Guidance on the use of cablebolts to support roadways in coal mines

This guidance is prepared, in consultation with HSE, by the Deep Mined Coal Industry Advisory Committee which was appointed by the Health and Safety Commission as part of its formal advisory structures. The guidance represents what is considered to be good practice by the members of the Committee. It has been agreed by the Commission. Following this guidance is not compulsory and you are free to take other action. But if you do follow this guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.

Introduction

1 The use of fully grouted long tendon anchors constructed from steel rope strands has become widespread within coal mines. These anchors are known as cablebolts. There are two main types in general use. A single birdcaged cable is one in which a seven wire, high tensile steel strand is rewound to form a structure of alternately tightly clustered, then open mesh wire. Double birdcaged cables are formed from two such strands. Other forms may be appropriate.

Application

2 This guidance applies to situations where cablebolts are installed as additional support when excessive strata movement is experienced or expected in places principally supported by rockbolts.

Definitions

3 The following definitions apply throughout this guidance:

Cablebolt: a partially rewound steel rope strand (birdcaged) used in conjunction with fully encapsulating grout to provide reinforcement of a mine roadway roof or side.

Rockbolt: a bar inserted into the roof or side of a roadway which is used in conjunction with fully encapsulating resin or some other appropriate substance to provide reinforcement of the roof and sides of a roadway or working place in a mine.

Rockbolted heading/roadway: a heading/roadway in which rockbolts provide the principal means of support.

Site investigation

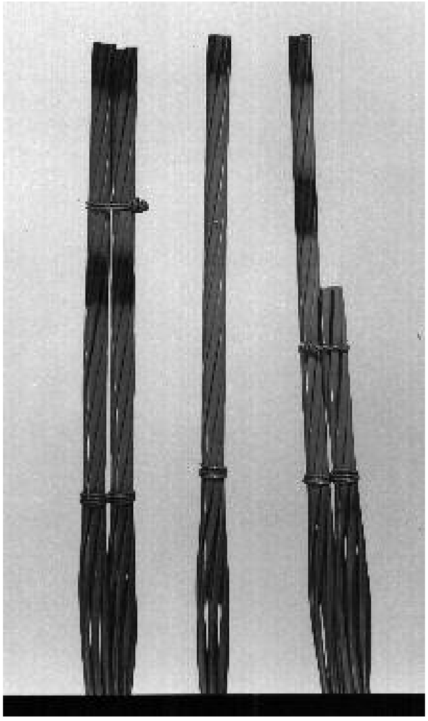
4 A full assessment of all factors which are likely to affect the performance of rockbolted support in a roadway needs to be carried out prior to the design of any principal rockbolt support system.

5 Cablebolts are normally applied as part of a rockbolt support system if monitoring and previous experience have shown that roof movement is occurring or likely to occur above the rockbolted height.

6 In these circumstances, the major additional requirements are for information regarding the geology, position and the mechanism of roof movement above the rockbolted height. This will determine the required length and the appropriate density of the cablebolts.

Cablebolt system design and specification

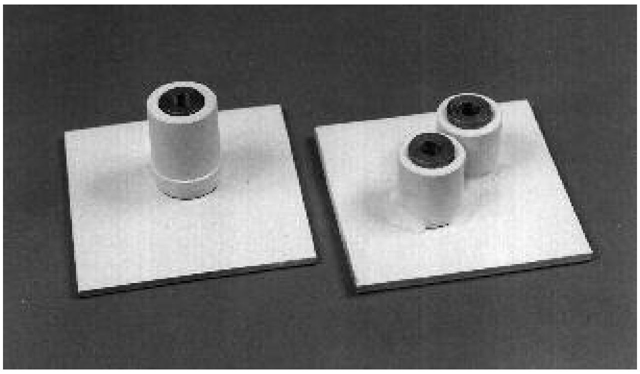
7 Where the site investigation and geotechnical assessment indicate that the strata require the use of cablebolts, a support design needs to be prepared. Where an existing design has already been proved, reference to it may be made for other roadways of similar dimensions, in the same seam, provided that suitable and sufficient steps are taken to show that the geological conditions, rock properties and stress fields at both sites are substantially similar.



Single and double birdcaged bolts (photograph courtesy of ANI Arnall)

8 The manager should appoint a suitably qualified and competent person to undertake and record the results of a geotechnical assessment and on the basis of the assessment design a safe and suitable support system. A suitable qualification for such a person would be a chartered engineer, or equivalent, who has had three years' appropriate experience in work related to mine strata control. For the purposes of this guidance, this person is referred to as the 'design engineer'.

9 The manager should appoint a suitably qualified and competent person to implement, audit and co-ordinate the cablebolting scheme. A suitable qualification would be a Higher National Certificate in a mining-related subject together with at least six months' relevant experience of strata control activities in a coal mine and the completion of a training course in rockbolting and cablebolting. For the purposes of this guidance this person is referred to as the 'rockbolting co-ordinator' ('co-ordinator'). Where appropriate, sufficient suitably trained and competent persons need to be appointed to assist in the performance of these duties.



Plates for single and double birdcaged bolts (photograph courtesy of ANI Arnall)

10 Where cablebolts are to form part of the systematic support, the design engineer should prepare the initial design of the cablebolting system on the basis of the results of the site investigation. As a minimum, the design needs to take account of the following:

- the profile of the heading;
- the length and type of cablebolts and any associated equipment to be used in the roof and ribs;
- the density and pattern of cablebolts in the roof;
- the distance of installation from the face of the heading.

11 When the initial design has been completed, documentation needs to be prepared detailing:

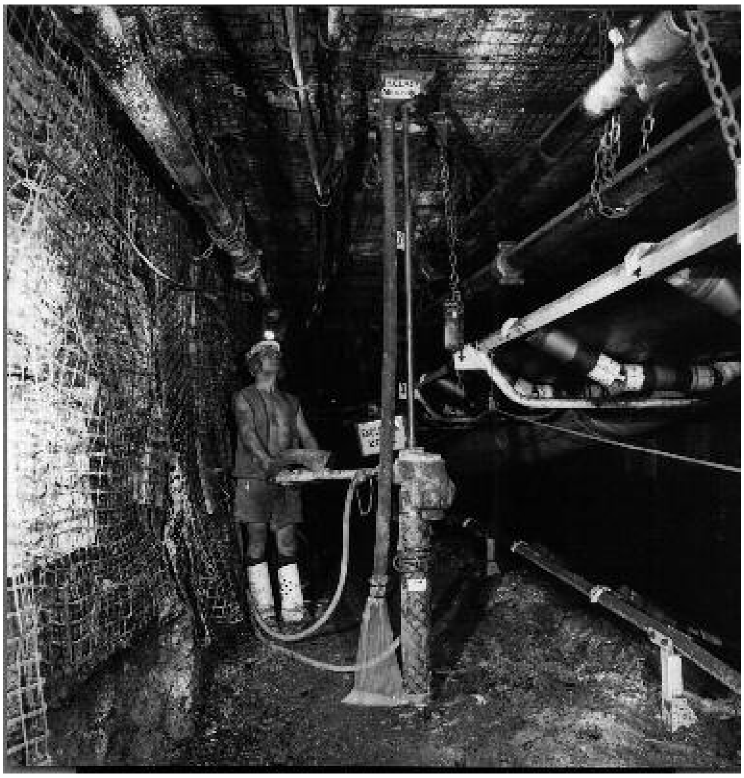
- the use of the roadway/junction;
- the free-standing supplementary support if applicable;
- the layout and dimensions of the cablebolting pattern;
- the specification of cablebolting consumables to be used;
- the method of work;
- the design verification monitoring system.

12 The design document should be signed by the design engineer and will form the basis of the manager's 'support rules'.

13 Where cablebolts are used as a remedial support system, their length, position and density should be determined by the mine manager. The design should take into account location, mechanism and degree of roof movement.

14 The use of double birdcaged cablebolts is recommended when used in roadways principally supported by rockbolts, because they have a high degree of stiffness and strength when compared to single birdcaged cablebolts.

15 Cablebolts should normally have a minimum length of 8 m when used in roadways less than 5 m wide, and 10 m when used in other applications, unless monitoring and geotechnical information indicates otherwise.



Drilling a hole for a cablebolt (photograph courtesy of RJB Mining)

16 A typical cablebolt reinforcement design for roadways comprises rows of alternately two, then one, double birdcaged cables spaced not more than 1.2 m apart measured along the roadway axis (equivalent to a density of 0.25 cables/sq metre in a 5 m wide roadway). Other designs/densities may be appropriate and will depend on geotechnical factors, including monitoring.

Installing a cablebolt in an arched roadway (photograph courtesy of Pozament Ltd)

17 Cablebolts should be full column grouted.

18 Where cementitious grouts are used, it is important that the liquid to solids ratio of the mixed grout is accurately measured to ensure the correct consistency for both pumping and strength. Recommendations on the correct liquid/solids ratio should be made by the grout supplier. Sampling frequency should be determined by the manager (see Appendix 1). Where possible, sufficient grout should be mixed to fill the hole in one operation. Failure to achieve the manufacturer's recommended figures may necessitate additional cablebolting being installed.

19 All cablebolts should be installed as near to vertical as is practicable, unless the design specifies otherwise.

Monitoring

20 The Deep Mined Coal Industry Advisory Committee's *Guidance on the use of rockbolts to support roadways in coal mines*[1] advises that the mine manager needs to prepare a scheme for the routine monitoring of roadways. Where cablebolts form part of the principal rockbolting support system the manager should prepare an addendum to the scheme which takes account of this

Cablebolts installed in the roof of a roadway (photograph courtesy of RJB Mining)

21 The addendum should set out the manager's requirements for:

- the procedures for the auditing of routine monitoring devices where cablebolts form part of the support system;
- the equipment to be used;
- the duties of individuals;
- plans, schedules and reports;
- the maximum levels of movement allowable on the monitoring devices before action is required;
- the action to be taken and the person responsible for taking the action.

22 The addendum needs to recognise:

- the need to monitor and report physical changes affecting the security of the support system;
- the need to take remedial measures.

Routine monitoring devices

23 'Dual height tell-tales' are used for the routine monitoring of roadways where cablebolts form part of the support system. The construction, installation procedures and method of reading of cablebolt tell-tales is shown in Appendix 2.

24 Tell-tales need to be installed:

- to at least the height of the cablebolt length + 1 m;
- at intervals not greater than 20 metres;
- as near vertical as practicable and sited as close to the centre of the roadway and as soon after cablebolting as practicable, or as directed by the co-ordinator.

25 Tell-tales can also be set at increased frequencies by persons working on site or through supervisory or managerial instruction.

26 All other arrangements for monitoring should be the same as for rockbolts.

Training (See Appendix 3)

27 All personnel involved with the installation of cablebolts should have received appropriate operational and safety training, and be duly authorised.

A roadway reinforced by cablebolts (photograph courtesy of Pozament Ltd)

28 Management and officials/supervisors should have general training on the action of cablebolts, correct installation techniques, monitoring arrangements and testing procedures.

29 Operators should receive training to ensure that they are familiar with the machinery and consumables to be used and the procedures to be followed when installing cablebolts. Emphasis needs to be given to maintaining satisfactory standards at all times.

Consumable items

30 All consumable items forming part of the roadway support system must be suitable for the purpose when installed in compliance with instructions provided by the supplier.

31 A product would be regarded as suitable:

- if it had previously received an acceptance number under the British Coal Corporation's procedures for the Acceptance of Strata Reinforcement Materials and Equipment between 1 April 1992 and 30 June 1995; or
- if it can be shown, by means of independently conducted and assessed type testing, to meet the criteria set out in *Strata reinforcement support system components used in coal mines* Part 2;[2] or
- if it does not meet the above criteria:
  - a laboratory test programme is set out to simulate, as closely as is practicable, operational conditions;
  - tests to this programme are conducted by an independent accredited test house and a report is prepared;
  - the results of the test are assessed independently and found to be satisfactory;
  - an assessment of any risk to safety and/or health has been undertaken; and
  - the supplier of the product is in possession of a letter, from the assessing body, setting out the conditions under which the product may be used underground. Field trials may be needed to validate performance.

Appendix 1 Sampling of grout mixed underground

Principle

1 A cementitious grout is prepared underground by mixing a known weight of powder with a specified volume of water in an approved mixing unit. Having mixed the grout it is then pumped into the prepared cablebolt hole, which contains the birdcaged cablebolt. The correct water/solids ratio of the grout is critical if the optimum strength development is to be achieved. The quality of the pumped grout is checked by sampling on a regular basis. The uniaxial compressive strength and density of these samples are then determined by laboratory testing.

Apparatus

2 Use a test machine calibrated to BS EN ISO 7500-1,[3] Grade 1.0, with a capacity and capability to apply load at a rate conforming to the requirements of paragraph 16.

Where spacing blocks are used between the test specimen and the platen the requirements of BS 6319: Part 2[4] apply.

3 The samples are collected in plastic bottles having nominal internal dimensions of 57 mm diameter x 100 mm deep, ie 250 ml capacity. After curing, the plastic bottle is removed from around the sample and the surfaces of the sample prepared for testing.

Procedure

Preparation of test specimens

4 After mixing the grout to the manufacturer's instructions, pump a sample into a plastic bottle of the size specified, sufficient to completely fill the bottle. At least three specimens should be prepared in this way.

5 The samples should be clearly labelled with the date sampled, name of the mine, district/heading location and type of grout.

6 Leave the samples to cure underground for 24 hours.

Test method

Density - Mine specimen testing

7 On the surface weigh the bottle, cap and grout (filled to the brim). Check this weight against a chart provided by the manufacturer. If this comes within the range indicated on the chart, the grout is being mixed correctly.

8 Frequency of sampling will be done in accordance with the manager's instructions.

9 If the bottle is not completely full of grout, the following procedure should be adopted. Weigh the bottle, cap and grout, and record the weight. Top up the bottle with water and record the weight. Take the difference between the two weights, double it and add to the original weight of bottle, cap and grout. Consult the manufacturer's chart.

Density and uniaxial compressive strength - Laboratory specimen testing

10 At the test laboratory remove the plastic bottle from around the sample and prepare the ends to give a cylinder 90 mm long with parallel faces.

11 Weigh and measure the samples and record the density.

12 Where samples are not tested within 24 hours of arriving at the test laboratory they should remain sealed in the bottle and stored at a temperature of 20°C ± 1°C until required for testing.

13 One of each of the three samples should be tested after 7, 14 and 28 days' curing periods.

14 Carry out all tests at a laboratory temperature of 20°C ± 5°C.

15 Wipe clean the bearing surfaces of the testing machine and of any auxiliary platens. Remove any loose grit or other material from the surfaces of the test specimen that are to be in contact with the compression platens. Place the test sample on the lower machine platen and carefully centre. Load should be applied to the prepared parallel faces. Do not use packing at any of the interfaces between the test specimen, auxiliary platens, spacing blocks and machine.

16 Apply load (without shock) and increase it continuously at a nominal rate of $45N/mm^2/min$ until no greater load can be sustained. Record the maximum load applied to the specimen.

Results

Sample calculation for density of mine specimen when the bottle is not completely filled

Weight of cap, bottle and grout	600 grams
Weight of cap, bottle, grout and water	610 grams
Weight of water	10 grams
Theoretical weight of water (10 grams) x 2	20 grams
Theoretical weight of full bottle = 600 + 20 =	620 grams

Refer to manufacturer's chart for density value.

17 The density of each laboratory test sample is calculated as follows:

$$\text{Density} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (cc)}}$$

Calculate values of density to the nearest 0.1 g/cc.

18 The uniaxial compressive strength (UCS) of each laboratory sample is calculated as follows:

$$\text{UCS (N/mm}^2\text{)} = \frac{\text{Maximum load (N)}}{\text{Original cross sectional area (mm}^2\text{)}}$$

Calculate values of UCS to the nearest 0.05 N/mm^2

If the height/diameter ratio (h/d) of the prepared sample is other than 2:1, then a correction should be applied as indicated below:

$$\text{Corrected UCS N/mm}^2 = \frac{\text{UCS (from Equation 1)}}{(0.304 \times d/h + 0.848)}$$

Where d = diameter of the sample (mm)
h = height of the sample (mm)

Refer to the manufacturer's bottle sample figures for UCS (N/mm^2) values.

Appendix 2 Cablebolt dual height tell-tale

Introduction

This device is designed to be installed following the installation of cablebolt reinforcement. Cablebolt tell-tales are available for use in a variety of hole sizes from nominal 27 mm to nominal 55 mm diameter. The general assembly is shown in Figure 1 (page 11).

Installation

1 Drill hole, using appropriate bit, to at least 1 m above reinforcement height or 6 m, whichever is the greater.
2 Insert top anchor, attached to smallest indicator 'B', to top of hole. Use purpose-designed insertion rods graduated to confirm anchor position. Check for firm anchorage.
3 Insert lower anchor attached to larger indicator 'A', 1 m below the top of the reinforcement height using purpose graduated insertion rods.
4 Secure reference tube.
5 Position indicator 'A', top of white band to be level with bottom of reference tube. Align to scale (see Figure 2, page 12). Crimp ferrule in position.
6 Position indicator 'B', top of white band to be level with bottom of indicator 'A'. Align to scale (see Figure 2). Crimp ferrule in position.
7 Record details: At all tell-tale sites a sign must be placed bearing a unique reference code for identification purposes giving the type of tell-tale, its position, date and time of installation and anchor heights. This information should be passed to relevant officials, eg the co-ordinator or command supervisor.

Reading methods

1 *By colour*

Report whole and part bands visible, eg:
'A' : white, blue, yellow
'B' : 3/4 white, blue, yellow

2 *By scale*

Report measurement, in millimetres, lining up with reference mark for each anchor.

Reference for ‘A’ is bottom of reference tube.

Reference for ‘B’ is bottom of indicator ‘A’.

Scale has millimetre divisions, with centimetre marks.

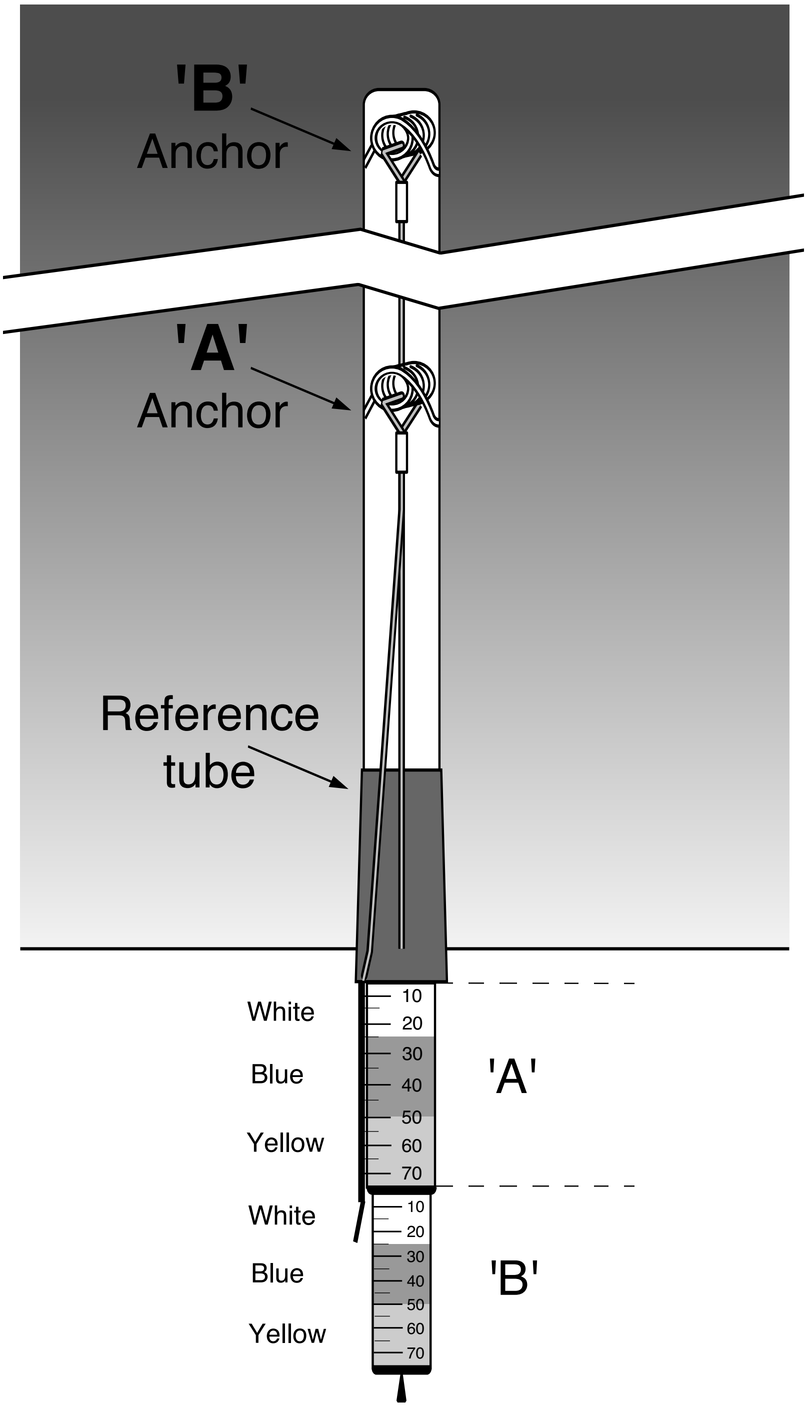


Figure 1 Dual Height tell-tale general assembly

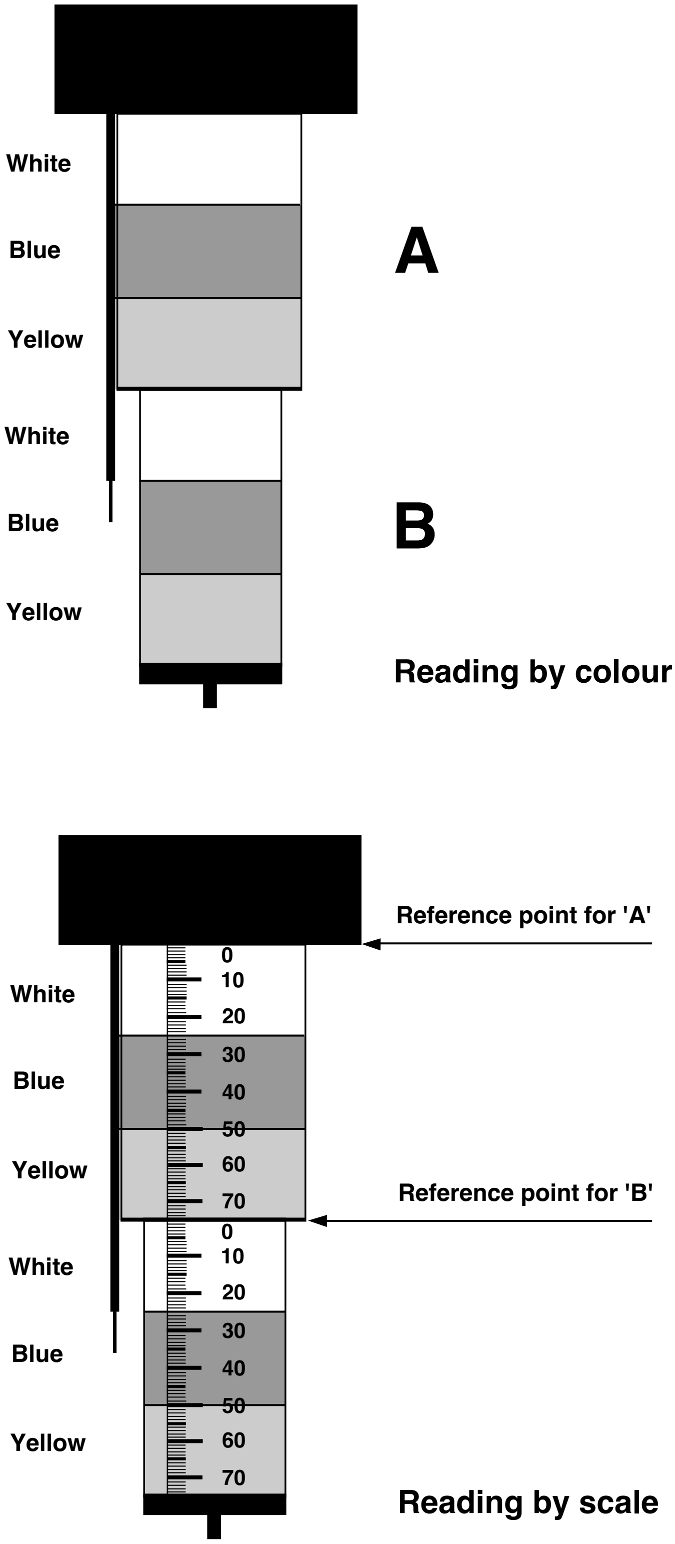


Figure 2 Cablebolt dual height tell-tale reading methods

Interpretation

1. Movement of 'A' relative to its reference (bottom of reference tube) is equal to the strata expansion within the cablebolt reinforcement height.
2. Movement of 'B' relative to its reference (bottom of 'A') is equal to the strata expansion at the top of the cablebolt reinforcement height.
3. The total strata expansion is 'A' plus 'B'.
4. Expansion of strata above the top anchor is not detected.

Appendix 3 Training

Training courses for those involved in cablebolting need to include the following aspects:

Managers

- provide an understanding of the forces present in the rock and the redistribution of these as a consequence of mining operations;
- illustrate the differences between passive support, rockbolting and cablebolting;
- explain the action of cablebolts in limiting roof movement and roadway deformation;
- highlight the adverse effects of poor installation standards;
- provide an appreciation of monitoring techniques and the information obtained, together with details of the installation and inspection procedures for the tell-tale monitoring system and also the setting of action levels and associated actions;
- give guidance on the construction and implementation of the manager's 'Scheme for the routine monitoring of rockbolted roadways';
- give instruction on the inspection of bolted roof and ribs for signs of excessive bolt loading or deterioration, and the action to be taken if these are discovered.

Bolting co-ordinator

- an introduction to rock mechanics principles as applied to cablebolting including such topics as stress, the strata, design of reinforcement systems, underground engineering, consumables and several detailed case histories, including site visits where possible;
- management of the manager's 'Scheme for the routine monitoring of rockbolted roadways';
- installation, replacement and reading of all routine monitoring devices used at the mine;
- familiarisation and use of the appropriate computer software;
- setting of appropriate routine monitoring action levels for each area of the mine;
- setting of appropriate corresponding remedial action for action levels for each area of the mine;
- determination of appropriate measuring frequencies for routine monitoring devices within the mine;
- follow up on remedial actions to secure stability;
- formulation and updating of the 'Schedule of measurement zones and measuring frequency' and related measuring timetables;
- production of tell-tale checklists for officials;

Officials

- an appreciation of basic rock mechanics as applied in cablebolting;
- all aspects of the mine monitoring system;
- action levels;
- action, duties and responsibilities;
- remedial measures;
- follow up actions;
- communication links;
- all aspects of the tell-tale checklist system at the mine;
- appreciation of tell-tales;
- the correct installation of tell-tales;
- the replacement of tell-tales;
- the identification of tell-tales;

- reading of tell-tales and appropriate action levels and the associated action to be taken;
- instruction on the inspection of bolted roof and ribs for signs of excessive bolt loading or deterioration and the actions to be taken if these are discovered;
- appropriate types of extra support to secure the roof in adverse conditions.

Operators

- the action of cablebolts and typical cablebolt patterns, highlighting the importance of good installation practice;
- correct installation of cablebolts including adequate practical on-site training;
- the sequence of operations and the time at which cablebolting is carried out;
- maintenance of the cablebolting equipment (drilling machines etc) to ensure that performance is maintained at designed levels. (Particular attention needs to be directed to ensuring provision of a sufficient supply of either hydraulic fluid, or compressed air (as appropriate) to allow the drilling equipment to operate within design parameters);
- provision of the correct length of drill-rods in an undamaged condition and arrangements to ensure that the correct depth of hole is drilled;
- the type of grout together with the importance of the recommended mixing and pumping procedures;
- an appreciation of the manager's 'Scheme for the routine monitoring of rockbolted roadways', the information indicated by means of the tell-tale monitoring system and action, where appropriate;
- an instruction that operators, in the event of difficulty in the application of cablebolting and monitoring, need to bring those matters to the attention of those having statutory responsibility for the supervision of operations;
- personal protective equipment.

References

1 *Guidance on the use of rockbolts to support roadways in coal mines* Mines01 HSE 1996 Web only: www.hse.gov.uk/pubns/mines01.pdf

2 BS 7861: 1996 *Strata reinforcement support system components used in coal mines* British Standards Institution
Part 1 – *Specification for rockbolting*
Part 2 – *Specification for birdcaged cablebolting*

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

4 BS 6319-2: 1983 *Testing of resin compositions for use in construction. Method for measurement of compressive strength* British Standards Institution

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