

BS EN ISO 22282-1:2012



BSI Standards Publication

# Geotechnical investigation and testing — Geohydraulic testing

## Part 1: General rules

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### National foreword

This British Standard is the UK implementation of EN ISO 22282-1:2012. Together with parts 2, 3, 4, 5, and 6 of BS EN ISO 22282, it partially supersedes BS 5930:1999+A2:2010, which is currently being revised in order to remove conflicting material. In the meantime, where conflict arises between these documents, the provisions of BS EN ISO 22282-1:2012 take precedence.

The test given in this standard is included in BS 5930:1999+A2:2010 (Clause 25.4), and conflicting parts are now withdrawn.

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 this subcommittee 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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## Foreword

This document (EN ISO 22282-1:2012) 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of an identical text or by endorsement, at the latest by December 2012, and conflicting national standards shall be withdrawn at the latest by December 2012.

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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 22282-1 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 22282 consists of the following parts, under the general title *Geotechnical investigation and testing — Geohydraulic testing*:

- *Part 1: General rules*
- *Part 2: Water permeability tests in a borehole using open systems*
- *Part 3: Water pressure tests in rock*
- *Part 4: Pumping tests*
- *Part 5: Infiltrometer tests*
- *Part 6: Water permeability tests in a borehole using closed systems*

## Introduction

The EU water directive requires the member states to increase activities that protect groundwater and fresh surface water both quantitatively and qualitatively<sup>[11]</sup>. At the same time, society requires more water and thus more construction projects below groundwater level in even deeper waters. In addition, the sea level may rise as a result of climate change. This contradiction requires engineers working on construction projects below groundwater level to make more reliable predictions on the effects of such structures on the groundwater conditions. This can partly be achieved by better assessment of the permeability of the ground by *in situ* tests as required in EN 1997-1:2004, 3.3.9.1. EN 1997-2:2007 contains the following stipulations, requirements and recommendations:

“2.1.4 Groundwater –

(1) Groundwater investigations shall provide all relevant information on groundwater needed for geotechnical design and construction.

(2) Groundwater investigations should provide, when appropriate, information on:

- the depth, thickness, extent and permeability of water-bearing strata in the ground, and joint systems in rock;
- the elevation of the groundwater surface or piezometric surface of aquifers and their variation over time and actual groundwater levels including possible extreme levels and their periods of recurrence;
- the pore water pressure distribution;
- the chemical composition and temperature of groundwater.

(3) The information obtained should be sufficient to assess the following aspects, where relevant:

- the scope for and nature of groundwater lowering work;
- possible harmful effects of the groundwater on excavations or on slopes (e.g. risk of hydraulic failure, excessive seepage pressure or erosion);
- any measures necessary to protect the structure (e.g. water proofing, drainage and measures against aggressive water);
- effects of groundwater lowering, desiccation, impounding, etc. on the surroundings;
- the capacity of the ground to absorb water injected during construction work;
- whether it is possible to use local groundwater, given its chemical constitution, for construction purposes.”





# Geotechnical investigation and testing — Geohydraulic testing —

## Part 1: General rules

### 1 Scope

This part of ISO 22282 establishes the general rules and principles for geohydraulic testing in soil and rock as part of the geotechnical investigation services in accordance with EN 1997-1 and EN 1997-2. It defines concepts and specifies requirements relating to permeability measurement in soil and rock.

The different purposes of geohydraulic testing are to obtain information on the permeability of soil or rock in natural or treated states, transmissivity and storage coefficient, and hydrodynamic parameters of aquifers.

Geohydraulic testing is used for many purposes, such as:

- a) absorption capacity and effectiveness of grouting in rock mass;
- b) assessment of seepage and drainage;
- c) assessment of groundwater lowering work;
- d) effects of cut-offs for dams;
- e) effects of tunnels and shaft sinking;
- f) checking fill or cover tightness;
- g) assessment of the flow of fluids and suspensions in the ground;
- h) planning for remedial measures.

NOTE 1 Geohydraulic testing for water supply is covered by ISO 14686.

NOTE 2 For most types of ground, field permeability tests yield more reliable data than those carried out in the laboratory, because a larger volume of material is tested, and because the ground is tested *in situ*, thereby including effects resulting from the structure of the ground mass but avoiding the disturbance associated with sampling.

This part of ISO 22282 deals with the execution of tests with groundwater and does not explicitly consider other fluids and suspensions. The flow of other fluids and suspensions can be considered by applying the different viscosities and relations between transmissivity, permeability coefficient and intrinsic permeability.

### 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.

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 22282-2, *Geotechnical investigation and testing — Geohydraulic testing — Part 2: Water permeability tests in a borehole using open systems*

ISO 22282-3, *Geotechnical investigation and testing — Geohydraulic testing — Part 3: Water pressure tests in rock*

ISO 22282-4, *Geotechnical investigation and testing — Geohydraulic testing — Part 4: Pumping tests*

ISO 22282-5, *Geotechnical investigation and testing — Geohydraulic testing — Part 5: Infiltrometer tests*

ISO 22282-6, *Geotechnical investigation and testing — Geohydraulic testing — Part 6: Water permeability tests in a borehole using closed systems*

ISO 22475-1:2006, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution*

EN 1990, *Eurocode: Basis of structural design*

EN 1997-1:2004, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 1997-2:2007, *Eurocode 7: Geotechnical design — Part 2: Ground investigation and testing*

### 3 Terms, definitions and symbols

#### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990, EN 1997-1, EN 1997-2, and ISO 22475-1 and the following apply.

##### 3.1.1

##### **flow rate**

volume of water added or discharged from the test section per time unit

##### 3.1.2

##### **hydraulic head**

sum of position head (elevation) and pressure head

##### 3.1.3

##### **test section**

section in a borehole where the test is carried out

##### 3.1.4

##### **skin effect**

effect of the wall of the test section on the test

##### 3.1.5

##### **permeability coefficient**

flow rate divided by area

##### 3.1.6

##### **transmissivity**

product of permeability coefficient and thickness of saturated aquifer

##### 3.1.7

##### **storage coefficient**

volume of water stored or released from a column of aquifer with unit cross-section under unit hydraulic head variation

##### 3.1.8

##### **steady state**

state when hydraulic head and the flow rate are constant with time

##### 3.1.9

##### **transient state**

state prior to the steady state when the flow rate or hydraulic head is not constant with time

**3.1.10**

**saturated condition**

condition of the tested ground with all voids filled with water

**3.1.11**

**unsaturated condition**

condition of the tested ground with voids partially filled with water and partially filled with air or another gas

**3.1.12**

**rising head test**

test where the pressure or head in the test section is initially decreased and the rising is recorded

**3.1.13**

**falling head test**

test where the pressure or head in the test section is initially increased and the falling is recorded

**3.1.14**

**variable head test**

rising or falling head test

**3.1.15**

**constant head test**

test where the pressure or head in the test section is kept constant and the change in inflow or outflow is recorded

**3.1.16**

**constant rate test**

test where the flow rate in the test section is kept constant and change in pressure or head is recorded

**3.1.17**

**mud cake**

solids deposited on the filter pack or the borehole wall

**3.1.18**

**clogging**

decrease of flow rate by blocking of flow paths due to sedimentation

**3.1.19**

**washing**

increase of flow rate by widening or opening of flow paths due to erosion

**3.1.20**

**shape factor**

model factor used for the interpretation of the test results

### 3.2 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

**Table 1 — Symbols**

Symbol	Designation	Unit
$A_c$	area of the inner cross-section of the casing	$m^2$
$A_m$	area of the inner cross-section of the measuring tube	$m^2$
$A_r$	area of the water surface in the reservoir	$m^2$
$D$	borehole diameter, diameter of the test section	m
$d$	thickness of aquifer	m
$F$	shape factor	m
$h$	hydraulic head	m
$h_o$	distance of the water surface from ground level	m
$h_1, h_2, h_3$	applied hydraulic heads	m
$\Delta h$	change in hydraulic head	m
$k$	permeability coefficient	$m\ s^{-1}$
$K$	intrinsic permeability	$m^2$
$L$	length (height) of the test section	m
$p$	pressure	kPa
$Q$	flow rate	$m^3\ s^{-1}$
$Q_1, Q_2, Q_3$	flow rate at test 1, 2 and 3	$m^3\ s^{-1}$
$S$	storage coefficient	1
$T$	transmissivity	$m^2\ s^{-1}$
$t$	time	s
$t_i$	time needed to reach the equilibrium	s
$t_o$	time at start of test	s
$V$	volume	$m^3$
$\eta$	dynamic viscosity of the fluid	Pa s
$\gamma$	density	$kgm^{-3}$

## 4 Equipment

### 4.1 General

According to the different test methods, the apparatus can comprise the following elements:

- test section support system;
- measuring tube;
- isolation of the test section;
- measuring and recording devices;
- additional equipment.

## 4.2 Test section support system

A system for supporting the test section shall be used for tests conducted in soil or rock which do not maintain the geometry of the test section throughout the test.

A filter or a gravel pack may be used to support the test section. The filter pack shall be stable against the surrounding ground and the sealing.

The filter material shall be a granular material selected to avoid plugging and/or erosion of the soil particles from or into the surrounding ground. The permeability of the filter material shall be considerably higher than the expected value of the permeability of the ground and shall not affect the test results.

A chemical effect between the filter material and the water shall be avoided.

## 4.3 Measuring tube

A measuring tube of known cross-section should be used to connect the test section to the ground surface. The tube shall not be deformed due to the applied hydraulic head. The measurement tube elements shall be chosen to give a minimum number of joints to minimize leakage. Their diameter shall be adapted to the rate of water level variation.

A valve may be provided on this measuring tube to allow isolation of the test section or establish contact with the atmosphere. The closing or opening of this valve shall not induce a change in volume which can lead to a change of the water pressure. Such changes can influence the quality of the test.

## 4.4 Isolation of the test section

The test section can be isolated either by:

- the casing;
- a sealing plug;
- single packer;
- double or multiple packers.

NOTE See Annex A.

A packer is a high pressure expanding element which is inflated, for example by compressed air and tightly pressed against the borehole wall to provide a seal. The sealed length shall depend on the evenness of the borehole wall and the soil and rock type to avoid leakage around the packer. The length of a packer shall be at least five times the borehole diameter when inflated to a minimum of 0,5 m. The effective pressure of the packer on the borehole wall shall be at least 30 % higher than the maximum test pressure.

Single packers only seal at the top of a test section, while double or multiple packers can also seal at the bottom. Special attention shall be paid to the detection of leakage of the packers, especially to potential leakage of the lower packer inflation line in the test section.

The packer shall be strong enough to resist the inflating pressure with no creep and homogeneous enough to avoid any perforation of the membrane.

## 4.5 Measuring and recording devices

### 4.5.1 Measuring devices for water level

The changes in water levels can be measured:

- by using a mechanical measuring tape with sounding device or an electrical measuring tape (water level meter);
- by using a float system;

- by using a pressure transducer system.

NOTE Rapid changes in depth are measured with greater accuracy with pressure sensing devices since they are able to detect the changes more rapidly than a float. Floats lose most of their accuracy from cable friction along the well walls.

#### 4.5.2 Measuring devices for flow rate

The changes in flow rate shall be measured:

- by using a flow meter;
- by using a calibrated container.

#### 4.5.3 Recording devices

The recording shall be carried out:

- manually;
- analogly;
- digitally.

#### 4.6 Additional equipment

Depending on the kind of test and the possible impact of local conditions, additional equipment shall be used in order to be able to make corrections for variations in water temperature and atmospheric pressure.

#### 4.7 Calibration

The instruments and devices used for geohydraulic testing shall be regularly calibrated according to manufacturers' manuals and relevant standards. Before starting the test, it shall be checked that the instruments and devices to be used have been calibrated. The calibration shall be recorded and documented and the results added to the test report as in ISO 22475-1:2006, 10.1.

### 5 Planning of geohydraulic investigation and testing

#### 5.1 General

Geohydraulic investigations shall be planned in such a way as to ensure that relevant geological and hydrogeological information and data are available at the various stages of the project. This information shall be adequate to manage identified and anticipated project risks. For intermediate and final project stages, information and data shall be provided to cover risks of accidents, delays, damages and pollution.

The aims of geohydraulic investigations are to establish the groundwater conditions, to determine the hydraulic properties of the ground, and to gather additional relevant knowledge about the site.

Before starting a geohydraulic investigation the geology and hydrogeology of the area to be investigated shall be characterized as preliminary information, such as:

- identification of soil and rock according to ISO 14688-1 and ISO 14689-1;
- identification of the aquifers and aquifer types (e.g. confined or unconfined);
- estimated permeability;
- the groundwater level(s).

Geohydraulic investigations should consider any activity which may influence the test or may be affected by the test, such as:

- a) existing constructions, e.g. buildings, bridges, tunnels;
- b) water lowering or de-watering;
- c) discharge of potable water.

The geohydraulic investigation programme should be reviewed as the results become available so that the initial assumptions can be checked.

The geohydraulic investigation programme shall contain:

- a plan with the locations of testing and the types of the tests;
- the depth and length of the test sections;
- specifications on the test procedures and measurements;
- the types of equipment to be used;
- the standards to be applied.

## 5.2 Selection of testing locations

The locations of testing and the depths of the test sections shall be selected on the basis of the preliminary information as a function of the geological and hydrogeological conditions, the dimensions of the structure and the engineering problems involved.

The test section shall be representative for the hydraulic head and the homogeneity of the ground.

When selecting the testing locations, the following should be observed:

- the testing and measuring points should be arranged in such a pattern that the geohydraulic conditions can be assessed over the investigation area;
- the area considered in the design investigations should extend into the neighbouring area to a distance where no harmful influence on the neighbouring area is expected;
- for testing and measuring points, the possibility of using the test equipment installed (during the ground investigation) for continued monitoring should be considered.

The depth and length of test sections shall be extended to all strata that will affect the project or are affected by it.

## 5.3 Selection of test procedure

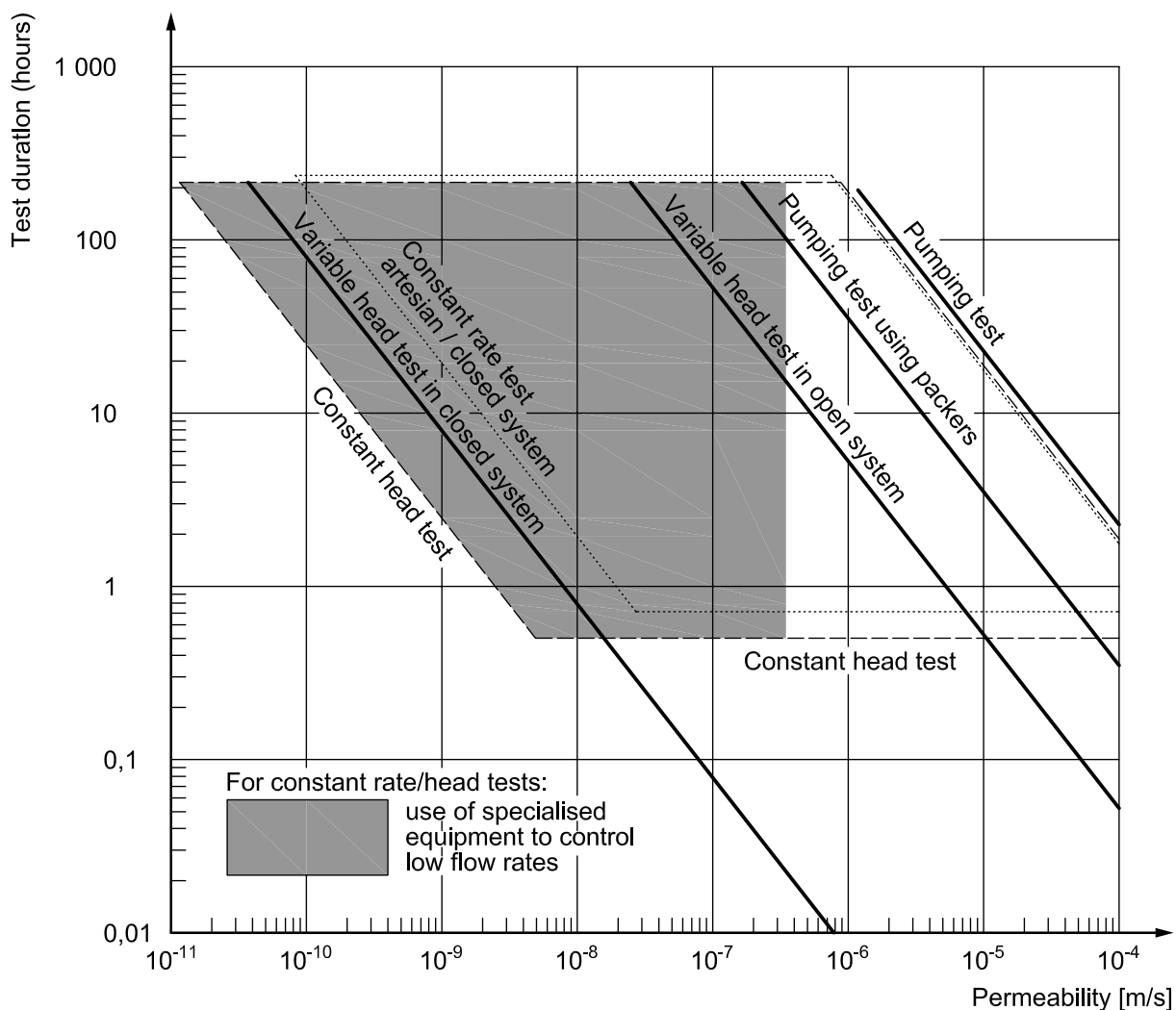
### 5.3.1 General

The test procedure shall be selected based on:

- ground conditions (e.g. expected permeability of the different layers);
- topographic and geomorphologic conditions;
- type of equipment.

Table 2 indicates relevant test procedures for different ground conditions and expected permeability and radius of influence.

Figure 1 indicates relevant test procedures and expected time of duration as a function of the expected ground permeability.



Variable head test in open systems according to ISO 22282-2.  
 Pumping test according to ISO 22282-4.  
 Variable head test in closed systems according to ISO 22282-6.

**Figure 1 — Test duration and permeability**

Due to the boundary condition, the appropriate test method shall be selected as follows:

- water permeability test in a borehole using open systems according to ISO 22282-2;
- water pressure test in rocks according to ISO 22282-3;
- pumping tests according to ISO 22282-4;
- infiltrometer tests according to ISO 22282-5;
- water permeability tests in a borehole using closed systems according to ISO 22282-6.

Tests can be carried out by withdrawing or by injecting water in the ground.

These tests can be carried out:

- by maintaining a constant head and monitoring the flow rate;
- by applying a constant flow rate and monitoring the pressure development;



— by lowering or raising the head (variable head) and monitoring the change of hydraulic head in the test section.

Some effects which may influence the test results can only be detected during the test execution. Such effects are:

- turbulent flow;
- hydraulic fracturing of rock or soil or hydraulic jacking of discontinuities.

These possible effects shall be considered.

In case of unstable borehole walls in rock, tests can only be carried out following the drilling process (such as single packer tests from the bottom of the casing against the borehole bottom).

Table 2 — Recommended applicability for different test procedures


Key  Recommended	Permeability tests using open systems ISO 22282-2			Water pressure tests in rock ISO 22282-3		Pumping tests ISO 22282-4	Infiltrometer tests ISO 22282-5		Permeability tests using closed systems ISO 22282-6	
	Constant flow	Variable head	Constant head	Upward test	Downward test	Pumping test	Constant head	Variable head	Pressure pulse test	
Purpose of test	2A	2B	2C	3A	3B	4	5A	5B	6	
Hydraulic barrier										
Fine soil										
Sand										
Gravel										
Mixed soils										
Rock with discontinuities (ISO 14689-1)										
Spacing	Aperture									
	Tight									
Wide	Open									
	Wide									
Medium	Tight									
	Open									
Close	Wide									
	Tight									
Wide	Open									
	Wide									

Table 2 (continued)

Key Recommended	Permeability tests using open systems ISO 22282-2			Water pressure test in rocks ISO 22282-3		Pumping tests ISO 22282-4	Infiltrometer tests ISO 22282-5		Permeability tests using closed systems ISO 22282-6
	Constant flow	Variable head	Constant head	Upward test	Downward test	Pum-ping test	Constant head	Variable head	
Purpose of test	2A	2B	2C	3A	3B	4	5A	5B	6
Permeability									
>1E-2 m/s									
1E-3 - 1E-2									
1E-4 - 1E-3									
1E-5 - 1E-4									
1E-6 - 1E-5									
1E-7 - 1E-6									
1E-8 - 1E-7									
1E-9 - 1E-8									
<1E-9 m/s									
Radius of influence									
0,1 m									
1,0 m									
10 m									
100 m									

## **5.3.2 Water permeability tests in a borehole using open systems**

### **5.3.2.1 Objectives**

The objective of a water permeability test in a borehole using open systems is to determine the local water permeability in soils and rocks below and above groundwater level.

### **5.3.2.2 Specific requirements**

The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in ISO 22282-2.

Any deviation from the requirements given in ISO 22282-2 shall be justified and reported. In particular, any influence on the results shall be commented upon.

### **5.3.2.3 Evaluation of test results**

The field and test reports according to ISO 22282-2 shall be used for evaluation purposes.

### **5.3.2.4 Use of test results and derived values**

Measurements in open holes can be done in formations where boreholes remain stable. An exact determination of the permeability of individual strata is not possible since the method is applied in an open hole and without packers. The test will therefore provide an average permeability of the geological formation(s) penetrated. The derived permeability is meaningful when the tested formation is hydraulically homogeneous.

## **5.3.3 Water pressure tests in rock**

### **5.3.3.1 Objectives**

The objective of a water pressure test in rocks is to determine:

- the hydraulic properties of the rock mass, which are mainly governed by discontinuities;
- the absorption capacity of the rock mass;
- the tightness of the rock mass;
- the effectiveness of grouting;
- the geomechanical behaviour, e.g. hydrofracturing, hydrojacking.

### **5.3.3.2 Specific requirements**

The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in ISO 22282-3.

Any deviation from the requirements given in ISO 22282-3 shall be justified and reported. In particular, any influence on the results shall be commented upon.

### **5.3.3.3 Evaluation of test results**

The field and test reports according to ISO 22282-3 shall be used for evaluation purposes.

#### **5.3.3.4 Use of test results and derived values**

The results of water pressure tests serve to determine and localize impervious and pervious rock sections, the water flow and absorption capacity of pervious rock, the grouting requirements, the success of grouting and the deformation behaviour of the rock section tested.

The packer test method is often used in dam foundation and tunnelling related projects. The advantage of the method lies in the precise depth orientated characterization of individual sections.

### **5.3.4 Pumping tests**

#### **5.3.4.1 Objectives**

The objective of pumping tests is to evaluate the hydraulic parameters of an aquifer and well parameters, such as:

- global permeability of the aquifer,
- radius of influence of pumping,
- pumping rate of a well,
- response of drawdown in an aquifer during pumping,
- skin effect,
- well storage,
- dimension and nature of outer aquifer limits (no flow type or constant head type).

#### **5.3.4.2 Specific requirements**

The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in ISO 22282-4.

Any deviation from the requirements given in ISO 22282-4 shall be justified and reported. In particular, any influence on the results shall be commented upon.

#### **5.3.4.3 Evaluation of test results**

The field and test reports according to ISO 22282-4 shall be used for evaluation purposes.

#### **5.3.4.4 Use of test results and derived values**

The test serves:

- to determine the transmissivity and the aquifer storage coefficient;
- to estimate the radius of influence of the pumping and to calculate the water permeability coefficient when the aquifer is known.

### **5.3.5 Infiltrometer tests**

#### **5.3.5.1 Objectives**

The objective of the infiltrometer test is to determine the infiltration capacity of the ground at the ground surface or at shallow depths (e.g. test pits). It is a simple test for determining permeability coefficient. The method can be applied using either steady state or transient conditions, in saturated or unsaturated soils.

### 5.3.5.2 Specific requirements

The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in ISO 22282-5.

Any deviation from the requirements given in ISO 22282-5 shall be justified and reported. In particular, any influence on the results shall be commented upon.

### 5.3.5.3 Evaluation of test results

The field and test reports according to ISO 22282-5 shall be used for evaluation purposes.

### 5.3.5.4 Use of test results and derived values

The method allows an estimation of the vertical permeability coefficient from observations of infiltration rate to be obtained.

## 5.3.6 Water permeability tests in a borehole using closed systems

### 5.3.6.1 Objectives

The objective of water permeability tests in a borehole using closed systems is to determine the local water permeability in low permeability soils and rocks below and above groundwater level.

### 5.3.6.2 Specific requirements

The tests shall be carried out and reported in accordance with a method that conforms to the requirements given in ISO 22282-6.

Any deviation from the requirements given in ISO 22282-6 shall be justified and reported. In particular, any influence on the results shall be commented upon.

### 5.3.6.3 Evaluation of test results

The field and test reports according to ISO 22282-6 shall be used for evaluation purposes.

### 5.3.6.4 Use of test results and derived values

The method is typically used as a local site characterization method for low permeability ground.

## 6 Preparation of the test section and installation of equipment

### 6.1 Requirements for drilling and the test sections

Drilling of wells and piezometers shall follow the specifications of ISO 22475-1, as applicable.

If a flushing medium is used, drilling concerning the test section shall be done with clean water (no bentonite or biodegradable slurry) and before each test the borehole wall shall be cleaned (by airlifting or successive passes of the tool with water injection until clear water comes out at the well head), in order to remove any fine deposits ("mud cake") that could clog the pores and cracks responsible for permeability and thereby distort measurements. A good hydraulic connection with the surrounding ground shall be established.

NOTE The drilling and test section isolation processes, and the choice of method based on the nature and consistency of the ground, are described in Annex A.

## 6.2 Installation of filter

The filter pack grading, the width of the slots in the filter or the distance between the slots in the screen shall be chosen with respect to the grain size distribution of the surrounding ground.

The diameter of the pipe shall be chosen with respect to expected discharge capacity.

The filter pipe shall be strong enough to resist stresses during installation, cleaning and predicted earth and water pressures.

## 6.3 Checking installation

Before starting the tests the correct functioning of all equipment shall be checked and recorded. Calibration records for measuring units shall be gathered and recorded.

The filter shall be flushed with water until it is clear.

After installation of the test equipment, the following shall be checked:

- leakages in joints, packers and measuring units;
- the cleanliness of the measuring tubes;
- the response of the whole system to increasing or decreasing hydraulic head;
- hydraulic head in the annular space between the injection rod and the temporary tube at the beginning and end of the test in order to detect and quantify any flow around the packer.

When carrying out pumping tests with separate piezometers the specifications of ISO 22475-1 apply.

## 6.4 Safety requirements

Geohydraulic testing in boreholes should be carried out according to the national safety regulations, e.g. regulations for:

- personal health and safety equipment;
- clean air, if working in confined spaces;
- ensuring the safety of the equipment;
- working on contaminated land;
- environmental impact;
- unexploded ordinance.

## 6.5 Decommissioning

### 6.5.1 General

The decommissioning process shall minimize potential risks to the environment, including:

- contamination by seepage of aquifer (i.e. in cases of landfill and waste storage);
- leakage of groundwater between aquifers;
- collapse of borehole.

## 6.5.2 Decommissioning of boreholes

All boreholes not converted to observation wells should be back-filled, plugged and recorded according to approved procedures provided in ISO 22475-1.

Backfilling methods shall achieve equal or lower permeability than the surrounding ground along the length of the hole.

## 6.5.3 Decommissioning of surface facilities

After completion of the backfilling of the boreholes and confirmation of its quality, the surface facilities shall be removed.

## 6.6 Factors influencing the test results

### 6.6.1 General

Test results may be influenced by natural boundary conditions, such as:

- viscosity of fluid;
- stratification and fissures,
- variable hydraulic heads (e.g. tidal effects).

The shape factor of the test section shall be considered for the interpretation of test results (see Annex B).

### 6.6.2 Viscosity of fluid

The determination of permeability for water is carried out under ambient conditions. Water flow is influenced by the viscosity of water that varies with temperature. For practical purposes, the determined permeability shall be reported for the ambient temperature and not corrected to a reference temperature (in laboratory it is usually 20 °C). Other fluids (contaminants, petroleum, etc.) lead to other permeabilities. The relation between transmissivity, permeability coefficient and intrinsic permeability are shown in Table 3.

**Table 3 — Relation between transmissivity, permeability coefficient and intrinsic permeability**

Index values	Symbol	Units	Transmissivity m <sup>2</sup> /s	Permeability coefficient m/s	Intrinsic permeability m <sup>2</sup>
Transmissivity	<i>T</i>	m <sup>2</sup> /s	<i>T</i>	<i>k</i> · <i>L</i>	( <i>K L</i> ) (η/γ)
Permeability coefficient	<i>k</i>	m/s	<i>T/L</i>	<i>k</i>	<i>K</i> (γ/η)
Intrinsic permeability	<i>K</i>	m <sup>2</sup>	( <i>T/L</i> ) (η/γ)	<i>k</i> (η/γ)	<i>K</i>
<i>L</i> length of test section in borehole (m) η dynamic viscosity of the fluid (Pa·s) γ density (t/m <sup>3</sup> )					

### 6.6.3 Stratification and fissures

Stratification and fissures may increase the flow rate in the beginning of a test. With time the flow rate will decrease to the flow rate of the tested aquifer. To obtain representative values of the permeability coefficient the test should be continued until steady state conditions are reached. The length of the test section depends on the spacing of discontinuities.



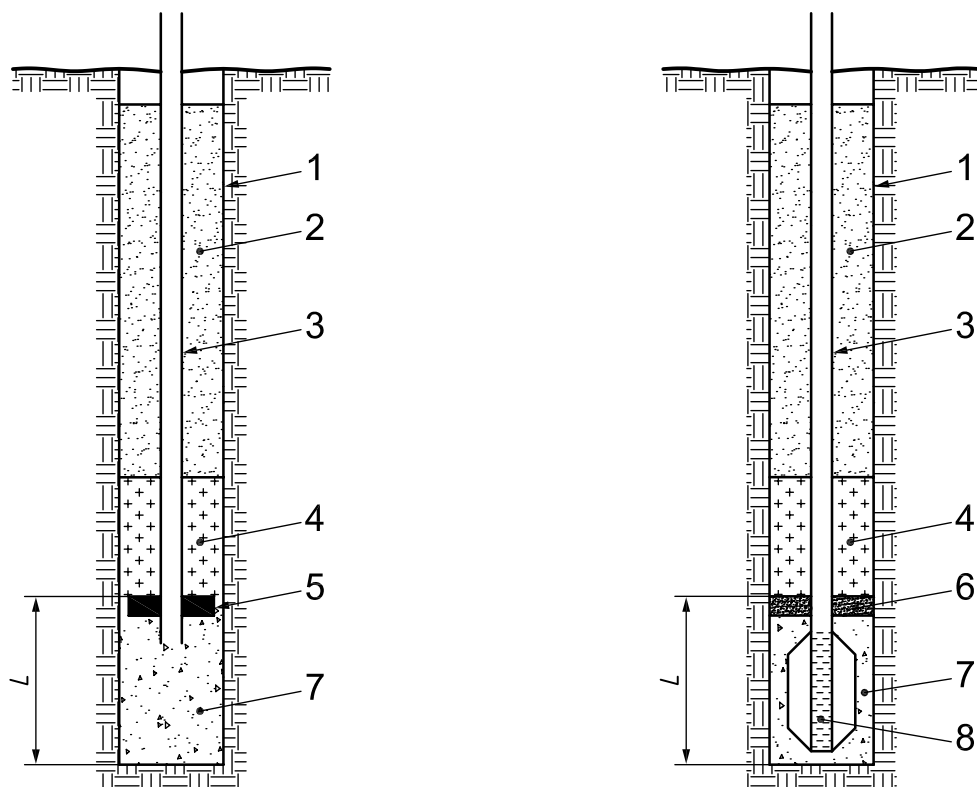
#### **6.6.4 Variable groundwater levels**

Variable groundwater levels in the surrounding ground from pumping or fluctuating nearby river or sea level will affect the test results by changes in the gradient. To limit these effects in long-term tests, possible sources that may affect the groundwater level should be investigated and these variations should be monitored during the test.

## Annex A (informative)

### Examples of possible test section isolation and support methods

The following figures show examples of possible test section isolation and support methods.



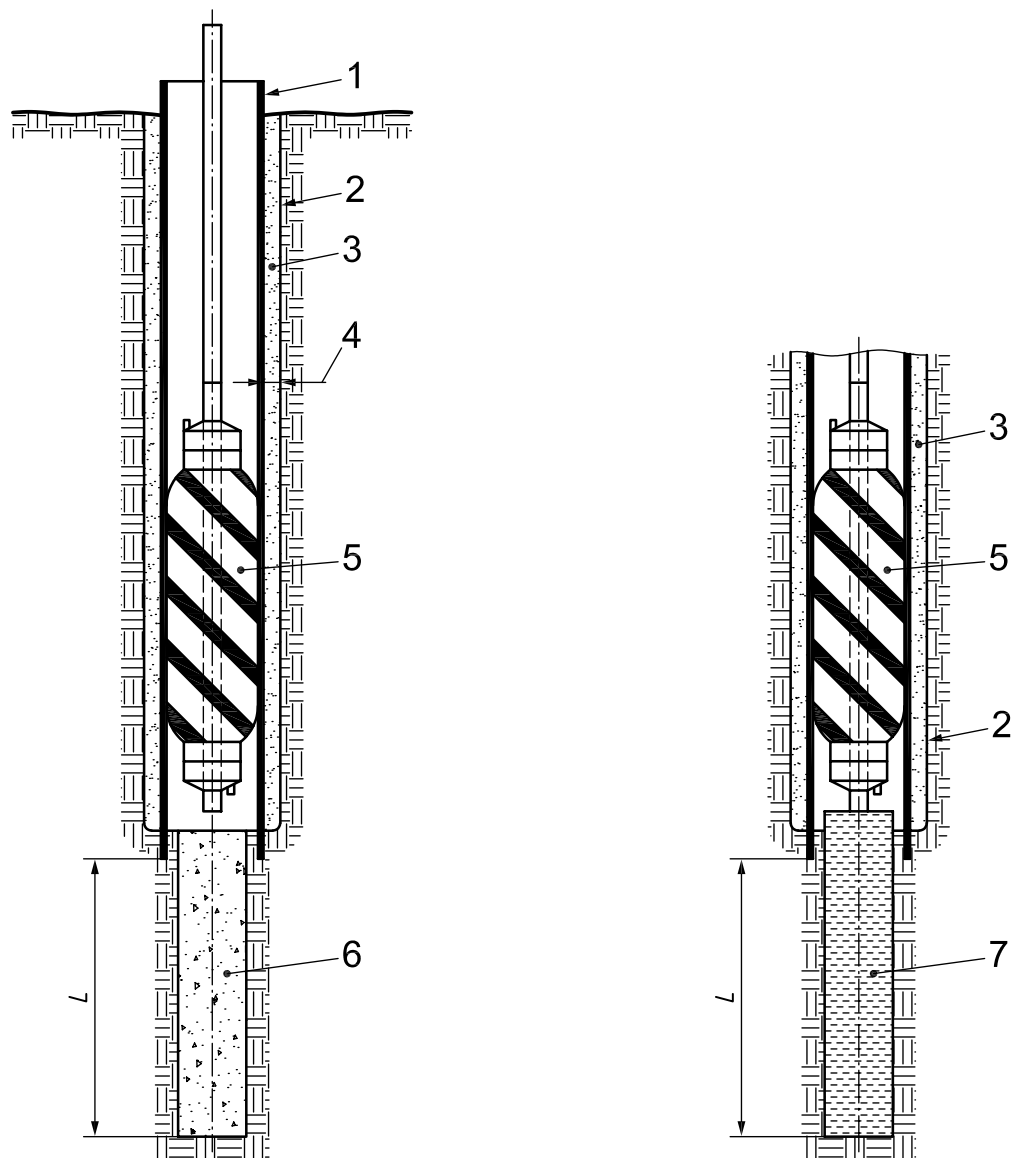
a) Support by gravel filter

b) Support by tight plug

**Key**

- 1 borehole
- 2 anchoring material
- 3 liaison tube
- 4 tight plug
- 5 centering-separating disk
- 6 fine sand
- 7 filter material
- 8 perforated tube with spacer

**Figure A.1 — Example of a support by gravel filter and isolation by tight plug**



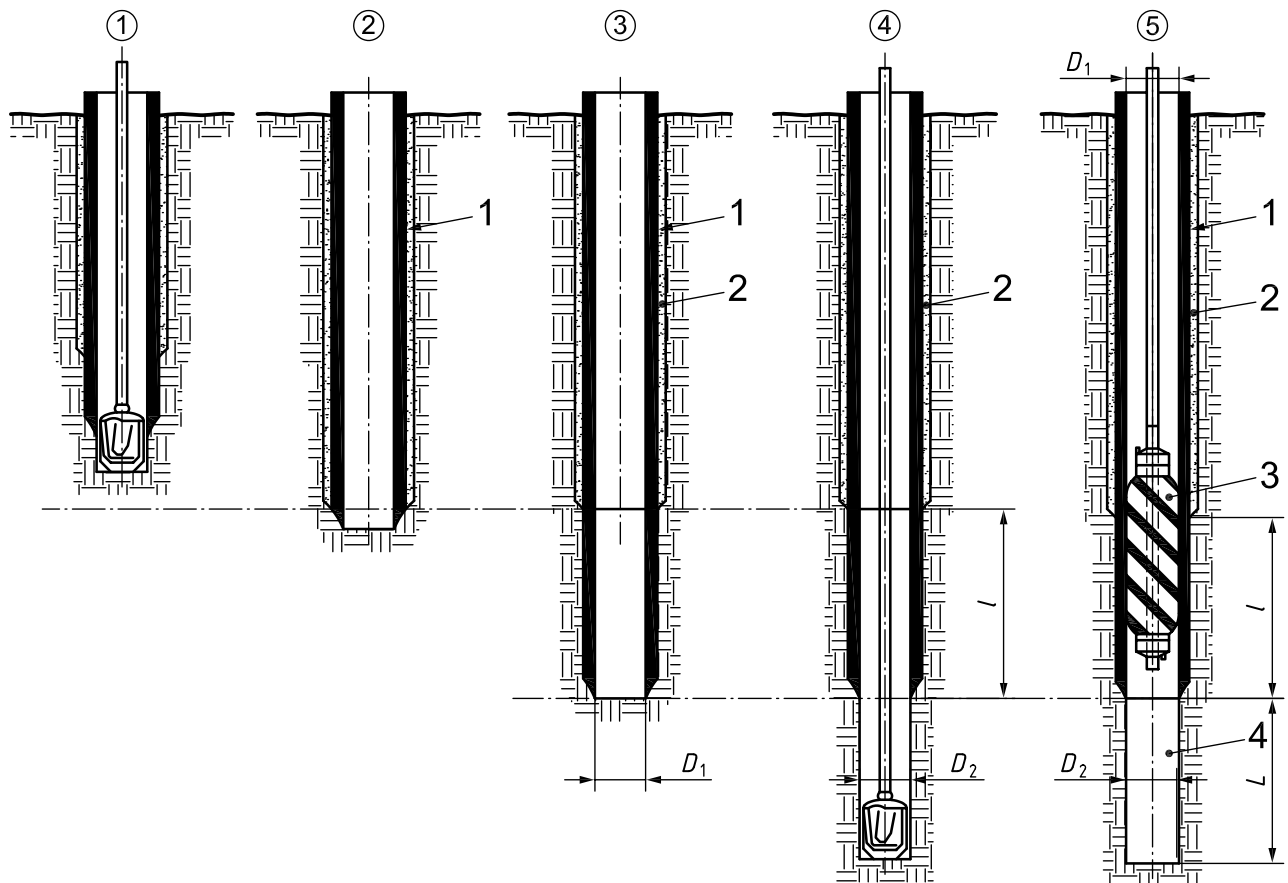
a) With filter material

b) With filter tube

**Key**

- 1 anchored tube
- 2 borehole
- 3 sealing anchoring
- 4 annular space ( $\geq 2$  mm)
- 5 removable packer
- 6 filter material
- 7 filter tube

**Figure A.2 — Example of an anchored tube with internal removable packer**



**Key**

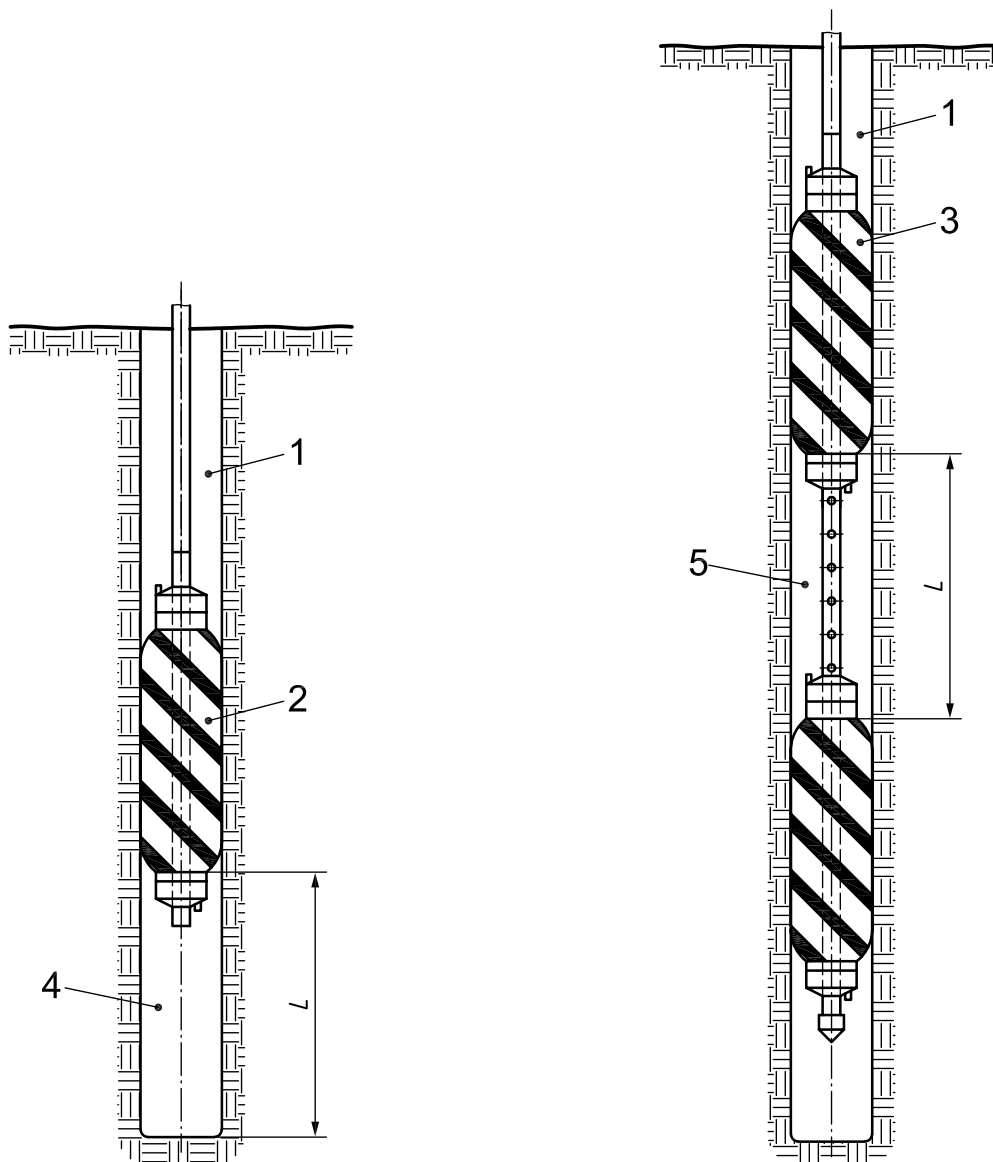
- 1 driven tube
- 2 bentonite-based grout
- 3 single removable packer
- 4 test section, of length  $L$ , with possible filtering material
- $l$  ungrouted tube section

**Different phases**

(the circled numbers indicate the different phases)

- 1, 2 Borehole with casing.
- 3 Driving of casing.
- 4 Drilling of the test section.
- 5 Isolation and possible support of the test section.

**Figure A.3 — Example of a driven tube with internal removable packer**



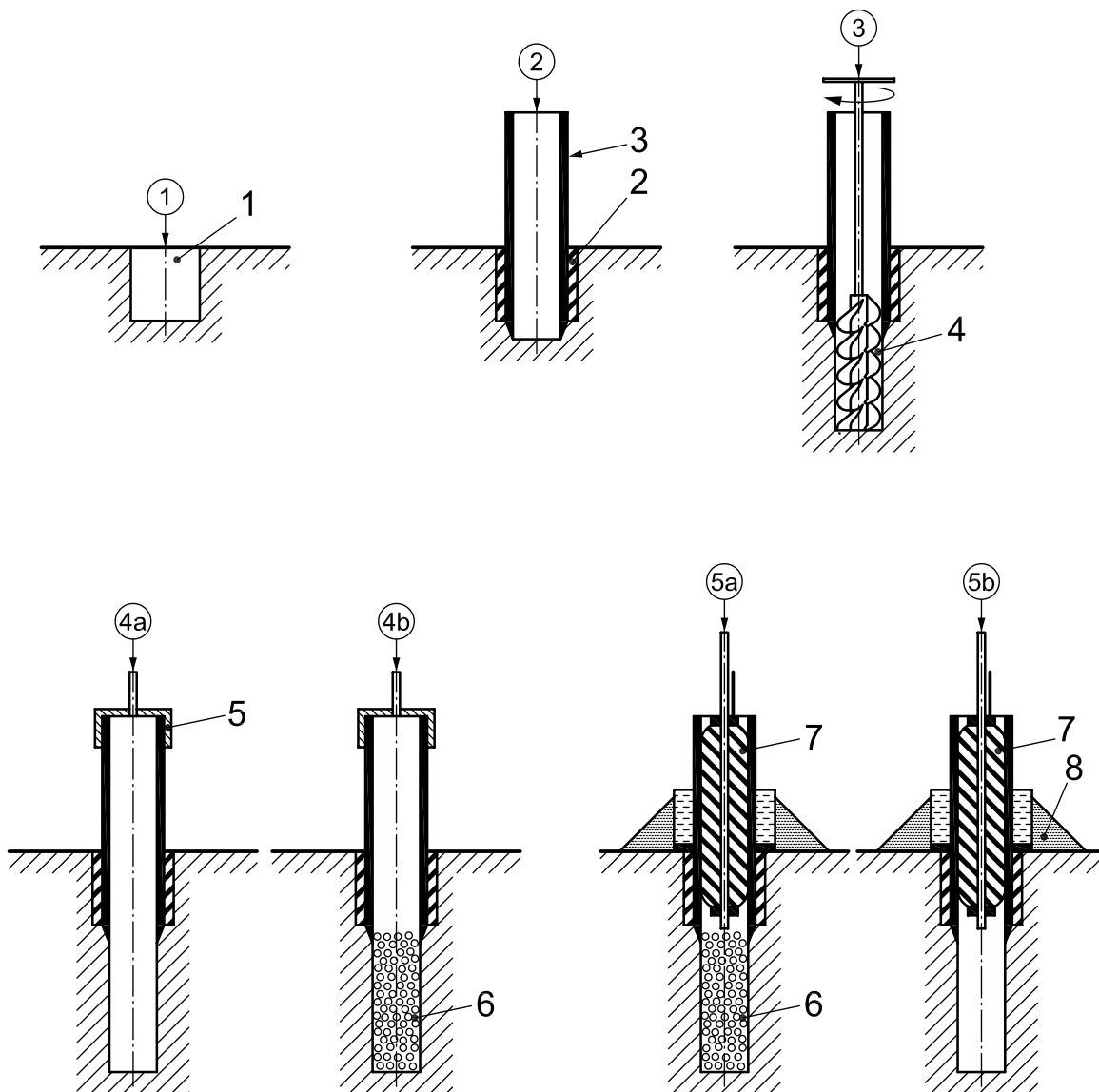
a) Single packer

b) Double packer

**Key**

- 1 borehole
- 2 single removable packer
- 3 double removable packer
- 4 test section, of length  $L$ , with possible filtering material
- 5 test section, of length  $L$

**Figure A.4 — Example of a removable packer, installed against the borehole walls**

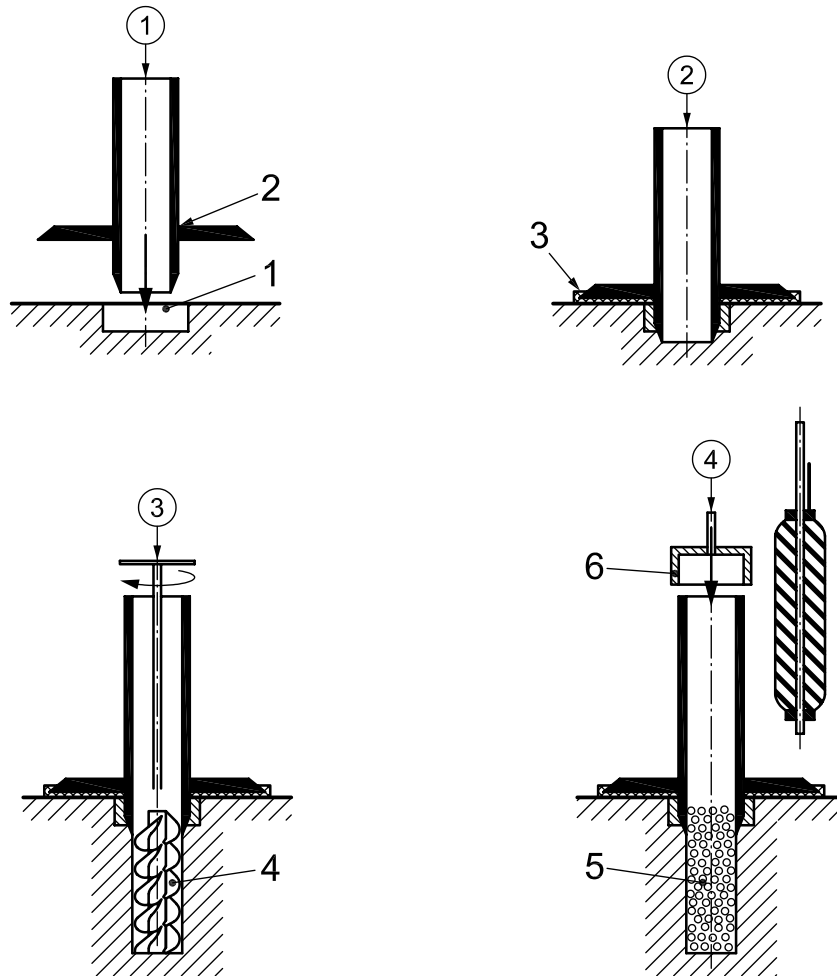


NOTE The circled numbers indicate the different phases.

**Key**

- 1 pilot hole
- 2 anchoring grout
- 3 extension tube driven into bottom of borehole
- 4 test section
- 5 tight plug
- 6 possible supporting gravel filter
- 7 packer
- 8 sealing foundation

**Figure A.5 — Example of an extension tube driven in and bonded, specific to shallow drilling tests**



NOTE The circled numbers indicate the different phases.

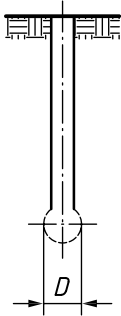
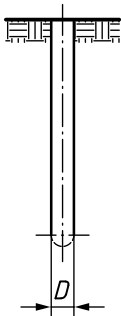
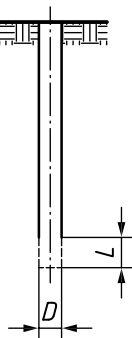
**Key**

- 1 pilot hole
- 2 tube with welded flanged
- 3 anchoring grout
- 4 borehole and test section
- 5 possible support (filtering foundation)
- 6 tube closing device (tight plug, packer, etc.)

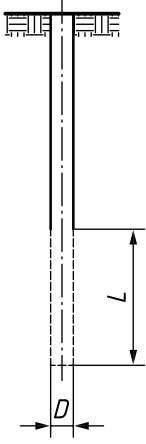
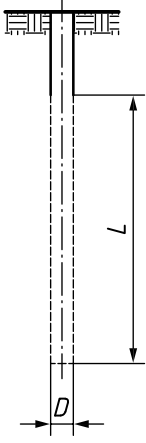
**Figure A.6 — Example of an extension tube and welded flange, specific for shallow drilling tests**

## Annex B (informative)

### Examples of shape factors

	$F = 2 \cdot \pi \cdot D$	<p>Spherical cavity at the bottom of the well</p>
	$F = \pi \cdot D$	<p>Semi-spherical configuration – bottom of the well</p>
	$F = \pi \cdot D \cdot \sqrt{4 \cdot \frac{L}{D} + 1}$	<p>Cylindrical cavity with:  <math>0,7 &lt; L/D &lt; 1,2</math></p>



	$F = \frac{2 \cdot \pi \cdot L}{\ln\left(\frac{L}{D} + \sqrt{\left(\frac{L}{D}\right)^2 + 1}\right)}$	<p>Cylindrical cavity with:  <math>1,2 &lt; L/D &lt; 10</math></p>
	$F = \frac{2 \cdot \pi \cdot L}{\ln(2 \cdot L/D)}$	<p>Cylindrical cavity with:  <math>L/D &gt; 10</math></p>

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