

Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for execution

The European Standard EN ISO 22475-1:2006 has the status of a
British Standard

ICS 93.020

National foreword

This British Standard was published by BSI. It is the UK implementation of EN ISO 22475-1:2006. It partially supersedes BS 5930:1999 which will be substantially revised in due course in order to remove conflict and provide supplementary guidance. In the meantime, where conflict arises between the two documents the provisions of BS EN ISO 22475-1:2006 should take precedence.

The UK participation in its preparation was entrusted by Technical Committee B/526, Geotechnics, to Subcommittee B/526/3, Site investigation and ground testing.

A list of organizations represented on B/526/3 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2007

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ISBN 978 0 580 50566 9

Amendments issued since publication

Amd. No.	Date	Comments

English Version

Geotechnical investigation and testing - Sampling methods and
groundwater measurements - Part 1: Technical principles for
execution (ISO 22475-1:2006)

Reconnaissance et essais géotechniques - Méthodes de
prélèvement et mesurages piézométriques - Partie 1:
Principes techniques des travaux (ISO 22475-1:2006)

Geotechnische Erkundung und Untersuchung -
Probenentnahmeverfahren und Grundwassermessungen -
Teil 1: Technische Grundlagen der Ausführung (ISO 22475-
1:2006)

This European Standard was approved by CEN on 30 December 2005.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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Foreword

This document (EN ISO 22475-1:2006) has been prepared by Technical Committee CEN/TC 341 "Geotechnical Investigation and Testing", the secretariat of which is held by ELOT, in collaboration with Technical Committee ISO/TC 182 "Geotechnics".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2007, and conflicting national standards shall be withdrawn at the latest by March 2007.

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INTERNATIONAL STANDARD

ISO
22475-1

First edition
2006-09-15

Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for execution

*Reconnaissance et essais géotechniques — Méthodes de prélèvement
et mesurages piézométriques —*

Partie 1: Principes techniques des travaux



Reference number
ISO 22475-1:2006(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22475-1 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical investigation and testing*, in collaboration with Technical Committee ISO/TC 182, *Geotechnics*, Subcommittee SC 1, *Geotechnical investigation and testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 22475-1 consists of the following parts, under the general title *Geotechnical investigation and testing — Sampling methods and groundwater measurements*:

- *Part 1: Technical principles for execution*
- *Part 2: Qualification criteria for enterprises and personnel*
- *Part 3: Conformity assessment of enterprises and personnel by third party*

Introduction

ISO 22475-1 specifies the technical principles for the execution of sampling and groundwater measurements for geotechnical purposes.

The quality of these services can be proven by:

- a) a declaration of conformity by a contractor (first party control);
- b) a declaration of conformity by a client (second party control);
- c) a declaration of conformity by a conformity assessment body (third party control).

Every enterprise or individual may decide, if and how they will prove the fulfilment of the technically related criteria: by first, second or third party control because no part of ISO 22475 requires such a declaration.

ISO/TS 22475-2 specifies the qualification criteria for enterprises and personnel that perform sampling and groundwater measurements according to ISO 22475-1.

The conformity assessment by third party control can be made according to the technical principles for execution of sampling and groundwater measurements specified in ISO 22475-1, as indicated in ISO/TS 22475-2, and in the conformity assessment procedure given in ISO/TS 22475-3.

Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for execution

1 Scope

This part of ISO 22475 deals with the technical principles of sampling of soil, rock and groundwater, and with groundwater measurements, in the context of geotechnical investigation and testing, as described in EN 1997-1 and EN 1997-2.

The aims of such ground investigations are:

- a) to recover soil and rock samples of a quality sufficient to assess the general suitability of a site for geotechnical engineering purposes and to determine the required soil and rock characteristics in the laboratory;
- b) to obtain information on the sequence, thickness and orientation of strata and joint system and faults;
- c) to establish the type, composition and condition of strata;
- d) to obtain information on groundwater conditions and recover water samples for assessment of the interaction of groundwater, soil, rock and construction material.

The quality of a sample is influenced by the geological and hydrogeological conditions, the choice and execution of the drilling and/or the sampling method, handling, transport and storage of the samples.

This part of ISO 22475 does not cover soil sampling for the purposes of agricultural and environmental soil investigation.

NOTE 1 Soil sampling for these purposes is to be found in ISO 10381.

Water sampling for the purposes of quality control, quality characterisation, and identification of sources of pollution of water, including bottom deposits and sludges is not covered.

NOTE 2 Water sampling for these purposes is to be found in ISO 5667.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 791, *Drill rigs — Safety*

EN 996, *Piling equipment — Safety requirement*

EN 1997-1, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 1997-2, *Eurocode 7: Geotechnical design — Part 2: Design assisted by laboratory testing*

ISO 22476-3, *Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 14689-1, *Geotechnical investigation and testing — Identification and classification of rock — Part 1: Identification and description*

ISO 3551-1, *Rotary core diamond drilling equipment — System A — Part 1: Metric units*

ISO 3552-1, *Rotary core diamond drilling equipment — System B — Part 1: Metric units*

GUM: *Guide to the expression of uncertainty in measurement*, BIPM/IEC/IFCC/ISO/OIML/IUPAC/IUPAP

ISO 10097-1, *Wireline diamond core drilling equipment — System A — Part 1: Metric units*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1997-1, EN 1997-2, ISO 14688-1 and ISO 14689-1 and the following apply.

NOTE Additional terms and definitions can be found in the books and literature listed in the Bibliography.

3.1 Site investigation methods

3.1.1

trial pit

open excavation constructed to examine the ground conditions *in situ*, recover samples or carry out field testing

3.1.2

shaft

open vertical or steeply inclined excavation, typically more than 5 m deep, constructed to examine the ground conditions *in situ*, recover samples or carry out field testing

3.1.3

heading

adit

small tunnel driven horizontally or with a slight inclination from a shaft or into sloping ground to examine the ground conditions *in situ*, recover samples and carry out field testing

3.1.4

borehole

hole of any predetermined diameter and length formed in any geological formation or man-made material by drilling

NOTE Investigations carried out in such a hole can be to recover rock, soil or water samples from a specified depth or to carry out *in situ* tests and measurements.

3.1.5

drilling

process by which a borehole is produced in any geological formation by rotary, rotary percussive, percussive or thrust methods and in any predetermined direction in relation to the drill rig

3.1.6

small diameter drilling

drilling in the soil with a diameter greater than 30 mm but less than 80 mm

3.1.7**drilling method**

technique employed to create and stabilise the borehole

3.2 Drilling rigs and equipment**3.2.1****drilling tool**

device attached to, or forming an integral part of, the drill string, used as a cutting tool for penetrating the geological formation

3.2.2**drill bit**

device attached to, or forming an integral part of, the drill string, used as a cutting tool to penetrate the formation being drilled by the drilling method employed

3.2.3**drill rig**

device which carries out the drilling function

3.2.4**casing**

tubing temporarily or permanently inserted into a borehole

NOTE Casing is used, e.g. to stabilise the borehole, to prevent the loss of flushing medium to the surrounding formation, or to prevent cross flow between different groundwater horizons

3.2.5**flushing medium**

liquid or gaseous medium used to move cuttings and/or samples and to lubricate and cool the drilling tool from the borehole

3.2.6**flushing additive**

substance added to the flushing medium in order to affect or change its properties to improve its functioning

3.2.7**core lifter**

split, internally slotted or serrated conical spring steel ring, grooves, flexible spring fingers, hinged wedge-shaped fingers or hinged flaps mounted in a carrier ring, to retain the core sample whilst the corebarrel is being hoisted from the borehole

3.2.8**sample retainer**

cylindrical retainer fitted with a split-ring core lifter; it is mounted at the lower end of the sampler tube and used to retain the sample in the tube as the sampler is being lifted from the ground

3.3 Sampling**3.3.1****sampling by drilling
continuous sampling**

process by which samples are obtained by the drilling tools as the borehole proceeds

NOTE The drilling process is designed to obtain complete samples of the length of the borehole. The drilling tools are used as sampling tools.

3.3.2

sampling by using sampler

process by which samples are obtained by samplers from trial pits, headings, shafts or borehole bottom at selected positions

3.3.3

soil sampling by small diameter drilling

sampling by drilling in soils, using drilling tools with a diameter greater than 30 mm but less than 80 mm

3.3.4

sample

defined amount of rock, soil or groundwater recovered from recorded depth

3.3.5

core, core sample

cylindrical sample of soil or rock obtained from a borehole from recorded depth

3.3.6

block sample

sample of soil or rock cut out by special techniques

3.3.7

cuttings

particles of geological formations formed in the borehole by the cutting action of the drilling tool

3.3.8

suspended matter

abraded ground material in the flushing medium generated by drilling, in which the individual particle size cannot be recognised with the naked eye

3.3.9

core run

length of the core drilling between the start and the finish for the removal of the sample

3.3.10

core loss

difference between a core run and the length of the core recovered

3.3.11

area ratio

C_a

ratio of the area of soil displaced by the sampler tube in proportion to the area of the sample

$$C_a = \frac{D_2^2 - D_1^2}{D_1^2} \cdot 100$$

See Figure 1.

NOTE 1 The area ratio is expressed in per cent.

NOTE 2 One of the factors that determines the mechanical disturbance of the soil.

3.3.12

inside clearance ratio

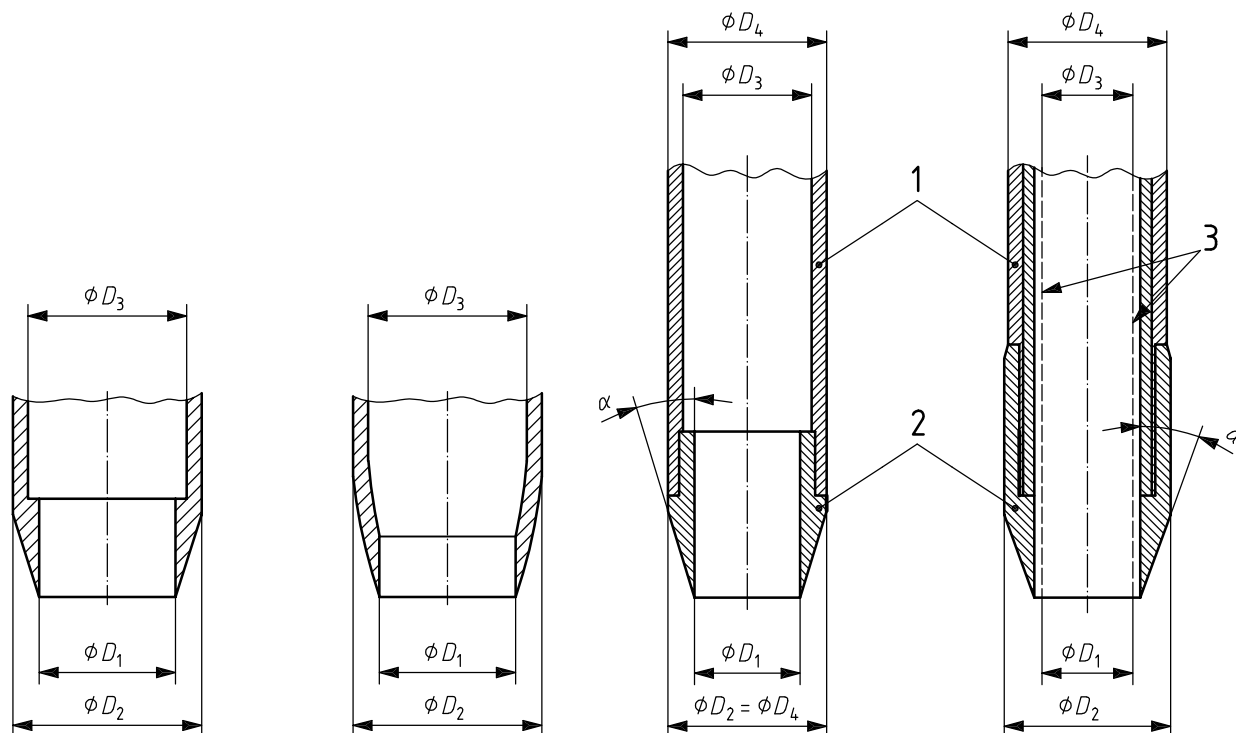
C_i

$$C_i = \frac{D_3 - D_1}{D_1} \cdot 100$$

See Figure 1.

NOTE 1 The inside clearance ratio is expressed in percent.

NOTE 2 One of the factors that determines the mechanical disturbance of the sample caused by the friction on the inside wall of sample tube or of the liner.



Key

D_1	inside diameter of the cutting shoe	α	taper angle
D_2	greatest outside diameter of the cutting shoe	1	sample tube
D_3	inside diameter of the sample tube or liner	2	cutting shoe
D_4	outside diameter of the sample tube	3	liner (optional)

Figure 1 — Definitions of the diameters D_1 , D_2 , D_3 and D_4

3.3.13

outside clearance ratio

C_o

$$C_o = \frac{D_2 - D_4}{D_4} \cdot 100$$

See Figure 1.

NOTE The outside clearance ratio is expressed in percent.

3.3.14 Fracture state terms

3.3.14.1
total core recovery in rock
TCR

total length of core sample recovered (solid and non-intact), expressed as a percentage of the length of the core run

See Figure 2.

3.3.14.2
rock quality designation
RQD

sum length of all core pieces with at least one full diameter that are 100 mm or longer between natural fractures, measured along the centre line of the core, expressed as a percentage of the length of the core run

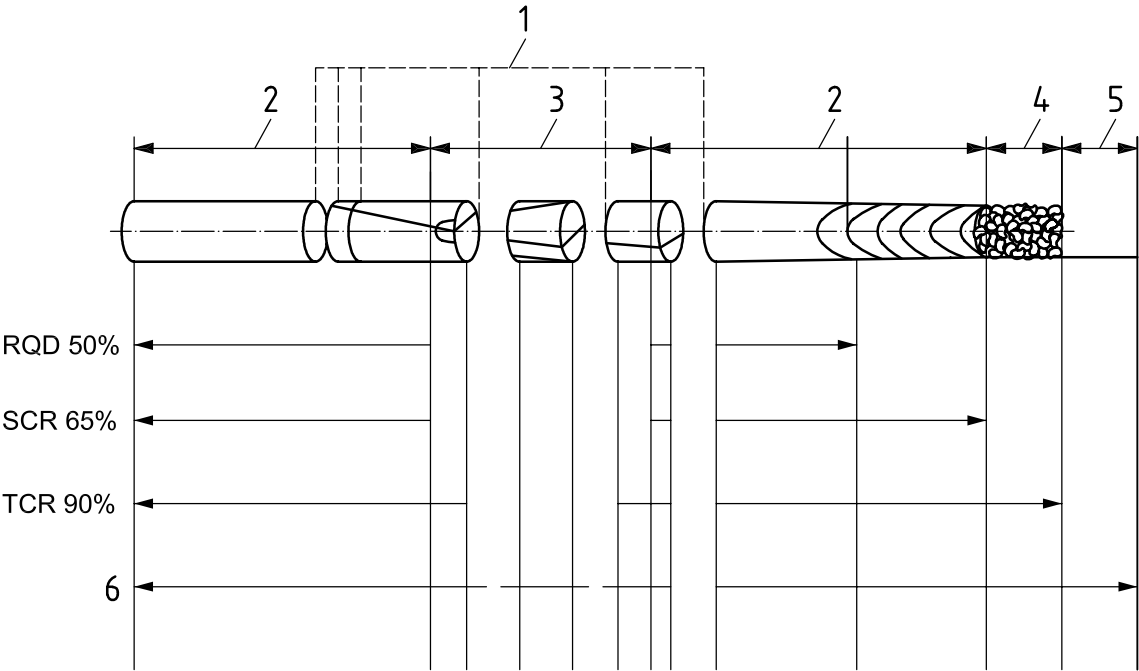
See Figure 2.

3.3.14.3
solid core recovery
SCR

length of core recovered as solid cylinders, expressed as a percentage of the length of the core run

See Figure 2.

NOTE A solid core has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference, and is commonly measured along the core axis or other scan line.



NOTE All features shown are natural discontinuities unless stated otherwise.

Key

- 1 drilling-induced fractures
- 2 at least one full diameter
- 3 no single full diameter
- 4 non-intact
- 5 no recovery
- 6 core run

Description of fracture state of rock cores:

- RQD rock quality designation
- SCR solid core recovery
- TCR total core recovery

Figure 2 — Application of fracture state terms for rock cores

3.3.15

sample recovery ratio in soil

TC

ratio of the length of the sample, l_g , to the length of the sample run, H

See Figure 3.

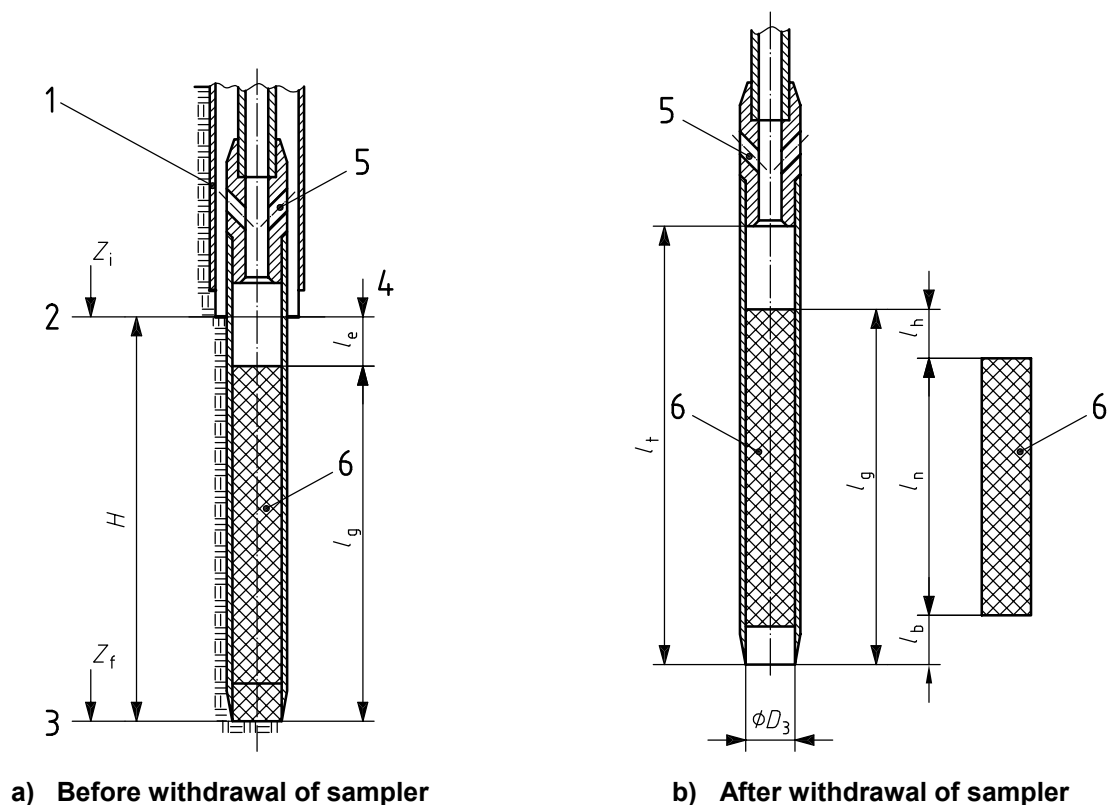
3.3.16

net sample recovery ratio

IC

ratio of the net length of the sample, l_n , to the length of the sample run, H

See Figure 3



Key

- | | |
|---|--|
| 1 casing | l_b length of the lower part of the sample, which was remoulded or lost |
| 2 beginning of coring | l_e difference between the sample run and the actual length of the sample |
| 3 end of coring | l_g total length of the sample after withdrawal of the sampler, measured from the top of the sample to the cutter edge, including the remoulded or lost parts at both ends of the sample |
| 4 bottom of predrilled borehole | l_h length of the remoulded or polluted upper part of the sample |
| 5 vent-hole | l_n net length of the sample, before its conditioning |
| 6 sample | l_t effective (useful) length of the sampling tube |
| D_3 inside diameter of the sample tube or liner | |
| H length of the sample run | |
| Z_f depth, under the natural ground level, of the lower end of the sampler after sampling and before withdrawing the sampler | |
| Z_i depth, under the natural ground level, of the borehole bottom before sampling, and before the beginning of the following core run | |

Figure 3 — Lengths of core run and sample

3.3.17

thin-walled sampler

soil sampler with a low area ratio and a low taper angle and thin edge

3.3.18

thick-walled sampler

soil sampler that has an area ratio, taper angle and/or edge larger than that of thin-walled sampler

3.4 Groundwater measurements

3.4.1

piezometric head

sum of pressure head and elevation

3.4.2

groundwater surface

upper boundary surface of the groundwater

3.4.3

aquifer

body of permeable rock or soil mass suitable for containing and transmitting groundwater

3.4.4

aquitard

confining layer that retards, but does not prevent, the flow of water to or from an adjacent aquifer

3.4.5

aquiclude

body of soil or rock with extremely low transmissivity, which effectively prevents the flow of water through the ground

3.4.6

confined aquifer

aquifer which is bounded above and below by aquicludes

3.4.7

unconfined aquifer

aquifer in which the groundwater surface forms the upper boundary

3.4.8

pore pressure

pressure of the fluid that fills the voids of a soil or rock mass

3.4.9

permeability

capacity of soil or rock for transmitting water

3.4.10

filter

water permeable section of a piezometer retaining the soil

3.4.11

filter pack

water permeable backfilling around the filter and retaining the soil

3.4.12

open filter area

opening percentage of the filter surface

3.4.13**groundwater measurement**

measurement of the groundwater surface or pore pressure

3.4.14**groundwater measuring station**

place where groundwater measuring equipment is installed or groundwater measurement is carried out

3.4.15**groundwater fluctuations**

variations of groundwater surface and/or pore pressure

3.4.16**groundwater pressure**

the pressure in pores, voids and fissures in the ground at a certain point and time

3.4.17**piezometer**

equipment for the determination of the groundwater or the piezometric head, including both open and closed systems

3.4.18**open system**

measuring system in which the groundwater is in direct contact with the atmosphere and in which the groundwater surface at the filter level is measured

3.4.19**closed system**

measuring system in which the groundwater is not in direct contact with the atmosphere and in which the pore pressure at the filter level is measured hydraulically, pneumatically or electrically

3.4.20**hydraulic system**

closed system in which the water pressure in the filter tip is transmitted to a measuring unit on or close to the ground surface through a liquid-filled pressure tube

3.4.21**pneumatic system**

closed system in which the water pressure acts on a membrane located behind the filter of the filter tip and which is balanced by gas pressure on the membrane's reverse side by a pressure tube from the ground surface

3.4.22**electrical system**

closed system in which the water pressure effects the membrane located behind the filter of the filter tip and where the water pressure is converted into an electrical signal

3.4.23**pick-up system**

electrical transducer system, in which the transducer can be added to and removed from the filter tip installed in the ground

3.4.24**filter tip**

tip for piezometers provided with a filter to prevent soil particles from entering the equipment

3.4.25**high air entry filter**

filter with small pores giving a high resistance to air entry when water saturated

3.4.26

time lag

time lapse between a change in pore pressure in the ground and its total recording by the measuring system

4 Drilling rigs and ancillary equipment

4.1 General

The drilling and sampling equipment selected shall be of the appropriate size and type in order to produce the required quality.

If applicable, the drilling and sampling equipment shall be in accordance with ISO 3351-1, ISO 3352-1 and ISO 10097-1.

4.2 Requirements for the drilling rigs and equipment

Drilling rigs with appropriate stability, power and equipment such as drill rods, casing, corebarrels and bits shall be selected in order that the required sampling and borehole tests can be carried out to the required depth of the borehole and sampling categories.

NOTE Annex C gives a selection of equipment which is currently used.

4.3 Equipment scope

The drilling rig and equipment shall allow all drilling functions to be adjusted accurately. When specified, the following drilling parameters should be measured and recorded against depth:

- drill head rotational torque (Nm)
- drill head rotational speed (min^{-1});
- feed thrust and pulling force (kN);
- penetration rate (m/min);
- depth of hammering intervals (on/off);
- topographical depth (m);
- azimuth and inclination when inclined drilling (degree);
- drilled length when inclined drilling (m);
- flushing medium pressure at the output of the pump (kPa);
- flushing medium circulation rate (input) (l/min);
- flushing medium recovery rate (l/min).

5 General requirements prior to sampling and groundwater measurements

5.1 General

The type and extent of sample recovery and groundwater measurements shall be specified in advance according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing (see EN 1997-2).

5.2 Selection of techniques and methods

5.2.1 The techniques and methods for sampling and groundwater measurements shall be selected according to the purpose of the investigations in relation to the expected geological and hydrogeological conditions.

5.2.2 Sampling techniques, sample transportation and storage procedures shall be selected on the basis of the required

- sample quality class according to EN 1997-2,
- sample mass, and
- sample diameter,

depending on the type of laboratory tests to be carried out.

5.2.3 A specific sampling category shall be selected in order to achieve a required sample quality class according to EN 1997-2 (see 6.2).

5.2.4 Different disturbance of sample can be expected when using different sampling methods. The quality class of a sample taken with the same sampler can vary depending on, e.g. the soil type to be sampled, the presence of groundwater and the sampling operation. The following sample disturbance can be generated by the drilling and sampling methods:

- mechanical sample disturbance due to compression, shearing, flushing or vibration during drilling or excavation;
- sample disturbance due to release of *in situ* stresses and related rebound;
- changes in material and chemical constituents such as water content and gases.

5.2.5 The sample diameter for soils containing large particles should be chosen with respect to the size of the largest particles of the sampled material.

5.2.6 If investigation below the groundwater surface or to greater depths is necessary, stable or stabilized boreholes are required.

5.2.7 Trial pits, headings and shafts give the possibility to investigate the ground in a larger scale e.g. to get information on the composition, sequence, structure and orientation of strata and possible rock surface. Without groundwater lowering, the depth is often limited to shallow depth above the groundwater surface. Large samples can be taken in order to analyse boulder content, bearing capacity, compactibility and permeability. At the same time, the excavability could be assessed and photographic documentation made.

5.3 Requirements for ground investigation sites and points

5.3.1 Site investigation points on land shall be marked on the site before the investigation process commences. Their location and elevation shall be surveyed and entered in a site plan on completion of the investigation.

5.3.2 Investigation sites shall be checked with respect to relevant hazards, underground utilities and unexpected, unexploded ordnance and, if necessary, appropriate actions have to be taken. Investigation locations on contaminated ground have to be dealt with by special procedures.

5.3.3 Trial pits should be situated outside the planned foundation area as the excavation can loosen the ground. There should have a distance between the nearest excavation wall and the planned foundation edge of at least 0,5 m plus half the intended excavation depth below the foundation level.

5.3.4 Trial pits (with or without access), headings and shafts shall be constructed in accordance with appropriate national or international standards and national safety regulations. They shall be sufficiently large to permit inspection, sampling and testing to be carried out *in situ*. Where necessary, they shall be protected against the effects of disturbance and weathering.

5.3.5 If visual logging, photographic evidence of the soil strata, sampling and *in situ* tests are to be carried out, this has to be done immediately after excavation.

5.3.6 The environmental impact of drilling and sampling shall be considered. Special principles have to be applied in water supply areas.

5.4 Preliminary information needed before starting sampling and groundwater measurements

At least the following preliminary information shall be available at the site before the sampling and/or groundwater measurements can start (see e.g. Annex A):

- a) objective of the sampling and groundwater measurements;
- b) location of the planned boreholes or excavations or groundwater measurements;
- c) orientation, inclination and acceptable deviations in boreholes;
- d) surveying requirements, and expected geological and hydrogeological conditions;
- e) required accuracy and uncertainty of measurements in accordance with the *Guide to the expression of uncertainty in measurement*;
- f) frequency of measurements;
- g) environmental and safety risks associated with, e.g. flushing media or suspensions intended to be used as well as regulations for their use;
- h) possible risks, e.g. underground and overhead services, traffic, unexpected and unexploded ordnance, contamination;
- i) identification and planned depths of boreholes and/or excavations;
- j) sampling method and sampling category intended;
- k) requirements on numbering of boreholes, excavations or samples;
- l) sample handling, storage and transport intended;
- m) *in situ* tests intended;
- n) borehole or excavation completion method and site reinstatement (backfilling or grouting);
- o) environmental care;
- p) emergency arrangements;
- q) name of contact person;
- r) the planned flow of information.

5.5 Backfilling and site abandonment

5.5.1 When sampling is completed it is of the utmost importance that the site is restored and no hazards are left which would be of potential harm to the public, the environment or animals. The backfilling shall be carried out in accordance with national regulations, technical or authority requirements, and take into consideration the strata, contamination of the ground and its bearing capacity.

5.5.2 Every borehole and excavation shall be fenced or temporarily capped in a safe manner until the borehole and excavation is finally and permanently capped or backfilled.

5.5.3 Unless a borehole is required to be kept open for a specific purpose, it should be infilled, consolidated and capped in such a manner that there will be no subsequent depression at ground level due to the settlement to the infill material.

5.5.4 Boreholes shall normally be filled with materials of equal or less permeability than the surrounding ground, e.g. in order to prevent contamination and connections between aquifers. If mixed grout is used, it should be placed by means of a tremie lowered to the base of the borehole. The tremie shall be slowly raised as the grout is placed. If there is an influence on future projects, special technical requirements for backfilling shall be specified in advance, e.g. for tunnel projects. Voids shall not occur during the placement of the filling material in the borehole.

5.5.5 The site should be left in a safe, clean and tidy state.

5.6 Safety and special requirements

5.6.1 Regarding safety on the site and safety of the working practices, the respective national standards, specifications or statutory requirements for execution of boreholes, trial pits, heading and shafts shall be applied, as long as respective international standards are not available.

Drill rigs shall be in accordance with EN 791 and EN 996.

5.6.2 Regarding nuisance and environmental protection, for each particular situation, as long as respective international standards are not available, the national requirements and the local requirements shall be applied.

6 Soil sampling methods

6.1 General

6.1.1 Techniques for obtaining soil samples can generally be divided into the following groups:

- a) sampling by drilling (continuous sampling);
- b) sampling using samplers;
- c) block sampling.

6.1.2 Combinations of these sampling methods are possible and sometimes required due to the geological conditions and the purpose of the investigation.

6.2 Categories of soil sampling methods

6.2.1 There are three categories A, B and C of sampling methods. For given ground conditions, they are related to the best obtainable laboratory quality class of soil samples (defined in EN 1997-2) as shown in Table 1 and Table 2, column 9:

- category A sampling methods: samples of quality classes 1 to 5 can be obtained;
- category B sampling methods: samples of quality classes 3 to 5 can be obtained;
- category C sampling methods: only samples of quality class 5 can be obtained.

6.2.2 Samples of quality class 1 or 2 can only be obtained by using category A sampling methods. The intention is to obtain samples in which no or only slight disturbance of the soil structure has occurred during the sampling procedure or in handling of the samples. The water content and the void ratio of the soil correspond to that *in situ*. No change in constituents or in the chemical composition of the soil has occurred. Certain unforeseen circumstances, such as varying of geological strata, can lead to lower sample quality classes being obtained.

6.2.3 By using category B sampling methods, this will preclude achieving sampling quality class better than 3. The intention is to obtain samples containing all the constituents of the *in situ* soil in their original proportions and the soil has retained its natural water content. The general arrangement of the different soil layers or components can be identified. The structure of the soil has been disturbed. Certain unforeseen circumstances, such as varying of geological strata, can lead to lower sample quality classes being obtained.

6.2.4 By using category C sampling methods, this will preclude achieving sampling quality class better than 5. The soil's structure in the sample has been totally changed. The general arrangement of the different soil layers or components has been changed so that the *in situ* layers cannot be identified accurately. The water content of the sample may not represent the natural water content of the soil layer sampled.

Table 1 — Quality classes of soil samples for laboratory testing and sampling categories to be used

Quality classes of soil samples for laboratory testing	1	2	3	4	5
Sampling categories	A				
	B				
					C

6.3 Sampling by drilling (continuous sampling)

6.3.1 General

6.3.1.1 This sampling method allows

- the identification and description of the soil at the site penetrated by the borehole;
- the differentiation of distinct soil layers and changes of soil material;
- the sampling as well as the investigation and testing of samples of all strata and depths.

NOTE Continuous sampling, combined with a sampling method according to category A (see Table 2), normally gives the most valuable information on the ground conditions out of all the ground investigation methods by drilling. Sampling by drilling is therefore the preferred sampling method for heterogeneously-layered soils.

6.3.1.2 Drilling methods and equipment shall be selected as a function of the required sampling category (see Table 2 and Table 4), tests and/or groundwater measurements to be carried out in the borehole.

6.3.1.3 Boreholes shall be stabilised, usually by casing, as drilling proceeds to prevent collapse of the borehole and caving.

6.3.1.4 When drilling below groundwater surface, the diameters of borehole casings and tools and the water level in the casing pipe shall be selected as to preclude the inflow of soil into the pipe. To prevent the drilling and cleaning tools from creating hydraulic failure in the soil, they shall be selected with sufficient annular clearance and withdrawn slowly. An adequate water pressure shall be maintained in the borehole.

6.3.2 Sampling by rotary drilling

6.3.2.1 Sampling by rotary dry core drilling

6.3.2.1.1 In sampling by rotary dry core drilling, a tube system fitted with a bit at its lower end is rotated and fed into the soil by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool can be single tube with a preferred borehole diameter of 100 mm to 200 mm or a hollow stem auger with a preferred borehole diameter of 100 mm to 300 mm. No flushing medium is used.

6.3.2.1.2 This technique is used for clay, silt and fine sand. If a hollow stem auger is used as a sampling tool, it will also be suitable for medium and coarse sand as well as organic soils. Sampling by rotary dry core drilling is generally unsuitable for sampling coarse gravel, cobbles and boulders.

6.3.2.2 Sampling by rotary core drilling

6.3.2.2.1 In sampling by rotary core drilling, a tube system fitted with a bit at its lower end is rotated and fed into the soil by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool can be single tube, double tube or triple tube. The preferred borehole diameter is between 100 mm and 200 mm. Flushing medium is used.

6.3.2.2.2 The single-tube corebarrel consists of a core tube with a bit at its lower end and a corebarrel head that attaches to the drill rods at its upper end. A core lifter can be fitted between the bit and the core tube or directly within the bit. The flushing medium passes between the inside of the core tube and the recovered soil core, continuously washing the length of the recovered sample.

6.3.2.2.3 The double-tube corebarrel consists of two concentric tubes and a bearing arrangement in the corebarrel head which allows the inner tube to remain stationary whilst the outer tube is rotated by the drill string. A core lifter is generally fitted between the core bit and the inner tube. The flushing medium passes through the annulus between the inner and outer tubes thus protecting the recovered core sample from damage. The double-tube corebarrel can be fitted with an optional additional plastic lining tube within the inner tube. When such a liner is fitted, the standard core bit and core lifter shall be replaced by a core bit and core lifter with a reduced inner gauge. The fitting of such a plastic liner will assist in improving core recovery in certain soil types and contain and protect the sample during transport. The double-tube corebarrel can also be fitted with an extension to the inner tube that passes through and protrudes just ahead of the core bit for use in very soft soil types.

6.3.2.2.4 The triple-tube corebarrel is similar in construction to the double-tube design but is fitted with an additional third tube within the inner tube as standard. This third tube is generally a thin wall steel tube split in half longitudinally so that, when it is removed from the inner tube, the top half can be removed to view the core sample. In some cases, the split inner tube can be replaced by a plastic liner. The triple-tube corebarrel can also be fitted with an extension to the inner tube that passes through and protrudes just ahead of the core bit for use in very soft soil types.

6.3.2.2.5 Sampling by rotary core drilling is generally suitable for clay, clayey and cemented composite soils and boulders; it is unsuitable for all non-cohesive soils.

6.3.2.2.7 After recovery of the corebarrel to the surface, the recovered core shall be handled in such a way that it as far as possible maintains its natural state. Extraction shall be made horizontally with a suitable extruder and in the same direction as it entered the barrel.

6.3.2.3 Sampling by flight auger drilling

6.3.2.3.1 In sampling by flight auger drilling, an auger consisting of a spiral flight, wound round a solid centre stem and fitted with a cutter head, is drilled into the ground. Two sampling methods can be used:

- continuous sampling method;
- non-continuous sampling method.

Table 2 — Sampling by drilling in soils

Column	1	2	3	4	5	6
Line	Drilling method				Equipment	
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm
1	Rotary drilling	No	Drilling tool	Rotary dry core drilling ^c	Single-tube corebarrel	100 to 200
					Hollow stem auger	100 to 300
2		Yes	Drilling tool	Rotary core drilling	Single-tube corebarrel	100 to 200
					Double-tube corebarrel ^a	
					Triple-tube corebarrel ^a	
3		Yes	Drilling tool	Rotary core drilling	Double/triple-tube corebarrel with extended inner tube	100 to 200
4	Hammer driving	No	Drilling tool	Auger drilling	Drill rods with shell or flight auger; hollow stem auger	100 to 2 000
5		Yes	Reverse flow of flushing medium	Reverse circulation drilling	Drill rods with hollow chisel	150 to 1 300
6		No	Drilling tool	Auger drilling with light equipment	Shell auger or spiral flight auger	40 to 80
7	Percussion	No	Drilling tool	Percussive core drilling	Percussion clay cutter with cutting edge inside; also with sleeve (or hollow stem auger) ^b	80 to 200
8		No	Drilling tool	Percussive drilling	Percussive clay cutter with cutting edge outside ^b	150 to 300
9		No	Drilling tool	Small diameter hammer driving	Hammer driving linkage with tube sampler	30 to 80
10	Rotary hammer driving	Yes	Drilling tool	Rotary percussive drilling	Single- or double-tube corebarrel	100 to 200
11	Vibration drilling with an optional slow rotation	No (only for lowering casing)	Drilling tool	Resonance drilling	Thick wall sampler or single tube corebarrel with optional plastic lining tube	80 to 200
12	Pneumatic/continuous thrust	No	Drilling tool	Cable percussion drilling	Cable with percussion shell auger	150 to 500
13		No	Drilling tool	Cable percussion drilling	Cable with valve auger	100 to 1 000
14	Pneumatic/continuous thrust	No	Drilling tool	Small diameter pneumatic/continuous thrust drilling	Pneumatic/continuous thrust linkage, with tube sampler	30 to 80
15	Grabbing	No	Drilling tool	Grab drilling	Cable with grab	400 to 1 500

^a Conventional or wireline corebarrel.

^b Using the hammer driving technique, the drilling tool will be driven by a special driving tool. Using the percussion technique, the drilling tool will be driven by its repetitive lifting and falling.

^c Rotary dry core drilling is commonly used if the observation of the groundwater surface is the most important aim of the ground investigation.

Table 2 (continued)

7	8	9	10	11	Column
Guideline for application and limitations ^d		Achievable sampling categories ^e	Achievable quality class ^e	Remarks	Line
Unsuitable for ^d	Preferred method for ^d				
coarse gravel, cobbles, boulders	clay, silt, fine sand, silt	B (A)	4 (2-3)	Good interior, outside dried out	1
	clay, silt, sand, organic soils	B (A)	3 (1-2)	—	
non-cohesive soils	clay, clayey and cemented composite soils, boulders	B (A)	4 (2-3)	—	2
		B (A)	3 (1-2)		
		A	1		
gravel, cobbles, boulders	clay, silt	A	2 (1)	—	3
boulders larger than $D_e/3$	all soils above water surface, all cohesive soils below water surface	B	4 (3)	—	4
—	all soils	C (B)	5 (4)	—	5
coarse gravel with a particle size larger than $D_e/3$, dense soils, cohesion-less soils beneath groundwater surface	clay to medium gravel above water surface; cohesive soils below water surface	C ^f	5	Only to be used for small depths	6
soils with a particle size larger than $D_e/3$ laminated soil, e.g. varve	clay, silt and soils with a particle size up to $D_e/3$	cohesive soil: A	2 (1)	Plotting of driving chart on the basis of number of impacts	7
		non-cohesive soil: B (A)	3 (2)		
soils with a particle size larger than $D_e/3$	gravel and soils with a particle size up to $D_e/3$	B	4		8
soils with a particle size larger than $D_e/2$	soils with a particle size up to $D_e/5$	C ^f	5	Only to be used for small depths	9
composite and pure sands with a particle size larger than 2,0 mm, gravel, firm and stiff clays	clay, silt, fine sand	cohesive soil: A	2 (1)	—	10
		non-cohesive soil: B	4 (3)		
—	—	cohesive soil: B	4	—	11
		non-cohesive soil: C	5		
gravel above water surface, silt, sand and gravel below water surface	clay and silt above water surface, clay below water surface	C (B)	4 (3)	—	12
recovery above water surface	gravel and sand in water	C (B)	5 (4)	Can also be used in cohesive soils if water is added	13
dense and coarse-grained soils	clay, silt, fine sand	C ^f	5	Only to be used for small depths	14
firm, cohesive soils, boulders of size larger than $D_e/2$	gravel, boulders of size less than $D_e/2$, cobbles	above water surface: B	4	—	15
		below water surface: C	5		

^d D_e is the internal diameter of the sampling tool.

^e The sampling categories and quality classes given in parentheses can only be achieved in particularly favourable ground conditions, which shall be explained in such cases.

^f Sampling category B is sometimes possible in light cohesive soils.

NOTE Straight flush drilling is not covered because the sample quality class that can be achieved is generally worse than class 5.

6.3.2.3.2 With the continuous sampling method, the flights act as a screw conveyor and continuously bring the cuttings to the surface. Additional sections of auger can be added until the required depth is reached. At the mouth of the borehole, the obtained samples are remoulded.

6.3.2.3.3 With the non-continuous sampling method, the flight auger is screwed into the soil with the penetration rate suitable for the auger rotational speed and the pitch of the flight auger. The sampling length into the soil shall not exceed the maximum length of the flight auger. During the screwing of the flight auger, the vertical displacement of the soil between the flights shall be minimised. After the screwing, the drilling tool shall be completely removed from the borehole without rotation of the auger and the samples shall be taken from the material adhering to the auger flights.

6.3.2.3.4 With the non-continuous sampling method, flight auger drilling shall be only used if the borehole is stable or if stabilized with an auxiliary casing.

6.3.2.3.5 Sampling by flight auger drilling is suitable for cohesive soils and soils above the groundwater surface.

6.3.2.4 Sampling by reverse circulation drilling

6.3.2.4.1 In sampling by reverse circulation drilling, the flushing fluid passes down the outside of the drill rods over the cutting face of the bit then, carrying the cuttings, passes through a central orifice in the bit and up through the drill rods to the surface.

6.3.2.4.2 The borehole diameter is usually between 150 mm and 1 300 mm.

6.3.2.4.3 This sampling technique is suitable for all soils.

6.3.2.5 Sampling by shell auger drilling

6.3.2.5.1 In sampling by shell auger drilling, a shell auger is used as the sampling tool. Single-edge shell augers shall be used for cohesive soils and double-edge shell augers for non-cohesive soils. Double-edge shell augers with an internal clack are sometimes used for non-cohesive soils. The sampling length into the soil shall not exceed the maximum length of the shell auger. During the penetration of the shell auger, the vertical displacement of the soil in the shell auger shall be minimised. After the screwing, the drilling tool shall be completely removed from the borehole and the sample shall be extracted from the auger.

6.3.2.5.2 Sampling by shell auger drilling shall be only used if the borehole is stable or with a casing.

6.3.3 Sampling by use of hammer driving methods

6.3.3.1 Sampling by percussive drilling

In sampling by percussive drilling, a clay cutter tube device with an internal cutting edge at the lower end is driven into the soil by hammer blows transmitted to it via appropriate drill rods. It is generally suitable for clay, silt and soils with a particle size up to $D_e/3$ ¹⁾ and with a borehole diameter up to 300 mm. The sample is retained within the clay cutter by a suitable retainer.

6.3.3.2 Sampling by rotary percussive drilling

In sampling by rotary percussive drilling, a clay cutter tube device with a cutting shoe fitted to the lower end is driven into the soil by hammer blows and the supporting drill rods slowly rotated. It is generally suitable for clays, silt and soils with a particle size up to $D_e/3$ and a borehole diameter up to 300 mm. The sample is retained within the clay cutter tube.

¹⁾ D_e is the internal diameter of the sampling tool.

6.3.4 Sampling by cable percussion drilling

6.3.4.1 In sampling by cable percussion drilling, appropriate percussive sampling, drilling and bailing tools are suspended on a cable, which is raised and free lowered by a winch so allowing the mass of the equipment to drive the tools into the soil. Boreholes up to 500 mm can be bored and sampled using this method.

6.3.4.2 Sampling by cable percussion drilling can be used in all soils by the selection of the appropriate equipment.

6.3.5 Sampling by hollow stem auger drilling

6.3.5.1 In sampling by hollow stem auger drilling, the hollow stem auger, which consists of a spiral flight wound round a hollow central tube and fitted with an appropriate cutting head, is drilled into the soil in a similar manner to the flight auger (see 6.3.2.3). Additional sections of hollow stem auger are added till the required depth is reached.

6.3.5.2 Once the required depth is reached, a sampling system or corebarrel can be lowered through the centre tube of the hollow stem auger to take samples from the bottom of the hole, without removing the hollow stem auger string.

6.3.6 Sampling by grab drilling

6.3.6.1 In sampling by grab drilling, the sampling tool is a cable with grab.

6.3.6.2 The borehole diameter should be between 400 mm and 1 500 mm.

6.3.6.3 This sampling technique is the preferred method for gravel, cobbles and boulders with a size less than $D_e/2$. It is unsuitable for firm, cohesive soils and boulders larger than $D_e/2$.

6.3.7 Soil sampling by small diameter drilling

6.3.7.1 Small diameter drilling refers to all drilling with a hole diameter between 30 mm and 80 mm. In principle, the same drilling methods and equipment described in Table 2 can be used.

6.3.7.2 Sampling by small diameter drilling is only suitable in sands and fine-grained soils.

When employing small diameter drilling methods, it should be noted that the samples recovered are sufficient in size and mass, suitable for the scheduled laboratory testing.

6.3.7.3 Generally the quality of a core sample obtained by small diameter drilling is lower than if larger diameter drilling with the same drilling method is used.

6.3.8 Sampling by resonance drilling

In sampling by resonance drilling, a tube fitted with a bit at its lower end is fed into the soil or soft rock by vibration of a frequency variable from 30 Hz to 150 Hz. The frequency is adjusted after each addition of extension rod in order to obtain a resonance.

When the penetration rate is too low, the sampler or corebarrel can be rotated (1 to 5 rotations per metre). The sampler or corebarrel can be equipped with a plastic lining tube.

6.4 Sampling using samplers

6.4.1 General

6.4.1.1 Sampling using samplers can be used in combination with many drilling methods. The drilling diameter shall be chosen so that the sampler can be lowered to the borehole bottom without hindrances.

6.4.1.2 Depending on the soil conditions, different samplers can be used (see Table 3). Usually sampling with samplers is used in combination with any drilling methods using drilling mud or a casing to support the borehole. The drilling method and technique shall be chosen in such a way that unacceptable disturbance of the soil samples is prevented.

6.4.1.3 The inside of the sampling tube or the liner shall be clean and smooth without any protruding edges or irregularities, which can cause disturbance of the sample.

6.4.1.4 Drilling of the casing with percussion is not allowed to the full depth in case of category A sampling. The percussion process shall be halted at least 0,25 m or 5 times the diameter of the borehole before reaching the sampling depth.

6.4.1.5 If a casing is used in sensitive clays, it shall not be brought closer than 2,5 times the outside diameter of the casing to the sampling depth to minimise disturbance. In other soils, the casing can be lowered to the borehole bottom. Samples shall be taken from the undisturbed soil below the casing in a pre-cased or slurry-supported borehole, slightly larger than the diameter of the sampler.

6.4.1.6 When drilling mud is used, its characteristics shall be chosen with respect to the drilling method, the soil and groundwater conditions to obtain a stable borehole.

6.4.1.7 Before taking undisturbed samples from borehole bottom, any loose or disturbed material shall be removed. In the case of cleaning the borehole bottom by circulating flushing medium, the rotary drill bit shall be advanced with utmost caution, and the fluid circulation reduced until the bit reaches the sampling depth. Remaining loose material shall be removed in a controlled manner.

Table 3 — Soil sampling using samplers

Column	1	2	3	4	5	6	7	8
Line	Type of sampler ^b	Preferred sample dimensions		Technique used	Applications and limitations		Sampling category for soils as in column 6 ^a	Achievable quality class ^a
		Diameter mm	Length mm		Unsuitable for	Recommended for use in		
1	thin-walled (OS-TW)	70 to 120	250 to 1 000	static or dynamic driving	gravel, loose sand below water surface, firm cohesive soils, soils including coarse particles	cohesive or organic soils of soft or stiff consistency (medium) dense sand below water surface cohesive or organic soils of stiff consistency	A B (A) A	1 3 (2) 2 (1)
2	thick-walled (OS-TKW)	>100	250 to 1 000	dynamic driving	gravel, sand below water surface, pasty and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of soft to stiff consistency, and including coarse particles	B (A)	3 (2)
3	thin-walled (PS-TW)	50 to 100	600 to 800	static driving	gravel, very loose and dense sands, semi-firm and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of pasty or stiff consistency, and sensitive soils sand above ground water	A B	1 3
4	thick-walled (PS-TKW)	50 to 100	600 to 1 000	static driving	gravel, sand below water surface, pasty and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of soft to stiff consistency, and sensitive soils	B (A)	2 (1)
5	cylinder (LS)	250	350	static rotating	sand	clay, silt	A	1
6	cylinder (S-SPT)	35	450	dynamic driving	coarse gravel, blocks	sand, silt, clays	B	4
7	window	44 to 98	1 500 or 3 000	static or dynamic driving	sand, gravel	silt, clay	C	5
^a The sampling categories and achievable quality classes given in parentheses can only be achieved in particularly favourable soil conditions, which shall be explained in such cases.								
^b OS-TW open-tube samplers, thin-walled OS-TKW open-tube samplers, thick-walled PS-TW piston samplers, thin-walled PS-TKW piston samplers, thick-walled LS large sampler S-SPT SPT (standard penetration test) sampler								

6.4.2 Sampling using open-tube or piston samplers

6.4.2.1 General

For recovering samples from boreholes in cohesive, sandy and organic soils, open-tube or piston samplers can be used. These samplers generally consist of a sampler tube with or without a piston and a sampler head with connection to the extension rods. The open-tube sampler (thin-walled and thick-walled) can be used in boreholes. The piston sampler can be pushed directly into soft to medium stiff soil.

6.4.2.2 General geometry

6.4.2.2.1 Tube inner diameters between 50 mm and 120 mm are common, but diameters up to 250 mm are used for special soil conditions. The lower end of the tube shall be shaped to form a cutting edge.

6.4.2.2.2 The sampling tube length should preferably be not greater than 20 times the sample diameter. An effective sampling length of 0,45 m to 1,00 m is considered sufficient for ordinary soil testing. Longer tubes can be used if friction reducing systems are applied.

6.4.2.3 Detailed geometry

6.4.2.3.1 The material of the sampling tube shall be rigid, resistant to corrosion and with a smooth surface. The thickness of the tube wall shall be chosen so that the tube resists distortion when pushed into the soil.

6.4.2.3.2 The thin-walled tube samplers used shall meet the following requirements, which apply by analogy to samplers with other internal diameters:

- a) the edge taper angle should not exceed 5 °;
- b) the area ratio, C_a (see 3.3.11), should be less than 15 %;
- c) taper angles between 5 ° and 15 ° and area ratios up to 25 % may only be used if it is demonstrated that the quality class is not affected;
- d) for tube samplers with C_a exceeding 15 %, the angle of the cutting edge shall decrease as the wall thickness increases;
- e) the tolerances on the cutting edge and the sample tube should be chosen to give a minimum inside clearance ratio, C_i (see 3.3.12), less than 0,5 %. When assessing the inside clearance, the worst case of manufacturing tolerances shall be applied.

6.4.2.4 Preparation of tubes

6.4.2.4.1 Prior to sampling, the sampler and its component parts should be carefully inspected, especially the cutting edge. Defective or damaged components should be replaced. In order to keep the sample as undisturbed as possible during extraction, transport and handling in the laboratory, samplers with rigid, low-friction liners are recommended.

6.4.2.4.2 The inside of the sampling tube or liner should be clean and smooth without any protruding edges or irregularities, which can cause disturbance of the sample. The tubes and liners shall have smooth walls to minimise friction in the soil. Tubes which are corroded on the inside, or have damaged cutting edge, shall not be used.

6.4.2.5 Field procedure

6.4.2.5.1 The sampler shall be pushed or driven into the soil (see column 4 of Table 3). If dynamic driving is used, the drop weight used shall impinge directly onto the sampler head, its mass being sufficient to effect the required penetration of the tube by a minimum number of blows from a small height.

6.4.2.5.2 Before sampling from the bottom of the borehole, any loose or disturbed material shall be removed. The sampler should be carefully lowered into a borehole as soon as practicable after the borehole bottom has been cleaned. The sampler tube shall be pushed down to at least 200 mm below any disturbed material at or below the base of the borehole. If a casing is used, samples shall be taken from the undisturbed soil below the casing.

6.4.2.5.3 The depth of the borehole and the position of the sampler shall be checked exactly when the sampler enters the borehole. The sampler shall not bear upon the soil at the bottom when the sampler reaches its full depth.

6.4.2.5.4 The sampler advance should be made in one continuous motion to the predetermined depth, and the length of advance should be measured. This length shall be assessed for each type of sampler. It is preferred to use not more than 90 % of the effective length. Advance in excess of the effective length is not allowed.

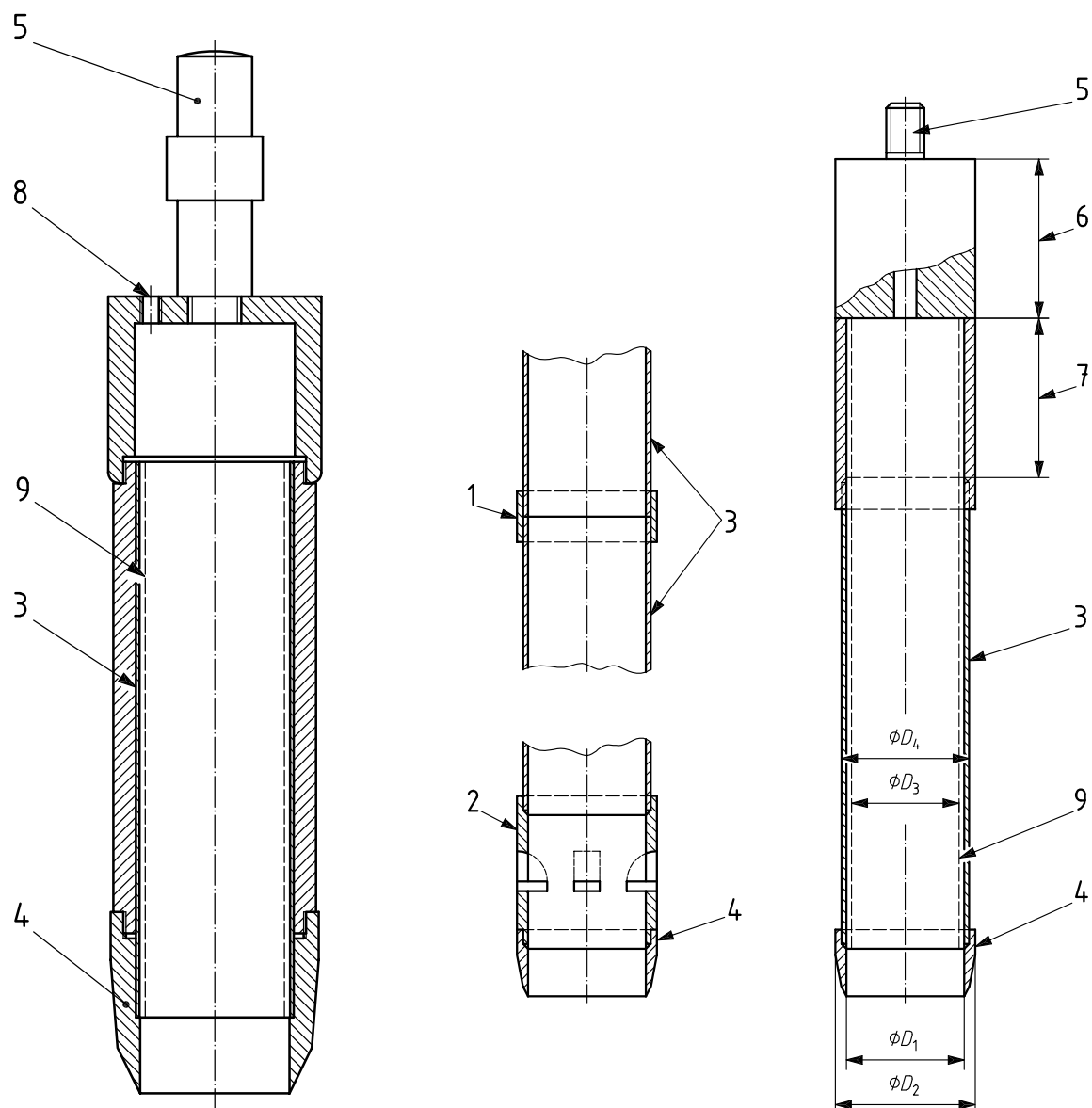
6.4.2.5.5 After driving, the sample shall be sheared off at the bottom edge of the sampler tube by rotating the rods or by slowly raising the sampler. The sampler should be carefully withdrawn without any vibrations or shocks in order to keep the sample undisturbed. It is often advisable to keep the sampler in position for a few minutes so that sufficient adhesion is developed between the sample and the sampling tube or liner.

6.4.2.5.6 After withdrawal the sampler should be disassembled and, if necessary, the samples carefully extracted without any bending or torsion of the sample. The sampling tube and the cutting edge should be checked for any deformations. Any such deformations should be noted in the sampling record. The occurrence of loosened soils or cuttings in the upper end shall also be checked and noted in the record.

6.4.2.5.7 The sampling process can disturb the soil underneath the sampler. This influence shall be considered.

6.4.2.6 Sampling using the open-tube sampler

6.4.2.6.1 In addition to the components mentioned in 6.4.2.3, open-tube samplers (OS) consist of a sampler tube with overdrive space and a sampler head with non-return valve tube. The sludge tube shall provide an overdrive space into which the softened material in the borehole can pass. The non-return valve ball and seat shall be adequately sized, so as to permit the free escape of the contained water and air when the sample enters the tube, and close tightly when the sampler is being withdrawn (see Figure 4). At its upper end, the sample tube is provided with a thread for connection to the sludge tube.



a) Schematic thick-walled open-tube sampler

b) Schematic thin-walled open-tube sampler

Key

D_1 inside diameter of the cutting shoe
 D_2 greatest outside diameter of the cutting shoe
 D_3 inside diameter of the sample tube or liner
 D_4 outside diameter of the sample tube

1 screw socket
 2 sample retainer

3 sample tube
 4 cutting shoe
 5 connection to drilling rods or sliding hammer
 6 non-return valve
 7 overdrive space
 8 valve
 9 liner (optional)

Figure 4 — Examples of open-tube samplers (OS) for recovering samples from boreholes

6.4.2.6.2 Sampling using the thin-walled open-tube sampler is usually regarded as either a category A or B sampling method, depending the soil conditions (see Table 3).

6.4.2.6.3 Thick-walled open-tube samplers are mostly suitable for stiff and dense soils and for soils containing coarse particles (see line 2 of Table 3). For soil types that are difficult to sample, sample-retaining or closure devices are necessary.

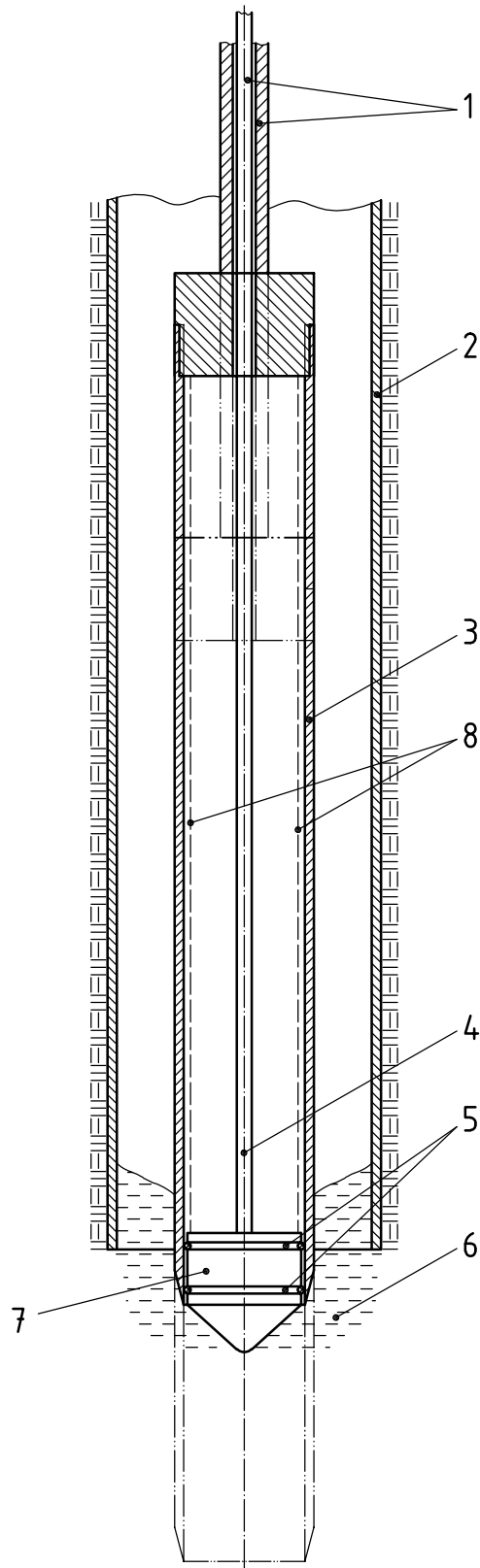
6.4.2.6.4 The thick-walled open-tube sampler is usually regarded as a category B sampling method.

6.4.2.7 Sampling using the piston sampler

6.4.2.7.1 The piston sampler can be used in low-strength fine soils such as silt and clay, including sensitive clays. It can be used either in boreholes or be pushed directly into the soil.

6.4.2.7.2 The piston sampler consists of a sample tube containing a close-fitting sliding piston, which is slightly coned at its lower face. The sample tube is fitted to the sampler head, whereas the piston is fixed to separate rods. This passes through a sliding joint in the sampler head and up inside the drill rods. Clamping devices, operated at ground level, enable the piston and sample tube to be locked together or the piston to be held stationary while the sample tube is driven down (see Figure 5). When shearing the sample, the piston shall be released or firmly fixed to the ground surface before further advance of the sampler is made. A movement of 1 % of the length of penetration in the piston rod due to tension is acceptable. The length of advance of the sampler shall not be more than the intended length of the sample to avoid compression of the sample.

6.4.2.7.3 Sampling using the piston sampler is usually regarded as a category A sampling method (see Table 3). In certain circumstances, the piston sampler can be used in sands by use of an appropriate core lifter. The sampling category in this case is usually regarded as a category B sampling method. For sampling in clay, a core lifter shall be avoided due to risk of disturbance. If used, it shall be noted in the sampling record.



Key

- | | |
|---|--------------------|
| 1 drill rod locking device above ground | 5 sealing ring |
| 2 casing | 6 disturbed soil |
| 3 sample tube | 7 piston |
| 4 vent | 8 liner (optional) |

Figure 5 — Schematic thin-walled stationary piston sampler (PS) for sampling from borehole bottom

6.4.3 Sampling using the standard penetration test sampler (SPT)

6.4.3.1 The standard penetration test sampler is mostly used in the standard penetration test according to ISO 22476-3. It takes samples 35 mm in diameter, 450 mm in length and has an area ratio, C_a , of about 100 %.

6.4.3.2 Sampling using the standard penetration test sampler is usually used as a category C sampling method (see Table 3). In certain homogenous fine-grained soils, it can also be used as a category B sampling method.

6.4.4 Sampling using the window sampler

6.4.4.1 A window sampler consists of a hollow tube with a longitudinal slot cut along part of its length (window) and fitted with a shoe having a sharp cutting edge at its lower end. Window samplers are used to take samples by the application of static thrust, by dynamic impact or by percussion. After driving and removal from the soil, the sample is removed from the window (see Figure C.23).

6.4.4.2 Sampling using the window sampler should only be done in the bottom of a borehole where the soil sample cannot be mixed with overlying soil layers, provided a shutter is not used.

6.4.4.3 Sampling using the window sampler is usually used as a category C sampling method (see Table 3).

6.5 Block sampling

6.5.1 Sampling from trial pits

6.5.1.1 In sampling from a trial pit, samplers with cutting procedure are used or block samples are recovered.

6.5.1.2 Block samples in cohesive soils can be cut by hand or by a handheld saw. The following precautions shall be taken:

- a) remoulded soil shall be carefully removed from the sampling spot;
- b) no extraneous water shall come into contact with the sample;
- c) the sample should be protected from sunshine, frost and winds;
- d) immediately after the sample has been cut, it shall be covered.

6.5.1.3 In soils with adequate cohesion, samples can be cut out by hand, care being taken to ensure that their dimensions are at least equal to those of the sampler tube shown in Figure C.31. Sampling from trial pits executed in such a way is usually used as category A or B sampling method.

6.5.1.4 In sampling from trial pits, samples are removed from the bottom, any slopes or walls of a trial pit using a sampling device as shown in Figure C.31. Sampler tubes according to Figure C.31 b) may only be used in soils with a maximum particle size up to 5 mm. The sampler tube shall be driven into the soil by hand or, where this is not possible, it shall be driven into the soil either by thrust or using a drop weight or sliding hammer and the sample recovered as shown in Figure C.31 c). In sampling dense sands, there is the possibility of losing sample material during extraction of the sampler tube. Such material shall be included in the sample to complete the sample.

6.5.2 Sampling using large samplers

6.5.2.1 The principles of sampling using a large sampler shall be as follows (see also C.15):

- a) Preparation of the borehole:

The preparation of a borehole for a large sampler requires the use of a solid auger with a larger diameter. The borehole can be supported by mud, or be cased down to the sampling level. Before lowering a large sampler into the borehole, any loose debris or disturbed material shall be removed from the bottom of the borehole using a flat bottom auger with a larger diameter.

b) Sampling procedure and sample recovery:

A large sampler can be operated by any drilling rod system that enables the relevant modes of operations for the sampler. The large sampler should be advanced at a slow rate into the soil, using a combination of static thrust, rotation and/or flushing. The sample shall be carefully separated from the surrounding soil before recovery and brought to the surface with minimum disturbance. Precautions should be taken to reduce the effect of suction when the sample is separated from the adjacent soil, and to avoid shocks and vibrations transferred to the rod system during upheaval of the sample.

6.5.2.2 Sampling using a large sampler is usually used as a category A sampling method.

Table 4 — Examples on sampling methods with respect to the sampling category in different soils

Soil type	Suitability depends on e.g.	Sampling method		
		Category A	Category B	Category C
Clay	Stiffness or strength sensitivity plasticity	PS-PU OS-T/W-PU ^b OS-T/W-PE ^a OS-TK/W-PE ^{a, b} CS-DT, CS-TT LS, S-TP, S-BB	OS-T/W-PE OS-TK/W-PE CS-ST HSAS AS ^a	AS
Silt	Stiffness or strength sensitivity groundwater surface	PS OS-T/W-PU ^b OS-TK/W-PE ^{a- b} LS, S-TP	CS-DT, CS-TT OS-TK/W-PE HSAS	AS CS-ST
Sand	sizes of the particles density groundwater surface	S-TP OS-T/W-PU ^b	OS-TK/W-PE ^b CS-DT, CS-TT HSAS	AS CS-ST
Gravel	size of the particles density groundwater surface	S-TP	OS-TK/W-PE ^{a, b} HSAS	AS CS-ST
Organic soil	state of decay	PS OS-T/W-PU ^b S-TP	CS-ST HSAS AS ^a	AS
^a Can be used only in favourable conditions. ^b See also 6.4.2.3 for the detailed geometry.				
Key OS-T/W-PU Open-tube samplers, thin-walled/pushed OS-T/W-PE Open-tube samplers, thin-walled/percussion OS-TK/W-PE Open-tube samplers, thick-walled/percussion PS Piston samplers PS-PU Piston samplers, pushed LS Large samplers				
		CS-ST	Rotary core drilling, single tube	
		CS-DT, CS-TT	Rotary core drilling, double or triple tube	
		AS	Augering	
		HSAS	Hollow stem augering	
		S-TP	Sampling from trial pit	
		S-BB	Sampling from borehole bottom	

7 Rock sampling methods

7.1 General

7.1.1 Techniques for obtaining rock samples can be divided in the following groups:

- a) sampling by drilling (see Table 5)
- b) block sampling;
- c) integral sampling.

Combinations of these sampling methods are possible and sometimes required due to the geological conditions.

7.1.2 Rock samples are of the following types:

- a) cores (complete and incomplete);
- b) cuttings and retained returns;
- c) block samples.

7.1.3 The quality of the rock recovery is achieved by applying the following three parameters (see also Figure 2):

- total core recovery, TCR (see 3.3.14.1);
- rock quality designation, RQD (see 3.3.14.2);
- solid core recovery, SCR (see 3.3.14.3);

7.1.4 After recovery of the corebarrels to the surface, the core recovery shall be assessed. In cases where core samples are extruded from the corebarrel and placed in a core box, the sample shall be logged. If liners are used, it shall be decided in advance where and when they shall be opened for examination of the core. Core losses shall be filled with a dummy. The drilling direction has to be marked on the core boxes or samples by arrows. The depths of the cores also have to be marked.

7.2 Categories for rock sampling methods

7.2.1 There are three categories of rock sampling methods, depending on the best obtainable quality of rock samples under given ground conditions:

- category A sampling methods;
- category B sampling methods;
- category C sampling methods.

7.2.2 By using category A sampling methods, it is intended to obtain samples in which no or only slight disturbance of the rock structure has occurred during the sampling procedure of the samples. The strength and deformation properties, water content, density, porosity and the permeability of the rock sample correspond to the *in situ* values. No change in constituents or in the chemical composition of the rock mass has occurred. Certain unforeseen circumstances, such as varying of geological conditions, can lead to lower sample quality being obtained.

7.2.3 By using category B sampling methods, it is intended to obtain samples that contain all the constituents of the *in situ* rock mass in their original proportions and the rock pieces have retained their