



BSI Standards Publication

Geotechnical investigation and testing — Sampling methods and groundwater measurements

Part 1: Technical principles for the sampling of soil, rock and groundwater

National foreword

This British Standard is the UK implementation of EN ISO 22475-1:2021. It is identical to ISO 22475-1:2021. It supersedes BS EN ISO 22475-1:2006, which is withdrawn.

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

A list of organizations represented on this committee can be obtained on request to its committee manager.

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(ISO 22475-1:2021)

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Principes techniques pour le prélèvement des sols, des
roches et des eaux souterraines (ISO 22475-1:2021)

Geotechnische Erkundung und Untersuchung -
Probenentnahmeverfahren für Boden, Fels und
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This European Standard was approved by CEN on 19 September 2021.

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European foreword

This document (EN ISO 22475-1:2021) has been prepared by Technical Committee ISO/TC 182 "Geotechnics" in collaboration with Technical Committee CEN/TC 341 "Geotechnical Investigation and Testing" the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by April 2022, and conflicting national standards shall be withdrawn at the latest by April 2022.

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

This document supersedes EN ISO 22475-1:2006.

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According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 22475-1:2021 has been approved by CEN as EN ISO 22475-1:2021 without any modification.

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical Investigation and Testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 22475-1:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

- clauses on groundwater measurement will be part of ISO 18674-4;
- new sampling categories for soils have been added;
- editorial updates have been made.

A list of all parts in the ISO 22475 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for the sampling of soil, rock and groundwater

1 Scope

This document deals with principles of sampling of soil, rock and groundwater as part of the programme of geotechnical investigation and testing.

NOTE 1 This document fulfils the requirements for sampling of soil, rock and groundwater, and groundwater measurements as part of the programme of geotechnical investigation and testing according to EN 1997-1 and EN 1997-2.

The aims of such ground investigations are:

- a) to recover soil, rock and water samples of a quality appropriate to assess the general suitability of a site for geotechnical engineering purposes and to determine the required ground characteristics in the laboratory;
- b) to obtain information on the sequence, thickness and orientation of strata and discontinuities;
- 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.

Soil sampling for the purposes of agricultural and environmental soil investigation is not covered.

NOTE 2 Guidance on soil sampling for these purposes including of contaminated or potentially contaminated sites is provided in the ISO 18400 series. ISO 18400-204 provides in addition guidance on sampling and measurement of soil (ground) gas.

NOTE 3 The sampling methods, presented in this document may not be suitable for all types of soil e.g. peat with strong fibrous structure.

NOTE 4 Some of the sampling methods presented in this document are suitable for both soil and rock.

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 5 Water sampling for these purposes can be found in the ISO 5667 series.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

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

ISO 14689, *Geotechnical investigation and testing — Identification, description and classification of rock*

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*

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

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 98-3:2008/Suppl 1:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) — Supplement 1: Propagation of distributions using a Monte Carlo method*

ISO/IEC Guide 98-1, *Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement*

3 Terms, definitions and abbreviated terms

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Ground investigation methods

3.1.1

trial pit

open excavation constructed to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.2

shaft

open or steeply inclined excavation, typically more than 5 m deep, constructed to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.3

heading

adit

small tunnel driven horizontally or with a slight inclination from a *shaft* (3.1.2) or into sloping ground to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.4

borehole

hole of any predetermined diameter and length formed in any geological formation or manmade material by *drilling* (3.1.5)

Note 1 to entry: Investigations carried out in such a hole can be to recover rock, soil or water *samples* (3.3.4) from a specified depth or to carry out field tests and measurements.

3.1.5

drilling

process by which a *borehole* (3.1.4) is produced in any geological formation by rotary, rotary percussive, percussive, resonance/sonic or thrust methods and in any predetermined direction in relation to the *drill rig* (3.2.3)

3.1.6**small diameter drilling**

drilling (3.1.5) 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* (3.1.4)

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

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

3.2.2**drill bit**

device, which is attached to, or an integral part of, the drill string that is used as a cutting tool to penetrate the formation being drilled by the *drilling method* (3.1.7) employed

3.2.3**drill rig**

device which carries out the *drilling* (3.1.5) function

3.2.4**casing**

tubing temporarily or permanently inserted into a *borehole* (3.1.4)

Note 1 to entry: It is used e.g. to stabilise it, to prevent the loss of *flushing medium* (3.2.5) to the surrounding formation or to prevent cross flow between different groundwater horizons.

3.2.5**flushing medium**

liquid or gaseous medium to remove *cuttings* (3.3.10) from the *borehole* (3.1.4), to aid sampling and to lubricate and cool the *drilling tool* (3.2.1)

3.2.6**additive**

substance added to the *flushing medium* (3.2.5) in order to affect or change its properties to improve its functioning and can include *borehole* (3.1.4) stabilization

3.2.7**core lifter**

split, internally slotted or serrated conical spring steel ring fitted to the core barrel to hold and retain the *core sample* (3.3.8) whilst the core barrel is being hoisted from the *borehole* (3.1.4)

3.2.8**sample retainer**

cylindrical device containing flexible spring fingers, hinged wedged-shaped fingers or a hinged flap mounted in a carrier ring and mounted at the lower end of the sampler tube and used to retain the *sample* (3.3.4) 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* (3.3.4) are obtained by the *drilling tools* (3.2.1) as the *borehole* (3.1.4) proceeds

Note 1 to entry: The *drilling* (3.1.5) 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 using sampler

process by which *samples* (3.3.4) are obtained by samplers from *trial pits* (3.1.1), *headings* (3.1.3), *shafts* (3.1.2) or *boreholes* (3.1.4) at selected positions

3.3.3

soil sampling by small diameter drilling

sampling by drilling (3.3.1) in soils using *drilling tools* (3.2.1) with a diameter greater than 30 mm but less than 80 mm

3.3.4

sample

representative specimen of rock, soil or groundwater recovered from a recorded location

3.3.5

sampling method

set of equipment and procedures employed in a sampling operation

3.3.6

sampling category

sampling methods (3.3.5) to enable a certain quality of soil or rock *samples* (3.3.4) to be obtained

3.3.7

sampling disturbance

changes to the sample due to the sampling operation

Note 1 to entry: These changes can be of physical, chemical and/or state properties of the sampled material.

3.3.8

core

core sample

cylindrical *sample* (3.3.4) of soil or rock obtained from a *borehole* (3.1.4)

3.3.9

block sample

sample (3.3.4) of soil or rock cut out by special techniques to minimise disturbance

3.3.10

cuttings

particles of geological formations formed in the *borehole* (3.1.4) by the cutting action of the *drilling tool* (3.2.1) and carried to the surface by the *flushing medium* (3.2.5) or by an appropriate device

3.3.11

suspended matter

abraded ground material in the *flushing medium* (3.2.5) generated by *drilling* (3.1.5), in which the individual particle size cannot be recognised with the naked eye

3.3.12

core run

length of core sampling in an exploratory hole defined by the start and end depths (or other linear measurement) of the sampling tool

3.3.13**core loss**

difference between a *core run* (3.3.12) and the length of the *core* (3.3.8) recovered

3.3.14**area ratio**
 C_a

ratio of the area of soil displaced by the sampler tube in proportion to the area of the *sample* (3.3.4):

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

Note 1 to entry: See [Figure 1](#).

Note 2 to entry: Area ratio is expressed in %.

Note 3 to entry: Area ratio is one of the factors that determine the mechanical disturbance of the soil.

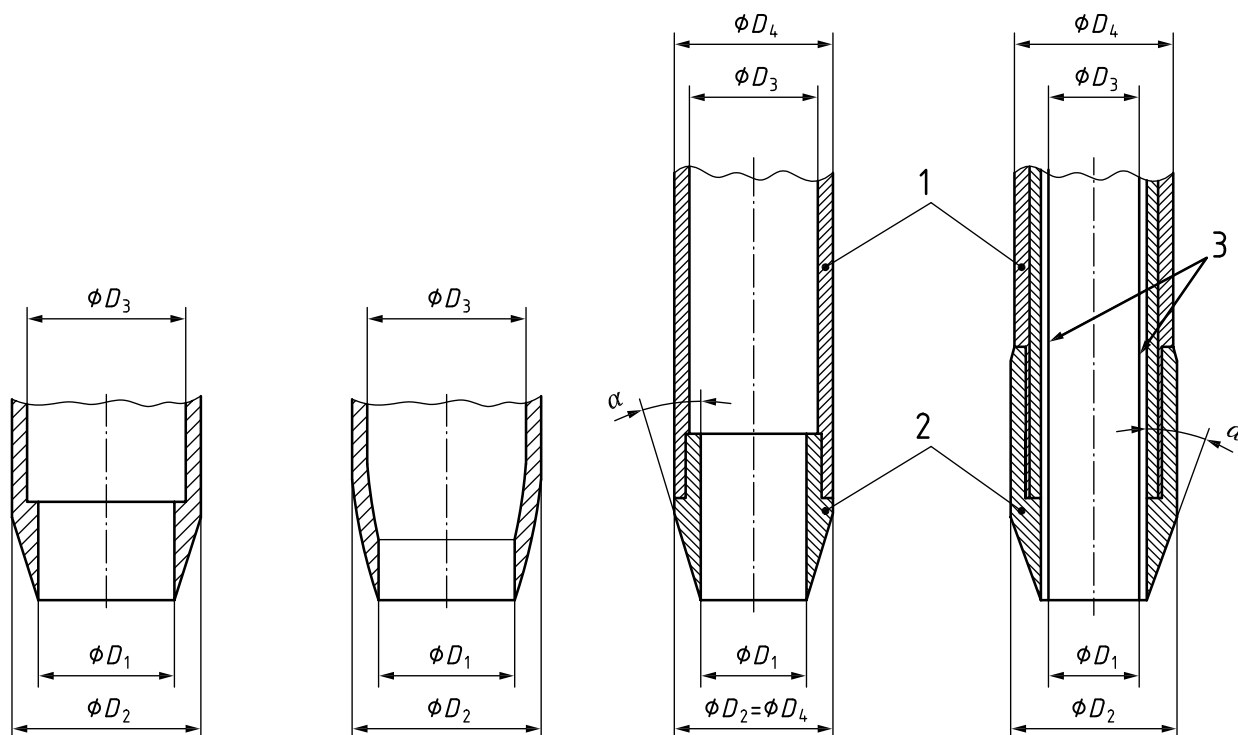
3.3.15**inside clearance ratio**
 C_i

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

Note 1 to entry: See [Figure 1](#).

Note 2 to entry: Inside clearance ratio is expressed in %.

Note 3 to entry: Inside clearance ratio is one of the factors that determine the mechanical disturbance of the *sample* (3.3.4) 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

3.3.16

total core recovery in rock

TCR

total length of *core sample* (3.3.8) recovered (solid and non-intact), expressed as a percentage of the length of the *core run* (3.3.12)

Note 1 to entry: See Figure 2.

3.3.17

rock quality designation

RQD

summed length of solid core pieces recovered in the *core run* (3.3.12) where each piece is at least 100 mm long between natural fracture, expressed as a percentage

Note 1 to entry: See Figure 2.

3.3.18

solid core recovery

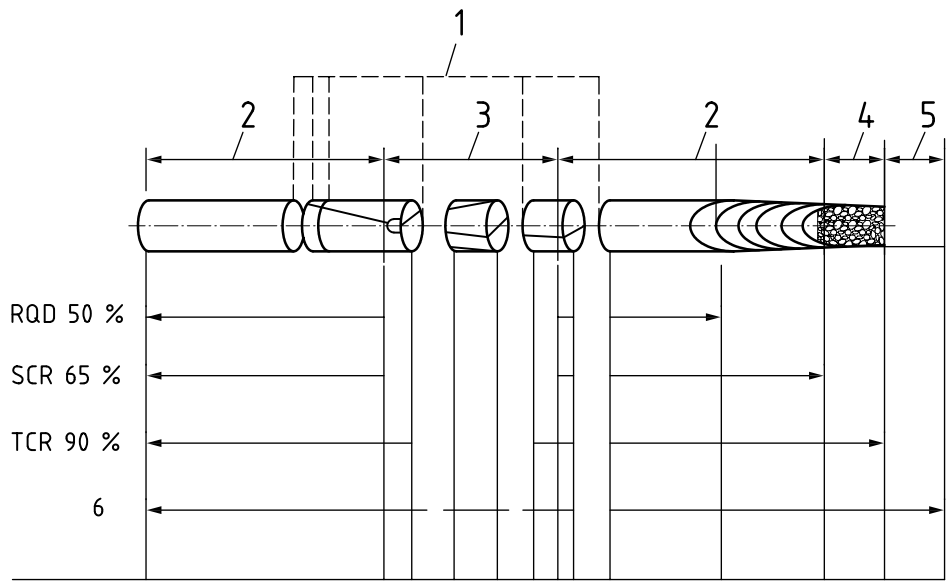
SCR

length of solid *core* (3.3.8) recovered in the *core run* (3.3.12), where solid core has at least one full diameter, expressed as a percentage of the length of the core run

Note 1 to entry: See Figure 2.

Note 2 to entry: 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 3 to entry: Core without at least one full diameter is termed non-intact.



Key

- | | |
|--------------------------------------|--|
| 1 drilling (3.1.5) induced fractures | RQD rock quality designation (3.3.17) |
| 2 at least one full diameter | SCR solid core recovery |
| 3 no single full diameter | TCR total core recovery in rock (3.3.16) |
| 4 non-intact | |
| 5 no recovery | |
| 6 core run | |

NOTE All features shown are natural discontinuities unless stated otherwise.

Figure 2 — Application of fracture state terms for rock cores

**3.3.19
sample recovery ratio in soil**

TC

ratio of the length of the sample (3.3.4) l_g to the length of the sample run H

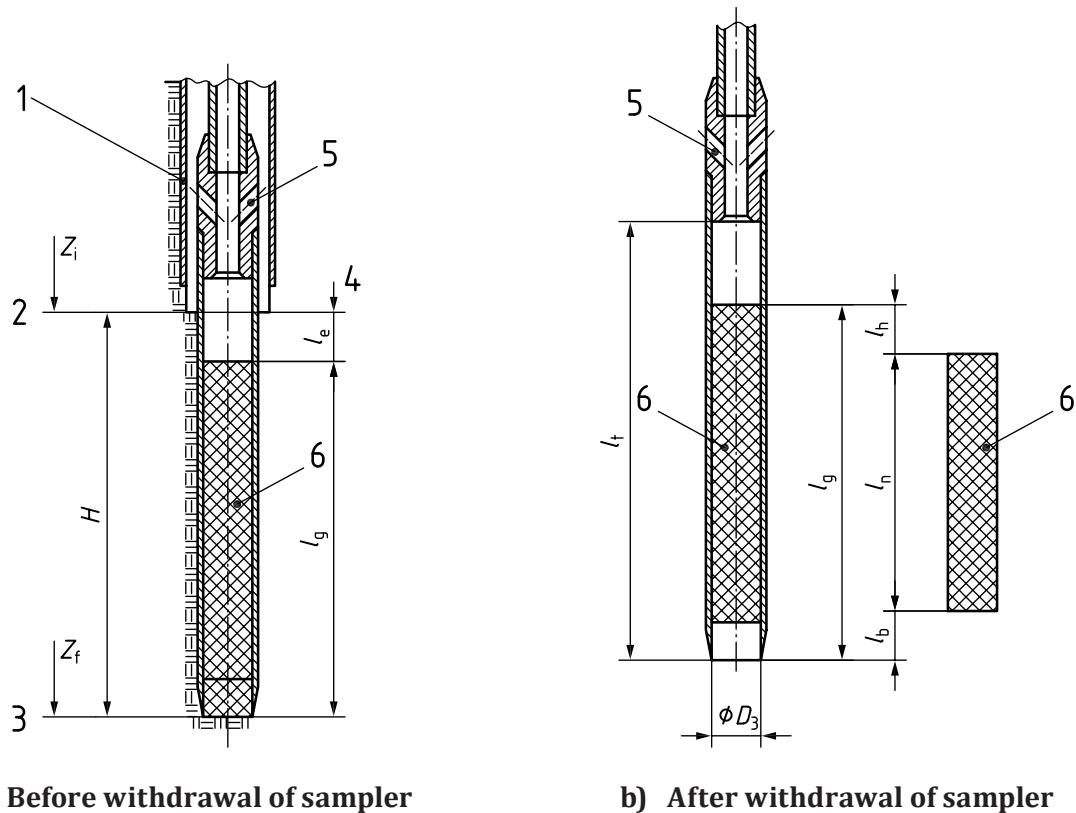
Note 1 to entry: See Figure 3.

**3.3.20
net sample recovery ratio**

IC

ratio of the net length of the sample (3.3.4) l_n to the length of the sample run H

Note 1 to entry: See Figure 3.



a) Before withdrawal of sampler

b) After withdrawal of sampler

Key

- | | | | |
|-------|--|-------|--|
| 1 | casing (3.2.4) | 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 (3.1.4) | 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 | the 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 with drawing the sampler | | |
| Z_i | depth under the natural ground level of the borehole bottom before sampling, and of the beginning of the following core run (3.3.12) | | |

Figure 3 — Lengths of core run and sample

3.3.21

thin-walled

<soil sampler> having a low *area ratio* (3.3.14), a low taper angle and a thin edge

3.3.22

thick-walled

<soil sampler> having an *area ratio* (3.3.14), taper angle and/or edge larger than that of a *thin-walled* (3.3.21) sampler

3.4 Rock and soil properties

3.4.1

structure

pattern of discontinuities in soil and rock mass which subdivides the mass into individual units

3.4.2

texture

size, shape and arrangement of the grains for soil and rock

3.5 Abbreviated terms

AS	disturbed sample from augering
B	bulk disturbed samples
BS	hand trimmed block sample
CP	cable percussion drilling
CPT	cone penetration testing
CS	rotary core sample
D	small disturbed sample
DLDS	Deltares large diameter sampler
DT	double tube drilling
GS	grab sample
HSAS	liner sample from hollow stem augering
LS	large samplers
OS	open-tube samplers
PE	percussion
PS	piston samplers
PU	pushed
RC	rotary coring
RO	rotary open holing
S-SPT	standard penetration test sampler
S-TP	disturbed sampling from trial pit
S-BB	sampling from borehole bottom
SN	resonance/sonic drilling
ST	single tube drilling
T/W	thin-walled
TK/W	thick-walled

TP	trial pitting
TT	triple tube drilling
WS	window sampler

4 Equipment

4.1 Requirements for the drilling rigs and equipment

Drilling rigs with appropriate stability, power and equipment such as drill rods, casing, core barrels 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.

If applicable, the drilling and sampling equipment shall be in accordance with ISO 3551-1, ISO 3552-1 and ISO 10097-1.

4.2 Drilling parameters

The drilling rig and equipment shall allow control of relevant drilling functions listed below. Following drilling parameters should be measured and recorded against depth, if required and applicable:

- drill head rotational torque (Nm);
- drill head rotational speed (rpm);
- 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).

NOTE Measuring while drilling is covered by ISO 22476-15.

4.3 Safety and special requirements

Precautions regarding the safety on the site and the safety of the working practices for the execution of boreholes, trial pits, heading and shafts shall be taken.

NOTE EN 16228-1 and EN 16228-2 deal with safety matters concerning drill rigs.

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 taken into consideration.

Trial pits, other excavations, headings and shafts shall be planned and executed under supervision. Slopes and walls can undergo sudden failure and shall be respected as such.

Excavations present gas and groundwater accumulation hazards, which shall also be considered in their planning and execution.

NOTE ISO 18400-103 provides general guidance on safety during sampling including on contaminated and potentially contaminated sites.

5 Procedures

5.1 General requirements for sampling

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

The type and extent of sampling shall be specified in advance according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing.

NOTE For further details see EN 1997-2.

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.

5.2 Selection of techniques and methods

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

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

A specific sampling category shall be selected in order to enable a required sample quality to be obtained in soil and rock (see [Table 1](#) and [Table 2](#)).

Different degrees of disturbance of the sample can be expected when using different sampling methods. The quality 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 types of 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.

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

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

5.3 Sampling categories for soil

5.3.1 General

Five sampling categories are defined for soil sampling. These represent the best practices that should be followed in order to match the quality of soil samples for suitable laboratory testing.

The best practices that should be followed by drilling for each sampling category can never guarantee that a certain quality is obtained as many factors can cause soil disturbance that are beyond the influence of the drilling.

5.3.2 Sample disturbance

Sample disturbance can cause a decrease in effective stress, a reduction in the inter-particle bonds, and a rearrangement of the soil particles, that determine the eventual quality of a soil sample.

NOTE An example for quality are given in [Annex H](#).

Soil sample disturbances can be caused by:

- hard pieces such as gravel, shell fragments or wood in the soil, which can cause voids to develop along the sides of the sampling tube during the sampling process;
- soil adjustment caused by stress relief when making a borehole;
- disruption of the soil structure due to rotation, hammering or pushing the sampling tube into the soil stratum;
- tensile and torsional stresses which are produced in separating the sample from the subsoil;
- creation of a partial or full vacuum below the sample as it is extracted from the subsoil;
- expansion of gas during retrieval of the sampling tube as the confining pressure is reduced to zero;
- roughly removing the soil from the sampling tube;
- time causing disturbance in sampling and laboratory analysis;
- handling, transportation and storage (see [Clause 9](#));
- crudely cutting the soil specimen to a specific size for a laboratory test;
- oxidation due to exposure to aerobic conditions;
- loss of soil moisture due to evaporation;
- geo-chemical processes due to temperature changes;
- physical disturbance due to freezing or damage of sampling containers;
- compaction and dewatering due to compression during sampling or extrusion of samples from sampling tubes;
- compaction and dewatering due to vibration during drilling, handling and transport;
- expansion due to pressure release at surface level.

It is recommended that laboratory testing be commenced as soon as practicable after sampling has taken place, as sample quality may suffer from long-term storage.

5.3.3 Category A sampling

The aim of category A sampling is to obtain samples in which structure, texture, consistency and in-situ stresses are intact. This would allow laboratory testing for strength, compressibility and stiffness.

As a practical matter, it should be recognized that no soil sample can be taken from the ground and be in a perfectly undisturbed state. For special conditions high class reference samples may be useful, e.g. liquefaction potential of loose coarse soils or strength of very soft clays or peat with high water contents near the soil surface. For soft clays block sampling techniques such as the Laval sampler, Sherbrooke sampler or Deltares large diameter sampler (DLDS) may be used to take representative samples. For very soft peat the DLDS sampler may be considered. For loose coarse soils ground freezing or gel push sampling may be considered. Details of these special samplers and techniques are presented in [C.15](#).

5.3.4 Category B sampling

The aim of category B sampling is to obtain samples in which the structure, texture and consistency are intact. This would allow laboratory testing such as permeability, porosity and density of fine soils and detailed layer boundary analyses.

5.3.5 Category C sampling

The aim of category C sampling is to obtain samples in which the structure and texture are intact. This would allow laboratory testing such as the determination of the water content.

NOTE 1 For loose coarse soils and silts this is difficult to achieve without additional preparation such as ground freezing or special sampling techniques. Usually, the sampling process disturbs the fabric of loose coarse soils, often increasing its packing and reducing its moisture content.

For very soft clays and peats near the soil surface with high water contents, care should also be taken to prevent compression, deformation and dewatering of the samples.

NOTE 2 Deviations of in-situ water content are expected in loose coarse soils, silt and peat. The presence and depth of loose coarse soils in a soil profile can often be determined by carrying out appropriate field testing in the vicinity before sampling.

NOTE 3 To avoid changes in soil moisture during handling, transport and storage, it could be considered to determine the water content of a soil layer or unconsolidated material on site. For this purpose, a sub sample with a known volume of material could be taken on site with minimal disturbance of the water content immediately after sampling. The weight of the material can be determined on site.

5.3.6 Category D sampling

The aim of category D sampling is to obtain samples in which the structure is intact. This would allow laboratory testing for particle size distribution and Atterberg limits as well as organic content.

NOTE For non-cohesive unconsolidated sands this means that all the fines are still contained in the sample. It is possible that secondary minerals such as glauconite or shells and calcareous skeletons have been crushed as a result of which the in-situ grain size distribution can deviate.

5.3.7 Category E sampling

The category E sampling only obtains samples where all the initial soil properties have changed is wholly or partially separated due to the drilling process. Typically, the fine grain content is missing. Furthermore, all initial soil properties have changed. Based on these samples only a rough indication of soil type, strata type and thickness (approximately 0,5 m) can be determined.

EXAMPLE Cuttings from rotary drilling or samples taken from a bailer during cable tool percussion drilling.

5.4 Sampling categories for rock

5.4.1 General

Five sampling categories are defined for rock sampling. These represent the best practices that should be followed in order to match the quality of rock samples for suitable laboratory testing.

The best practices that should be followed by drilling for each sampling category can never guarantee that a certain quality is obtained as many factors can cause rock disturbance.

5.4.2 Sampling disturbance

Sample disturbance can be ground-related whilst others relate directly to the drilling. Disturbances can be caused by:

- rock adjustment caused by stress relief when making a borehole;
- reduction in the inter-particle bonds;
- rearrangement of the rock grains;
- disruption of the rock structure due to rotation, hammering or pushing the sampling tube (core barrel) into the rock stratum;
- tensile and torsional stresses in separating the sample from the rock mass;
- inappropriate core size, core run length, core bit, flushing medium;
- inappropriate thrust and torque during drilling;
- removal of the rock from the sampling tube;
- time causing disturbance in sampling and laboratory analysis;
- handling, transportation and storage (see [Clause 9](#));
- crudely cutting the rock specimen to a specific size for a laboratory test;
- oxidation due to exposure to aerobic conditions;
- loss of moisture due to evaporation (more critical for mudstones);
- geo-chemical processes due to temperature changes and oxidation;
- physical disturbance due to freezing, heating or damage of sampling containers;
- compaction and dewatering due to vibration during drilling, handling and transport;

It is recommended that laboratory testing be commenced as soon as practicable after sampling has taken place, as sample quality may suffer from long-term storage.

Any combination of the factors listed above could cause a reduction in the achievable quality and so whilst category A sampling can be specified, in practice if inappropriate combinations of drilling equipment are employed, the sampling category achieved could be one or more classes lower.

5.4.3 Category A sampling

The aim of category A sampling is to obtain samples in which structure, texture, strength and in-situ stresses are intact. This would allow laboratory testing for strength, and deformation properties. In addition, category A sampling would allow discontinuities and RQD to be accurately assessed.

As a practical matter, it should be recognized that no rock sample can be taken from the ground and be in a perfectly undisturbed state. For special conditions high class reference samples may be useful. For example, in weak rocks block sampling techniques may be used to take representative samples.

5.4.4 Category B sampling

The aim of category B sampling is to obtain samples in which the structure and texture are intact. This would allow laboratory testing such as permeability, porosity and density of rock samples and detailed layer boundary analyses. It should be noted that category B sampling can also allow non-definitive strength determinations to be made via tests such as the point load test. In addition, category B sampling would also normally allow discontinuities and RQD to be accurately assessed.

5.4.5 Category C sampling

The aim of category C sampling is to obtain samples in which the overall rock structure and texture are intact. This would allow laboratory testing such as the determination of the water content. Fine strata boundaries and weathering should be discernible and in favourable circumstances (see 5.4.1) it may be possible to identify discontinuities.

5.4.6 Category D sampling

The aim of category D sampling is to obtain samples in which the overall material structure is intact, and in which mineralogical composition is unchanged. This would allow laboratory testing for thin sections and Atterberg limits. Layer succession and broad strata boundaries should be discernible.

5.4.7 Category E sampling

The category E sampling only obtains samples where all initial rock properties have changed due to the drilling process. Based on these samples only a rough indication of strata type and layer thickness (approximately 0,5 m) can be determined.

EXAMPLE Cuttings obtained from flush returns during rotary drilling.

5.5 Sampling in trial pits, other excavations, headings and shafts

Trial pits, other excavations, headings and shafts should be used to investigate the ground at a larger scale e.g. to get information on the composition, sequence, structure, geotechnical units, excavation circumstances and orientation of strata and possible rock surface.

Without groundwater lowering the depth is often limited to shallow depth above the groundwater table surface in permeable ground. Generally, test pits down to 5 m in depth can be carried out with ordinary available excavators. To reach larger depth special equipment is needed at sequenced excavation levels.

The following shall be determined and reported at least:

- geometry of the pit/excavation/heading/shaft;
- occurrence of very coarse material (cobbles and boulders);
- stratigraphy and recognised geological units;
- stability of excavated walls;
- inflow of groundwater and observed groundwater level.

5.6 Requirements for ground investigation sites and points

Ground investigation points on land shall be set out on the site before the investigation process commences. The "as-built" location and elevation shall be surveyed and indicated on a site plan on completion of the investigation.

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

Guidelines are given in ISO 18400-103. Unless deliberately located to investigate proposed foundation lines or existing foundations trial pits should be situated outside the planned foundation area as the excavation can loosen the ground. These 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.

Trial pits (with or without access), headings and shafts shall be constructed in accordance with appropriate national or international standards; national safety regulations shall be followed.

consideration. 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.

Visual logging, photographic evidence of the soil strata, sampling and field tests should be carried out during and immediately after excavation.

The environmental impact of drilling and sampling shall be considered. Special requirements may apply on some ground investigation sites, e.g. water supply areas, near water courses and when drilling into aquifers.

5.7 Preliminary information needed before starting sampling

At least the following preliminary information shall be available at the site before the sampling can start (see e.g. [Annex A, Table A.1](#)):

- a) objective of the sampling and groundwater measurements;
- b) location of the planned borehole or excavation or groundwater measurements;
- c) orientation, inclination and acceptable deviations in boreholes;
- d) surveying requirements;
- e) expected geological and hydrogeological conditions;
- f) required accuracy and uncertainty of measurements in accordance with ISO/IEC Guide 98-3, ISO/IEC Guide 98-3:2008/Suppl 1:2008 and ISO/IEC Guide 98-1;
- g) frequency of measurements;
- h) environmental and safety risks associated with e.g. flushing media or suspensions intended to be used as well as regulations for their use and possible presence of flammable, explosive or toxic gas underground mine workings or deposited wastes;
- i) possible risks, e.g. underground and overhead services, traffic, unexpected and unexploded ordnance, contamination;
- j) identification and planned depth of borehole and/or excavation;
- k) sampling method and category intended;
- l) requirements on numbering of boreholes, excavations or samples;
- m) sample handling, storage and transport intended;
- n) field tests intended;
- o) borehole or excavation completion method and site reinstatement (backfilling or grouting);
- p) environmental care;
- q) emergency arrangements;
- r) name of contact person;

5.8 Backfilling and site reinstatement

When sampling is completed the site shall be restored and no hazards shall be left which would be of potential harm to the public, the environment or animals. The backfilling shall be carried out taking into consideration national regulations, technical or authority requirements, the strata, contamination of the ground and its bearing capacity.

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.

Unless an exploratory hole is required to be kept open for a specific purpose, it should be backfilled and reinstated so as to minimise subsequent depression at ground level due to subsequent settlement to the backfill material.

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. Techniques which prevents voiding shall be used during the placement of the filling material in the borehole.

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.

6.1.3 There are five categories A to E of sampling methods for soil (see [Table 1](#)).

6.2 Sampling by drilling (continuous sampling)

6.2.1 General

6.2.1.1 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 1](#)) gives normally the most valuable information of the ground conditions of all ground investigation methods by drilling. Sampling by drilling is therefore the preferred sampling method for heterogeneously layered soils.

6.2.1.2 Drilling methods and equipment shall be selected as a function of the required sampling category (see [Table 1](#)), tests and/or groundwater measurements to be carried out in the borehole.

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

6.2.1.4 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, it shall be selected with

sufficient annular clearance and withdrawn slowly. An adequate water pressure shall be maintained in the borehole.

Table 1 — Sampling by drilling in soils

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment	Guideline values of borehole diameter range mm	Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by	Designation	Tool		Unsuitable for ^d	Preferred method for ^d		
	1	a	No	Drilling tool	Rotary dry core drilling ^c	Single-tube core barrel	100 to 200	coarse gravel, cobbles, boulders	clay, silt, fine sand, silt	D
b		Hollow stem auger with core barrel				100 to 300	clay, silt, sand, organic soils			
2	a	Yes	Drilling tool	Rotary core drilling	Single tube core barrel	100 to 200	coarse soils	clay, clayey and cemented composite soils, boulders	D C (A-B) A	—
	b				Double-tube core barrel ^a					
	c				Triple-tube core barrel ^a					

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

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NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

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Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Designation	Equipment		Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by		Tool	values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d		
3		Yes	Drilling tool	Rotary core drilling	Double/triple-tube core barrel with extended inner tube	100 to 200	gravel, cobbles, boulders	clay, silt	B (A)	—
4		No	Drilling tool	Auger drilling	Drill rods with shell or flight auger; hollow stem auger	100 to 2 000	boulders larger than $D_e/3$	all soils above water surface, all fine soils below water surface	D (C)	—
5		Yes	Reverse flow of flushing medium	Reverse circulation drilling	Drill rods with hollow chisel	150 to 300	—	all soils	E (D)	—

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

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Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Designation	Equipment		Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by		Tool	Guideline values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d		
6		No	Drilling tool	Auger drilling with light equipment	Shell auger or spiral flight auger	40 to 80	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; fine soils below water surface	E ^f	Only to be used for shallow depths
^a Conventional or wireline core barrel. ^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. ^d D_e is the internal diameter of the sampling tool. ^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases. ^f Sampling category D is sometimes possible in fine soils. ^g A method according to sampling category for coarse soils is given in Annex G . NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5. NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.										

Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Designation	Equipment		Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by		Tool	Guideline values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d		
7		No	Drilling tool	Percussive core drilling	Percussion clay cutter with cutting edge inside; also, with sleeve ^b	80 to 200	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 $D_e/3$	fine soil: B (A) coarse soil: C (B) ^g	Plotting of driving chart on the basis of number of impacts
8	Hammer driving	No	Drilling tool	Percussive drilling	Percussive clay cutter with cutting edge outside ^b	150 to 300	soils with a particle size larger than $D_e/3$	gravel and soils with a particle size up to $D_e/3$	D	
9		No	Drilling tool	Small diameter hammer driving	Hammer driving linkage with tube sampler (window)	30 to 80	soils with a particle size larger than $D_e/2$	soils with a particle size up to $D_e/5$	E ^f	Only to be used for shallow depths

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d		
10	Rotary hammer driving	Yes	Drilling tool	Rotary percussive drilling	Single- or double-tube core barrel	100 to 200	composite and pure sands with a particle size larger than 2,0 mm, gravel, firm and stiff clays	clay, silt, fine sand	fine soil: B (A) coarse soil: D (C)	—
11	Vibration drilling with an optional slow rotation	No (only for lowering casing)	Drilling tool	Resonance/sonic drilling	Thick wall sampler or single tube core barrel with optional lining tube	80 to 200	—	all soils	fine soil: D (C) coarse soil: D	—

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Designation	Equipment		Guideline for application and limitations ^d		Sampling categories ^e	Remarks
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by		Tool	Guideline values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d		
12	Percussion	No	Drilling tool	Cable percussion drilling	Cable with clay cutter	150 to 500	gravel above water surface, silt, sand and gravel below water surface	clay and silt above water surface, clay below water surface	D (C)	—
13		No	Drilling tool	Cable percussion drilling	Cable with shell bailer	100 to 1 000	recovery above water surface	gravel and sand in water	E (D)	Can also be used in fine soils if water is added
14	Pneumatic/hydraulic continuous thrust	No	Drilling tool	Small diameter pneumatic/hydraulic continuous thrust drilling	Pneumatic/hydraulic continuous thrust linkage, with tube sampler	30 to 80	dense and coarse-grained soils	clay, silt, fine sand	E ^f	Only to be used for shallow depths

^a Conventional or wireline core barrel.

^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.

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

^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

^f Sampling category D is sometimes possible in fine soils.

^g A method according to sampling category for coarse soils is given in [Annex G](#).

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

Table 1 (continued)

Column	1	2	3	4	5	6	7	8	9	10
Line	Soil cutting technique ^b	Drilling method			Equipment		Guideline for application and limitations ^d			Remarks
		Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for ^d	Preferred method for ^d	Sampling categories ^e	
15	Grabbing	No	Drilling tool	Grab drilling	Cable with grab	400 to 1 500	firm, fine soils, boulders of size larger than $D_e/2$	gravel, boulders of size less than $D_e/2$, cobbles	above water surface: D below water surface: E	—
^a Conventional or wireline core barrel. ^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. ^d D_e is the internal diameter of the sampling tool. ^e The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases. ^f Sampling category D is sometimes possible in fine soils. ^g A method according to sampling category for coarse soils is given in Annex G. NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5. NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.										

6.2.2 Sampling by rotary drilling

6.2.2.1 Sampling by rotary dry core drilling

6.2.2.1.1 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 a 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.

6.2.2.1.2 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 core drilling is generally unsuitable for sampling coarse gravel, cobbles and boulders.

6.2.2.2 Sampling by rotary core drilling

6.2.2.2.1 The equipment for sampling by rotary core drilling shall consist of a tube system fitted with a bit at its lower end which 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 may be used.

6.2.2.2.2 The single tube core barrel shall consist of a core tube with a bit at its lower end and a core barrel 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 should pass between the inside of the core tube and the recovered soil core continuously washing the length of the recovered sample.

6.2.2.2.3 The double tube core barrel shall consist of two concentric tubes and a bearing arrangement in the core barrel head which allows the inner tube to remain stationary whilst the outer tube is rotated by the drill string. A core lifter should be fitted between the core bit and the inner tube. The flushing medium shall pass through the annulus between the inner and outer tubes thus protecting the recovered core sample from damage. The double tube core barrel 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 should assist in improving core recovery in certain soil types and contain and protect the sample during transport. The double tube core barrel 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.

6.2.2.2.4 The triple tube core barrel is similar in construction to the double tube design but shall be fitted with an additional third tube within the inner tube as standard. This third tube should be a thin-walled 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 core barrel 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.

6.2.2.2.5 Sampling by rotary core drilling is generally suitable for clay, clayey and cemented composite soils and boulders; but it is unsuitable for all coarse soils.

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

6.2.2.3 Sampling by flight auger drilling

6.2.2.3.1 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.

6.2.2.3.2 With the continuous sampling method, the flights act as a screw conveyor and continuously can bring the cuttings to the surface. The rotation of the auger shall be permanent and the penetration can be easier with additive movements of going up and down. Additional sections of auger can be added until the required depth is reached. At the mouth of the borehole, the obtained samples are remoulded.

6.2.2.3.3 With the non-continuous sampling method, the flight auger can be 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 may 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.

6.2.2.3.4 Sampling by flight auger drilling shall be only used if the borehole is stable.

6.2.2.3.5 Sampling by flight auger drilling is suitable for fine soils and soils above the groundwater surface.

6.2.2.4 Sampling by shell auger drilling

6.2.2.4.1 In sampling by shell auger drilling, a shell auger shall be used as the sampling tool. The auger shall be screwed into the soil with the penetration rate suitable for the auger rotational speed. The sampling length into the soil may 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.

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

6.2.2.4.3 Sampling by shell auger drilling is suitable for fine soils and clay to medium gravel above groundwater surface.

6.2.2.5 Sampling by reverse circulation drilling

6.2.2.5.1 In sampling by reverse circulation drilling, the flushing fluid shall pass 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. In certain cases, duplex drill rods can be used to protect the borehole wall.

6.2.2.5.2 The borehole diameter should be between 150 mm and 300 mm.

6.2.2.5.3 This sampling technique is suitable for all soils.

6.2.3 Sampling by use of hammer driving methods

6.2.3.1 Sampling by percussive drilling

In sampling by percussive drilling, a clay cutter tube device with an internal cutting edge at the lower end shall be 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 $D_e/3$, where D_e is the internal diameter of the sampling tool, and with a borehole diameter up to 300 mm. The sample shall be retained within the clay cutter by a suitable retainer.

6.2.3.2 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 shall be 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 shall be retained within the clay cutter tube.

6.2.4 Sampling by cable percussion drilling

6.2.4.1 In sampling by cable percussion drilling, a tool string comprising sampling, drilling or bailing tools shall be attached to the drilling line (wire rope), which passes over a crown sheave at the top of the tripod/mast structure and then to a winch drum on the base unit. The tool string shall be raised by the winch and dropped by freefall action causing crushing and fragmentation of the formation and loosening of unconsolidated soils in the borehole being drilled.

6.2.4.2 The tools used when drilling by cable percussion in fine soils shall comprise a clay cutter or stubber and in coarse soils shall comprise a shell (bailer). These are used in conjunction with one or two additional weights (sinker bars). Chiselling may be used to penetrate boulders and other hard obstructions such as concrete and to prove the presence of harder formations at the base of a borehole.

6.2.4.3 Samplers used when sampling by cable percussion are typically driven thick-walled or thin-walled open tube samplers.

6.2.4.4 When drilling in silts, sands and gravels the water level in the casing shall be higher than the water level in the surrounding soil outside the casing to minimise soil disturbance.

6.2.5 Sampling by hollow stem auger drilling

6.2.5.1 In sampling by hollow stem auger drilling, the hollow stem auger which shall consist 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 [6.2.2.3](#)). Additional sections of hollow stem auger may be added till the required depth is reached.

6.2.5.2 Once the required depth is reached, a sampling system or core barrel 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.

6.2.6 Sampling by grab drilling

6.2.6.1 In sampling by grab drilling, the sampling tool shall be a cable with grab.

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

6.2.6.3 This sampling technique is the preferred method for gravel, cobbles and boulders of size less than $D_e/2$. It is unsuitable for firm, fine soils, boulders of size larger than $D_e/2$.

6.2.7 Soil sampling by small diameter drilling

6.2.7.1 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 1](#) can be used.

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

6.2.7.3 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.

6.2.7.4 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.

6.2.8 Sampling by resonance drilling

In sampling by resonance (sonic) drilling, a tube fitted with a bit at its lower end shall be fed into the soil or rock by vibration of a frequency variable from 30 Hz to 150 Hz. The frequency shall be adjusted appropriate to the depth of the borehole and the formation being drilled such that optimum resonance is maintained at all times. When the penetration rate is too low the core barrel can be rotated in order to distribute the resonant energy evenly. The core barrel can be equipped with a plastic lining tube.

Dedicated samplers may also be incorporated into the drilling technique and advanced solely by either static or dynamic means, without the use of resonance.

6.3 Sampling using samplers

6.3.1 General

6.3.1.1 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.

6.3.1.2 Depending on the soil conditions, different samplers can be used (see [Table 2](#), see [Annex D](#)). Usually sampling with samplers can be 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.

6.3.1.3 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.

6.3.1.4 Drilling of the casing with percussion is not allowed to the full depth in case of category A sampling when the water level or fluid pressure in the borehole is lower than in the surrounding soil.

6.3.1.5 If a casing is used in sensitive clays, it may 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.

6.3.1.6 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.

6.3.1.7 Before taking undisturbed samples from borehole bottom, any loose or disturbed material shall be removed. In 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 2 — Tube and block samplers

Column	1	2	3	4	5	6	7
Line	Type of sampler	Preferred sample dimensions		Technique used	Applications and limitations		Sampling category for soils as in column 6 ^a
		Diameter mm	Length mm		Unsuitable for	Recommended for use in	
1	thin-walled (OS-T/W)	70 to 120	250 to 1 000	static or dynamic	gravel, loose sand below water surface, firm fine soils, soils including coarse particles	fine or organic soils of soft to stiff consistency (medium) dense sand below water surface fine or organic soils of very stiff consistency	A C (B) B (A)
2	thick-walled ^b (OS-TK/W)	>75	250 to 1 000	dynamic	gravel, sand below water surface, very soft and very stiff fine or organic soils, soils including coarse particles	fine or organic soils of soft to stiff consistency, and including coarse particles	C (B)
3	thin-walled (PS-T/W)	50 to 100	600 to 1 000	static	gravel, very loose and dense sands, very stiff fine or organic soils, soils including coarse particles	fine or organic soils of very soft or stiff consistency, and sensitive soils	A C
4	thick-walled (PS-TK/W)	50 to 100	600 to 1 000	static	gravel, sand below water surface, soft and very stiff fine or organic soils, soils including coarse particles	fine or organic soils of soft to stiff consistency, and sensitive soils	B (A)
Key OS-T/W open-tube samplers, thin-walled OS-TK/W open-tube samplers, thick-walled PS-T/W piston samplers thin-walled PS-TK/W piston samplers thick-walled TS large sampler SPT SPT sampler If the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – the higher quality indicated in the brackets can be achieved. Includes windowless samplers.							

Table 2 (continued)

Column	1	2	3	4	5	6	7
Line	Type of sampler	Preferred sample dimensions		Technique used	Applications and limitations		Sampling category for soils as in column 6 ^a
		Diameter mm	Length mm		Unsuitable for	Recommended for use in	
5	cylinder (LS)	250	350	static or rotating	sand	clay, silt	A
6	cylinder (S-SPT)	35	450	dynamic	coarse gravel, boulders	sand, silt, clays	D
7	windowless	44 to 120	500 or 2 000	static or dynamic	sand, gravel	silt, clay	D (C)
Key OS-T/W open-tube samplers, thin-walled OS-TK/W open-tube samplers, thick-walled PS-T/W piston samplers thin-walled PS-TK/W piston samplers thick-walled LS large sampler S-SPT SPT sampler ^a If the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – the higher quality indicated in the brackets can be achieved. ^b Includes windowless samplers.							

6.3.2 Sampling using the open-tube sampler and the piston sampler

6.3.2.1 General

For recovering samples from boreholes in fine, sandy and organic soils, open-tube or piston samplers can be used. These samplers should 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 open tube sampler can be pushed directly into soft to stiff soil.

6.3.2.2 General geometry

6.3.2.2.1 Tube inner diameters should be between 50 mm and 120 mm, 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.

6.3.2.2.2 The sampling tube length should preferably be not greater than 10 times the sample diameter. An effective sampling length of 0,45 m to 1,00 m should be sufficient for ordinary soil testing. Longer tubes may be used if friction reducing systems are applied.

6.3.2.3 Detailed geometry

6.3.2.3.1 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.

6.3.2.3.2 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 , should be less than 15 %;
- c) taper angles between 5° and 15° and area ratios up to 25 % may be considered, but a reduction in sample quality may result;
- 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 maximum inside clearance ratio C_i of 0,5 %. When assessing the inside clearance, the worst case of manufacturing tolerances shall be applied.

6.3.2.4 Preparation of tubes

6.3.2.4.1 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.

6.3.2.4.2 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, may not be used.

6.3.2.5 Field procedure

6.3.2.5.1 The sampler shall be pushed or driven into the soil (see column 4 of [Table 2](#)). If dynamic driving is used, either by a drop weight, sliding hammer or percussive head, the number of blows should be kept to a minimum. Thin wall tube samplers should be pushed into the soil by continuous static thrust. All open tube samplers which are dynamically driven create disturbance within the sample leading to a reduction in the sample quality, particularly in fine and sensitive soils. This influence shall be considered when the field procedure is chosen.

6.3.2.5.2 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.

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

6.3.2.5.4 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.

6.3.2.5.5 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 to 20 min so that sufficient adhesion is developed between the sample and the sampling tube or liner.

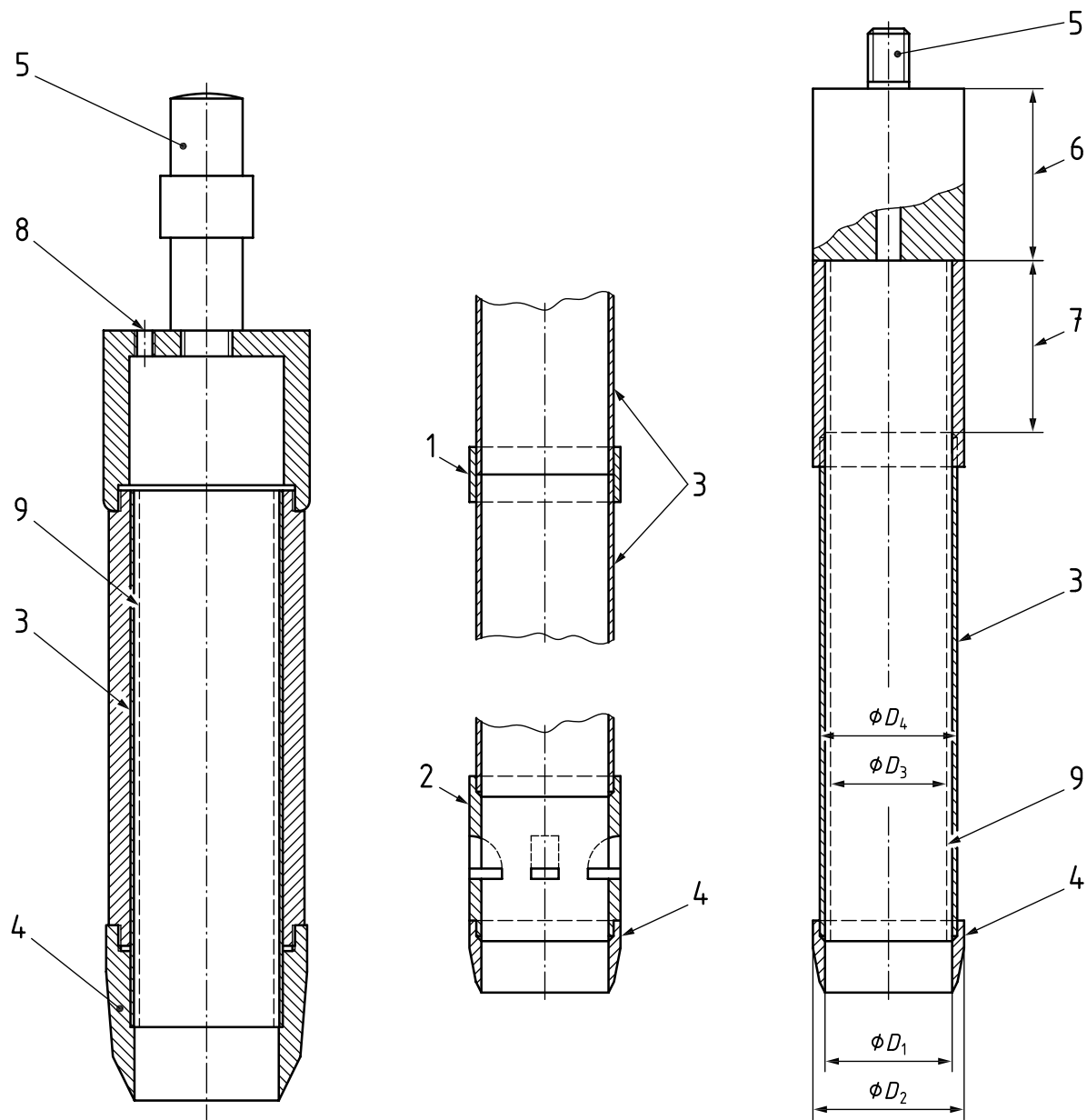
6.3.2.5.6 After withdrawal the sampler should be disassembled and, if necessary, the samples should be carefully extracted without any bending or torsion. The sampling tube and the cutting edge should be checked for any deformations. Any such deformations should be noted in the sampling record. The occurrence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

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

6.3.2.6 Sampling using the open-tube sampler

6.3.2.6.1 In addition to the components mentioned in [6.3.2.3](#), open-tube samplers (OS) consist of a sampler tube with overdrive space and a sampler head with non-return valve tube. An overdrive space into which the softened material in the borehole can pass shall be provided. 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 overdrive space.

6.3.2.6.2 Windowless samplers may also be used to sample fine soils. The windowless sampler is generally a category C or D sampler in fine soils.



a) Schematic thick-walled open-tube sampler b) Schematic thin-walled open-tube sampler

Key

- | | |
|---|---|
| D_1 inside diameter of the cutting shoe | 3 sample tube |
| D_2 greatest outside diameter of the cutting shoe | 4 cutting shoe |
| D_3 inside diameter of the sample tube or liner | 5 connection to drilling rods or sliding hammer |
| D_4 outside diameter of the sample tube | 6 non-return valve |
| 1 screw socket | 7 overdrive space |
| 2 sample retainer | 8 valve |
| | 9 liner (optional) |

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

6.3.2.6.3 The sampling using the thin-walled open-tube sampler is usually regarded as category A to C sampling method depending on the soil conditions and whether the sampler is pushed or dynamically driven before (see Table 2).

6.3.2.6.4 Thick-walled open-tube samplers should be used for stiff and dense soils and for soils containing coarse particles (see line 2 of [Table 2](#)). For soil types that are difficult to sample, sample retaining or closure devices should be used.

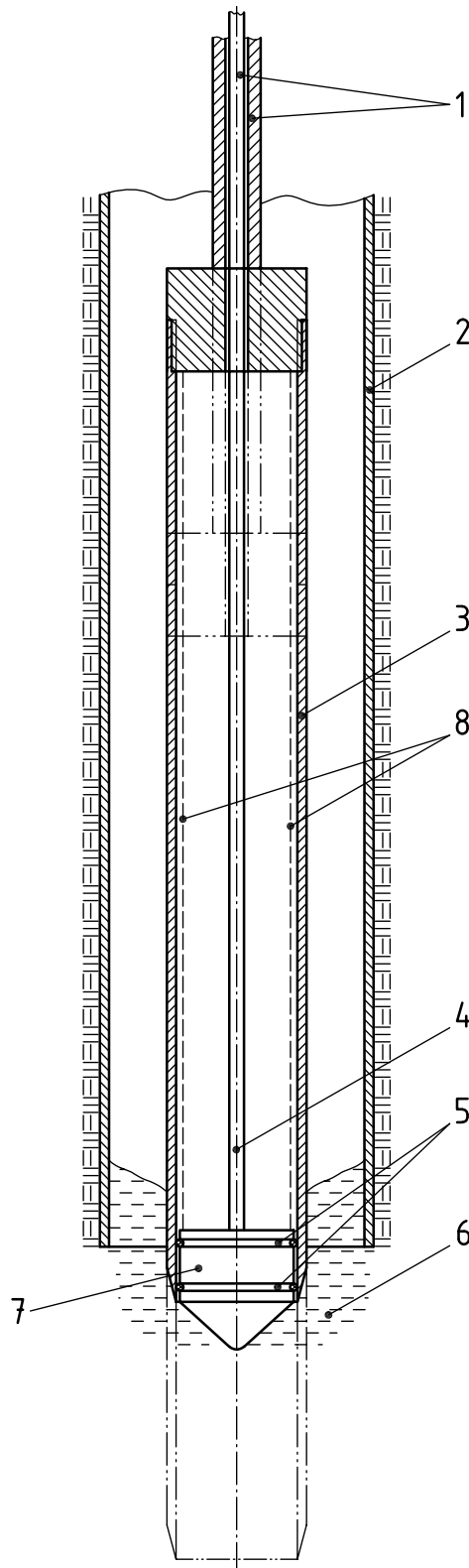
6.3.2.6.5 The thick-walled open-tube sampler can be usually regarded as a category C sampling method.

6.3.2.7 Sampling using the piston sampler

6.3.2.7.1 The piston sampler can be used in low strength fine soils like silt and clay, including sensitive clays. The method can be used either in boreholes or be pushed directly into the soil.

6.3.2.7.2 The piston sampler shall consist of a sample tube containing a close-fitting sliding piston, which is slightly coned at its lower face. The sample tube shall be fitted to the sampler head, whereas the piston is fixed to separate rods. This shall pass through a sliding joint in the sampler head and up inside the drill rods. Clamping devices, operated at ground level, shall 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.

6.3.2.7.3 Sampling using the piston sampler should be regarded as a category A or B sampling method (see [Table 2](#)). In certain circumstances, the piston sampler can be used in sands by use of an appropriate core lifter. The sampling category in this case should be regarded as a category C 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
- 2 casing
- 3 sample tube
- 4 vent
- 5 sealing ring

- 6 disturbed soil
- 7 piston
- 8 liner (optional)

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

6.3.3 Sampling using the standard penetration test sampler

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

6.3.3.2 The sampling using the standard penetration test sampler can be usually used as category D sampling method (see [Table 2](#)). In certain homogenous fine-grained soils it can also be used as a category C sampling method.

6.3.4 Sampling by using the window sampler

6.3.4.1 Window samplers consist 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 and 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 shall be removed from the window (see [Annex C](#)).

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

6.3.4.3 The sampling using the window sampler can be usually used as category D sampling method, locally category C (see [Table 2](#)).

6.3.5 Sampling using the windowless sampler

6.3.5.1 Windowless samplers consist of a hollow tube containing a plastic liner, fitted with a shoe having a sharp cutting edge at its lower end and a pressure release valve or mechanism at its upper end. They are used to take samples by the application of static thrust or dynamic impact. After driving and removal from the soil, the cutting shoe is removed, the plastic liner extracted from the tube and the liner cut open to access the sample. In loose or soft soils, a sample retainer can be fitted between the hollow tube and the cutting shoe.

6.3.5.2 The sampling using the windowless sampler can be usually used as category D sampling method, locally category C (see [Table 2](#)).

6.4 Block sampling

6.4.1 Sampling from trial pits

6.4.1.1 In sampling from a trial pit, a sampler with cutting procedure should be used or block samples should be recovered.