

Grout for prestressing tendons — Grouting procedures

The European Standard EN 446:2007 has the status of a
British Standard

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National foreword

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

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de coulis

Einpressmörtel für Spannglieder - Einpressverfahren

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Foreword

This document (EN 446:2007) 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of an identical text or by endorsement, at the latest by April 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.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 446:1996.

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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.

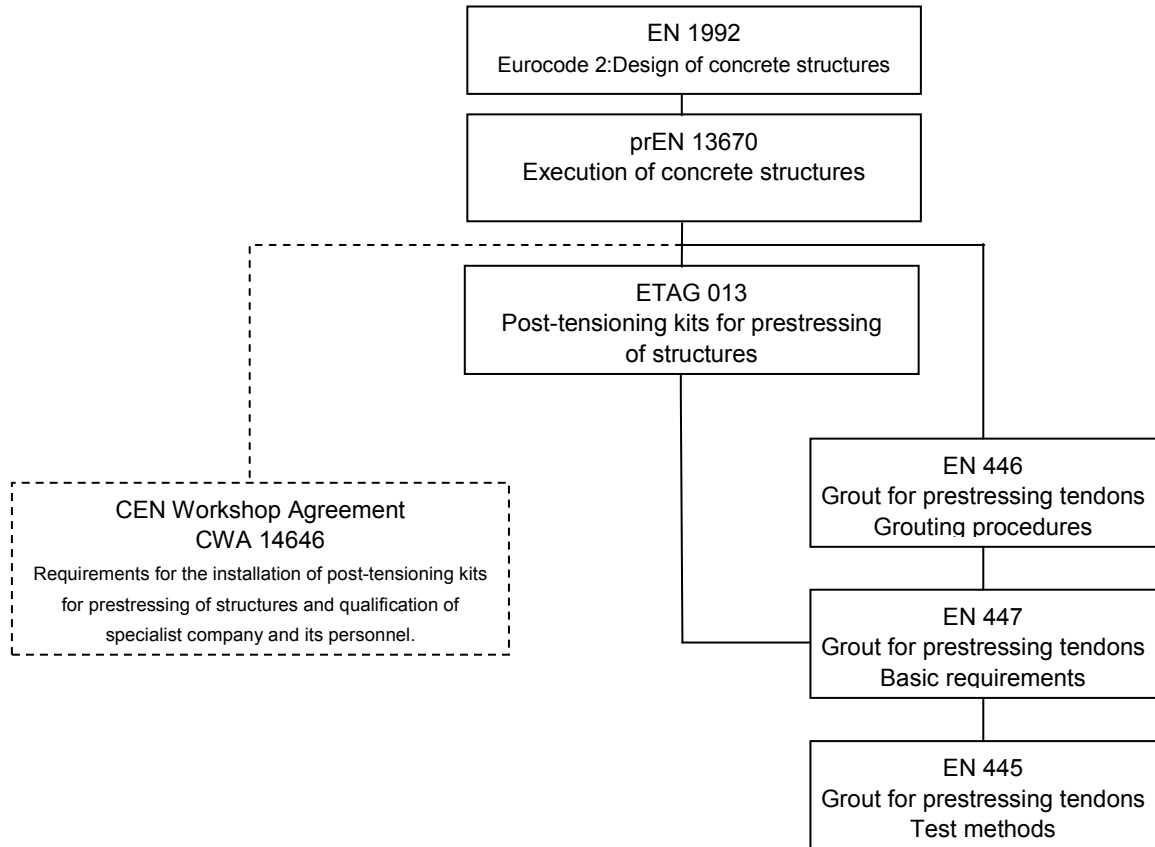
The main function of grouting is to

- Provide protection to the prestressing steel against corrosion;
- Provide a bond between the prestressing steel and the ducts where required for the design of the structure;
- Allow the transfer of compressive stresses in the structure in a direction transverse to the internal tendons;
- Fill all voids where water may accumulate and cause frost damage.

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 this standard;
- (3) Inspection during the production of grout on a specific project in accordance with this standard.

The test methods for each of the regimes are given in EN 445.



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 gives the procedures to be used for grouting of tendons in post-tensioned prestressed concrete. It is applicable to all types of structures including bridges and buildings.

This standard also covers suitability testing and inspection testing for grouts and their component materials used on a project.

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 445, *Grout for prestressing tendons – Test methods*

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

prEN 13670, *Execution of concrete structures*

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
- 3.2
grouting**
injection of grout into ducts in a continuous operation
- 3.3
tendon**
assembly of prestressing steel and sheath with anchorages and all necessary auxiliary components to permit grouting, either placed internally or externally to the concrete structure
- 3.4
specialist contractor**
contractor or construction enterprise which carries out grouting of tendons

4 Documentation

4.1 Execution specification

Before starting any part of the grouting works, the execution specification relevant to that part of the works shall be complete and available.

The following items shall be included in the execution specification:

- reference to this European standard;

- reference to other relevant European standards;
- reference to ETAs for the post-tensioning kit;
- reference to other relevant national regulations and standards;
- information and requirements for the particular project prepared to supplement and qualify the requirements of the above listed documents;
- drawings and other technical documents needed for the execution.

In addition where relevant, procedures shall be established for:

- making alterations to previously agreed requirements;
- distribution, the filing and recording of technical documents used for the works.

4.2 Quality plan

If a quality control procedure for grouting works is required by the execution specification, it shall be available at the site.

4.3 Execution documentation

The specialist contractor shall keep available on site written method statements covering materials, equipment, grouting procedures and inspection all adapted to the extent and complexity of the project. Provisions for the case of unusually low or high temperatures or delayed grouting, if likely to occur during the project duration, shall be specified.

The specialist contractor shall have shop drawings showing the position and details of the inlets and outlets, and the details of the sealing of the tendon anchorages.

The specialist contractor shall keep available on site documented records of:

- materials and grout used;
- initial type testing according to EN 447;
- suitability testing according to this European standard;
- results of the project specific grouting tests, if specified.

The specialist contractor shall keep documented records of the conformity of the materials, equipment, grout, grouting operations, and inspection with this standard and the execution specification according to Table 2, Table 3 and Table 4. These records shall be kept for the duration, as required by national provisions.

Any eventual corrective actions taken shall also be recorded.

If special documentation beyond the requirements of this European standard is required for grouting works, the type and extent of the documentation shall be stated in the execution specification.

5 Materials

The individual materials and the grout to be used shall comply with EN 447.

6 Grout assessment

6.1 Suitability testing

The suitability of the grout shall be assessed for each project sufficiently in advance of grouting operations, to enable any necessary adjustments to be made in the use of the materials, equipment or personnel. The extent of suitability testing and number of tests shall be in accordance with Table 1.

Suitability testing may be waived for structures in Inspection Class 2 subject to there being documented testing during production in accordance with EN 447.

Table 1 – Extent of suitability testing

Test in accordance with EN 445 ²⁾	Suitability testing	Number of tests
Sieve	✓	1 test
Fluidity	✓	1 test immediately after mixing 2 tests 30 min after mixing
Inclined tube	Only required if not already subject to initial type testing with the same type of mixer intended to be used on the project	1 test if required
Wick-induced bleed ¹⁾	✓	3 tests
Volume change ¹⁾	✓	3 tests
Compressive strength	✓	3 tests
Density	✓	1 test
¹⁾ Tests for bleeding and volume change are performed on the same sample.		
²⁾ Other test methods may be used if the correlation or safe relationship between the results of these test methods and the reference methods in EN 445 have been established.		

The grout assessment shall consist of the preparation of the grout using the materials, equipment and personnel proposed for the project, and testing in accordance with EN 445. The preparation of the grout shall be carried out under the conditions expected on site for the project. The assessed grout properties shall comply with EN 447. The range of acceptable temperatures specified for the particular grout shall be compatible with the expected conditions of the project.

6.2 Project specific grouting tests

If required by the execution specification, project specific grouting tests on tendons in representative forms of the project shall be performed.

NOTE Such tests should be planned and carried out well in advance of the site operations. Such project specific grouting tests may be advisable, e.g. when tendon geometry and details are specified on the project for which no prior experience for successful grouting is available. Experience has shown that full-scale tests of grout and grouting procedures can be valuable to prove adequacy.

7 Equipment

7.1 General

Grouting equipment shall consist of a mixer and a pump with all the necessary connection hoses, valves, measuring devices for water, cement, admixtures and additions and testing equipment as required to perform the grouting of the project.

The grouting equipment shall be such that the ducts can be filled without interruption and at the anticipated speed.

Grouting equipment shall include a storage reservoir if required for continuous filling of the tendons on the project. Such storage reservoirs shall have an agitator to keep the grout moving continually before it is pumped into the ducts.

The grouting equipment shall be compatible with the post-tensioning kit provided for the project.

7.2 Mixer

The mixing equipment shall be capable of producing grout, which possesses an even distribution of cement, and an even dispersal of admixtures, additions, if any, and water. The mixed grout shall contain no cement lumps as confirmed with the sieve test of EN 445. The mixed grout shall comply with the requirements of EN 447.

7.3 Pump

The pump shall be capable to provide a continuous flow of grout and to maintain the anticipated pressure for grouting. It shall be equipped with a pressure gauge and means to prevent unsafe pressure during grouting.

The pump shall be constructed in such a way as to prevent introduction of air, oil or other foreign substances into the grout.

NOTE 1 Limiting the grout pressure serves to: (a) prevent blow-outs of hoses, inlets and outlets; (b) prevent damage to the concrete structure; (c) protect the equipment and valves from damage; (d) protect the operators.

NOTE 2 The use of a pump with a variable output gives the advantage that it can be adapted to the requirements of ducts of different diameters.

7.4 Hoses

The diameter and rated pressure capacity of the grout hoses shall be compatible with the pump output, the assumed maximum pressure and the length needed.

7.5 Inlet connections

The connections of the grout hoses to the inlets of the ducts shall be leak tight.

NOTE 1 Narrow openings in hose connectors or inlet connections, through which the grout must pass, should be avoided since the resulting pressure build-up can increase the risk of bleeding which in turn may lead to blockage.

NOTE 2 A pressure gauge should be mounted at the grout inlet if the hose length is greater than 30 m. In the event of sudden and abnormal pressure increase, an additional pressure gauge located at the grout inlet will indicate whether the reason for the pressure build-up lies within the tendon ducts or in the grout hoses.

7.6 Stand-by and emergency equipment

Stand-by and emergency equipment shall be provided if required in the execution specification.

8 Grouting procedures

8.1 Inlets, outlets and tendon anchorages

Tendon anchorages or tendon anchorage recesses shall be sealed with a temporary or permanent cover which is compatible with the post-tensioning kit and which can be removed after grouting for inspection of the quality of grouting.

Inlets and outlets shall be provided in general, at both tendon ends and at those points of the tendons where air and water may accumulate.

All inlets and outlets shall be suitably marked to identify the tendon, and their location along the tendon.

NOTE 1 Likely points of the tendons where air and water may accumulate are: Anchorages, couplers, at high points and in the slope of the duct beyond these.

NOTE 2 Drainage outlets should be provided at all low points if freezing temperatures may be expected before grouting is carried out. These drainage outlets should be left open until shortly before grouting starts.

8.2 Precautions before grouting

During the time before grouting the tendons shall be adequately sealed against an ingress of water.

Ducts in precast segmental construction shall be verified to be sufficiently leak tight to avoid grout migration into adjacent ducts.

Ducts shall be confirmed to be free of debris, water and blockages that could prevent or harm grouting operations as provided in the method statement of the specialist contractor or as required in the execution specification. This may be done by blowing dry air through the tendon ducts. Verification by flushing of water through the tendon ducts shall be prohibited, in general.

Precautions shall be taken for temporary protection of the prestressing steel and post-tensioning kit anchorages if the construction periods recommended in prEN 13670 are likely to be exceeded.

NOTE 1 Ducts in precast segmental construction may be checked for sufficient leak tightness with compressed air. Any leakage of concern may be repaired before grouting.

NOTE 2 For certain types of tendons with filling ratios larger than 0,45, e.g. bar tendons, it may still be considered necessary to flush the tendons with water before grouting.

NOTE 3 Ducts should be grouted as soon as possible after it is verified that the tensioning of the prestressing steel has been successful. If the delay between inserting the prestressing steel and grouting the ducts is likely to permit corrosion of the prestressing steel, consideration should be given to the use of protective soluble oils on the prestressing steel or circulation of dry air in the ducts. It shall be verified that the use of protective soluble oils will not have an adverse effect upon the prestressing steel or the properties of the grout, and that the bond properties of the prestressing steel with protective soluble oils are acceptable for the design of the structure.

8.3 Temperature at grouting

Records shall be kept of the maximum and minimum ambient temperatures and the temperature of the structure adjacent to the tendons to be grouted.

No grout shall be placed if the temperature of the structure adjacent to the tendon is below 3 °C, or is likely to fall below 3 °C during the following 48 h, or a higher temperature limit specified by the manufacturer for which he has confirmed compliance of the grout with EN 447, unless the structure adjacent to the tendons is heated so as to maintain the temperature of the placed grout above 5 °C, or 2 °C above the temperature specified by the manufacturer, for at least 48 h.

No material in which frost, snow or ice is present shall be used. The ducts and equipment shall be free of frost and ice.

No grout shall be placed if the temperature of the grout or the temperature of the structure adjacent to the tendon is above 35 °C or the temperature for which the manufacturer has confirmed and documented the grout to satisfy the performance requirements of EN 447 (higher value is governing).

8.4 Grouting operations

The grouting procedures shall ensure that ducts are adequately filled with grout.

Grouting shall proceed in one continuous operation for the tendon.

The grouting operations shall be executed in accordance with the method statement of the specialist contractor. Records shall be kept of quantities of materials used.

Grout shall be used within 30 minutes after mixing or the time limit for which the manufacturer has confirmed the properties specified in EN 447 to be satisfied at the temperature.

Grouting shall continue until the fluidity of the grout flowing from the outlets is the same as the grout being injected, to within the limits specified in EN 447. The outlets shall be successively closed as the filling of the duct progresses. The grout taken at the outlet at the end of the tendon shall not exhibit variation in liquid density in excess of 3 % compared with the grout taken at the mixer.

When all the outlets are closed, the grout pressure shall be maintained for about one minute to confirm that there is no unintended loss of grout due to leakage. If the pressure cannot be maintained without pumping grout, the leakage shall be located and repaired, and the procedure repeated.

Shortly after grouting, and within the time limit for which properties specified in EN 447 have been documented to be satisfied, all inlets, outlets and anchorage covers shall be verified to be full, e.g. by light tapping. If any of the inlets, outlets and anchorage covers are not full, consideration should be given for remedial action.

NOTE In some countries repeated pumping called post-grouting is carried out at this stage.

8.5 Precautions after grouting

When the grout has set, all inlets, outlets and anchorage covers shall be inspected to confirm adequate filling with grout. If any of the inlets, outlets and anchorage covers are not adequately filled, these voids shall be filled with freshly mixed grout.

All grout inlets and outlets shall be suitably sealed to prevent ingress of water or other aggressive agents into the tendon.

Anchorage, inlets and outlets shall be permanently protected with suitable methods as specified in the method statement of the specialist contractor or as required in the execution specification.

Anchorage, vents and other metallic items that are to remain permanently in place shall be protected against corrosion as required in the execution specification.

9 Quality Management

9.1 General

Further detailing of the requirements for the quality management regime in excess of what is given in this document, may be stated in the execution specification.

9.2 Personnel

Grouting operations shall be under the charge of a supervisor with appropriate knowledge, training and experience in production, testing, injection and inspection who shall be responsible for the production and injection of the grout. That supervisor, or an appropriately trained representative, shall be present during all grouting procedures and shall be responsible for all safety precautions relating to the preparatory and grouting operations.

Grouting operators shall be suitably trained for the grouting activities they are anticipated to perform on the project.

NOTE 1 In some countries there are special requirements regarding the level of knowledge, training and experience of the supervisor in charge of grouting, and of the operators carrying out the grouting activities. The CEN Workshop Agreement CWA 14646 gives guidance for the qualification and acceptance of the supervisor and operators.

NOTE 2 Some countries require inspection of grouting by an independent and competent organisation.

9.3 Inspection

Supervision and inspection shall ensure that the grouting works are completed in accordance with this standard and the provisions of the execution specification.

Inspection refers to verifying conformity of the properties of materials to be used as well as inspection of the execution of the works.

Requirements for inspection shall be specified using one of the following two classes according to prEN 13670:

- Inspection Class 2;
- Inspection Class 3.

The inspection class to be used shall be stated in the execution specification.

Inspection shall be carried out by the specialist contractor and shall be recorded.

The scope of inspection of materials, products and execution of works to be performed is given in Table 2.

NOTE 1 Inspection class may refer to the grouted tendon or to certain materials and technologies used for the execution. prEN 13670 gives guidance for the selection of the inspection class.

NOTE 2 The two inspection classes give the option to specify the required inspection based on the complexity of the structure and the criticality of the execution for its ability to fulfil its function.

NOTE 3 Inspection Class 2 and 3 of ENV 13670-1 relate to Execution Class 2 and 3 of prEN 13670.

Table 2 – Inspection requirements prior to grouting

Subject	Inspection Class 2	Inspection Class 3
Incoming grout materials and products	In accordance with EN 447 and the execution specification according to 4.3 ¹⁾	
Other items ²⁾	In accordance with the execution specification	
Availability of results of initial type testing according to EN 447	In accordance with 4.3	
Availability of results of suitability testing according to EN 446	In accordance with 4.3	
Availability of results of project specific grouting tests	In accordance with 4.3	
Grouting equipment	In accordance with 7.2, 7.3	
Method statement	In accordance with 4.3	
Grouting supervisor	In accordance with 9.2	
Grouting operators	In accordance with 9.2	
Identification marking of inlets, outlets and anchorages	In accordance with 8.1	
Verification of leak tightness of ducts in precast segmental construction	In accordance with 8.2	
Verification of sheaths to be free for grouting	In accordance with 8.2	
Precautions for temporary protection of prestressing steel and anchorages	In accordance with 8.2	
Temperature of structure adjacent to tendons	In accordance with 8.3	
¹⁾ Products bearing the CE-mark or third party product certification (ETA) shall be checked against the delivery ticket and visually inspected. In cases of doubt, further inspection shall be undertaken to check that the product complies with its specification. Other products / items shall be subject to inspection and testing as defined in the execution specification. ²⁾ For example, items like inlets, outlets, mortar for filling of anchorage recesses, etc.		

Table 3 – Inspection requirements during grouting

Subject	Inspection Class 2	Inspection Class 3
Temperature of structure adjacent to tendons, and of grout.	In accordance with 8.3	
Quantities of materials used in grout preparation.	In accordance with 8.4	
Testing of grout during grouting - casting of tests for compressive strength testing; - wick-induced bleed ¹⁾ ; - volume change ¹⁾ ; - fluidity ²⁾ ; - density;	In accordance with EN 445 ³⁾ : - 3 tests per project with samples taken at mixer; - 1 test / day with sample taken at mixer but minimum of 3 tests per project; - 1 test / day with sample taken at mixer but minimum of 3 tests per project; - 1 test / half day with sample taken at mixer; - 1 test with sample taken at mixer and 1 test with sample taken at outlet at end of tendon per project (density variation in accordance with 8.4).	In accordance with EN 445 ³⁾ : - 3 tests / day with samples taken at mixer; - 1 test / half day with sample taken at mixer but at least 3 tests per grouting stage ⁴⁾ ; - 1 test / half day with sample taken at mixer but at least 3 tests per grouting stage; - 3 tests / day or every 4 h with samples taken at mixer; - 1 test / half day with 1 sample each taken at mixer and at outlet at end of tendon but at least 2 tests per grouting stage ⁴⁾ (density variation in accordance with 8.4).
Results of holding pressure when outlets are closed	In accordance with 8.4	
Inspection of all inlets, outlets and anchorage covers	In accordance with 8.4	
¹⁾ Tests for bleeding and volume change are performed on the same sample. ²⁾ Fluidity testing by either by the Cone Method or the Grout Spread Method of EN 445, measured immediately after mixing only. ³⁾ Other test methods may be used if the correlation or safe relationship between the results of these test methods and the reference methods given in EN 445 have been established. ⁴⁾ A grouting stage is the period of one continuous grouting operation.		

Table 4 – Inspection requirements after grouting

Subject	Inspection Class 2	Inspection Class 3
Inspection of all inlets, outlets and anchorage covers	In accordance with 8.5	
Sealing of inlets, outlets and anchorages	In accordance with 8.5	
Protection of steel parts of anchorages, inlets and outlets	In accordance with 8.5	
Inspection records	Required	

9.4 Conformity criteria

Where testing at the time of preparation of the grout shows results outside the limiting value in fluidity and density, the testing shall be repeated and if confirmed, the particular grout mix shall be rejected.

Conformity assessments for strength, wick-induced bleed, volume change, fluidity and density shall be made on the running production for each project. The assessments shall be based on the method of attributes.

Conformity of strength, wick-induced bleed and volume change, with the required property, is confirmed if the number of results outside the limiting value are not greater than the acceptance number in Table 5. No single result shall be outside the maximum allowed deviation, Table 6.

Table 5 – Acceptance number for conformity criteria for strength, wick-induced bleed and volume change

Acceptance Quality Limit (AQL) = 4 %	
Number of test results	Acceptance number
1 to 12	0
13 to 19	1
20 to 31	2
32 to 39	3
40 to 49	4
50 to 64	5
65 to 79	6
80 to 94	7
95 to 100	8
NOTE Where the number of test results exceeds 100, the appropriate number may be taken from Table 2-A of ISO 2859-1:1999.	

Table 6 – Maximum allowed deviation

Property	Maximum allowed deviation
Compressive strength	5 MPa
Wicked-induced bleed	0,3 %
Volume change	± 0,5 %

9.5 Action in the event of a non-conformity

Where inspection reveals a non-conformity, appropriate action shall be taken to ensure that the structure remains fit for its intended purpose.

In this case, the following aspects shall be investigated in the order listed:

- implications of the non-conformity on further execution and fitness for intended purpose;
- measures necessary to make the component acceptable;
- necessity of rejection and replacement of the possible non-repairable component.

If required in the execution specification, the rectification of non-conformity shall be in accordance with a procedure stated in the execution specification or a procedure agreed by the parties.

Bibliography

- [1] ETAG 013, Guideline for the European Technical Approval of post-tensioning kits for prestressing of structures
- [2] EN 1992-1-1 Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings
- [3] ISO 2859-1:1999 Sampling procedures for inspection by attributes -- Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

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