

Grout for prestressing tendons — Test methods

The European Standard EN 445:2007 has the status of a
British Standard

ICS 91.100.10; 91.100.30

National foreword

This British Standard is the UK implementation of EN 445:2007. It supersedes BS EN 445:1997 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/2, Structural use of concrete.

A list of organizations represented on this committee 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.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2007

© BSI 2007

ISBN 978 0 580 55812 2

Amendments issued since publication

Amd. No.	Date	Comments

English Version

Grout for prestressing tendons - Test methods

Coulis pour câble de précontrainte - Méthode d'essais

Einpressmörtel für Spannglieder - Prüfverfahren

This European Standard was approved by CEN on 21 June 2007.

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

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Contents

Page

Foreword.....3

Introduction4

1 Scope5

2 Normative references5

3 Terms and definitions5

4 The testing of grout5

4.1 General.....5

4.1.1 Personnel.....5

4.1.2 Test conditions5

4.1.3 Test reports5

4.2 Sieve test6

4.2.1 Principle of test6

4.2.2 Apparatus6

4.2.3 Procedure6

4.2.4 Reporting6

4.3 Fluidity test.....6

4.3.1 Cone method6

4.3.2 Grout spread method8

4.4 Inclined tube test9

4.4.1 Principle of test9

4.4.2 Test equipment and set-up10

4.4.3 Test procedure10

4.4.4 Reporting of results11

4.5 Wick-induced test12

4.5.1 Principle of test12

4.5.2 Equipment12

4.5.3 Procedure12

4.5.4 Reporting of results12

4.6 Compressive strength test13

4.6.1 Principle of the test.....13

4.6.2 Apparatus13

4.6.3 Test procedure14

4.7 Density test.....14

4.7.1 Principle of test14

4.7.2 Apparatus14

4.7.3 Reporting of results14

Bibliography15

Foreword

This European Standard (EN 445:2007) has been prepared by Technical Committee CEN/TC 104 "Concrete and related products", the secretariat of which is held by DIN.

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 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.

This document supersedes EN 445:1996.

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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

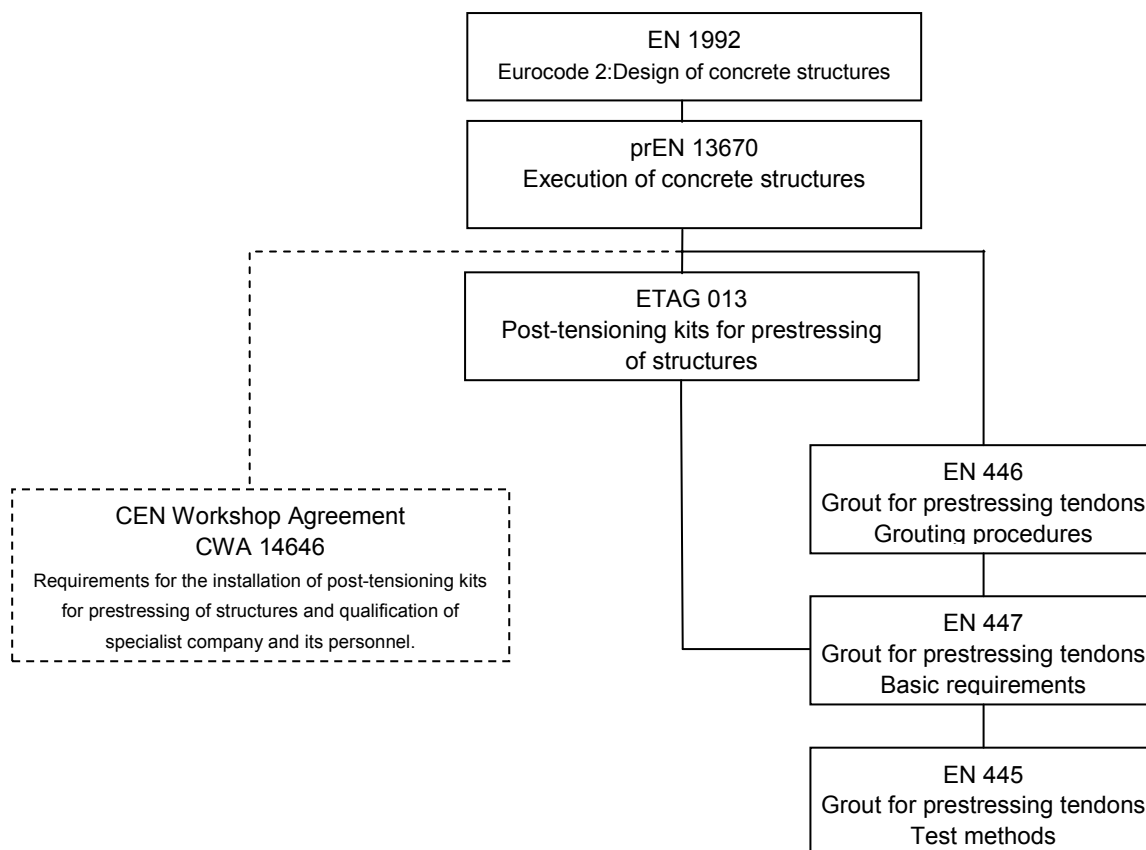
Introduction

In post-tensioned prestressed concrete construction, the grouting of tendons is an important operation. The intention of this European Standard is to provide a specification for grouting, compliance with which will satisfy the requirements in prEN 13670.

The testing regimes anticipated by this European Standard include three levels:

- (1) Initial type and audit testing in accordance with EN 447;
- (2) Suitability testing for confirmation of the selected grout for a specific project in accordance with EN 446;
- (3) Inspection during the production of grout on a specific project in accordance with EN 446.

The test methods for each of the regimes are given in this standard. Some tests given herein are alternatives and it will be necessary to relate the chosen test method to the specified requirements. The tests are reference tests for checking suitability of grout for use with any type of tensile steel element.



System of CEN and EOTA documents as basis for design, execution and materials selection for protective measures of prestressing systems (only main modules).

1 Scope

This European Standard describes the test methods for grout specified in EN 447. Testing shall be performed in accordance with the test methods given in this standard (reference test methods). The test methods are applicable to grout for all types of structures including bridges and buildings.

2 Normative references

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

EN 196-1, *Methods of testing cement – Determination of strength*

EN 447, *Grout for prestressing tendons – Basic Requirements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

grout

homogeneous mixture of cement and water, it may contain admixtures and additions

4 The testing of grout

4.1 General

4.1.1 Personnel

The grouts shall be tested by competent personnel experienced in the subject.

4.1.2 Test conditions

Testing shall be carried out at specified temperatures.

The grout for the tests shall be made from materials specified in EN 447 and mixed in accordance with EN 447.

NOTE EN 446 requires suitability testing to be carried out using the same type of mixing equipment as is used for the actual site operations, hence it is preferable to also use the same type of equipment for all testing.

4.1.3 Test reports

All test reports shall include the following information as a minimum:

- a) reference to this European Standard;
- b) name and address of the testing laboratory;
- c) identification number of the test report;
- d) name and address of the organisation or person who ordered the test;

- e) name and address of the manufacturer or supplier of the product(s);
- f) name or other identification mark of the product;
- g) date of fabrication, and if relevant, supply of the product;
- h) date of manufacture of test specimens;
- i) date of test;
- j) temperature of the fresh grout and ambient temperature;
- k) batching and mixing procedures used;
- l) specification of the grout mixer used;
- m) identification of test equipment used, including where appropriate, calibration details;
- n) individual results for the required test;
- o) any inaccuracies or uncertainty of test results;
- p) date and signature of the person responsible for the tests.

4.2 Sieve test

4.2.1 Principle of test

The test consists of pouring a quantity of grout through a sieve to check for the absence of lumps on the sieve

4.2.2 Apparatus

A 150 mm diameter sieve with an aperture ≤ 2 mm.

4.2.3 Procedure

Pour a minimum of 1 l of freshly mixed grout through the sieve.

NOTE This may be carried out while filling the fluidity test cone.

4.2.4 Reporting

Report the absence of lumps on the sieve.

4.3 Fluidity test

NOTE Two test methods are described, only one is to be performed as appropriate for the type or characteristics of the grout.

4.3.1 Cone method

4.3.1.1 Principle of test

The fluidity of grout, expressed in seconds, is measured by the time necessary for a stated quantity of grout (1 l) to pass through the orifice of the cone, under stated conditions.

4.3.1.2 Apparatus

The following apparatus is required for the test:

- a) Cone of the dimensions given in Figure 1. The cone shall be of smooth non-absorbent material. The volume of the cone (excluding the cylindrical portions at top and bottom) shall be $(1,7 \pm 0,17)$ l.
- b) Stopwatch showing time to 0,1 s.
- c) Graduated cylinder of minimum 1 l capacity and with a diameter of approximately 60 mm.
- d) Thermometer.

NOTE The cone in Figure 1 is available in plastic.

4.3.1.3 Test procedure

4.3.1.3.1 Preparation

Mount the cone with its axis vertical and its largest diameter uppermost and support firmly in position. During the test prevent the cone from vibrating. Place the cylinder under the cone outlet. All surfaces of the cone shall be clean and shall be dampened so that the surfaces are moist but without free water. Close the lower cone orifice.

4.3.1.3.2 Procedure

Pour the grout to fill the conical section of the cone. The grout shall be poured sufficiently slowly to prevent a build-up of air. Open the lower cone orifice and at the same time start the stopwatch. Measure the time taken to the nearest 0,5 s, for 1 l of grout to run into the cylinder. The grout shall be kept agitated while waiting further testing if required.

4.3.1.4 Reporting of results

Report the time measured.

Dimensions in millimetres

Dimensions are internal

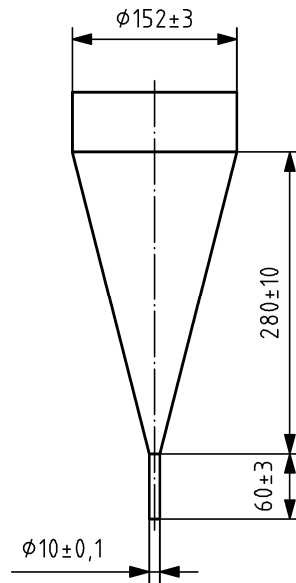


Figure 1 — Cone for fluidity test

4.3.2 Grout spread method

4.3.2.1 Principle of test

The grout spread test measures the fluidity of thixotropic grouts. The fluidity is measured by the diameter of the circle of grout spread on a smooth plate after a fixed period.

4.3.2.2 Apparatus

The following apparatus is required for the test:

- Glass or polished steel plate with a minimum diameter of ϕ 300 mm.
- Stiff mould made of steel or plastic with an internal diameter of ϕ 39 mm and a height of 60 mm.
- Stopwatch showing time to 0,1 s.
- Thermometer.
- Ruler with a minimum length of 300 mm and a 1 mm graduation.

4.3.2.3 Test procedure

4.3.2.3.1 Preparation

The spread test is carried out on the horizontal plate. Ensure that the surfaces of the mould and plate are clean and slightly moistened. If necessary apply a thin film of petroleum jelly (e.g. Vaseline) to the brim of the mould in contact with the plate to prevent the mould from leaking during filling with grout.

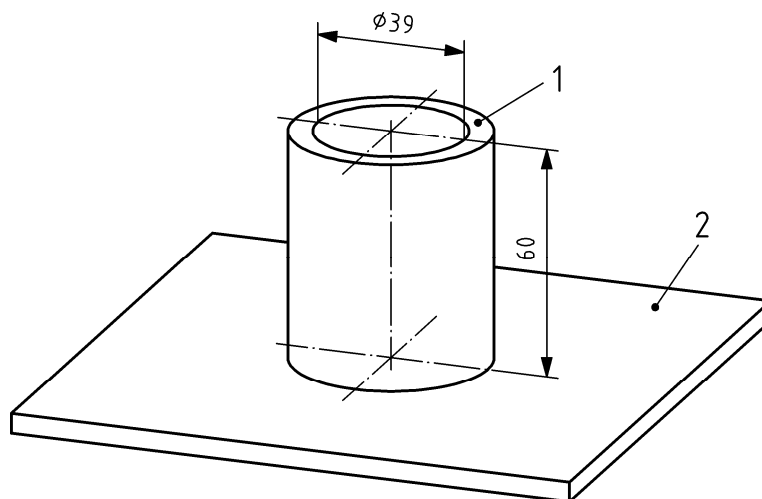
4.3.2.3.2 Procedure

Put the mould on the plate and prevent it from sliding. Pour the grout slowly into the mould until the level of the grout has reached the upper brim. The mould is steadily lifted from the plate and kept above the spread for a maximum of 30 s before it is taken away. The spread is measured in two perpendicular directions at 30 s after the start of lifting the mould.

4.3.2.4 Reporting of results

Report the spread diameter as the average measured in the two perpendicular directions across the grout spread in millimetres.

Dimensions in millimetres



Key

- 1 – Cylinder (steel or plastic tube)
- 2 – Smooth plate

Figure 2 — Grout spread test

4.4 Inclined tube test

4.4.1 Principle of test

This test serves to determine the bleed properties and volume stability of grout at full scale and includes the filtering effect of strands. The test consists of measuring the quantity of water and air remaining on the surface of the grout which has been allowed to stand protected from evaporation.

NOTE In a first test phase, the bleed water and air accumulated on top of a tube filled with grout should be determined. The grout is injected and is allowed to set so that water losses due to evaporation are prevented. In a second phase, the effect of re-grouting of a tube on bleed water and air accumulated can be determined.

4.4.2 Test equipment and set-up

- a) 2 transparent tubes, of approximately 80 mm diameter and 5 m long, equipped with caps at each end including grout inlet at the lower end, and grout vent at the top. The tubes and caps shall be able to sustain the proposed grout pressure.
- b) 12 prestressing strands \varnothing 15-16 mm per tube, i.e. a total of 24, length (approximately 5 m) to just fit between the caps on the tubes.
- c) Thermometer.

4.4.3 Test procedure

4.4.3.1 General

The two tubes are fixed on their supports to avoid noticeable deflections, at an inclination of $(30 \pm 2)^\circ$ against a horizontal reference line. Twelve strands shall be installed in each tube. The caps are subsequently sealed on the tube ends, see Figure 3. The cap shall allow internal inspection for presence of any air or water.

The grout is prepared in accordance with the grouting method statement. Specimens shall be taken from the grout mix to measure its fluidity.

4.4.3.2 Grouting of first tube (Tube 1)

Grout is injected into Tube 1 from the bottom end. When the grout exits from the vent at the top with the same consistency as it enters at the bottom, the valve shall be closed. Subsequently, the grout inlet is closed, and grouting of Tube 1 is complete.

The level of air, water, and any other resulting liquid on top of the grout shall be measured, see details in Figure 3. A minimum of four measurements of levels shall be made between 0 h and 24 h after completing grouting, with one measurement just before the re-grouting of Tube 2 is started (see next subclause).

NOTE 1 Liquid on top of the grout can be distinguished from the grout by its whitish to yellowish colour, usually clearer than the grout.

NOTE 2 The following four measuring intervals are suggested: 30 min, 1 h, 3 h and 24 h after grouting.

4.4.3.3 Grouting of second tube (Tube 2)

Grout Tube 2 simultaneously with Tube 1 using the same procedure and mix. At a time specified in the method statement for re-grouting, or 30 min, if not stated, the valves of inlet and vent of Tube 2 are opened, the grout pump is started again, and the flow time of the grout is measured again.

This will allow any liquid accumulated on top to be replaced by grout. When grout exits from the vent on top, the valve is closed. Subsequently, the valve at the bottom is closed, and re-grouting of Tube 2 is complete.

NOTE 1 Similar to Tube 1, the measurements of levels are done between 0 h and 24 h after completion of the initial grouting. One of the measurements should be made just prior to re-grouting Tube 2 followed by measurements 30 min, 1 h and 3 h after completion of re-grouting, with a final measurement at 24 h.

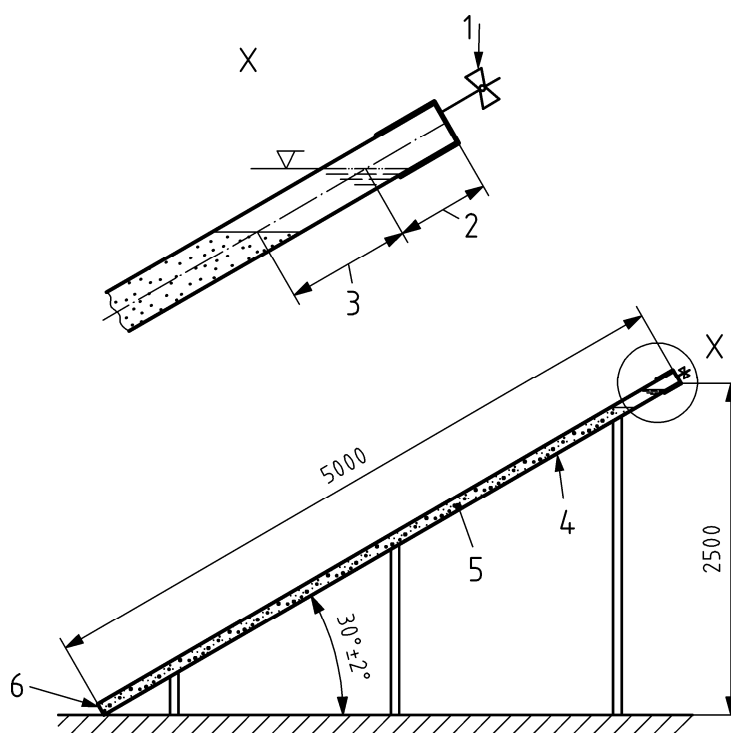
NOTE 2 The re-grouting of Tube 2 should be carried out in the test even if re-grouting is not envisaged as part of the site procedures.

4.4.4 Reporting of results

The following results and observations shall be recorded:

- Description of test set-up.
- Grout mix design, origin and certificates of all grout constituents.
- Mixing procedure of grout.
- Fluidity of grout mix before initial grouting, and before re-grouting.
- Method statement for grouting, including pressurisation details.
- Measurements of levels of air, water and residual liquid on top of the grout.
- Any observation and comment on the formation of bleed or liquid within or on top of the grout, or on difficulties encountered during the test.
- Any observation and comment on cracks of the grout, with location, orientation and approximate width.
- Development of ambient temperature during the entire test period.
- Photos illustrating test set-up, and details of the top end of the tube with air, water and residual liquid.

Dimensions in millimetres



Key

- | | |
|-------------------------|------------------------|
| 1 – Vent and stop valve | 4 – Transparent tube |
| 2 – Air | 5 – 12 strands |
| 3 – Water | 6 – Injection of grout |

Figure 3 — Inclined tube test set-up

4.5 Wick-induced test

4.5.1 Principle of test

This test provides both volume change and bleeding measurements. Bleeding is measured as the volume of water remaining on the surface of the grout which has been allowed to stand protected from evaporation.

The volume change is measured as a difference in percentage of the volume of grout between the start and the end of the test. The test measures mainly the volume change caused by sedimentation or expansion.

4.5.2 Equipment

- One transparent tube, of approximately 60 mm to 80 mm internal diameter, and approximately 1 m long, equipped with caps at each end.
- One 7-wire strand approximately 900 mm long which fits inside the tube.
- Thermometer.

4.5.3 Procedure

Set up tube in a vertical position with its open end at the top. Provide rigid fixing so that no movement or vibration can occur.

Install the strand in the tube, ensuring that it is firmly located on the base, and held centred.

Pour the grout into the tube at a steady flow rate (either from the bottom or using a small diameter tremie tube) to ensure there is no trapped air. Fill the tube to a height, h_0 , about 10 mm above top of the steel. Seal top of tube to minimise evaporation. Record the temperature of the grout and ambient air temperature.

Record starting time t_0 and height h_0 of the grout.

Record height of grout, h_g , at 15 min intervals for first hour and subsequently at 2h, 3h and 24h. Measurements shall ignore the meniscus on the grout.

Record height of bleed water, h_w , at the same times as for the grout (see Figure 4).

Record inhomogeneities that may develop in the appearance of the grout as seen through the transparent tube. Examples of inhomogeneities are:

- formation of lenses of bleed water below top of grout;
- segregation leading to areas of different coloured grout.

NOTE The purpose of recording at intervals instead of simply taking the final value is to be able to follow the behaviour of expansive grouts.

4.5.4 Reporting of results

Bleeding is expressed as

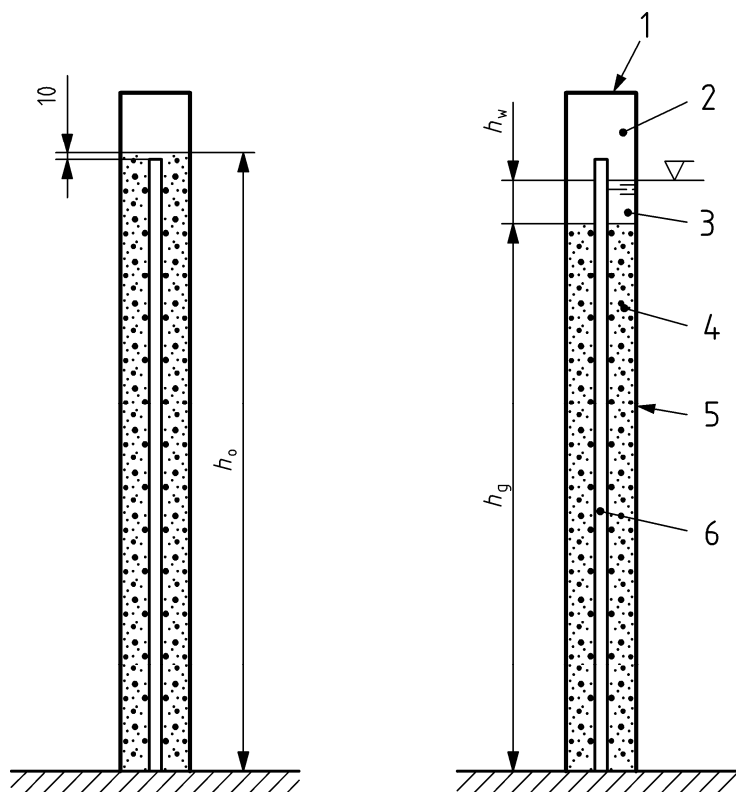
$$h_w/h_0 \times 100 \% \quad (1)$$

Volume change is

$$h_g - h_0/h_0 \times 100 \%$$

(2)

Dimensions in millimetres

**Key**

1 – Seal

4 – Grout

 h_0 – height at t_0

2 – Air

5 – Transparent tube

 h_g – height at t_n

3 – Water

6 – Strand, wires or bar

Figure 4 — Wick-induced test set-up**4.6 Compressive strength test****4.6.1 Principle of the test**

The compressive strength of grout in this test (which is an adaption to grout of the mechanical tests described in EN 196-1) is determined on the broken halves of prisms.

4.6.2 Apparatus

The following apparatus is required for the test:

- Mixer for grout in accordance with the requirements of EN 447.
- Curing equipment in accordance with EN 196-1 and an accuracy of ± 2 °C.
- Test machines and devices in accordance with EN 196-1.
- Metal moulds 40 mm x 40 mm x 160 mm in accordance with EN 196-1.

e) Metal straightedge.

4.6.3 Test procedure

4.6.3.1 Preparation

The moulds and accessories shall be prepared and the specimens made in accordance with EN 196-1, with the exception noted as follows:

Each mould shall be filled with the prepared grout. As an exception to the procedure in EN 196-1 (and because of the liquidity of grouts) the test specimens shall not be subject to any vibration or shock.

Immediately strike off the excess grout with the metal straightedge held almost vertically and moved slowly, with a transverse sawing motion once in each direction. Smooth the surface of the specimens using the same straightedge held almost flat. Then cover the specimens with a glass plate. Label or mark moulds to identify specimens.

The test specimens shall be demoulded according to EN 196-1.

4.6.3.2 Curing of test specimens

The test specimens shall be submerged in water at (20 ± 2) °C until they are tested.

4.6.3.3 Compressive test

The compressive testing shall be carried out in accordance with EN 196-1. The compressive strength shall be measured on at least two specimens from prism(s) broken in flexure.

4.6.3.4 Reporting of results

The report shall provide all results of the compressive strength tests, in N/mm^2 .

The value obtained for each test shall be the mean of the individual results.

4.7 Density test

4.7.1 Principle of test

The density is measured as the ratio of mass to volume in the fluid state.

4.7.2 Apparatus

The apparatus comprises calibrated equipment for weight and volume measurement.

NOTE Mud balance test equipment may be an acceptable alternative.

4.7.3 Reporting of results

The method of sampling, measuring weight and volume, the equipment used and the density determined shall be reported.

Bibliography

- [1] ETAG 013, Guideline for the European Technical Approval of post-tensioning kits for prestressing of structures
- [2] EN 446, Grout for prestressing tendons – Grouting procedures
- [3] prEN 13670, Execution of concrete structures
- [4] EN 1992 (all parts), Eurocode 2: Design of concrete structures
- [5] CWA 14646, Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.
Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001.
Fax: +44 (0)20 8996 7001. Email: orders@bsi-global.com. Standards are also available from the BSI website at <http://www.bsi-global.com>.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre.
Tel: +44 (0)20 8996 7111. Fax: +44 (0)20 8996 7048. Email: info@bsi-global.com.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.
Tel: +44 (0)20 8996 7002. Fax: +44 (0)20 8996 7001.
Email: membership@bsi-global.com.

Information regarding online access to British Standards via British Standards Online can be found at <http://www.bsi-global.com/bsonline>.

Further information about BSI is available on the BSI website at <http://www.bsi-global.com>.

Copyright

Copyright subsists in all BSI publications. BSI also holds the copyright, in the UK, of the publications of the international standardization bodies. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI.

This does not preclude the free use, in the course of implementing the standard, of necessary details such as symbols, and size, type or grade designations. If these details are to be used for any other purpose than implementation then the prior written permission of BSI must be obtained.

Details and advice can be obtained from the Copyright & Licensing Manager.
Tel: +44 (0)20 8996 7070. Fax: +44 (0)20 8996 7553.
Email: copyright@bsi-global.com.