

BS 8081:2015+A2:2018

Incorporating Corrigenda Nos. 1 and 2



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Code of practice for grouted anchors

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30 September 2017	A1: see Foreword
30 November 2017	C1: 11.3 subclause heading corrected
30 September 2018	A2: see Foreword
30 December 2019	C2: 3.2 and Annex B symbols and equations corrected

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Summary of pages

This document comprises a front cover, and inside front cover, pages i to iv, pages 1 to 116, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 August 2015. It was prepared under the authority of Technical Committee B/526, *Geotechnics*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

BS 8081:2015+A2:2018 supersedes BS 8081:2015+A1:2017, which is withdrawn.

BS 8081:2015+A1:2017 superseded BS 8081:2015, which was withdrawn.

Information about this document

Text introduced or altered by Amendment No. 1 is indicated in the text by the tags A1 A1. Minor editorial changes are not tagged. Amendment No. 1 introduces the following changes:

- [Table 2](#) has been updated;
- a new [Clause 11.3](#) has been inserted and the following subclauses renumbered; and
- Clause 11.3.5 has been deleted.

Text introduced or altered by Corrigendum No. 1 is indicated in the text by the tags C1 C1.

Text introduced or altered by Amendment No. 2 is indicated by the tags A2 A2. Minor editorial changes are not tagged. Amendment No. 2 introduced the following changes:

- Annex G and associated citations in the text have been deleted; and
- References to BS EN ISO 22477-5 have been introduced.

Text introduced or altered by Corrigendum No. 2 is indicated in the text by the tags C2 C2.

Relationship with other publications

BS 8081 gives non-contradictory, complementary information for use with BS EN 1997-1:2004+A1:2013 and its UK National Annexes, BS EN 1537:2013 and BS EN ISO 22477-5.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations.

It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

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

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

The auxiliary verb “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the Clause. The auxiliary verb “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

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.

1 Scope

- 1.1 This British Standard, as a code of practice, gives recommendations for the design, construction, stressing, testing, monitoring and maintenance of grouted anchors as defined in BS EN 1997-1:2004+A1:2013, BS EN 1537:2013 and BS EN ISO 22477-5.
- 1.2 Further general recommendations for corrosion hazards and protective measures, construction techniques and quality controls, stressing procedures, and the testing of grouted anchor components and complete installations are provided. Information supporting the practical implementation of these recommendations are provided in annexes to this code of practice.
- 1.3 [Annex A](#) provides examples of records that are developed during the execution and testing of grouted anchors.
- 1.4 [Annex B](#) provides information on the design of a fixed anchor length with respect to the bond or shear resistance at:
- a) the ground/grout interface;
 - b) the grout/encapsulation interface;
 - c) the grout/tendon interface.
- 1.5 [Annex C](#) provides information on the pre-grouting and post-grouting of ground, where necessary.
- 1.6 [Annex D](#) provides information on the use of appropriate Young's modulus for the steel used in the design of the anchor tendon.
- 1.7 [Annex E](#) provides information on the types of corrosion that affect the steel elements of an anchor and the influence on the corrosion of the tendon of the ground and groundwater in which the anchor is installed.
- 1.8 [Annex F](#) provides information on the types of corrosion protection available for use in the fabrication and installation of the anchor.
- 1.9 [Annex G](#)  (not used) 
- 1.10 [Annex H](#) provides information on monitoring anchors in the long term, including appropriate acceptance criteria and remedial measures that can be applied in the event of non-compliance with the acceptance criteria.
- 1.11 [Annex I](#) draws attention to the statutory regulations affecting the safety, welfare and health of persons in the execution of anchor construction.
- 1.12 This code of practice is for the use of clients who commission the use of grouted anchors, ground engineering contractors, and geotechnical and structural designers.

 Text deleted 

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 3148:1980, *Methods of test for water for making concrete (including notes on the suitability of the water)*

BS 6319 (all parts), *Testing of resin and polymer/cement compositions for use in construction*

BS EN 206, *Concrete — Specification, performance, production and conformity*

BS EN 445:2007, *Grout for prestressing tendons — Test methods*

BS EN 446:2007, *Grout for prestressing tendons — Grouting procedures*

BS EN 447, *Grout for prestressing tendons — Basic requirements*

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

BS EN 934-2, *Admixtures for concrete, mortar and grout — Concrete admixtures — Part 2: Definitions, requirements, conformity, marking and labelling*

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

BS EN 1537:2013, *Execution of special geotechnical works — Ground anchors*

BS EN 1992-1-1:2004+A1:2014, *Eurocode 2 – Design of concrete structures — Part 1-1: General rules and rules for buildings*

BS EN 1992-2:2005+A1:2014, *Eurocode 2 – Design of concrete structures — Concrete bridges — Part 2: Design and detailing rules*

BS EN 1993-1-1:2005, *Eurocode 3 – Design of steel structures — Part 1-1: General rules and rules for buildings*

BS EN 1997-1:2004+A1:2013, *Eurocode 7 – Geotechnical design — Part 1: General rules*

BS EN 1997-2:2007, *Eurocode 7 – Geotechnical design — Part 2: Ground investigation and testing*

BS EN 12715:2000, *Execution of special geotechnical works — Grouting*

BS EN 13391:2004, *Mechanical tests for post-tensioning systems*

BS EN ISO 1461:2009, (E), *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

BS EN ISO 12944-1:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

BS EN ISO 14713-1:2009, *Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures — General principles of design and corrosion resistance*

BS EN ISO 22477-5, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 5: Testing of grouted anchors*

A2 Text deleted **A2**

ETAG 013, *Post-tensioning kits for prestressing of structures*

NA+A1:2014 to BS EN 1997-1:2004+A1:2013, *UK National Annex to Eurocode 7 – Geotechnical design – Part 1: General rules*

Other publications

- [N1] INTERNATIONAL SOCIETY FOR ROCK MECHANICS (ISRM). The Complete ISRM Suggested Methods For Rock Characterization, Testing And Monitoring: 1974-2006. Ulusay, R. and Hudson, J.A. (Eds.). Commission on Testing Methods, ISRM, 2007.
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- [N3] BARTON, N. and BANDIS, S. 1982. Effects of block size on the shear behaviour of jointed rock. Keynote Lecture, 23rd US Symposium on Rock Mechanics, Berkeley, California.
- [N4] BARTON, N. 1999. General report concerning some 20th Century lessons and 21st Century challenges in applied rock mechanics, safety and control of the environment. Gen. Rept., Theme 1, Proc. 9th ISRM Cong., Paris, 3, 21p, Balkema, Rotterdam.
- [N5] HOEK, E. and BRAY, J.W. 1977. Rock Slope Engineering. Institute of Mining and Metallurgy, London, 2nd ed., 1-402.
- [N6] HOEK, E. and BROWN, E.T. 1981. Underground Excavation in Rock. Institute of Mining and Metallurgy, London.
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- [N14] MOTHERSILLE, D.K.V, JACKMAN, S., & FERRIER, J. 2007. Performance and condition assessment of 30 year old anchorages, River Clyde Glasgow. Proceedings of International Conference on Ground anchorages and anchored structures in service, ICE, London, 33-42.
- [N15] LITTLEJOHN, G.S. and MOTHERSILLE, D.K.V. Maintenance and monitoring of anchorages: guidelines. *Geotech. Eng.* 2008 April, 161 pp. 93–106

3 Terms, definitions, symbols and abbreviations

For the purposes of this British Standard, the terms, definitions, symbols and abbreviations given in BS EN 1997-1:2004+A1:2013 and the following apply.

3.1 Terms and definitions

3.1.1 anchor

3.1.1.1 anchor head

element of a ground anchor that transmits the tensile load from the tendon to the bearing plate or the structure

[SOURCE: BS EN 1537:2013]

3.1.1.2 bond-type grouted anchor

grouted anchor, the load of which is transferred via a steel tendon bonded to grout, with or without an encapsulation, and from there via the borehole grout into the ground

3.1.1.3 compression-type anchor

grouted anchor, the load of which is transferred via a decoupled steel tendon down to the bottom of the borehole, and from there via a compression element and the borehole grout into the ground

NOTE The transfer device may take a number of forms of which the most common is either a plate washer at the distal end, or a concentric tube restrained similarly at the distal end. This is sometimes referred to as a compression tube anchor.

3.1.1.4 detensionable anchor head

anchor head that has all the properties of the **restressable anchor head** (see [3.1.1.5](#)) and, in addition, permits the tendon to be detensioned in a controlled way at any time during the working life of the anchor

3.1.1.5 restressable anchor head

anchor head that permits the tendon load, throughout the working life of the anchor, to be measured by check lifting and enables small losses of up to 10% of the service state load to be recovered by shimming or thread-turning

[SOURCE: BS EN 1537:2013, modified]

3.1.1.6 stressing head

component of the anchor head attached to the tendon

NOTE For example, a nut and washer for bar tendons or steel plate with tapered holes and wedges for strand tendons.

3.1.2 bearing plate

element located under the stressing head that distributes the tendon force into the supported structure

NOTE See [A1](#) [11.5.3](#) [A1](#)

3.1.3 bond

3.1.3.1 adhesion bond

initial bond before slip that arises mainly from the physical interlocking

NOTE 1 Molecular attraction can also contribute to the bond.

NOTE 2 The adhesion bond reduces to zero when slip comparable with the size of the micro-indentations on the steel occurs.

3.1.3.2 friction bond

bond depending on the confining pressure, the surface characteristics of the steel and the amount of slip, but largely independent of slippage

NOTE The phenomena of dilatancy and wedge action also contribute to this frictional resistance as radial strains are mobilized where the tendon stretches.

3.1.3.3 mechanical interlock

bond similar to micromechanical locking but on a much larger scale, as the shear strength of the grout is mobilized against major tendon irregularities

NOTE Major tendon irregularities can include ribs, twists or deformed bars.

3.1.4 borehole diameter

diameter of the borehole as defined by the drill bit or casing diameter, excluding any enlargements

[SOURCE: BS EN 1537:2013]

3.1.5 centralizer

device to maintain the tendon's minimum grout cover in the borehole or within the encapsulation

NOTE See 12.3.5 and Figure 4 and Figure 5.

3.1.6 creep

movement of any part of the fixed anchor with time under constant tendon load

NOTE Creep can occur at both grout/tendon and ground/grout interfaces.

3.1.7 debonding

breakdown of adhesion bond, mechanical bond and friction bond at the grout/tendon or ground/grout interfaces

3.1.8 decoupling

separation of components

NOTE 1 For example, when tendons are separated from the surrounding ground by grease and sheathing.

NOTE 2 The term also relates to the breakdown into subdivisions of the grouted fixed anchor or encapsulation due to the presence of spacers or centralizers that inhibit the flow of grout during the injection process or create artificial boundaries, thereby producing a discontinuous medium.

3.1.9 distal

situated furthest from the anchor head

NOTE That is, deepest in the borehole.

3.1.10 duct

tube or covering used in corrosion protection

NOTE This is usually of semi-rigid plastic and may be smooth or corrugated.

3.1.11 encapsulation

corrosion protection barrier that is typically a plastic or metallic tube applied to the tendon

[SOURCE: BS EN 1537:2013]

3.1.12 enlargement

concentric or irregular local increase in the borehole diameter within the fixed anchor length

3.1.13 ground/grout safety factor

ratio of the geotechnical ultimate ground/grout interface resistance of the anchor to the specified load used for design

[SOURCE: BS 8081:1989]

3.1.14 grout

fluid mixture of a binding and/or setting agent (usually cement) and water that hardens after being placed in position

[SOURCE: BS EN 1537:2013]

3.1.14.1 primary grout

grout placed or injected before or after tendon homing and prior to stressing, to secure the fixed anchor to the surrounding ground

3.1.14.2 secondary grout

grout injected after stressing to protect the free length of the tendon or to fill any remaining space or void in the borehole or duct above the primary grout

3.1.15 hydrofracturing

process of high-pressure injection of grout in the borehole

NOTE This allows grout to travel extensively in the fissures in a non-uniform way.

3.1.16 interface resistance

ultimate bond value at the ground/grout interface of the fixed anchor

3.1.17 length**3.1.17.1 apparent tendon free length**

length of tendon that is estimated to be fully decoupled from the surrounding grout

NOTE This is calculated from the load-elastic displacement data following testing.

[SOURCE: BS EN 1537:2013]

3.1.17.2 encapsulation length

overall length of the outer perimeter of the encapsulation, which is bonded to the surrounding grout in the case of a protected anchor

3.1.17.3 fixed anchor length

designed length of an anchor over which the load is transmitted to the surrounding ground, through a grout body

[SOURCE: BS EN 1537:2013]

NOTE This may be the same length as the tendon bond length.

3.1.17.4 free anchor length

distance between the proximal end of the fixed anchor length and the anchorage point at the anchor head

[SOURCE: BS EN 1537:2013]

3.1.17.5 shaft length

length of grout-filled borehole between the proximal end of the fixed anchor and the anchor head

NOTE The grout is often placed prior to stressing and therefore is capable of mobilizing resistance to withdrawal.

3.1.17.6 tendon bond length

length of the tendon that is bonded directly to the grout and capable of transmitting the applied tensile load

[SOURCE: BS EN 1537:2013]

3.1.17.7 tendon free length

length of tendon between the anchorage point at the anchor head and the proximal end of the tendon bond length

[SOURCE: BS EN 1537:2013]

NOTE During the initial stressing operation, the tendon free length may be extended by the stressing length, depending on the type of stressing system employed.

3.1.18 load**3.1.18.1 lock-off load**

load transferred to an anchor head immediately on completion of a stressing operation

[SOURCE: BS EN 1537:2013]

3.1.18.2 proof load

maximum test load to which an anchor is subjected

[SOURCE: BS EN 1537:2013]

3.1.18.3 proof load factor

ratio of proof load to the service state load

3.1.18.4 service state load

load in the anchor at any point during its service life and is no greater than $F_{\text{Serv;k}}$

3.1.19 noding**3.1.19.1 general noding**

reduction in tendon diameter at an intermediate point between spacers along the tendon bond length

NOTE 1 Where a tendon comprises a number of strands or wires, and the clearance is controlled by spacers, the spacing between the tendon units may be reduced by the use of smaller spacers or by banding the units together.

NOTE 2 The reduction in tendon diameter at intervening points creates a wave effect or general noding that improves mechanical interlock.

3.1.19.2 local node

formed as a strand node by unravelling the helical wires to separate them and rewinding them around a spacer to provide separation of the individual wires

NOTE 1 For example, by fitting a small steel washer around the core or king wire, so that when the helical wires are returned to their former lay, these wires remain apart.

NOTE 2 Strand or local noding is formed at regular intervals along the tendon bond length to improve mechanical interlock.

3.1.20 pitting

local corrosion of steel resulting in the formation of a pit

NOTE 1 A condition where the rate of corrosion into a metal from the surface is significantly greater than the rate of attack parallel to the metal surface.

NOTE 2 A width/depth ratio of 1 is commonly recognized for a pit.

3.1.21 protection

components of the anchor protected physically by one or more continuous impermeable barriers to corrosion

NOTE These are often described as single or double protection, describing one or two physical barriers, respectively.

3.1.22 proximal

situated nearest to the anchor head

3.1.23 reinforcement

3.1.23.1 primary reinforcement

rock anchors installed in underground excavations to maintain overall stability of the excavation

3.1.23.2 secondary reinforcement

rock anchors (generally low-capacity rock bolts) installed in underground excavations or an exposed rock face such as a cut slope to overcome localized stability problems

NOTE 1 These are generally low-capacity rock bolts.

NOTE 2 Secondary reinforcement can be used as the sole reinforcement or in conjunction with primary reinforcement.

NOTE 3 Localized stability problems can include spalling or surface instability.

3.1.24 relaxation

decrease of stress or load with time while the tendon is held under constant strain

3.1.25 sheath

flexible plastic covering to the tendon

3.1.26 slenderness ratio

vertical depth (or distance normal to steep slopes) from the ground surface to the top of the fixed anchor, divided by the diameter of the fixed anchor for downward-inclined anchors

3.1.27 spacer

apparatus to ensure separation between individual components of the tendon in multi-unit tendons

3.1.28 tendon

part of a ground anchor that is capable of transmitting the tensile load from the fixed anchor length to the anchor head

[SOURCE: BS EN 1537:2013]

3.1.29 tube á manchette

equipment used to permit multiphase, pressure grouting or regrouting along the fixed anchor length

NOTE See [B.2.4](#) and [Figure B.1](#).

3.1.30 ultimate ground/grout interface resistance (R_{gg})

anchor designer's best estimate of the maximum pull-out resistance provided by the anchor fixed length with the mobilization of the maximum shear resistance at the ground/grout interface, resulting in ongoing displacement

NOTE 1 The best estimate is found by calculation ([Annex B](#)) or by testing $\boxed{A_2}$ in accordance with BS EN ISO 22477-5. $\boxed{A_2}$

NOTE 2 Sketches of bond-type and compression-type grouted anchors are shown in [Figure 1](#).

Figure 1 — Grouted anchors

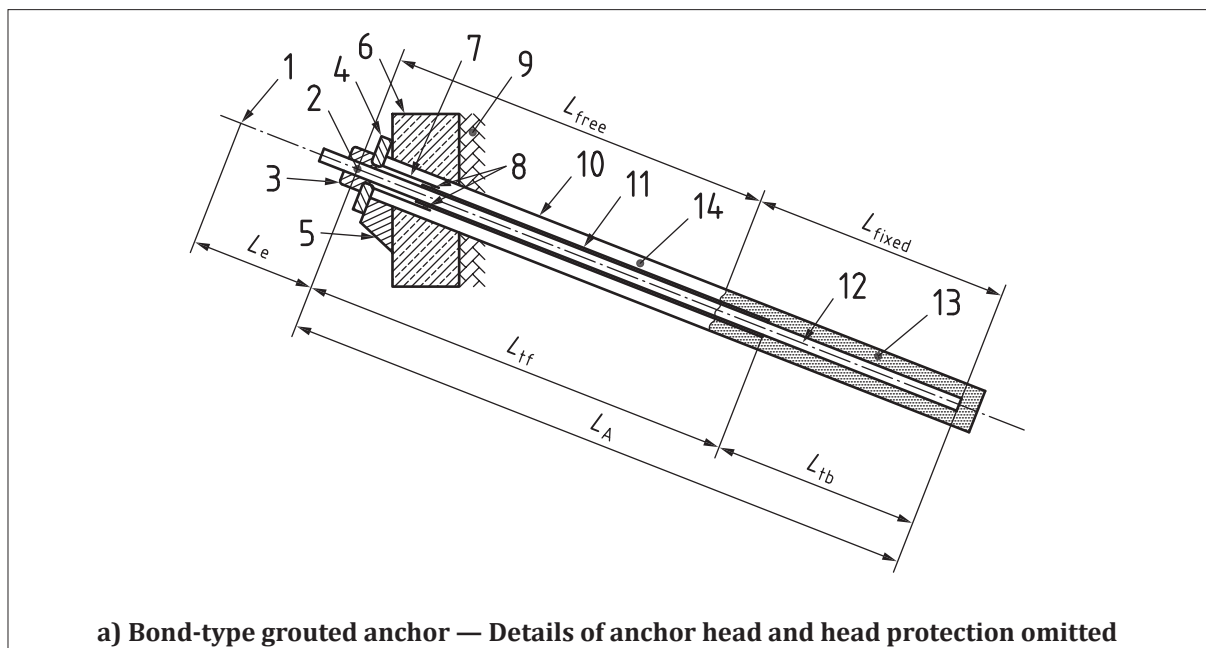
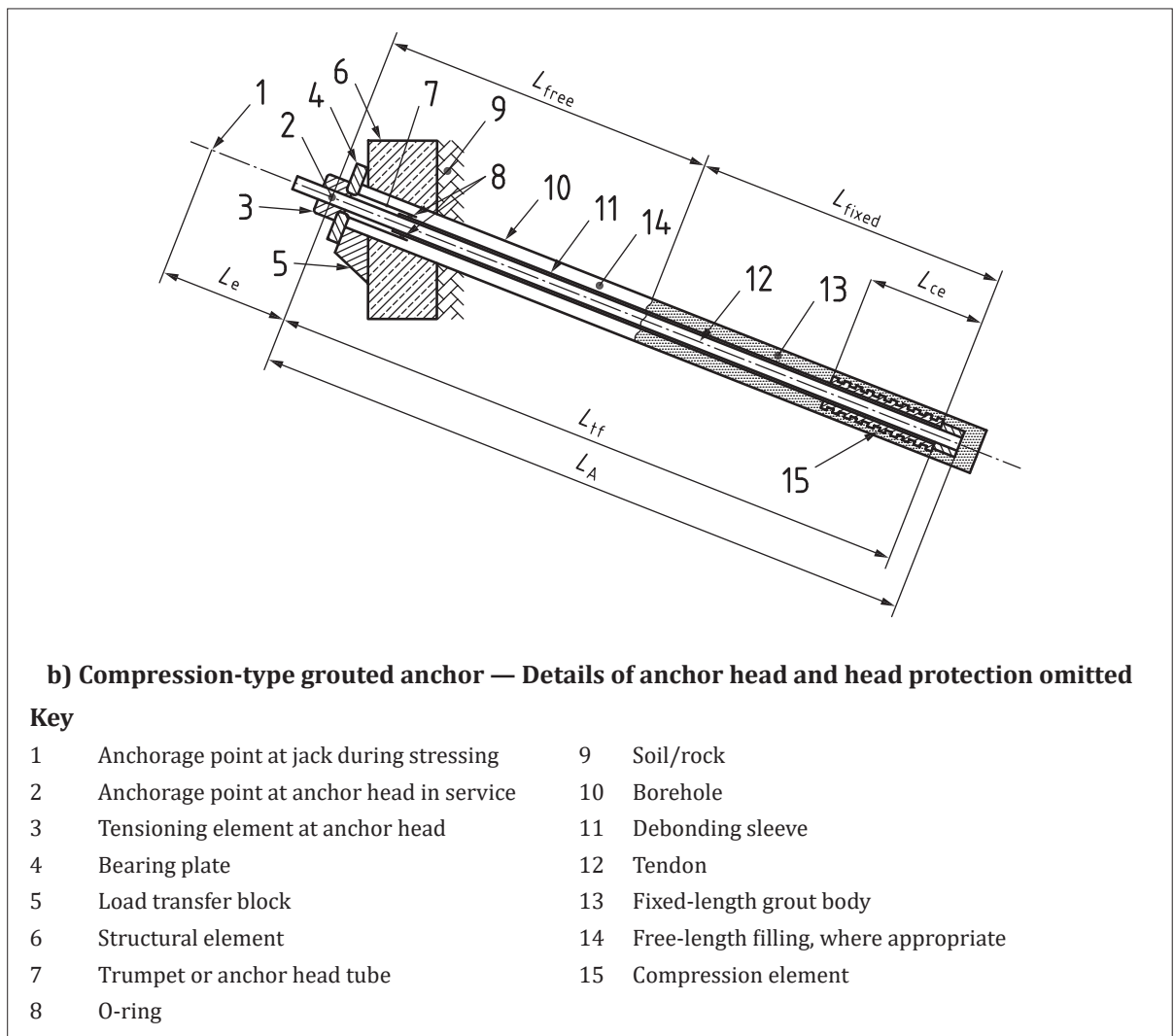


Figure 1 (continued)



3.2 Symbols

Symbol	Description	Unit
A	ratio of contact pressure at the fixed anchor/soil interface to average effective overburden pressure	
A_t	cross-sectional area of tendon	mm ²
B	bearing capacity factor equivalent to $N_q/1.4$	
c	undrained shear strength	kPa
c_a	shaft adhesion	kPa
c_b	undrained shear strength at proximal end of fixed anchor length	kPa
c_s	average undrained shear strength over the anchor shaft length	kPa
D	diameter of fixed anchor or enlargement	m
d	diameter of shaft or neck between enlargements or free length	m
E	Young's modulus	kPa
E_c	Young's modulus of concrete or grout	kPa
E_R	Young's modulus of rock	kPa
E_s	Young's modulus of tendon unit	kPa
E_t	Young's modulus of steel tendon	kPa
$E_{ULS;d}$	ultimate limit state design force to be resisted by the anchor [SOURCE: BS EN 1997-1:2004+A1:2013]	kN

Symbol	Description	Unit
f	friction coefficient	
f_{ck}	characteristic compressive cylinder strength of concrete at 28 days [SOURCE: BS EN 1992-1-1:2004]	kPa
f_{eff}	resistance efficiency factor	
f_{pk}	characteristic tensile strength of tendon	kN
f_s	efficiency factor for undrained shear strength along the shaft	
$F_{serv;k}$	characteristic value of the maximum anchor force, including effect of lock-off load, and sufficient to prevent a serviceability limit state in the supported structure [SOURCE: BS EN 1997-1:2004+A1:2013]	kN
f_u	efficiency factor for undrained shear strength along underreamed fixed anchor	
$F_{ULS;d}$	design value of the force required to prevent any ultimate limit state in the supported structure [SOURCE: BS EN 1997-1:2004+A1:2013]	kN
h	depth to top of fixed anchor in a vertical anchor	m
H_v	Vickers Pyramid Number	GPa
$\langle C2 \rangle k_w \langle C2 \rangle$	ground permeability	m/sec
$\langle C2 \rangle k_0 \langle C2 \rangle$	coefficient of earth pressure at rest	
L_A	length of anchor	m
L_e	external length of tendon measured from the tendon anchorage in the anchor head to the anchorage point in the stressing jack	m
L_{fixed}	fixed anchor length	m
L_{free}	free anchor length	m
L_{tb}	tendon bond length	m
L_{tf}	tendon free length	m
n	empirical factor related to anchor installation technique and ground conditions taking into account drilling technique (rotary percussive with water flush), depth of overburden, fixed anchor diameter, grouting pressure, <i>in situ</i> stress field and dilation characteristics	
P_a	datum load, or initial seating load, normally equivalent to 10% P_p or 10% f_{pk} or 10% $F_{serv;k}$ depending on the test undertaken	kN
p_i	grout injection pressure	kPa
P_L	limiting pressure in a pressuremeter test	MPa
P_0	lock-off load	kN
P_p	proof load to which the anchor is tested	kN
$R_{GG;calc}$	calculated ultimate ground/grout interface resistance	kN
$R_{GG;k}$	characteristic ultimate ground/grout interface resistance	kN
$R_{GG;m}$	measured ultimate ground/grout interface resistance	kN
$R_{GT;k}$	characteristic ultimate grout/tendon interface resistance	kN
$R_{T;d}$	ultimate limit state design resistance of the structural elements of an anchor	kN
$R_{T;k}$	characteristic ultimate tendon resistance	kN
t	time	min
T_w	working load of anchorage [SOURCE: BS 8081:1989, Clause 3]	kN
w	natural moisture content	%
$\langle C2 \rangle w_L \langle C2 \rangle$	liquid limit	%
w_p	plastic limit	%

Symbol	Description	Unit
α	adhesion factor	
γ_{GE}	resistance factor for ultimate grout/encapsulation interface resistance	
γ_{GG}	resistance factor for ultimate ground/grout interface resistance	
γ_{GT}	resistance factor for ultimate grout/tendon interface resistance	
γ_s	partial factor for reinforcing or prestressing steel [SOURCE: BS EN 1992-1-1:2004+A1:2014]	
γ_T	resistance factor for ultimate resistance of tendon	
Δ_a	elastic displacement of tendon at datum load	mm
Δ_e	elastic displacement of tendon at proof load	mm
Δ_{eSLS}	displacement induced by a load equal to 55% of characteristic tendon strength	mm
Δ_{eULS}	displacement defining ultimate limit state resistance of an anchor	mm
Δ_p	peak cycle load minus datum load	
Δ_s	elastic displacement of the tendon	mm
δ_u	maximum spacing of underreams	m
ϕ'	angle of shearing resistance in terms of effective stress	degrees
σ_v'	vertical effective stress	kPa
τ_M	theoretical skin friction	kPa
τ_{ult}	ultimate bond or skin friction at soil/grout and rock/grout interface	kPa

NOTE 1 Regarding the relationship between the “working load of anchorage” T_w (BS 8081:1989, Clause 3) and the characteristic value of the maximum anchor force, $F_{Serv,k}$, the design and testing of grouted anchors in the UK was traditionally based on a specified “working load” termed T_w . BS 8081:1989, 2.21.7 defines the working load as “the safe load (T_w) of the anchor”, the magnitude of which is routinely derived from limit equilibrium stability analysis of the anchored structure.

In order to allow for load losses (a large component of which was historically due to relaxation of prestressing steel), it has been routine practice that anchors have been locked off at 110% T_w . This took account of the fact that relaxation in prestressing steels could account for up to approximately 9% prestress loss. In situations where the lock-off load is set at 110% T_w and no greater load is reasonably expected during the service life of the anchor, then T_w can be taken as equivalent to $F_{Serv,k}/1.1$, since, by definition, $F_{Serv,k}$ includes the effect of the lock-off load.

However, as it is currently acknowledged that modern prestressing steels account for prestress losses of less than 1.5%, a lock-off load of about 102% T_w might be more appropriate. In the context of this code of practice, it is therefore adopted that T_w approximates to the maximum characteristic anchor force $F_{Serv,k}$.

NOTE 2 In certain circumstances, such as staged construction, $F_{Serv,k}$ can be greater than the initial lock-off load.

3.3 Abbreviations

CPC	corrosion protection compound
GFR	geotechnical feedback report
RoGEP	UK Register of Ground Engineering Professionals
SCC	stress corrosion cracking
SLS	serviceability limit state
SOB	sulfur-oxidizing bacteria
SPT	standard penetration test
SRB	sulfate-reducing bacteria
ULS	ultimate limit state

4 General rules

4.1 General

4.1.1 The design of grouted anchors should conform to BS EN 1997-1:2004+A1:2013 and [Clause 8](#) and [Clause 9](#) of this code of practice.

4.1.2 The execution of grouted anchors should conform to BS EN 1537:2013 and [Clause 14](#) of this code of practice.

4.1.3 The testing of grouted anchors should conform to BS EN ISO 22477-5.  Text deleted 
 Note deleted 

4.2 Responsibilities

4.2.1 Since grouted anchors form one part of an anchored structure the design responsibilities of the supported structure designer and specialist anchor designer/contractor should be defined properly.

NOTE [Table 1](#) shows an appropriate separation of duties. The table has been prepared based on the assumption that it is only the supported structure designer who is in a position to judge how the grouted anchor will interact with the ground/structure system.

4.2.2 The supported structure designer should assess, with the assistance of the specialist anchor designer/contractor, the degree of risk in the use of grouted anchors and should obtain agreement from the client to employ grouted anchors.

Table 1 — Recommended design and construction duties

Supported structure designer ^{A)}	Specialist anchor designer/contractor
(1) Site investigation data for grouted anchors (borings at the location and depth fixed anchor locations which can be outside the site working area) in accordance with 4.4.1 of this code of practice	(1) Anchor components and details
(2) Decision to use grouted anchors, required trials and testing and provision of a specification	(2) Determination of fixed anchor dimensions
(3) Overall design of anchored structure, and calculations of anchor force required. Definition of partial factors to be employed	(3) Anchor spacing, anchor orientation and individual anchor loads if not specified by the supported structure designer (i.e. if only horizontal capping or waling beam load per metre is specified)
(4) Definition of anchor life (permanent/temporary) and requirement for corrosion protection	(4) Detailing of the corrosion protection system for anchor
(5) Anchor spacing and orientation. Waling beam capacity	(5) Supply and installation of anchor monitoring system
(6) Free anchor length and anchor characteristic serviceability limit state load, $F_{\text{Serv};k}$ and design ultimate limit state load, $E_{\text{ULS};d}$	(6) Quality control of works
(7) Anchor behaviour monitoring system (structure/anchors) and interpretation of results	(7) Anchor maintenance as directed by the specialist anchor designer/contractor
(8) Supervision of the works (inspection by testing and sampling)	
(9) Maintenance specification for anchors	
(10) Instruction of all contracting parties regarding key items within design philosophy to which special attention should be directed	

^{A)} The supported structure designer may be employed by the client, the main contractor, a specialist subcontractor or a consultant.

Whilst the distribution of the duties set out in Table 1 are recommended, these may be allocated differently depending on the project requirements.

- 4.2.3** The supported structure designer and the specialist anchor designer/contractor should be clear what their respective responsibilities and duties are and that these should be defined in the contract documents.
- 4.2.4** A geotechnical advisor should be appointed who is directly responsible for the planning, direction, execution and supervision of the anchor installation.
- 4.2.5** The geotechnical advisor should be registered with the UK Register of Ground Engineering Professionals (RoGEP) or have demonstrated the equivalent level of competence.
- 4.2.6** More than one advisor may be appointed to take responsibility for different aspects of the work.

NOTE Examples include:

- a) *scoping planning and design;*
- b) *execution and supervision.*

4.3 Basis of geotechnical design

4.3.1 Design situations

The design of anchors should conform to the limit states in accordance with BS EN 1997-1:2004+A1:2013 and NA+A1:2014 to BS EN 1997-1:2004+A1:2013. This code of practice provides recommendations for the method of anchor design to conform to the requirements of the limit states for the supported structure.

4.3.2 Design considerations

The specification of design should conform to BS EN 1997-1:2004+A1:2013, **8.4**. In addition, the following should be considered:

- a) the disposition and classification of the various zones of soil and rock, both vertically and horizontally, and the elements of construction that could be involved in a limit state event;
- b) effects due to the environment within which the design is set, such as:
 - 1) scouring, erosion and excavation, leading to changes in the geometry of the ground surface;
 - 2) weathering;
 - 3) the presence of gases emerging from the ground;
 - 4) other effects of time and environment on the strength and other properties of materials;
- c) cavities due to mining or other causes;
- d) possible changes in the groundwater levels due to temporary or permanent modification;
- e) for anchors installed in or near rock, the consideration of:
 - 1) interbedded hard and soft strata;
 - 2) faults, joints and fissures;
 - 3) solution cavities such as swallow holes or fissures, filled with soft material, and continuing solution processes.

NOTE To assist users of this code of practice, flow charts (see [7.7](#), [Figure 2](#) and [Figure 3](#)) are included, covering the preliminaries to design, detailed design and construction, and maintenance. Where it is appropriate, key steps are cross-referenced to sections or clauses in the code of practice so that the user may consult the detailed recommendations.

4.3.3 Determination of the size of an anchor

The determination of the size of the fixed length of an anchor should be based on a calculation of an anchor ultimate ground/grout interface resistance and should be intended to ensure that an anchor of this size satisfies all test criteria in BS EN 1997:2004+A1:2013, **8.6** and NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.6 (4)p**.

NOTE 1 Guidance on geotechnical engineering principles, problematic soils and site investigation can be found in the ICE manual of geotechnical engineering, Volume 1: Geotechnical engineering principles, problematic soils and site investigation [1].

NOTE 2 Guidance on geotechnical design, construction and verification can be found in the ICE manual of geotechnical engineering, Volume 2: Geotechnical design, construction and verification [2].

4.4 Assessment of the ground into which the anchor is to be fixed

4.4.1 General

A ground investigation should be carried out that conforms to BS EN 1997-2:2007 to provide the necessary information upon which the design of an anchor can be based. The focus of the ground

investigation should be on providing appropriate data for the design of the anchor with respect to its capacity, its durability and location of the fixed anchor length.

NOTE The design of an anchor requires information on the physical conditions in the vicinity of the anchor, in particular, the fixed anchor length, including the topography and layout of the site, details of adjacent foundations and services, and the nature of the ground and the groundwater conditions, including, where applicable, the tidal and seasonal variations.

4.4.2 Soil properties

The ground investigation should determine the nature of the block of ground that can be influenced by, or can influence, the installation and behaviour of grouted anchors. Because inclined grouted anchors are installed at least as commonly as vertical anchors, lateral variations in ground properties should be investigated as thoroughly as the more easily investigated vertical variations.

NOTE 1 Since investigation methods are often vertical, it can follow that an inclined anchor system requires more boreholes than is usual for other structures.

NOTE 2 Notwithstanding these considerations, it is emphasized that minor structural or fabric changes can occur in a known geological formation that can significantly affect the behaviour of a grouted anchor.

4.4.3 Rock and rock mass properties

4.4.3.1 General

4.4.3.1.1 Ground investigation should determine the properties of the rock materials and rock mass through and into which anchors are to be installed. It is important that both the individual rock materials and the overall rock mass characteristics are considered during design, particularly for stratified formations.

4.4.3.1.2 The rock materials and the overall rock mass should be identified, described, sampled and tested in accordance with BS EN 1997-2:2007 and *The Complete ISRM Suggested Methods For Rock Characterization, Testing And Monitoring: 1974-2006* [N1].

NOTE The behaviour of rock masses is governed by the properties of individual rock materials and the discontinuities within the masses.

4.4.3.2 Rock mass characterization

4.4.3.2.1 Rock material properties should be determined by laboratory testing, in accordance with BS EN 1997-2:2007 and *The Complete ISRM Suggested Methods For Rock Characterization, Testing And Monitoring: 1974-2006* [N1], on intact specimens of rock materials. These provide a measure of the strength and deformability characteristics of the rock materials themselves.

4.4.3.2.2 The determination of rock mass properties and behaviour should be based on the characterization and testing of the discontinuities and any infill [N2], [N3], [N4], in accordance with *The Complete ISRM Suggested Methods For Rock Characterization, Testing And Monitoring: 1974-2006* [N1].

4.4.3.2.3 From such characterization and testing, the strength and deformation properties of a rock mass should be estimated [N5], [N6], [N7], [N8], [N9].

NOTE Rock mass characterization systems such as the Rock Mass Rating (RMR) system [3], [4], the Q system [N2] and the Geological Strength Index (GSI) [5], [6], [7], can be utilized to determine rock mass strength and deformation characteristics.

4.4.3.2.4 For projects involving the use of large numbers of rock anchors, the characteristics of the rock mass should be determined by *in situ* tests.

- 4.4.3.2.5** Although correlations of general application are available, it is recommended that site-specific correlations are developed for large projects.

4.4.3.3 Durability and weathering

The slake durability test [N1] should be used to assess the susceptibility of weak rock to weathering or softening in the presence of water.

NOTE This test gives an indication of the potential loss of strength of the rock around the borehole and the period for which a borehole can be left open prior to installation of the anchor. The results of the test can have a considerable influence on the design of the fixed anchor length.

4.5 Materials to be used in anchor construction

4.5.1 Grout

Cement grout used in the execution of the anchor should conform to BS EN 1537:2013, 6.4.

4.5.2 Concrete

All concrete used in the execution of the anchor, including the bedding of the bearing plate and associated works, should conform to BS EN 206.

4.5.3 Admixtures for concrete, mortar and grout

Admixtures for concrete, mortar and grout should conform to BS EN 934-2.

4.5.4 Steel, including prestressing steel

Steel components of the anchor tendon and associated steel parts, including the bearing plate, locking arrangement and caps, should conform to BS EN 1537:2013.

4.5.5 Plastics

Plastics used in grouted anchors should conform to BS EN 1537:2013, 6.5.1. Sheaths and ducts should be continuous, impermeable to water, resistant to age brittleness and resistant to ultra-violet radiation damage during storage, transportation and installation.

4.5.6 Corrosion protection compounds

Corrosion protection compounds should conform to BS EN 1537:2013, Annex B.

4.6 Effect of water on durability

Water for mixing should not contain ingredients harmful to steel or cement grout. The water should not contain oil, organic matter or deleterious substances and should conform to BS 3148:1980, Appendix A.

4.7 Geotechnical analysis

- 4.7.1** The design of an anchor should consider the behaviour of the anchor as a structural element and the interaction between the ground and the anchor itself. It includes the performance of two sets of calculations:

- a) a set of calculations to determine the overall proportions and the geometry of the fixed anchor length and the free anchor length of the anchor necessary to provide resistance, taking into account the loads that will be applied to the anchor during its working life, the inclination of the anchor and the location of stable ground into which the anchor can be fixed;
- b) structural design calculations to determine the size of the structural elements comprising the anchor necessary to resist the tensile forces to which it will be subjected in its lifetime.

- 4.7.2** The design of anchors should conform to BS EN 1997-1:2004+A1:2013 and Clause [8](#), Clause [9](#) and Clause [11](#) of this code of practice.

4.8 Structural design

The structural design of the steel tendon, all components of the bearing plate and associated waling beams and support systems for the anchor should conform to BS EN 1992-1-1 and BS EN 1993-1-1 where appropriate and [10.1](#) and [10.2](#) of this code of practice.

4.9 Execution

4.9.1 Supervision of construction and testing

The supervision and assessment of all anchor execution phases should conform to BS EN 1537:2013.

4.9.2 Service monitoring

- 4.9.2.1** In assessing the need for service monitoring, the following factors should be considered:

- a) the nature of the structure and the consequence to it of the malfunction of one or more anchors with respect to contravention of both its serviceability limit state and its ultimate limit state (see [Annex H](#));
- b) the nature of the ground (see [H.2](#));
- c) the extent, if any, to which the malfunctioning of an anchor would become apparent without monitoring, before jeopardizing the safety of the supported structure (see [H.3](#));
- d) the nature of the anchors, including the type of anchor, the quality of the corrosion protection and the extent to which the long-term performance of similar anchor systems under similar circumstances is known;
- e) the consequence of failure of the supported structure upon life or property.

- 4.9.2.2** It should be decided at the planning or design stage, in advance of the installation of anchors, whether or not they are to be monitored after installation. The monitoring can include both external inspection of the accessible anchor elements and load testing.

- 4.9.2.3** The use of load cells is preferred when anchor prestress fluctuation over time is monitored, but load cells designed and constructed for long-term reliability should be installed.

4.9.3 Maintenance

4.9.3.1 Precautionary measures

- 4.9.3.1.1** Precautionary measures should be included in the design of the anchor system to ensure that the necessity for maintenance during the service life of the anchor is minimized.

- 4.9.3.1.2** Attention should be given to the corrosion proofing of the internal elements of the anchor, including the head and tendon.

NOTE In many cases it is necessary to protect the anchor head from mechanical damage by construction plant and vehicles.

- 4.9.3.1.3** Precautionary measures can be the provision of structural protection using recesses for the location of the anchor head, the provision of anchor head caps and the application of corrosion protection compounds to exposed elements of the anchor.

4.9.3.2 Remedial measures

Remedial measures should be taken in exceptional cases. They can consist of the following:

- a) restressing the anchor;
- b) replacing defective anchors with new anchors or struts, or stressing substitute anchors, if already provided.

4.9.4 Reporting

4.9.4.1 Ground investigation report

The results of a geotechnical investigation specifically focused on acquisition of the data for the design and execution of grouted anchors should be compiled in a ground investigation report, that forms a part of the geotechnical design report that conforms to BS EN 1997-1:2004+A1:2013 and BS EN 1997-2:2007.

4.9.4.2 Drilling and grouting report

During the drilling operation, all changes in ground type should be recorded, together with notes on water levels encountered, drilling rates, flushing losses or gains and stoppages. The drilling and grouting report should conform to BS EN 1537.

4.9.4.3 Load test report

4.9.4.3.1 Load test reports should be compiled for the three classes of tests for all anchors, where they have been executed:

- a) investigation tests;
- b) suitability tests;
- c) acceptance tests.

4.9.4.3.2 Following the completion of all investigation tests on trial anchors, the results should be available from the specialist anchor designer/contractor in the form of a report preferably before any working anchor is installed. The report should contain all the details necessary to determine every aspect of the work, such as the organization responsible for installation and construction, the testing organization, supervising engineers and dates, times and places of tests.

4.9.4.3.3 Stressing details for suitability tests and acceptance tests should be recorded, including the final locking-off of the anchor. Details of all forces, displacements, and seating 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.

4.9.4.4 Geotechnical feedback report

On completion of the works, a geotechnical feedback report (GFR) should be prepared (see [7.5.2](#) and [17.2](#)).

5 Limit states

5.1 The ultimate limit states set out in BS EN 1997-1:2004+A1:2013, **8.2** (both individually and in combination) should be considered for all anchors.

- 5.2** The serviceability limit states set out in BS EN 1997-1:2004+A1:2013, **8.2** (both individually and in combination) should be considered for all anchors.
- 5.3** The anchor performance at these limit states should be verified by testing that conforms to BS EN 1997-1:2004+A1:2013, **8.5**, Annex NA+A1:2014 to BS EN 1997-1:2004+A1:2013, **A.6** and BS EN ISO 22477-5 **A2** *Text deleted* **A2**.

6 Design situations

The design situations and actions should conform to BS EN 1997-1:2004+A1:2013 (**2.2** and **8.3**) and NA+A1:2014 to BS EN 1997-1:2004+A1:2013.

7 Design considerations

7.1 General

NOTE Design and construction considerations for grouted anchors are given in BS EN 1997-1:2004+A1:2013 and BS EN 1537:2013. The design considerations given in this Clause are more specific examples of the issues that can affect the performance of grouted anchors.

- 7.1.1** Anchor design, as set out in this code of practice, is based on the determination of a calculated or measured anchor ultimate ground/grout interface resistance that is sufficient so that the anchor will satisfy all test criteria in accordance with BS EN 1997-1:2004+A1:2013 and NA+A1:2014 to BS EN 1997-1:2004+A1:2013.
- 7.1.2** The design of an anchor should consider:
- a) the design considerations given in BS EN 1997-1:2004+A1:2013, **8.4**;
 - b) material compatibility in the anchor elements with respect to potential corrosiveness;
 - c) the influence of stray currents on corrosion protection;
 - d) the effect of variation of ground properties within the fixed anchor length on anchor behaviour.

NOTE [Figures 2](#) and [3](#) are flow charts showing the main stages of design of anchors to support anchored structures and the detailed design, construction and maintenance of anchors, respectively, in accordance with [Table 1](#). Where appropriate, key steps are cross-referenced to sections or Clauses in this code of practice so that the user may consult the detailed recommendations.

7.2 Design of supported structure

- 7.2.1** The supported structure designer should consider and specify the grouted anchor requirements and acceptance criteria to conform to the project requirements. Necessary permissions should be sought and the prospective owner advised of obligations, including monitoring, maintenance and eventual decommissioning of the anchors.
- 7.2.2** The supported structure designer should prepare and specify as-built requirements; liaise with the specialist anchor designer/contractor during anchor execution and commissioning, and agree acceptable conditions for handover to the asset owner. These conditions should conform at least to the minimum recommendations in this code of practice.

7.3 Grouted anchor design

The specialist anchor designer should develop the design of the anchors to meet the specified requirements, install and test the anchors and confirm their acceptance into the works conforms BS EN 1997-1 and the recommendations in this code of practice.

7.4 Initial determination of anchor dimensions

The anchor dimensions, in particular those of the fixed anchor length, should be determined prior to anchor testing, based on calculations and available data, as set out in [Clause 8](#) to [Clause 11](#).

7.5 Final design

7.5.1 Final design of the anchors should be verified by testing.

NOTE This confirms the acceptability of the initial determination of the fixed anchor length and the quality of anchor execution, or may demonstrate changes necessary, as identified by the testing.

7.5.2 A geotechnical feedback report (see [4.9.4.4](#)) should be prepared and issued by the specialist anchor designer, for acceptance by the supported structure designer on behalf of the owner.

7.6 Ongoing maintenance and monitoring

7.6.1 The asset owner should be responsible for the ongoing maintenance and ultimate decommissioning of ground anchors.

NOTE Specialists can be appointed (who may be same as those responsible for the original works) to assist with ongoing duties of management, interpretation and monitoring.

7.6.2 The handover information should include clear guidance on monitoring requirements, acceptability criteria and actions that may be necessary in the event of anchors failing to meet the service requirements during their working life.

7.7 Sustainability

Provision should be made, in accordance with this code of practice, to ensure best practical sustainability of the anchors, including scope to best adopt and utilize the anchors if circumstances change in the future.

NOTE This relies on best practice in ongoing maintenance, monitoring and record keeping.

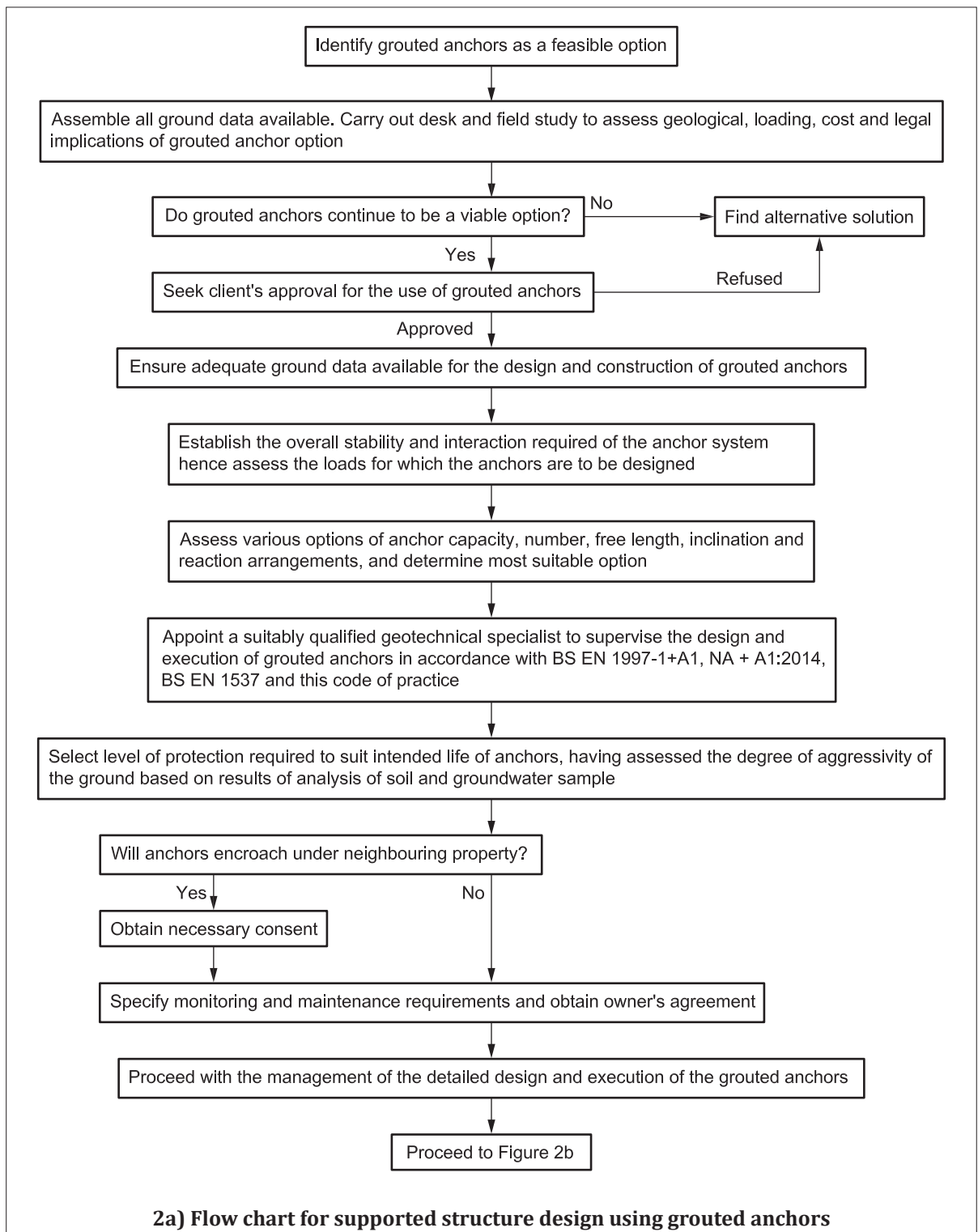
Figure 2 — *Grouted anchors*

Figure 2 (continued)

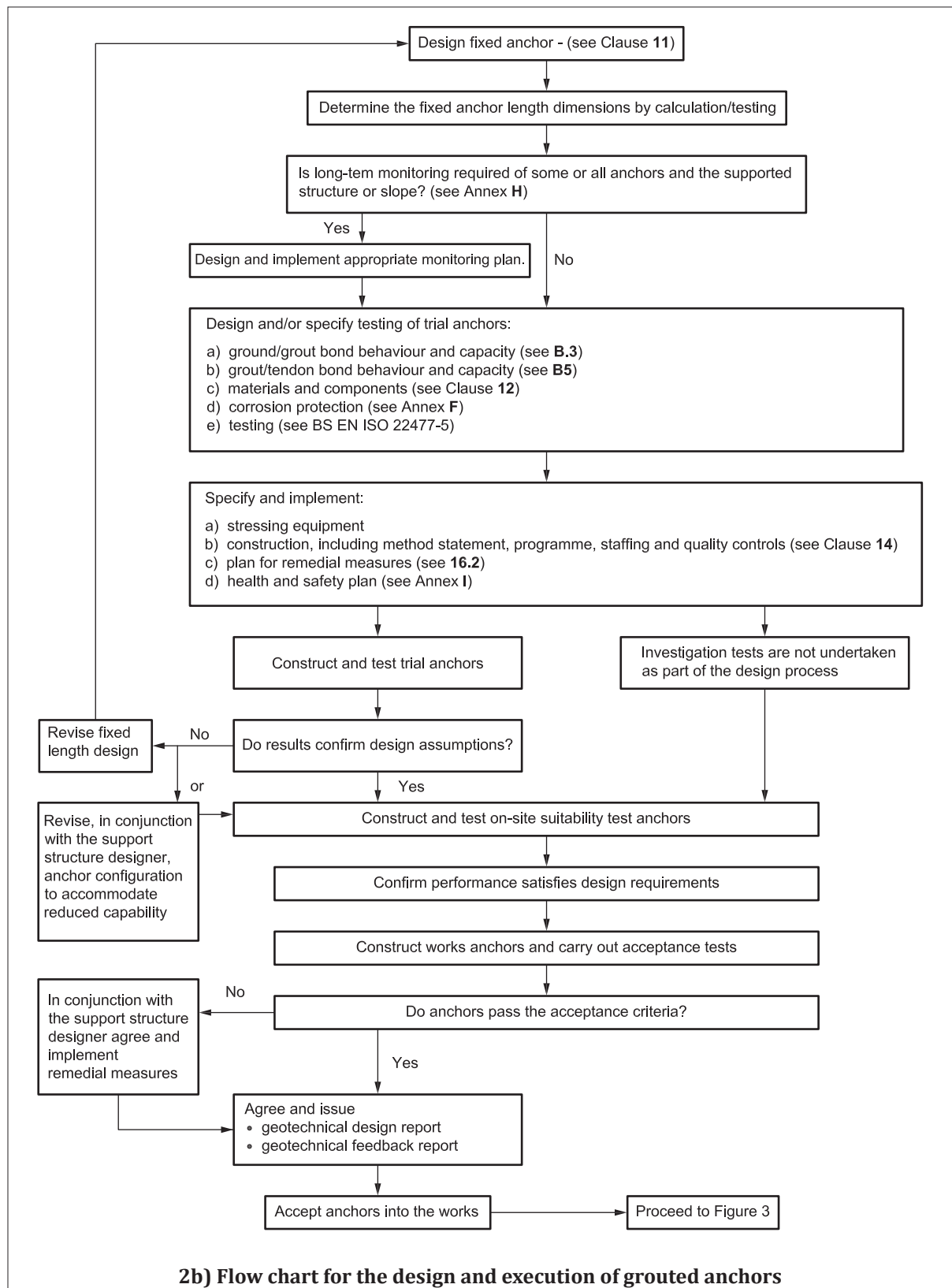
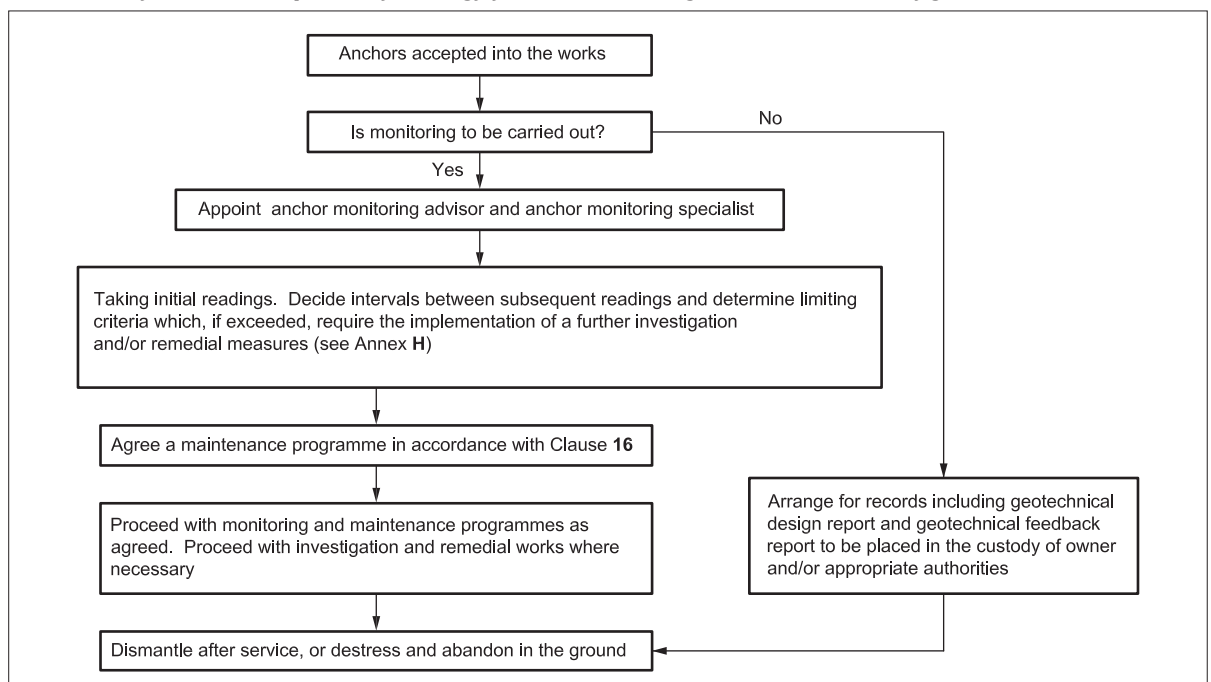


Figure 3 — Flow chart for the development of strategy for the monitoring and maintenance of grouted anchors

8 Ultimate limit state design

8.1 Tendon

The ultimate limit state design of a high-tensile steel tendon should conform to the ultimate limit state provisions of BS EN 1992-1-1:2004, 3.3.

8.2 Anchor head

The ultimate limit state design of a steel anchor head should conform to the ultimate limit state provisions of BS EN 1993-1-1:2005.

8.3 Fixed anchor length

The ultimate limit state design of a fixed anchor length should conform to the ultimate limit state provisions of BS EN 1997-1:2004+A1:2013.

8.4 Free anchor length

The ultimate limit state design of a free anchor length should conform to the ultimate limit state provisions of BS EN 1997-1:2004+A1:2013 and [11.2.2](#) and [B.6.1](#) of this code of practice.

9 Serviceability limit state design

The serviceability limit state design of all elements of an anchor should conform to the serviceability limit state provisions of BS EN 1997-1:2004+A1:2013.

10 Structural design

10.1 Tendon

The structural design of a tendon should conform to the ultimate limit state provisions of BS EN 1997-1:2004+A1:2013 and BS EN 1537:2013.

10.2 Anchor head

The structural design of an anchor head should conform to the ultimate limit state provisions of BS EN 1993-1-1:2005 and BS EN 1537:2013.

10.3 Grout

The structural design of grout should conform to the ultimate limit state provisions of BS EN 447:2000 and BS EN 1537:2013.

11 Anchor design

11.1 General

11.1.1 The design of an anchor should address all elements of the anchor.

11.1.2 The following values should be used for the dimensioning of the fixed anchor length, anchor tendon and head plate design:

$F_{\text{Serv};k}$ and $F_{\text{ULS};d}$ (see BS EN 1997-1:2004+A1:2013).

11.1.3 The values given in [11.1.2](#) should be provided for the anchor design by the supported structure designer.

NOTE The values of $F_{\text{Serv};k}$ and $F_{\text{ULS};d}$ are derived from analyses for serviceability and ultimate limit states, respectively, of the anchor-supported structure in accordance with BS EN 1997-1:2004+A1:2013.

11.2 Minimum free anchor length design

The free anchor length design should conform to BS EN 1997-1:2004+A1:2013 [8.4\(6\)](#).

11.2.2 A free anchor length should be determined so that the anchor can perform adequately to maintain overall stability of the supported structure. The minimum free anchor length should be sufficient so that the fixed anchor length is located beyond the critical failure surface or potential zone of ground rupture induced by a mechanism of failure, leading to an overall instability of the supported structure. The fixed anchor should also be located in ground that is appropriate to the selected anchor construction method.

NOTE The free anchor length might need to be increased in order to locate the fixed anchor length in ground that is appropriate to the selected anchor construction method.

11.2.3 A minimum free length of 2 m should be used for threadbar systems as an element of thread bedding (slip) is known to occur.

11.2.4 A minimum free anchor length of 5 m should be used for strand anchors, as an additional extension should be available to allow for wedge draw.

11.3 Anchor tendon design

11.3.1 The ultimate limit state design resistance of a prestressing steel tendon $R_{T;d}$ should be determined in accordance with BS EN 1992-1-1 clause [3.3.6](#), where prestressing steel is used, and BS EN 1992-1-1 clause [3.2.7](#), where reinforcing steel is used.

11.3.2 The following inequalities should be satisfied by calculation when establishing the capacity of a tendon (bar or strand).

$$R_{T;d} \geq \max(F_{\text{ULS};d}; P_p; \gamma_T F_{\text{Serv};k}) \quad (1)$$

Where:

$$R_{T;d} = f_{pd} \times A_T \quad (2)$$

in the case where prestressing steel is used;

or

$$R_{T;d} = f_{yd} \times A_T \quad (3)$$

in the case where reinforcing steel is used.

Where prestressing steel is used:

$$f_{pd} = f_{p0.1k} / \gamma_s \quad (4)$$

and

where reinforcing steel is used:

$$f_{yd} = f_{yk} / \gamma_s \quad (5)$$

NOTE 1 f_{pd} , $f_{p0.1k}$, f_{yk} , f_{yd} and γ_s are defined in BS EN 1992-1-1, 3.2 and 3.3. The value of γ_T is given in [Table 2](#).

NOTE 2 Typically an anchor tendon is formed from a bar or strand made from prestressing steel which conforms to BS EN 1992-1-1, 3.3. Where a bar tendon is formed from reinforcing steel (i.e. with a characteristic yield strength in the range 400 MPa < f_{yk} < 600 MPa), the provisions of BS EN 1992-1-1, 3.2 apply and the design yield strength of the tendon f_{yd} , is used in place of f_{pd} .

NOTE 3 The upper limit of f_{yk} within this range is defined in the UK National Annex to Eurocode 2. A1

11.4 Fixed anchor length design

11.4.1 General

The fixed anchor length should be designed to provide resistance at load levels $F_{\text{Serv;k}}$ and $F_{\text{ULS;d}}$ in accordance with the acceptance criteria set out in BS EN 1997-1:2004+A1:2013 and NA+A1:2014 to BS EN 1997-1:2004+A1:2013, Table A.NA.21.

NOTE For the normal range of the fixed anchor length see [B.3.3.6](#), [B.3.4.5](#) and [B.3.5.4](#).

11.4.2 Design of fixed anchor length by consideration of ground/grout interface resistance

11.4.2.1 To establish the dimensions of the fixed anchor diameter and length, D and L_{fixed} , the following procedure should be adopted. The dimensions should be determined to provide the characteristic ultimate ground/grout interface resistance, $R_{\text{GG;k}}$, by:

- empirical or analytical calculation methods, the validity of which have been demonstrated by load tests in comparable situations, or by previous experience; and/or
- the results of investigation tests, which have been demonstrated, by means of calculations or otherwise, to be consistent with other relevant experience.

NOTE [Annex B](#) presents example analytical and empirical calculation methods that can be used to derive $R_{\text{GG;k}}$. It is normal practice to designate the diameter prior to the derivation of the fixed anchor length based on experience, feasibility of construction in the site conditions and the required number of strands/encapsulations. The application of an efficiency factor, taking into account progressive debonding, in the derivation of $R_{\text{GG;k}}$ is presented.

11.4.2.2 Where the size of the fixed anchor length is determined by calculation, the calculated ultimate ground/grout interface resistance, $R_{GG;calc}$, should be found using characteristic values of geotechnical parameters in accordance with BS EN 1997-1:2004+A1:2003, **2.4.5.2**.

11.4.2.3 Where the size of the fixed anchor length is determined by investigation tests, the measured ultimate ground/grout interface resistance, $R_{GG;m}$, should be derived from the investigation test **A2** *Text deleted* **A2**.

11.4.2.4 The characteristic ultimate ground/grout interface resistance, $R_{GG;k}$, should be derived from:

$$R_{GG;k} = \min(R_{GG;calc}; R_{GG;m}) \quad (6)$$

11.4.2.5 The following inequalities should be satisfied when establishing the fixed anchor length by calculation or by the results of investigation tests.

$$F_{Serv;k} \leq \frac{R_{GG;k}}{\gamma_{GG}} \quad (7)$$

and

$$F_{ULS;d} \leq R_{GG;k} \quad (8)$$

NOTE Minimum resistance factors recommended for the size of individual fixed anchor lengths prior to testing are given in [Table 2](#).

Table 2 — Minimum resistance factors recommended for the calculation of the size of individual fixed anchor lengths prior to testing

Anchor category	Minimum resistance factor			
	Ground /grout interface, $\gamma_{GG}^{C), D)}$	Grout/ encapsulation interface, $\gamma_{GE}^{D)}$	Grout /tendon interface, $\gamma_{GT}^{D)}$	Tendon, γ_T
Permanent anchors and temporary anchors	3.0 ^{B)}	3.0 ^{A)}	3.0	A1 1.5 A1

^{A)} Minimum value of 2.0 may be used if investigation tests are undertaken but not less than $F_{ULS;d}/F_{Serv;k}$. This value should be increased in cases where $F_{ULS;d}/F_{Serv;k} > 2$.

^{B)} This might need to be raised to 4.0 to limit ground creep.

^{C)} Minimum resistance factors for the ground/grout interface generally lie between 2.5 and 4.0. However, these may vary, where investigation tests provide sufficient additional information to permit a reduction.

^{D)} The resistance factors applied to the ground/grout interface will invariably be higher compared with the grout/tendon or grout/encapsulation interface values, the additional magnitude representing a margin of uncertainty in the magnitude of the ultimate resistance of this interface. The magnitudes of the minimum resistance factors are recommended where previous experience provides insufficient confidence that the anchor will ultimately satisfy the test criteria in BS EN 1997-1:2004+A1:2013.

NOTE This table defines minimum recommended resistance factors at the major component interfaces of an anchor system.

11.4.3 Design of fixed anchor length by consideration of grout/encapsulation bond length

11.4.3.1 General

Owing to the complexity of the encapsulation system, only the ultimate values of average bond stresses on the major interfaces, which have been measured historically or currently in large or full-scale tests, should be used in design.

11.4.3.2 Magnitude of bond

The ultimate grout/encapsulation interface bond stress should not exceed 3.0 MPa for cementitious grouts unless proven by tests on the current project using encapsulations with pitch, amplitude and profile of the corrugations on the encapsulation surface similar to those to be used on the project ([Annex B](#)).

11.4.3.3 Encapsulation length

Encapsulation should be not less than 2 m in length for straight-shafted fixed anchors. Where underreams are used, encapsulation lengths should equate to those of the fixed anchor to avoid the risk of crushing the grout shaft between upper underreams.

11.4.3.4 Concentration of steel within encapsulation

Each encapsulation system should be checked to ensure adequate internal clearances for the passage of the grout and to ensure that the encapsulation capacity is at least equal to that of the steel tendon. When tendons comprise a large number of strands, particular attention should be given to the transfer of the tendon force from the inner layers of strands and to the grout/encapsulation interface, taking into account the location of any curtailment of strands. In these circumstances, investigation tests should be undertaken to confirm the adequacy of the proposed strand geometry.

NOTE 1 The cross-sectional area of the steel within an encapsulation can be considerably greater than the acceptable cross-sectional area of steel in the borehole (see [B.4.3](#)) due to the fabrication of the encapsulation under controlled conditions and the incorporation of high-strength cementitious or resinous grouts.

NOTE 2 Load transfer mechanisms for typical encapsulation systems are shown in [Figure B.9](#).

11.4.4 Design of fixed anchor length by consideration of grout/tendon bond length

11.4.4.1 Grout/tendon interface resistance

11.4.4.1.1 The grout/tendon interface resistance should be determined by consideration of the tendon bond length and the bond between the tendon and the grout over this length.

11.4.4.1.2 The ultimate bond stress may be assumed to be uniform over the tendon bond length. Values of recommended maximum ultimate bond stresses are given in [B.5](#).

11.4.4.1.3 The following inequalities should be satisfied when establishing the tendon bond length by calculation.

$$F_{\text{Serv};k} \leq \frac{R_{\text{GT};k}}{\gamma_{\text{GT}}} \quad (9)$$

and

$$F_{\text{ULS};d} \leq R_{\text{GT};k} \quad (10)$$

11.4.4.1.4 For resinous grouts, ultimate bond values should be obtained from investigation tests in the absence of relevant, documented test data, $\square_{A2}$ see BS EN ISO 22477-5:2018, 5.2. $\square_{A2}$

11.4.4.1.5 For cement or resin grouted anchors, the bond length should be not less than the following, unless full-scale tests confirm that shorter bond lengths are acceptable:

- a) 3 m where the tendon is homed and bonded *in situ*; and
- b) 2 m where the tendon is bonded under factory controlled conditions.

11.4.4.1.6 Where doubt exists concerning the adequacy of tendon bond length, the proposed design should be confirmed by investigation tests on trial anchors **A2** *Text deleted A2*.

NOTE The above values are based on a minimum grout compressive strength of 30 MPa prior to stressing. These values can be applied to single unit tendons and to parallel, multi-unit tendons, provided that the clear spacing is not less than 5 mm [N10], [N11]. For noded strands and tendons that can mobilize mechanical interlock or the shear strength of the grout, the minimum spacing criterion does not apply.

11.4.4.2 Effects of surface condition on grout/tendon bond

11.4.4.2.1 The surface of the tendons should be free from loose rust, soil, paint, grease, soap or other lubricants. Where the tendon has been supplied coated with protective oils or greases, these should be removed thoroughly using steam or approved chemical solvents, for which purpose it might be necessary to temporarily unravel strands over the length to be bonded.

11.4.4.2.2 Tendons showing signs of pitting should not be used.

11.4.4.3 Concentration of steel tendon in the anchor borehole

Unless full-scale tests confirm satisfactory performance in accordance with agreed acceptance criteria **A2** *Text deleted A2*, the cross-sectional area of the steel tendon should not exceed 15% of the borehole area for parallel, multi-unit tendons and 20% of the borehole area for single-unit tendons or suitably noded, multi-strand tendons, in order to minimize debonding [N10], [N11].

A1 *Text deleted A1*

11.5 Anchor head design

11.5.1 General

11.5.1.1 The anchor head design should conform to BS EN 1537:2013, **6.2.2**.

11.5.1.2 All steel components should be designed in accordance with BS EN 1993-1-1:2005.

11.5.1.3 The form of the anchor head system should conform to BS EN 1537:2013.

NOTE See also 12.4.1.

11.5.2 Stressing head

11.5.2.1 In addition to conforming to BS EN 1537:2013, the stressing head should be designed to anchor the tendon without damaging it and also permit an angular deviation of $\pm 5^\circ$ from the axial position of the tendon. It should be verified in a static tension test as described in BS EN 13391:2004 that this angular deviation does not have an adverse influence on the ultimate load-carrying capacity of the anchor head.

11.5.2.2 Stressing heads and components for decoupled tendons (tendon free length not bonded to grout) should be equipped with a means to prevent any accident due to the energy released by a tendon failure.

NOTE See also 12.4.2.

11.5.3 Bearing plate

11.5.3.1 The bearing plate design should conform to BS EN 1993-1-1:2005 and BS EN 1992-1-1:2004.

11.5.3.2 Where the bearing plate is bedded on to concrete, the bedding mortar thickness should not exceed 10% of the plate width nor 100 mm in thickness. The bearing stress should not exceed $35\% f_{ck}$ (28-day strength) at $F_{Serv,k}$.

11.5.4 Concrete support plinth or pad

Where the bearing plate is bedded to the main structure through a concrete support plinth or pad, i.e. where the depth of concrete exceeds 10% of the bearing plate width or 100 mm, the concrete support plinth or pad should be designed in accordance with BS EN 1992-1-1:2004, or BS EN 1992-2:2005 for the design of post-tensioned, concrete end blocks. Anchor plinths on retaining walls should be considered as part of the wall design.

11.5.5 Design of support structures for a group of anchor heads

In cases where part of the main structure contains a group of anchor heads, e.g. a waling of a tied wall, this part of the structure should be designed so that any one anchor can fail without the load in other anchors exceeding that proof load to which they were initially tested.

11.6 Fixed anchor interaction

11.6.1 To limit interaction between fixed anchors, a spacing of not less than four times the diameter (D) centre-to-centre should be adopted (where D is the largest diameter within the fixed anchor).

NOTE In practice, a minimum spacing in the range 1.5 m to 2 m is commonly adopted (see [B.3](#) [A2](#) Text deleted [A2](#)).

11.6.2 The distance between a fixed anchor and an adjacent foundation or underground service should be at least 3 m. For surface foundations it might be necessary to increase the fixed anchor depth to 5 m or more, either to improve the ultimate resistance to withdrawal (the geotechnical ultimate limit state resistance of the anchor), or to encourage the possibility of local shear failure around the fixed anchor, as opposed to general shear failure, under anchor ultimate limit state conditions.

11.6.3 In locating the fixed anchor length, the ability to form boreholes with the necessary accuracy should be taken into account (see BS EN 1537, **8.1.2**).

12 Materials

12.1 Cement grouts

12.1.1 Cements

For grouted anchor construction in general, cement for grouting should conform to BS EN 1537:2013, **6.4**.

12.1.2 Fillers

Inert fillers such as sand or limestone dust are permissible in cement grouts. The use of fillers in tendon bonding grout is relatively rare and should conform to BS EN 447.

12.1.3 Water

Water for use in grout should be in accordance with BS EN 1008.

12.1.4 Admixtures

Admixtures should only be used if tests have shown that their use improves the properties of the grout, e.g. by improving workability or durability, reducing bleed or shrinkage or increasing the rate of strength development. Admixtures should conform to BS EN 447.

12.1.5 Grout properties

12.1.5.1 General

The design parameters of the grout should conform to BS EN 1537:2013.

12.1.5.2 Borehole anchor grout

12.1.5.2.1 Borehole anchor grout should conform to BS EN 1537:2013, **6.4** and the mix should attain a minimum unconfined compressive strength of 40 MPa at 28 days.

12.1.5.2.2 For anchors, the water/cement ratio of tendon bonding grouts should generally lie in the range 0.35 to 0.60.

12.1.5.2.3 For anchors installed in low-permeability ground, e.g. rock or clay, the water/cement ratio should not exceed 0.45.

12.1.5.3 Encapsulation grout

Where tendon bonding grout acts as part of the corrosion protection, the maximum bleed should not exceed 0.5%, measured over a two-hour period.

12.1.5.4 Capsule grout

The water/cement ratio in capsules with high alumina should not exceed 0.4.

12.1.5.5 Borehole pre-grout

In pre-grouting operations (see [Annex C](#)), strength requirements are insignificant and should not be specified.

12.1.5.6 Health hazards and safety

Some chemicals used as admixtures in grouts are harmful and can also be severe skin irritants [8], [9]. Appropriate personal protective equipment should be worn, as identified by a site-specific risk assessment. The manufacturer's safe handling instructions should always be followed. If no instructions are provided with an admixture, the user should seek advice from the manufacturer.

NOTE Attention is drawn to section 6 of the Health and Safety at Work, etc. Act 1974 [10] on the responsibility of the manufacturer to provide this information.

12.2 Resin grouts

12.2.1 Resins

Resins used for fixed anchor protection encapsulations should be specifically designed by the manufacturer. Use of resin grouts should conform to BS EN 1537:2013, **6.4.4**.

12.2.2 Fillers

For capsule or encapsulation grouts, fillers should be graded, with 100% passing a 200 µm sieve. For the rare case of resin injection of boreholes *in situ*, the maximum particle size may be increased

to 1 mm. Many crushed minerals are suitable as fillers but, to ensure compatibility of materials, pre-packed fillers supplied by the resin manufacturer should be used.

NOTE The use of inert fillers can be beneficial technically and economically, e.g. reduced exotherm and shrinkage.

12.2.3 Health hazards and safety

NOTE For health hazards and safety pertaining to resin grouts, see [Annex I](#).

12.3 Tendon

12.3.1 General

Tendons should generally consist of steel bar(s), strand(s) or wire(s), either singly or in groups. Developments with other materials and material forms might find application in grouted anchors and should be subject to appropriate tests.

12.3.2 Prestressing steel

Prestressing steel for anchor tendons should be specified in accordance with BS EN 1992-1-1:2004.

12.3.3 Couplers

Couplers should conform to BS EN 1537:2013, **6.2.3**.

12.3.4 Protective coverings

12.3.4.1 Sheathing

12.3.4.1.1 Within the free anchor length, the tendon may be covered with a protective grease and an outer, flexible, plastic sheath, applied either during manufacture or when fabricating the complete tendon on site.

12.3.4.1.2 The manufacturer's recommendations should be sought about their specific product, followed by pull-out tests on greased and sheathed tendon samples to confirm the efficiency of decoupling. Plastic sheathing should conform to BS EN 1537:2013, **6.5.1**.

12.3.4.2 Ducting

The tendon bond length should have the same degree of protection as the free anchor length. Since the protective elements have to transmit high tendon stresses to the ground, semi-rigid, corrugated ducting should be used where the strength and deformability characteristics have been checked structurally.

*NOTE BS EN 1537:2013, **6.5.1.4** provides guidance on dimensional requirements for plastic ducts.*

12.3.5 Centralizers

12.3.5.1 Centralizers should be provided on all tendons or encapsulations to ensure that the tendon or encapsulation has sufficient cover to the borehole wall. Centralizers should ensure, within the borehole, a minimum grout cover of 10 mm to the tendon or encapsulation at the centralizer, and should be provided at centres according to the angle of inclination of the grouted anchor and the possible sag between points of support, in order to provide a minimum grout cover of 5 mm to the tendon or encapsulation (see [Figure 4](#)).

12.3.5.2 The design of centralizers within encapsulations should ensure a minimum 5 mm grout cover.

12.3.5.3 The design of centralizers for bar tendons should ensure a minimum 5 mm grout cover (see [Figure 5](#)).