

BS 7861-2:2009



BSI Standards Publication

Strata reinforcement support systems components used in coal mines –

Part 2: Specification for flexible systems for roof reinforcement

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ISBN 978 0 580 68800 3

ICS 73.100.10

The following BSI references relate to the work on this standard:

Committee reference MRE/1

Draft for comment 09/30203688 DC

Publication history

First published September 1997

Second (present) edition October 2009

Amendments issued since publication

Date	Text affected
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Contents

Foreword *iii*

Introduction 1

- 1 Scope 1
- 2 Normative references 1
- 3 Terms and definitions 2
- 4 Information and requirements to be agreed and documented 4
- 5 Flexible reinforcement systems 5
- 6 Cementitious grout 9
- 7 Resin grout 10
- 8 System performance 12
- 9 Mechanical performance criteria 13

Annexes

- Annex A (normative) Tensile testing of end fitting/coupling assemblies 14
 - Annex B (normative) Determination of 0.2% proof load and strain at maximum load in tendons 16
 - Annex C (normative) Grout encapsulation tests 17
 - Annex D (normative) Determination of uniaxial compressive strength (UCS) of cementitious grout 23
 - Annex E (normative) Determination of the elastic modulus of grout 24
 - Annex F (normative) Determination of the expansion of grout 25
 - Annex G (normative) Determination of uniaxial compressive strength (UCS) of resin grout 28
 - Annex H (normative) Determination of elastic modulus of resin 29
 - Annex I (normative) Determination of creep of resin 31
 - Annex J (normative) Determination of bond strength and system stiffness of a resin anchored system 33
 - Annex K (normative) Determination of bond strength and system stiffness of a cementitious grout anchored system 40
 - Annex L (normative) Shear test on a tendon/grout system 45
 - Annex M (informative) Notes on corrosion 47
- Bibliography 48

List of figures

- Figure 1 – Examples of use of deformed strands 7
- Figure 2 – Example of a coupling assembly under load 8
- Figure A.1 – Typical end fitting/coupling assembly with a yielding plate 15
- Figure A.2 – Typical end fitting without yielding plate 15
- Figure B.1 – Example of load-strain trace 17
- Figure C.1 – Example arrangement for grout encapsulation test: bottom-up grouting 19
- Figure C.2 – Example arrangement for grout encapsulation test: top-down grouting 22
- Figure E.1 – Details of moulds 27
- Figure H.1 – Location of measuring devices for indirect strain measurement 31
- Figure J.1 – Machine tool lathe 37
- Figure J.2 – Hydraulic biaxial pressure cell 38
- Figure J.3 – Pull testing equipment 38
- Figure J.4 – Tensile testing machine 39
- Figure J.5 – Rock core type test: Performance control envelope 40
- Figure L.1 – Sectional diagram of shear frame 46

List of tables

Table 1 – Uniaxial compressive strength 10

Table 2 – Gel, setting and half-strength times for mixed resins 11

Table J.1 – Standard consumables and criteria for rock core performance testing 34

Table K.1 – Standard consumables and criteria for rock core performance testing 42

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 48, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 October 2009. It was prepared by Subcommittee MRE/1/1, *Roof supports and strata reinforcements*, under the authority of Technical Committee MRE/1, *Mining mechanical equipment and machinery*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 7861 supersedes BS 7861-2:1997, which is withdrawn.

Information about this document

Assessed capability. Users of this part of BS 7861 are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

Product certification/inspection/testing. Users of this part of BS 7861 are advised to consider the desirability of third-party certification/inspection/testing of product conformity with this part of BS 7861. Appropriate conformity attestation arrangements are described in BS EN ISO/IEC 17025. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Where optional recommendations are included, they are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

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.

In particular, attention is drawn to the following statutory regulations.

The Health and Safety at Work etc. Act 1974 [1]

The Chemicals (Hazard Information and Packaging for Supply) Regulations 2009 [2]

The Control of Substances Hazardous to Health Regulations 2002 [3]

Introduction

This part of BS 7861 meets the need for specifying the quality and performance of components and systems used as flexible reinforcement in coal mines.

Flexible systems for roof reinforcement are formed from steel wire and are generally used to provide strata reinforcement in addition to that provided by conventional rigid rockbolts.

Flexible reinforcement can comprise wound strands, deformed strands or systems assembled from individual wires, which are grouted in place using resins, cementitious materials or a combination of such materials.

NOTE The various methods for performance testing are specified in Annexes A to L. Annex M gives notes on corrosion.

1 Scope

This part of BS 7861 specifies dimensional, material and performance requirements for flexible reinforcement systems used in coal mine roofs.

This standard does not cover the assembly or installation of these components to form a support system on site.

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.

BS 1881-121, *Testing concrete – Part 121: Method for determination of static modulus of elasticity in compression*

BS 5896, *Specification for high tensile steel wire and strand for the prestressing of concrete*

BS 6319-1, *Testing of resin compositions for use in construction – Part 1: Method for preparation of test specimens*

BS 6319-2, *Testing of resin and polymer/cement compositions for use in construction – Part 2: Method for measurement of compressive strength*

BS EN 196-1:2005, *Methods of testing cement – Part 1: Determination of strength*

BS EN 1008:2002, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

BS EN 10016-4, *Non-alloy steel rods for drawing and/or cold rolling – Part 4: Specific requirements for rod for special applications*

BS EN 10244-2, *Steel wire and wire products – Non-ferrous metallic coatings on steel wire – Part 2: Zinc or zinc alloy coatings*

BS EN 10264-2, *Steel wire and wire products – Steel wire for ropes – Part 2: Cold drawn non alloy steel wire for ropes for general applications*

BS EN 10264-3, *Steel wire and wire products – Steel wire for ropes – Part 3: Round and shaped non alloyed steel wire for high duty applications*

BS EN 12385-10, *Steel wire ropes – Safety – Part 10: Spiral ropes for general structural applications*

BS EN 12390-1, *Testing hardened concrete – Part 1: Shape, dimensions and other requirements for specimens and moulds*

BS EN 12390-3, *Testing hardened concrete – Part 3: Compressive strength of test specimens*

BS EN 12390-4, *Testing hardened concrete – Part 4: Compressive strength – Specification for testing machines*

BS EN ISO 7500-1:2004, *Metallic materials – Verification of static uniaxial testing machines – Part 1: Tension/compression testing machines – Verification and calibration of the force-measuring system*

BS EN ISO 15630-3:2002, *Steel for the reinforcement and prestressing of concrete – Test methods – Part 3: Prestressing steel*

3 Terms and definitions

For the purposes of this part of BS 7861, the following terms and definitions apply.

3.1 bond strength

load in a flexible reinforcement tendon/grout/rock system at which the system stiffness falls below 20 kN/mm, when measured by pull testing, for a given bond length

3.2 capsule loading tube

device used for inserting a resin capsule(s) and its retainer(s) to the distal end of the drilled hole to ensure effective bolt installation

3.3 captivation device

device located at the distal end of a post-grouted flexible reinforcement tendon for effectively retaining the tendon in the hole during and after installation, and during grouting

3.4 cementitious grout

pumpable mixture of cement binder, additives, fine filler and water that hardens after application to form an encapsulating material which provides a bond between the flexible reinforcement tendon and the strata

3.5 compacted strand

strand that has been drawn through a die, or compacted by other means

3.6 coupling assembly

assembly used to connect the proximal ends of two or more tendons

3.7 end fitting assembly

means of transferring load from the proximal end of the tendon to the mine roof surface

3.8 flexible reinforcement system

complete system of strata reinforcement for the roof or sides of roadways and other working places at a mine, comprising a flexible reinforcement tendon; resin or cementitious grout encapsulation, or a combination of both to achieve full encapsulation; and an end fitting assembly or a coupling assembly

NOTE The flexible reinforcement system could also contain a resin-retaining device, a grouting tube, a captivation device (distal end), and a bearing plate and tensioning or termination assembly.

- 3.9 flexible reinforcement tendon**
flexible tendon of steel wire wound into plain strands, deformed strands or assemblies of individual wires, which is secured into the strata to resist ground movement
- 3.10 gel time**
period during which a resin can be mixed with no appreciable change in viscosity, i.e. before it begins to turn from fluid to solid state
- 3.11 grouting tube**
tube forming part of the flexible reinforcement system, through which grout flows during the grouting process, and which remains in situ during service
- 3.12 grouted systems**
- 3.12.1 composite grouted system**
flexible reinforcement system in which more than one type of grout is used for encapsulation, in a single installation
- 3.12.2 post-grouted system**
flexible reinforcement system, in which the tendon is installed and anchored at the distal end, after which the annulus is filled with grout using a bottom-up or top-down grouting system
- 3.12.3 bottom-up grouting system**
flexible reinforcement system in which grout is introduced at the bottom of the hole, feeds up to the top and displaces air down a breather tube to vent at roof level
- NOTE This method necessitates a seal(s) at the proximal end of the hole. Full column encapsulation is indicated by the cessation of air bubbles/or a show of grout issuing from the breather.*
- 3.12.4 top-down grouting system**
flexible reinforcement system in which grout is introduced through a tube to the top of the hole and then, as it is forced down the annulus, displaces air to vent at the end fitting
- NOTE No breather tube is required and full column encapsulation is indicated by grout showing at the end plate. This system requires a suitable grout to achieve a controlled feed down the annulus.*
- 3.13 half-strength time**
period after the setting time required for the resin to achieve a uniaxial compressive strength (UCS) of 40 MPa
- NOTE This is determined by testing in accordance with Annex D.*
- 3.14 resin grout**
non-cementitious encapsulating material, which hardens after application, and is used to achieve a bond between the flexible reinforcement tendon and the strata
- 3.15 resin retainer**
device used to anchor a resin capsule at the distal end of the hole prior to insertion of the strand
- 3.16 setting time**
- 3.16.1 cementitious grout**
period taken for the grout, when mixed to the manufacturer's instructions, to achieve a solid state
- NOTE See BS EN 196-3:2005, Clause 6.*

3.16.2 resin grout

period following the gel time required for a resin to attain enough strength to resist the pull exerted on a resin encapsulated rockbolt when the rockbolt nut is tightened

[BS 7861-1:2007, 3.14]

3.17 strand

product consisting of a number of wires spun together, the outer cover wires spun in the same direction and with the same lay length

3.18 system stiffness

stiffness of the flexible reinforcement tendon/grout/rock system for a given bond length over a specified load interval in load per unit displacement (kN/mm), when measured by pull testing

3.19 tensionable reinforcement system

flexible reinforcement system, which has:

- a) a facility to anchor the distal end of the tendon, against which tension can subsequently be applied;
- b) a proximal end fitting, which allows tension to be applied and retained;
- c) the facility to ensure full column encapsulation with pre-tensioning

3.20 wire

product manufactured from one unit of wire rod by cold working

3.21 wire rod

hot rolled steel, delivered in coils, used for cold working treatment, such as wire drawing

4 Information and requirements to be agreed and documented

4.1 Information to be supplied by the purchaser

The following information to be supplied by the purchaser shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

- a) The shape and dimensions of the wire and significant details of ribs, indentations or crimping (see 5.1.2).
- b) Whether zinc or zinc alloy coated wires are required (see 5.1.4).

4.2 Items to be agreed

The following items to be agreed between the contracting parties are specified in the clauses referred to and shall be fully documented. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

- a) The shape and dimensions of the wire and significant details of ribs, indentations or crimping (see 5.1.2).
- b) Mass coating values for zinc or zinc alloy coated wires (see 5.1.4).

- c) The inspection and testing of round wires subsequently indented, crimped or formed (see 5.1.6).
- d) The values to which stress-relieved wound strand is to be inspected and tested (see 5.2).
- e) Whether non stress-relieved wound strand is to be supplied un-galvanized and/or with an indented, crimped or formed outer wire, and the values to which this is to be tested (see 5.2).
- f) The gel and setting times of mixed resin if other than as specified in Table 2 (see 7.6).

4.3 Information to be supplied for system testing of tendons

The tendon supplier shall specify to the testing house:

- a) the hole diameters and drill bit types to be used for system testing;
- b) the cementitious grout and/or resin grout to be used for system testing; and
- c) the official designation or product number for tendons supplied for testing.

Additionally, the tendon supplier shall provide the testing house with a summary of critical dimensions and tolerances for the tendons tested.

4.4 Information to be supplied to the user about tendons

The tendon supplier shall provide the following installation information to the user:

- a) suitable installation hole diameters;
- b) the drill bit types used for the system tests performed on the product;
- c) resin grouts and/or cementitious grouts suitable for use with the tendon, based on the system tests performed on the product;
- d) installation instructions, including deployment of captivation device;
- e) maximum pre-tension load, if appropriate; and
- f) safe handling and transport information.

5 Flexible reinforcement systems

5.1 Wire

5.1.1 Material

The wire rod shall be manufactured in accordance with BS EN 10016-4.

5.1.2 Wire form and types of deformation

The wire shall have a cross-sectional shape and size capable of completely enveloping a 4 mm diameter circle. It may be of any shape or dimension and may be plain, ribbed, indented or crimped, as specified by the purchaser (see Clause 4).

5.1.3 Determination of wire size

Where the cross-sectional area (or diameter) of a wire is required it shall be determined as follows.

- a) The cross-sectional area of a plain round wire shall be calculated from the average of two diameter measurements in perpendicular directions.
- b) The cross-sectional area of an indented, crimped or formed wire shall be determined from the diameter of the plain round wire prior to indenting, crimping or forming operation.

In the case of shaped wire, or where it is necessary to measure the actual cross-sectional area (or determine the equivalent diameter) of an indented, crimped or formed wire, this shall be determined from the mass in accordance with BS 5896.

5.1.4 Wire condition

The wire shall be free from defects that would impair the performance of the flexible reinforcement.

Rusted wire shall not be used for the wire drawing process during tendon manufacture.

Products with rusted steel shall not be used in the production of wire, unless the rust is a thin film and the underlying steel surface appears smooth and unpitted to the naked eye.

Where zinc or zinc alloy coated wires are specified in the order for corrosion protection (see Annex M), manufacture, inspection and testing shall be in accordance with BS EN 10244-2. The mass coating shall be to values agreed between purchaser and manufacturer (see Clause 4).

5.1.5 Welds

Wire may contain welds made before cold working, but shall not contain any welds made during or after cold working. There shall be not more than one such weld in any strand of a tendon assembly.

NOTE Strands that include a welded wire should achieve a breaking load of not less than 98% of the breaking strength of the strand.

5.1.6 Systems assembled from individual wires

Systems assembled from individual stress-relieved wires shall comprise wires manufactured, inspected and tested in accordance with BS 5896. Systems assembled from individual wires that are not stress-relieved shall comprise wires manufactured, inspected and tested in accordance with BS EN 10264-2 for plain wires or BS EN 10264-3 for shaped wires.

Round wires, which are subsequently indented, crimped or formed, shall be inspected and tested to values agreed between purchaser and manufacturer [see 4.2c)].

5.2 Wound strand

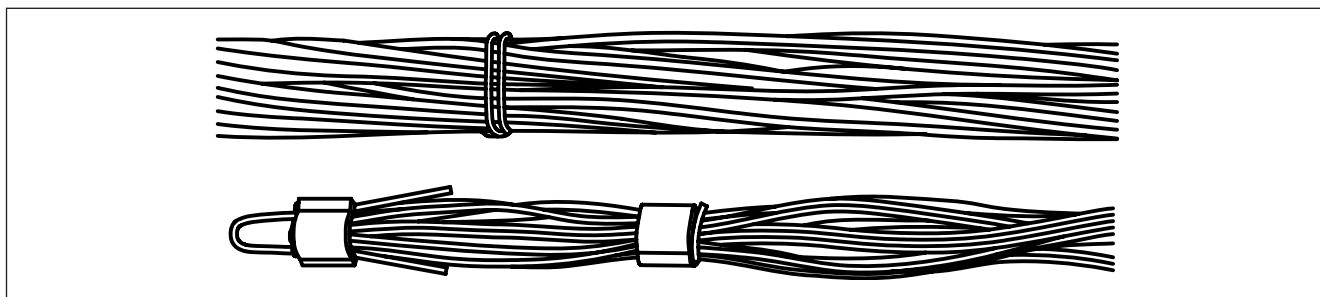
Wound strand which is to be given a stress-relieving heat treatment as the final manufacturing process (typically seven wires or less) shall be manufactured in accordance with BS 5896. The strand shall be inspected and tested in accordance with BS 5896 to values agreed between purchaser and manufacturer [see 4.2d)].

Strand which is not to be given a stress-relieving heat treatment as the final manufacturing process (typically more than seven wires) shall be manufactured in accordance with BS EN 12385-10 but may, by agreement between purchaser and manufacturer, be supplied un-galvanized and/or with an indented, crimped or formed outer wire. The strand shall be inspected and tested in accordance with BS EN 12385-10 to values agreed between purchaser and manufacturer [see 4.2e)].

5.3 Deformed strand

Plain strand may be bulbed, either by mechanical means or by unwinding and then rewinding the outer wires over a king wire spacer to form a bulb. These deformed strands can be used either singly or in pairs to form a flexible reinforcement tendon as shown in the examples given in Figure 1.

Figure 1 Examples of use of deformed strands



5.4 End fitting and coupling assemblies

5.4.1 End fitting assembly

Every reinforcement system shall include an end fitting assembly to provide support to the immediate roof. A tensionable reinforcement system shall include an end fitting assembly which can also provide and retain a preload to the tendon.

An end fitting assembly may be either yielding, i.e. allow controlled pull-through of the tendon, or non-yielding.

When tested in accordance with Annex A:

- the average ultimate tensile strength (UTS) for the end fitting assembly of a single strand tendon shall be not less than 90% of the average UTS of the tendon determined in accordance with 5.5;
- the average UTS for the end fitting assembly of a double strand tendon shall be not less than 45% of the average UTS of the tendon determined in accordance with 5.5.

5.4.2 Coupling assembly

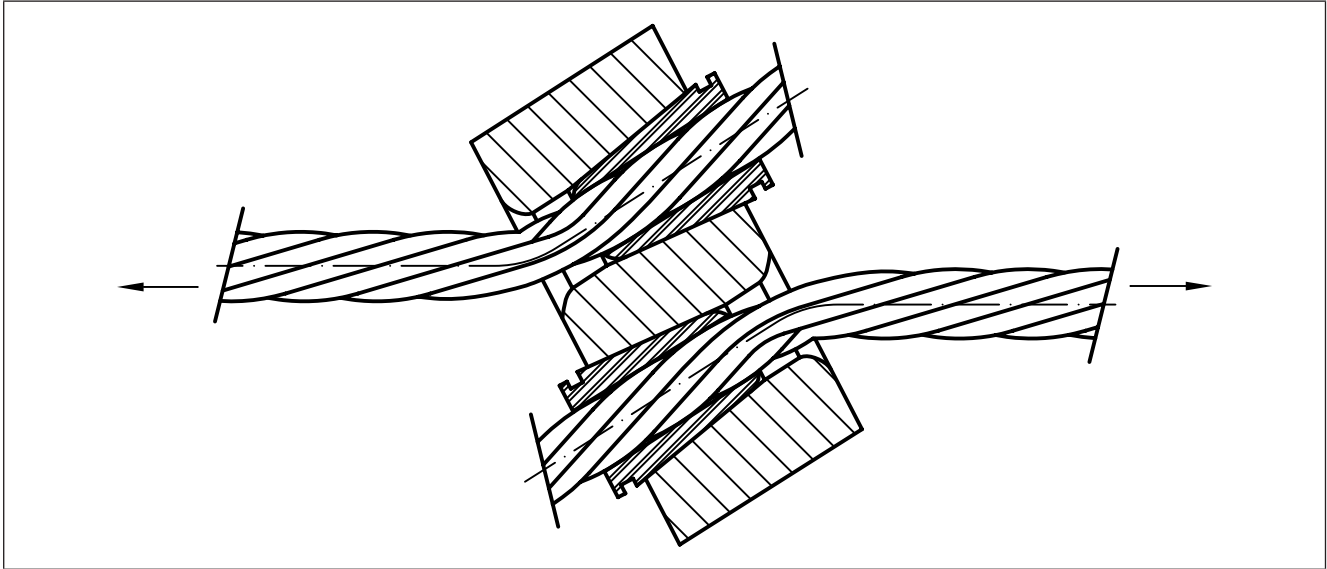
When tested in accordance with Annex A, the average maximum load of the coupling assembly shall be not less than 90% of the UTS of the tendon specified by the tendon supplier.

When tested in accordance with the intended application in terms of loading geometry and direction, the minimum maximum load of the coupling assembly shall be as declared by the supplier.

Each coupling assembly shall be marked with a unique indelible identification mark.

NOTE An example of a coupling assembly under load is shown in Figure 2.

Figure 2 Example of a coupling assembly under load



5.5 Mechanical performance of the tendon

When determined in accordance with Annex B:

- a) for each test the 0.2% proof load shall be not less than 400 kN;
- b) the UTS determined in accordance with Annex A shall be at least 15% greater than the 0.2% proof load on each tensile test; and
- c) for each test the strain at maximum force shall be not less than 4% when corrected for constructional effects.

5.6 Post-grouted systems

Post-grouted flexible reinforcement systems shall be designed to achieve and indicate full column resin and/or grout encapsulation. They shall incorporate a captivation device designed to be effective over the manufacturer's range of hole diameters.

5.7 Tensionable tendon systems

5.7.1 Distal anchor

A tensionable tendon system shall incorporate a facility to anchor its distal end with a resin grout conforming to Clause 7.

The resin-bonded length of the anchor shall be capable of withstanding a tensile load not less than the minimum UTS of the tendon as specified by its manufacturer. This may be calculated using the formula:

$$\text{Minimum distal anchor bond length (mm)} = 3 \times \text{UTS (kN)}.$$

NOTE This is based on Clause 8, which requires a bonded length of 450 mm to have a minimum system bond strength of 300 kN and a 2:1 in situ factor of safety (FOS).

5.7.2 Proximal end fitting assembly including tensioning facilities

A tensionable tendon system shall incorporate a facility to allow the designed tension to be applied and retained. The proximal end fitting shall provide a means of applying tension in the tendon, such as attachment of a hydraulic tensioning kit, and a means of retaining this tension when the tensioning device is removed.

NOTE The manufacturer should specify the maximum designed pre-tension.

The proximal end fitting assembly shall incorporate a means of introducing resin and/or grout to fill the annulus after the tension has been applied, such that full encapsulation can be achieved. Tubes or ports within the end fitting may be used to achieve this. Any external tubes shall be such that the feed and return are not compromised during installation.

6 Cementitious grout

6.1 General

When tested in accordance with Annex C, the grout shall fully encapsulate the tendon in a pre-drilled hole.

Grout shall be supplied in a form in which it can be readily transported, mixed and pumped, in order fully to encapsulate a long tendon installed in a pre-drilled hole underground.

6.2 Storage life

The manufacturer shall specify the storage life and conditions.

6.3 Packaging

Containers shall be capable of withstanding transportation, handling and storage consistent with a mining environment. The containers shall be clearly marked with the following information:

- a) net weight of grout;
- b) the required water/solids ratio;
- c) the volume of water (L) to be combined with the container net weight in order to achieve the required water/solids ratio;
- d) date of manufacture;
- e) batch referencing;
- f) manufacturer and grout name;
- g) the symbols, risk and safety phrases as required under the current legislation [2];
- h) type of installation for which the grout is suitable, e.g. "bottom-up" or "top-down".

The actual weight of material shall be within $\pm 1\%$ of the quoted net weight.

NOTE Attention is drawn to the Chemical (Hazard Information and Packaging) Regulations 1995 [2].

6.4 Mechanical performance criteria

6.4.1 Uniaxial compressive strength (UCS)

When determined in accordance with Annex D, the UCS of the grout shall be greater than the minimum values in Table 1.

Table 1 Uniaxial compressive strength

Curing period	Minimum UCS
Days	N/mm ²
1	30
3	50
7	60
14	70
28	80

6.4.2 Elastic modulus

When determined in accordance with Annex E, the elastic modulus of the grout shall be greater than 15.5 GPa.

6.4.3 Expansion

When tested in accordance with Annex F, the grout shall demonstrate a minimum positive expansion after setting of 0.01%.

6.5 Mixing water quality

Water used to mix grout shall conform to BS EN 1008:2002, Clause 4. The chloride content of mixing water shall be a maximum of 500 mg/L as specified for pre-stressed concrete and grout in BS EN 1008:2002, Table 2.

7 Resin grout

7.1 Capsules

Resins shall be supplied in capsule form and shall be such as to achieve full column bonding when used with non post-grouted flexible reinforcement systems.

7.2 Capsule material

The capsules shall contain a filled polyester resin and a catalyst in separate compartments within a frangible sheath.

7.3 Capsule size

Capsules shall be of a diameter and length suitable to the combination of tendon size (diameter and length) and hole diameter, so that, when adequately mixed, the required length of encapsulation of the tendon is achieved. Capsule tolerances shall be ± 0.5 mm on diameter and $^{+10}_{-5}$ mm on length when measured between the crimped ends.

7.4 Shelf life of resins

Resins shall be such that, when stored in accordance with the manufacturer's instructions, they retain sufficient rigidity to enable insertion using a capsule loading tube and resin retainer, and continue to conform to 7.6 and 7.7.

7.5 Packaging of capsules

7.5.1 Capsules shall be so packaged that they are capable of withstanding transport, handling and storage in a mining environment.

7.5.2 The package shall be of a suitable size, shape and weight for manual handling.

7.5.3 The following information shall be displayed on all packages.

- a) Manufacturer's name.
- b) Type of resin.
- c) Size of capsule.
- d) Quantity of capsules.
- e) Colour code as specified in Table 2.
- f) Gel and setting time at 27 °C.
- g) Shelf life and storage conditions.
- h) Date of manufacture.
- i) Weight.
- j) Batch or time reference.
- k) Manufacturer's identification.
- l) The symbols, risk and safety phrases as required under the current legislation [2].
- m) Installation procedure.

NOTE Attention is drawn to the Control of Substances Hazardous to Health Regulations 2002 [3].

7.6 Gel, setting and half-strength times of resins

The gel and setting times of the mixed resin, tested at a temperature of 27 °C, shall be as specified in Table 2 or as otherwise agreed between the purchaser and the manufacturer to suit particular reinforcement systems [see 4.2f)].

The manufacturer shall provide information indicating gel, setting and half-strength times within a temperature range of 20 °C to 35 °C.

Table 2 Gel, setting and half-strength times for mixed resins

Resin type (Colour)	Gel times s	Setting times s	Half-strength times min
Fast set (red)	13–18	7–10	2.5
Medium set (yellow)	40–55	10–15	3
Slow set (green)	70–200	30–50	12
Ultra slow set (blue)	270–330	80–140	13

NOTE Times are cumulative, i.e. the setting time starts after the gel time (as tabulated) has passed; similarly, the half-strength time starts after the setting time (as tabulated) has passed.