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# Code of practice for the selection and installation of post-installed anchors in concrete and masonry

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# Contents

**Summary of pages**

This document comprises a front cover, and inside front cover, pages i to vi, pages 1 to 81, 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 October 2012. It was prepared by Technical Committee B/514, *Access and support equipment*. A list of organizations represented on this committee can be obtained on request to the committee manager.

## Supersession

BS 8539:2012+A1:2021 supersedes BS 8539:2012, which is withdrawn.

## Information about this document

This British Standard is intended to be used by a wide range of people involved in the selection and installation of anchors, and some clauses are of particular interest to specific parties, as follows:

- all parties: Clause **3** and Clause **4**;
- designers: Clause **5**, **6.3** and Clause **10**;
- specifiers: Clause **5**, **6.4**, **6.6**, Clause **9**, Clause **10**, Annex A, Annex B, Annex C and Annex D;
- manufacturers/suppliers: Clause **5**, **6.2**, **6.5** and Clause **10**;
- contractors: Clause **7**, Clause **8** and **10**;
- installers: Clause **7** and Clause **10**;
- testers: Clause **9** and Annex B.

It is recommended that all parties read the whole document.

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

Amendment A1 introduces the following principal changes:

- the change in the anchor design method from ETAG001 in BS EN 1992‑4:2018, Annex C;
- changes to ensure consistency with the Construction Product Regulations [3];
- replacing references to European Technical Approval Guidelines (ETAGs) with the relevant European Assessment Documents (EADs) references;
- updating other references, including associated terminology.

**Product certification/inspection/testing.** Users of this British Standard are advised to consider the desirability of selecting anchors with a relevant European Technical Assessment (ETA)[1]. ETAs are awarded by Approval Bodies after a comprehensive test and assessment regime carried out to the relevant European Assessment Document (EAD) or Common Understanding of Assessment Procedure (CUAP), which also contain appropriate conformity attestation arrangements. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

*NOTE Anchors with ETAs, depending on the particular EAD and options within it, can be designed to suit a wide range of application conditions (see Clause **5** and Annex A). Guidance on ETAs is given in ETAs and design methods for anchors used in construction [1] and the EOTA website (www.eota.be).*

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[1] Text deleted.

This publication can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this publication can be found in the Standards Catalogue on the BSI website at bsigroup.com/standards, or by contacting the Customer Services team.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

## 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.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

## Presentational conventions

The provisions in 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").

## Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard cannot confer immunity from legal obligations.**

In particular, attention is drawn to the Construction Products Regulations 1991 [3] and Construction Products (Amendment) Regulations 1994 [4].

## Introduction

Anchors play an important role in construction, in particular:

a) they allow for the secure attachment of a fixture, which can be a structural element, to the base material;

b) there is a wide variety of anchors available for different applications.

Every anchorage has three elements:

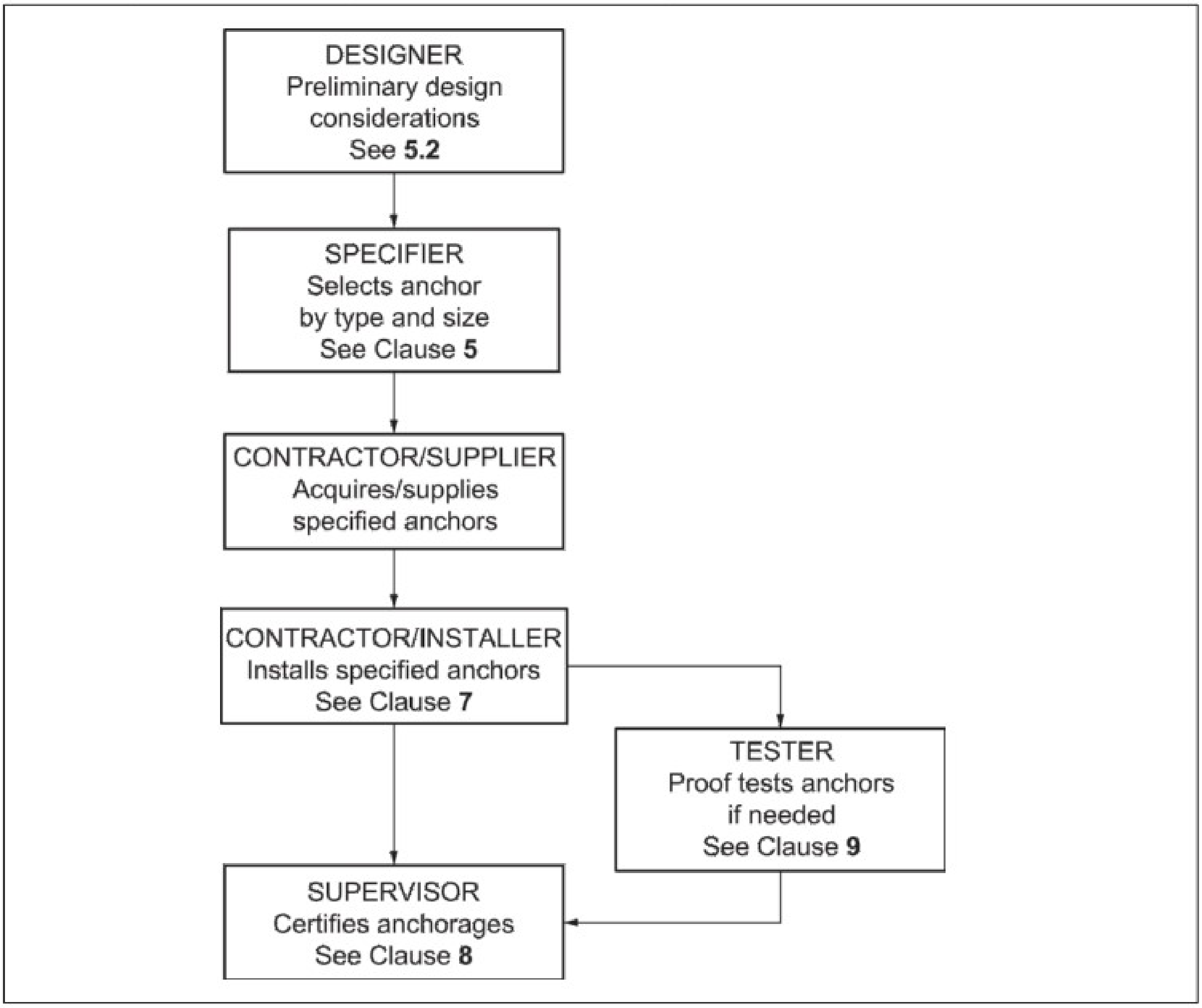
- anchor: the device that fastens the fixture to the base material;
- base material: the material into which the anchor is installed;
- fixture: the item to be fixed to the base material.

The performance of anchors is influenced by many application parameters, which need to be taken into account in their selection. Performance is also affected by the quality of installation.

If anchors are not selected and installed correctly, they might not have the capability to resist loads as intended. The security of the fixture and, in some cases, the structure might then be compromised, leading to failure with consequential economic loss, injury, or even death. This British Standard is intended to facilitate all stakeholders involved in the use of anchors to achieve the security required by the design.

Figure 1 shows a simple outline of the overall approach to be taken to ensure that connections are safe and that they meet the overall design requirements.

**Figure 1** — *Flowchart for overall process of selection and installation of anchors*



## 1 Scope

This British Standard gives recommendations for the safe selection and installation of anchors for use in concrete and masonry. It is intended to provide practical guidance for designers, specifiers, manufacturers, suppliers, contractors, installers and testers of anchors.

In particular, this British Standard applies to the selection and installation of anchors which are used in safety‑critical applications.

This British Standard is restricted to the use of anchors which are inserted into concrete and masonry in drilled holes.

## 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.

[N1] CONSTRUCTION FIXINGS ASSOCIATION. *Procedure for site testing construction fixings – 2012*. CFA Guidance Note. Thurmaston , Leicestershire: CFA, 2012.

## 3 Terms, definitions and symbols

*NOTE Where possible, terminology and notation have been used which are common with European standards. Some new terminology and notation have been developed for aspects not covered by European standards.*

### 3.1 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

#### 3.1.1 actions

#### 3.1.1.1 action

load (force) transferred into a base material by a fixture via an anchor

#### 3.1.1.2 bending action

action applied to an anchor with a lever arm

#### 3.1.1.3 characteristic action

action applied by a fixture to an anchor or group of anchors

*NOTE This is sometimes known as an "unfactored load" or "applied load".*

#### 3.1.1.4 characteristic permanent action

component of a characteristic action that is likely to act throughout the life of the structure, and for which the variation in magnitude with time is negligible

*NOTE This is commonly known as a "dead load".*

#### 3.1.1.5 characteristic variable action

component of a characteristic action for which the variation in magnitude with time is neither negligible nor monotonic (i.e. in the same direction)

*NOTE This is commonly known as an "imposed load" or "live load".*

#### 3.1.1.6 combined action

combination of tensile and shear actions applied simultaneously

#### 3.1.1.7 design action

action derived from the characteristic action by application of a partial safety factor for the action

*NOTE This is sometimes known as a "factored load".*

#### 3.1.1.8 non-static action

action which can be characterized by fatigue, seismic or shock actions

#### 3.1.1.9 quasi-static action

variable action which is treated as being static

#### 3.1.1.10 seismic action

action resulting from seismic activity (earthquakes) transmitted from the ground to the anchorage via the building structure

#### 3.1.1.11 shock action

single action of high magnitude occurring over short duration (milliseconds)

### 3.1.1.12 static action

action comprising loads which are constant (permanent actions) and/or those which change only slowly (variable actions)

### 3.1.2 anchor

manufactured device for achieving a connection between a fixture and the base material

*NOTE This is also known as a fixing or fastener. In CEN Technical Specifications, the terms "anchor" and "fastener" are used synonymously.*

### 3.1.3 anchor group

two or more anchors used in combination to achieve a connection between a single fixture and the base material

*NOTE This is not the same as multiple use (**3.1.26**).*

### 3.1.4 anchorage

assembly comprising a base material, an anchor or anchor group, and a fixture

*NOTE In CEN Technical Specifications, the term "fastening" is used.*

### 3.1.5 base material

material of a structure into which an anchor is installed

### 3.1.6 base plate

part of a fixture forming the direct contact between an anchor or group of anchors and the base material

### 3.1.7 bending moment

result of an action applied to a fixture at a lever arm which can result in a tensile action being applied to an anchor

### 3.1.8 client

person who commissions or procures the carrying out of a project

### 3.1.9 competent

suitably trained and qualified by knowledge and practical experience, and provided with the necessary instructions, to enable the required task(s) to be carried out correctly

### 3.1.10 compression

direction of loading along the axis of an anchor toward the base material

*NOTE When used as an adjective, this is known as "compressive".*

### 3.1.11 concrete strength

compressive strength of the concrete base material into which an anchor is to be installed

*NOTE This is derived from compression tests on cylinders/cubes, e.g. C20/25.*

### 3.1.12 contractor

organization or employer whose employees undertake, carry out or manage construction work

### 3.1.13 construction stage

period of time starting when preparation of a construction site begins and ending when work on the project is completed

### 3.1.14 cracked concrete

concrete likely to be subjected to tension at any point in its lifetime

*NOTE Guidance on the determination of cracked concrete is given in BS EN 1992‑4.*

### 3.1.15 creep

time‑dependent phenomenon that results in an increase in initial deformation under constant load, which in turn could result in relaxation in a fixture

*NOTE Anchors which suffer from creep might sustain significant loads under short-term test conditions but fail at significantly lower loads if applied over the long term.*

### 3.1.16 design life

period for which an anchorage is intended to remain in use

*NOTE This is normally 50 years for building structures.*

### 3.1.17 designer

person with overall responsibility for the design of a structure, which includes the anchorage, throughout the whole design and construction stage

*NOTE The designer might or might not be the specifier.*

### 3.1.18 embedment depths

### 3.1.18.1 effective embedment depth

depth from the surface of a load‑bearing structure to the lowest point where an anchor engages with the base material

### 3.1.18.2 nominal embedment depth

depth from the surface of a load‑bearing structure to the lowest part of an anchor

### 3.1.19 elevated temperature

temperature higher than the range of service temperatures normally considered

### 3.1.20 fixture

component to be fixed to the base material

### 3.1.21 global safety factor approach

determination of recommended resistance by application of a single safety factor ($\nu$) to either the characteristic or ultimate (mean average) resistance of an anchor

### 3.1.22 installer

person or organization trained in the process of installing anchors

*NOTE The installer is usually employed by a contractor.*

### 3.1.23 lateral

direction of loading perpendicular to the axis of an anchor

### 3.1.24 manufacturer

person or organization who develops, manufactures, and supplies anchors

### 3.1.25 masonry

building element constructed from masonry units, such as bricks, blocks or stones

### 3.1.26 multiple use

particular application category where multiple anchors are employed to support an installation system, in which failure of a single anchor will not cause collapse of the whole supported structure

*NOTE 1 This applies only to anchors qualified to certain ETAGs, and requires specific application parameters to be satisfied. An application qualifies as multiple use if the number ($n_1$) of fixing points, the number ($n_2$) of anchors per fixing point are in accordance with EAD 330747-00-0601 [6]2) and PD CEN/TR 17079:2018:*

- $n_1 \geq 3$ and $n_2 \geq 1$

*NOTE 2 Examples include suspended ceilings or runs of mechanical/electrical containment.*

*NOTE 3 This is not the same as reuse.*

### 3.1.27 non-cracked concrete

concrete unlikely to be subjected to tension at any point in its lifetime

*NOTE Guidance on the determination of non-cracked concrete is given in BS EN 1992-4.*

### 3.1.28 partial safety factor approach

application of partial factors of safety to characteristic actions and resistances to determine the respective design values, in order to verify that no relevant limit state is exceeded

### 3.1.29 partial safety factor for action

partial safety factor applied to the characteristic action to derive the design action

### 3.1.30 partial safety factor for material

partial safety actor applied to the characteristic resistance to determine the design resistance

### 3.1.31 preliminary test

test carried out on site to determine the allowable resistance in the case where no characteristic resistance or recommended resistance is available

*NOTE Also known as "test for allowable resistance (simplified approach)"; see **B.2.3.1**.*

### 3.1.32 progressive collapse

sequential spread of local damage from an initiating event, from element to element, resulting in the collapse of a number of elements

### 3.1.33 proof load

load applied in a proof test

### 3.1.34 proof tests

tests carried out on a proportion of anchors to validate correct installation

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2) ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing this British Standard it has not been implemented.

### 3.1.35 resistance

#### 3.1.35.1 resistance

capacity of an anchorage to resist actions

#### 3.1.35.2 allowable resistance

maximum working load derived from tests carried out on site when the proposed anchor is to be used in a base material approved by the manufacturer but for which there is no recommended resistance (load)

#### 3.1.35.3 characteristic resistance

resistance derived as the 5% fractile of the mean ultimate resistance, determined from tests or by empirical calculation depending on mode of failure

*NOTE This is based upon a 90% probability (confidence level) that 95% of anchors will exceed the characteristic resistance.*

#### 3.1.35.4 design resistance

resistance derived from the characteristic resistance by the application of partial safety factors

#### 3.1.35.5 mean ultimate resistance

average failure load determined in a series of tests

#### 3.1.35.6 recommended resistance

maximum working load recommended by a manufacturer

*NOTE This is sometimes referred to as "recommended load" or "permissible load". It is associated with the global safety factor approach, where it is derived from the characteristic action divided by a global safety factor.*

### 3.1.36 redundancy

situation where there are more load paths than strictly necessary to carry the load through the structure, or part thereof

### 3.1.37 robustness

ability of a structure/structural system to accept a certain amount of damage without that structure failing to any degree

*NOTE Robustness implies insensitivity to local failure.*

### 3.1.38 safety-critical application

application in which the failure of anchors can:

a) result in collapse or partial collapse of the structure; and/or

b) cause risk to human life; and/or

c) lead to significant economic loss

*NOTE This definition is adapted from BS EN 1992-4.*

### 3.1.39 selection

overall process of selecting the type and size of an anchor or group of anchors

*NOTE The process of design of the anchor will be one part of this process.*

### 3.1.40 shear

lateral loading that can be coincident with the face of a base material or applied at a lever arm

*NOTE Where used to describe anchor performance, "shear" is taken to mean coincident with the face of the base material.*

### 3.1.41 specification

complete reference of an anchor in sufficient detail to facilitate its supply and installation

### 3.1.42 specifier

person or organization responsible for the selection (including anchor design) and specification of an anchor

*NOTE The specifier might or might not be the designer.*

### 3.1.43 statically determinate

application in which the stability of a fixture is dependent on every anchor supporting it

### 3.1.44 statically indeterminate

application in which stability of a fixture is not dependent on every anchor supporting it, i.e. there is a degree of redundancy

### 3.1.45 supplier

person or organization that supplies anchors

### 3.1.46 supervisor

person who supervises the installer, usually employed by the contractor

### 3.1.47 tension

direction of loading along the axis of an anchor and tending to pull the anchor out of the base material

*NOTE When used as an adjective, this is known as "tensile".*

### 3.1.48 test load

load to be applied during a test

### 3.1.49 tester

person or organization that tests anchors on site

## 3.2 Symbols

For the purposes of this British Standard, the following symbols apply.

| | |
|---|---|
| $\alpha$ | factor used in checking the compatibility of design actions compared with design resistances in the case of combined actions |
| $c_{cr}$ | characteristic edge distance, at which full performance may be used<br>*NOTE 1 Previously referred to as "critical edge distance".* |
| $c_{min}$ | minimum edge distance, at which performance has to be reduced according to manufacturer's data |
| $d_0$ | nominal diameter of drill bit |
| $F$ | action or resistance with direction unspecified |

| | |
|---|---|
| $F_{\mathrm{R,all}}$ | allowable resistance |
| $F_{\mathrm{Rd}}$ | design resistance |
| $F_{\mathrm{Rk}}$ | characteristic resistance |
| $F_{\mathrm{Ru,m}}$ | mean ultimate resistance from a series |
| $F_{\mathrm{Ed}}$ | design action |
| $F_{\mathrm{Ek}}$ | characteristic action |
| $F_{\mathrm{rec}}$ | recommended resistance |
| $f_{\mathrm{ck,cube}}$ | concrete compressive strength (cube) |
| $f_{\mathrm{ck,cylinder}}$ | concrete compressive strength (cylinder) |
| $G_{\mathrm{k}}$ | characteristic permanent action |
| $H$ | thickness of base material |
| $h_0$ | depth of cylindrical drilled hole with full diameter |
| $h_1$ | depth of drilled hole to deepest point |
| $h_{\mathrm{ef}}$ | effective embedment depth from the surface of the load-bearing structure |
| $h_{\mathrm{nom}}$ | nominal embedment depth of the anchor from the surface of the load-bearing structure |
| $K$ | special factor that adjusts the width of the tolerance interval to account for uncertainty |
| | *NOTE 2 In this British Standard, the K factor is taken from standard statistical tables, to give a 90% probability (confidence level) that 95% will exceed the calculated characteristic resistance.* |
| $M_{\mathrm{Rd}}$ | design bending moment |
| $N$ | tensile actions or resistances |
| $N_{\mathrm{1st}}$ | load at first movement in a test |
| $N_{\mathrm{1st,m}}$ | mean load at first movement in a test series |
| $N_{\mathrm{p}}$ | tensile load applied in a proof load test |
| $N_{\mathrm{R,all}}$ | allowable tensile resistance |
| $N_{\mathrm{Rd}}$ | design tensile resistance |
| $N_{\mathrm{Rk}}$ | characteristic tensile resistance |
| $N_{\mathrm{Rk,ETA}}$ | characteristic tensile resistance quoted in an ETA for this category of base material |
| $N_{\mathrm{Rk1}}$ | characteristic tensile resistance for a specific base material in a test |
| $N_{\mathrm{Ru}}$ | ultimate tensile resistance recorded in a single test |
| $N_{\mathrm{Ru,m}}$ | mean ultimate tensile resistance from a series of tests |
| $N_{\mathrm{rec}}$ | recommended tensile resistance |
| $N_{\mathrm{Ed}}$ | design tensile action |
| $N_{\mathrm{Ek}}$ | characteristic tensile action |

| | |
|---|---|
| $N_{\mathrm{test}}$ | tensile test load applied in preliminary tests |
| $N_{\mathrm{u,ave}}$ | average tensile load recorded in preliminary tests |
| $N_{\mathrm{u,low}}$ | lowest tensile load recorded in preliminary tests |
| $n_0$ | number of anchors originally required in a test |
| $n'$ | new number of anchors required with the allowable resistance derived from a test |
| $n_1$ | number of fixing points |
| $n_2$ | number of anchors per fixing point |
| $n_3$ | limiting value of design action on a fixing point for multiple use |
| $Q_{\mathrm{k}}$ | characteristic variable action |
| $s_{\mathrm{cr}}$ | characteristic spacing, at which full performance may be used |
| | *NOTE 3 Previously referred to as "critical spacing".* |
| $s_{\mathrm{min}}$ | minimum spacing, at which performance has to be reduced according to manufacturer's data |
| $s$ | standard deviation of failure loads about the mean |
| $T_{\mathrm{inst}}$ | manufacturer's recommended installation torque |
| $V$ | shear actions or resistances |
| | *NOTE 4 All actions and resistances shown beginning N, to denote tensile actions or resistances, can be converted to the equivalent for shear actions or resistances by replacing N with V.* |
| $V_{\mathrm{Rd}}$ | design shear resistance |
| $V_{\mathrm{rec}}$ | recommended shear resistance |
| $V_{\mathrm{Ed}}$ | design shear action |
| $V_{\mathrm{Ek}}$ | characteristic shear action |
| $v$ | coefficient of variation of the ultimate load in a test series |
| $\beta$ | influencing factor used in determining results of site tests |
| | *NOTE 5 The values of this factor are given in the relevant approval document for the anchor.* |
| $\beta_{\mathrm{N}}$ | ratio of design tensile action to design tensile resistance |
| $\beta_{\mathrm{V}}$ | ratio of design shear action to design shear resistance |
| $\delta_{\mathrm{N0}}$ | tensile displacement, short-term |
| $\delta_{\mathrm{N\infty}}$ | tensile displacement, long-term |
| $\delta_{\mathrm{V0}}$ | shear displacement, short-term |
| $\delta_{\mathrm{V\infty}}$ | shear displacement, long-term |
| $\gamma_{\mathrm{F}}$ | partial safety factor for action, general case |
| $\gamma_{\mathrm{G}}$ | partial safety factor for action, permanent action |
| $\gamma_{\mathrm{M}}$ | partial safety factor for material, general case |

| | |
|---|---|
| $\gamma_{Mc}$ | partial safety factor for material, concrete |
| $\gamma_{Mp}$ | partial safety factor for material, pull‑out |
| $\gamma_{Msp}$ | partial safety factor for material, splitting |
| $\gamma_{Ms}$ | partial safety factor for material, steel |
| $\gamma_{Q}$ | partial safety factor for action, variable action |
| $\nu$ | global safety factor |
| $\nu_{ave}$ | factor used in determining allowable resistance, from average test result |
| $\nu_{low}$ | factor used in determining allowable resistance, from lowest test result |
| $\nu_{P,test}$ | factor for determining proof test loads |
| $\nu_{test}$ | factor used in preliminary tests to determine $N_{test}$ |
| $\Omega$ | adjustment factor for site conditions |

## 4 Roles and responsibilities

*COMMENTARY ON CLAUSE* ***4***

*It is vital that all persons and organizations involved in the use of anchors understand their role and responsibilities, in order that the recommendations made in this British Standard can be implemented at each stage of the fulfilment of a project.*

*A person or organization can take on more than one role.*

*Any person who at any time changes a specification without notifying the original specifier is deemed to have taken on the role and responsibilities of the specifier (see* ***4.3****).*

*It is recommended that one person be identified as having overall responsibility for the structure within which an anchorage is expected to function, from commencement of its consideration through the construction stage to commissioning of the building/project. This person will normally be the designer. As certain parts of this activity, such as the specific acts of selection, design and or specification of the anchor itself, may be delegated to others, e.g. specialist subcontractors, the role of specifier is identified so as to set out the responsibilities to be fulfilled by the person with that role. The specifier may be the designer.*

*The installation of anchors might require the use of procedures or products that are potentially hazardous. Attention is drawn to the Health and Safety at Work, etc. Act 1974 [9].*

### 4.1 Manufacturer/supplier

Anchor manufacturers and suppliers should provide such information as is necessary for the specifier and the installer to ensure the safe selection, specification, installation, use, maintenance, cleaning, dismantling or disposal of the anchor without risk to safety or health.

*NOTE See Clause* ***6*** *for details of the information to be supplied.*

While anchor manufacturers and suppliers may provide advice, for which they should take responsibility, that does not make them the specifier in the context of this British Standard, as they do not have responsibility for the selection of the anchor within the project.

Suppliers of anchors should take care to supply anchors as ordered by customers. Specifications of anchors that have been ordered should not be changed unless the change management procedure in Clause **10** has been followed and the proposed change has been approved by the specifier.

## 4.2 Designer

The designer should take into account the preliminary design considerations listed in **5.2**. The designer should also supply all necessary information to the specifier as required to complete the selection process as outlined in **6.3**.

## 4.3 Specifier

The specifier should determine the most appropriate anchor for the particular application, by following the selection process given in Clause **5** and using the appropriate design method for that anchor.

*NOTE 1 Guidance on design methods is given in Annex A.*

The specifier should seek technical assistance from the manufacturer/supplier where necessary and, if the specifier is not the designer, should seek information from the designer as recommended in **6.3**. The selection process should take into account the most onerous loads to which the anchor might be subjected, and the direction of the loads, including temporary loading applied during the erection phase.

Once the selection and design processes are completed, the specifier should specify the anchor explicitly and completely, so that the anchor installed on site fulfils the design criteria (see **5.5** and **6.4**).

If any party proposes an alternative anchor to that specified, the specifier should ensure that the change management procedure outlined in Clause **10** is carried out.

If for any reason the specifier determines that site tests of anchors are needed, then the need for such tests should be communicated to all relevant parties, e.g. the contractor and tester, so that they know the objective of such tests and when they are to be carried out, and that they have all the necessary data to carry out such tests (see **6.6**). The specifier should then ensure that any actions consequent on the results of such tests are put in hand.

*NOTE 2 In the case of tests to determine the allowable resistance, this might mean that the proposed anchor is confirmed as the specified anchor, or that it is not suitable and an alternative anchor is to be proposed and, possibly, tested. In the case of proof tests, it might mean confirmation to the contractor and installer that the quality of installation has been proven to be satisfactory and no further action is necessary, or that it has been found to be unsatisfactory and that specified remedial action is needed.*

## 4.4 Contractor

The contractor should ensure that the specified anchor is procured and that the installer is trained for the correct installation of that anchor type. In addition, the contractor should ensure that the installer is working under competent supervision. If any party proposes an alternative anchor to that specified, the contractor should ensure that the specifier or other responsible person carries out the change management procedure outlined in Clause **10**.

It is essential that the contractor is satisfied at the time of installation of anchors that the strength of the base material is at least that assumed by the specifier in the design and selection of anchors. If not, the contractor should liaise with the specifier and await instructions.

If site tests are deemed necessary, the contractor should ensure that the required tests are carried out by a competent tester, using the appropriate procedure as set out in Annex B and in the location prescribed by the specifier or a location appropriate to the test objective. The contractor should also ensure that the information required by the tester is communicated to them before the tests are carried out, and that the results of the tests are communicated to the specifier and recorded in project documentation. They should ensure that any actions deemed necessary following such tests are carried out.

### 4.5 Installer

The installer should familiarize themselves with the correct installation procedures. Installation of anchors should be undertaken only by installers who have received adequate training from a competent trainer.

The installer should ensure that the correct drilling and setting tools are available for the proper installation of the anchor. The installer should comply in all respects with the manufacturer's installation instructions and material safety data sheets.

The installer should not proceed with the installation of the anchors if, due to site conditions, e.g. hitting reinforcement during drilling, the anchors cannot be set in accordance with the manufacturer's instructions. Any conflict should be referred back to the specifier and, if necessary, the anchor supplier, so that a solution can be designed and an alternative anchor or an alternative method can be specified (see Clause **10**).

If the installer is required to install anchors specifically for the purpose of tests, they should ensure that the anchors are installed in the locations prescribed by the specifier or contractor.

### 4.6 Supervisor

The supervisor should ensure that the anchors have been installed in accordance with the manufacturer's instructions and the design criteria, and should complete certification of the completed anchorage to that effect (see Clause **8**). The supervisor should ensure that the installer is aware of the consequences of failing to adhere to the correct installation instructions.

In the case of small projects, the role and responsibilities of the supervisor may be undertaken by the installer if so authorized by the contractor.

### 4.7 Tester

Where deemed necessary, the tester should carry out tests using the appropriate procedure as set out in Annex B. The tester should ensure that the anchors are installed in accordance with the manufacturer's installation instructions and in the test locations prescribed by the specifier or other person responsible for the supervision of the tests, e.g. contractor. The tester should record results in a full and comprehensive manner and communicate them to the specifier or responsible person requesting the tests.

## 5 Selection and specification of anchors

*COMMENTARY ON CLAUSE **5***

*The term "selection" is used for the overall process of choosing an anchor, including both type and size, and within that process the term "design" is reserved for the specific process of determining the size of anchor required.*

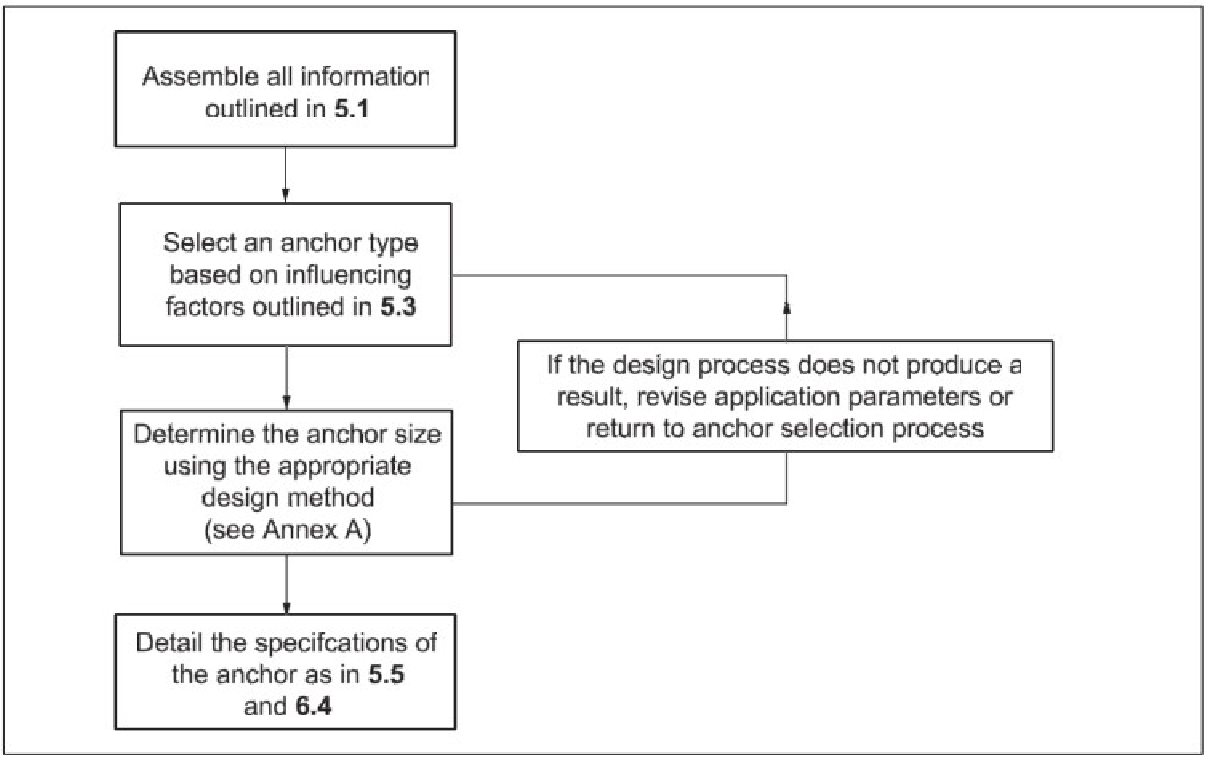
*The selection of an anchor for any application, and especially those which are safety-critical, requires consideration of a great many different factors which can broadly be divided into two main subjects, with some overlap:*

*a) those to do with determining the type of anchor, including its suitability for the base material concerned, its ability to cope with various environmental factors (temperature, humidity, fire) and its fitness for the practicalities of the application, e.g. the need for immediate loading, the need to be installed through the fixture or to be removable after use or even reused. These aspects are dealt with in **5.3** and different anchor types are described in Annex C;*

*b) those to do with determining the size of the anchor (diameter and length) – the process known as design. This process is essentially governed by the actions to be carried and the chosen anchor's resistance needed to withstand those actions. These aspects are discussed in* ***5.4*** *and Annex A.*

*The selection process is summarized in Figure 2.*

**Figure 2** — *Flowchart for selection process*



## 5.1 Information to be assembled

In order to undertake the anchor selection process, a minimum amount of information should be assembled beforehand by the specifier. This should include:

- project details;
- the design actions applied to the anchor and their nature (static/dynamic etc.);
- details of the base material type, thickness and likely strength at the time of installation, including condition of the concrete in the area of anchorages, i.e. cracked or non-cracked;
- preferred edge distance and centre spacings;
- details of the base plate, material and thickness, and proposed hole diameter;
- possible need for shims or grouting;
- environmental conditions including elevated temperatures or fire rating requirements, corrosion conditions and required durability, likely temperature at time of installation (only if resin bonded anchors are being considered);
- details of the type of anchor being considered;
- the European Technical Assessment (ETA) of the anchor, in its most up to date edition, if it has one;
- manufacturer's software for the selection of the anchor being considered;
- manufacturer's technical catalogue if no ETA or software is available;
- the results of the preliminary design considerations (see **5.2**).

## 5.2 Preliminary design considerations

The following three aspects should be assessed by the designer, before the specifier determines the choice of anchor.

a) **Ability of the structure to sustain the design actions**.

The designer should confirm that the structure to which the fixture is to be attached has the ability to sustain the design action. The application of test loads with test equipment which directs reaction loads into the structure will not inform this decision.

b) **Concrete status**.

The designer should determine the status of the concrete in the area of the anchors, i.e. is it cracked or non-cracked, in line with **5.3.3.2.2**. If this cannot be determined then cracked concrete should be assumed.

c) **Robustness, redundancy and progressive collapse**

The designer should assess the level of robustness (see **3.1.37**) required for the anchorage(s) and take account of the following factors:

- sufficient redundancy is needed in the system such that one isolated failure of an anchorage does not result in the overloading of other anchorages, leading to progressive collapse;
- appropriate material specifications are needed for anchorages where this is relevant to load patterns, substrate conditions or corrosion control, due to environmental conditions;
- anchorages working in shear often have a greater robustness compared to anchors working in pure tension, e.g. there might be an option, when locating top fixings for a suspended ceiling, of fixing into a vertical rather than a horizontal surface.

To ensure robustness from the point of view of anchors, and to avoid failures generally, it is necessary to determine whether or not the application is statically determinate or statically indeterminate, as anchors may be qualified in relation to these definitions and this feature is fundamental to the selection of properly qualified anchors (see Annex D, Figure D.1 and Figure D.2).

Applications in which the failure of any anchor supporting the fixture will lead to its collapse are referred to as being "statically determinate" (see **3.1.43**), while those which have been designed with sufficient redundancy (see **3.1.36**) that the failure of one anchor will not lead to progressive collapse (see **3.1.32**) are referred to as "statically indeterminate" (see **3.1.44**). The majority of applications are statically determinate. If determinacy is not known then anchors qualified for statically determinate use should be selected.

*NOTE 1 The majority of anchors with an ETA are qualified for statically determinate use. The status of different EADs in relation to statical determinacy is indicated in the CFA Guidance Note ETAs and design methods for anchors used in construction [1][3].*

*NOTE 2 If the application conforms to the definition of "multiple use" (see **3.1.26**) as defined in EAD 330747-00-061 [6] or in ETAG 20 [7][3], then it can be regarded as statically indeterminate, and anchors conforming to those EAD or ETAGs may be specified without the need for special consideration of the stiffness of the supported structure.*

Applications vulnerable to progressive collapse (including suspended ceilings, and suspended services such as pipework, ductwork or cable tray), and which do not satisfy the preconditions of multiple use, should be designed using anchors qualified for statically determinate use.

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[3] ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard has not, as yet, been implemented.

*NOTE 3 Guidance on robustness is given in the ISE publication Practical guide to structural robustness and disproportionate collapse in buildings [10].*

## 5.3 Factors determining anchor type

### 5.3.1 General

The specifier should determine the type of anchor to be specified, taking account of the factors described in **5.3.2** to **5.3.6**, along with the features and capabilities of the different anchor types as outlined in Annex C.

### 5.3.2 Anchor reliability

Specifiers should satisfy themselves that the selected anchor will function reliably in the range of conditions which could be encountered on site.

*NOTE Factors which can influence the performance of an anchor include its tolerance to drilled hole diameter, its functioning in concrete of different strengths and at different installation or service temperatures, and, depending on the type of anchor, its tolerance to likely variations in the installation method, e.g. tightening torque (torque-controlled anchors), hole cleaning, reliable formation of an undercut (undercut anchor), etc. One means of ensuring that all such factors have been taken into account is to select an anchor conforming to an ETAG appropriate to the application.*

### 5.3.3 Base material

### 5.3.3.1 General

Not all anchors work in all base materials, so the specifier should ensure that the proposed anchors are suitable for the base material concerned.

*NOTE Guidance on concrete is given in **5.3.3.2**, and on masonry in **5.3.3.3**.*

### 5.3.3.2 Concrete

***Product certification/inspection/testing.*** *Users of this British Standard are advised to consider the desirability of selecting anchors with a European Technical Assessment (ETA)*[4]*. Annex D Figure D.1 shows the selection process for anchors in concrete with and without an ETA.*

### 5.3.3.2.1 Structural form

The specifier should evaluate the type and strength of concrete structure, as there might be factors which could influence the choice of anchor or its positioning.

a) **In-situ cast concrete**. This is the most commonly encountered concrete structure for which most anchors, claimed by the manufacturer to be suitable for concrete, are expected to work. All of the issues described in **5.3.3.2.2** to **5.3.3.2.5** should be taken into account when selecting anchors to be installed in in-situ cast concrete. Anchor positions should be specified so as not to damage any embedded reinforcement/pre-stressing steel.

b) **Pre-cast concrete**. Again, most anchors claimed by the manufacturer to be suitable for in-situ cast concrete are expected to work in solid pre-cast concrete. Pre-cast components are likely to have reinforcement, which may be either passive or pre-stressed. Anchor positions should be specified so as not to damage any embedded reinforcement/pre-stressing steel. For pre-cast sections that are hollow, special anchors might be needed.

c) **Concrete blocks**. The factors outlined for masonry should be taken into account when selecting anchors to be installed in concrete blocks.

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[4] Text deleted.

### 5.3.3.2.2 Cracked/non-cracked concrete

*COMMENTARY ON* ***5.3.3.2.2***

*Concrete is likely to be cracked from a variety of causes including stress conditions inherent in the structure, those induced by characteristic permanent actions and characteristic variable actions, thermal movements, shrinkage and the restraint of deformation. Anchors qualified for use in cracked concrete are expected to function reliably in the expected widths of cracks developed as a result of tensile stresses in concrete structures designed in accordance with BS EN 1992. In the region of an anchor, the concrete might be cracked or non-cracked.*

Anchors should be chosen that are suitable for use in cracked or non-cracked concrete, as appropriate. The specifier should assume the concrete to be cracked unless an exercise has been carried out to determine whether it is cracked or non-cracked (see Note 2).

*NOTE 1 Anchors conforming to EAD 330232-00-0601 [8] and EAD 330499-00-0601 [11], options 1 to 6, and tEAD 330747-00-0601 [6], are suitable for use in concrete which is cracked or non-cracked. Anchors conforming to EAD 330232-00-0601 [8] and EAD 330499-00-0601 [11], options 7 to 12 are suitable for use only in concrete which is non-cracked.*

*NOTE 2 Under some conditions, e.g. restricted structural dimensions, the higher performance allocated to anchors in non-cracked concrete might warrant carrying out the necessary stress analysis to prove that the concrete is non-cracked and utilize the higher performance available for use in that condition. BS EN 1992-4 includes a means of determining this by stress analysis. In certain structures the designer might, by experience, be able to declare the concrete to be non-cracked.*

### 5.3.3.2.3 Concrete strength

*COMMENTARY ON* ***5.3.3.2.3***

*Concrete strength is quoted in terms of its compressive strength as measured either from cubes,* $f_{ck,cube}$*, or from cylinders,* $f_{ck,cylinder}$*, but most commonly these two designations are combined in a reference to strength classes according to BS EN 206, e.g. C20/25, which denotes respectively the mean cylinder and cube strengths in N/mm*$^2$*.*

*Manufacturers' performance values are generally quoted for a concrete base material, usually at least C20/25. However, certain options in EAD 330232-00-0601 [8] and EAD 330499-00-0601 [11] allow for increased capacities for higher concrete strengths up to C50/60, and in EAD 330747-00-0601 [6] for concrete strengths as low as C12/15. If the specifier has assumed a concrete compressive strength greater than the minimum allowed by the manufacturer, then it is important that this information is communicated to the installer (see* ***6.4****) so that the installer can check that the assumed strength has been reached prior to the time of installation (see* ***7.4****).*

When selecting anchors for use in concrete structures where the concrete strength is not known, the design should be carried out with data published for the lowest concrete strength, typically C20/25, as most concrete is likely to be stronger than this in practice.

### 5.3.3.2.4 Structural dimensions

Specifiers should take into account the following dimensional limitations of the structure, as these limitations affect anchor performance.

a) **Edge and spacing parameters**.

All anchors require an amount of the base material around them, to support the forces induced during their installation and/or those transferred from the fixture in service. Data should be acquired from the manufacturer identifying the edge distances and centre spacings that will provide full performance (characteristic edge distance, $c_{cr}$, or characteristic spacing, $s_{cr}$), and absolute minimum dimensions (minimum edge distance, $c_{min}$, or minimum spacing, $s_{min}$), for which performance should be reduced according to the prescribed design model (see Figure 3).

*NOTE 1 Anchors conforming to EAD 330232-00-0601 [8] and EAD 330499-00-0601 [11] will, depending on their option, include this data. Some options allow design using minimum dimensions, while others allow anchors to be specified only at the critical distances with no closer dimensions allowed.*

There is, however, a relationship between the anchor spacing and the edge distance. It might not be possible to use the minimum edge distance, $c_{min}$, simultaneously with the minimum spacing, $s_{min.}$

Minus tolerances should not be specified.

b) **Embedment depth**.

The embedment depth should be taken into account in the calculation of tensile resistance of the anchor.

The embedment depths quoted by manufacturers may be measured from the surface of the load-bearing structure to either the deepest point of engagement of the anchor with the base material, $h_{ef}$, or to the deepest part of the anchor, $h_{nom}$. (See **7.3.3**.) Any non-load-bearing element, such as a screed topping, plaster or render, should be regarded, not as part of the base material and therefore not contributing to the embedment depth, but as part of the fixture and an anchor should be chosen with sufficient fixture thickness capability.

The concrete cone resistance for all anchors is influenced by the effective embedment depth, $h_{ef}$, from which the failure cone emanates. The deeper the effective embedment, the larger the cone and the higher the characteristic tensile resistance, $N_{Rk}$ (see Figure 4), until the mode of failure changes, e.g. from concrete cone failure to steel failure.

The size of the concrete cone is a function of the anchor's embedment depth; this also means that the deeper the anchor is set, the greater the critical anchor spacing and edge distance becomes. When anchors are in groups, the negative effect from edge and spacing criteria might negate any increase in performance gained from deeper embedment.

c) **Structural thickness**.

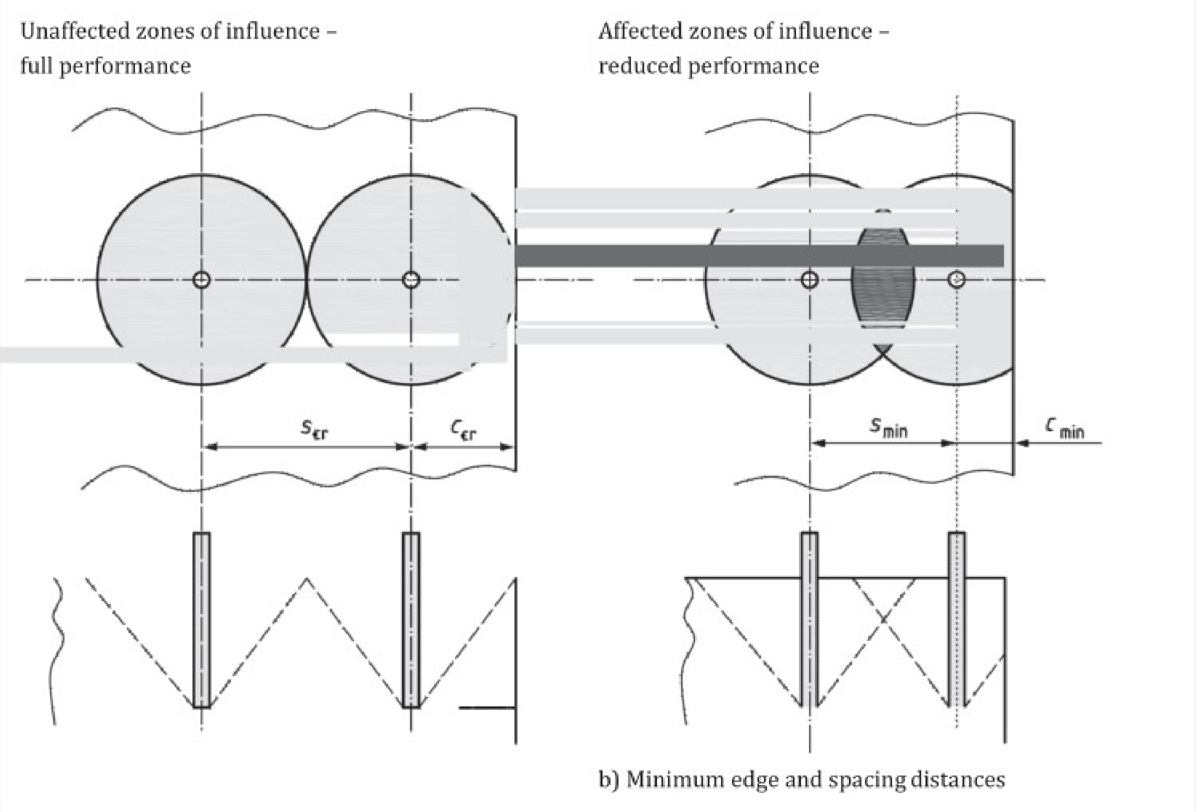
Some anchors require the structural thickness, $h$, to be very little thicker than the embedment depth of the anchor in order to transfer their rated performance into the structure (e.g. bonded anchors, see **C.1.4**), while others, such as torque-controlled expansion anchors (see **C.1.1**) need an increased thickness. Others (e.g. deformation-controlled expansion anchors, see **C.1.3**) need even more to sustain the impact loads of the anchor being set. Also, for most anchors, there needs to be sufficient material behind the drilled hole to avoid the spalling of the back of the concrete due to the hammer action of the drilling operation; the manufacturer's instructions should be followed.

*NOTE 2 A typical allowance is twice the drill diameter, $d_0$, or at least 30 mm.*

If compressive actions are to be transferred through the anchor (see **5.3.4.2.4**), this too needs to be taken into account in the overall structural thickness.

Specifiers should check that the minimum structural thickness, as required by the manufacturer for the proposed anchor, is available.

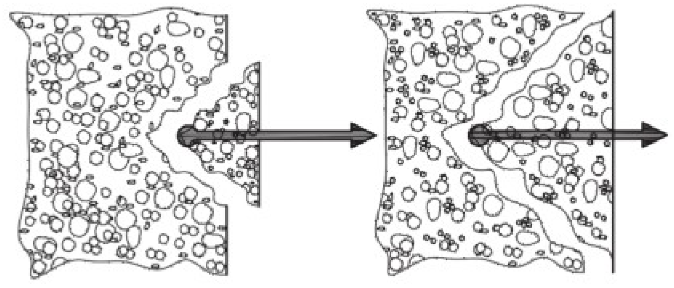
**Figure 3** — *Characteristic and minimum edge and spacing dimensions*



b) Minimum edge and spacing distances

a) Characteristic edge and spacing distance

**Figure 4** — *The relationship between embedment depth and concrete cone failure*



#### 5.3.3.2.5 Reinforcement

*COMMENTARY ON **5.3.3.2.5***

*The performance of anchors is usually quoted by manufacturers for non -reinforced concrete. However, reinforcement is required in concrete for many reasons and will usually be present. There are advantages in sufficient (and fully tied) edge reinforcement, although this can impose further restrictions on locating anchors in these areas. This reinforcement provides a design benefit, but only in cracked concrete conditions and then only in shear towards an edge. In the case of densely reinforced structures, anchors with shallow embedment depths might be negatively affected.*

Specifiers should take into account the likelihood of reinforcement being encountered during drilling and set out the action to be taken by the installer in that case. Options include the possibility of drilling through the reinforcement, if that will not be detrimental to the structure and if the specifier is satisfied that the anchor will still function despite the reinforcement. Anchors conforming to an EAD can be expected to function in a hole drilled in contact with rebar. This avoids the need for repositioning anchors, which invariably means designing and fabricating new brackets or moving the complete fixture.

If reinforcement is not to be drilled through, then this fact should be clearly stated in the instructions accompanying the anchor specification, and an alternative approach provided. The preferred approach is to locate the reinforcement using non-destructive instruments and dimension the fixture accordingly. Alternatively, brackets or base plates can be detailed with alternative mounting holes, in which case the anchor spacing criteria of the manufacturer should be taken into account and the effect on anchor loading also catered for.

*NOTE Guidance for installers in the case of hitting reinforcement is given in **7.5**.*

#### 5.3.3.3 Masonry

*COMMENTARY ON **5.3.3.3***

*The term "masonry" covers all constructions built from masonry units and bonded together via mortar joints, including brickwork, blockwork and stonework. It can be an unpredictable material to fix into. The strength can vary from as low as 1.8 N/mm² (aerated blocks) to 90 N/mm² (engineering bricks). Masonry units can be solid or have perforations, and the mortar might be weak or non-existent in parts of the joints.*

***Product certification/inspection/testing.** Users of this British Standard are advised to consider the desirability of selecting anchors with a European Technical Assessment (ETA)[5]. Annex D Figure D.2 shows the selection process for anchors in masonry with and without an ETA.*

#### 5.3.3.3.1 General

Specifiers should select anchors proven to be able to function reliably in the type of masonry for which the application is intended.

*NOTE 1 Plastic anchors conforming to ETAG 020 [7][5] are suitable only for multiple use (statically indeterminate applications). Part 3 relates to plastic anchors used in solid masonry structures and Part 4 is for plastic anchors used in hollow or perforated masonry structures. Bonded anchors conforming to EAD 330076-00-0604 [15] are suitable for use in applications that are both statically determinate and indeterminate, in masonry which is (depending on the scope of ETA gained) solid, hollow or perforated. Other anchors might also be approved by the manufacturer as being suitable.*

Injection-type bonded anchors are particularly suitable for use in masonry as they exert no expansion stresses in the base material. They will also fill any small voids present.

Where suitable anchors conforming to an EAD are available and the masonry of a particular project falls within the general category of the masonry type referred to in the ETA but does not conform to the dimensions and/or strength of the defined masonry type, then tests should be carried out on site to determine the allowable resistance [see **9.2**a)]. Where an anchor is being considered which does not conform to an EAD (or which does conform to an EAD but is not qualified for the category of masonry used on the project) and no published recommended resistance is available, then the tests called up in **9.2**b) should be carried out to determine the allowable resistance. The project documentation should clearly state which tests have been used.

*NOTE 2 Details of appropriate test regimes are given in Annex B.*

If considering a mechanical anchor, suitable types include self-tapping concrete screws, thin-walled sleeve anchors and some types of shield anchor in smaller diameters.

*NOTE 3 The suitability of specific anchor types for use in masonry is further discussed in Annex C and CFA Guidance Note Fixings for brickwork and blockwork [16]. It is expected that the suitability of the anchor will be clearly stated by the manufacturer.*

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[5] It is expected that ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard has not, as yet, been implemented.

#### 5.3.3.3.2 Positioning anchors in masonry

For anchors which are qualified according to an EAD , spacing and edge criteria are given in the relevant ETA. For anchors which are not qualified according to an EAD , the following guidelines should be used in the absence of guidance from manufacturers of specific masonry types or specific anchor types, which would take precedence over these recommendations.

In deciding anchor positioning within masonry units, specifiers should take into account the ability of the masonry to withstand forces imposed by the action and/or the anchor (e.g. due to expansion). This will be influenced by factors such as the mass of masonry above and adjacent to the anchor location, the strength of individual masonry units and of mortar joints, and the presence of mortar within such joints.

The following positioning guidelines, illustrated for brickwork in Figure 5, should be followed.

a) Fix only in structural load-bearing masonry; ideally install in the body of the masonry unit (in bricks ideally on the horizontal centreline).

b) The distance below the top of an unrestrained wall should be sufficient to withstand the forces imposed by either the action or the anchor (e.g. by expansion).

c) Anchors should ideally not be set in mortar joints.

d) Centre spacings between anchors should be such as to avoid setting two anchors in the same masonry unit or, if loads are high, in adjacent masonry units.

   *NOTE 1 Centre spacings might need to be increased substantially in the case of masonry that is rendered or plastered.*

e) Anchors should not be set in the edge unit of a wall; an edge distance of at least 280 mm from a vertical edge is recommended for brickwork and 550 mm for blockwork.

*NOTE 2 The above positioning guidelines are designed to optimize anchor performance in masonry, and are valid in the absence of guidance from manufacturers of specific types of masonry unit or of specific anchor types, which would take precedence over these recommendations. Practical considerations might mean that these guidelines cannot be met, in which case anchor performance might be affected.*

It is strongly recommended that wherever possible, anchors should be located within the solid part of masonry units (see Figure 5). However, where it is specifically required that anchors are installed in the mortar joints to avoid locating them in the bricks themselves, e.g. in the case of a conservation order, then the following guidance should be adopted.

1) Choose an anchor with a diameter significantly larger than the width of the mortar joints, e.g. 14 mm in a 10 mm joint.

2) Fix the anchor into the base of the junction between horizontal and vertical joints (see Figure 6).

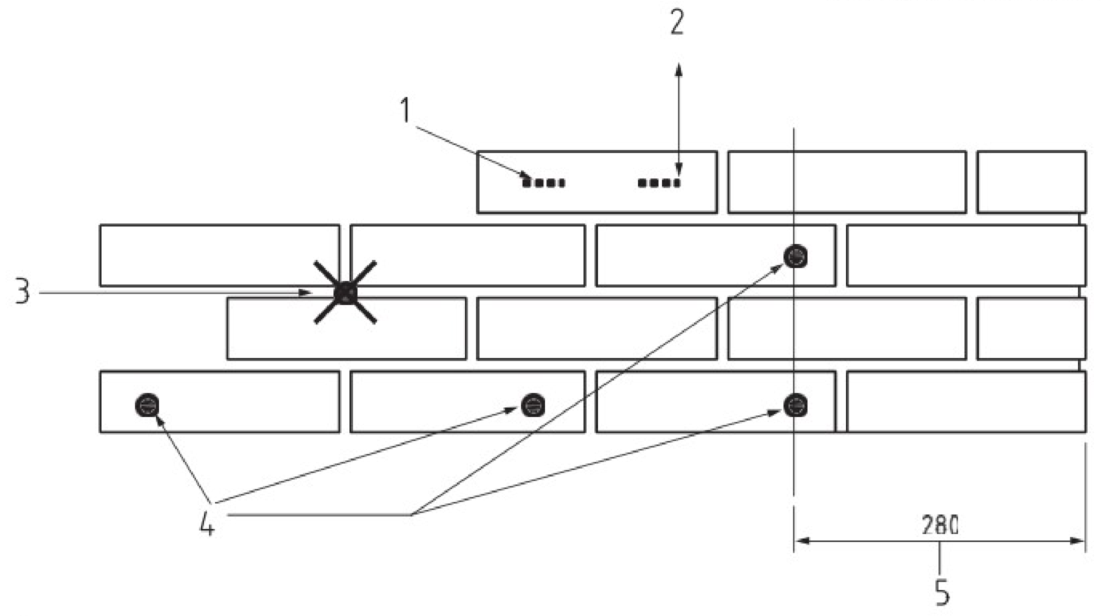
3) Carry out preliminary tests, with all tested anchors located in joints as shown in Figure 6.

   *NOTE 3 Preliminary tests are described in Annex B, **B.2.3.1**.*

4) Carry out proof tests as called up in **9.3** and detailed in Annex B, **B.3**, doubling the rate of proof testing.

**Figure 5** — *General anchor positioning guidance in brickwork*

Dimensions in millimetres



**Key**

1 Anchor located within structural load-bearing masonry unit

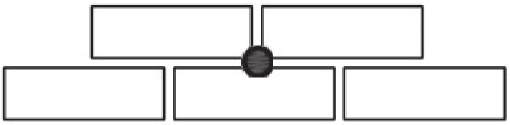
2 Anchor set sufficiently below the top of an unrestrained wall so as to withstand the forces imposed by the action or the anchor

3 Anchor not to be set in mortar joints

4 Anchors located in adjacent masonry units or, if loads are high, with at least one clear unit between

5 Anchors set away from the edge unit of a wall

**Figure 6** — *Anchor positioning for fixing anchors in joints*



Where the application dictates that anchors may be positioned anywhere in the brickwork, either in solid parts of the brick or in joints (e.g. due to a bracket design and location or due to the presence of render or plaster), then anchors may be fixed through the render, without the need to determine where the anchors are located in relation to the joints, provided that one of the following conditions is satisfied.

i) For anchors conforming to ETAG 020 [7][6] and EAD 330076-00-0604 [15], the design resistance should be reduced by a factor quoted in the EAD .

ii) For anchors not conforming to ETAG 020 [7] and EAD 330076-00-0604 [15]:

- Anchors should have a diameter significantly larger than the joint, e.g. 14 mm in a 10 mm joint.
- Carry out preliminary tests as called up in **9.2** and detailed in Annex B, **B.2.3.1**, on a sample of at least five anchors. All five test anchors should be set in areas where the joints have been exposed for the purpose of the tests, and should be set in joints in a variety

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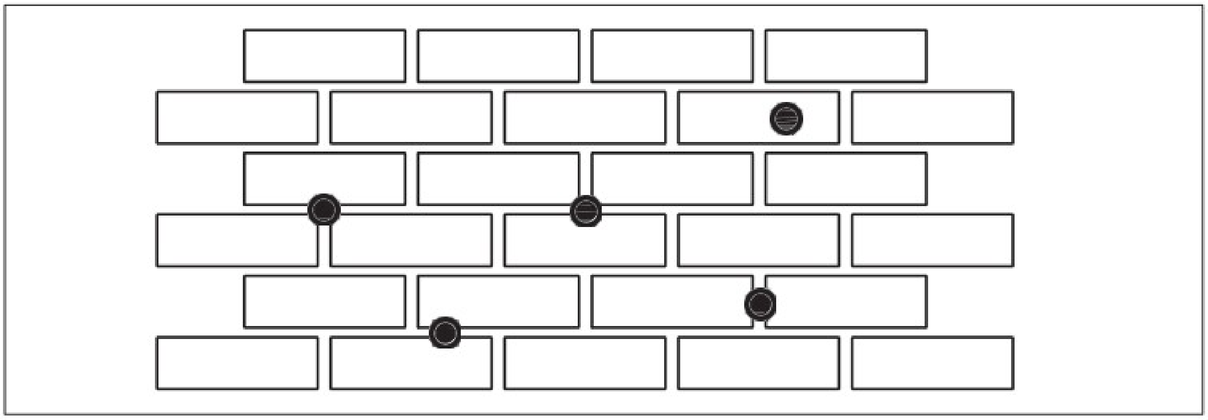
[6] ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard has not, as yet, been implemented.

of positions, including those shown in Figure 7, but with spacing between anchors large enough to avoid damage from one test affecting another. Tests which result in damage which might affect another test should be ignored and repeated at larger spacings.

- Carry out proof tests as called up in **9.3** and detailed in Annex B, **B.3**, doubling the rate of proof testing.

**Figure 7** — *Locations in joints for test anchors when anchors are to be installed through render or plaster*



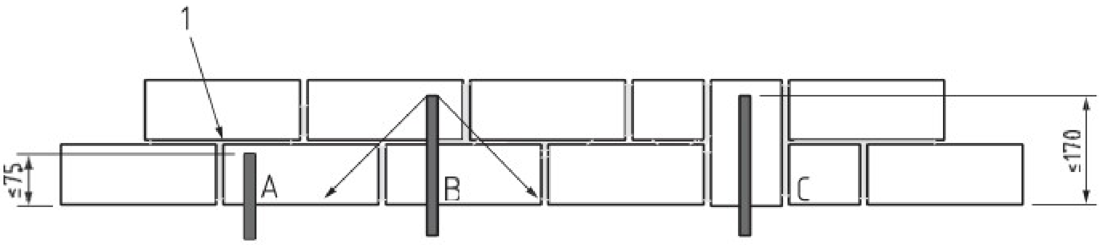
Where anchors are to be used in groups, e.g. fixing brackets, these should ideally be designed to avoid the possibility of two anchors being located in the same brick and, where possible, even in adjacent bricks. Closer spacings may be used with the use of resin anchor systems, as these impose no setting stresses in the brickwork and will also cope with installation in joints where this occurs. A minimum vertical spacing of 150 mm should still be aimed for, and setting two anchors in the same brick should be avoided.

### 5.3.3.3.3 Embedment depths in brickwork

When resisting actions in double‑skinned (215 mm/9 in thick) or triple‑skinned (330 mm/13 in thick) brickwork, maximum resistance in anchors will be achieved when anchors are embedded in the rearmost leaf (see B in Figure 8). The hole depth for anchoring into the rear brick of 215 mm structures should be not more than 170 mm. Any deeper risks breaking the back of the brick out under the drilling action.

**Figure 8** — *Embedment and hole depths in brickwork*

Dimensions in millimetres



**Key**

1 Joint between leaves might be poorly filled; avoid using this area for holding power

A Anchorage in the front leaf for low loads only

B Anchorage in the rearmost leaf benefits from interlock with the front

C Anchorage into headers

Only where loads are small should anchors be set into the front leaf (see A in Figure 8), and when this is done, the embedment depth should be chosen to optimize the strength in the brick. The depth

to avoid spalling the back of the front brick should be not more than 75 mm. Hole depths vary with anchor type. Where possible, the anchor should not be set with its effective embedment in the joint between leaves (particularly resin anchors). The rate of proof testing anchors set in header bricks (which might be loosened during drilling) should be doubled to make sure that the whole installation (including the brick and surrounding mortar joints) can take any tensile loads involved. Anchorage into headers (see C in Figure 8) is ideal if loads are in shear and mortar joints are sound, but preliminary tests, as called up in **9.2**, should be carried out.

In the case of weak masonry (including weakness of mortar joints), or where tests show that the required performance cannot be achieved, the specifier may consider other options, such as incorporating sufficiently sized concrete padstones into the masonry structure. In this case the padstone should have sufficient dimensions to satisfy the edge and spacing limits of the anchor as specified by the manufacturer.

### 5.3.4 Actions

#### 5.3.4.1 Statically determinate or indeterminate applications

Anchors should be chosen that are suitable for use in statically determinate or indeterminate applications, as appropriate [see **5.2**c)].

*NOTE Anchors conforming to EAD 330232 -00 -0601 [8] and EAD 330499 -00 -0601 [11] are suitable for use in applications which are statically determinate or statically indeterminate. Anchors conforming to EAD 330747 -00 -061 [6] are suitable for use only in applications which are statically indeterminate, and which satisfy the qualifications for multiple use specified in that part of EAD 330747 -00 -061 [6].*

#### 5.3.4.2 Direction of loading

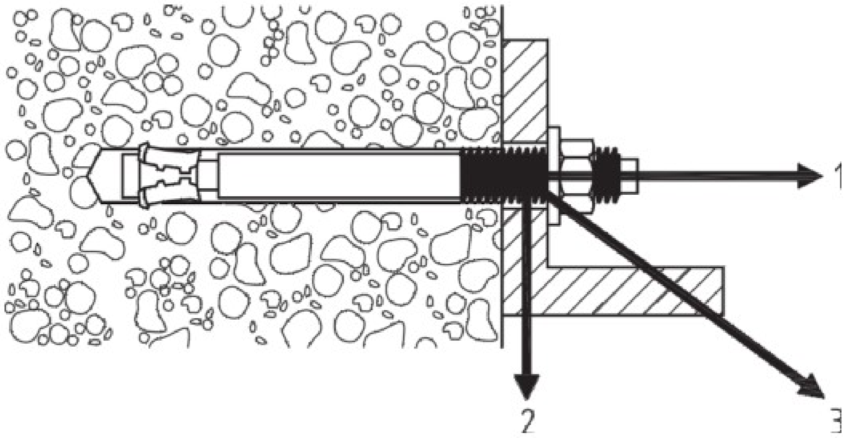
##### 5.3.4.2.1 Tensile and shear actions

Specifiers should match the anchor capability to that of the proposed anchor in terms of the direction of loading.

*NOTE 1 Different anchor types have different capabilities in terms of their resistances at different angles of loading (see Figure 9). Tensile anchor performance is dependent on a variety of factors including anchor type, anchor rod material, base material strength and quality of installation, whereas shear performance is dependent broadly on anchor rod material and base material strength (provided sufficient edge distance is present) and is little affected by installation quality. Anchors conforming to EAD 330232 -00 -0601 [8] and EAD 330499 -00 -0601 [11] might be qualified according to various options, some of which allow the anchor performance in shear and tension to be assessed independently, while others allow only the lowest value to be declared for all directions. This lower value can limit the design capability of the anchor.*

*NOTE 2 Various notations are used to denote the different actions and resistances: F is used where loading direction is not specified, N is used to denote tensile actions, and V to denote shear actions.*

**Figure 9** — *Tensile, shear and combined actions*



**Key**

1 Tensile

2 Shear

3 Combined

### 5.3.4.2.2 Combined actions

When anchors are loaded in both tension and shear simultaneously, it is not sufficient to check that the design tensile action, $N_{\mathrm{Ed}}$, is less than or equal to the design tensile resistance, $N_{\mathrm{Rd}}$, and do the same for shear; a check for combined actions should be carried out (see **A.3**).

### 5.3.4.2.3 Bending actions

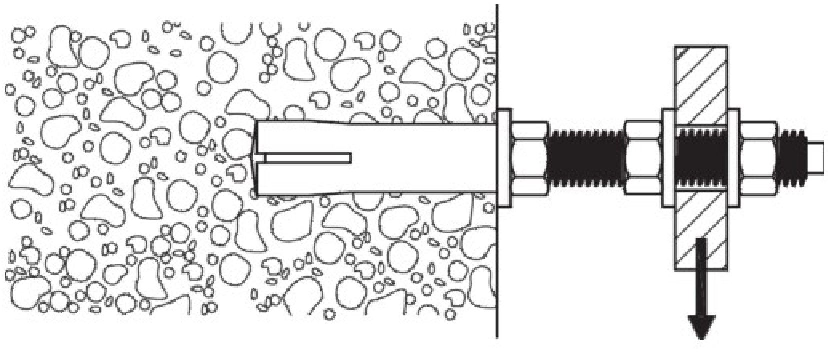
Most anchors have relatively poor bending resistance. As far as possible, fixtures should be designed so as to avoid bending actions being applied to anchors. This is best facilitated by taking all lateral loads into the anchor in pure shear or as a combination of tension and shear.

Where bending moments exist, the specifier should ensure that the bending resistance specified for the anchor, $M_{\mathrm{Rd}}$, is not exceeded.

*NOTE 1 Bending does not only occur where there are stand-off applications. The same condition can occur where shimming or grout exists under a shear-loaded base plate.*

*NOTE 2 An example of a bending action is shown in Figure 10.*

**Figure 10** — *Example of a bending action*

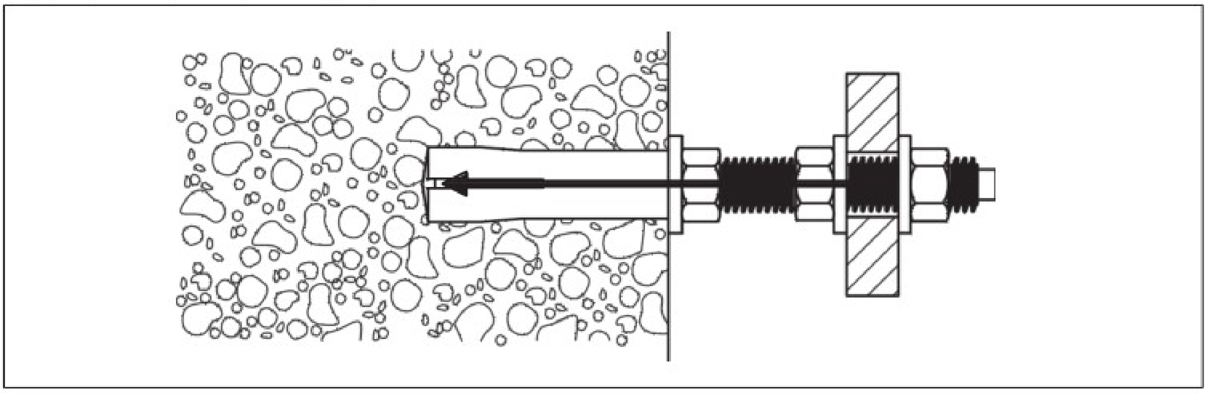


### 5.3.4.2.4 Compressive actions

Compressive actions, if applied, are normally transferred from the fixture directly into the base material with little or no effect on the anchor. If the arrangement is such that the compressive action is taken from the fixture into the base material via the anchor, the specifier should check that the anchor is capable of taking such an action, and that there is sufficient base material behind the anchor to support the action.

*NOTE An example of a compressive action is shown in Figure 11.*

**Figure 11** — *Example of a compressive action*



### 5.3.4.3 Nature of loading

#### 5.3.4.3.1 General

The nature of the load application can significantly affect the ability of the anchor to resist it. There are two aspects which the specifier should take into account when determining the design resistance and the type of anchor:

a) the nature of the load application: is it static, or non-static? (see **5.3.4.3.2**);

b) the duration of the loading: is it applied over the short term or the long term? (see **5.3.4.3.3**).

#### 5.3.4.3.2 Static and non-static actions

Specifiers should choose an anchor capable of sustaining the nature of the action, i.e. static or non-static. If in doubt as to how to treat applications involving non-static actions, specifiers should seek advice from the manufacturer or their agent.

*NOTE Annex E gives further guidance on static and non-static actions.*

#### 5.3.4.3.3 Duration of loading

Specifiers should choose an anchor with a design life appropriate to the application. For applications requiring a design life of more than 50 years, the manufacturer's advice should be sought.

*NOTE 1 Anchors conforming to most EADs are qualified for a design life of 50 years, in terms of both their resistance to corrosion in the environmental conditions quoted, and their ability to sustain the design resistance for that period. Currently there is little information available regarding design lives greater than 50 years.*

*NOTE 2 For temporary loading (e.g. scaffold anchoring and steeplejacking), reduced factors are used in the determination of allowable resistance (see Annex B, **B.2.3.1.1** and Table B.1).*

### 5.3.5 Environmental parameters

#### 5.3.5.1 General

Two environmental parameters can influence the performance of an anchor and hence its correct selection: corrosion conditions (see **5.3.5.2**), and temperature (see **5.3.5.3**). Specifiers should select anchors suitable for the conditions pertaining.

### 5.3.5.2 Corrosion

### 5.3.5.2.1 General

*COMMENTARY ON **5.3.5.2.1***

*One of the final things to consider when selecting an anchor is the environment in which the anchor is set. Corrosion takes several different forms, resulting in different types and rates of corrosion, which are described in Annex F. It is therefore important to have an understanding of the potential causes in order to plan to avoid them. Guidance is given in the CFA Guidance Note Fixings and corrosion [17].*

Risk of corrosion of anchors can be minimized by specifying measures appropriate to the environment, e.g. the specifier can specify protective coatings or stainless steel but should check the availability of the selected anchor with the required protective coating or steel grade (see Table 1). Corrosion protection requires special attention, if in doubt; the anchor specifier should seek specialist advice.

For anchoring applications, the designer should avoid creating crevices in bolted joints (see Annex F, **F.6**).

### 5.3.5.2.2 Minimizing the risk of corrosion

The specifier should choose an appropriate material that is likely to be corrosion-resistant in the particular application conditions (see Annex F).

*NOTE 1 It is advisable to check with the anchor manufacturer if the anchor is to be installed in an environment which might contain exceptional pollutants.*

*NOTE 2 Table 1 gives a list of materials that are expected to be suitable in specific conditions. The information is provided as guidance only, and the list of materials is not exhaustive.*

**Table 1** — *Anchor materials used to minimize the risk of corrosion*

| **Application condition** | **Anchor materials for required duration**A), B) | | |
|---|---|---|---|
| | **Short term** | **Medium term** | **Long term** |
| Dry internal | FE-Zn | FE-Zn | FE-Zn |
| Internal humid, no chlorides, or acid condensates | FE-Zn | HDG + | SS A2<br>SS D2 |
| External – rural, urban, light industrial areas with light/modest pollution. Internal permanently damp | HDG + | HDG + | SS A2<br>SS D2 |
| ExternalC) – industrial or coastal but not immersed or splash zone, see special applications | HDG + | SS A4<br>SS D4 | SS A4<br>SS A5<br>SS D4<br>SS D6 |
| Special applicationsD) | Special alloys of stainless steel | | |

**Table 1** *(continued)*

| Application condition | Anchor materials for required duration A), B) | | |
|---|---|---|---|
| | **Short term** | **Medium term** | **Long term** |

A) Approximate duration:

- short term = ≤2 years;
- medium term = ≤10 years;
- long term = ≤50 years.

B) Materials:

- FE-Zn = zinc-plated carbon steel with or without chromate passivation;

*(Chromate passivation can prevent "white rust" of zinc caused by chemicals in packaging. Yellow chromate is being phased out in favour of "blue" – clear – passivation. Some manufacturers use the term "galvanized" for zinc electro-plated products.)*

- HDG + = Hot dip galvanized carbon steel and other coating processes such sherardizing;
- stainless steel grades:
- SS A2 = austenitic stainless steel grade A2 as defined in BS EN ISO 3506-1:2009, Table 1 – suitable alloy 1.430 1 as defined in BS EN 10088-1:2005 (grade A2 will eventually stain);
- SS A4 = austenitic stainless steel grade A4 – suitable alloys 1.4401; 1.443 6 (grade A4 is unlikely to stain in normal use);
- SS A5 = austenitic stainless steel grade A5 – suitable alloy 1.4571;
- SS D2 = duplex stainless steel grade D2 – suitable alloys 1.4162; 1.4062; 1.4482 (a revision to include these materials in BS EN ISO 3506-1 and BS EN ISO 3506-2 is currently in process);
- SS D4 = duplex stainless steel grade D4 – suitable alloy 1.4362;
- SS D6 = duplex stainless steel grade D6 – suitable alloy 1.4462.
- special alloys of stainless steel = high corrosion-resistant stainless steels of the duplex type and austenitic steels with higher alloy content than A4 (sometimes referred to as grade C or HCR) – suitable alloys 1.452 9 and 1.456 5.

C) External applications involve normal conditions with no exceptional pollutants.

D) Special applications include: permanent or alternating immersion in sea water or the splash zone of marine installations, chloride atmospheres of swimming pools (especially those within roof spaces), atmospheres with high chemical pollution such as road tunnels and other road and rail applications where de-icing salts are used, desulfurization plants, and others.

#### 5.3.5.3 Temperature

Specifiers should take into account the performance limitations of some anchor types as specified by the manufacturer against the following conditions.

*NOTE 1 Types of anchor are described in Annex C.*

a) **Service temperature ranges.** Specifiers should take into account the temperature likely to be prevailing during the service life of the installed anchor, and should specify an anchor system which is suitable.

*NOTE 2 Steel anchors (carbon steel, and stainless steel) are normally suitable for service temperature ranges from −40 °C with no upper limit in normal applications. Bonded anchors are usually suitable in lower temperatures from −40 °C but are offered with different upper service temperature limits (typically 80 °C to 120 °C) depending on type. For most bonded anchors, two limits will be specified: a short-term temperature* *limit, e.g. for day/night cycles, and a (lower) long-term temperature limit for continuous conditions such as boiler rooms. Plastic anchors also have a more limited range of service temperatures, typically for nylon anchors of PA6, from −40 °C to +80 °C.*

*NOTE 3 The design life might be restricted for anchors used in higher temperatures; refer to the EAD or to the manufacturer.*

b) **Installation temperature ranges**. Bonded anchors are the only type of anchors which should be installed within a limited temperature range. Specifiers should take into account the temperature likely to be prevailing at the time of installation, and should specify a bonding material which is suitable.

*NOTE 4 The lower installation temperature limit can range from below zero to +5 °C while the upper limit can vary from +20 °C to +40 °C; this is a practical limit for the mixing of the resin and for inserting the metal part.*

*NOTE 5 Manufacturers quote these limits in technical data sheets, which can be either base material temperature (usually) or ambient temperature. Appropriate guidance for installers is given in 7.2.*

c) **Fire**. The specifier should obtain the relevant data before confirming the specification of an anchor for an application requiring a fire rating.

*NOTE 6 The performance of anchors in fire conditions will depend on the duration of exposure and the type of anchor, but is frequently limited by the strength of the connection at the surface, even in the case of resin bonded anchors. Some products have characteristic resistances for particular durations of exposure to fire conditions. Others have data based on tests against typical fire curves which relate the loading on the anchor to the duration of exposure. Stainless steel anchors usually perform significantly better than carbon steel anchors in such tests. Duration can be extended by the application of suitable fire protection. Guidance is given in the CFA Guidance Note Fixings and fire [18].*

#### 5.3.5.4 Creep

*COMMENTARY ON **5.3.5.4***

*Anchor types that are most susceptible to creep (**3.1.15**) are plastic anchors and some particular types of resin bonding materials not generally available within the UK.*

*Creep characteristics can be more emphasized at elevated temperatures.*

*Resin anchors can exhibit symptoms of creep if loaded or tightened before the appropriate curing time is reached.*

*Creep of plastic materials requires higher safety factors to be used in the on-site test procedure outlined in **B.2.3.1**.*

*The characteristics of creep are taken into account in anchors conforming to EADs.*

Specifiers should ensure that the chosen anchor will remain functional with the amount of creep that is anticipated to occur over the service life of the anchor.

### 5.3.6 Practicalities

#### 5.3.6.1 Design of the fixture

*NOTE 1 The overall design of fixtures is outside the scope of this British Standard, but there are some factors that directly affect the anchor.*

The following factors should be taken into account in the design of fixtures.

a) **Diameter of the clearance hole in the fixture**. The manufacturer's recommendations for clearance hole diameters should be met. The clearance hole should take account of the diameter of the drill bit for through drilling, as the tips of hammer drills are slightly larger than their nominal diameter to take account of wear.

*NOTE 2 Manufacturers' recommendations will normally be in accordance with BS EN 1992-4:2018 Table 6.1.*

*NOTE 3 Additional clearance or slots might be necessary to take account of application conditions such as tolerances and installation procedures, but if clearance holes are larger than the manufacturer's recommendations then special plate washers might be needed.*

*NOTE 4 Some manufacturers recommend the injection of resin mortar into clearance holes under certain circumstances to improve the transfer of shear loads, which might be a condition of the design.*

b) **Edge distance of clearance holes in fixture and base plate stiffness**. Design methods may be based on the assumption of a stiff base plate (fixture). This will be affected by the edge distance within the base plate to the clearance holes and the base plate thickness. These aspects should be designed in accordance with normal structural steel practice.

*NOTE 5 BS EN 1993 recommends at least 1.2 × clearance hole diameter for drilled holes and 1.5 × clearance hole diameter for punched holes.*

### 5.3.6.2 Need for through fixing

Some anchor types cannot be installed through the fixture, e.g. shield type anchors, drop-in anchors and most types of resin bonded anchors. Specifiers should take into account the implications of this when selecting the anchor type, as these anchors require more care in setting out hole locations, drilling holes and placing fixtures over projecting studs.

### 5.3.6.3 Immediacy of loading

If it is important that anchors can be tightened or loaded immediately after installation, specifiers should choose an anchor that is capable of achieving this.

*NOTE This might rule out most types of resin anchor, although resin formulations are already available which can cure in a matter of minutes. Otherwise, the fixture might need to be temporarily supported while the resin is curing.*

### 5.3.6.4 Removability

If the fixture is likely to need to be removed at some time in the future, then this should be taken into account at the selection stage. Some anchors can be readily removed, while others are virtually impossible to remove. If such anchors are nevertheless specified, they will need to be cut off, and if in an external application they should be of stainless steel to avoid staining and possibly damaging the structure.

*NOTE In some cases, e.g. "throughbolt" types of expansion anchor, which are difficult to remove, over-drilling the hole depth will facilitate burying the anchor body in the concrete, if it is necessary to permanently remove the fixture and eliminate the projection of the anchor from the substrate.*

### 5.3.6.5 Reuse of anchors

Most anchors are not removable, and where removal is possible, the anchor is generally damaged, rendering it unusable. Some manufacturers have products such as concrete screws, which they approve for limited reuse, under strict conditions. Adjustment of concrete screws can be carried out in accordance with EAD 330011-00-0601 [30].

## 5.4 Factors determining anchor size

Once the type of anchor has been provisionally chosen, the specifier should determine the size of anchor.

*NOTE 1 The anchor diameter is determined primarily from considerations of actions in accordance with design methods outlined in Annex A. The anchor length usually derives from a combination of the fixture thickness and effective embedment depth, which may also be determined in the design process (particularly bonded anchors) or is* *directly related to the diameter and predetermined by the manufacturer. Some anchor types have different lengths covering ranges of fixture thicknesses.*

If the base material includes a non‑structural screed or topping, plaster or render, this should be included in the calculation of the fixture thickness. Any shims allowed for in the design should also be included in the fixture thickness.

*NOTE 2 If the proposed anchor does not satisfy the design criteria, then changing edge and spacing criteria might resolve the problem; otherwise an alternative anchor of a different type or from a different manufacturer might need to be considered.*

### 5.5 Completing the specification

Once the chosen design method has been fully completed, the specifier should complete the selection process by specifying the anchor in detail (see **6.4**), in order to ensure that the correct anchor is procured and correctly installed. To achieve this, the specifier should use the full anchor designation that is in the anchor manufacturer's literature, including any relevant reference numbers or designations.

*NOTE As anchors of similar types and sizes can have significantly different performance, it is insufficient to specify a general description such as "M16 x 200mm Heavy duty sleeve anchor", as this could lead to an anchor with inadequate performance being used.*

The manufacturer's full installation instructions should also be detailed, rather than the phrase "Install as per manufacturer's instructions".

This specification should be communicated to the contractor and installer in appropriate project documentation, including the printout from the anchor manufacturer's software, if used.

These recommendations do not preclude a change of specification at any stage, but if the anchor specification is to be changed, then the change management procedure outlined in Clause **10** should be followed.

## 6 Information to be provided by manufacturer/supplier, designer and specifier

### 6.1 General

In order that all parties involved in the use of anchors can fulfil their responsibilities, the information listed in **6.2** to **6.6** should be provided by the relevant parties.

Additional information regarding detailed anchor technology and design, ETA reports and safety data sheets, where applicable, should also be made readily available.

### 6.2 Information to be provided by the manufacturer/supplier to the specifier

Comprehensive technical data should be provided by the manufacturer/supplier to the specifier, including the following:

- designation of anchor including size and type;
- material type used to manufacture the anchor, e.g. stainless steel/carbon steel;
- design method (see Annex A);
- performance data, including:
  - characteristic resistance;
  - design resistance (or partial safety factor, for the material, to enable it to be calculated);
  - recommended resistance (or appropriate safety factor, to enable it to be calculated);
- edge and spacing criteria;

- minimum thickness of base material;
- setting details including effective embedment depth, temperature limits and curing times where relevant;
- installation equipment;
- installation instructions;
- maximum and minimum fixture thickness.

*NOTE The anchor manufacturer generally provides the required information in any (or all) of the following formats:*

- *technical manuals;*
- *anchor design software;*
- *any associated information on anchor technology and design, ETAs and safety data sheets (SDS), where applicable;*
- *website.*

### 6.3 Information to be provided by the designer to the specifier

If the designer is not also the specifier, they should supply all the necessary information to enable the specifier to select and specify the anchor (except where information is already known to the specifier, e.g. if the specifier works for the contractor). This information should include, for example:

- confirmation that the structure is capable of sustaining the characteristic action;
- the status of the concrete (cracked/non-cracked);
- whether the application is statically determinate or statically indeterminate;
- the design actions and their nature (static/non-static etc.);
- details of the base material type, thickness and likely strength at the time of installation;
- preferred edge distance and centre spacings;
- details of the base plate, material and thickness;
- environmental conditions, including elevated temperatures or fire rating requirements, corrosion conditions and required durability or life expectancy.

### 6.4 Information to be provided by the specifier to the contractor/installer

The following information should be provided by the specifier in project documentation to the contractor/installer:

- full description, including:
  - make;
  - type;
  - ETA number where applicable;
  - size (nominal diameter and overall length);
  - designation;
  - manufacturer's catalogue/reference or order number;
- instruction to follow manufacturer's installation instructions;
- full installation instructions, including:
  - hole diameter in base material;

  - clearance hole diameter in fixture;
  - hole depth, taking account of fixture thickness (see 7.3.3);
  - installation torque, where applicable;
- anchor spacings and edge distances on project drawings (these should be specified with no minus tolerances);
- minimum base material thickness;
- minimum compressive strength of concrete (or mortar in masonry structures) assumed in the calculation of design resistance;
- instructions as to what action is to be taken in the event of hitting reinforcement during drilling (see 5.3.3.2.5);
- additional requirements specific to the particular anchor or application;
- a warning that the anchor specification should not be changed without a full selection process being undertaken.

## 6.5 Information to be provided by the manufacturer/supplier to the contractor/installer

The following information should be clearly marked on the packaging or contained within the packaging of the anchors supplied by the manufacturer/supplier:

- manufacturer, type, designation and size (diameter and length);
- setting details;
- installation instructions;
- setting tools required with catalogue numbers/order codes;
- curing time and temperature limits where applicable;
- hazard warnings;
- storage instructions where applicable.

## 6.6 Information to be provided by the specifier to the tester

The following information should be provided by the specifier (or responsible engineer requesting site tests) to the tester:

- test objective – determination of allowable resistance (e.g. by preliminary tests) or validation of installation quality (e.g. by proof tests);
- designation of anchor to be tested;
- installation details;
- base material – strength if known;
- preliminary test load, $N_{test}$ (for preliminary test);
- proof test load, $N_p$ (for proof test);
- direction of loading;
- number of tests required;
- location and specific requirements for edge distances;
- details of accessibility of anchors to be tested;
- if testing involves work at height – full details.

# 7 Installation of anchors

## 7.1 General

The contractor should ensure that the person installing the anchors is competent and has the following.

*a)* **Training**. Training in the setting of the particular anchor may be provided on site by the contractor or by the supplier/manufacturer.

*NOTE Training from other projects might not be applicable, as the installation requirements vary between different anchors. Competent installer training schemes are available from trade associations and some manufacturers.*

*b)* **Knowledge**. The installer should have knowledge of the function of the anchor, and the consequence if the installation procedures are not adhered to.

*c)* **Experience**. The installer should have experience of installing the particular type of anchor. If the installer has limited experience, closer supervision should be provided by the contractor, to ensure that the installation is correct.

Each anchor type will have different requirements for its correct installation. Subclauses **7.2** to **7.6** give a summary of the key stages of the installation of an anchor, which should be carried out in sequence so as to ensure its correct installation.

## 7.2 Installation procedures

Installers should install anchors strictly in accordance with the manufacturer's installation instructions.

*NOTE A typical installation procedure is as follows.*

*a) Prior to installation, confirm that the age of the concrete or mortar of masonry structure is at least 28 days, or, if it is not, that it has at least reached the compressive strength assumed in the selection process and stated in the information supplied by the specifier.*

*b) Drill the hole with the correct nominal diameter drill bit, using a suitable drilling machine fitted with a depth gauge which facilitates drilling to the correct hole depth. Unless otherwise stated, drill the hole perpendicular to the surface, i.e. at 90° ±5°.*

*c) Clean the hole according to the manufacturer's written installation instructions. For most mechanical anchors, using a blow out pump might be adequate to remove dust and fragments from the hole. For resin bonded anchors, use a brush (of the correct diameter and material) in addition to the blow out pump (follow the manufacturer's recommended sequence). If the use of compressed air is recommended, check that no oil contamination is present in the compressed air.*

*d) Use setting tools as recommended/supplied by the manufacturer and appropriate to the type and size of anchor being installed.*

*e) For bonded anchors, allow the full curing time (this is dependent on base material temperature) before tightening or loading.*

*f) Tighten the anchor to the recommended tightening torque as stated by the anchor manufacturer.*

*g) If the hole has been produced using diamond drilling techniques, check with the anchor manufacturer whether this is a suitable technique or if roughening is required, e.g. in the case of resin bonded anchors.*

## 7.3 Aspects of installation

### 7.3.1 General

The manufacturer's recommendations for the specified anchor should take precedence over all other guidance. Installation procedures for products of a similar type but from different manufacturers might be different, so installers should never assume that the same process applies as for other products.

Installers should also follow the recommendations in **7.3.2** to **7.3.8**.

### 7.3.2 Hole diameter

Holes should be drilled with the drill bits that are recommended by the anchor manufacturer.

*NOTE Manufacturers usually specify hammer drill bits for use in concrete and masonry that conform to BS ISO 5468, which specifies plus tolerances for the tip diameter to allow a certain amount of wear before the hole becomes too small for insertion of the anchor.*

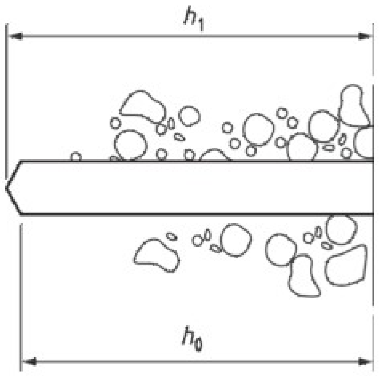
### 7.3.3 Hole depths and embedment depths

Hole depths should conform to the manufacturer's instructions.

a) If the instructions refer to the deepest point in the hole (designation $h_1$), the measurement should be to the point of the drill tip, as shown in Figure 12.

b) If the instructions refer to the depth of the cylindrical part of the hole (designation $h_0$), the measurement should be to the shoulder of the drill, as shown in Figure 12.

**Figure 12** — *Hole depths*

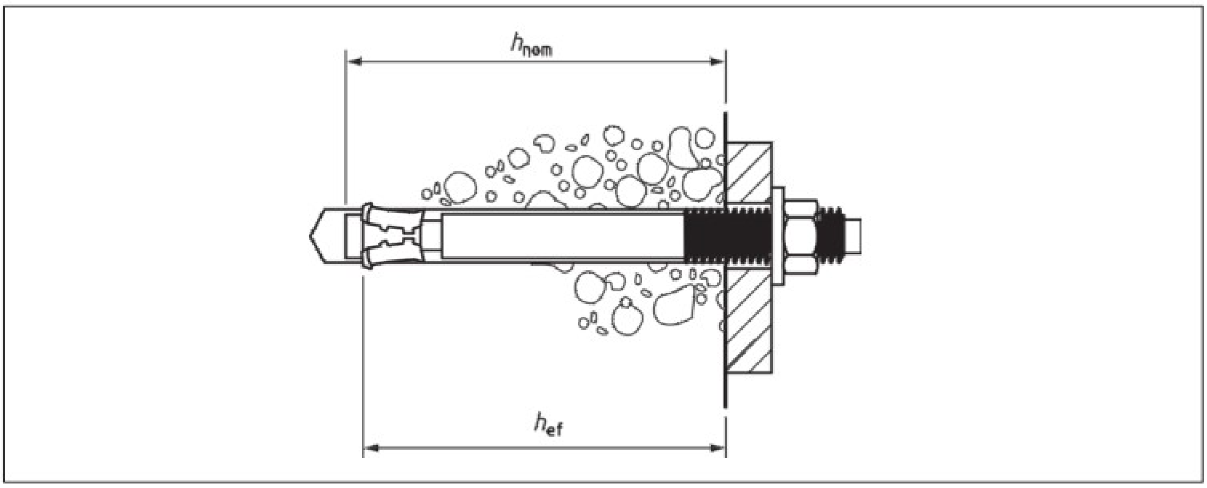


If hole depths are quoted by the manufacturer for the largest allowable fixture thickness [typically this is done for anchor types such as heavy duty sleeve anchors, thin-walled sleeve anchors and throughbolts (stud-type expansion anchors); see Annex C], then the hole depth might need to be increased pro rata for thinner fixtures. A check should also be made to ensure that there is enough structural thickness beyond the anchor, to ensure that the drilling operation does not cause the remote face of the base material to spall away [see **5.3.3.2.4**c)].

Installers should always install anchors so as to achieve the effective embedment depth implied by the specification.

*NOTE 1 The embedment depth can be referred to as either the embedment depth, $h_{nom}$, meaning the hole depth from the surface to the lowest part of the anchor, or the effective embedment depth, $h_{ef}$, the depth from the surface to the lowest point of the anchor that engages with the base material (see Figure 13). In the case of resin bonded anchors, it is possible for $h_{nom}$, $h_{ef}$ and $h_0$ to be the same. It is the effective embedment depth that determines the relative performance of the anchor: the deeper the effective embedment depth, the greater the design resistance for concrete cone capacity.*

**Figure 13** — *Embedment depths*



Anchors should be obtained which are the correct length as specified, anchors should never be shortened for any reason, and where shims, packers or grout are used, their thickness should be included in the overall fixture thickness. If shimming or grout thicker than specified are used, the specifier should be informed so that the effect on the design (bending effects) can be checked. Longer anchors might need to be specified to compensate for increased fixture thickness.

*NOTE 2 If this is not done, the effective embedment depth actually achieved will be reduced and consequently the design resistance might be reduced.*

### 7.3.4 Installation equipment

Setting equipment for products of a similar type but from different manufacturers might be different, so installers should always use the specific setting equipment for the particular anchor being installed.

### 7.3.5 Tightening torques

A calibrated torque wrench should be used to apply the manufacturer's recommended installation torque, $T_{inst}$. Most torque wrenches used on site can be set to a certain torque setting indicated by a click. Tightening should not continue beyond this point, or the anchor might be over-tightened. Torque wrenches can have more than one scale, so users should ensure that they set the wrench to the correct scale, or anchors might be significantly over- or under-tightened. Deep reach sockets should be used for anchors with projecting threads. Torque wrenches should be recalibrated at intervals not exceeding 12 months.

*NOTE For applications of a high safety criticality where the fixture is clamped, and it is desirable to ensure that it remains clamped throughout the design life of the anchorage, it might be advantageous to re-tighten anchors to the manufacturer's recommended installation torque after a few days. This reduces the effect of relaxation of the pre-tensioning force, and ensures that a higher residual clamping force is retained through the fixture in the long term.*

### 7.3.6 Installation aspects specific to resin anchor systems

#### 7.3.6.1 Installation temperature ranges

Installers should install anchors only within the installation temperature range as stated on the packaging, and should allow the full curing time relating to the prevailing temperature, as these vary significantly with make and type. The temperatures quoted will usually relate to the base material, and installers should take account of the fact that the base material temperature can be significantly different from the ambient.

*NOTE The lower installation temperature limit might range from below zero to +5 °C, while the upper limit can vary from 20 °C to 40 °C: this is a practical limit for the mixing of the resin and for inserting the metal part.*

The curing time is that time after mixing/insertion during which the anchor should be left undisturbed before it is either tightened or loaded. Resins might appear to be cured at times significantly shorter than the manufacturer's quoted curing time, but tightening or loading resin systems before the stated time carries the possibility of overstraining the resin bond and reducing the safety margin significantly. Curing times should therefore never be reduced.

Injection systems will also carry a recommendation for the time after mixing in which the metal part should be inserted, sometimes referred to as "gel time", "setting time", "working time" or "open time". It is best practice, however, to insert the metal part immediately the resin mortar has been injected into the hole.

#### 7.3.6.2 Shelf life and storage conditions

Prior to use, resin materials should be stored in conditions recommended by the manufacturer.

*NOTE This will usually mean "dark and cool", with a typical storage temperature range of +5 °C to +25 °C. If kept in these conditions, resin materials are expected to remain usable for the shelf life declared on the packaging (usually by means of a "use by" date).*

If the resin of a capsule system is found no longer to be liquid when at normal room temperature (it should flow, albeit slowly), this is an indication that the resin has been exposed to an excessive storage temperature, and has cured. If this is the case, it should not be used. If resin injection cartridges show signs of leakage, these too should not be used.

#### 7.3.6.3 Installing resin materials into wet holes

Installers should check with the manufacturer before installing anchors in wet holes, as some resin materials are not compatible with this condition.

If installation in wet or damp holes is allowed, the curing time will be increased due to the cooling effect of the water. Unless otherwise stated, the curing time should be doubled for wet conditions.

Care should be taken to ensure that all dust has been removed from the hole before it is allowed to become wet.

Some manufacturers allow hole cleaning by flushing with clean water, in which case all excess water should be removed, unless the specific resin material is approved for installation in flooded holes (or under water), in which case the manufacturer's instructions should be strictly followed. Holes which have become flooded after drilling and before insertion of the resin, e.g. by rainwater, should have all excess water removed along with any dust or spoil taken into the hole by the rain and, where relevant, the curing time increased.

### 7.3.7 Installation accuracy of pre-positioned anchors

If the specified anchor is one which cannot be installed through the fixture, e.g. shield type anchors, drop-in anchors and most types of resin bonded anchors, care should be taken in setting out hole locations, drilling holes and placing fixtures over projecting studs. Templates should be used where necessary for drilling holes, to ensure correct location.

### 7.3.8 Modifying anchors

Proprietary anchors should never be adapted, altered or modified in any way without the written permission of the manufacturer. Such permission should be retained within the project documentation.

## 7.4 Strength of concrete at the time of installation

Ideally, concrete, and the mortar of masonry structures, should have reached at least its specified design strength prior to the installation of the anchor.

Some anchor types will not function correctly if installed in concrete that has not reached its specified design strength, or in masonry with mortar that has not fully cured. If for construction reasons it is required that anchors are installed in concrete that has not reached its design strength, then the contractor should ascertain the actual compressive strength pertaining at the time of installation, and ensure that anchors are not installed if that strength is lower than that stated as the assumed strength according to the information supplied by the specifier. If the actual strength is lower than the assumed strength then the specifier should be asked for instructions. The specifier may choose to recalculate the design resistance relating to the actual concrete compressive strength, as long as this is greater than the minimum allowed by the manufacturer; or may decide that the installation should be delayed until the assumed strength is reached.

## 7.5 Hitting reinforcement

If reinforcement is hit during the drilling process then the installer should check with the responsible engineer as to what action is to be taken (see **5.3.3.2.5**).

Options might include drilling through the reinforcement if this action is approved by the engineer; but if not then the anchor should be moved.

The new hole should be located away from the aborted hole by at least the depth of the aborted hole. A smaller distance is allowed if the aborted hole is filled with high strength non-shrinkable mortar. If no shear or oblique tension is acting in the direction of the aborted hole, then the minimum distance between aborted and new drill hole should be:

- 1 × hole diameter for aborted hole depth $<0.4 \times h_{ef}$;
- 3 × hole diameter for aborted hole depth $\geq 0.4 \times h_{ef}$.

If shear or oblique tension is acting in the direction of the filled aborted hole, then the minimum distance should be at least $1 \times h_{ef}$ or 5 × hole diameter, whichever is the greater. (Different recommendations might be made by the manufacturer in the case of particularly deep embedment depths.) This might mean designing and fabricating new brackets or base plates, in which case the anchor spacing criteria of the manufacturer should be taken into account along with the effect on loadings.

On no account should any anchor be cut short or replaced with a shorter one and set into a hole limited in depth by the reinforcement. Nor should attempts be made to enlarge the hole diameter or force drills past the rebar if this will result in a hole that is no longer straight.

## 7.6 Installing anchors in masonry

*NOTE 1 See also 5.3.3.3.2 and 5.3.3.3.3.*

Installers should take account of the fact that when drilling into softer types of masonry, especially when using powerful hammer drilling machines, holes can open up significantly over size, which can reduce anchor performance.

*NOTE 2 Some types of brick are prone to shake loose from mortar joints during drilling. These effects can be minimized by using a less powerful drilling machine, reducing the drilling speed and occasionally by drilling on a rotary setting only.*

Care should be taken to check that no damage is done to the brick or surrounding mortar joints by drilling or anchor setting, e.g. by looking for cracks across bricks and around mortar joints.

*NOTE 3 Certain types of anchor which work on the expansion principle, including torque-controlled anchors such as shield anchors and thin -walled sleeve anchors and plastic anchors (see Annex C), and which are approved for use in masonry, can crack weaker bricks, especially if mortar joints are also weak and when larger diameters are used.*

# 8 Supervision, inspection and certification of installed anchors

## 8.1 Supervision

Close supervision of the installation of anchors should be undertaken by a supervisor who is a competent member of the site management team. The supervisor appointed to undertake this role by the contractor should be trained in the installation of anchors and be competent to undertake this role.

The supervisor should ensure that the following issues have been adequately addressed:

- the anchor type being used satisfies the design requirements of the specifier:
  - anchor make;
  - anchor type;
  - anchor material;
  - anchor diameter and length;
- the anchor position is in accordance with the design:
  - anchor embedment depth;
  - anchor location;
- the base material condition and hole dimensions are as specified:
  - concrete strength;
  - anchor hole diameters and depths in accordance with manufacturer's recommendations;
  - setting out of anchors on the base material as per design;
- the condition of the fixture is suitable:
  - fixture thickness (including the thickness of grout or shims);
  - fixture type and material;
  - hole locations and diameters, as per design, especially edge distances;
- the anchor is installed using correct equipment and to manufacturer's instructions including:
  - drill bits;
  - hole cleaning method;
  - setting tools;
  - correct installation torque;
  - curing times respected where relevant;
- change of requirements: if amendments are required due to hitting reinforcement, quality of concrete base material, etc., a revised installation procedure should be agreed with the specifier and then communicated to the installer in writing.

## 8.2 Inspection

Immediately following installation and prior to loading, the anchorage should be inspected so that any observations regarding rotation, movement, deformation, cracking or other damage can be recorded and communicated to the specifier.

If, at any stage, the supervisor has any concerns regarding the suitability of the anchorages, the placing of further units should not proceed and the anchorages in question should be made safe until the concerns have been addressed to the satisfaction of the specifier.

A similar inspection should be undertaken at each stage of subsequent loading.

### 8.3 Certification

The installer and/or supervisor should issue a certificate to certify that the anchors have been correctly installed in accordance with the specification and are in a condition to be loaded.

## 9 Testing of anchors

*COMMENTARY ON CLAUSE* ***9***

*Testing of anchors on site might be required at two stages of a project, either:*

*a) before the installation of anchors, in order to validate that the proposed anchors are suitable for use in the base material concerned and to determine the allowable resistance (see* ***9.2****); or*

*b) after installation, when a sample of all anchors may be proof tested to validate the quality of installation (see* ***9.3****).*

*On -site testing to validate the suitability of anchors conforming to ETAGs is not required prior to selection for anchors qualified for use in concrete. On -site testing to validate anchors conforming to EADs qualified for use in masonry might be required if the anchor has been approved for use in a particular category of masonry, and the masonry of the project falls within this category but does not match or exceed the strength or dimensions of the approval.*

*Proof testing, to validate the quality of installation, might not be necessary if approved anchors are installed by trained operatives working under supervision. If this condition is not satisfied then proof testing might be required.*

### 9.1 General

Tests should be carried out by persons who are not only competent in carrying out tests but, ideally, by persons who also have a knowledge of anchors, how they work, how they are installed, and how they are likely to fail, as this will improve significantly the manner in which the tests are carried out and the feedback that might be given by the tester to the responsible engineer requesting the tests.

*NOTE For each of these purposes the requirements are different in terms of sample size, magnitude of load, rig dimensions etc. General details of test regimes are outlined in* ***9.2****,* ***9.3****,* ***9.4*** *and Annex B, and specific procedures for load application are given in the CFA Guidance Note Procedure for site testing construction fixings – 2012 [N1].*

### 9.2 Tests to determine the allowable resistance

*COMMENTARY ON* ***9.2***

*In general, these tests are required only when the strength or precise nature of the base material is unknown and no recommended resistance is available from the manufacturer for the specifier to complete the selection process, e.g. in brickwork, blockwork or stonework. They are not expected to be needed for anchors to be used in concrete for general applications. For special applications such as the anchoring of safety fences on motorways, bridge parapets, scaffold anchors or fall arrest anchors, there are usually industry-specific requirements published separately that apply, on which guidance is available from the manufacturer.*

These tests should be carried out only on anchors for which the manufacturer approves their use in the general category of base material involved, e.g. solid, hollow or perforated masonry, etc. They should be carried out before the selection of anchors is finalized to ensure that anchors are suitable for the base material concerned and have an adequate allowable resistance. They should be carried out on anchors specially installed in the base material of the project but which are not to be used for the project.

In practice there are two different circumstances when these tests should be carried out.

a) Where an anchor is available that conforms to an EAD covering the category of masonry of the project, but does not meet the qualifications for dimensions and strength, then the test regime should be in accordance with either **B.2.2** or the relevant EAD.

b) Where there is no suitable anchor conforming to an EAD, and an anchor is proposed to be used which is approved by the manufacturer for use in the type of masonry concerned but for which there is no published recommended tensile resistance, $N_{\mathrm{rec}}$, or design resistance, $N_{\mathrm{Rd}}$, then the test regime should be in accordance with **B.2.3**.

The test procedures in both cases should be in accordance with CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1].

## 9.3 Tests to check the quality of installation

*COMMENTARY ON* ***9.3***

*In some industries, the percentage of fixings tested is detailed in the relevant industry standard (e.g. suspended access where any failure is unacceptable, see BS EN 1808; fall arrest where 100% testing is required for some conditions, see BS 7883.)*

These tests, referred to as proof tests, should be carried out on a sample of working anchors on every safety‑critical application (unless approved anchors have been installed by trained operators working under supervision), after the anchors have been installed, to ensure that they have been installed correctly.

The tests are intended to demonstrate that anchors to be used in service have a modest safety margin without risking their integrity. The tests are not generally appropriate for determining the suitability of an anchor in a particular base material or for determining its allowable resistance, for which the test regimes given in **9.2**, **B.2.2** and **B.2.3** should be used.

Proof test regimes should be in accordance with **B.3**. The test procedures should be in accordance with CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1].

*NOTE EAD 330076‑00‑0604 [15] and EOTA TR053 [28] details "job site tests" in which the term "proof load" is used for tests used to determine the characteristic resistance in masonry. These tests do not fulfil the same objectives as proof tests outlined here and in* ***B.3****.*

## 9.4 Testing in tension and shear

*COMMENTARY ON* ***9.4***

*Anchor performance in tension depends on the anchor being suitable for the base material, well designed and correctly installed. Testing in tension is therefore justified for both of these reasons.*

*The shear performance of anchors in concrete is dependent primarily on the strength of the anchor rod and base material, and is therefore determined in concrete by calculation. Tests to determine allowable shear actions are not normally needed in concrete. Performance in shear is little affected by installation quality, so proof tests are also normally unnecessary in shear. Shear tests might be requested when edge distances are closer than those recommended by the manufacturer and edge reinforcement is present. In these cases, it is suggested the issue be discussed with the manufacturer, as site testing might not resolve the issue satisfactorily.*

*Shear tests might be justified for anchors to be used in masonry solely to determine allowable resistance, which will often be limited by displacement.*

If shear tests on site are agreed, then a regime described in detail in the CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1] should be used. This regime is similar to that described in **B.2.3.1**, but involves the detailed monitoring of displacement and should be stopped as soon as any failure or significant displacement occurs.

### 9.5 Test procedures and recording of results

Whatever their purpose, any tests should be carried out using the correct procedures, and the results should be presented in the correct manner, such that the tests fulfil the objectives and the results can be transmitted to the responsible person who requested the tests.

The equipment and specific procedures for applying test loads, monitoring movement, etc. should be in accordance with the CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1].

## 10 Change management – alternative anchors

*COMMENTARY ON CLAUSE **10***

*Anchor specifications are frequently qualified with the phrase "equal and approved". Such a phrase obliges that a full change management process needs to be carried out by the specifier.*

*It might be necessary to change the specification of an anchor for a variety of reasons.*

*Some typical reasons for changing specifications include:*

- *unavailability of the specified anchor;*
- *contractor has a preferred supplier;*
- *a change in the design loading information leading to inappropriate anchor specification;*
- *economic reasons.*

Irrespective of the reason for the change request, the alternative specification should be determined by either the original anchor specifier or a responsible engineer on site who assumes the role and responsibilities of anchor specifier and has access to the original design data.

The validation of the proposed anchor should be carried out by the completion of the full selection procedure as outlined in Clause **5**, as this is the only way that a specifier can be sure that all of the selection criteria have been fulfilled by the alternative anchor.

NOTE *It is not sufficient to change the specified anchor for one which appears to be similar, or to compare headline performance figures quoted in catalogues (e.g. ultimate resistances, characteristic resistances or recommended resistances) of the proposed alternative anchor with those of the originally specified anchor. To do so might not take into account the way in which the performance of different anchors changes with the specific edge distances, anchor spacings and other factors of the particular application. Nor is it acceptable to carry out proof load tests of the proposed alternative anchor on site, as this does not validate the required safety margin.*

Any revision to the specification of an anchor should be recorded and the information communicated in writing in accordance with Clause **6**.

# Annex A (informative)
# Design methods

## A.1 General

Once the type of anchor has been selected against the criteria set out in Clause 5, the specifier needs to determine the size of anchor required according to the most appropriate design method as outlined in this annex.

If this process fails to produce a suitable result (e.g. the proposed anchor is too large for the structural thickness or close edge and spacing dimensions restrict available capacity), then the specifier needs to repeat the selection process outlined in Clause **5** to find an anchor type and size which is capable of satisfying both the various influencing factors and the design process. Alternatively, the proposed anchor spacings and/or edge distances might need to be revised to maximize the capacity of the available base material.

## A.2 Choice of design method

### A.2.1 General

There are two different design approaches for the types of anchors covered by this British Standard: the partial safety factor approach (PSF) and the global safety factor approach (GSF). They are different and are valid for different circumstances, so are not generally interchangeable. Subclauses **A.2.2** and **A.2.3** contain brief summaries of the design methods within these two approaches. A comprehensive guide to how the different design methods relate to the different EADs is given in the CFA Guidance Note *ETAs and design methods for anchors used in construction* [1].

The method used is determined according to whether or not the anchor under consideration conforms to an EAD. If it does, then the design method to be used will be detailed in the EAD and is usually based on the PSF approach.

*NOTE 1 The PSF approach, used within the EAD system, is sometimes referred to as the "concrete capacity" design method.*

If the anchor does not conform to an EAD, then the appropriate method will be the one that is recommended by the manufacturer; this might be based on the PSF approach if sufficient data is available, otherwise it is based on the GSF approach.

*NOTE 2 The relation between the various actions and resistances, as applying to the PSF and GSF approaches, is illustrated in Figure A.1.*

Anchor manufacturers sometimes quote the ultimate resistance of the anchor within their technical data. It is not appropriate to use the ultimate resistance in the design process; the characteristic resistance is the starting point for calculating the design resistance of an anchor, irrespective of the design method used.

The design method according to the appropriate EAD and referred to in the ETA is based on a limit state approach. Anchor resistance is designed to ultimate limit state, but a serviceability limit state check for displacement also needs to be carried out.

a) **Ultimate limit state**.

To satisfy the ultimate limit state, it is essential that the connection does not fail when subjected to the peak design action for which it was designed. A connection is deemed to satisfy the ultimate limit state criteria if all factored bending, shear and tensile or compressive actions are below the factored resistances calculated for the connection under consideration. See Figure A.1.

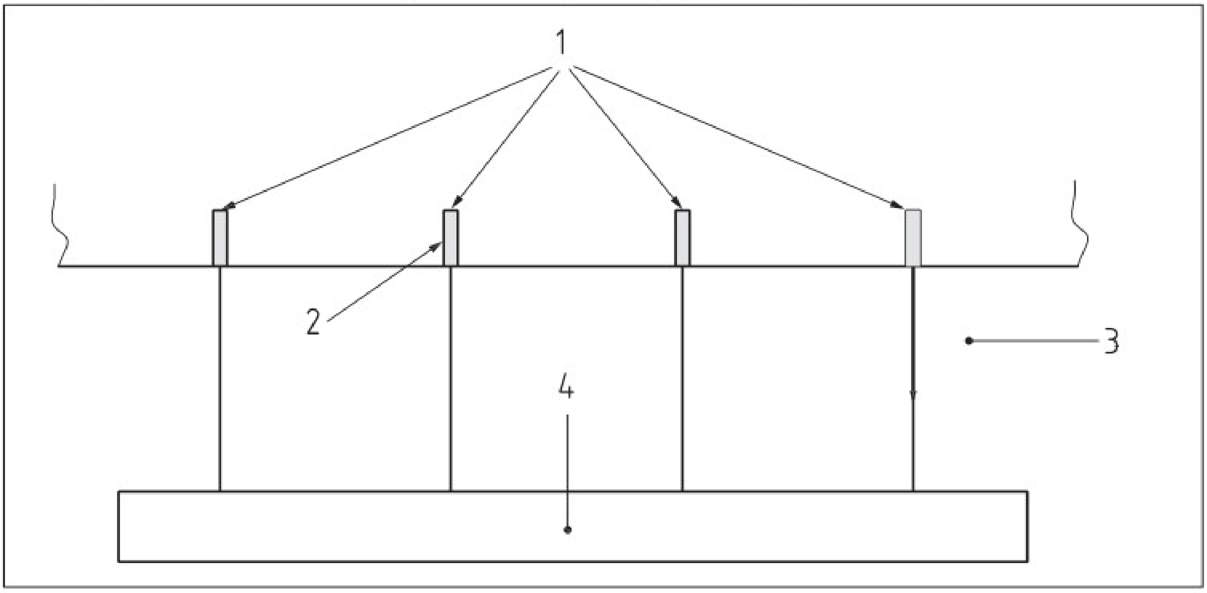
b) **Serviceability limit state**.

To satisfy the serviceability limit state criteria, a connection has to remain functional for its intended use subject to routine everyday loading. A connection is deemed to satisfy the serviceability limit state when the constituent elements do not deflect by more than certain limits laid down in the building codes or by the designer of the structure.

In the serviceability limit state, it has to be shown that the displacement occurring under the characteristic actions is not greater than the characteristic displacement. The characteristic displacements are given in the ETA in relation to the characteristic action for short- and long-term loadings for both tension and shear. So to check the anchor displacement for a particular connection, the design action first needs to be converted back to the characteristic (service) action.

The short-term characteristic displacements for tension and shear are shown in the ETA as $\delta_{N0}$ and $\delta_{V0}$, with long-term values as $\delta_{N\infty}$ and $\delta_{V\infty}$. The admissible displacement depends on the application in question and needs to be decided by the designer of the structure taking account of any limits dictated by codes. It may be assumed that the characteristic displacements are a linear function of the characteristic action. In case of combined tension and shear actions, the displacements for the tension and shear components of the resultant action need to be geometrically added. In the case of shear actions, the influence of the hole clearance in the fixture on the expected displacement of the whole anchorage needs to be taken into account.

**Figure A.1** — *Comparison between load levels of partial and global safety factor approaches*



## A.2.2 Partial safety factor method

This method, sometimes referred to as the concrete capacity method, is the method which is applied to anchors qualified to EADs, and is elaborated in more detail within the relevant EAD or within BS EN 1992-4.

The fundamental requirement for safety is that the design action, $F_{Ed}$, applied by the fixture to the anchor, is less than or equal to the design resistance, $F_{Rd}$, of the anchor in the base material concerned, i.e.:

$$F_{Ed} \le F_{Rd} \tag{A.1}$$

A partial safety factor, γF, is used to determine the design action from the characteristic action, $F_{Sk}$. In the general case this is stated as:

$$F_{Ed} = F_{Sk} \cdot \gamma_F \tag{A.2}$$

When the characteristic (static) action can be identified in terms of its permanent and variable components (respectively *G*k and *Q*k), then appropriate partial safety factors ($\gamma_G$ and $\gamma_Q$) can be used, so that equation (A.2) can be restated as:

$$F_{Ed} = G_k \cdot \gamma_G + Q_k \cdot \gamma_Q \tag{A.3}$$

Values for $\gamma_G$ and $\gamma_Q$ are given in BS EN 1991 (see Annex E for a guide to which actions may be regarded as permanent and which variable).

The design resistance is determined from the characteristic resistance, $F_{Rk}$, by the application of a partial safety factor for the material, $\gamma_M$, i.e.:

$$F_{Rd} = F_{Rk} / \gamma_M \tag{A.4}$$

Specifically, the design resistance for each potential mode of failure is determined from its characteristic resistance using the relevant partial safety factor, and the lowest characteristic resistance thus found is taken as the decisive value.

Failure modes can, depending on anchor type, be one of the following:

a) tensile actions:
  - steel failure;
  - pull-out failure ( text deleted );
  - concrete cone failure;
  - splitting failure;
  - text deleted ;

b) shear actions:
  - steel failure;
  - concrete pry-out failure;
  - concrete edge failure.

Partial safety factors are given in the approval document for the particular anchor, e.g.

- steel failure, $\gamma_{Ms}$;
- concrete cone failure, $\gamma_{Mc}$;
- splitting failure, $\gamma_{MSp}$;
- pull-out failure, $\gamma_{Mp}$.

Once the design resistance has been determined for each loading direction, it is necessary to carry out a check to ensure that the performance of the anchor with combined tensile and shear actions is acceptable (see **A.3**).

Some of the factors listed in Clause **5** will be taken into account in the design process, such as edge distances and centre spacings, in accordance with the design process specified by the manufacturer.

The design method enshrined in CEN Technical Specifications includes consideration of factors such as fatigue, seismic actions, fire, and durability (corrosion). Not all approved anchors will have specific information within their approval document to cover all of these factors. It is advisable to consult the manufacturer for advice.

This process is comprehensive but sufficiently complex that it is best carried out using software, which most manufacturers provide. Manufacturers' software will prompt the specifier to enter all required application parameters, and as long as these are entered correctly, the resulting recommendation effectively carries a degree of manufacturer endorsement that is not present if a straightforward selection process is carried out from technical data.

To help users relate this approach to the GSF approach, some manufacturers quote a "recommended load" (recommended resistance), which is derived from the design resistance divided by the partial safety factor, e.g.

$$N_{\text{rec}} = \frac{N_{\text{Rd}}}{\gamma_{\text{F}}} \tag{A.5}$$

It is customary to use $\gamma_{\text{F}} = 1.4$ in this case.

### A.2.3 Global safety factor method

This design approach is based on the use of a global safety factor, which is used to relate the performance of the anchor in the base material to the recommended resistance.

The requirements for the characteristic action are:

a) When manufacturer's data is used and site tests have not been needed:

characteristic action ≤ recommended resistance, i.e.:

$$F_{\text{Ek}} \leq F_{\text{rec}} \tag{A.6}$$

b) When the allowable resistance has been determined from site tests:

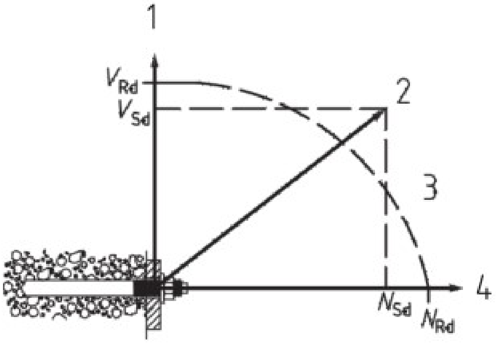
characteristic action ≤ allowable resistance, i.e.:

$$F_{\text{Ek}} \leq F_{\text{R,all}} \tag{A.7}$$

## A.3 Check for combined actions

In the case of combined actions, when tensile and shear actions are applied together, it is not sufficient to simply check that the tensile and shear design actions, $N_{\text{Ed}}$ and $V_{\text{Ed}}$, are less than their respective design resistances, $N_{\text{Rd}}$ and $V_{\text{Rd}}$, as would be the case in Figure A.2. This is because the actual combined action might well be greater than the design resistance at the appropriate angle (if this were known), as is shown by the curve connecting the tensile and shear design resistances.

**Figure A.2** — *Relationship of resolved components of combined action to design resistance at angles between tension and shear – PSF approach*



**Key**

1 Shear action

2 Combined action

3 Curve of design resistance at angles between tension and shear

4 Tensile action

A check needs to be carried out to ensure that the combined design actions do not exceed the design resistance. The particular approach depends on the design method used for the anchor which will be stated in the approval document. EADs and CEN Technical Specifications use similar approaches, and require the following conditions to be satisfied.

a) BS EN 1992-4 requires:

$$\beta_N \leq 1 \quad (A.8)$$

$$\beta_V \leq 1 \quad (A.9)$$

$$\beta_N + \beta_V \leq 1.2 \quad (A.10)$$

where:

$\beta_N = N_{Ed}/N_{Rd}$

$\beta_V = V_{Ed}/V_{Rd}$

BS EN 1992-4 also allows the more accurate approach of equation (A.11):

$$(\beta_N)^{\alpha} + (\beta_V)^{\alpha} \leq 1 \quad (A.11)$$

where:

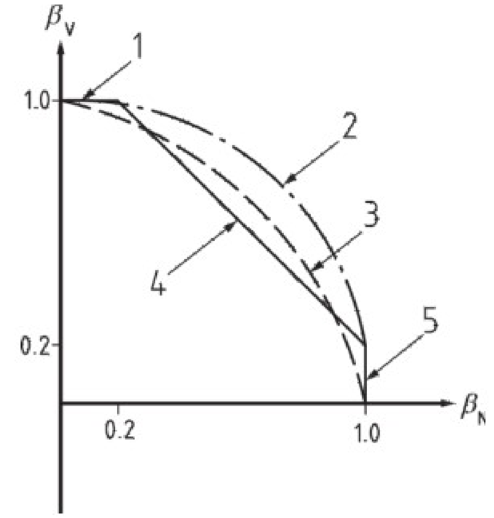
$\alpha$ = 2.0 when $N_{Rd}$ and $V_{Rd}$ are governed by steel failure;

$\alpha$ = 1.5 for all other failure modes.

Equations (A.8) to (A.11) are illustrated in Figure A.3.

b) Text deleted.

**Figure A.3** — *Interaction diagram for combined tensile and shear actions according to BS EN 1992 -4*



**Key**

1 Equation (A.9)

2 Equation (A.11) with $\alpha = 2.0$

3 Equation (A.11) with $\alpha = 1.5$

4 Equation (A.10)

5 Equation (A.8)

Anchors designed according to the global safety factor method may use a similar approach, as recommended by the manufacturer.

The following is typical:

$$N_{\mathrm{Ek}} \leq N_{\mathrm{rec}} \tag{A.12}$$

$$V_{\mathrm{Ek}} \leq V_{\mathrm{rec}} \tag{A.13}$$

$$\frac{N_{\mathrm{Ek}}}{N_{\mathrm{Rd}}} + \frac{V_{\mathrm{Ek}}}{V_{\mathrm{Rd}}} \leq 1.2 \tag{A.14}$$

Other approaches might be equally valid.

## A.4 Using manufacturers' information

When selecting anchors qualified to an EAD using the PSF approach, the values are ideally taken directly from the approval document (unless the manufacturer's design software is used). If using manufacturer's literature such as technical manuals etc., care needs to be taken to confirm that any performance values quoted are taken from the approval document, as some manufacturers quote their own performance data, even when referring to approved anchors contrary to what is allowed by the ETA.

Anchor manufacturers sometimes quote technical data for anchors involving the "ultimate resistance" of the anchor. This value is not to be used in any design process, irrespective of the design approach used. The characteristic resistance is the starting point for calculating the design resistance for an anchor.

# Annex B (normative)
# Site testing regimes

*COMMENTARY ON ANNEX B*

*This annex recommends test regimes designed to achieve certain stated objectives, along with methods for assessing results to produce the required values. Detailed procedures for applying test loads and using test equipment are outlined in the CFA Guidance Note Procedure for site testing construction fixings – 2012 [N1]. Aspects of the testing procedure that are covered in the CFA Guidance Note include:*

- *spacing of the feet of the load spreader bridge (or frame) used to support the test unit or load cell in order to prevent reaction loads from interfering with the anchor support within the base material;*
- *rate of loading;*
- *monitoring of movement;*
- *precision of load gauge;*
- *calibration of load gauge;*
- *means of applying the test load to the anchor.*

*The recommendations in Annex B are for load testing anchors in the tensile direction. Where shear performance needs to be investigated, this can be done in accordance with procedures outlined in the CFA Guidance Note Procedure for site testing construction fixings – 2012 [N1]. These procedures use similar approaches to those outlined in this annex, with the additional requirement that displacement is monitored in more detail, as this might be the deciding factor.*

## B.1 General

In all cases, the anchors to be tested should be installed strictly in accordance with the manufacturer's installation instructions. This includes, as far as possible, tightening the anchor against a representative fixture using the manufacturer's recommended tightening torque. If the anchors to be tested are not installed by the person carrying out the tests, then the installer should certify that they have been installed in accordance with the manufacturer's instructions, and should record the details as recommended in **B.4**.

Drill bit tip diameters should be measured before installation and recorded as part of the test report.

## B.2 Regimes for on-site tests to determine allowable resistance

### B.2.1 General

*NOTE 1 These tests are not required for anchors conforming to EADs for use in concrete, as the design resistance is readily determined from the approval document; however, they might be needed for anchors to be used in masonry in conditions outlined in* ***B.2.2*** *and* ***B.2.3****. In the procedures outlined in* ***B.2.2****, the method used for anchors conforming to EADs will initially determine the characteristic resistance from which the design resistance and allowable resistance can be derived, while the method for anchors not conforming to EADs (see* ***B.2.3****) will determine the allowable resistance directly.*

It is essential that anchors used in tests to determine the allowable resistance are installed specifically for the tests only. They should not be anchors which are part of the project. They should be installed in the base material typical of the project but located well away from anchors that will be used on the project. If space is restricted, the minimum distance that test anchors should be located from working anchors is three times the effective embedment depth in concrete with at least two clear masonry units between anchors in masonry. Once the tests are completed, the test anchors should be removed, if possible, and the holes filled with a suitable, strong non-shrink grout or filler.

*NOTE 2 When tests to failure are used and assessed using statistical analysis (**B.2.3.2**), the greater the number of tests carried out, the more reliable the overall result will be and, usually, the higher the result, as a smaller K factor will be involved. However, this technique also increases the risk of damage to the structure.*

## B.2.2 Test regime for anchors conforming to EADs

*NOTE For anchors conforming to EADs, where the masonry of the project does not conform to all aspects of the strength and dimensions of the masonry as defined in the approval document, then the design resistance specific to the masonry of the project may be determined by carrying out tests either to the procedure for "job-site tests" as detailed in the appropriate EADs, or as outlined in this subclause. The following procedure is based on the "job-site test" procedure as outlined in EOTA Technical Report TR 053 [28], but with various amendments to improve clarity and consistency of results.*

### B.2.2.1 Test regime

Test between 5 and 15 anchors. Load each anchor carefully to failure.

Note the load at which the fixture (or anchor if there is no fixture) first moves from the base material and record as "load at first movement", $N_{1st}$. Note the ultimate load, $N_{Ru}$, and mode of failure.

On completion of all the tests in a series, calculate the mean load at first movement, $N_{1st,m}$, and mean ultimate load, $N_{Ru,m}$.

The detailed test procedures should be as given in CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1].

*NOTE More tests may be carried out, and usually the greater the sample size, the more confidence can be attributed to the resulting characteristic resistance. This is reflected in the use of a K factor to determine the characteristic resistance, which reduces as the sample size increases. K factors for up to 15 tests are given in **B.2.2.2**.*

### B.2.2.2 Evaluation of test results

The characteristic resistance is given by equation (B.1):

$$N_{\mathrm{Rk1}} = N_{\mathrm{Ru,m}}\,(1 - \mathrm{K}\cdot \mathrm{v})\cdot\beta \le N_{\mathrm{Rk,ETA}} \tag{B.1}$$

where:

the values of *K* are:

- $K = 3.4$ for 5 tests;
- $K = 2.57$ for 10 tests;
- $K = 2.33$ for 15 test;

$v$ is the coefficient of variation of the failure loads, and is given by $v = (s/N_{Ru,m}) \cdot 100\%$;

$\beta$ is an influencing factor whose values are given in the approval document.

The design resistance is given by equation (B.2), from which the allowable resistance is derived using equation (B.3):

$$N_{\mathrm{Rd}} = N_{\mathrm{Rk1}} / \gamma_{\mathrm{M}} \tag{B.2}$$

$$N_{\mathrm{R,all}} = N_{\mathrm{Rd}} / \gamma_{\mathrm{F}} \tag{B.3}$$

*NOTE $\gamma_M$ is given in the approval document. $\gamma_F$ can be taken as 1.35 if actions are permanent and 1.5 if variable, or 1.4 if the nature of the actions is unknown or they are mixed.*

Check that $N_{R,all} \leq N_{1st,m}$.

If $N_{R,all} > N_{1st,m}$ then $N_{R,all}$ is limited to $N_{1st,m}$.

### B.2.3 Test regime for anchors not conforming to EADs

*NOTE For applications where there is no suitable anchor conforming to an EAD , the following methods may be used to establish the allowable resistance of an anchor, as long as the manufacturer approves its use in the base material concerned. Two methods are described. The first, **B.2.3.1**, is designed to yield a result on thesafe side while minimizing the potential damage to the base material, while the second, **B.2.3.2**, is intended to give a more accurate value but might result in more damage to the structure.*

#### B.2.3.1 Tests for allowable resistance (simplified approach)

*NOTE This is a method of determining the allowable resistance of an anchor with the minimum amount of damage to the structure. These tests are hereinafter referred to as "preliminary tests", a term traditionally used in the fixings industry for this approach.*

#### B.2.3.1.1 Test regime

Test at least five anchors to a test load as given in equation (B.4):

$$N_{test} = N_{Ek} \times v_{test} \tag{B.4}$$

where $v_{test}$ depends on the type of anchor being tested and the loading being either short-term or long-term. Values for $v_{test}$ are shown in Table B.1.

**Table B.1** — *Factors used in preliminary tests*

| Application | Anchor material | Factors to give test load, $N_{test}$ | Factors to determine allowable resistance, $N_{R,all}$ | |
|---|---|---|---|---|
| | | $v_{test}$ | $v_{ave}$ | $v_{low}$ |
| Long-term loading for general purposes | Nylon[A] | 5 | 7 | 5 |
| | All other | 3 | 4 | 3 |
| Short-term loading for e.g. scaffold anchoring, steeplejack anchoring | Nylon[A] | 3 | 5 | 3 |
| | All other | 2 | 3 | 2 |

[A] Nylon anchors require higher factures due to the effects of creep (see **5.3.5.4**).

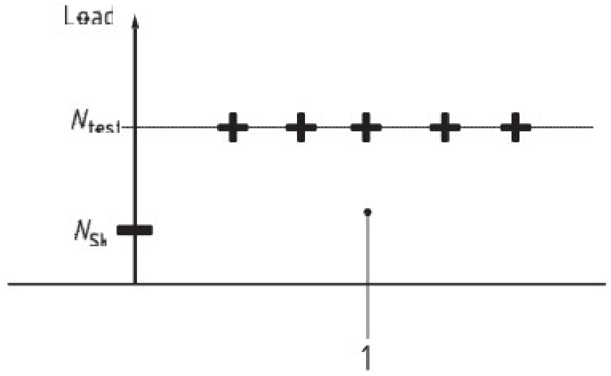
If all test anchors hold the test load, as shown in Figure B.1, then the allowable resistance may be taken as being equivalent to the characteristic action, which may therefore be applied in this base material, i.e. as shown in equation (B.5):

$$N_{R,all} = N_{Ek} \tag{B.5}$$

If any anchor fails to reach the test load, then the situation should be reviewed with the specifier. If the number of anchors being used can be readily increased then the approach in **B.2.3.1.2** may be applied using the same anchor type. This should only be contemplated if the failure is close to the required test load (e.g. $N_{Ru} > 0.8 \times N_{test}$).

If the number of anchors cannot readily be increased, then the anchor specification should be changed – options include increasing the diameter and/or embedment depth of the anchor or changing to a different type of anchor. In these cases, the preliminary tests should be repeated with the new anchor.

**Figure B.1** — *Preliminary tests – relationship between characteristic action and test load*



**Key**

1 Test results – all five test anchors hold the load

### B.2.3.1.2 Test regime following one failure before reaching $N_{test}$

If the number of anchors to be used on the project can be increased and the failure load is close to the required test load, then the test regime should be as follows.

Load all test anchors carefully to failure. If an anchor moves during loading, the tests should be halted at approximately 1.0 mm movement to avoid damaging the structure. The load at this point should be taken as the failure load for that test.

### B.2.3.1.3 Evaluation of test results

The new allowable resistance, $N_{R,all}$, is calculated by dividing the average failure load and lowest failure load by factors, as shown in (B.6) and (B.7) and taking the lowest result:

$$\frac{N_{u,ave}}{V_{ave}} \tag{B.6}$$

$$\frac{N_{u,low}}{V_{low}} \tag{B.7}$$

where the factors $v_{ave}$ and $v_{low}$ are as shown in Table B.1.

The above process is illustrated in Figure B.2, Figure B.3, and Figure B.4.

Check that $N_{R,all} \leq N_{1st,m}$.

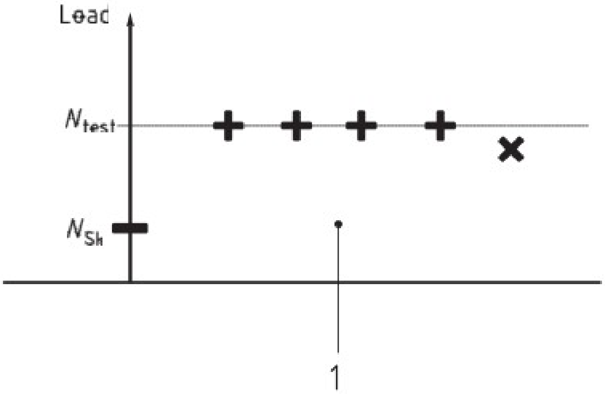
If $N_{R,all} > N_{1st,m}$ then $N_{R,all}$ is limited to $N_{1st,m}$.

*NOTE Illustrative example of tests taken to failure to determine allowable resistance: on initial test, as shown in Figure B.2, four anchors hold the required load satisfactorily but one fails at a slightly lower load. The first four anchors are then carefully loaded to failure, as shown in Figure B.3.*

If the number of anchors (originally $n_0$) can be increased pro rata by, for instance, simply reducing spacings between anchors, then the new number of anchors required for the project, $n'$, comes from equation (B.8):

$$n' = \frac{n_o \cdot N_{Ek}}{N_{R,all}} \tag{B.8}$$

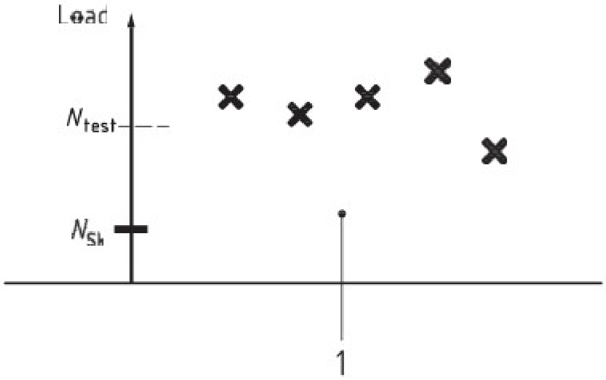
**Figure B.2** — *Illustration of tests when one anchor fails to reach $N_{test}$*



**Key**

1 Test results

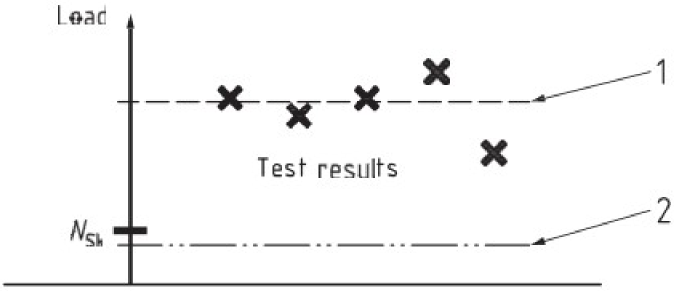
**Figure B.3** — *Illustration of test results when all anchors have been loaded to failure*



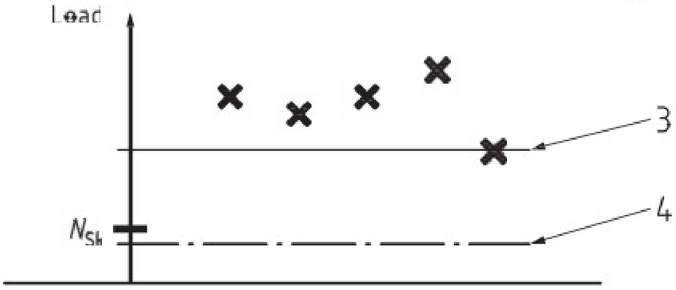
**Key**

1 Test results

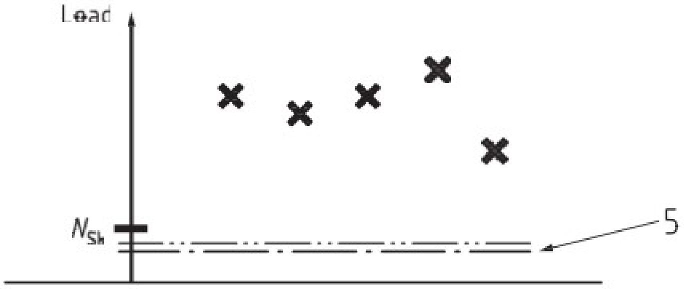
**Figure B.4** — *Illustration of treatment of results to determine allowable resistance*



a) First possible allowable resistance determined from the average failure load, $N_{u,ave}$



b) Second possible allowable resistance determined from the lowest failure load, $N_{u,low}$



c) Allowable resistance taken as the lowest of the above results

**Key**

1 Average failure load, $N_{u,ave}$

2 $N_{u,ave}/v_{ave}$

3 Lowest failure load, $N_{u,low}$

4 $N_{u,low}/v_{low}$

5 Allowable resistance, $N_{R,all}$ is the lowest of 2 and 4, and in this example it is $N_{u,ave}/v_{ave}$. It is inevitably lower than the required characteristic action, so more fixings will be needed

### B.2.3.2 Tests for allowable resistance (statistical approach)

*NOTE This method for determining the allowable resistance of an anchor will produce a more accurate result than that outlined in* ***B.2.3.1****, but is more likely to cause some local damage to the structure.*

#### B.2.3.2.1 Test regime

Test a minimum of five anchors. Load each anchor carefully to failure.

Note the load at which the fixture (or anchor if there is no fixture) first moves from the base material and record as "load at first movement", $N_{1st}$. Note the ultimate load, $N_{Ru}$, and mode of failure.

On completion of all the tests in a series, calculate the mean load at first movement, $N_{1st,m}$, and mean ultimate load, $N_{Ru,m}$.

The detailed test procedures should be as given in CFA Guidance Note *Procedure for site testing construction fixings – 2012* [N1].

*NOTE More tests may be carried out, and usually the greater the sample size, the more confidence can be attributed to the resulting characteristic resistance. This is reflected in the use of a K factor to determine the characteristic resistance, which reduces as the sample size increases. K factors for up to 15 tests are given in **B.2.3.2.2**.*

#### B.2.3.2.2 Evaluation of test results

The characteristic resistance is given by equation (B.9):

$$N_{\mathrm{Rk1}} = N_{\mathrm{Ru,m}}(1 - K \cdot v) \cdot \Omega \tag{B.9}$$

where:

the values of $K$ are:

- $K$ = 3.4 for 5 tests;
- $K$ = 2.57 for 10 tests;
- $K$ = 2.33 for 15 test;

$\Omega$ is an adjustment factor based on the conditions that will apply to the application and whose value should be decided by the designer.

*NOTE Guide -only values could be:*

- *$\Omega$ = 0.8 for installation in wet substrate;*
- *$\Omega$ = 0.8 for effect of elevated temperature [temperature above the service temperature range normally recommended by the manufacturer; see **5.3.5.3**a)];*
- *$\Omega$ = 0.9 for long-term loading;*
- *$\Omega$ = 0.75 for rendered/plastered walls where the mortar joints are not visible or where the positioning of anchors cannot be guaranteed to be within the brick.*

Where more than one condition applies (see Note) then all factors should be multiplied together.

The coefficient of variation, $v$, should be <30%, where $v = (s/N_{\mathrm{Ru,m}}) \cdot 100\%$.

The allowable resistance is then derived using equation (B.10):

$$N_{\mathrm{R,all}} = N_{\mathrm{Rk1}} / \nu \tag{B.10}$$

where ν = global factor of safety, e.g. 2.5 (the factor recommended for static and quasi-static actions).

Check that $N_{\mathrm{R,all}} \leq N_{\mathrm{1st,m}}$.

If $N_{\mathrm{R,all}} > N_{\mathrm{1st,m}}$ then $N_{\mathrm{R,all}}$ is limited to $N_{\mathrm{1st,m}}$.

---

## B.3 Procedure for carrying out proof tests

*NOTE 1 These tests are usually carried out on the installed anchors to show that they have been installed correctly and are not intended to prove suitability.*

The minimum sample size should be 2.5% of the total number of anchors installed (1 in 40 anchors), with a minimum of three tests.

*NOTE 2 The minimum number (three) applies in any discrete area where:*

- *different anchors might have been used;*

- *the base material is different;*
- *the condition of the base material has been affected by different weather conditions, e.g. on a different elevation; or*
- *more than one installation crew installed the anchors.*

The proof test load, $N_p$, should normally be the characteristic action, $N_{Ek}$, multiplied by $v_{P,test}$, as shown in equation (B.11):

$$Np = N_{Ek} \cdot v_{P,test} \tag{B.11}$$

where $v_{P,test}$ is 1.5 when 2.5% of anchors are tested and 1.25 when 5% are tested.

The proof test load factor, $v_{P,test}$, should never exceed 1.5.

If, in any discrete area, one failure is encountered, then the reason for failure should be investigated, the number of anchors tested in that discrete area should be doubled to 5% (or 10% depending on level of proof load) and at least 6.

If more than one anchor fails then 100% of the anchors should be tested, the reasons for failure determined and the specification reconsidered.

Reasons for failure should be communicated to those responsible for the installation, to avoid further failures on future installations.

## B.4 Test report

A test report should be prepared, which should record at least the following information:

*NOTE This list is comprehensive but not necessarily exhaustive. Additional information might be required depending on the specific circumstances of the test.*

a) administration details:
   1) date of test;
   2) reason for test;
   3) name of person requesting the test;
   4) unique report reference number;
   5) client's company name, address, contact name and position;
   6) site location, contact name and position;
   7) name and company of tester with job title or appropriate qualifications;
   8) name and companies of witnesses;
   9) name and company of installer of anchors;

b) anchor/application details:
   1) name of manufacturer;
   2) anchor type, size and finish;
   3) proposed application of anchor;
   4) design resistance and manufacturer's recommended resistance in the base material concerned (for proof tests);

c) test objectives:
   1) proof tests or tests for allowable resistance;

  2) required proof load;

d) test location:
  1) detail of the location of each test within the structure, with sketch where appropriate;
  2) edge distance, centre spacing and structural thickness, if appropriate;

e) base material:
  1) type and strength at time of test, if known;
  2) whether solid or hollow;

f) installation details, if installation is carried out at the time by the tester:
  1) nominal hole diameter;
  2) drill bit cutting diameter, recorded to 0.1 mm;
  3) hole depth;
  4) effective embedment depth;
  5) hole cleaning method in detail;
  6) tightening torque applied;
  7) for bonded anchors:
    - ambient temperature when installed;
    - manufacturer's recommended curing time;
    - actual curing time allowed;

g) test equipment details:
  1) make, type and load capacity of hydraulic ram/gauge or tester;
  2) date of last calibration, calibrating authority;
  3) make and type of movement recorder, dial gauge, etc.;
  4) loading frame: dimension between anchor and closest support;
  5) make and range of torque wrench;

h) test results, depending on purpose, for each anchor tested:
  1) load:
    - maximum load applied;
    - condition of anchor and surrounding base material, if affected;
    - load at first movement;

i) movement (if required) at different load increments and maximum load;

j) mode of failure where appropriate:
  1) base material failure by cone failure, spalling, cracking or splitting;
  2) bolt breakage;
  3) failure of resin or bonding material, e.g. bond shear (may be combined with cone failure);
  4) pull through/excessive movement;

k) method statement;

l) gauge calibration certificate.

# Annex C (informative)
# Types of anchors

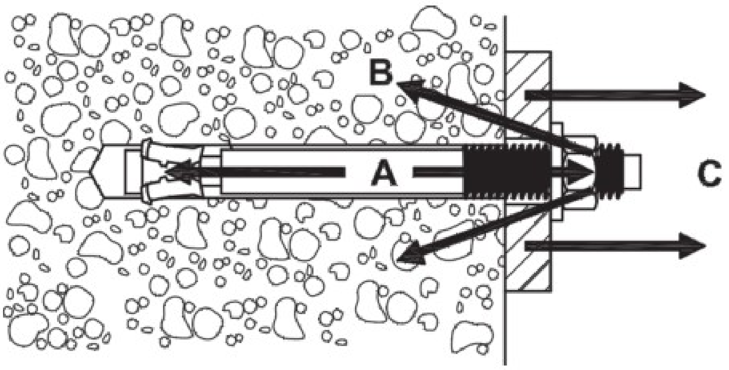
*NOTE The illustrations shown in this annex are general examples only; other configurations of anchors also fall within these categories. References to different anchor types are those commonly used in the industry and are those adopted by the Construction Fixings Association; they might have other meanings when used by some manufacturers who sometimes use different terms for a particular type.*

## C.1 Metal anchors for use in concrete

### C.1.1 Torque-controlled expansion anchors

Tightening the nut (or bolt head) draws the tapered end of the bolt into a metal expansion collar or sleeve causing it to expand and generating a tension (A) in the bolt and an equal clamping force (B) through the fixture, both of which are directly proportionate to the applied tightening torque (see Figure C.1). For a well designed anchor, the manufacturer's recommended installation torque is expected to ensure that the clamping force exceeds the service action (C) by a suitable margin. This means that the fixture will not move, while safeguarding the bolt material and, in the case of bonded anchors the resin bond, from being over-stressed.

**Figure C.1** — *Relationship between bolt tension, clamping force and service action*



There are three general sub-types of the torque-controlled expansion anchor:

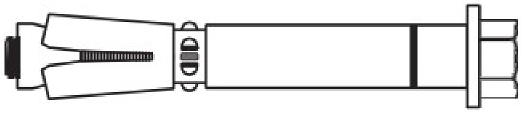
- "throughbolt" type torque-controlled expansion anchor (sometimes known as a "stud" anchor) with one or more expander cones, as shown in Figure C.2, which can be installed through the fixture; suitable for use in concrete only (not to be confused with a "through bolt", which can be bolted all the way through a structure);
- sleeve type torque-controlled expansion anchor, with one or more expansion cones, which can also be installed through the fixture:
  - thick-walled sleeve anchors (see Figure C.3), sometimes known as heavy duty expansion anchors, are suitable for use in concrete only;
  - thin-walled sleeve anchors (see Figure C.4) are suitable for use in both concrete and dense masonry but have generally lower resistance;
- shield type expansion anchor (see Figure C.5), which cannot be installed through the fixture; suitable for use in concrete and hard masonry.

*NOTE Requirements for torque-controlled anchors are given in EAD 330232-00-0601 [8]. See also the CFA Guidance Notes Throughbolt expansion anchors [20], Shield type expansion anchors [21] and Heavy duty expansion anchors [22].*

**Figure C.2** — *Throughbolt type of expansion anchor*

*NOTE Single expander type shown.*

**Figure C.3** — *Thick-walled sleeve anchor*



*NOTE Single expander type shown.*

**Figure C.4** — *Thin-walled sleeve anchor*

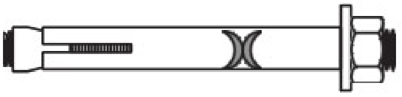
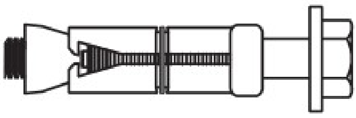


**Figure C.5** — *Shield type expansion anchor*



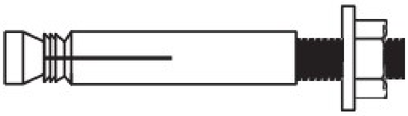
### C.1.2 Undercut anchors

Undercut anchors, intended for use in concrete only, are characterized by a strong mechanical interlock provided by the undercut in the base material. The mechanical interlock is formed by segments, which are made to open into the undercut shape either by turning the nut to draw the tapered cone into the segments or by driving the sleeves over the tapered cone. Some types may be installed through the fixture. The undercut may be formed by a special drilling system or by the anchor itself; this characterizes the two main sub-types:

- undercut drilled before anchor installation (see Figure C.6);
- undercut made during the setting of the anchor (self-undercut anchors) (see Figure C.7).

**Figure C.6** — *Undercut anchor, undercut pre-formed during drilling process*

**Figure C.7** — *Self-undercutting anchor*

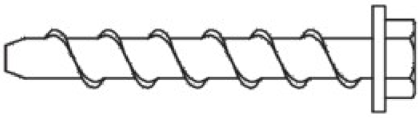


Self-tapping screws are defined as a type of undercut anchor in EAD 330232-00-0601 [8].

Although they are sometimes referred to as "concrete screws", these anchors nevertheless work in other hard base materials, including brickwork and stonework. They can be inserted through the fixture and then screwed into the drilled hole either by a conventional ratchet spanner with a socket, or by means of an impact wrench when multiple anchors are to be installed. The thread form (see Figure C.8), cuts a corresponding thread in the base material forming the interlock with the anchor. These anchors are removable. The wear which takes place on the cutting surfaces means that performance is likely to be reduced if subsequently reused, and reuse is therefore not recommended.

*NOTE Requirements for all anchors of the undercut type are referred to in EAD 330232-00-0601 [8]. See also the CFA Guidance Note Undercut anchors [23] and CFA Guidance Note Self-tapping (concrete) screws [24].*

**Figure C.8** — *Self-tapping screw type anchor*



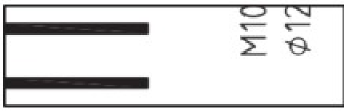
## C.1.3 Deformation-controlled expansion anchors

These internally threaded anchors, as shown in Figure C.9, are suitable for use in concrete only.

Expansion is achieved and controlled by the displacement of an expander element, or plug, with respect to a sleeve or shell or vice versa. Although in theory several types of such anchors exist, the "drop-in" type shown in Figure C.9 is the most common. It is occasionally referred to as a "hammer set socket anchor". Figure C.10 shows the installed condition, which can only be achieved by using the setting punch of the correct diameter and supplied by the same manufacturer.

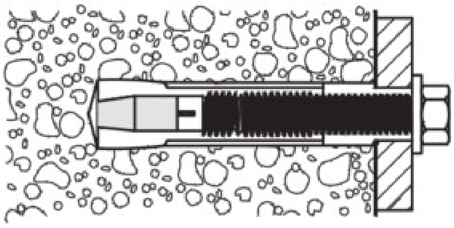
*NOTE Requirements for deformation-controlled expansion anchors are referred to in EAD 330232-00-0601 [8]. See also the CFA Guidance Note Deformation controlled expansion anchors [25].*

**Figure C.9** — *Deformation-controlled expansion anchor*



*NOTE "Drop-in" or hammer set type shown.*

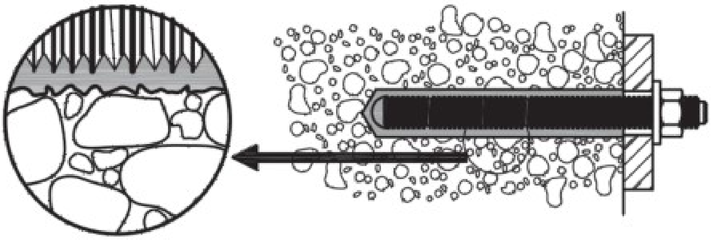
**Figure C.10** — *Drop-in type anchor with expander plug driven fully to the base of the anchor*



## C.1.4 Bonded anchors

The anchor, which can be a threaded rod, internally threaded socket or reinforcement bar, is bonded to the base material by either a cementitious grout or two-part resin mortar, which may be introduced either in a capsule or from an injection cartridge with a special mixing nozzle. The strength of the anchorage comes primarily from the interlock formed between the rough surface of the concrete and the hardened resin on one hand, and the hardened resin and the threaded or knurled surface of the anchor element on the other (see Figure C.11).

**Figure C.11** — *Diagram illustrating mechanical interlock between resin of bonded anchor and base material*



These types of anchors are based on a wide variety of mixing techniques and installation procedures.

The anchor element may be a threaded rod (see Figure C.12), internally threaded socket (see Figure C.13), or post-installed rebar anchoring (see Figure C.14).

**Figure C.12** — *Bonded anchor with threaded anchor rod*

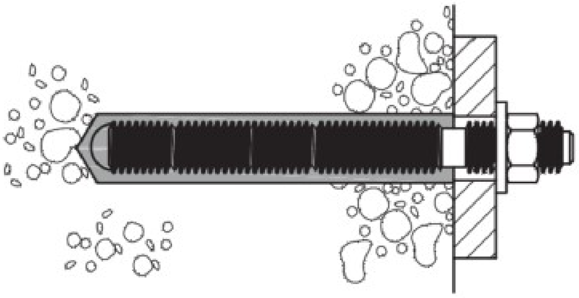


**Figure C.13** — *Bonded anchor with internally threaded socket*

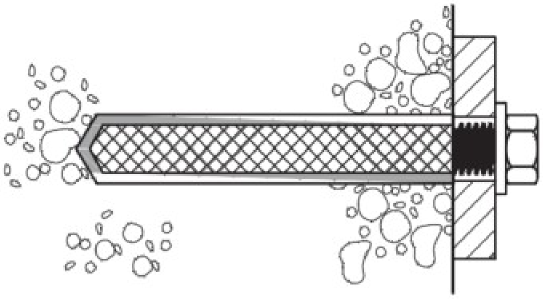
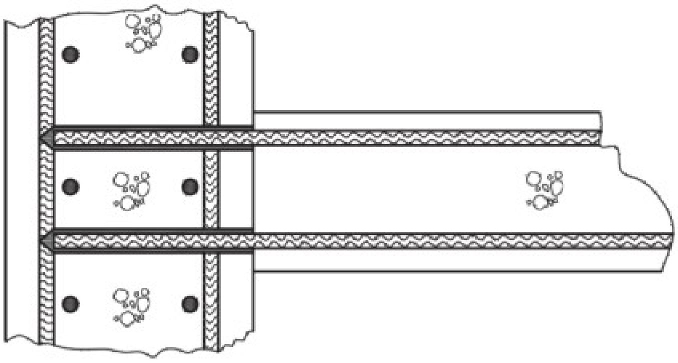
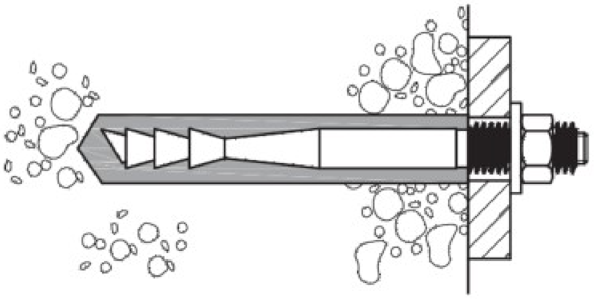


**Figure C.14** — *Post-installed rebar anchors (starter bars) installed using injection resin systems*



Torque-controlled bonded anchors (see Figure C.15) are a special type of bonded anchor, intended for use in cracked concrete. This type of anchor combines the technique of bonding the hardened resin and base material with that of follow-up expansion by virtue of the tapered elements, which take up any displacement allowed by cracking of the concrete. Their action is controlled by the tightening torque, hence the name.

**Figure C.15** — *Torque-controlled bonded anchor*



There are also sub-types of resin bonded anchors, which are also based on the different techniques for mixing the bonding agent and include:

- glass or soft skin capsule anchors (see Figure C.16 and Figure C.17), which use capsules containing the various components of resin aggregate and curing agent or catalyst, and are designed to be mixed by the spinning of an anchor rod or socket into the capsule using a drilling machine and special driving adaptors. Foil and glass capsules use very similar components, work in basically similar ways and are intended for similar applications, usually restricted to installation into concrete only (see Figure C.12 and Figure C.15). The anchor rods or sockets are required to have a chisel point on the end that mixes the resin;

  *NOTE 1 These anchors are not to be confused with "hammer-in" type capsules, which have limited applications, usually for rebar anchoring only, and are not covered here.*

- injection type, where the components of the resin are contained in two compartments which may be tandem or co-axial, and are delivered into the hole by injection through a special nozzle which ensures complete mixing (see Figure C.18). Injection systems are commonly used with anchor rods and internally threaded sockets similar to those shown in Figure C.12, Figure C.13, and Figure C.15, as well as for post-installed rebar (see Figure C.14);

- bulk mixing type, sometimes known as "free mix", where the resin components are packaged separately and mixed by the installer in a container.

  *NOTE 2 Due to the problems of controlling the mix proportions and mixing technique, with consequent influence on performance, this anchor type is not recommended for applications of a safety-critical nature. EAD 330499-00-0601 [11] and EAD 330076-00-0604 [15] do not cover this type of resin anchor.*

**Figure C.16** — *Traditional glass "spin-in" resin capsule*

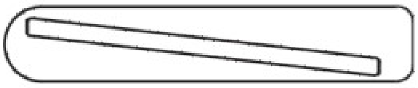
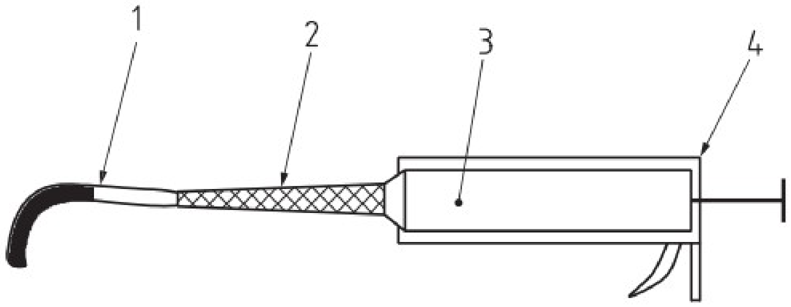


**Figure C.17** — *Foil or soft skin type "spin-in" resin capsule*

**Figure C.18** — *Injection cartridge*



**Key**

1 Resin pumped from mixer nozzle; an even colour shows correct mixing

2 Mixer nozzle

3 Resin cartridge (coaxial type shown)

4 Dispensing gun

*NOTE Coaxial type shown, with special mixing nozzle and dispensing gun.*

Bonded anchors use resins of various formulations:

- polyester;
- vinylester;
- epoxy acrylate;

  *NOTE 3 The resin formulation known as "epoxy acrylate" bears no relation to pure "epoxy" resin, whose characteristics, applications and method of installation are different. They are not to be confused or interchanged.*
- hybrids, whose formulation includes cementitious material;
- pure epoxy;
- cementitious;
- hybrids;
- methacrylate.

When switching from one type of resin formulation to another, installers need to take care to familiarize themselves with all aspects of the new material, especially installation temperature range and curing times, which might be different.

When considering a bonded anchor type, the anchor specifier is advised to seek competent advice on the most suitable type for the intended application, environment and installation conditions.

*NOTE 4 Requirements for anchors of this type are referred to in EAD 330499-00-0601 [11]. See also the CFA Guidance Note Resin bonded anchors [26].*

## C.2 Metal anchors for multiple use for non-structural applications

*NOTE The term "multiple use" does not imply that anchors with this qualification may be reused.*

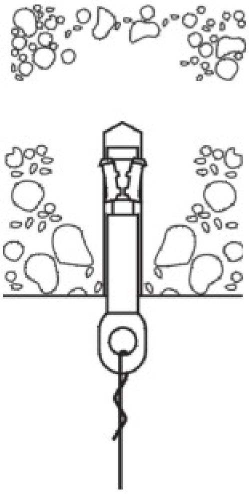
These types of anchor are generally intended for use in suspended ceilings and similar lightweight suspension applications.

Deformation-controlled expansion anchors, as shown in Figure C.9 and Figure C.10, in smaller diameters (typically M6), are suitable for multiple use if they conform to

EAD 330747-00-0601 [6]. Two further examples of anchors suitable for multiple use are shown in Figure C.19 and Figure C.20.

The anchor shown in Figure C.19 works on the same principle as the "throughbolt" type of expansion anchor, and is set by pulling the eye down using a claw hammer. It accepts wire or angle hangers using small bolts.

**Figure C.19** — *Force-controlled expansion anchor for suspended ceilings*

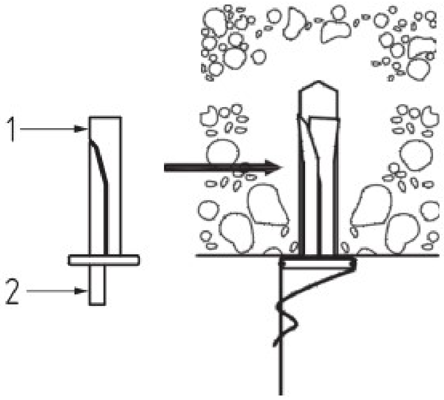


*NOTE Sometimes called "wire hanger".*

Another type of deformation-controlled anchor, for use with hangers, is shown in Figure C.20. A tapered steel shaft is hammered up alongside the tapered steel shank of the anchor to expand it. This anchor is used predominantly with angle hangers.

Other anchor types conforming to EAD 330747-00-0601 [6] are available.

**Figure C.20** — *Deformation-controlled expansion anchor for suspended ceilings – all steel components*



**Key**

1 Steel shaft

2 Steel expander pin

## C.3 Plastic anchors

Plastic is a general term which includes several different types of material, of which nylon has been proven over years of use and research to have the most favourable characteristics in anchor applications. Within this category, one generic type of nylon, PA6, has become pre-eminent.

All plastic materials are subject to creep (see **5.3.5.4**) and nylon is no exception. Responsible manufacturers are expected to apply global safety factors of typically 5:1 to the characteristic resistance when determining the recommended resistance of anchors. When plastic anchors are subjected to preliminary load tests, higher factors need to be applied (see **B.2.3.1**).

A wide variety of different plastic anchor configurations is available. A small selection of the most common types is shown in Figure C.21, Figure C.22 and Figure C.23.

Anchor types shown in Figure C.21 and Figure C.22 are set by turning the screw until fully engaged in the sleeve. Anchor types shown in Figure C.23 are set by turning the screw eye until a designated mark on the shaft reaches the mouth of the sleeve. They are thus all distance-controlled types of anchor, for which installation torques are not required.

*NOTE Requirements for plastic anchors are given in ETAG 020 [7][7] and in EAD 330196-00-0604 [27].*

**Figure C.21** — *Traditional plastic plug*

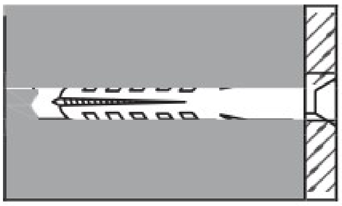


**Figure C.22** — *Frame fixing*

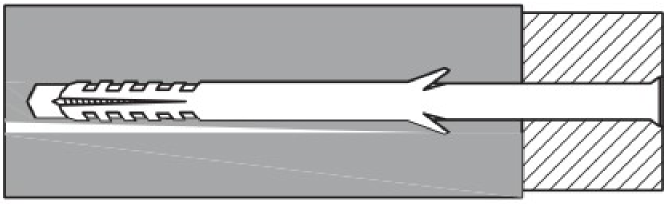
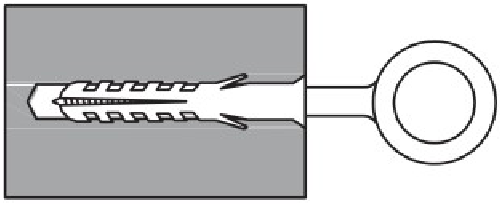


**Figure C.23** — *Plastic plug with screw-in eye*



*NOTE Larger sizes frequently used for scaffold ties.*

## C.4 Metal injection anchors for use in masonry

Injection systems identical or similar to those to be used for anchoring into concrete might be suitable for masonry material (see Figure C.24), as they cater well for porous materials, voids in brickwork due to frogs or poorly filled mortar joints and, with suitable accessories, for perforated bricks and hollow blocks (see Figure C.25 and Figure C.26).

Special systems are available for use in aerated concrete involving the drilling of an outwardly tapering hole (see Figure C.27), to form an interlock with a large volume of this relatively weak material.

They frequently provide the strongest anchorage possible in these materials.

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[7] ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard has not, as yet, been implemented.

*NOTE Requirements for metal injection anchors are given in EAD 330076-00-0604 [15].*

**Figure C.24** — *Bonded anchor used in single skin brickwork, solid brick*

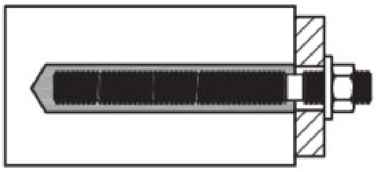
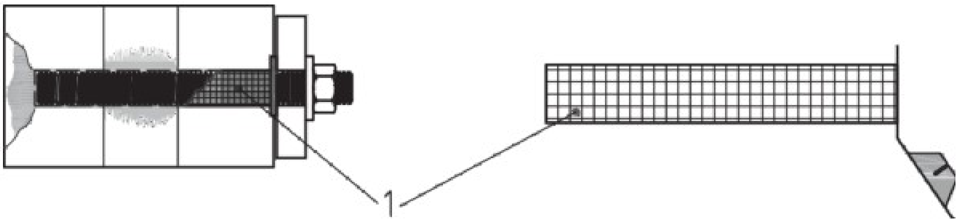


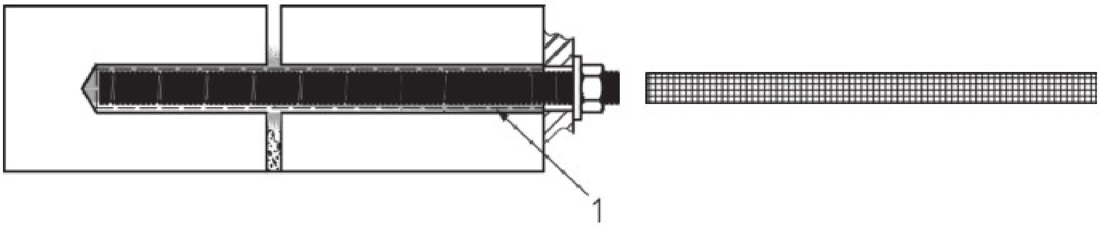
**Figure C.25** — *Bonded anchor used in single skin brickwork, perforated brick, using mesh sleeve to control resin loss in voids*



**Key**

1 Mesh sleeve (may be plastic or wire)

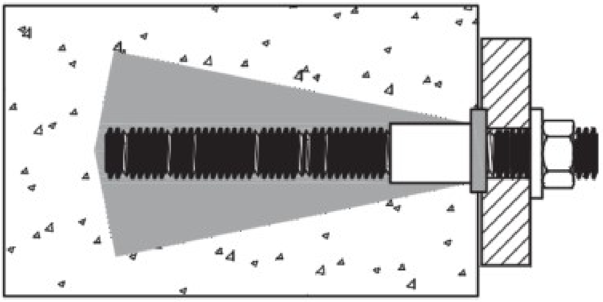
**Figure C.26** — *Bonded anchor used in solid double skin (not cavity) brickwork using steel mesh sleeve to control resin loss in gap between bricks*



**Key**

1 Steel mesh sleeve

**Figure C.27** — *Special injection anchor with outward tapering hole for use in aerated concrete*



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# Annex D (informative)
# Selection process for anchors with and without ETAs

Anchors with ETAs according to EAD 330232-00-0601 [8] and EAD 330499-00-0601 [11] will be qualified for use in applications which are either statically determinate or indeterminate [see **5.2**c) and **5.3.4.1**) and to one of 12 options; options 1 to 6 may be used in either cracked or non-cracked concrete and will have performance quoted for both (generally higher for non-cracked concrete), while options 7 to 10 restrict the anchor for use in non-cracked concrete only. See Annex C.

Anchors with ETAs according to EAD 330747-00-0601 [6] or ETAG 020 [7]8) (Part 2 deals with use in normal weight concrete) are intended for "multiple use" only, i.e. for applications considered to be statically determinate, and are qualified for use in concrete which might be cracked or non-cracked. The scope of applications covered by the different EADs means that the vast majority of applications can be covered by anchors with an ETA. However, some specialized applications might not be covered, such as safety fences for motorways and bridge parapets, which are usually covered by requirements detailed in specifications of other standards or issued by the relevant authorities. Anchors for scaffolding, steeplejacking and fall arrest also fall into specialist applications and are dealt with separately by their respective trade regulations. Anchors with ETAs might still satisfy these applications.

In cases where no anchor is available with an ETA, then an anchor with detailed performance published by the manufacturer may be chosen and the size determined according to the manufacturer's design method, as long as the performance is verified by an independent test laboratory. If, for any reason, no such independently verified performance data is available, then the allowable resistance in the concrete of the particular project may be determined by tests according to Annex B, **B.2.3**. In these cases (anchors without ETA) the design will be carried out according to the global safety factor approach outlined in Annex A.

Figure D.1 outlines the process for determining which anchor type may be used in concrete in relation to the various ETAs that are available.

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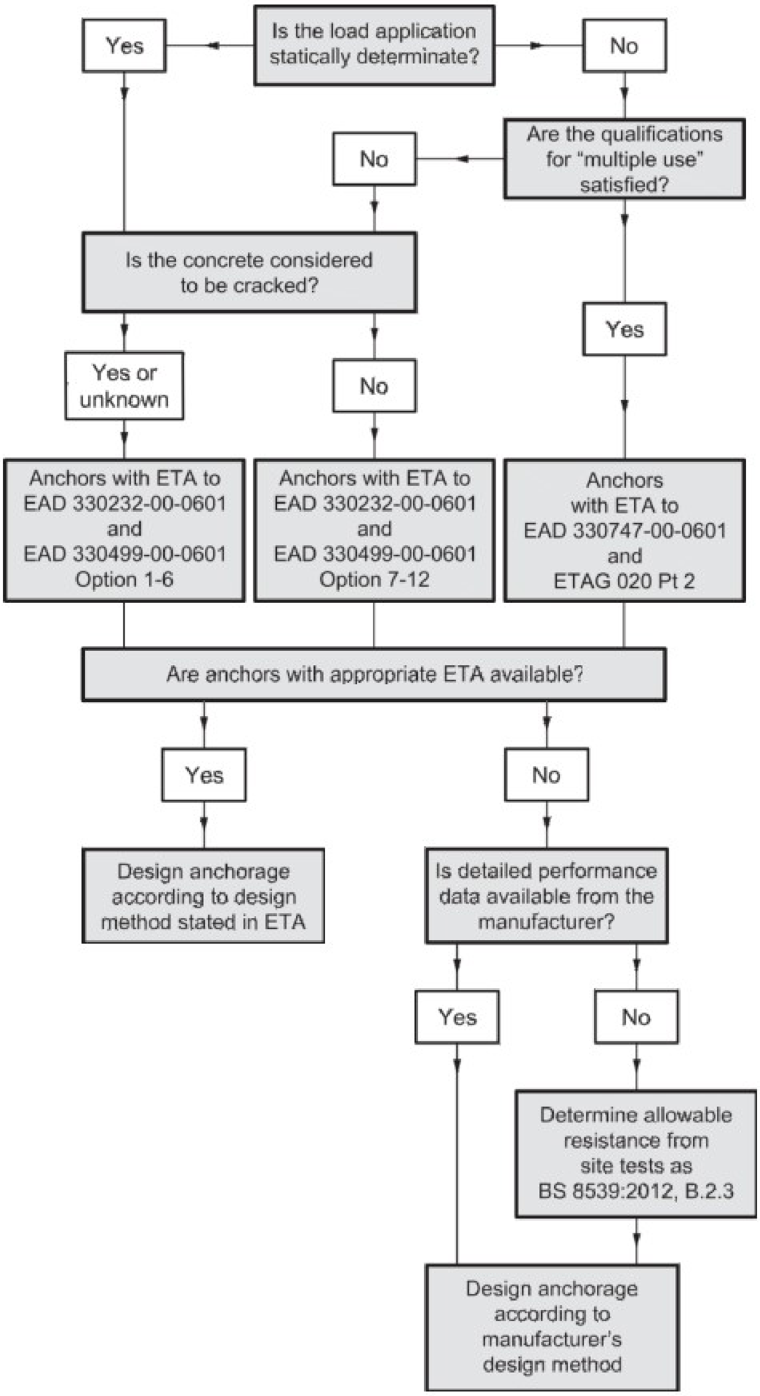
7) ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard has not, as yet, been implemented.

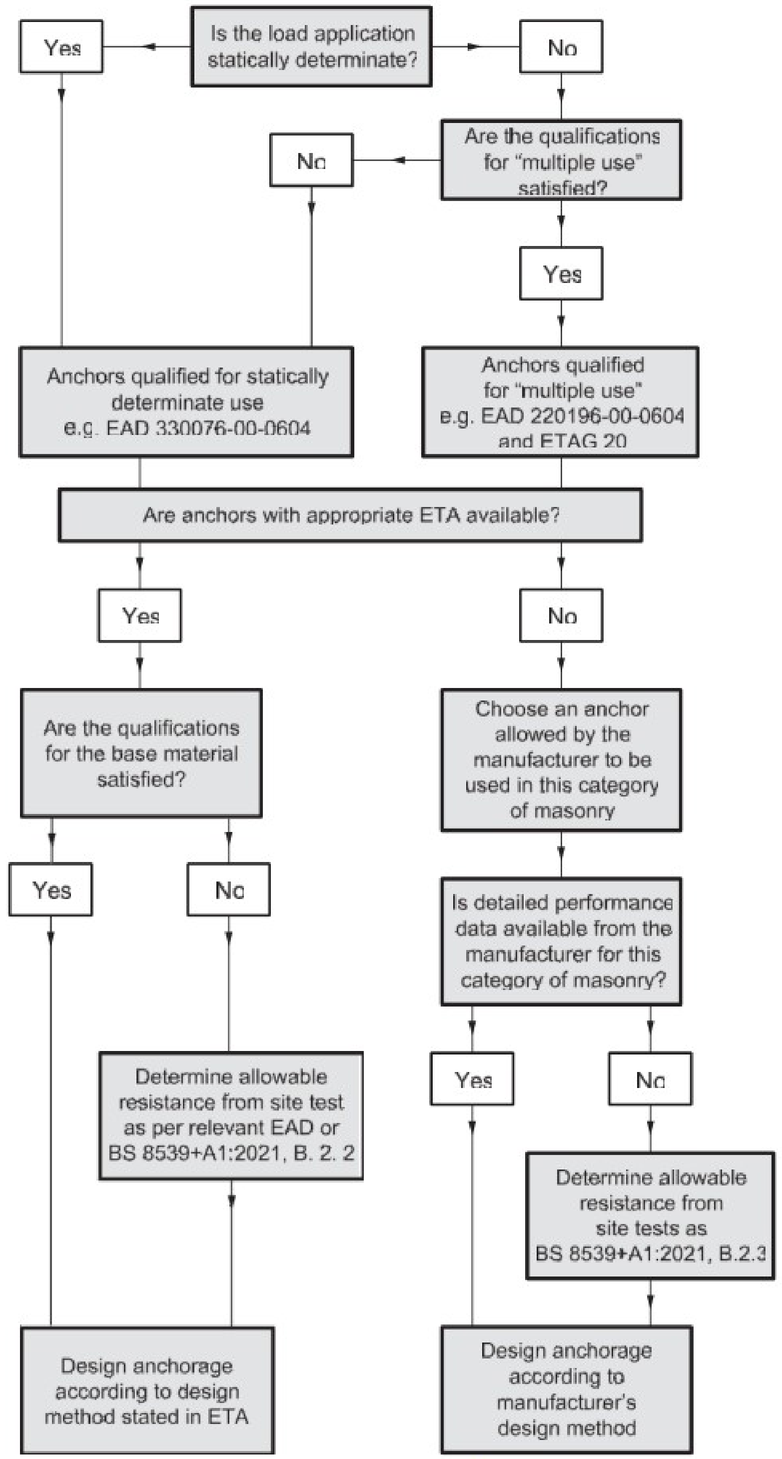
**Figure D.1** — *Flow chart for process of determining anchor usage in relation to ETAs in concrete*



NOTE ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard have not, as yet, been implemented.

Figure D.2 outlines the process for determining which anchor type may be used in concrete in relation to the various ETAs that are available.

**Figure D.2** — *Flow chart for process of determining anchor usage in relation to ETAs in masonry*



NOTE ETAG 020 will be replaced by EAD 330284-00-0601 [29], but at the time of publishing of this British Standard have not, as yet, been implemented.

# Annex E (informative)
# Static and non-static actions

## E.1 Static actions

Static actions are the sum of two types of action: those which are constant (permanent actions), and those which change only slowly (variable actions).

a) Permanent actions include the weight of structural elements and permanent unchanging loads such as floor screeds.

b) Variable actions include those arising from the use of a building: furniture, fixtures and fittings, human traffic, and snow loads. Loads caused by the effect of changing temperatures are also considered to be variable actions. Wind loads are a type of variable action considered to be quasi-static and treated as a static action.

All anchors described in this British Standard are suitable for static actions, both permanent and variable.

*NOTE Most load data published by manufacturers in catalogues and technical literature will, unless otherwise stated, refer to the static loading case only.*

In determining the design action, different partial safety factors ($\gamma_G$ and $\gamma_Q$) may be applied to the permanent and variable components of static actions ($G_k$ and $Q_k$).

## E.2 Non-static actions

Not all anchors are suitable for non-static actions. For the purposes of this British Standard, three types of non-static action are relevant.

a) **Fatigue (cyclic) actions**. Loads which are constantly alternating are called fatigue actions. They can be repetitive and cyclic by nature, with low magnitude, such as vibrations caused by machinery (e.g. fans); or repeated loading and unloading with lower frequency and high magnitude loads, such as are found in lifts, hydraulic production machinery, cranes, bridge traffic, etc.

Text deleted.

b) **Seismic actions**. Earthquakes are responsible for seismic actions. Their effects require special understanding of the various design considerations for both the structure and anchorages.

c) **Shock actions.** Shock actions are those of short duration (milliseconds) and high magnitude, i.e. impact events, and usually occur on a once-only basis, e.g. safety fences, fall arrest anchor device. They usually require anchors qualified specifically for these applications.

# Annex F (informative) Types of corrosion

## F.1 Oxidation

Oxidation occurs in the presence of humidity. In carbon steel, this is exhibited as rust, the development of which can be delayed by protective coatings such as zinc plating. Normal electroplating of, typically, minimum thickness 5 μm is regarded as suitable only for keeping components in good condition up to the point of installation, and in application terms is therefore considered suitable for use in dry internal conditions only. Thicker coatings from processes such as hot dip galvanizing and sherardizing will offer better protection. In application terms, these coatings are normally regarded as suitable for medium-term use in external situations of limited pollution, or in damp internal conditions. Very few anchors are available with these thicker coatings. (The term "galvanized", when used by manufacturers from continental Europe, usually means electroplating of, typically, only 5 μm.)

Oxidation of stainless steel and aluminium, on the other hand, is what produces the slightly dull patina which, under normal conditions, protects these materials form further corrosion.

## F.2 Bi-metallic (galvanic) corrosion

This type of corrosion occurs when two dissimilar metals are in contact in the presence of an electrolyte, e.g. rain water or seawater. The rate of corrosion can be accelerated depending on the particular metals in contact, as shown in Table F.1. For example, if a stainless steel fixture is fixed with a zinc plated carbon steel anchor, the anchor will corrode much faster than would normally be the case.

If contact between dissimilar metals in the presence of an electrolyte is unavoidable, then the dissimilar metals need to be electrically isolated. This can be done using non-conducting sleeves and washers, but needs a high level of care and supervision during installation to avoid unintended contact. It is most important in marine environments.

**Table F.1** — *Galvanic effect on the rate of corrosion of anchors and fixtures in rural or urban areas*

| **Fixture metal** | **Galvanic effect**[A)] | |
|---|---|---|
| | **HDG anchor** | **Stainless steel anchor**[B)] |
| Zinc-plated steel | 0 | F2 |
| Hot dip galvanized coated steel | 0 | F2 |
| Aluminium | A1 | 0 |
| Structural steel un-plated | 0 | F2 |
| Cast steel un-plated | 0 | F2 |
| Stainless steel austenitic and austenitic-ferritic | A2 | 0 |

**Table F.1** *(continued)*

| **Fixture metal** | **Galvanic effect**[A)] | |
|---|---|---|
| | **HDG anchor** | **Stainless steel anchor**[B)] |

[A)] The effect on the rate of corrosion refers to the possibility of additional bi‑metallic corrosion occurring to the anchor or fixture metal where an aqueous electrolyte is present.

- 0 = no effect on the rate of corrosion (does not mean no corrosion, simply no change to the rate of corrosion) of fixture or anchor;
- F1 (A1) = moderate increase in corrosion of fixture (anchor);
- F2 (A2) = heavy increase in rate of corrosion of fixture (anchor).

[B)] Austenitic and austenitic‑ferritic stainless steel, often referred to as "duplex".

Zinc‑plated steel is not recommended as a material for anchors for use of any duration, even short‑term, in conditions which might give rise to galvanic corrosion. Hot dip galvanized anchors will only offer short‑term resistance in such conditions, and medium‑term resistance when in contact with fixtures of a similar finish where there is no increase in the rate of corrosion.

Anchors set in reinforced concrete might come into contact with the reinforcement. When this occurs in marine conditions, the reinforcement might be exposed to the seawater and could suffer an increased likelihood of corrosion, which will be exacerbated if the anchor in question is of stainless steel. One means to prevent this is to use resin bonded stainless steel anchors. The rebar will be protected from the corrosive effects of the sea water, as the resin will prevent the sea water from entering the drilled hole.

## F3 Chemical corrosion

This type of corrosion occurs in areas of high atmospheric pollution or marine environments, and in this case even grade A4 stainless steel might have a reduced life expectancy. Special alloy stainless steels are available for these situations (see F.6).

## F4 Stress corrosion

Stress corrosion occurs in conditions where elevated temperatures coincide with moisture and the presence of corrosive gases, particularly chlorides, e.g. swimming pool roof spaces and road tunnels. Normal materials, including grade A4 stainless steel, might not be suitable. The risk of stress corrosion cracking is greater for leaner alloys (grade A2 and grade A4) austenitic stainless steels. The use of more highly alloyed austenitic or duplex stainless steels can mitigate the risk of stress corrosion cracking occurring.

## F5 Pitting corrosion

Pitting corrosion is the local breakdown of the passive layer on passively protected materials such as stainless steel and aluminium, and results in pitting which can affect appearance, might cause some staining and, depending on section thickness, can eventually lead to complete perforation. It can be initiated by chemical contamination, including seawater and other chlorides, or even by steel fragments from non‑stainless tools.

It is important that materials chosen to resist stress corrosion cracking are also resistant to other likely forms of corrosion.

## F.6 Crevice corrosion

Crevice corrosion is a form of corrosion affecting materials which develop a passive layer, such as stainless steel or aluminium, in the presence of an electrolyte or corroding medium. It is similar to pitting corrosion in that the passive layer breaks down in a gap, which might be a design feature of a component or a crevice between two components, or in shielded areas beneath surface deposits. For crevice corrosion to occur, the crevice needs to be wide enough to allow the corroding electrolyte in and then provide stagnant conditions, i.e. no circulation of the electrolyte. It can therefore be a concern where gaps are a few microns wide but there are no absolute or critical dimensions for crevices, below which corrosion is certain.

Stainless steels with higher chromium content are generally better at resisting crevice corrosion, and the addition of molybdenum is also beneficial.

The use of isolating gaskets is helpful but will not always prevent corrosion occurring, so it is important that a good fit between the gasket and the metal is achieved, to avoid crevices being formed in stagnant conditions. Materials which are capable of resisting pitting corrosion are usually capable of resisting crevice corrosion.

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