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Geotechnical investigation and testing — Geohydraulic testing —

Part 1: General rules

Reconnaissance et essais géotechniques — Essais géohydrauliques — Partie 1: Règles générales

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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.

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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.

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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[11]. 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
Δh	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
η	dynamic viscosity of the fluid	Pa s
γ	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).