no significant variation, in which case the interval between calibrations may be extended up to a maximum of one year, when a routine calibration should be carried out using test equipment with an accuracy more than 0.5%.

14.6.3 Stressing procedure

14.6.3.1 General

14.6.3.1.1 Stressing procedure should conform to BS EN 1537:2013, **8.4.3**.

14.6.3.1.2 For cementitious grouts, stressing should not commence until the primary grout forming the fixed anchor has attained a crushing strength of at least 30 MPa.

14.6.3.1.3 Stressing should not be carried out when a column of ice is present in the free anchor length.

14.6.3.2 Lift-off checks

14.6.3.2.1 When a stressing operation is the start point for future, time-related, load measurements, the stressing operation should be concluded with a lift-off check load measurement, following the exact procedure to be used for subsequent lift-off checks in order to minimize operational error.

NOTE 1 Lift-off checking is the technique of using the stressing jack straddling over the stressing head to lift it clear of its bearing plate to record the tendon load with the jack pressure gauge or load cell.

NOTE 2 Field experience has highlighted difficulties in relation to accuracy when using load cells to measure the absolute values of load in anchors.

NOTE 3 Field experience has shown that load cells are more reliable when recording load change over defined periods.

14.6.3.2.2 The distance the anchor head is raised should be prescribed prior to the works and the method of measurement should ensure that all sides of the stressing head are clear of the bearing plate.

NOTE The distance the anchor head is raised is normally 1 mm, although this distance can be as low as 0.1 mm.

14.6.3.3 Tendon load measurement

Where the stressing equipment has duplicate tendon reading capability, e.g. by load cell and by pressure gauge, the instruments should be recalibrated if the discrepancy between them exceeds 5% and cannot be eliminated by re-centring or reseating the equipment.

NOTE There is often a slight variance between the perpendicularity of the bearing plate and the tendon. Such occurrences are usually not a problem in respect of anchor performance but may be identified markedly by load cells.

14.6.3.4 Unit stressing

The procedure for stressing multiunit tendons using a number of hydraulically synchronized monojacks, or individual monojacks, should conform to **14.6.3.1**, and should allow for the fact that, when stressing is carried out using an individual monojack, the possible change in load in adjacent tendon units should be appreciated.

NOTE 1 During monojack stressing, the load loss due to wedge pull-in is repeated during each load application and, thus, the load recorded from the jack pressure gauge does not represent the load locked into the tendon unit. The actual service state load in the strand can be measured by a lift-off check and the load loss due to wedge pull-in can be determined and then allowed for by duly overloading. Load loss due to wedge pull-in is generally related to the type of jack and to the tendon free length. If the tendon free length is particularly short, thereby inducing high load

loss due to wedge pull-in, the use of shims between the collet and the headplate can reduce the amount of overload required to achieve specified, locked-in, tendon element loads.

NOTE 2 For anchors that have failed a proof load criterion, tendon unit stressing might help to ascertain the location of the failure, e.g. for a temporary anchor, the pull-out of individual tendon units might indicate debonding at the grout/tendon interface, whereas, if all tendon elements hold their individual proof loads, attention is directed towards failure of the fixed anchor at the ground/grout interface.

14.6.4 Records

Details of all forces, displacements, seatings and other losses observed during all stressing operations, and the times at which the data were monitored, should be recorded in an appropriate form for every anchor (see Annex A).

14.6.5 Health hazards and safety

14.6.5.1 During stressing, precautions (e.g. erection of protective screen) should be taken to protect personnel and property from injury and damage due to the rupture of a tendon or failure of the stressing equipment [N13].

14.6.5.2 Persons not engaged in the works, including members of the public, should also be protected. In this regard, strong barricades should be erected beyond the anchor head in line with any exposed ends during tensioning. The barricades should be strong enough to absorb a significant proportion of the tendon energy if it is accidentally released (see Annex I).

14.6.5.3 The space between the anchor head and the barricade should be roped off to prevent unauthorized passage. Implementation of further safety precautions should conform to BS EN 1537:2013, **11.5**.

14.7 Stressing equipment

14.7.1 General

The stressing equipment for anchors should be able to tension the complete tendon in a single operation. Where circumstances do not permit the use of a single stressing operation and multi-unit stressing operations are used, the recommendations given in **14.7.2** to **14.7.4** should be followed accordingly.

14.7.2 Hydraulic jacks

Hydraulic jacks should meet the following general requirements.

a) The means of attachment of the tendon to the jack should conform to the efficiency requirements of BS EN 13391:2004.

b) The equipment should be capable of tensioning the tendon to not less than 80% of its characteristic strength within the rated pressure capacity of the pumping unit.

c) The equipment should be designed so that a total controlled force is imposed gradually and no dangerous secondary stresses are induced in the tendons, anchor head, supported ground or supported structure.

d) The equipment should permit the tendon to be tensioned, initially, in increments and anchored at intermediate loads, so that the force in the tendon can be raised or lowered in accordance with the tensioning recommendations (see Clause **15** 〈A2〉 *Text deleted* 〈A2〉) and, finally, conclude with a check-lift to ascertain the tendon load.

e) The design of the equipment should permit the tendon elongation at every stage to be measured to an accuracy appropriate for the test requirements. The accuracy of reading should be as fine as ±0.2 mm for short duration (< 1 h) testing of rate of loss of load or displacement, but for

conventional proof loading cycles, or long duration (> 1 day) testing, an accuracy of ±1 mm will normally be adequate.

f) Facilities and instrumentation should be provided to measure any movement of the tendon in the gripping devices.

14.7.3 Load measurement

14.7.3.1 Load cells

14.7.3.1.1 Where load cells are provided, these should be robust and protected for site work and long-term performance. They should have a means of accurately centring them on the jack to ensure they are co-axial with the tendon. Load cells should be provided with calibration certificates and, where appropriate, the effects of sustained loading on the cell should also be recorded on the certificate. As a general rule, a load cell should be employed in the range of 10% to 100% of its rated capacity.

14.7.3.1.2 Load read-outs or recording instruments should be calibrated with the actual cable that is to be used on site. The instruments should be provided with input voltage indicators, whether mains or battery operated.

14.7.3.2 Pressure gauges

Pressure gauges should, as a minimum, conform to accuracy class 2 of BS EN 837-1:1998. They should be supplied with a calibration certificate. Pressure gauges should be mounted not more than 5 m from the jack. Where the pump unit on which the gauge is mounted is over 5 m from the jack, a duplicate pressure gauge should be provided adjacent to the jack. The maximum capacity of pressure gauges should lie within the range of 80% to 160% of the characteristic strength of the tendon.

14.7.4 Hydraulic pumping units

14.7.4.1 Hydraulic pumps should be rated to operate through the pressure range of the stressing jack. The controls of the pump should allow the tendon extension to be easily adjusted to within a millimetre, whether the jack is extending or retracting. The pressure gauge should be mounted such that it is reasonably free from vibration during pumping. All flexible connections between the pump and the jack should have a burst pressure of at least twice the maximum rated pump pressure, and should be fitted with self-sealing connectors.

14.7.4.2 The hydraulic pump unit should be fitted with a site-regulated, pressure overload relief valve to prevent tendon damage by over-tensioning.

15 Considerations related to testing

〚A2〛 The detailed testing of grouted anchors should be in accordance with BS EN ISO 22477-5. 〚A2〛

〚A2〛 *Note deleted* 〚A2〛

NOTE Monitoring the service behaviour of an anchor is also addressed in Annex H, with further detailed considerations summarized by Littlejohn and Mothersille [N15]: Guidelines.

16 Maintenance

16.1 Precautionary measures

16.1.1 The protection of the anchor head from mechanical damage by construction plant and vehicles should be done by the provision of a recess in the structure being anchored, or by the provision of

covers. Aluminium should not be used because corrosion might result from the bimetallic junction produced. Similar provisions should apply to the selection of materials for holding down bolts used to secure protective caps to the bearing plates.

NOTE Suitable materials for covers are chromate dip galvanized pressed steel or plastic-coated steel.

16.1.2 In the case of important temporary or permanent structures, the overall performance of the anchored structure or excavation should be monitored. The load in selected anchors should be checked at regular intervals. This should be done by carrying out lift-off checks or by taking readings from load cells installed in the anchor head at the time of construction.

16.1.3 Where groundwater levels are a critical factor in design, e.g. regarding slope stability, levels should be monitored by means of piezometers. Regular sampling for chemical analysis should also be carried out, particularly on sites where the groundwater might be aggressive.

16.1.4 Where a regular survey of selected points on the anchored structure is carried out to check for movement, any movement should be plotted and analysed. Permissible limits for total movement should be indicated at the design stage.

16.1.5 Where permanent anchors have been installed for a period in excess of 15 years with corrosion protection considered inadequate by present standards [N14], and where anchor load monitoring is not possible, then, if feasible, a sample number of anchor heads should be exposed to permit examination of the tendon in the region of the inner anchor head.

16.2 Remedial measures

Remedial measures may be taken in exceptional cases. They might consist of the following:

a) restressing the tendon: if a possible need for this is foreseen, the tendon should not be cut off too short on installation or, alternatively, restressable anchor heads should be used;

b) replacing defective anchors with new anchors or struts, or stressing substitute anchors, if already provided.

16.3 Replacement criteria during service

The permissible variation of load or range of movements should be indicated at the design stage and checked at intervals.

16.4 Dismantling after service

16.4.1 Ideally, temporary anchors should be destressed after use, in an agreed sequence, and the locking devices at the anchor heads should be removed or otherwise rendered inoperative.

NOTE If the necessity to remove tendon is foreseen at the design stage, it is possible to incorporate within the anchor the means to remove the tendon. Various methods [13], [14] are available that enable the whole or part of the tendon to be withdrawn from the borehole.

16.4.2 All operations associated with the removal of the tendon should be carried out under the supervision of a competent engineer, experienced in this type of work.

NOTE The National Federation of Demolition Contractors [15], the Health and Safety Executive and the British Standards Institution all provide useful guidelines on the demolition of prestressed concrete structures, some of which are relevant to grouted anchors.

17 Reporting

17.1 General

17.1.1 Records should be maintained for all anchor installations that conform to requirements of BS EN 1537:2013, **10.2**. There should also be a check on groundwater lowering in the area.

NOTE Attention is drawn to the requirements of the Control of Pollution Act 1974 [16].

17.1.2 Lack of knowledge of the location of anchors might lead to damage of construction plant. Copies of the records should be deposited at the local authority building regulations department.

17.1.3 Records might also be required by the owners of the adjacent property. Plans showing the details and locations of the anchors should therefore be retained with the deeds of the property. The owner should keep a regular check on deep construction in the area that might lead to damage to the grouted anchors securing the property.

17.1.4 With regard to grouted anchor construction, records covering ground investigation, drilling, grouting and stressing should be compiled for future reference.

NOTE Typical pro formas for anchor records are shown in Annex A.

17.2 Geotechnical feedback report

17.2.1 On completion of the works, a GFR should be prepared that covers the following broad classes of information:

a) a record of anchor construction and any changes to its design; and.

b) results of monitoring and testing of anchors during construction.

NOTE The GFR is also known as a "close-out report".

17.2.2 The GFR should be tailored to suit the size and complexity of the works.

17.2.3 The record of construction should include:

a) a general description of the works;

b) weather conditions;

c) application of acceptance criteria;

d) plant used and details of any problems encountered;

e) any instability problems and unusual ground conditions;

f) any ground and groundwater conditions encountered;

g) any temporary works required and their effectiveness;

h) any contaminated and hazardous material encountered on site and the location of disposal, both on and off site;

i) any area of the specification or standards used that should be reviewed in the light of problems encountered on site;

j) any requirements for ongoing monitoring or abnormal maintenance requirements;

k) any unexpected ground conditions that required changes to design;

l) any problems not envisaged in the design process and the solutions to them; and

m) as-built drawings.

17.2.4 The results of monitoring and testing should include:

a) details of testing and types of test applied;

b) summary of site laboratory testing on materials;

c) location and details of instrumentation;

d) readings from instrumentation (with dates) and predicted values;

e) the results of compliance testing (e.g. *in situ* density measurement, unconfined compressive strength, etc.).

NOTE Guidance on the preparation of close-out reports can be found in the ICE manual of geotechnical engineering (2012), Volume II, Chapter 101 [2].

Annex A (informative)
Indicative record sheets

A.1 General

A.1.1 This Annex gives examples of typical record sheets. Field data sheets that record the correct information regarding each particular operation are an essential part of the anchor works. The installation operations, including drilling, grouting and tendon installation, might be recorded on a single sheet in the form shown by Table A.1, or might, in certain circumstances, need to be either more extensive, for strata logging, or more specific, to cover details such as grout testing, water testing or borehole alignment checking.

A.1.2 Stressing records (see Table A.2) and analysis sheets (see Table A.3) not only present the load/displacement results, but also provide complete information on stressing equipment, the monitoring system, tendon measurements, tendon properties and grout strength records. The monitoring of anchor head displacement in the direction of the tendon axis due to structural movement might be difficult and therefore require calculation or interpolation. Where anchor head displacement continues during load monitoring periods it is normally recorded and due correction made for resulting load loss or gain in the anchor. The completion of the record sheet and the graphical plotting of load/displacement during a stressing operation allows ongoing assessment of the anchor performance and immediate confirmation regarding conformance to the acceptance criteria (apparent tendon free length and percentage load or displacement change). If conformance is not attained, then additional load cycles or an extension of monitoring periods may be carried out whilst equipment is already *in situ*.

Table A.1 — *Typical drilling, grouting and tendon installation record sheet*

Contact name Anchor location			Anchor no. Sheet no. Date	
Drilling details		**Grouting details**		
Drill method Drill machine Casing diameter Underream diameter Underream spacing Entry level Inclination Casing length Overall length Groundwater level Flushing medium	…….. …….. m m m M.O.D. …….. m m m ……..	Grouting plant Cement type Pre-grout w/c ratio Pre-grout consumption Primary grout w/c ratio Primary grout consumption Primary grout injection pressure Secondary grout w/c ration Secondary grout consumption Secondary grout injection pressure	**Fixed anchor length (m)** …… …… …… …… …… …… …… ……	**Free anchor length (m)** …… …… …… …… …… …… …… ……

Tendon installation details

Tendon reference no.	……..	Overall length supplied	m
Date homed	……..	Fixed or encapsulated	m
Temporary or permanent	……..	Length cut off	m
No. of bars and strands	……..	Length outside hole	m
Diameter of bars and strands	mm	Characteristic strength of tendon	kN

Depth (m)		**Strata description**		**Time**
From	**To**			

Remarks and contact for test data

Company	
Driller	

NOTE M.O.D: metres above datum; w/c: water/cement ratio.

Table A.2 — Typical stressing record sheet

Contact name		Anchor no.	
Anchor location		Sheet no.	
Type of test	Suitability or acceptance	Date	

Stressing details		**Tendon details**	
Date stressed	.....	Date homed	
Head type y	.....	No. of bars or strands	
Jack type/capacity	.....kN	Diameter of bars or strands	mm
Jack reference	.....	Tendon free length (stressing)	m
Load measurement system	.....	Tendon free length (service)	m
System reference	.....	Tendon bond length	m
Displacement measurement system	.....	Characteristic strength of tendon	kN
Datum point	.....	Young's modulus	GPa
Serviceability limit state specified load	..... kN	Tendon area	mm^2
Proof load	..... kN		
Lock-off load	.....kN		

Grout strength details			**Cube size**			
Identification						
Date cast						
Age (days)						
Strength (N/mm^2)						

Load **% $F_{ser;}$**	**Load** **kN**	**Pressure** **kg/ cm^2 bar**	**Displacement (mm) at**		**Ram/tendon displacements** **mm**	**Anchor head displacement** **mm**	**Corrected displacement** **mm**	**Time**	**Remarks**
			0 min	**1 min**					
1st cycle									
10									
50									
100									

