BRITISH STANDARD

Strata reinforcement support system components used in coal mines –

Part 1: Specification for rockbolting

ICS 73.100.10

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Foreword

Publishing information

This part of BS 7861 is published by BSI and came into effect on 31 October 2007. It was prepared by Subcommittee MRE/1/1/1, *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This part of BS 7861 supersedes BS 7861-1:1996, which is withdrawn.

Assessed capability. Users of this British Standard 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 British Standard are advised to consider the desirability of third-party certification/inspection/testing of product conformity with this British Standard. 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. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

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 2002 [2]

The Control of Substances Hazardous to Health Regulations 1995 [3]

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1 Scope

This Part of BS 7861 specifies dimensional, material and performance requirements for rockbolting support system components used in coal mines. Components included are steel rockbolts, glass reinforced plastics (GRP) rockbolts, resins, nuts, conical seats and domed washer plates.

This British Standard does not cover the assembly or installation of these components to form a rockbolting 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 6319-1:1983, *Testing of resin compositions for use in construction – Part 1: Method for preparation of test specimens*

BS 6319-2:1983, *Testing of resin compositions for use in construction – Part 2: Method for measurement of compressive strength*

BS EN 837-1, 1998, *Pressure gauges – Part 1: Bourdon tube pressure gauges – Dimensions, metrology, requirements and testing*

BS EN 10002-1:2001, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

BS EN 10045-1:1990, *Charpy impact test on metallic materials – Part 1: Test method (V- and U-notches)*

BS EN 13463-1, *Non-electrical equipment for potentially explosive atmospheres – Part 1: Basic method and requirements*

BS EN ISO 527-1, *Plastics – Determination of tensile properties – Part 1: General principles*

BS EN ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

BS EN ISO 4034, *Hexagon nuts – Product grade C*

BS EN ISO 6789, *Assembly tools for screws and nuts – Hand torque tools – Requirements and test methods for design conformance testing, quality conformance testing and recalibration procedure*

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 9513:2002, *Metallic materials – Calibration of extensometers used in uniaxial testing*

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 rockbolt/resin/rock system at which the system stiffness falls below 20 kN/mm, when measured by pull testing, for a given bond length

3.2 breakout facility
facility whereby the nut is held in position on the thread of the rockbolt, enabling mixing of the resin to take place during rockbolt installation, but which allows the nut to be spun up the thread to tighten on the domed washer plate when a predetermined torque value is reached

3.3 brittle fracture
failure of a steel rockbolt without plastic deformation

3.4 conical seat
accessory which, when used in conjunction with a rockbolt, nut and domed washer plate, accommodates a degree of misalignment between the rockbolt and the strata surface

3.5 domed washer plate
accessory which, when used in conjunction with a rockbolt, nut and conical seat, facilitates load distribution, ensures correct alignment and reduces weathering around the mouth of the rockbolt hole

3.6 equivalent diameter
diameter of an equivalent circular bar calculated from the weight and density of a 150 mm long sample of actual bar

NOTE For steel rockbolts that are to be galvanized, the equivalent diameter is determined from a sample of un-galvanized bar.

3.7 flexural strength
maximum flexural stress occurring at the surfaces of the test specimen during a bending test, based on the maximum load sustained during the test and assuming that the neutral axis is through the middle of the section

3.8 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

3.9 hand held machine
drilling machine where the drill thrust is provided solely by human power

3.10 resin
encapsulating material used to achieve a bond between rockbolt and strata

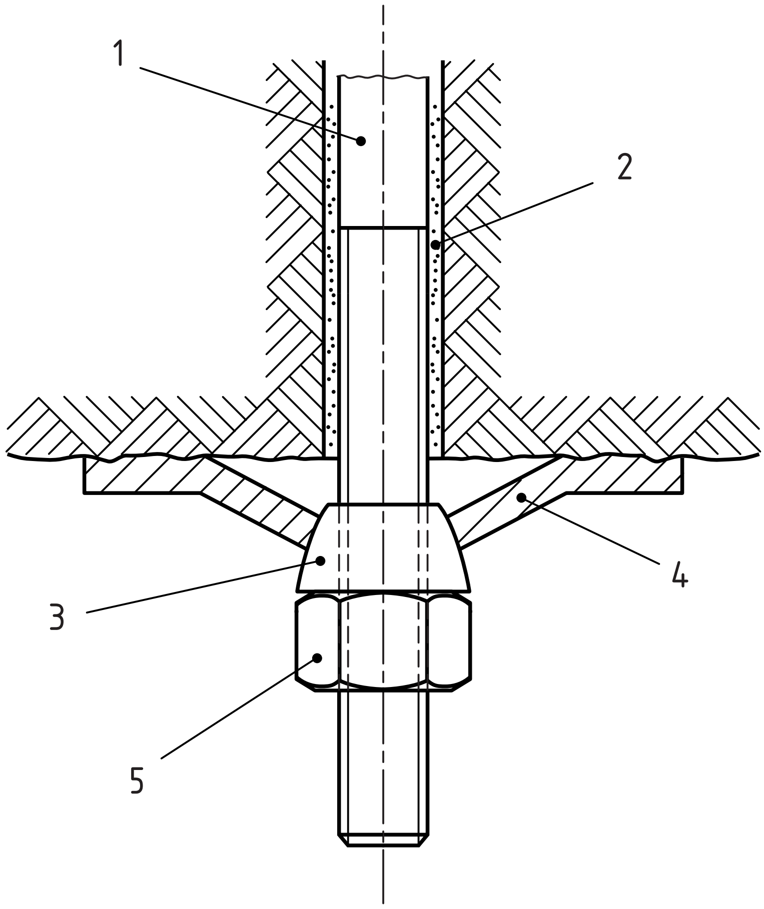
3.11 rockbolt
bar inserted into the roof or side of a roadway, used with fully encapsulating resin as part of a rockbolting support system

3.12 rockbolt assembly

rockbolt complete with appropriate end fittings

NOTE An example of a steel rockbolt assembly is given in Figure 1.

Figure 1 **Example of a steel rockbolt assembly in situ**



Key

1 Rockbolt
2 Resin
3 Conical seat
4 Domed washer plate
5 Nut

3.13 rockbolting support system

rockbolt assemblies installed systematically to provide principal roof and/or side support for mine roadways

3.14 setting time

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

3.15 system stiffness

stiffness of the rockbolt/resin/rock system for a given bond length in load per unit displacement (kN/mm), when measured by pull testing

4 Steel rockbolts and components

4.1 Rockbolt

4.1.1 Rockbolt bar

4.1.1.1 Composition

The bar of a rockbolt shall be made from steel with a homogenous structure having a chemical composition of carbon 0.3% max., manganese 1.6% max., sulfur 0.05% max. and phosphorus 0.05% max.

4.1.1.2 Profile

The bar of a rockbolt shall be of rolled circular section and may be ribbed or threaded.

4.1.1.3 Diameter

The minimum equivalent diameter of the bar of a rockbolt shall be not less than 21.5 mm. The minimum measurement across the minor axis of the bar shall be not less than 20 mm.

4.1.1.4 Straightness

Straightness shall be within 0.4% of the length of the rockbolt bar.

4.1.1.5 Tensile properties

When tested in accordance with Annex A:

a) the minimum yield strength shall be 640 N/mm^2;

b) the tensile strength shall be at least 20% greater than the yield strength on each tensile test;

c) the elongation after fracture (A) shall be a minimum of 18% and the elongation at maximum force (A_{gt}) shall be a minimum of 8%.

4.1.1.6 Resistance to brittle fracture

NOTE The bar of a rockbolt should be tough enough to resist brittle fracture at the lowest expected operating temperature.

When tested in accordance with Annex B:

a) no more than two of the individual values shall be lower than 27 J;

b) no more than one individual value shall be lower than 19 J;

c) the average value of all tests shall be no lower than 27 J.

4.1.2 Manufacture

4.1.2.1 Proximal end

The minimum length of the thread at the proximal end of the rockbolt shall be 150 mm. The thread shall be compatible with the nut.

4.1.2.2 Distal end

The distal end of the rockbolt shall be capable of passing through a 450 mm long cylinder gauge with a diameter not more than 1.5 mm greater than the maximum diameter of the rockbolt bar.

4.1.2.3 Length

The tolerance on the manufactured length of the rockbolt shall be ± 5 mm.

Colour coding on the proximal end in accordance with Table 1 shall identify rockbolt length. Rockbolt lengths other than those listed in Table 1 shall be identified by colour(s) other than those listed in Table 1.

Table 1 **Colour coding of rockbolt length**

Nominal rockbolt length m	**Colour code**
3.0	Brown
2.4	Red
2.1	Green
1.8	Yellow
1.5	White
1.2	Blue

4.1.2.4 Corrosion protection

Where corrosion protection is required rockbolts shall be hot dipped galvanized in accordance with BS EN ISO 1461 with a minimum coating thickness of 85 µm. Rockbolts shall not be passivated after galvanizing as this can affect the resin bond strength.

4.1.3 Supplier identification

Either the nut or conical seat supplied with the rockbolt shall be marked with the identity of the supplier.

4.2 Nut

4.2.1 General

The nut shall be manufactured from black hexagon steel grade 8 conforming to BS EN ISO 4034, except that its thickness shall be not less than 26 mm. The nut shall be compatible with the bar thread and conform to **7.1**.

The nut shall have a breakout facility, unless it is intended for installation in the side with a hand held machine; in which case a breakout facility is optional.

4.2.2 Nut breakout type test

When tested in accordance with **C.1**, the nut breakout facility shall operate at torques in the following ranges:

a) high torque range 100 Nm to 185 Nm;

b) low torque range 35 Nm to 80 Nm.

4.3 Domed washer plate/conical seat

4.3.1 Material

The domed washer plate and conical seat shall be manufactured from steel.

4.3.2 Form

The form of the domed washer plate and conical seat shall be as shown in Figure 1 and be compatible with other components of the rock bolt assembly.

4.3.3 Supplier identification

Each domed washer plate shall be marked with a unique supplier identification mark.

4.3.4 Performance requirements

4.3.4.1 Assembly load

When tested in accordance with Annex D, the steel domed washer plate shall:

a) flatten under a load of 50% to 70% of the nominal breaking load of the bar, based on the equivalent diameter and a stress of 770 N/mm^2;

b) allow pull-through of the rockbolt, nut and conical seat assembly under a load (the maximum tensile load or pull-through load) of 70% to 95% of the breaking load of the bar, based on the equivalent diameter and a stress of 770 N/mm^2.

NOTE Failure of the domed washer plate and conical seat might occur in a ductile manner. Brittle fracture in either component is not acceptable.

4.3.4.2 Alignment

When tested in accordance with Annex E, the conical seat shall allow a minimum misalignment of 18° between the rockbolt and the domed washer plate.

5 Glass fibre reinforced plastic (GRP) rockbolts and components for use in the sides

5.1 Rockbolt

5.1.1 Rockbolt bar

5.1.1.1 Composition

The bar of the GRP rockbolt shall be made from a polymer resin matrix with a minimum glass content of 75% by weight.

5.1.1.2 Profile

The bar of the GRP rockbolt shall be of circular section and may have a rough or threaded surface.

5.1.1.3 Diameter

The minimum equivalent diameter of the GRP rockbolt bar shall be not less than 21.5 mm. The minimum measurement across the minor axis shall be not less than 20 mm.

5.1.1.4 Straightness

Straightness shall be within 0.4% of the length of the GRP rockbolt bar.

5.1.1.5 Electrical resistance

The antistatic properties of the GRP rockbolt bar shall be in accordance with BS EN 13463-1.

5.1.1.6 Fire resistance

When tested in accordance with Annex F, the persistence of flame time of the GRP rockbolt bar shall be less than 10 s.

5.1.1.7 Torsional strength

When tested in accordance with Annex G, the minimum torsional strength of the GRP rockbolt bar shall be 100 Nm in both directions.

5.1.2 Manufacture

5.1.2.1 Proximal end

The minimum length of the thread of the GRP rockbolt bar shall be 150 mm. The thread shall be compatible with the nut.

5.1.2.2 Distal end

The distal end the GRP rockbolt bar shall be machined and free from burrs or edges which protrude beyond the profile of the rockbolt.

5.1.2.3 Length

The tolerance on the manufactured length of the GRP rockbolt bar shall be ± 5 mm.

Rockbolt lengths shall be identified by colour coding on the proximal end as specified in Table 1. Rockbolt lengths other than those listed in Table 1 shall be identified as such by colour(s) other than those listed in Table 1.

5.1.3 Type tests

5.1.3.1 Tensile strength

When tested in accordance with Annex H and BS EN ISO 527-1, the GRP rockbolt bar shall have a tensile strength of not less than 850 N/mm^2.

When tested in accordance with Annex I the peak load shall be at least 320 kN.

5.1.3.2 Flexural strength

When tested in accordance with Annex J, the material shall have a flexural strength of not less than 750 N/mm^2 based on the maximum load recorded during the test.

5.2 Nut, conical seat and domed washer plate

5.2.1 Material properties

5.2.1.1 Electrical resistance of the nut, conical seat and domed washer plate

The antistatic properties of the nut, conical seat and domed washer plate shall be in accordance with BS EN 13463-1.

5.2.1.2 Fire resistance of domed washer plate

When the domed washer plate is tested in accordance with Annex F, the persistence of flame time shall be less than 10 s.

5.2.2 Form of the nut, conical seat and domed washer plate

The form of the nut, conical seat and domed washer plate shall be compatible with the other components of the rockbolt assembly.

NOTE An example is shown in Figure 1.

5.2.3 Supplier identification

Either the nut or the conical seat supplied with the GRP rockbolt shall be marked to identify the supplier.

5.2.4 Breakout facility for the nut

The nut shall have a breakout facility, unless it is intended for installation in the side with a hand held machine, in which case a breakout facility is optional.

5.2.5 Type tests

5.2.5.1 Nut breakout test

Where torque nuts are used, they shall enable breakout at a predetermined torque setting in the range of 35 Nm to a maximum of 80% of the maximum torsional strength of the GRP rockbolt bar, when tested in accordance with **C.2**. The breakout shall function correctly without damaging the rockbolt bar.

5.2.5.2 Assembly load test

When tested in accordance with Annex K the assembly shall fail under a tensile loading of not less than 50 kN.

NOTE Failure of the assembly should occur in a progressive manner.

5.2.5.3 Alignment test

When tested in accordance with Annex E, the conical seat and domed washer plate shall allow a minimum misalignment between the rockbolt and the domed washer plate of:

- 18° when using a steel domed washer plate; and
- 10° when using a non-metallic plate.

6 Resins and capsules

6.1 General

Resins shall be supplied in capsule form and shall achieve full column bonding when used with rockbolts as a means of strata reinforcement.

6.2 Capsule material

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

6.3 Capsule size

Capsules shall be of a diameter and length (dependent on the combination of bolt diameter and length) and hole diameter that permit full encapsulation of the bolt. Capsule tolerances shall be ± 0.5 mm on diameter and $^{+10}_{-\ 5}$ mm on length when measured between the crimped ends.

6.4 Shelf life of resins

Resins shall:

- retain their ability to conform to **6.6** and **6.7**; and
- retain sufficient rigidity to enable insertion using a capsule loading tube

for a minimum period of six months, when stored in accordance with the manufacturer's instructions.

6.5 Packaging of capsules

6.5.1 Capsules shall be supplied in boxes of a size and shape suitable for manual handling in a mining environment and which weigh no more than 25 kg.

6.5.2 The following information shall be displayed on all boxes:

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 (see **6.6**);

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, taking into account the Control of Substances Hazardous to Health Regulations 2002 [3].

6.6 Gel and setting times of mixed resin

The gel and setting times of the mixed resin at a temperature of 27 °C shall be as specified in Table 2.

The manufacturer shall provide information for gel and setting times for an ambient temperature range of 20 °C to 35 °C.

NOTE This information may be provided electronically or on a data sheet.

Table 2 **Resin setting times at 27 °C**

Resin type (colour)	Gel times s	Setting times s
Fast-set (red)	13–18	7–10
Medium-set (yellow)	40–55	10–15
Slow-set (green)	70–200	30–50
Ultra slow-set (blue)	350–500	80–140

6.7 Mechanical performance criteria for resins

6.7.1 Uniaxial compressive strength (UCS)

The UCS, as determined by the test method in Annex L, shall be greater than 80 MPa.

6.7.2 Elastic modulus

The elastic modulus, as determined by the test method in Annex M, shall be greater than 11 GPa

6.7.3 Resistance to creep

Creep, as determined by the test method in Annex N, shall be no greater than 0.12%.

6.7.4 Re-testing of resin

All resin shall be re-tested when there is a change in constituents or a change in the manufacturer's production process.

7 System type tests – Steel rockbolts

7.1 Tensile test of threads

When tested in accordance with Annex O, the threaded portion of the rockbolt, or the thread of the assembled nut, shall not fail at a load less than the nominal breaking load of the bar based on a stress of 770 N/mm^2 and the equivalent diameter of the bar.

7.2 Shear test

When tested in accordance with Annex P the shear strength of the rockbolt/resin system shall be at least 640 N/mm^2.

7.3 Bond strength and system stiffness

When tested in accordance with Annex Q, the minimum system bond strength shall be 130 kN and the minimum system stiffness shall be 240 kN/mm measured between loads of 40 kN and 80 kN.

8 System type tests – GRP rockbolts

8.1 Tensile test of threads

When tested in accordance with Annex O, the threaded portion of the rockbolt, or the thread of the assembly nut, shall not fail at a load less than 60 kN and shall not fail in a sudden manner.

8.2 Shear test

When tested in accordance with Annex P, the shear strength of the rockbolt/resin system shall be at least 260 N/mm^2.

8.3 Bond strength and system stiffness

When tested in accordance with Annex Q the minimum system bond strength shall be 120 kN and the minimum system stiffness shall be 100 kN/mm measured between loads of 40 kN and 80 kN.

Annex A (normative) Tensile test on steel bar

A.1 Principle

The mechanical properties of the steel bar are determined by tensile testing in accordance with BS EN 10002-1:2001. The yield strength, for this purpose, is the upper yield strength (R_{eH}) or, if not applicable, the 0.2% proof strength ($R_{p\,0.2}$), both of which are defined in BS EN 10002-1:2001.

A.2 Apparatus

A.2.1 *Tensile test machine*, calibrated to a minimum of Class 1 in accordance with BS EN ISO 7500-1:2004.

A.2.2 *Extensometer*, calibrated to a minimum of Class 1 in accordance with BS EN ISO 9513:2002 for the determination of proof strength.

A.3 Procedure

A.3.1 Sample size

One sample of finished product shall be taken from every ''heat'' of steel processed into rockbolt material.

A.3.2 Method

Determine the yield strength (R_{eH} or $R_{p\,0.2}$) and the tensile strength (R_m) on the actual cross-sectional area, based on equivalent diameter, of the bar. Apply load at a stress rate not exceeding 10 (N/mm^2)/s prior to the yield point.

Measure the percentage elongation after fracture (A) over a gauge length of 100 mm, in accordance with BS EN 10002-1:2001, Clause **11**.

Measure the percentage elongation at maximum force (A_{gt}) in accordance with BS EN 10002-1:2001, Clause **12**.

A.4 Results

Record the results.

Annex B (normative) Resistance to brittle fracture

B.1 Principle

The resistance to brittle fracture of a rockbolt bar conforming to **4.1.1.6** is determined by Charpy V-notch impact testing in accordance with BS EN 10045-1. The specified Charpy impact energy value is based on Charpy impact-fracture toughness correlations derived for rockbolt materials. See Shuter [4] and Shuter et al. [5].

B.2 Apparatus

B.2.1 *Charpy impact test machine*, calibrated in accordance with BS EN ISO 7500-1:2004.

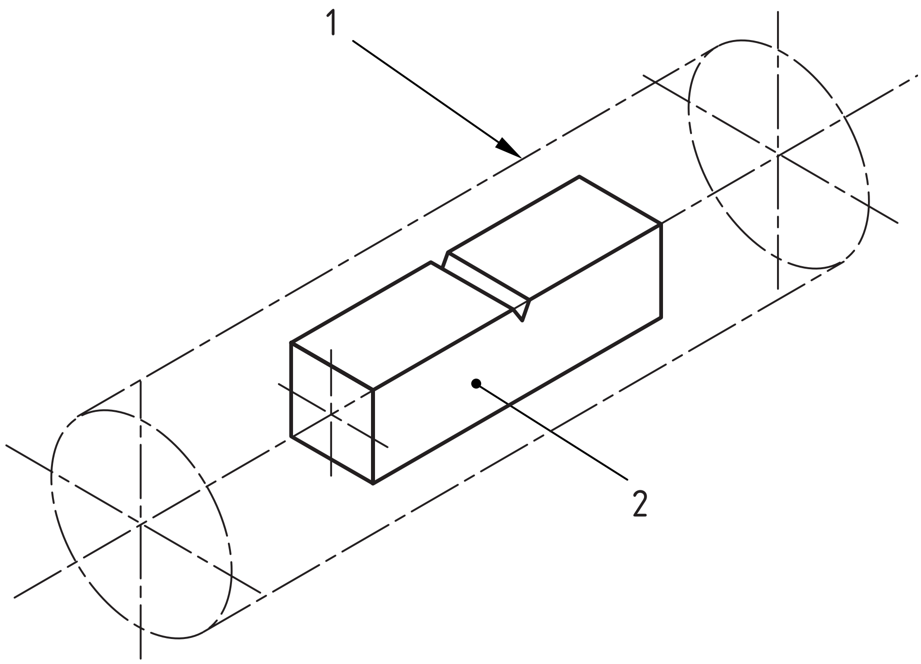
B.3 Procedure

B.3.1 Sampling

Take three specimen lengths of bar at random positions from each ‘‘heat’’ of steel.

Machine one Charpy V-notch test specimen from each specimen length according to the dimensions specified in BS EN 10045-1, the position and orientation being as shown in Figure B.1.

Figure B.1 **Charpy impact specimen – machining from bar details**



Key
1 Bar
2 Charpy impact test specimen

B.3.2 Method

Carry out Charpy V-notch impact tests on each of the three specimens in accordance with BS EN 100045-1 at a temperature between 18 °C and 22 °C.

B.3.3 Results

Record the individual energy values from each of the three tests and calculate the average value.

If the average value of the three original energy values is lower than 27 J, or if any one value is lower than 70% of this value (i.e. 19 J), then test three additional test pieces from the bar.

When re-tests are necessary, the average value of the six tests shall meet the specified energy value of 27 J.

Annex C (normative) Breakout facility torque test

C.1 Procedure for steel rockbolts

C.1.1 Sample size

Test a minimum of five specimens.

C.1.2 Method

Secure the free end of the rockbolt/nut combination in a driven chuck such that the free length is (250 ± 5) mm from the securing arrangement to the back of the nut. Tighten the rockbolt sufficiently to prevent slippage of the test specimen. Attach a calibrated torque meter via a suitable adaptor to the specimen. Rotate the rockbolt to a speed of approximately 75 rpm.

C.1.3 Results

Record the torque at which the nut breaks out.

NOTE After the breakout the nut should be free running on the thread.

C.2 Procedure for GRP rockbolts

C.2.1 Sample size

Test a minimum of five specimens.

C.2.2 Method

Tighten the free end of the rockbolt/nut combination in a suitable gripping device to prevent slippage of the test specimen, ensuring that the free length is (250 ± 5) mm from the gripping device to the back of the nut.

To maintain inline stability use a centre support with the torque wrench (see Figure C.1).

Measure the torque resistance of the nut by attaching a torque wrench calibrated to BS EN ISO 6789 to the nut and applying manually a uniform load until the nut breaks out.

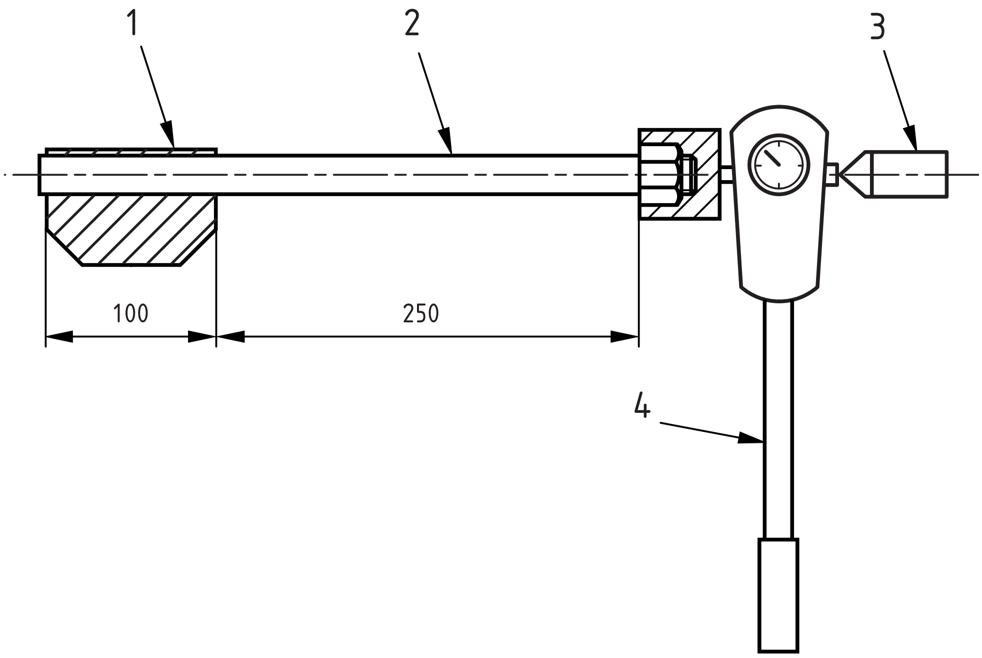
C.2.3 Results

Record the torque at which the nut breaks out and any damage to the rockbolt bar.

NOTE After the breakout the nut should be free running on the thread.

Figure C.1 **Arrangement for nut breakout torque test for GRP rockbolts**

Dimensions in millimetres



Key

1 Gripping device
2 Test specimen
3 Centre support
4 Torque wrench

Annex D (normative) Tensile test to establish flattening and pull through loads of steel domed washer plate assemblies

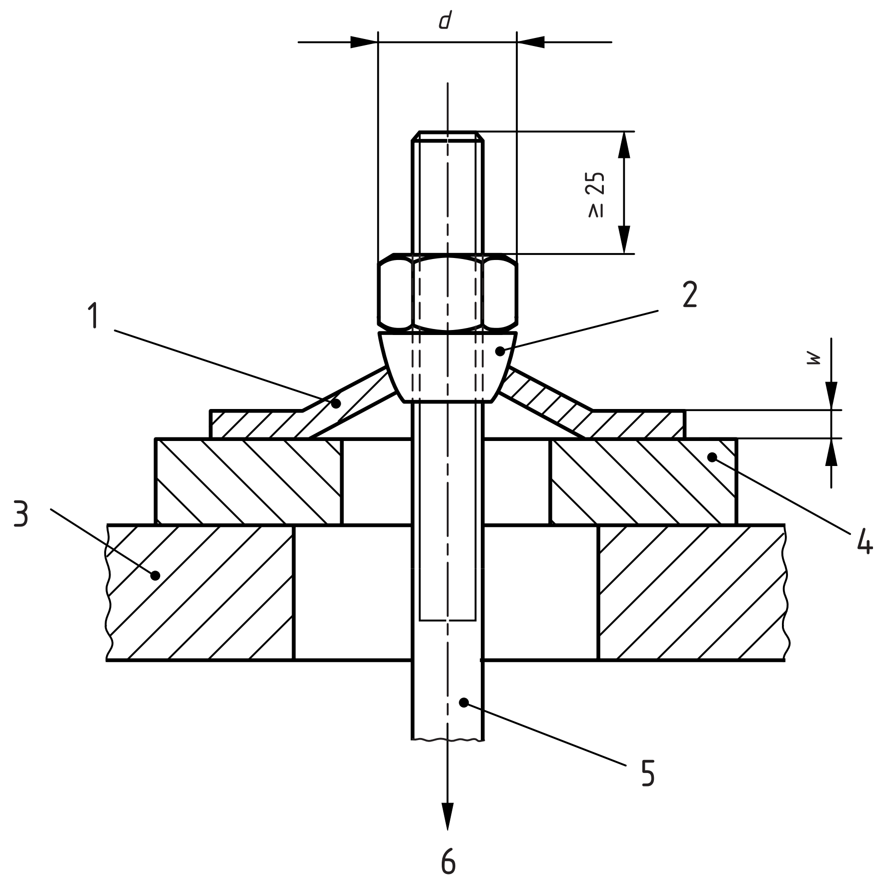
D.1 Apparatus

D.1.1 *Tensile test machine*, calibrated in accordance with BS EN ISO 7500-1 having an autographic recording facility or other means of providing a load/extension graph.

The load test arrangement is illustrated in Figure D.1.

Figure D.1 **Load test arrangement for tensile test flattening and pull through loads of steel domed washer plate**

Dimensions in millimetres



Key

1 Steel domed washer plate
2 Conical seat
3 Testing machine platen
4 Backing plate, with a hole of min. dia. of (d + 2.5w), where:
   d is the diameter of the conical seat
   w is the thickness of the dome washer plate
5 Rockbolt
6 Applied load

D.2 Procedure

D.2.1 Sample size

Use five specimens per test.

D.2.2 Method

Apply an increasing load and record the corresponding extension values.

D.3 Results

Prepare a load/extension graph, with the flattening load and maximum tensile (pull-through) load as the two maxima.

Annex E (normative) Alignment test

E.1 Principle

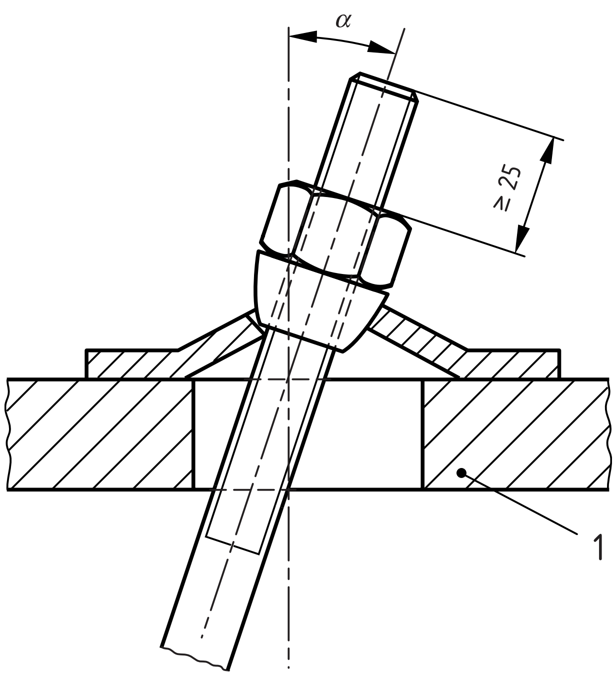
When used as part of a rockbolt assembly, the conical seat provides a face against which the nut can be tightened, and also accommodates a degree of misalignment between the rockbolt and the domed washer plate. The maximum misalignment tolerance of complete rockbolt assemblies is measured.

E.2 Apparatus

E.2.1 *Steel rockbolt test arrangement*, shown in Figure E.1.

Figure E.1 **Alignment capacity of conical seat and domed washer plate assembly**

Dimensions in millimetres



Key

1 Support plate, 30 mm thick with a hole sufficient to allow full out-of-line movement of the rockbolt

E.3 Procedure

E.3.1 Sample size

Test three assemblies.

E.3.2 Measurement

Maintain contact between domed washer plate and conical seat.

Measure the maximum misalignment tolerance (α) as indicated in Figure E.1 using an inclinometer or other means of measuring the misalignment angle. The limiting factor on the misalignment capacity of the conical seat and domed washer plate is that full circumferential contact is always maintained between the conical seat and the inside edge of the hole in the domed washer plate.

Repeat the measurement for all three test samples.

E.4 Results

Record the smallest of the three maximum misalignment tolerances measured for the three samples.

Annex F (normative) Fire resistance test on non-metallic components

F.1 Principle

The persistence of flame is determined by subjecting test pieces of a given size to a naked flame for a specified time.

F.2 Apparatus

F.2.1 *Draught-free flame test cabinet*, as shown in Figure F.1, consisting of a box with:

- a dark interior;
- a hole in the top to allow the escape of fumes;
- a sliding door with a viewing panel of acrylic or other suitable material;
- a suitable stand for supporting the test piece inside the cabinet, the side of which is provided with a hand hole and a flap to permit handling of the burner (see **F.3.2**).

F.2.2 *Barthel burner*, as the source of ignition.

F.3 Procedure

F.3.1 Sample size

Test six 300 mm lengths of rockbolt bar.

Test six samples of domed washer plate.

F.3.2 Method

Prior to the test adjust the flame in subdued lighting conditions to a height of 150 mm with the burner standing vertically. Mount the burner at an angle 45° to the horizontal with the top burner 50 mm from the specimen under test such that the flame impinges at an angle of 90° to the test specimen's longitudinal axis.

Allow the flame to impinge on the specimen for 60 s and then withdraw.

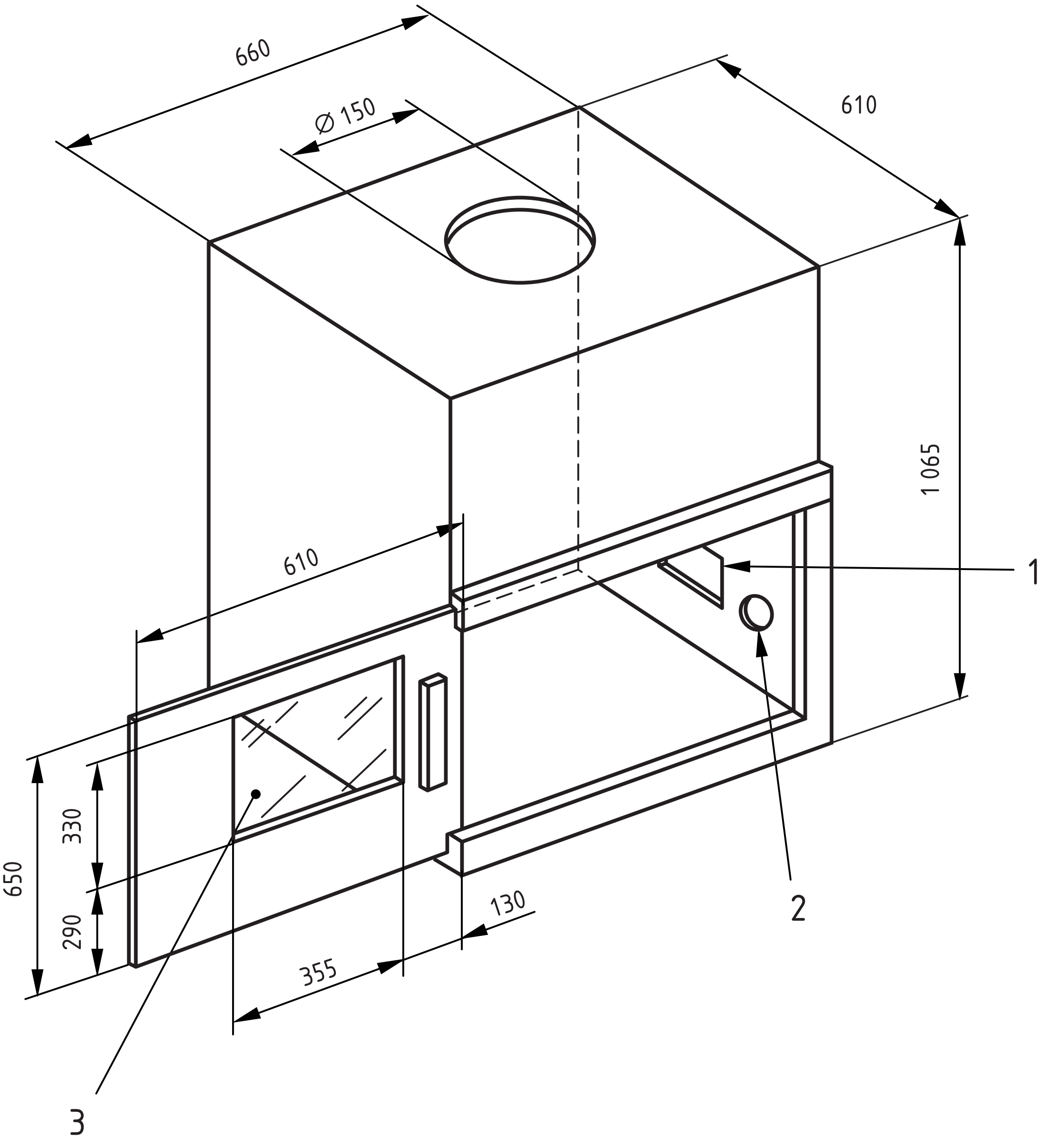
F.4 Results

After withdrawing the flame measure the persistence time of any visible flame or glow on the test piece.

Calculate the mean of the persistence times determined for the six specimens.

Figure F.1 **Draught-free cabinet for flame test**

Dimensions in millimetres



Key

1 Opening with flap for access to burner

2 2 × 40 dia. air hole

3 Acrylic sheet fitted to door

Annex G (normative) Torsional strength test on GRP bar

G.1 Principle

The torque strength of the GPR bar is determined by subjecting the test sample to a torsional force in both directions until failure occurs.

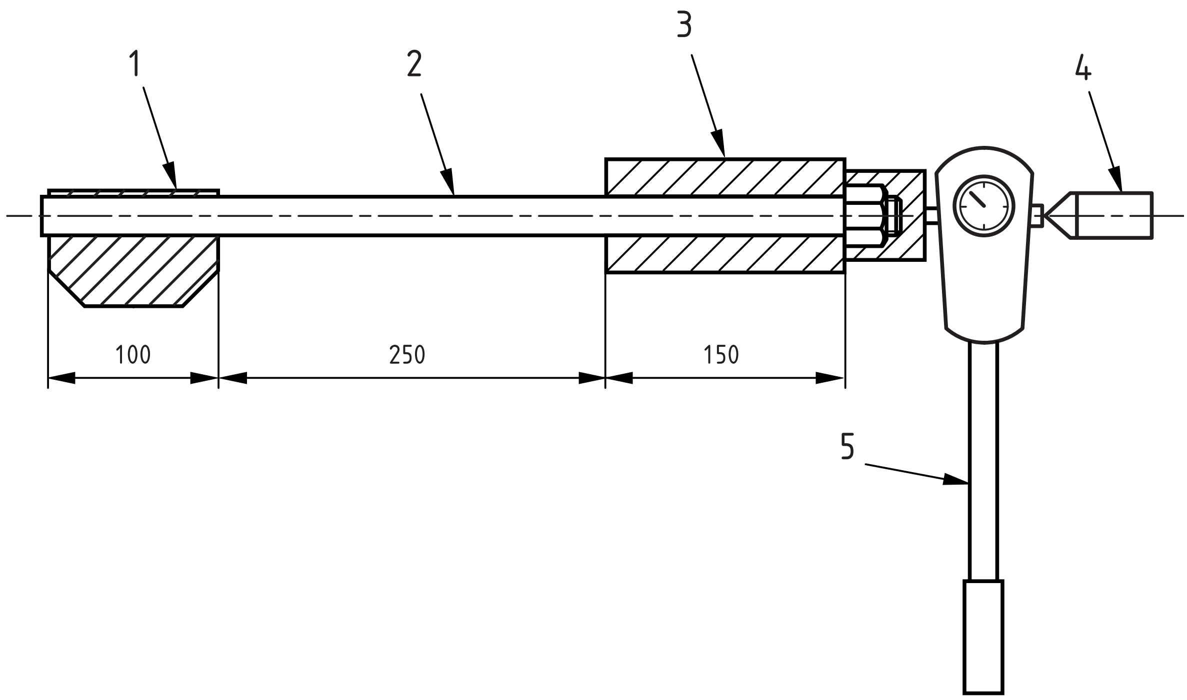
G.2 Apparatus

G.2.1 *Torque wrench*, calibrated in accordance with BS EN ISO 6789.

G.2.2 *Steel clamping block*, for securing the end of the bar, which is custom made to suit the bar diameter with suitable attachment for the torque wrench socket and capable of clamping the bar over a length of 150 mm as shown in Figure G.1.

Figure G.1 **Arrangement for torsional strength test on GRP bar**

Dimensions in millimetres



Key

1 Gripping device
2 Test specimen
3 Steel clamping block
4 Machine centre
5 Torque wrench

G.2.3 *Centre support*, used with the torque wrench to maintain inline stability (see Figure G.1).

G.2.4 *Gripping device*, with a minimum jaw length of 100 mm.

G.3 Sample size

Test five samples, each with a length of 500 mm.

G.4 Procedure

Clamp the sample securely in the gripping device with 400 mm of overhang. With the steel clamping block jaws in the open position, slide the two ends over the sample until it reaches the back end stop. This will give 250 mm overhang between the gripping device and clamping block. Tighten the clamping block to prevent the test sample from rotating within the block. Attach the torque wrench to the clamping block and set the wrench-indicating needle to zero. Apply, manually, a uniformly increasing torque until failure occurs.

Repeat the procedure for all five samples in each rotational direction.

G.5 Results

Record the maximum torque in Nm for each specimen in each rotational direction. The lowest maximum torque in each direction will constitute the torsional strength of the bar in that direction.

Annex H (normative) Tensile strength test on GRP bar

H.1 Principle

The tensile strength of GRP bar is determined by subjecting the test sample to a tensile force until failure occurs.

H.2 Apparatus

H.2.1 *Testing machine*, calibrated in accordance with BS EN ISO 7500-1 and of a type with a constant rate of crosshead movement and comprising the following.

- A fixed stationary member carrying one grip.
- A moveable member carrying a second grip.
- An autographic recording facility or other means of producing a load/extension graph.

H.2.2 *Self-aligning wedge type grips*, for holding the test specimen between the fixed member and the moveable member of the testing machine in such a manner that they will move freely into alignment as soon as the load is applied without any slippage relative to the grips.

H.3 Test specimens

Test five specimens with the dimensions shown in Figure H.1.

H.4 Procedure

H.4.1 Measure and record the diameter of the machined portion of the specimen under test to the nearest 0.01 mm at a minimum of two points along their length.

H.4.2 Ensure that the teeth of the wedge grips are clean and free of debris before inserting the test specimen.

H.4.3 Place the specimen in the testing machine, taking care that it is aligned with both top and bottom wedge grips. The distances between the ends of the gripping surfaces are shown in Figure H.1.

Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

H.4.4 Apply a force at a rate of 5mm/min until failure.

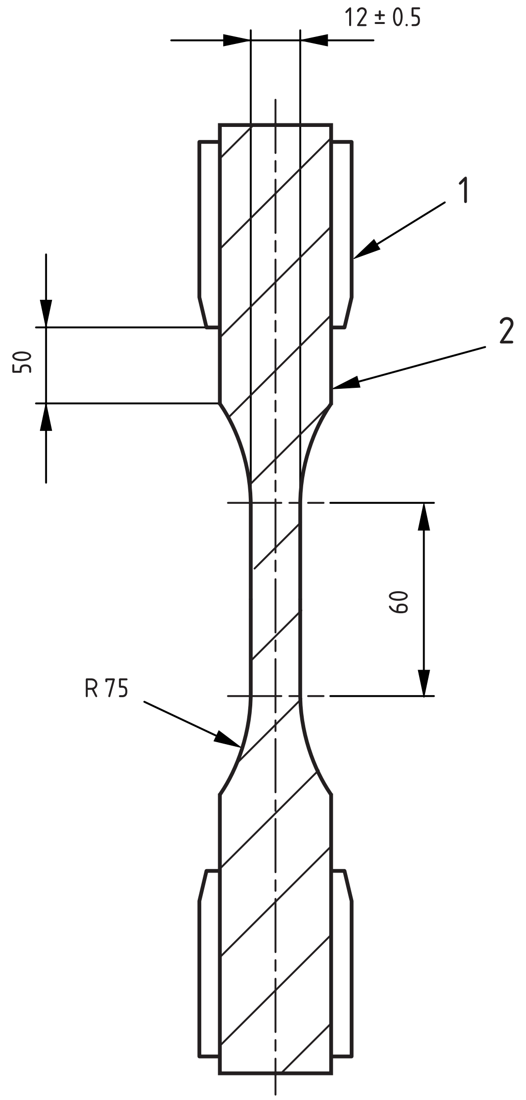
H.4.5 Record the load extension curve of the specimen under test and the maximum force achieved.

H.5 Results

Calculate the tensile strength for each specimen by dividing the maximum load in newtons by the original minimum cross-sectional area of the machined portion in mm^2. All specimens are required to pass the tensile strength of 850 N/mm^2.

Figure H.1 **Arrangement for tensile test on GRP bar**

Dimensions in millimetres



Key

1 Wedge grips

2 Test specimen

Annex I (normative) Minimum tensile strength of GRP rockbolt bar

I.1 Principle

The maximum load achievable, when a GRP bar is encapsulated in two 450 mm long steel tubes, is determined from a double embedment pull test. The test consists of tensile loading a jointed tube assembly in which a sample of GRP bar has been embedded using high-strength slow-set polyester resin.

I.2 Apparatus

I.2.1 *Testing apparatus*, comprising:

a) a tensile testing machine calibrated in accordance with BS EN ISO 7500-1, having a suitable recording facility;

b) a suitably calibrated test rig which permits application of load at a steady rate and in an axial direction relative to the tube assembly.

I.2.2 *Instrumentation device*, suitably calibrated, for measuring the load.

I.2.3 *Sample tubes*, consisting of two thick walled tubes (at least 10 mm), each:

- 450 mm long;
- with a minimum internal diameter equal to the maximum diameter of the GRP bar plus 5 mm;
- with a 1 mm deep by 2 mm pitch thread machined into the surface of the bore to provide a standard surface finish and inhibit failure between this surface and the resin; and
- designed with the test rig to ensure uniaxial loading.

I.3 Procedure

I.3.1 Sample preparation

Prepare three test assemblies such that a 900 mm long sample of the GRP bar is centrally located within the two 450 mm steel sample tubes butted together and fully encapsulated by hand-mixed, high-strength, polyester resin (see Figure I.1). When pushing the GRP bar through the resin, rotate it slowly to ensure centralization. Prepare the resin according to the manufacturer's instructions, ensuring that the assembly is completed within the resin gel time. Ensure that the finished assembly is straight and that the GRP bar and embedment tubes are axially aligned.

I.3.2 Testing

Test each of the three sample test assemblies not less than 24 h after their preparation.

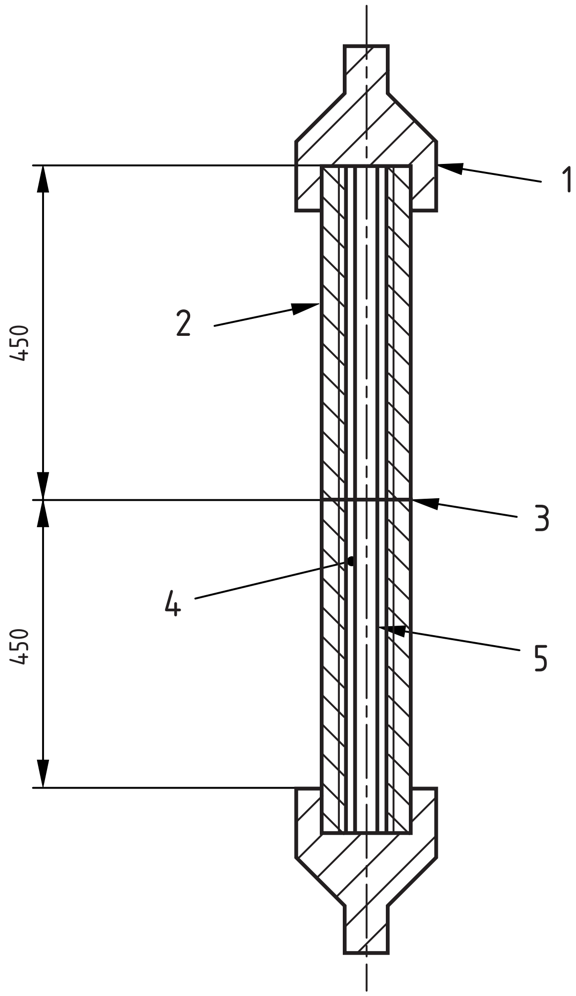
Locate each assembly in the testing machine or test rig. Set the recording system to record load at a suitable rate. Apply load in a controlled manner at a rate of approximately 3 kN/s until such time as the maximum load is achieved.

I.3.3 Results

The minimum tensile strength of the GRP bar is the lowest maximum load from the three tests.

Figure I.1 **Double embedment tensile test – schematic diagram**

Dimensions in millimetres



Key

1 Chuck

2 Internally threaded adaptor

3 Joint

4 Resin

5 GRP rockbolt

Annex J (normative) Flexural strength tests on GRP rockbolt bar

J.1 Principle

The flexural strength of the GPR bar is determined by subjecting a test specimen to a three point bend test.

J.2 Apparatus

J.2.1 *Testing machine*, calibrated in accordance with BS EN ISO 7500-1, having

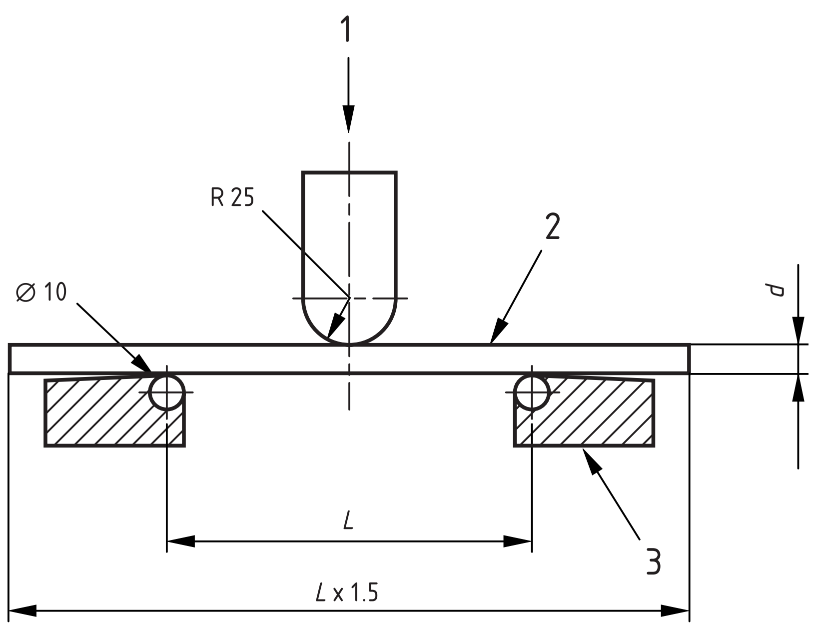
- an autographic recording facility or other means of producing a load/extension graph;
- a central fulcrum of 50 mm × 0.02 mm; and
- end support diameters of 10 mm × 0.1 mm.

J.2.2 *Calibrated vernier gauge*, accurate to within 0.1% of the span length.

J.2.3 *Flexural strength test apparatus*, arranged on GRP bar as shown in Figure J.1.

Figure J.1 **Arrangement for flexural strength test on GRP bar**

Dimensions in millimetres



Key

1 Applied force

2 Test specimen

3 Support

J.3 Sample size

Test five specimens, each with an equivalent diameter of 21.5 mm and a total length of 1.5 × span length.

J.4 Procedure

J.4.1 Measure and record the diameter d of each test specimen at the mid-point along its length with the vernier gauge to the nearest 0.01 mm. Calculate the mean diameter for the set of specimens.

J.4.2 Discard any specimen(s) with a thickness exceeding the tolerance of 0.5% of the mean value and replace it with another specimen chosen at random.

J.4.3 Adjust the end fulcrums to the span length, L, with the following equation.

$$L = (16 \pm 1)\, d \tag{J.1}$$

and measure the resulting span to the nearest 0.1%.

J.4.4 Position each test specimen symmetrically on the end fulcrums and apply a force at mid span by the central fulcrum at 5 (N/mm^2)/s until bar failure.

J.4.5 Record the force and corresponding deflection of each specimen during the test.

J.4.6 Repeat the procedure for all five samples.

J.5 Results

Calculate the flexural strength, F, expressed in newtons per square millimetre (N/mm^2), of each test specimen using the equation:

$$F = \frac{8WL}{\pi d^3} \tag{J.2}$$

where:

W is the maximum force in newtons (N);

L is the span length in millimetres (mm);

d is the diameter in millimetres (mm).

Annex K (normative) Tensile test to establish GRP bolt assembly failure load

K.1 Principle

The failure load of the GRP bolt assembly is determined by subjecting the assembly to a load test.

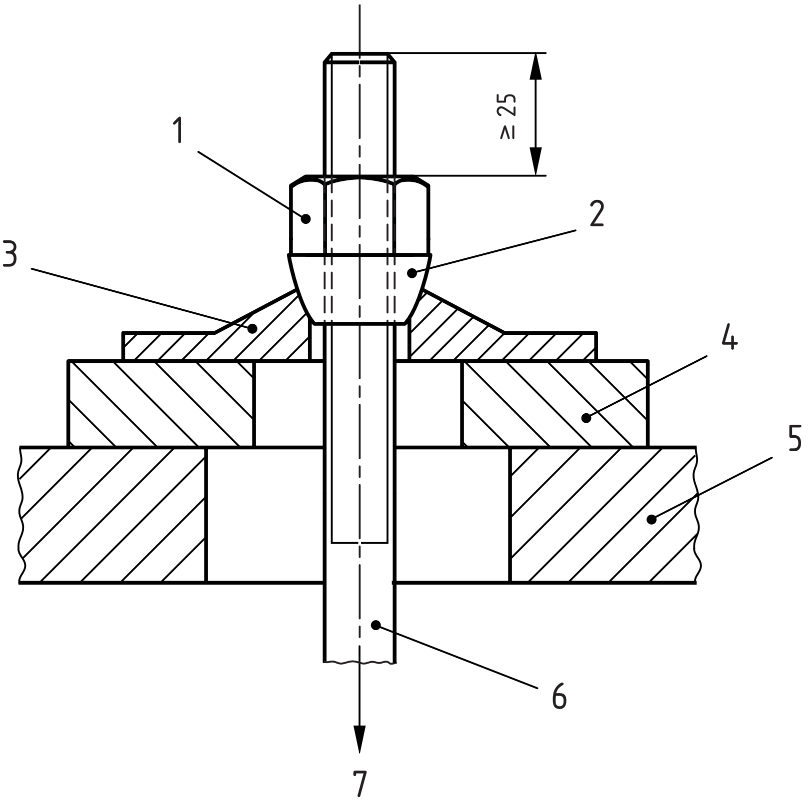
K.2 Apparatus

K.2.1 *Tensile test machine*, calibrated in accordance with BS EN ISO 7500-1, having an autographic recording facility or other means of providing a load/extension graph.

The load test arrangement is illustrated in Figure K.1.

Figure K.1 **Load test arrangement for GRP components**

Dimensions in millimetres



Key

1 GRP torque nut
2 Conical seat
3 Domed washer plate
4 Backing plate with 55 dia. hole
5 Testing machine platen
6 21.5 dia. GRP bolt
7 Applied load

K.3 Procedure

K.3.1 Sample size

Test five sample assemblies.

K.3.2 Method

Apply an increasing load and record the corresponding extension values.

K.4 Results

Record the maximum tensile load, the load at which pull-through of the assembly occurs.

Annex L (normative) Determination of uniaxial compressive strength (UCS) of resin

L.1 Principle

The UCS is determined by subjecting test pieces of a defined geometry to a compressive force until failure of the specimen occurs. The maximum compressive force is then used to calculate the compressive strength.

L.2 Apparatus

L.2.1 *Test machine*, calibrated in accordance with BS EN ISO 7500-1 with a capacity and capability to apply load at the rate specified in **L.3.2**.

Where spacing blocks are used between the test specimen and platen, the requirements of BS 6319-2 are applicable.

L.2.2 *Moulds*, conforming to BS 6319-1 for producing prism samples in accordance with **L.3.1**.

L.3 Procedure

L.3.1 Preparation of test specimens

Prepare eight test specimens from the same batch of resin, each measuring 12.5 mm × 12.5 mm × 25 mm.

Prepare the test specimens, including the conditioning, proportioning and mixing of the materials and the conditioning and filling of the moulds, in accordance with BS 6319-1:1983, but condition, cast and cure the specimens at a laboratory temperature of (20^{+1}_{-5})°C.

L.3.2 Method

L.3.2.1 Carry out all tests at a laboratory temperature of (20 ± 1) °C 24 to 26 h after preparation of the test specimens.

L.3.2.2 Measure the width and thickness of each specimen at its centre to the nearest 0.1 mm and calculate the cross-sectional area.

L.3.2.3 Wipe clean the bearing surfaces of the testing machine and of any auxiliary platens. Remove any loose grit or other materials from surfaces of the test specimen that are to be in contact with the compression platens. Carefully place the test specimen on the lower platen and centre it in such a manner that the load is applied axially, i.e. parallel to the long axis of the test specimen.

L.3.2.4 Apply load without shock to five of the eight specimens at a strain rate of 1 mm/m and record the maximum load.

L.3.2.5 If, after testing, a specimen is found to be incompletely mixed (i.e. not homogenous) or to contain voids of sufficient size to affect its strength, exclude this specimen from the results, test one of the spare specimens and include the results of the test on the spare specimen.

L.4 Results

Calculate the UCS of each cube to the nearest 0.1 MPa as follows:

UCS = Maximum force / Original cross-sectional area (mm^2)

Discard the highest and lowest load values recorded during testing and use the mean value from the remaining three test specimens to calculate the UCS.

Annex M (normative) Determination of elastic modulus of resin

M.1 Principle

A prism of 4:1 aspect ratio is subjected to a controlled axial compressive load, and the compressive stress is related to the longitudinal strain induced by that stress.

M.2 Apparatus

M.2.1 *Test machine*, calibrated in accordance with BS EN ISO 7500-1 with a capacity and capability to apply load at the rate specified in **M.3.2.5**.

Where spacing blocks are used between the prism and the platen, the requirements of BS 6319-2 are applicable.

M.2.2 *Moulds*, conforming to BS 6319-1 of a size to produce rectangular prisms in accordance with **M.3.1**.

M.2.3 *Two strain measuring devices*, each:

- providing a minimum gauge length of 20 mm and a maximum sensitivity of 5 units of micro strain and a continuous indication of change in gauge length;
- calibrated such as to ensure that the error does not exceed 2% of the actual strain; and
- preferably incorporating a means of directly recording and plotting the load deformation curves with defined scales.

The strain measuring devices may be of the direct or indirect type. Examples of such devices are electrical resistance strain gauges, linear variable differential transducers (LVDTs), dial micrometers and optical devices.

M.3 Procedure

M.3.1 Preparation of test specimens

Prepare eight specimens from the same batch of resin, each measuring 12.5 mm × 12.5 mm × 50 mm.

Prepare the test specimens, including the conditioning, proportioning and mixing of the materials and the conditioning and filling of the moulds, in accordance with BS 6319-1:1983, but condition, cast and cure the specimens at a laboratory temperature of (20^{+1}_{-5}) °C.

M.3.2 Method

M.3.2.1 Carry out all tests at a laboratory temperature of (20 ± 1) °C 24 to 26 h after preparation of the test specimens.

M.3.2.2 Measure the width and thickness of each specimen at its centre to the nearest 0.1 mm and calculate the cross-sectional area.

M.3.2.3 For direct measurement, fit the strain measuring devices to opposite cast sides of the test specimen at least 15 mm from the specimen ends, their gauge lengths being centrally disposed over the axis of the test specimens.

For indirect measurement locate the strain measuring devices between the machine platens ensuring that they are positioned equidistant from the specimen and diagonally opposite each other as shown in Figure M.1.

M.3.2.4 Wipe clean the bearing surfaces of the testing machine and of the auxiliary platens. Remove any loose grit or other materials from surfaces of the test specimen that are to be in contact with the compression platens. Carefully place the test specimen on the lower machine platen and centre it in such a manner that the load is applied axially, i.e. parallel to the long axis of the test specimen.

M.3.2.5 Without interrupting the loading cycles, apply the load smoothly to five of the eight specimens, at a rate of (0.75 ± 0.25) (N/mm^2)/s to a load of 7.5 kN, recording the strain at 2.5 kN and 7.5 kN. Smoothly remove the load at the same constant rate at which it was applied to a load of 2.5 kN.

Re-apply and remove the load for a further two cycles, ensuring the specimen and platen are well seated and that the strain gauges are indicating consistently. Record the strain for each cycle while the load on each specimen is increasing.

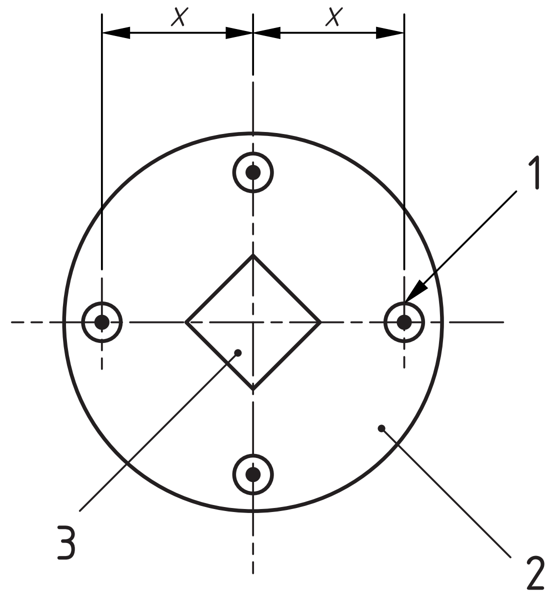
M.3.2.6 If, after testing, a specimen is found to be incompletely mixed (i.e. not homogenous) or to contain voids of sufficient size to affect its strength, exclude this specimen from the results, test one of the spare specimens and include the results of the test on the spare specimen.

M.4 Results

The elastic modulus is the mean of the three-secant moduli measured between the two levels of the applied load.

Discard the highest and lowest strain values recorded during testing and use the mean value from the remaining three test specimens to calculate the elastic modulus.

Figure M.1 **Arrangement for elastic modulus test and creep test: machine platen**



Key

1 LVDT
2 Machine platen
3 Test specimen

Annex N (normative) Determination of creep of resin

N.1 Principle

Test pieces of a defined geometry are subjected to a defined compressive force, and deformation is recorded against time.

N.2 Apparatus

N.2.1 *Test machine*, calibrated as Class 1 in accordance with BS EN ISO 7500-1, and of sufficient capacity and capability to apply load at the rate specified in **N.3.2.5**.

Where spacing blocks are used between the prism and the platen, the requirements of BS 6319-2 are applicable.

N.2.2 *Moulds*, conforming to BS 6319-1 of a size to produce rectangular prisms in accordance with **N.3.1**.

N.2.3 *Two strain measuring devices*, each:

- providing a minimum gauge length of 20 mm and a maximum sensitivity of 5 units of micro strain and a continuous indication of change in gauge length;
- calibrated such as to ensure that the error does not exceed 2% of the actual strain; and
- preferably incorporating a means of directly recording and plotting the load deformation curves with defined scales.

The strain measuring devices may be of the direct or indirect type. Examples of such devices are electrical resistance strain gauges, linear variable differential transformers (LVDTs), dial micrometers and optical devices.

N.3 Procedure

N.3.1 Preparation of test specimens

Prepare eight specimens from the same batch of resin, each measuring 12.5 mm × 12.5 mm × 50 mm.

Prepare the test specimens, including the conditioning, proportioning and mixing of the materials and the conditioning and filling of the moulds, in accordance with BS 6319-1:1983, but condition, cast and cure the specimens at a laboratory temperature of (20^{+1}_{-5}) °C.

N.3.2 Method

N.3.2.1 Carry out all tests at a laboratory temperature of (20 ± 1) °C 24 to 26 h after preparation of the test specimens.

N.3.2.2 Measure the width and thickness of the specimen under test at its centre to the nearest 0.1 mm and calculate the cross-sectional area.

N.3.2.3 For direct measurement, fit the strain measuring devices to opposite cast sides of the test specimen at least 15 mm from the specimen ends, their gauge lengths being centrally disposed over the axis of the test specimens.

For indirect measurement locate the strain measuring devices between the machine platens, ensuring that they are positioned equidistant from the specimen and diagonally opposite each other as shown in Figure M.1.

N.3.2.4 Wipe clean the bearing surfaces of the testing machine and of any auxiliary platens. Remove any loose grit or other materials from surfaces of the test specimen that are to be in contact with the compression platens. Carefully place the test specimen on the lower platen and centre it in such a manner that the load is applied axially, i.e. parallel to the long axis of the test specimen.

N.3.2.5 Apply the load smoothly to five of the eight specimens, at a rate of (0.75 ± 0.25) (N/mm^2)/s to a load of 5 kN and maintain this load for a duration of 15 min. Record the strain between 0.5 and 15 min for each specimen.

N.3.2.6 If, after testing, a specimen is found to be incompletely mixed (i.e. not homogenous) or to contain voids of sufficient size to affect its strength, exclude this specimen from the results, test one of the spare specimens and include the results of the test on the spare specimen.

N.4 Results

The resistance to creep is the recorded strain between 0.5 and 15 min expressed as a percentage.

Discard the highest and lowest strain values recorded during testing and use the mean value from the remaining three test specimens to calculate the resistance to creep.

Annex O (normative) Tensile test on rockbolt threaded end

O.1 Principle

The tensile strength of the rockbolt threaded end is determined by subjecting the rockbolt and nut assembly to a tensile force until failure occurs.

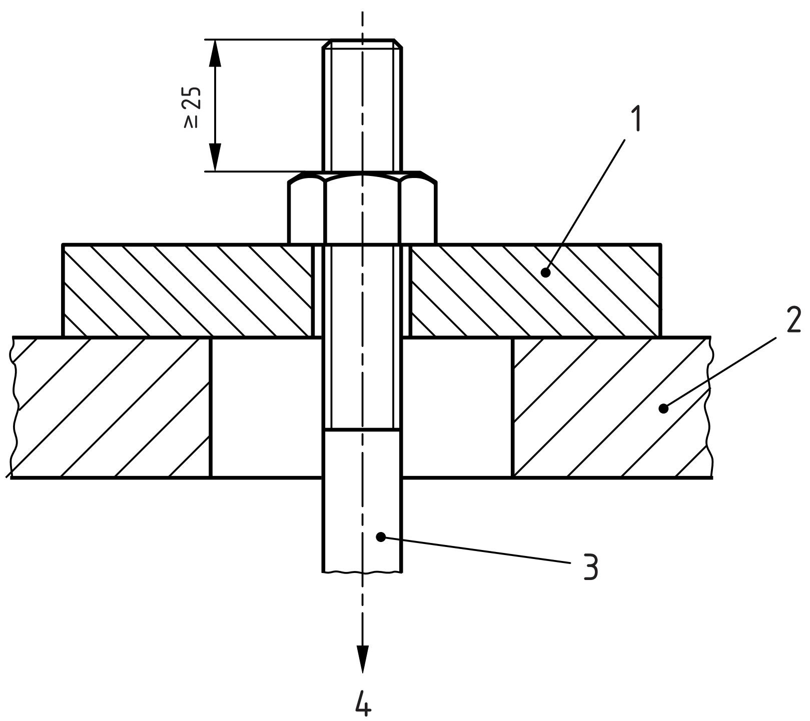
O.2 Apparatus

O.2.1 *Tensile test machine*, calibrated in accordance with BS EN ISO 7500-1, having an autographic recording facility or other means of producing a load/extension graph.

O.2.2 *Rockbolt assembly arrangement*, as shown in Figure O.1.

Figure O.1 **Arrangement for tensile test on rockbolt threaded end**

Dimensions in millimetres



Key

1 Backing plate with clearance hole
2 Testing machine platen
3 Rockbolt
4 Applied load

O.3 Procedure

O.3.1 Sample size

Test a minimum of five specimens.

O.3.2 Loading

Place each test assembly in the tensile test machine and apply load at a stress rate not exceeding 10 (N/mm^2)/s until failure occurs.

O.4 Results

For each specimen, record the maximum load at the point of failure and note the mode of failure. The failure load is the lowest maximum from all of the specimen tests.

Annex P (normative) Shear test on rockbolt/resin system

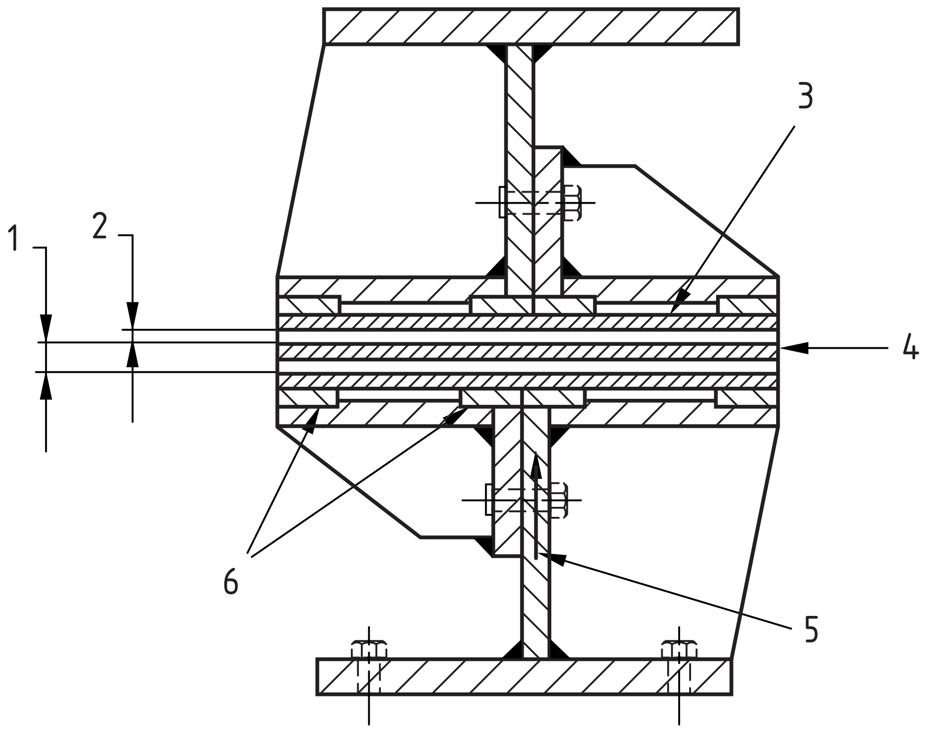
P.1 Principle

The ultimate shear strength of a rockbolt/resin system is determined using a single shear frame in conjunction with a rockbolt/resin double embedment assembly.

P.2 Apparatus

P.2.1 *Single (guillotine) shear frame*, as shown in Figure P.1 suitable for the testing of a rockbolt/resin assembly.

Figure P.1 **Sectional diagram of shear frame**



Key

1 Internal tube diameter 5 mm greater than nominal bolt diameter
2 Wall thickness at least 50% of bolt nominal diameter
3 Double embedment assembly containing steel rockbolt resin
4 Bolt
5 Load applied to lower section of shear frame only, upper section remains static
6 Hardened steel bushes interchangeable to accommodate different tube sizes

P.2.2 *Tensile test machine*, calibrated to Class 1 in accordance with BS EN ISO 7500-1:2004, having an autographic recording facility or other means of producing a force/displacement graph.

P.2.3 *Three test assemblies*, consisting of two thick-walled hollow steel tubes, each tube having:

- a length of 125 mm, an internal diameter 5 mm greater than the nominal rockbolt diameter and a wall thickness of at least half the rockbolt diameter; and
- a 1 mm deep by 2 mm pitch metric thread machined onto its internal surface in order to provide a standard surface finish and thereby inhibit failure between this surface and the resin.

The arrangement of the test assembly is shown in Figure P.1.

P.2.4 *Displacement transducer*, used to record accurately the separation of the two tubes.

P.3 Procedure

P.3.1 Sample size

Test three specimen assemblies.

P.3.2 Preparation of test assemblies

Blank off the end of one of the tubes, butt together the open ends and secure the joint temporarily with adhesive tape. Fill the tube assembly with slow-set resin, which has been pre-mixed in accordance with the manufacturer's instructions. Push a 250 mm length of the rockbolt bar into the resin by hand, while at the same time slowly rotating the bar and ensuring, as far as is possible, that the bar is centrally positioned within the tube assembly.

P.3.3 Curing

Allow each test assembly to cure for at least 24 h before testing.

P.3.4 Method

Place each test assembly in the test machine and apply load at a stress rate not exceeding 10 (N/mm^2)/s until such time as the maximum load is achieved. Record the maximum load and displacement at maximum load.

P.4 Results

For each specimen calculate the shear strength from the maximum load divided by the cross-sectional area based on the equivalent diameter of the specimen. The shear strength of the rockbolt resin system is the mean of the shear strengths of the 3 specimens.

Annex Q (normative) Determination of bond strength and system stiffness

Q.1 Principle

The bond strength and system stiffness are determined from a laboratory short encapsulation pull test. A rockbolt sample is installed in a confined rock core, using capsule resin, and, after resin curing, is pull-tested under controlled conditions. Bond performance is assessed in terms of the bond displacement measured against the applied load.

Q.2 Apparatus

Q.2.1 *Testing apparatus*, comprising a machine tool lathe, such as that shown in Figure Q.1, a hydraulic biaxial cell, a water feed system and drill assembly.

Q.2.2 *Pull test equipment:*

- comprising a hydraulic hollow ram jack, a pressure bearing plate or stressing stool, a hydraulic hose, a pressure gauge calibrated in accordance with BS EN 837-1:1998 and/or load cell with a calibration error no greater than that of the pressure gauge, and a hydraulic pump fitted with a non-return valve, as shown in Figure Q.2; and

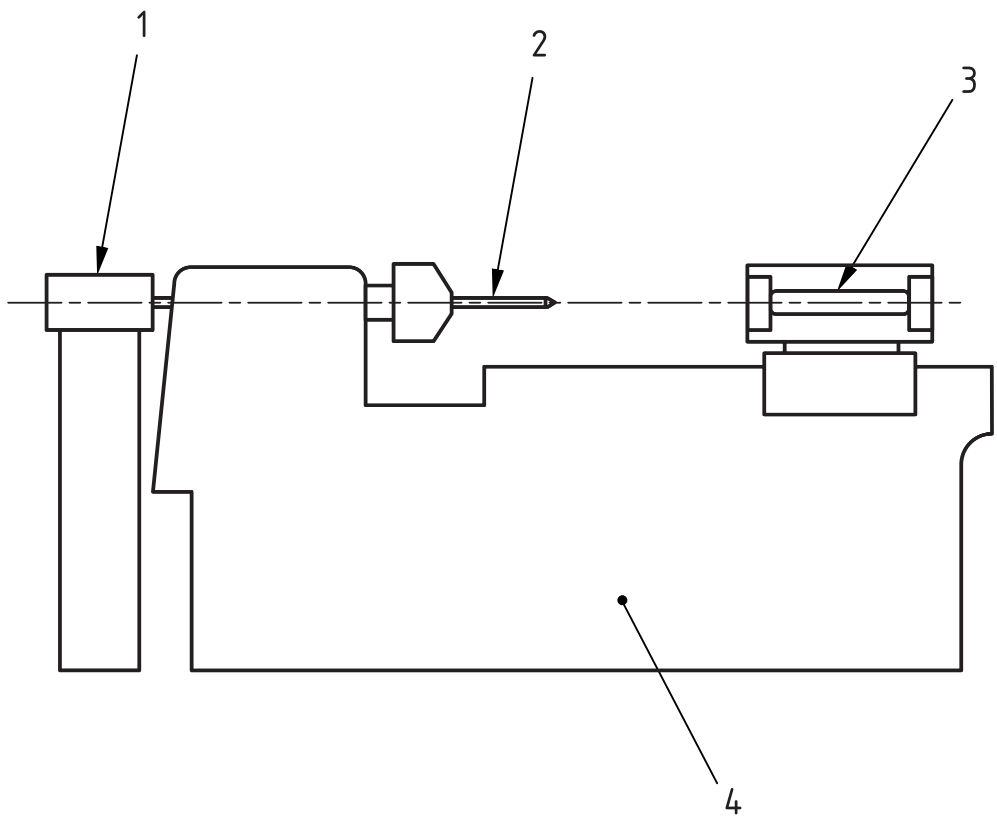
  NOTE The hydraulic cylinder has to have an effective area within 0.2% of the nominal value provided by the manufacturer.

- capable of applying a load at least equivalent to 90% of the yield strength of the rock bolt under test.

Q.2.3 *Autographical recording facility* or other means of producing a load/extension graph for recording the test data during pull testing, as shown in Figure Q.2.

A linear variable differential transducer (LVDT) or dial gauge may be used to record bolt, end displacement and an in-line pressure gauge, preferably with an electronic transponder and/or suitable capacity load cell, to record the applied load/pressure.

Figure Q.1 **General arrangement of lathe-based pull test apparatus**



Key

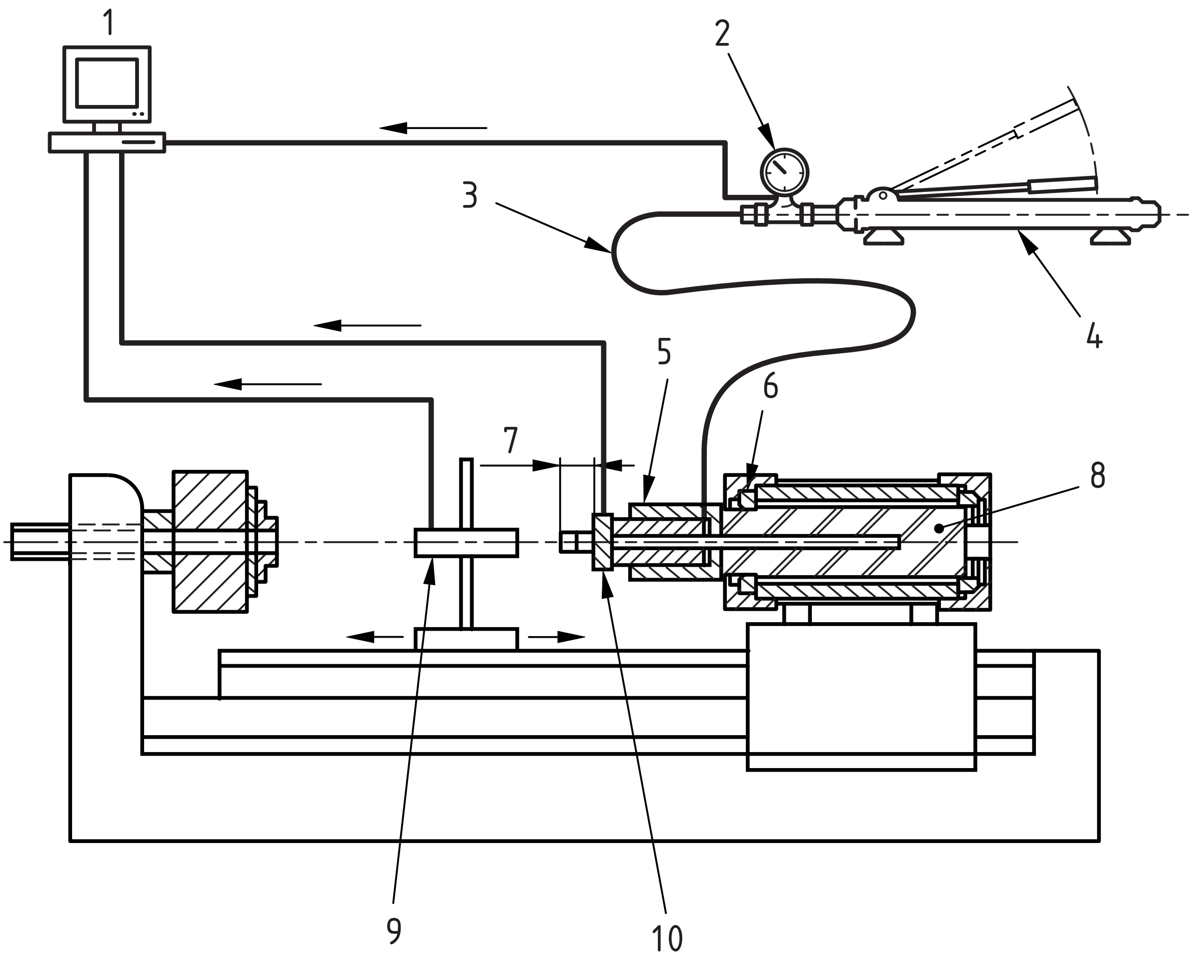
1 Water feed unit

2 Drill rod and drill bit assembly

3 Biaxial cell mounted on carriage

4 Machine tool lathe

Figure Q.2 **General arrangement of hydraulic pull test apparatus**



Key

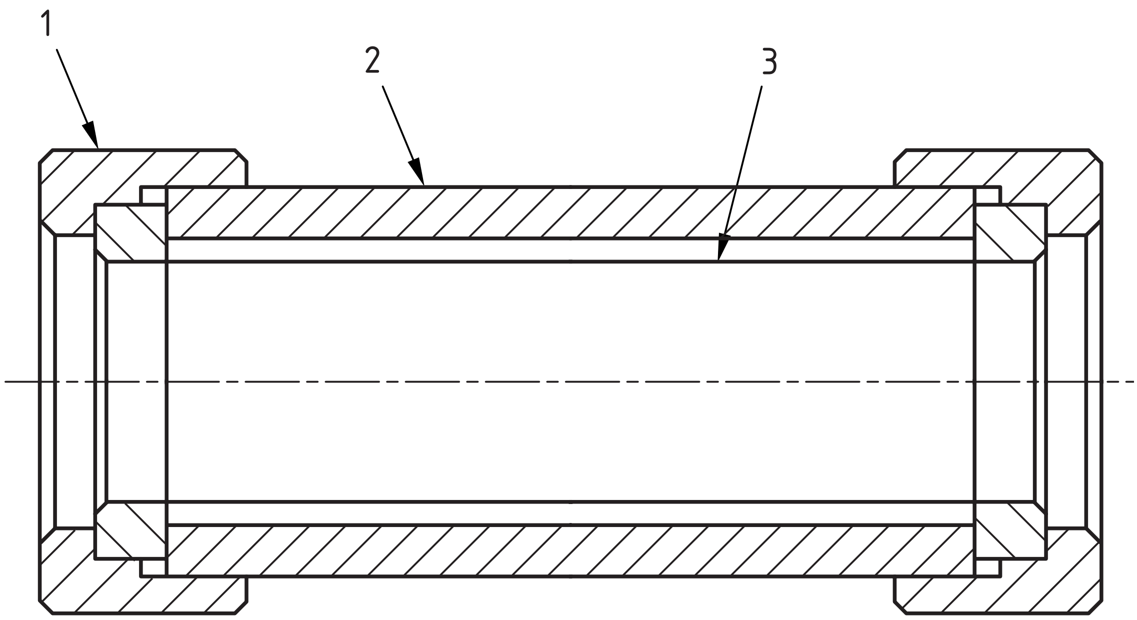
1	Data collection	6	Stressing stool/bearing plate
2	Pressure gauge	7	100 mm thread
3	Hydraulic hose	8	Rock core
4	Hydraulic pump	9	LVDT/Dial gauge to measure bolt end displacement
5	30 tonne hydraulic jack	10	Load cell

Q.2.4 *Machine tool lathe*:

- having sufficient bed length to allow the drilling operations to be carried out in a single pass;
- capable of a throw of 190 mm or more and a rotation speed of 440 rpm;
- offering a minimum torque of 200 Nm; and
- preferably having an automated feed rate of 1.25 mm/rev.

Q.2.5 *Biaxial cell*, having a nominal internal diameter of at least 145 mm and a minimum confining membrane length of 200 mm, capable of applying a confining pressure of at least 10 MPa. A hydraulic biaxial pressure cell is shown in Figure Q.3

Figure Q.3 **Hydraulic biaxial pressure cell**



Key

1 End cap

2 Cell body

3 Membrane

Q.2.6 *Water feed*, allowing flushing water to be delivered effectively through a rotating drill rod, fixed in the chuck of the lathe to the tip of the drill bit during drilling operations.

Q.2.7 *Drilling consumables*, preferably with a twin wing, negative rake, carbide-tipped drill bit, to produce an average finished hole diameter of (6.5 ± 0.5) mm greater than the equivalent bolt diameter.

Q.2.8 *Rock test specimens*, consisting of sandstone rock cores, each:

- with a minimum length of 220 mm and an external diameter to match the internal diameter of the biaxial cell used;
- comprising poorly cemented, medium grained, homogeneous sandstone with rounded, well-sorted grains;
- meeting the performance criteria specified in **Q.5**; and
- when tested according to ISRM Suggested Methods[1)], having uniaxial compressive strength of between 21 and 31 MPa and a Young's Modulus of between 7 and 10 GPa[1)].

[1)] International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests, "Suggested Methods for Determining the Uniaxial Compressive Strength and Deformability of Rock Materials", *Int. J. Rock Mechanics & Min. Sci. & Geomech. Abs.* Vol. 16. No. 2, pp. 135–140 (1979). [6]

Q.3 Procedure

Q.3.1 Rock core preparation

Do not use core specimens with major irregularities, bedding or discontinuities.

Remove or fill with a suitable self-hardening filler compound any minor irregularities or depressions found in the outer surface of the rock core to avoid localized deformation of the cell membrane under pressure.

Q.3.2 Installing rock core in biaxial cell

Place the rock core inside the biaxial cell, ensuring that the cell membrane has full circumferential and axial contact with the rock core.

Do not permit more than 10 mm of rock core to protrude from one end of the cell.

Apply a confining pressure of 10 MPa to the rock core using the biaxial cell, and maintain this throughout testing.

Securely mount the biaxial cell on the lathe stock such that the axis of the rock core is in alignment with the axis of the lathe chuck and the end, with no more than 10mm of core protruding from the biaxial cell, faces the lathe chuck.

Q.3.3 Drilling

Use only sharp undamaged drill bits of the correct type and dimensions (see **Q.2.7**) and correct specification drill rods in good condition that are clear of debris and have full flushing functionality.

Mark the drill rod 160 mm from the bit end. Mount the drill rod in the lathe chuck such that it is concentric, not more than the required length of drill rod extends beyond the face of the chuck and the water feed is attached.

Advance the lathe stock until the face of the rock core is close to the drill bit.

Operate the lathe at the correct rotation speed (approximately 440 rpm), apply flushing water, then manually advance the lathe stock to initiate drilling. Once the drill bit has begun to penetrate the rock core, ensure that rock penetration continues at the appropriate rate (approximately 1.25 mm/rev).

When the rock core has been drilled to the correct depth (160 mm), withdraw the stock slowly, maintaining lathe rotation and flushing water pressure. Ensure the hole is free of debris and is 160 mm long.

Q.3.4 Bolt installation

Measure and record the internal diameter of the drilled hole using a calibrated borehole micrometer, recording the diameter for at least four positions evenly distributed along the length of the borehole. From these readings determine the average borehole diameter, checking that the average diameter is 6.5mm ± 0.5mm greater than the equivalent rock bolt diameter.

Ensure the rockbolt to be tested is clean and free from contaminants, and is long enough to allow assembly of pull testing equipment after bolt installation (see Figure Q.2). Cut the end of the bolt to be inserted into the rock core normal to the axis of the bolt.

Remove the confined rock core from the lathe and place it upright on a bench. Fill the borehole with slow set-resin, which has been pre-mixed according to the manufacturer's instructions, ensuring that the catalyst has been fully dispersed. Push the rockbolt to be tested into the borehole by hand, ensuring as far as possible that the bar is central and fully to the back of the hole. Leave the assembly for at least one hour and pull-test within 2 hours of mixing.

Q.3.5 Pull testing

Assemble pull test equipment on the installed bolt and core in the lathe as shown in Figure Q.2.

Operate the hydraulic pump at 1 kN/s, applying increasing pressure to the hydraulic jack. Record the bolt end displacement at regular load intervals. Cease pump operation either when the bolt end displacement exceeds 10 mm in total or at 90% of the load at which the yield strength of the rockbolt would be reached.

After pull testing, relieve the pressure from the pull test jack before relieving the pressure from the biaxial cell to prevent tensile failure of the rock core.

Q.3.6 Core examination

After testing, withdraw the rock core from the biaxial cell and split the core in the axial plane in order to inspect the quality of installation and mode of bond failure. Examine both the resin/bolt and the resin/rock interfaces and note the location of any shear failure.

Q.4 Results

Prepare a load/extension graph for applied load against bond displacement where:

Bond displacement (mm) equals measured displacement minus extension in bolt free length (see Equation Q.1)

The extension in bolt free length, X, expressed in millimetres (mm), is given by the equation:

$$X = \frac{4(FL)}{E\pi d^2} \qquad \text{(Q.1)}$$

where:

F is the applied force in newtons (N);

L is the bolt free length in millimetres (mm);

E is the Young's Modulus of the bolt material in megapascals (MPa);

d is the nominal bolt diameter in millimetres (mm).

Determine the system stiffness and the bond strength, i.e. the applied force at which the slope of the graph falls below 20 kN/mm, from the mean of the best three results of five tests.

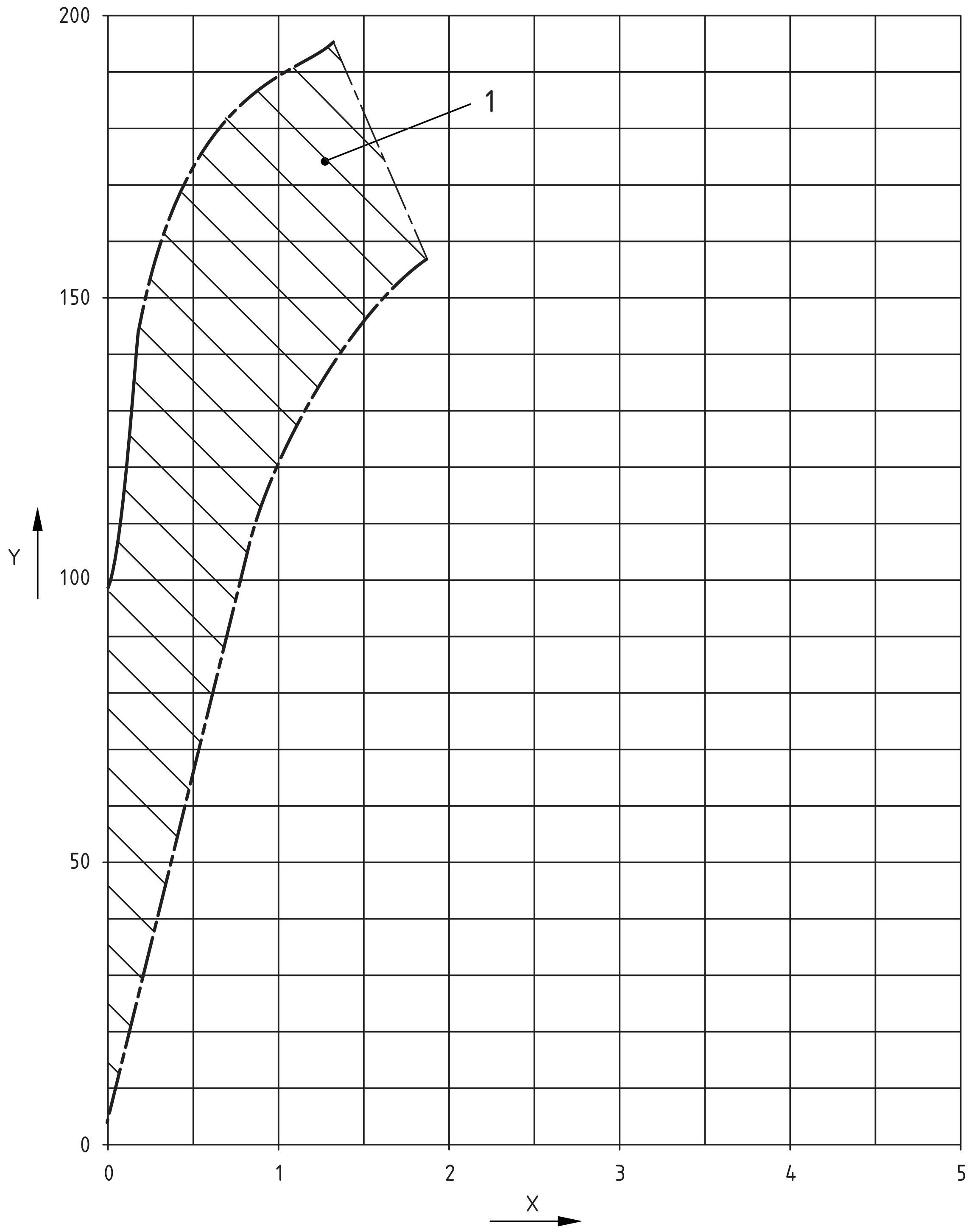
Q.5 Rock core performance criteria

When tested in accordance with the procedure described in **Q.3** and using the standard consumables and criteria listed in Table Q.1, the rock core shall provide test results which lie within the performance envelope shown in Figure Q.4. Bond failure shall be at the rock/resin interface.

Table Q.1 **Standard consumables and criteria for rock core performance testing**

Hole diameter:	28.5 mm ± 0.5 mm
Bond length	160 mm
Confining pressure (biaxial cell)	10 MPa
Drill rod type	19 mm A/F, hollow, hexagonal
Bar type	M24 high tensile continuously threaded steel bar, grade 10.9 steel (yield strength 312 kN, UTS 346 kN)
Resin	Conforming to Clause **6**

Figure Q.4 **Rock core performance envelope**



Key
X = mm
Y = kN

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