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Geotechnical Standards – Eurocodes. An update

Professor David Norbury
David Norbury Ltd
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EUROCODE 7 (EN 1997)

- Part 1 published. 2004
  - National Annex published 2007
- Part 2 published Mar 2007
  - National Annex published 2010
- NAs are an integral part, do not ignore!

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EUROCODE 7 (EN 1997)

- Part 1 published. 2004
  - National Annex published 2007
  - Corrigendum to EN 1997 – 1 published 2009

- Part 2 published Mar 2007
  - National Annex published 2010
  - Corrigendum to EN 1997 -2 published 2010

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Did you know?

How are you to know?

Subtle indications within document

Ensure you are aware of and using the current version

BRITISH STANDARD

BS EN 1997-1:2004

Incorporating Corrigendum 2009

Eurocode 7: Geotechnical design —

Part 1: General rules

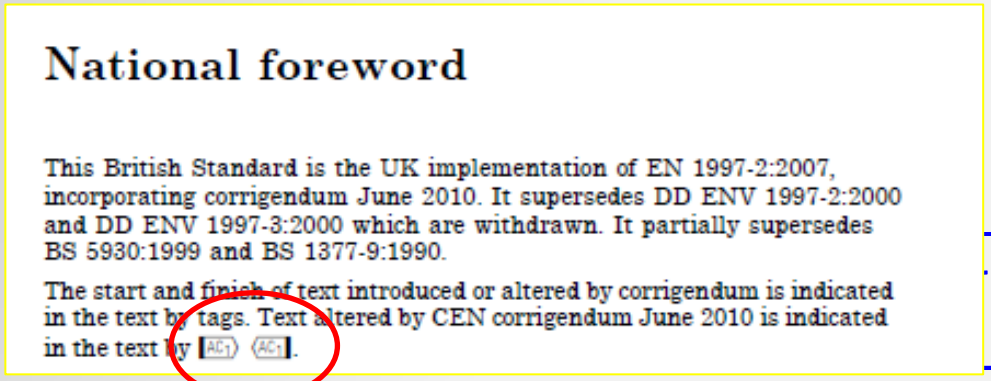
BRITISH STANDARD

BS EN 1997-2:2007

Incorporating Corrigendum 2010

Eurocode 7 — Geotechnical design —

Part 2: Ground investigation and testing



National foreword

This British Standard is the UK implementation of EN 1997-2:2007, incorporating corrigendum June 2010. It supersedes DD ENV 1997-2:2000 and DD ENV 1997-3:2000 which are withdrawn. It partially supersedes BS 5930:1999 and BS 1377-9:1990.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CEN corrigendum June 2010 is indicated in the text by [AC1⟩ ⟨AC1].

THE EUROCODE 7 SUITE

- Eurocode 7
  - Part 1 Geotechnical Design
    - Execution Standards
  - Part 2 Ground Investigation and Testing
    - 22475 Sampling Methods and Groundwater Measurement
    - 22476 Field Testing
    - 22477 Geotechnical Structure Tests
    - 22282 Geo-hydraulic Tests
    - 17892 Laboratory Testing
    - 14688 and 14689 Soil and Rock Description

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HOW MANY STANDARDS?

			TOTAL
Eurocodes	EC 0 - 9	**0 1 2 3 4 5 6 7 8 9**	
Eurocode 7	Parts 1 - 2	**1* 2***	2
National Annexes		1 **2**	4
Execution Standards		**1* 2* 3* 4 5 6 7 8 9 10 11 12 13**	17
Test Standards			
22475		**1 2 3**	20
22476		**1 2* 3*** 4 5 6 7 8 9 **10 11 12** 13	33
22477		1 2 3 4 5 6 7 8	41
22282		**1 2 3 4 5 6**	47
17892		1 2 3 4 5 6 7 8 9 10 11 12	59
14688		**1 2 3**	62
		YES THAT IS	**62**

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EC7 Part 1 - GENERAL RULES

1 General
2 Basis of geotechnical design
3 Geotechnical data
4 Supervision of construction, monitoring and maintenance
5 Fill, dewatering, ground improvement and reinforcement
6 Spread foundations
7 Pile foundations
8 Anchorages
9 Retaining structures
10 Hydraulic failure
11 Overall stability
12 Embankments

PLUS:

Annexes A to J

NATIONAL ANNEX

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CHANGE TO DESIGN PROCEDURE

- "Limit State design" takes over from "Working State design"
- Working state design: Analyse the expected working state, then apply margins of safety
- Limit state design: Analyse various states at which the structure reaches an unacceptable limit, applying partial factors to all inputs

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LIMIT STATE AND PARTIAL FACTORS

- Ultimate Limit States (STR, GEO, EQU, UPL, HYD)
  - failure of structure or ground
  - serious and expensive
  - must be very unlikely
- Serviceability Limit States (settlement, deflection, vibration)
  - inconvenient, discomfort
  - less expensive
  - should be rare but may be allowable
- Partial Factors (>100)
  - no longer use lumped factors as in working state design

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DERIVATION

The "derived value" of a geotechnical parameter is defined in Eurocode 7 as

"the value ... obtained by theory, correlation or empiricism from the test"

Test results directly (includes theory of test)

Test results indirectly

Converted test results using correlations

Adjusted test results using theory or empiricism

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EN 1997

- Characteristic value = 5% fractile (EN 1990)
- Eurocode 7 “re-defines” the characteristic value of a geotechnical parameter as ‘a cautious estimate of the value affecting the occurrence of the limit state’ under consideration
- The selection of characteristic values for geotechnical parameters shall be based on derived values … complemented by well-established experience.

- No such thing as <u>the</u> characteristic value of a geotechnical parameter
  - There are potentially several characteristic values, which can be different for each limit state being considered

EC 7 Part 2

1 General

2 Planning of GI

3 Soil and rock sampling and groundwater measurements

4 Field tests in soil and rock

5 Laboratory tests on soil and rock

6 Ground Investigation report

Annexes + **NATIONAL ANNEX**

- A – B Planning
- C – K Field Testing
- L – W Laboratory testing
- X Bibliography

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22475 – Sampling, measuring testing and qualifications

- Geotechnical investigation and testing – Sampling methods and groundwater measurements
  - Part 1: Technical principles for execution
  - Part 2: Qualification criteria for enterprises and personnel
  - Part 3: Conformity assessment of enterprises and personnel by third party
- Part 1 = NORMATIVE
- Parts 2 and 3 = BS

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FIELD TESTING – 22476

/1	Cone penetration tests	Publication imminent
/2	Dynamic probing	Implemented
/3	Standard penetration tests	Implemented
/4	Menard pressuremeter	Publication soon?
/5	Flexible dilatometer	Publication soon?
/6	Self boring pressuremeter	Enquiry complete
/7	Borehole jacking test	Publication soon?
/8	Full displacement p/meter	Enquiry complete
/9	Field vane test	Enquiry complete
/10	Weight sounding test	Published 2005 - TS
/11	Flat dilatometer test	Published 2005 - TS
/12	Mechanical CPT cone	Implemented
/13	Plate loading test	Now in collaboration with TC 396 …

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PROGRESS to date

Standards published and implemented (+ 4 EN 1997 and NA)

22475/1		Sampling and groundwater measurement	
BS 22475/2		Qualification of enterprises and personnel	
BS 22475/3		Conformity assessment of enterprises and personnel	
22476/2		Dynamic probing	
22476/3		Standard Penetration test	
22476/10	(TS)	Weight sounding test	
22476/11	(TS)	Flat dilatometer test	
22476/12		Mechanical CPT	
14688/1		Soil description	see Norbury (2010)
14688/2		Soil classification	
14689/1		Rock description and classification	see Norbury (2010)

That is 11 standards to date in the UK

Plus the 13 executions - NB: the execution standards for soil nailing and a revised bored pile standard appeared in 2010

That gets us to 28 out of 62

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STANDARDS OUT OR IMMINENT

22476 - Field testing

/1	Electrical Cone and piezocone penetration tests	IMMINENT
/2	Dynamic Probing – Amendment 1	IMPLEMENTED
/3	Standard Penetration test – Amendment 1	IMPLEMENTED
/4	Ménard Pressuremeter	SOON
/5	Flexible dilatometer	SOON
/7	Borehole Jacking test	SOON

22282 - Geohydraulic tests

/1	General rules	PUBLISHED
/2	Water permeability test in borehole without packer	PUBLISHED
/3	Water pressure test in rock	PUBLISHED
/4	Pumping tests	PUBLISHED
/5	Infiltrometer tests	PUBLISHED
/6	Closed packer systems	PUBLISHED

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The NEW Standards

Summary of contents as part of the implementation process

22476-1 to 3

22282-1 to 6

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QUALITY in EN 1997 & 22475-1

- Quality of investigation services
- Required quality classes of samples
- Achieved quality - before laboratory test?
- Water quality (test before, during and after)
- QA system in field, laboratory and office
- Quality of comparable (precedent) experience

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Standards published in 2011

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22476-1

Electrical cone and piezocone penetration test

- The results are used to evaluate:
- stratification
- soil type
- geotechnical parameters such as
  - soil density
  - shear strength parameters
  - deformation and consolidation characteristics

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SPECIFICATION

- type of cone penetration test
- application class
- penetration length or penetration depth
- elevation of the ground surface or the underwater ground surface at the location of the cone penetration test with reference to a datum
- location of the cone penetration test relative to a reproducible fixed location reference point
- pore pressure dissipation tests

TYPE OF CONE TEST

- Select a cone penetrometer to fulfil the requirements of the penetration test

Type of cone penetration test	Measured parameter
TE 1	Cone resistance and sleeve friction = **CPT**
TE 2	Cone resistance, sleeve friction and pore pressure = **CPTU**

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APPLICATION CLASSES

- Class 1 for **soft to very soft soil** deposits; not for mixed bedded soil profiles with soft to dense layers (although pre-drilling through stiff layers can overcome the problem). Tests can only be performed using CPTU.
- Class 2 for **precise evaluation** for **mixed bedded soil profiles** with soft to dense layers, in terms of profiling and material identification. Interpretation in terms of engineering properties is also possible, with restriction to indicative use for the soft layers. Penetrometer type depends on project requirements.

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APPLICATION CLASSES (2)

- Class 3 for **evaluation of mixed bedded soil profiles** with soft to dense soils, in terms of profiling and material identification. Interpretation in terms of engineering properties is achievable for very stiff to hard and dense to very dense layers. For stiff clays or silts and loose sands only an indicative interpretation can be given. Penetrometer type depends on project requirements.
- Class 4 for **indicative profiling and material identification** for mixed bedded soil profiles with soft to very stiff or loose to dense layers. No appreciation in terms of engineering parameters can be given. Tests are to be performed with an electrical cone penetrometer (type TE1)

Applic. Class	Test type	Measured parameter	Allowable minimum accuracy [a]	Maximum length between measurements	Use	
					Soil [b]	Interpre-tation / evaluation [c]
1	TE2	Cone resistance	35 kPa or 5 %	20 mm	A	G, H
		Sleeve friction	5 kPa or 10 %			
		Pore pressure	10kPa or 2 %			
		Inclination	2°			
		Penetration length	0,1 m or 1%			
2	TE1 TE2	Cone resistance	100 kPa or 5 %	20 mm	A B C D	G, H* G, H G, H G, H
		Sleeve friction	15 kPa or 15 %			
		Pore pressure [d]	25 kPa or 3 %			
		Inclination	2°			
		Penetration length	0,1 m or 1 %			
3	TE1 TE2	Cone resistance	200 kPa or 5 %	50 mm	A B C D	G G, H* G, H G, H
		Sleeve friction	25 kPa or 15 %			
		Pore pressure [d]	50 kPa or 5 %			
		Inclination	5°			
		Penetration length	0,2 m or 2 %			
4	TE1	Cone resistance	500 kPa or 5 %	50 mm	A B C D	G* G* G* G*
		Sleeve friction	50 kPa or 20 %			
		Penetration length	0,2 m or 2 %			

NOTE For extremely soft soils even higher demands on the accuracy may be needed.

[a] The allowable minimum accuracy of the measured parameter is the larger value of the two quoted. The relative accuracy applies to the measured value and not the measuring range

[b] According to EN ISO 14688-2:
- A Homogeneously bedded soils with very soft to stiff clays and silts (typically $q_c < 3$ MPa)
- B Mixed bedded soils with soft to stiff clays (typically $q_c \leq 3$ MPa) and medium dense sands (typically 5 MPa $\leq q_c < 10$ MPa)
- C Mixed bedded soils with stiff clays (typically 1,5 MPa $\leq q_c < 3$ MPa) and very dense sands (typically $q_c > 20$ MPa)
- D Very stiff to hard clays (typically $q_c \geq 3$ MPa) and very dense coarse soils ($q_c \geq 20$ MPa)

[c]
- G profiling and material identification with low associated uncertainty level
- G* indicative profiling and material identification with high associated uncertainty level
- H interpretation in terms of design with low associated uncertainty level
- H* indicative interpretation in terms of design with high associated uncertainty level

[d] Pore pressure can only be measured if TE2 is used.

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22476/2 and /3
DYNAMIC PROBING and SPT

- IMPLEMENTED 2007 when
  - BS1377 Part 9 Clause 3.2 (DP) and
  - BS1377 Part 9 Clause 3.3 (SPT)

WERE WITHDRAWN

Do not refer to these

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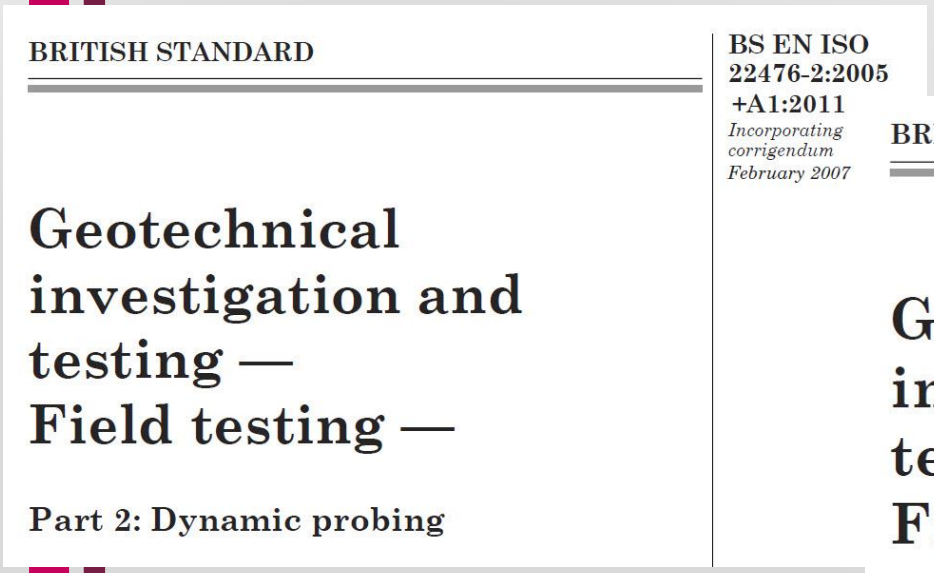
STANDARDS IN THE SYSTEM published in 2012

- Both now amended (2012)
- UK comments influenced these amendments!



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GEOHYDRAULIC TESTING - Part 1: General rules

- ISO 22282 consists of the following parts
  - *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*

Will replace clauses 25.4, 25.5, 27 and 28 in BS5930

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GENERAL

- According to the different test methods, the apparatus can comprise the following elements:
  - test section support system, such as a filter pack;
  - measuring tube;
  - isolation of the test section by casing, sealing plug, packer(s);
  - measuring and recording devices using manual, analogue or digital systems such as dipmeters, pressure transducers, flow meters;
  - additional equipment.
- The instruments and devices used for geohydraulic testing shall be regularly calibrated according to manufacturers' manuals and relevant standards. This shall be checked before the test starts.

PLANNING

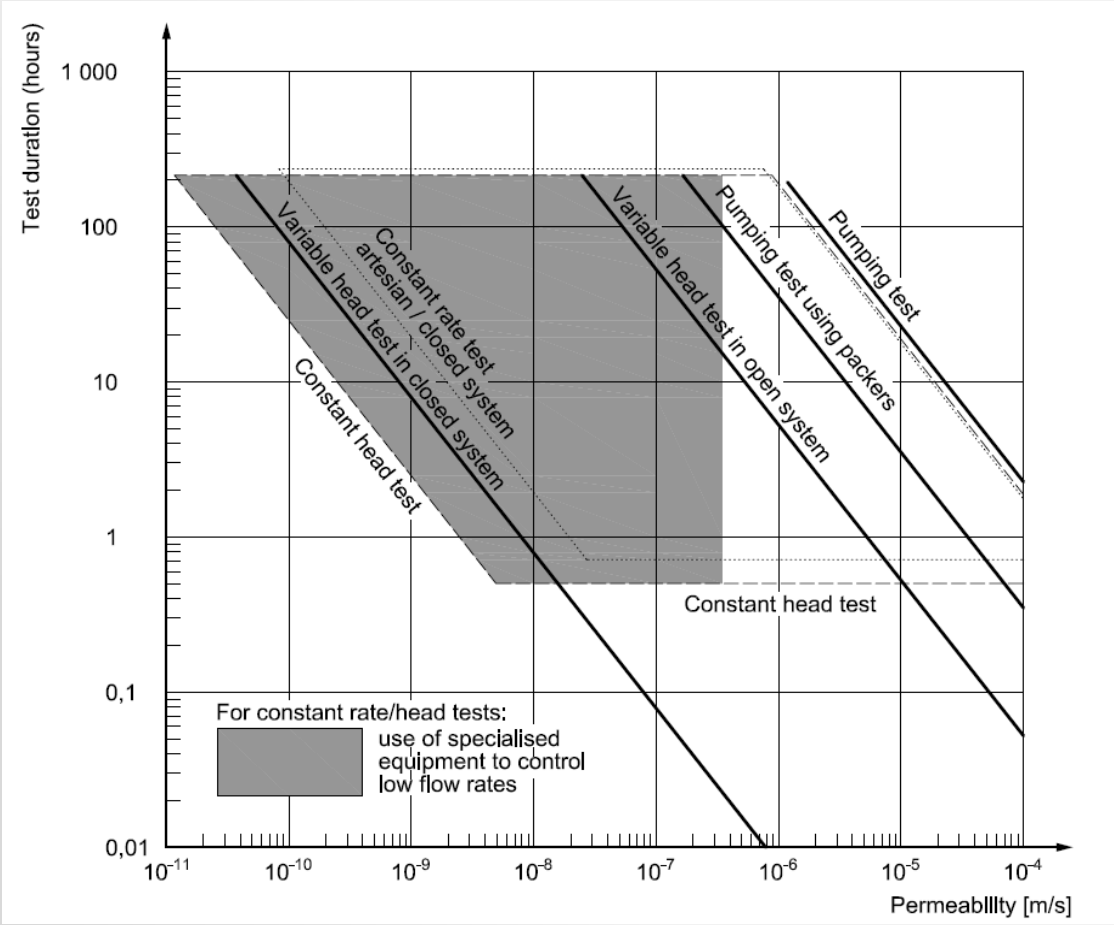
- Geohydraulic investigations shall be planned in such a way as to ensure that relevant geological and hydrogeological information and data are available at the various stages of the project. This information shall be adequate to manage identified and anticipated project risks.
- Before starting a geohydraulic 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).

PLANNING (2)

- Geohydraulic investigations should consider any activity which may influence the test or may be affected by the test, such as:
  - existing constructions, e.g. buildings, bridges, tunnels;
  - water lowering or de-watering;
  - discharge of potable water.
- The geohydraulic investigation programme should be reviewed as the results become available so that the initial assumptions can be checked.

SELECTION OF:

- **Test locations** on the basis of the preliminary information as a function of the geological and hydrogeological conditions and the engineering problem
- **Test procedure** on the basis of the ground conditions



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PREPARATION OF THE TEST SECTION AND INSTALLATION OF EQUIPMENT

- Drilling and flushing in accordance with BS EN ISO 22475-1.
- All testing in accordance with H&S regulations
- Filter selection according to ground and screen
- The correct functioning of all equipment shall be checked and recorded before the test starts
- Decommissioning process shall minimize potential risks to the environment (aquifer and surface conditions)

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22282-2

- **Water permeability test in a borehole using open systems** to determine the local water permeability in soils and rocks below and above groundwater level

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22282-2 COVERAGE

- Preparation of a test section in non-stable soil and rock below the groundwater surface
- Preparation of a test section in stable soil and rock
- Preparation of the test section in unsaturated conditions
- **Conducting the test**
  - Constant flow rate test
  - Variable head test
  - Constant head test

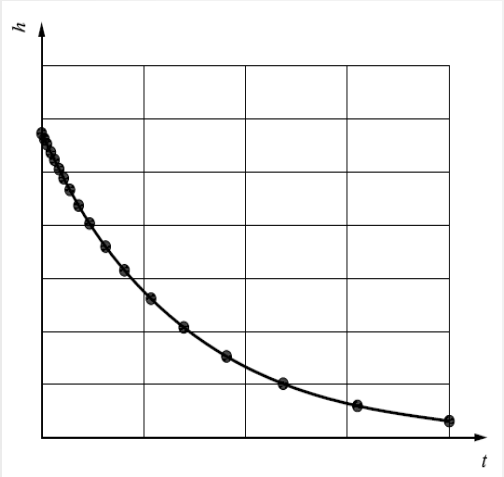

Figure 6 — Example of test results of a variable head test

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INTERPRETATION – variable head tests

- In some cases, the relationship between ln[*ho*/*h*(*t*)] and (*t*-*to*) is not a straight line. It is necessary to plot the velocities *dh*/*dt*, calculated on each measurement step *dt*, as a function of the average head variation *h* during the time step *dt*. The line intercepts the *h* axis at a value *h*st corresponding to the corrective term on the estimation of the initial static level.
- The corrected values of *h*(*t*), designated *h*cor(*t*), are obtained by applying the following correction:

$$h\text{cor},(t) = h(t) - h\text{st}$$

- The plotting of the corrected *h*cor values against time gives a straight line which allows the characterization of the theoretical slope a. The value of *k* is calculated.

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22282-3

- **Water pressure tests in rock** 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

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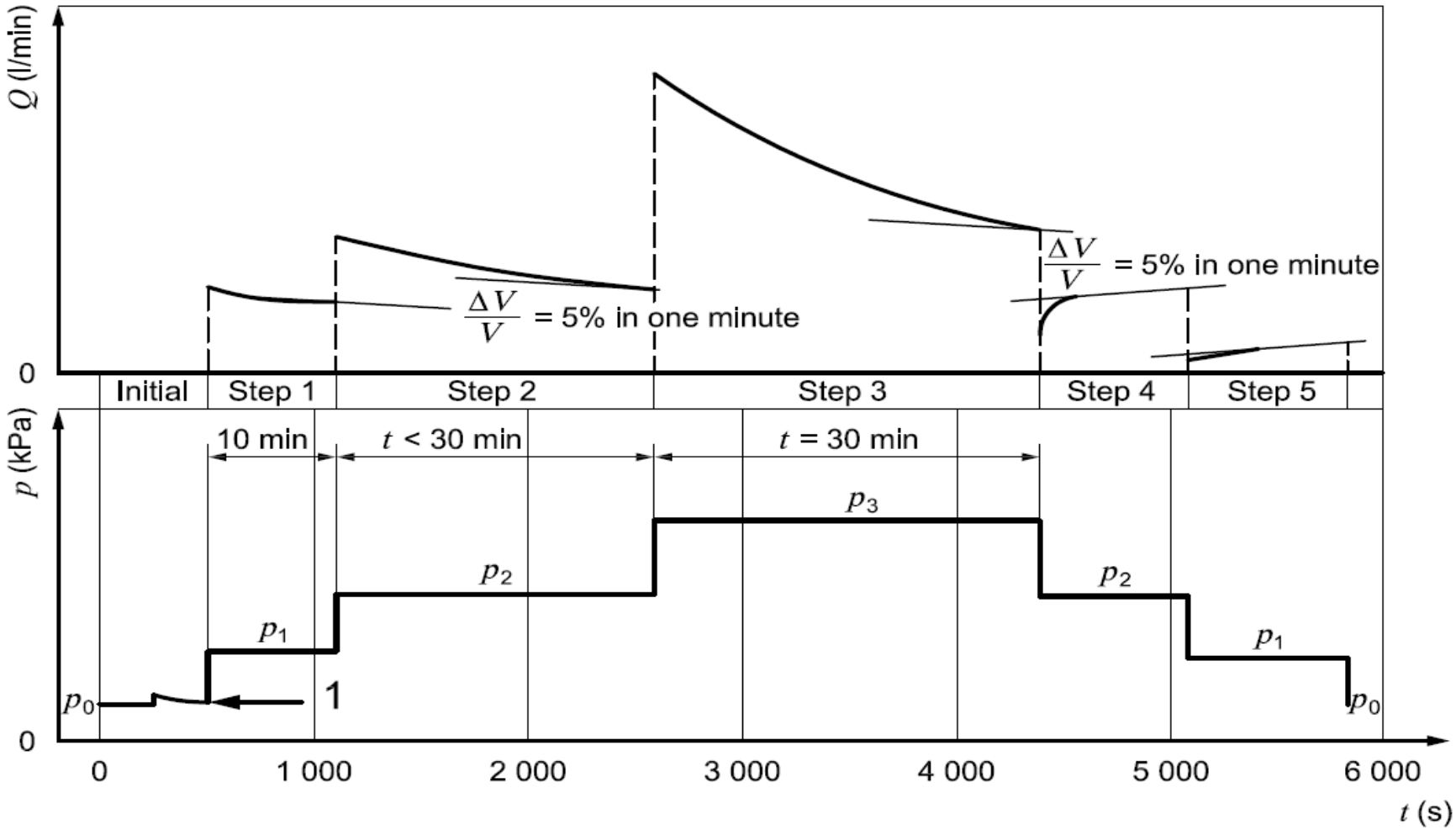
22282-3 Test procedure



22282-4

- **Pumping tests** to evaluate the hydraulic parameters of an aquifer and well parameters such as permeability, radius of influence, pumping rate, drawdown, skin effect, well storage, aquifer limits

22282-4 Contents

- Conducting the test
- Determining the discharge rate for the pumping test
- Arranging the disposal of discharge water
- Executing and equipping the well including: Design of the test well, Installation procedure, Preparation of the well
- Executing and equipping the piezometers
- Execution of the test
- Pre-pumping monitoring, Preliminary pumping phase, Pumping test, Post-pumping monitoring
- Interruptions in pumping
- Decommissioning

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22282-5

- **Infiltrometer tests** 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

22282-5 Equipment

a) a test cell for infiltrating the water into the soil; open or closed (sealed and weighted to prevent swelling or soil alteration). Rings are >200 mm pushed into ground >50 mm

b) a device for measuring pressure, water level and/or infiltrated volumes as a function of time. In some cases (e.g. with constant head procedure) equipment and piping connecting the pressure and volume controller to the test cell is also needed;

c) equipment for installation of the rings (pushing, anchoring, bonding and/or sealing)

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22282-6

- **Water permeability tests in a borehole using closed systems** to determine the local water permeability in low permeability soils and rocks ($<10^{-8}$ m/s) below and above groundwater level
- It can also be used to determine the transmissivity *T* and the storage coefficient *S*
- Determination of the pre-test stabilized hydraulic head – below and above water table (includes saturation stage)

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TEST REPORTS

… shall include the following:

a) the field report (in original and/or computerized form);

b) a graphical presentation of the test results and the recorded values of the hydraulic head or the flow rate (or the volume) versus time, for every step of hydraulic head applied when relevant;

c) any corrections in the presented data;

d) any limitations of the data (e.g. irrelevant, insufficient, inaccurate and adverse test results);

e) name and signature of the responsible expert.

STANDARDS COMING NOW

22476 - Field testing

/1	Cone penetration test	√
/4	Menard Pressuremeter	
/5	Flexible dilatometer	
/6	Self boring p/meter	
/7	Borehole Jacking test	
/8	Full displacement p/meter	
/9	Field vane test	

22282 - Geohydraulic tests

/1	General rules	√
/2	Water permeability test in borehole without packer	√
/3	Water pressure test in rock	√
/4	Pumping tests	√
/5	Infiltrometer tests	√
/6	Closed packer systems	√

That will be a further 7 + 6 standards in 2012/2013 to be implemented into practice

That gets us to 35 and then 41 out of 62

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STANDARDS TO COME

- 22476-13 Plate loading test
- 22477-1 to 8 Geotechnical structure tests
- 17892-1 to 12 Laboratory testing

That is a further 21 in the middle distance

Significant implementation task as we get to 62

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LABORATORY STANDARDS

/1 Water content	Batch 1
/2 Density of fine grained soils	Batch 1
/6 Fall cone test	Batch 1
/3 Density of solid particles	Batch 2
/4 Particle size distribution	Batch 2
/5 Oedometer test	Batch 2
/9 Consolidated triaxial test	Batch 3
/12Atterberg limits	Batch 3
/7 Compression test	Batch 4
/8 Unconsolidated triaxial test	Batch 4
/10 Direct shear test	Batch 4
/11 Permeability test	Batch 4

- imminent (2012)
- shortly (2012?)
- soon (2013)
- later (2013/4)

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OTHER TEST STANDARDS

(not included in above document counts)

- Geothermal testing methods for geothermal heat exchanger
- Geotechnical monitoring installations
- Drilling parameters recording

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BS 5930
AMENDMENTS & REVISIONS

- Initial Amendment 1 2007
  - Section 6 on description
- Further Amendment 2 2010
  - Dynamic probing
  - Standard Penetration Test
  - Effects of 22475 on sampling and testing
- NB - Predecessors withdrawn;
  - take care with referencing
  - BS5930 = BS5930:1999+A2

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BS 5930
AMENDMENTS & REVISIONS

- Initial Amendment 1 2007
  - Section 6 on description
- Further Amendment 2 2010
  - Dynamic probing
  - Standard Penetration Test
  - Effects of 22475 on sampling and testing
- REVISION 2015?
  - Under way now

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For you to help!

Existing Documents

- Tell us if there are technical errors/issues
- Tell us if there are problems
- Tell us if changes are needed – and whether these essential or desirable

(us = UK Mirror committee = John Powell and me)

Future Documents

- Watch for opportunities to comment, much easier to get changes at the public comment stages

Don’t assume others will do it for you!

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GET ON WITH THE CHALLENGE

And good luck!!

We, the mirror committee,

NEED YOUR HELP

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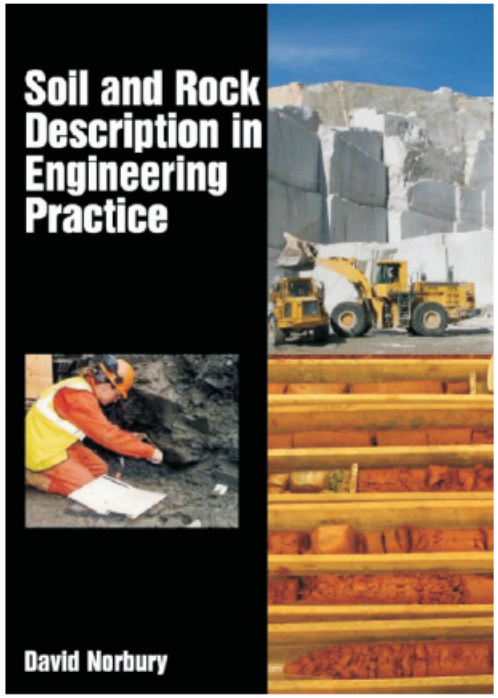
Soil and Rock Description in Engineering Practice



David Norbury, Consultant; Director, David Norbury Limited, Reading, UK

- **A practical guide to the engineering geological description of soils and rocks in the field**
- **The definitive work by an acknowledged expert**

In ground investigation, the description of soils and rocks in engineering practice forms a major input to the field log. The log records the materials and strata seen in any sample, core or exposure and is a basic element of the factual information that underpins the entire understanding and interpretation of the ground conditions on site. The field log is also all that remains after the investigation is over and so has a life well beyond that of the investigation report.