drilled and tested with geotechnical tools.

Precautions against gas through the drill string

Safety valve on top of the power swivel while using wire line operated down hole tools.

Precautions against gas outside the drill string

Offset between the vessel and the borehole. The direction of the offset is selected based on wind and current conditions.

In high risk areas additional precautions are recommended such as

- non return valve in the lower part of the drill string while drilling and pulling pipe,
- TV camera on the seabed frame,
- pull out sampler or in situ tool by lifting drill string while the down hole tool is latched into the bottom hole assembly,
- in situ gas measuring system in order to get an early warning before the gas charged layer is penetrated (BAT, DGP or similar).

Annex B (Normative) Sampling

B.1 Background with definitions

Samplers can in principle be deployed in the following two ways:

- penetration from the seabed and into the soil to a predetermined depth or until it cannot penetrate more (this is in the following called *seabed sampling*). This can be very short samples like for instance a grab sample (see B.2.2) or long seabed samples to more than 30 m in extreme cases;
- penetration from the bottom of a borehole and into the soil to a predetermined length of for instance 1 m, or until refusal (this is in the following called *down-hole sampling*).

The length of sample that can be obtained for both cases mentioned above will depend on several factors, e.g.:

- geometry, size and characteristics of the sampler;
- soil type;
- the available penetration force and how this is applied, e.g. by a steady pushing force, vibration or hammering/percussion.

If required the contractor shall, based on his experience, give documentation on what penetration can be expected for the different sampling methods he proposes and the expected soil conditions.

B.2 Seabed sampling equipment and procedures

B.2.1 General

The description shall, as a minimum, include the following:

- weight of equipment in air and in water;
- handling requirements:
 - deck space;
 - crane lifting force and arm length.
- manufacturer and name of equipment;
- any limitations as to water depth, soil type etc.

The retrieval from seabed and handling of seabed samples shall be done in such a way that the sampler is not subjected to significant shock or vibration that may cause disturbance to the sample.

B.2.2 Grab

For grab samplers the following information shall be given:

- maximum penetration below sea bed;
- maximum volume of sample;
- release mechanism;
- how wash out during retrieval of sample is prevented.

B.2.3 Gravity corer

For gravity corers the following information shall be given:

- geometry and dimensions of cutting shoe;
- inside and outside diameter of core barrel and liner;
- type of core catcher/retainer;
- whether a piston is used;
- weight and lengths available;

- any special handling requirements, including free fall mechanism, if relevant.

The gravity corers shall have a non-return valve at the top of the tube to avoid water ingress and sample washing out when pulling the sampler back to surface. Both penetration and recovery should be measured and reported. Limitations with penetration measurement system to be discussed.

For advanced long seabed samplers designed to give high recovery and a minimum of sample disturbance the following information is also required:

- precautions taken to reduce inside friction of liners;
- precautions taken to reduce outside friction of cutting shoe and core barrel;
- reference of piston position during sampling;
- method of measuring penetration.

B.2.4 Vibrocorer

For vibrocorers the following information shall be given:

- specifications of vibrator unit, power, frequency;
- geometry and weight of rig;
- umbilical required;
- geometry and dimensions of cutting shoe;
- inside and outside diameter of core barrel and liner;
- type of core catcher;
- sampling lengths available;
- any special handling requirements.

It is essential that recovery versus penetration is recorded and reported. It is therefore recommended that the vibrocorer is fitted with a device that measures continuously the progress of the sampler into the soil.

B.2.5 Box corers

For box corers the following information shall be given:

- dimensions of sample;
- weight and geometry;
- any special handling requirements;
- any other relevant information;
- how wash out during retrieval of sample is prevented.

B.2.6 Other corers

For other seabed corers the following information shall be given:

- description of driving mechanism;
- geometry and dimensions of sampler cutting shoe;
- inside and outside diameter of liner if applicable;
- type of core catcher/retainer;
- geometry and weight of sampling device;
- length(s) of sample available;
- any special handling requirements;
- any other relevant information.

B.3 Down-hole samplers

The drilling of a borehole should be carried out in such a way that the disturbance to the soil below the drill bit is minimised. Annex A gives detailed requirements to the geotechnical aspects of drilling. It is important that retrieval and handling of down-hole samplers are done in such a way that any shock or vibration is avoided with undue sample disturbance. In soil layers where shallow gas may be expected it is important that the sample cylinder is pulled out very slowly to avoid "swabbing" effects, see also Annex A.

To cover a wide range of possible soil types systems shall be available for taking hammer, push and piston samples. The following contains a description of the information needed in connection with drilling and sampling, depending on the scope of work:

- system for piston sampling including principle used as well as diameter and length of sample;
- system for push sampling including principle used as well as diameter, length of sample, available force and length of sample tube penetration;
- complete system for hammer sampling, including hammer weight. All vital data on the equipment including fall height of hammer and type of winch to be submitted;
- system for taking rotary core samples if applicable;
- drill pipe control (if applicable) including seabed rig and heave compensation system. Drill pipe heave compensation system connected to the seabed rig (e.g. hard tie system);
- sample tubes:
 - cutting shoe angle;
 - inside and outside diameter (inside clearance if applicable);
 - maximum sample length;
 - inside liners or stocking (if applicable);
 - core catching system (if applicable);
 - steel quality;
 - method of sealing sample tube if samples are not to be extruded offshore.

It is especially important that sample tubes shall not be reused without cleaning and a thorough check. Tubes with damaged tip shall be discarded. For push and piston sampling thin wall steel tubes shall preferably be used. A thin wall tube shall have a wall thickness not exceeding 2,0 mm. A 76,2 mm (3 in) thin wall sample tube will thus have outer and inner diameters of about $D_o = 76$ mm and $D_i = 72$ mm respectively. Inside clearance $C_i = (D_i - D_c)/D_c$, where D_c is internal diameter of cutting shoe, shall be in the range 0 % to 1 %. In soft clays where sample disturbance is of particular concern, some sample tubes with cutting shoe angle of 5 degrees should be available. Recovering of the sample on deck should be done in such a way as to cause a minimum of additional disturbance to the sample.

B.4 Choice of equipment according to expected soils

Equipment and procedures (with options if necessary) to use in the following soil types shall be available:

- very soft to soft clays;
- stiff to hard clays;
- loose silty sand;
- dense sand;
- dense gravel;
- hard boulder clay with stones;
- soft rock (chalk).

The aim is to have as undisturbed samples as possible and a satisfactory recovery. For soft soils the type of sampler should be considered in the following sequence:

- piston sampler, thin walled;
- push sampler, thin walled;
- push sampler, thick walled.

For very stiff to hard clay it is possible that carefully performed rotary coring may give the best quality sample.

B.5 Sample handling and storage

B.5.1 General

After retrieval of a soil sample (seabed or down-hole sample techniques) on board the survey vessel, the sample shall be handled with care.

B.5.2 Offshore handling

B.5.2.1 Down-hole steel tube samples

An end cap shall be mounted on the bottom of the cylinder (cutting edge side) immediately after retrieval in order to prevent soil and water escaping from the cylinder.

So-called "cuttings" and drill mud shall be removed from the top of the cylinder before the total length of sampled soil is measured. Each cylinder shall be labelled and marked uniquely, with location, borehole, cylinder number, depth to top of sample and date of sampling.

Depending on the subsequent testing (investigation) of the sampled soil, this shall now either be securely sealed in the cylinder or extruded in the offshore laboratory. Whether a sample part designated to be used for advanced onshore testing should be kept in the sample cylinder or extruded and sealed will depend on the strength and stiffness of the soil and the possible access to free water or mud. Generally for soft clays with undrained shear strength less than about 50 kPa, and with no suspicion of shallow gas, it is recommended to keep the soil in the sample cylinder to minimize the disturbance due to handling and transportation.

Extruded sample parts intended for subsequent testing in the onshore laboratory shall be securely wrapped in plastic and aluminium foil and then waxed and sealed, preferably in a cardboard cylinder. It is important that any mud or excess water be removed to avoid potential swelling of the sample. Each waxed sample part shall be uniquely marked including information on vertical orientation.

B.5.2.2 Seabed samples in plastic liner

The plastic liner with sample inside shall be carefully cut in 0,5 m or 1 m lengths. How much of the sample to split open or extrude and describe/test onboard will vary from project to project. Samples for transportation to onshore laboratory testing shall be clearly marked, with the vertical orientation the soil had in the ground, and properly sealed in each end by plastic cups and tape or similar.

B.5.3 Offshore storage

The sealed and marked sample cylinders and waxed samples shall be put in boxes or stacks suitable for transportation and stored, while on the board survey vessel, in a cool place with steady temperature. Rooms adjacent to heavy engines or generators, which generate excessive vibrations, shall be avoided. It is recommended that samples are stored vertically with the same orientation as the soil had in the ground.

B.5.4 Onshore transport, handling and storage

The boxes with sealed soil samples shall be transported to the onshore laboratory with caution and handled with care. Special precautions shall be made to prevent shock and impact loads to the soil samples during handling of the boxes. It is recommended that samples in tubes or liners are stored vertically, with the same orientation as the soil had in the ground, during transportation. Horizontal storing of samples may also be acceptable, especially for firm and stiff soils.

The soil samples shall not be exposed to temperatures below 0 °C.

Whether samples shall be air freighted or trucked to the onshore laboratory shall be decided in each case.

The sealed samples shall be stored in a humid room at about 7 °C in the onshore laboratory.

Each cylinder and waxed sample shall be registered and stored for convenient retrieval.

B.6 Sample log

Upon completion of the field work a sample log shall be prepared. For down-hole sampling in conjunction with drilling the log shall be complimentary to the drilling log.

The sample log shall include the following information:

- site area;
- borehole or core number;
- sample number;
- water depth;
- date of sampling;
- type of sampler;