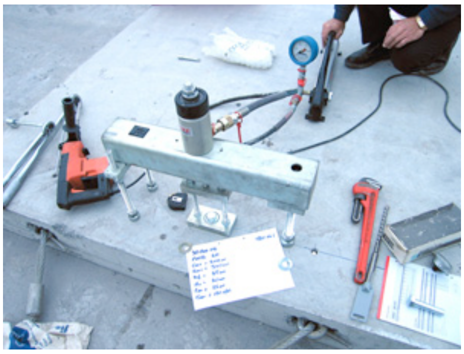
CFA Guidance note:
Procedure for Site Testing Construction Fixings - 2012

1 INTRODUCTION



The primary purpose of this Guidance Note is to provide guidance as to how anchors should be tested when it is necessary to do so on the construction site, in particular when this is being carried in accordance with the recommendations of the British Standard BS 8539:2012 *Code of Practice for the selection and installation of post-installed anchors in concrete and masonry*[1]. The Code of Practice sets out the roles and responsibilities of all stakeholders in the use of construction fixings including testers for whom it defines the test regimes. This Guidance Note is a Normative Reference within the code i.e. it is indispensible for its application, and provided details of how tests should be carried out. Testers should have a copy of the code and be familiar with especially clauses 4.7, 9 and Annex B.

BS 8539 was drawn up by a drafting panel lead by the Construction Fixings Association and, as far as on-site testing is concerned, it follows many of the recommendations already established by the Association. Some minor details have been revised to match recent developments in anchoring technology.

Another British Standard, BS 5080[2] deals with how anchors may be tested in laboratory conditions but, for most purposes, the recommendations of that standard will be over ridden by the recommendations of the various ETAGs (European Technical Approval Guidelines[3]) which are used to award ETAs (European Technical Approvals[4]) for anchors to be used in safety critical applications.

Full Members of the CFA may carry out tests free of charge when tests are required to prove the suitability of a fixing for a particular application and where there is no existing data on which the suitability could reasonably be assessed. When the purpose of the test is to validate the quality of installation members may make a charge or refer clients to independent testing companies, see to Section 9 for details of the CFA Approved Tester scheme.

Contents

1.1 Terminology and notation

In this Guidance Note the terms listed are taken to have the following meanings (Some terms and notation are defined within the text):

Note: Terminology adopted here is that used in in BS 8539:2012 and similar to that used in the European context e.g. Eurocodes, and in particular in CEN Technical Specifications [CEN TS 1992-4-1] which detail design methods for anchors with ETA[6]. Some of this terminology is different to that traditionally used in the fixings industry. Key terms used here are defined below, (the traditional reference is shown in brackets). A key difference to be aware of is that loads are now referred to as either "actions" – loads applied from the fixture – or "Resistances" – the ability of the anchors to withstand actions. For more on the terminology see [5]. In the definitions referred to below the notation N is used for tensile actions or resistances, V would be substituted for the same term in shear.

Anchor (Fixing)
Manufactured device for achieving a connection between the fixture and the base material. (In CEN TS 1992-4-1 the terms "anchor" and "fastener" are used interchangeably.) BS 8539 uses only the term "Anchor", here we use both anchor and fixing.

Anchorage
The combination of anchor, a fixture, e.g. a bracket, and the immediately surrounding base material on which the anchor depends in order to transfer the relevant forces. (In CEN TS 1992-4-1 the term "fastening" is used.)

Allowable Resistance (Allowable Load), $N_{R,all}$
Safe working load determined from tests carried out on site when no Recommended Resistance is published by the manufacturer. In designs carried out to Eurocode 2 there is no equivalent term see [3].

Characteristic Resistance (Characteristic Load), N_{Rk}
Resistance derived as the 5% fractile of the mean ultimate resistance when determined from a series of tests based on a 90% probability that 95% of all anchors will exceed the characteristic value. In some ETAGs it may be derived by other means, e.g. by empirical calculation depending on the mode of failure.
$N_{Rk,ETA}$ is the characteristic resistance quoted in the ETA for the relevant base material.

Characteristic Action (Applied Load), N_{Sk}
Actual load to be applied to the anchor according to the design. A term in common usage is "unfactored load".

Designer
Person with overall responsibility for the design of the structure which includes the anchorage.

Design action, N_{Sd}
Sometimes referred to as the "Factored load" it is the action determined by the application of a partial safety factor, γ_F, to the characteristic action. There was no traditional equivalent to this term.

Installer
Person or organisation who installs the specified anchors or the test anchors.

Masonry unit
Individual brick, block or stone within a masonry wall.

Recommended Resistance (Recommended Load), N_{rec}
The load which may be applied to the anchor as quoted by the manufacturer for a specific base material. In designs carried out to Eurocode 2 there is no directly equivalent term see [3].

Ultimate Resistance (Failure load) N_{Ru}
Failure load determined in a test (Mean ultimate resistance, $N_{Ru,m}$, is the average from a series of tests)

Specifier
Person or organisation who designs the connection between the fixture and the substrate and is responsible for the selection and specification of the anchor.

Tester Person or organisation who tests anchors

Loads in tests:

N_p tensile load applied in a proof load test

N_{test} tensile test load applied in preliminary tests

$N_{Ru,m}$ mean ultimate tensile resistance recorded in a series of tests

$N_{u,ave}$ average tensile failure load recorded in preliminary tests

$N_{u,low}$ lowest tensile failure load recorded in preliminary tests

$N_{1st,m}$ load at first movement

2 SCOPE

BS 8539 outlines the test regimes (number of tests, test load, assessment of results) which need to be satisfied to achieve the appropriate objectives. These are summarised below. This GN gives the details of how tests should be carried out: equipment, how loads are applied, how movement may be monitored, reaction spacings, etc. Some elements of the recommendations of BS 8539 are repeated here to provide a single reference.
This Guidance Note covers the procedures for applying Ultimate, Preliminary or Proof Loads in concrete and masonry materials. Tests in the tensile direction are covered in the main body of the document. Tests in shear are not usually needed as shear performance is generally limited by the material strength of either the structure or the anchor. They may be needed when fixing to low strength masonry. Procedures for testing in shear are covered in Appendix 1.

3 PURPOSE OF TESTS, TEST REGIMES AND ASSESSMENT OF RESULTS

Tests for anchors on site may be required for two distinct purposes.

A) To determine the suitability of a fixing and the Allowable Resistance of an anchor in the case where no manufacturer's data is available for the specific base material concerned, see 3.1, or

B) To validate the quality of installation of anchors used on the job, i.e. Proof tests , see 3.2. Proof tests are not generally recommended for assessing the suitability of fixings for use in a particular base material, i,e, purpose A above, except in cases where tests as prescribed in 3.1 cannot be carried out, e.g. anchors used for seasonal decorations[7]. In such cases proof tests should be carried out on 100% of the fixings of a project.

Site tests are not required for objective A) above in cases where an anchor with an ETA is used and the base material satisfies the criteria of the ETA.

Site tests are not required for objective b) above in cases where an anchor with an ETA is used and it is installed, as required in the ETA, by a competent person working under supervision.

3.1 Tests regimes for determining Allowable Resistance.

Tests to determine Allowable Loads are called up in BS 8539 in Clause 9.2 for two conditions, Anchors with or without ETA, and for each there are two approaches, these four approaches are first summarised in 3.1.1 and described in detail in 3.1.2. **NOTE:** The test procedures for all regimes are detailed in section 4.

3.1.1 Test regimes for determining Allowable Resistance - SUMMARY:

Anchors with ETA
(where the base material of the application is within the category of the ETA
but does not comply in terms of strength and/or dimensions)
Test to BS 8539 Annex B.2.2
See 3.1.2 a) and b) below

This allows either:

Test to relevant ETAG Test ≥ 15 anchors to failure N_{Rk} = .5 (alt .6*) x ave of lowest 5 results See 3.1.2.1 below. (*ETAG 014)	OR	Test to BS 8539 Annex B.2.2.1 Test 5 to 15 anchors to failure N_{Rk1} from statistical analysis See 3.1.2.2 below

These two approaches will give different results but both on the safe side. The ETAG approach potentially requires more tests so will take more time and cost more. In the BS 8539 alternative approach, the basis of the statistical analysis of the results means that the larger the number of anchors tested the higher the resulting allowable resistance is likely to be.

Anchors without ETA
Test to BS 8539 Annex B.2.3
See 3.1.2.c) below

This allows either:

Test to BS 8539 Annex B.2.3.1 Preliminary test procedure Test ≥ 5 anchors to a test load, N_{test}. $N_{R,all}$ derived from simplified approach See 3.1.2.3 below	OR	Test to BS 8539 Annex B.2.3.2 Test ≥ 5 anchors to failure. N_{Rk1} derived from statistical analysis See 3.1.2.4 below

Of these two approaches the CFA recommends the "Preliminary test procedure" as it requires fewer tests and is less likely to involve damaging the base material as the initial tests are taken only to a test load and tests to failure of all samples are only required if any of those fails to reach the required test load. The results from the alternative approach are more likely to be an accurate assessment of the anchor performance but may cause more damage. Again the two approaches will give different results and, in the tests taken to failure the more tests are carried out the more accurate the results are likely to be due to the statistical benefits of a larger sample size.
Tests under this heading are not usually required for anchors to be used in concrete as BS 8539 recommends that only anchors with ETA should be used and full performance will be stated in the ETA. They may be required for anchors to be used in concrete if for some reason no anchors with ETA are available on the market or if the condition of the concrete gives reason to believe that performance quoted in the ETA is unlikely to be achieved. They are therefore normally expected to be required only for anchors to be used in masonry as outlined below.

3.1.2 Test regimes for determining Allowable Resistance – DETAILED EXPLANATIONS:

a) Where the proposed anchor carries an ETA for the category of masonry of the job and that masonry conforms to the qualifications of the ETA in terms of strength and dimensions. i.e. the masonry units have a nominal strength at least that quoted in the ETA and their dimensions the same as ort larger than those quoted in the ETA, then site tests are not needed and the anchor can be selected using the load data quoted within the ETA.

b) Where the proposed anchor carries an ETA for the category of masonry of the job but that masonry **does not** conform to the qualifications of the ETA in terms of strength and dimensions. i.e. the masonry units have a nominal strength lower than that quoted in the ETA OR their dimensions are not as large as those quoted in the ETA, then tests should be carried out to EITHER:

- the test regime outlined for Job-site tests in the relevant ETAG, (see BS 8539 Annex B.2.2) see 3.1.2.1. below

or

- the test regime detailed in BS 8539 Annex B.2.2.1 see 3.1.2.2 below

c) Where there is no anchor available on the market which carries a relevant ETA the tests called for in BS 8539 Annex B.2.3 should be carried out as long as the proposed anchors are of a type approved by the manufacturer for use in the category of base material involved. Within this Clause there are two possible approaches.

The test regime described in 3.1.2.3 below relates to BS 8539 Annex B.2.3.1 where it is referred to as "Tests for allowable resistance (simplified approach)" but is traditionally referred to as "Preliminary Testing".

> *The test regime was devised some years ago by the CFA to provide a test method which is on the safe side, and would minimise both the number of tests required and – if possible – damage to the structure.*

The test regime described in 3.1.2.4 below relates to BS 8539 Annex B.2.3.2 where it is referred to as "Tests for allowable resistance (statistical approach)".

> *This test regime is more traditional. It may, depending on how many tests are carried out, produce a more accurate result than the Preliminary testing approach but is more likely to damage the structure. In common with tests called for in Annex B.2.2.1 the larger the sample size the higher the result is likely to be.*

Note: If for any reason an anchorage is to be made in concrete for which no anchor with an ETA is available (and no other industry specific test regime is appropriate), or into concrete whose condition may give rise to concern regarding anchor strength, then tests to either BS 8935 Clause 9.2 condition b) to Annex B.2.3.1 or Clause B.2.3.2 may be done.

Determination of Allowable Resistance.
For completeness and ease of use the regimes for determining allowable resistances are repeated from BS 8539, together with the treatment of results, and for clarity the references for equations used in BS 8539 are retained.

3.1.2.1. Test regime – anchors with ETA – as ETAG

The regimes for anchors under this heading should be taken from the relevant ETAG. They are summarised below for reference and comparison with other regimes outlined here.
The output from these test regimes is the Characteristic Resistance from which the Allowable Resistance is determined by dividing the characteristic resistance by a partial safety factor, γ_F.

In the following ETAGs the basis of the tests is common:
Test at least 15 anchors to failure.
In assessing the results N_1 = mean of the lowest 5 results

- ETAG 014 Plastic anchors for fixing of external thermal insulation composite systems with rendering.
  Characteristic resistance, $N_{Rk} = .6N_1 < 1.5kN$
- ETAG 020 Plastic anchors for multiple use in concrete or masonry for non-structural applications
  Characteristic resistance, $N_{Rk} = .5N_1 \leq N_{Rk,ETA}$* *(for the same category of material)
- ETAG 029 Metal injection anchors for use in masonry
  Characteristic resistance, $N_{Rk} = .5N_1 \leq N_{Rk,ETA}$* *(for the same category of material)

3.1.2.2. Test regime – anchors with ETA – to BS 8539 Annex B.2.2.1

Between 5 and 15 anchors are loaded carefully to failure.
For each tests record the load at first movement N_{1st}, the failure load N_{Ru}, and the mode of failure (see 4.2)
For the series calculate the mean load at first movement $N_{1st,m}$, the mean failure load $N_{Ru,m}$.

Determination of Allowable Resistance:

Characteristic resistance, $N_{Rk1} = N_{Ru,m} (1 - K \cdot v) \cdot \beta \quad \leq N_{Rk,ETA}$ (B.1)

where: the values of K are taken from standard statistical tables:
- For 5 tests K = 3.4
- For 10 tests K = 2.57
- For 15 tests K = 2.33
- v is the coefficient of variation of the failure loads, and is given by $v = (s \div N_{Ru,m}) \cdot 100\%$;
- β is an influencing factor whose values are given in the approval document.
- s is the standard deviation of failure loads about the mean value.

The design resistance, N_{Rd} is given by equation (B.2), from which the allowable resistance, N_{Rall}, is derived using equation (B.3).

$$N_{Rd} = N_{Rk1} \div \gamma_M \qquad \text{(B.2)}$$

$$N_{R,all} = N_{Rd} \div \gamma_F \quad \leq N_{1st,m} \qquad \text{(B.3)}$$

γ_M is given in the approval document.

γ_F = 1.35 for permanent actions, 1.5 for variable actions or 1.4 if the nature of the actions is unknown or they are mixed.

3.1.2.3. Test regime – anchors without ETA – to BS 8539 Annex B.2.3.1 - "Preliminary Tests".

Procedure Test **5** anchors to a load of $N_{test} = N_{Sk} \cdot \nu_{test}$ (B.4)

Where N_{Sk} is the characteristic tensile action.
and ν_{test} depends on the type of anchor being tested. Values for ν_{test} are shown in Table 1 below.

It is essential that anchors used for preliminary tests are installed specifically for the tests and will not be used on the job.

<u>If all 5 anchors hold the test load, see figure 1, then the characteristic action N_{Sk}, may be taken to be the allowable resistance in this base material.</u>

$$N_{R,all} = N_{Sk} \qquad \text{(B.5)}$$

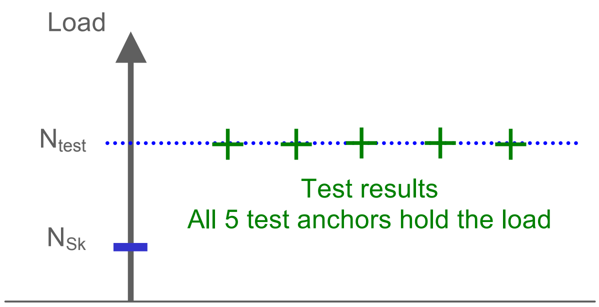


Figure 1. All five anchors hold the test load satisfactorily.

If any anchor fails to reach the test load then the situation should be reviewed with the specifier. If the number of anchors cannot readily be increased then the anchor specification should be changed – options include using the same type of anchor, but with a larger diameter or increased embedment depth, or changing to a different type of anchor. In either of these cases the Preliminary tests will need to be repeated with the new anchor.

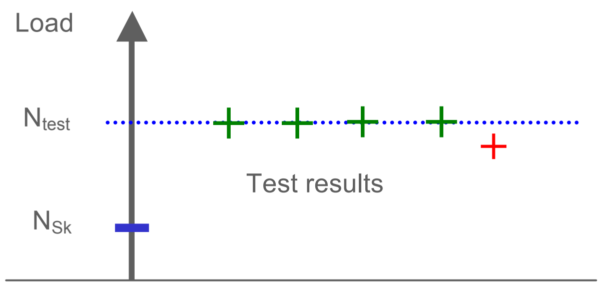


Figure 2. EXAMPLE TEST SERIES.
On initial test four anchors hold the required load satisfactorily but one fails at a slightly lower load.

If the number of anchors being used can be readily increased then the following approach 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. $N_{Ru} > 0.8 \cdot N_{test}$.

Procedure following one failure before reaching N_{test}

Load all five 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, $N_{Ru,m}$, for that test.

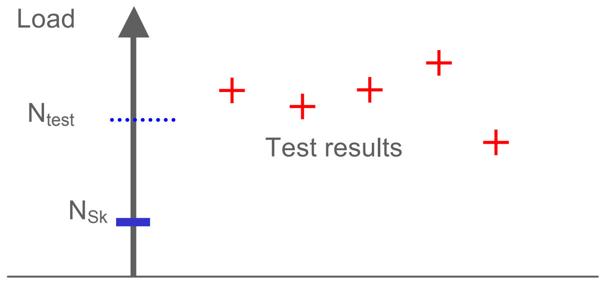


Figure 3. EXAMPLE TEST SERIES cont'd.
The remaining anchors which held the test load (four in this example) are then *carefully* loaded to failure.

The new Allowable Resistance, $N_{R,all}$, is then calculated as the lowest result from equations B.6 and B.7:

Average failure load, $N_{u,ave} \div \nu_{ave}$ (B.6)

Lowest load, $N_{u,low} \div \nu_{low}$ (B.7)

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

Where the factors ν_{ave} and ν_{low} are shown in the table 1

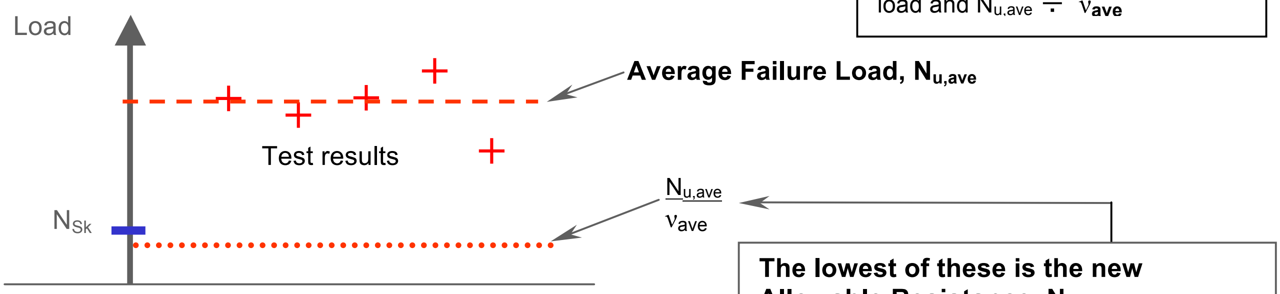
Table 1. Factors used in preliminary tests

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

* Nylon anchors require higher factures due to the effects of creep[8].

Determining the Allowable Resistance, $N_{R,all}$, from the test results:

Figure 4. Finding average failure load and $N_{u,ave} \div \nu_{ave}$



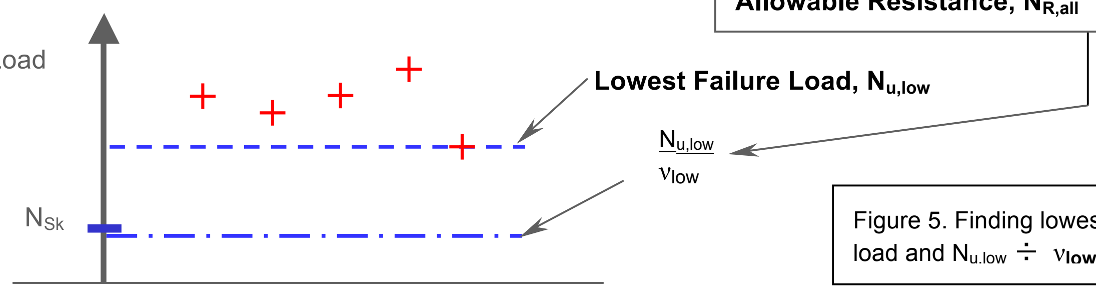
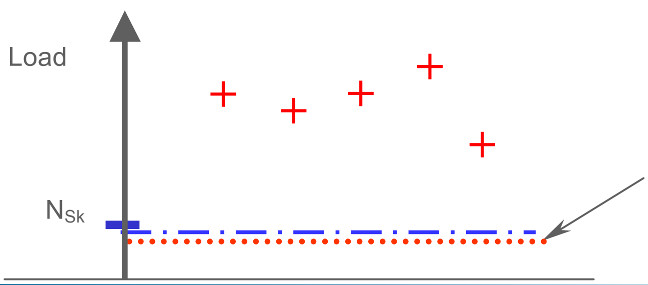


Figure 5. Finding lowest failure load and $N_{u.low} \div \nu_{low}$

Figure 6. Determining allowable resistance from lowest result.



In this case the $N_{u,ave} \div \nu_{ave}$ becomes the new "Allowable Resistance", $N_{R,all}$. It is inevitably lower than the required "Characteristic action" so more fixings will be needed.

If the number of anchors may be increased pro rata by, for instance, simply reducing the spacing between anchors, then the new number of anchors required on the job, n' comes from:

Revised number of anchors required

$$n' = n_0 \cdot N_{Sk} \div N_{R,all} \quad \text{(B.8)}$$

Where n_0 = number of anchors originally assumed
and n' = number of anchors required with the Allowable Resistance $N_{R.all}$

3.1.2.4. Test regime – anchors without ETA – to BS 8539 Annex B.2.3.2 Ultimate load tests with statistical analysis.

Between 5 and 15 anchors are loaded carefully to failure.
For each tests record the load at first movement N_{1st}, the failure load N_{Ru}, and the mode of failure (see 4.2)
For the series calculate the mean load at first movement $N_{1st,m}$, the mean ultimate load N_{Ru},m.

Determination of Allowable Resistance:

Characteristic resistance, $N_{Rk1} = N_{Ru,m} (1 - K \cdot v) \cdot \Omega \quad \leq N_{Rk,ETA}$ (B.9)

where: definitions of K, v and s are as section 3.1.2.2

v should not be greater than 30%

Ω is an adjustment factor based on conditions pertaining to the application and whose values should be decided by the designer (or specifier). The following values are mentioned in BS 8539.

Ω = 0.8 for installation in wet substrate

Ω = 0.8 for the effect of temperatures above the service temperature range normally recommended by the manufacturer.

Ω = 0.75 for rendered or plastered walls where the mortar joints are not visible or where positioning of anchors cannot be guaranteed to be within the brick.
Where more than one of these conditions applies then all relevant factors should be multiplied together.

The allowable resistance, $N_{R,all}$ is given by equation (B.10).

$$N_{R,all} = N_{Rk1} \div \nu \quad \leq N_{1st,m} \quad \text{(B.10)}$$

where ν is a global safety factor (to be chosen by the specifier) e.g. 2.5, which is the factor recommended in BS 8539 for static and quasi static actions for anchors other than those of nylon for which higher factors should be considered e.g. 5.0 .

3.2 Tests to validate the quality of installation – Proof tests

Tests to meet this objective are called up in BS 8539 in Clause 9.3 and the test regime outlined in BS 8539 Annex B.3.

The term "Proof load" as used here and in BS 8539 bears no relation to "Proof Load" tests carried out to ETAG 029 B.3.3.

BS 8539 recommends, in section B.3, that the level of Proof Load, Np is given by

$$N_p = N_{Sk} \cdot \nu_{P,test} \quad \text{(B.11)}$$

Where the level of the factor $\nu_{P,test}$ should be decided by the engineer responsible for the fixing specification.

BS 8539 recommends $\nu_{P,test}$ = 1.5 when $\geq$ 2.5% of all anchors are tested and
= 1.25 when $\geq$ 5% of all anchors are tested
$\nu_{P,test}$ should not exceed 1.5 x the manufacturer's recommended resistance, N_{rec}, for the type and size of fixing in the base material concerned at the same strength, if known, and taking account of any spacing and/or edge distance reduction factors.

The minimum number of fixings to be proof tested should always be at least 2.5% and at least 3 of the total number of anchors installed on a job. The minimum of 3 applies in any discrete area where different anchors may have been used, the base material is different, the condition of the base material has been affected by weather conditions e.g. on a different elevation or where anchors have been installed by different installation teams.

3.2.1 Acceptance criteria

Anchors can be said to have satisfied a proof test if the required load is held without movement or any damage or deformation occurring to either the fixing or the base material.
Any anchor suffering movement or damage should be recorded as a failure.

3.2.2 Failures during Proof Testing

If the correct selection and installation procedures have been carried out as recommended by respectively BS 8539 and the manufacturer then no failures should be encountered. Failures indicate that one or other of these processes may not have been carried out correctly so must be treated seriously.

If, in any discreet area, 1 failure is encountered then the reason for failure should be investigated, the number of anchors tested in that area should be doubled to 5% and at least 6. If more than one 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 specification of the fixing and for its installation as they may prompt either the improvement of the installation method or a revised fixing specification.

3.2.3 Replacing failed fixings

Failed fixings will usually need to be replaced. This should be carried out by a competent installer observing all installation procedures as set out in BS 8539 and in manufacturer's installation instructions. The specification of replacement fixings should be confirmed with the specifier before replacement is carried out in case a revised specification is deemed necessary. Depending on the nature of the failure it may, under certain circumstances, be possible to install new fixings in the original holes – specialist advice, including from the anchor manufacturer, should be sought before pursuing this option. If replacement anchors are not permitted to be located in the same holes then the location of new holes should be determined by the specifier.

4 PROCEDURE FOR TESTS

The following is a general procedure which covers preliminary tests, test to failure and poof tests.
Any deviations from this procedure should be noted in the test report.

SAFETY: All testing operations must be carried out with due regard for the safety of the tester and all bystanders.

- Ensure that the anchors to be tested are as specified on the job or by the client and that the test objective is known, including proof load levels (if appropriate).
- In the case of tests into new construction - Ensure that the base material is at least the strength assumed by the specifier in the design of the fixing.
- Ensure the positioning of anchors to be tested is as required. See section 5.
- Ensure the fixing is or has been installed as per the manufacturer's instructions.
- Assemble the test rig (See 6) – check that reaction spacings meet the recommendations of section 6.3 in relation to the test objective.
- Connect the test meter or hydraulic load cell to the fixing, see section 6.2.
- **If movement is to be monitored in detail** (not usually required for proof tests)
  - Put in place displacement measuring equipment, e.g. dial gauge on remote mounted stand.
  - With load at zero record reading of dial gauge.
  - Apply the load slowly and progressively and record the load at first movement (see section 6.4) and at the manufacturer's recommended resistance if known.
  - Increase the load in increments to give at least 10 readings up to the expected failure load.
  - For each increment allow both load and displacement to substantially stabilise then record load and displacement (see notes on Load relaxation 4.1 below).
  - When the maximum load is reached record the load and, if possible, displacement.
  - Record the condition of the fixing and base material, e.g. cracks
  - If failure has occurred record the mode of failure (see 4.2 below) and the size of any material cone that may have detached from the base material.
  - If failure has not taken place release the load and record the residual displacement.
- Detach the movement monitoring and test equipment. Make good any damage to the base material if possible.
- **If movement is not to be recorded in detail**
  - Apply the load slowly and progressively and record the load at first movement (see section 6.4)
  - Increase the load steadily at a rate to reach the required proof load in 30 seconds or, if testing to ultimate load, the maximum load in between 60 and 90 seconds.
  - When the proof or maximum load is reached record the load and, if possible, any displacement, by estimation if necessary.
  - If failure has occurred record the mode of failure (see below) and the size of any material cone that may have detached from the base material.
  - Detach the test equipment and make good any damage to the base material if possible.
- Complete the test report and pass to the person who requested the test.

NOTE: All anchors tested to failure or failing to reach the required proof test load should be removed or marked such that they are not put into service.

4.1 Load Relaxation

When loading is halted (before failure) relaxation takes place in the anchorage as stresses are distributed into the base material. (This effect continues at a reducing rate throughout the life of the anchorage.) This results in reduction of the indicated load and is to be expected. When the test load is applied in increments, for the sake of monitoring movement, readings of movement and load should therefore be taken simultaneously as far as possible and after the indicated load has substantially stabilised. Load relaxation should not be confused with failure of the anchor which is sometimes possible especially when resin anchors fail as they do not fail suddenly but progressively, this is because a significant force may be required to extract a failed fixing even after the resin bond has failed. These conditions can be distinguished by returning the load to its previous level. If the anchor is failing the load will relax again and the anchor slip progressively from the substrate. In the case of load relaxation reapplying the load will show very little further relaxation. For more information see an Article: *Load relaxation and anchor testing*[9].

4.2 **Modes of failure** may include the following:

- Pull out of the fixing (with no breakage of anchor or base material)
- Bolt breakage
- Concrete cone failure
- Resin bond failure (shear failure of bond typically between resin and concrete – upper two thirds of stud – and between resin and stud – lower one third)
- Combined resin bond/concrete cone failure (As resin bond failure with shallow concrete cone adhering to top of stud)
- Base material cracking
- Base material splitting
- Pry out of the fixing (shear tests only – no breakage of anchor, maybe some bending, but some damage to base material)

5 POSITIONING TEST FIXINGS

In all tests the location of test fixings should be recorded as accurately as possible by means of drawings or accurate description in such as way that they can be included in the test report and, if necessary, can be revisited for inspection by site personal.

Guidance on the location of test fixings should be given by the specifier or other responsible engineer calling for tests, especially if the location is pertinent to the test objective.
If fixings are required to be positioned closer to an edge, or to each other, than is recommended by the manufacturer, or called for in the project design, this should be noted in the test report. These dimensions are referred to as the characteristic (previously called critical) edge and spacing distances, notated as respectively Ccr and Scr.

The dimensional requirements of the test apparatus must be taken into account or test apparatus chosen to suit site restrictions.

Positioning of fixings for tests to determine allowable resistance. Preliminary tests and tests to failure.
The location of fixings for tests to determine allowable resistance should be chosen carefully. The base material and any edge distances should be representative of the application concerned but tests should be positioned where damage to the structure will not be detrimental to its strength and can be made good. They should be installed well away from the position of anchors that will be used on the job. If space is restricted the minimum distance which test anchors should be located from working anchors is 3 x h_{ef} (h_{ef} = effective embedment depth i.e. depth to the lowest part of the anchor engaging with the base material, see figure 20).

Positioning of fixings for Proof tests.
Fixings for Proof Loads will of course already be in place. They should be chosen as far as possible at random throughout the project or throughout each discrete area in which tests are required.

Positioning of fixings for tests into masonry.
Fixings into masonry should ideally be positioned away from mortar joints and edges of masonry structures see BS 8539 Clause 5.3.3.3.2.
It may be that tests are called for because anchor positions cannot be chosen to avoid mortar joints e.g. fixing through render or plaster or fixing brackets with hole centres which do not relate to mortar courses. In these case the guidance of Figure 7 in BS 8539 Clause 5.3.3.3.2 should be followed.

6 TEST EQUIPMENT

The correct equipment is vital if tests are to meet their objectives and produce accurate and reliable results while being safe in use. The necessary equipment will usually comprise a means of applying the test load, such as a test meter or hydraulic ram, some means of linking that to the anchor under test and a bridge to support the test meter/ram and at the same time direct the reaction loads away from the anchor under test.

6.1 Load application

Load application is usually done using test equipment such as specialist test meters or hydraulic rams which allow the progressive application of the load without it falling back for hydraulic reasons. Any hydraulic ram or meter used to apply the test load should have a stroke exceeding the expected movement of the fixing under test. All components expected to transmit test loads should have adequate strength with a suitable safety margin with respect to the maximum load to be applied. This applies to all threaded rod, nuts, clevises, special adaptors and bridges. Some hollow rams have central holes which allow only threaded rods which are relatively small compared to the load they can apply. In these cases high strength rod should be used. The condition of all threaded rods used to transmit high loads should be checked before each test to ensure they have suffered no damage which might reduce their strength. Nuts should also be of a suitable strength grade.

Typical means of applying test loads.
See figures 7, 8 and 9.

Figure 7. Light duty tester 0 – 30kN shown mounted to bridge which spans a complete brick course and thus also tests the mortar joints. Bolt type anchor being tested via special adaptor.

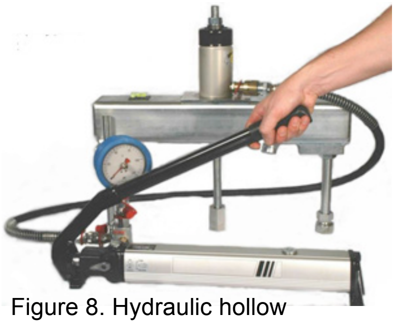


Figure 8. Hydraulic hollow cylinder mounted on heavy duty beam with adjustable legs with pump mounted gauge calibrated to 125kN. Load applied via threaded pulling rod connected to fixing by a threaded coupler. Can also use a pulling frame.

Figure 9 Hydraulic hollow cylinder with integral pump and digital readout calibrated to 145kN, mounted on a tripod with adjustable legs. Load applied via pulling frame. Threaded couplers also shown.

Gauges
Most test equipment includes hydraulic load gauges but digital gauges are available, usually with very good levels of accuracy. Gauges should ideally be calibrated directly in units of load i.e. kN, and while laboratory levels of precision and accuracy are not demanded they should be good enough to allow determination of allowable resistances to reasonable accuracy.
Precision. Gauges should be calibrated in divisions of no more than 5% of full scale deflection (FSD) i.e. ≤1kN on a 20kN gauge (readings can be taken to half a division i.e. 0.5kN).
Accuracy should be within ±10% of the actual reading. This can generally be achieved with a gauge having an accuracy of ±2% of FSD. For example: on a 20kN gauge, with an accuracy of ±2% FSD all readings will have an accuracy of ±0.4kN. This means that the potential error at 4kN is 10% and at lower loads the error is, in percentage terms, greater. For this reason gauges with this level of accuracy should not be used for readings below 20% of full scale deflection.

Gauges should be capable of indicating the maximum load reached during the test even after this has declined. They should be supplied with calibration certificates confirming their accuracy and should be re-calibrated, by a laboratory using equipment traceable to national standards, at intervals not exceeding 12 months and whenever equipment is dropped or shows signs of inaccurate readings e.g. needles not returning to zero.

6.2 Linkage to the anchor under test

Means of connecting the test meter or ram to the anchor to be tested depends on the type of fixing and whether or not movement is to be measured. Possible techniques include:

Pulling frame – see figure 10. Suitable for all anchor types that have a bolt or nut as the bottom pulling plate can be bolted down and clamped by the recommended tightening torque so testing can demonstrate first movement and clamping force. Bushes of different internal diameters cater for anchors of different sizes.
Threaded couplers – see figure 11. Suitable for anchors with projecting threaded and where movement is not to be recorded in detail.
Special adaptors
Bolt testing adaptor. For testing small anchors with bolt heads or threaded anchors using top hat adaptors. See figure 12.
Clevis. For testing anchors with rings or eyes. See figure 13.
Clevis with U Bracket. For testing small anchors with bolt heads.

Examples of methods of linking testers and anchors.

Figure 10
Pulling frame with enough internal height to mount a dial gauge.

Figure 11
Threaded couplers for connection to anchors with projecting threads.

Figure 12
Bolt testing adaptor used with top hat adaptor to test anchor with projecting thread.

Figure 13
Clevis for testing rings and eyes.

Points to be aware of:

Threaded couplers.
Figure 14 shows two ways in which threaded couplers may be used for testing fixings with projecting threaded studs. The diagram on the right shows how fixings may be tested with the fixture in place, this also enables clamping force to be demonstrated. The nut should be tightened to the manufacturer's recommended installation torque. As the load is increased the washer will become loose when the clamping force is reached - this load can be taken as first movement. The diagram on the left shows an anchor without a fixture in place and without a nut to generate a clamping force. This method is suitable only for fixings which do not require a torque to be applied for their correct installation, e.g. bonded anchors, displacement controlled anchors and some undercut anchors.
When using threaded couplers to link anchors with projecting threads to a test rod it is important to ensure that there is enough thread projecting from the test anchor to engage adequately with the coupler. A thread engagement of at least 1.5 x bolt diameter is recommended. If this is not available then it may be necessary to remove the nut from the anchor before connecting via the coupler.

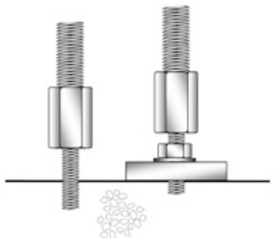


Figure 14
Threaded couplers. The arrangement on the right can demonstrate clamping force.

Anchors with bolt heads.
Linking to pre-installed anchors with bolt heads for proof testing cannot be achieved without removal of the bolt from the anchor and this may cause problems when a test bolt is inserted. An alternative may be to specify a bolt of the same basic make and type but in a bolt projecting version if available.

6.3 Bridges

Different bridges are required to support the tester or hydraulic ram. They key requirements are that they are strong enough to support the test loads and that they cater for the different linking arrangements between the tester and the fixing in which case adjustable legs may be useful as this also provides the facility to adjust the angle of load application either to ensure it is at right angles to the base material or that it is applied along the axis of the fixing as installed. For rigs intended to test to high loads beams with rigid legs and no adjustment, see figure 18, may be suitable if the load is applied via a hollow cylinder and threaded rod which will cater for the different linking arrangements. The rigid legs are less prone to bend under high loads.

Figure 15
Bridge with 2 adjustable legs and wide spacing. For use with smaller test meter.

Figure 16
Tripod for heavy duty load testing
- adjustable legs.

Figure 17
Asymmetrical tripod with adjustable legs. Medium duty load testing.

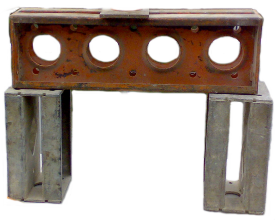
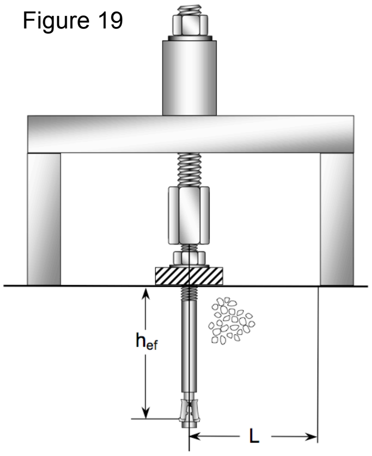


Figure 18
Heavy duty beam.
Very heavy, but strong!
For use with hollow ram and threaded rod.

6.3.1 Reaction spacing for tests in concrete

Figure 19



The distance between the anchor centre line and closest bridge support, the reaction spacing, can affect the result but only if the fixing is to be loaded close to its failure load and the failure is likely to be by concrete cone breakout. In that case, if the feet of the bridge are within the potential concrete failure cone they might reinforce the concrete and enhance the result.

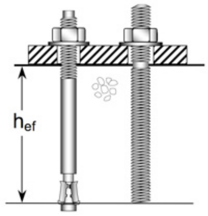


Figure 20 Effective embedment depths.

For ultimate load tests (see 3.1.2.1, 3.1.2.2 & 3.1.2.4) therefore the closest bridge support should, ideally, be at least **L = 1.5 x h_{ef}** from the anchor centre line, see figure 19, where h_{ef} is the effective embedment depth of the anchor, (depth to the lowest point of engagement in the structure) see figure 20.
Structural constraints on site may mean that requirements for ' L ' cannot be met, especially with large fixings. If smaller spacings are used the failure cone falls well within the bridge supports then the results can be relied upon. If the area of the cone includes the supports then they have restricted the cone and this must be noted on the test report and tests should be repeated with larger reaction spacings.

For preliminary tests (see 3.1.2.3) at the stage when tests are carried out to the test load, **L $\geq$ 1.0 x h_{ef}** but may need increasing if anchors are eventually loaded to failure.

For proof load tests (see 3.2) , including loads up to 1.5 x Manufacturer's recommended resistance, the closest support may be significantly closer, **L $\geq$ .5 x h_{ef}** is suitable for most cases as this allows observation of the interface between the anchor and the concrete but in fact there is nothing wrong with the bridge supports going to within L = .1 x h_{ef} if necessary.

6.3.2 Reaction spacing for tests in masonry

For tests to be carried out in masonry the size of the masonry units affects the situation. For brickwork, with its relatively small unit size, it is important to test not only the strength of the anchor in the brickwork but the strength of the mortar joints surrounding the brick. Mortar joints may be inherently weak, especially in older structures, and bricks may be shaken loose due to aggressive hammer drilling. It is therefore recommended that for testing anchors set in conventional bricks the bridge supports should be such that they rest on adjacent bricks rather than the brick itself. For tests in blocks the bridge supports should be at least 150mm or L = 1 x h_{ef} whichever is the larger. This guidance applies to all tests.

Where masonry units are not of conventional sizes the following guidance can be taken:

A) In the case of masonry units with a surface area of up to 25000 mm^2 the reaction loads should be directed into adjacent units and not into the same unit. (This includes normal bricks with a face 215 x 65mm.)
B) In the case of masonry units with a surface area of greater than 25000 mm^2 the reaction loads should be directed into the base material at a distance equal to at least 150mm or the embedment depth of the fixing under test whichever is greater. (This includes typical blocks with a face of 440 x 215mm.) Where the mode of failure is "pullout" i.e. the anchor pulls from the base material with no cone failure, splitting or bolt breakage, the reaction spacing may be reduced.

6.4 Monitoring movement

One of the criteria for selecting fixings is the potential displacement at the service load (serviceability limit state) so BS 8539 calls for the recording of the load at first movement in all site tests. (This requirement is not called for in site tests according to ETAGs.) First movement is particularly useful for applications where the fixture is clamped down against the base material as the fixing will generally show no significant movement until loaded well beyond the manufacturer's recommended resistance. It is not generally necessary to record first movement to a high degree of precision as once a fixing starts to move it is usually quite obvious and the load recorded will not be very different at .1mm or .2mm for instance. The junction between the pulling plate and the base material is a convenient reference point for the visual check of movement or for checks made using a feeler gauge. A movement of 0.1 mm is generally regarded as a suitable point to record first movement. If a threaded coupler is used the loosening of a washer under a previously tightened nut (as figure 14) is a good indication of first movement.
In ultimate load tests or preliminary load tests some movement may occur after the clamping force induced by tightening has been overcome and before the failure load or test load has been reached. As this movement is expected it may not be vital that it be recorded. Some authorities consider excessive tensile movement, in the order of 5mm, to constitute failure, it may be reasonable to halt tests at this point (with this failure criterion noted). The engineer responsible for the application (e.g. specifier in BS 8539) should decide whether or not movement is to be recorded. Some safety critical applications may warrant the recording of movement in accurate detail to enable the displacement at different loads to be compared with that shown in a European Technical Approval.

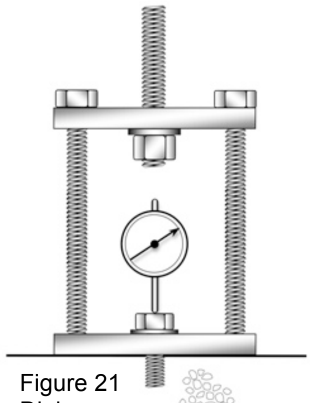


Figure 21
Dial gauge, remotely mounted, set within pulling frame, bearing on anchor bolt head.

Recording movement in detail requires a dial gauge to be located so that it can register the movement of the anchor under test as directly as possible. Siting the gauge itself within a pulling frame is one way to achieve this, see figure 21. It is important that the dial gauge is mounted remotely from the anchor on a support that will not move – i.e. NOT on the bridge itself as that may deflect during loading – and where it will not be affected by displacement of the concrete, see figure 22. Dial gauges should be accurate to least 0.02mm. They should be re-calibrated if dropped or if the needle fails to return to zero.

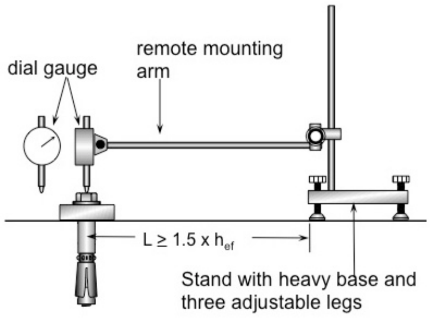


Figure 22 Dial gauge – remote mounting.

During Proof Load Tests no movement should be experienced therefore it is generally adequate that a visual check is made but any movement that is observed must be recorded as it will constitute a failure, see 3.2.1.

The recording of movement inevitably slows testing considerably and may increase the cost of the test programme.

7 INSTALLING ANCHORS & TEST APPARATUS

SAFETY All installation operations must be carried out with due regard for the safety of the installer and all bystanders.

Fixings should be installed by a competent person and strictly in accordance with the manufacturer's Installation Instructions or Method Statement.

In all cases the drill bit diameter used to install the test anchors should be within the tolerances of $d_{cut,m}$ (medium tolerance range) according to ISO 5468 as summarised in table 2 below.
Commercially available drill bits showing the PGM inspection mark, see right, will fall within these tolerances when new.

PGM mark 

Table 2 Drill bit diameter tolerances to ISO 5468.

Drill bit Nominal diameter mm	Medium diameter tolerance "$D_{cut,m}$" mm
6	+ .20 to + .30
7 - 18	+ .25 to + .35
19 - 30	+ .30 to + .40
32 - 38	+ .35 to + .50
40	+ .40 to + .60

Installing bonded anchors

In the case of bonded anchors, tests may only be carried out after at least the recommended curing time has elapsed.

Security of test rig.

When testing anchors in vertical surfaces or under soffits all apparatus should be fixed in place so as to be secure, taking account of the possible failure of the fixing under test.

8 Test report

It is vital that all relevant information is correctly recorded to enable the person requesting the tests to determine whether or not the test objectives have been met and, if not, what action needs to be taken.

The test report should be a statement of results only and the conclusion limited to a statement as to whether or not the tested fixings met the test objective. Testers should not, unless they are sufficiently qualified in anchoring technology, make statements as to the reasons for anchor failures or recommendations as to what remedial measures should be taken. The test report should include a statement to this effect e.g.

> "This test report is a factual statement of the test carried out and results observed and does not constitute an endorsement of the tested fixing(s) for the application concerned."

See 8.1 below, for the list of information recommended by BS 8539 to be included in the test report.

8.1 Information to be recorded in a test report.

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

Administration details:
Date of test.
Unique report reference number.
Client's company name, address, contact name and position.
Site location, contact name and position.
Name and company of installer of anchors.
Name of tester with job title and relevant qualifications.
Name and companies of witnesses. It is strongly recommended that tests are witnessed by a representative of the client or engineer requesting the tests.
Name of installer of anchors.

Anchor / application details :
Anchor : manufacturer, type, size and finish.
Proposed application of anchor and Characteristic Resistance to be applied to the anchor.
Design resistance and/or Manufacturer's Recommended Resistance in the base material concerned.

Test objectives:
Ultimate Load test or Preliminary Load test to determine allowable resistance OR Proof test
Procedure used e.g. "Preliminary load tests as section 3.1.2.3."
Required test load.

Test location :
Detail the location of each test within the structure. Sketch where appropriate.
Edge distance, centre spacing and structural thickness - if appropriate

Base material :
Type and strength at time of test if known.
Whether solid or hollow.

Installation details - if carried out at the time by, or witnessed by, the tester:
Hole diameter, nominal.
Drill bit cutting diameter, recorded to .1mm
Hole depth.
Effective embedment depth.
Hole cleaning method in detail.
Manufacturer's recommended installation torque and Tightening torque applied in the test.
For bonded anchors:
ambient temperature when installed, manufacturer's recommended curing time, actual curing time allowed.

Test equipment details :
Make, type and load capacity of hydraulic ram/gauge or tester.
Date of last calibration, calibrating authority.
Make and type of movement recorder, dial gauge etc.
Loading frame: dimension between anchor and closest support.
Make and type of torque wrench.

Test results, depending on test objective:
For each anchor tested:
Load – maximum load applied.
– condition of anchor and surrounding base material if affected.
– load at first movement, 0.1mm, if required
Movement – (if required) at different load increments and maximum load
Mode of failure where appropriate:
- Base material failure by cone failure, spalling, cracking or splitting
- Bolt breakage.
- Failure of resin or bonding material i.e. Bond Shear or combined bond/cone failure
- Pull through / excessive movement

Method Statement

Gauge calibration certificate

Statement to the effect that the test complied with this procedure and any exceptions

Statement as to whether or not fixing(s) met the test objective.

9 Competent Testers – CFA Approved Tester scheme

BS 8539 recommends that all aspects of anchor usage, including their testing, are carried out by competent persons. The CFA has an Approved Testers scheme to provide a source of companies – Associate Members of the CFA - that have been assessed to be capable of carrying out site testing. They have the necessary equipment to carry out tests to the categories for which they are accredited and have staff who have been trained in anchor technology and testing procedures and have been assessed to be competent in both. They should test fixings and record the results in accordance with CFA recommended procedures as outlined here. Clients can check that staff from members of the CFA Approved Tester scheme are competent to test anchors in the relevant Testing Category by logging on to the CFA website at www.the-cfa.co.uk and clicking on Approved Testers where all companies within the scheme are listed along with all Competent Testers and the category for which they have been accredited. For most tests carried out to the recommendations detailed here the General Purpose category will be appropriate. For other testing categories testing procedures specific to the application and not detailed here may be appropriate although for scaffold anchors and anchors for steeplejacks the procedures set out here are basically in line with those contained in guidance notes specific to these industries:

Guidance Note: Anchorage systems for scaffolding
Guidance Note: Anchorages for steeplejacking
Guidance Note: Anchorage systems for seasonal decorations

10 References.

The following references may be of interest to readers of this Guidance Note. They are not vital to the application of this Guidance Note or the code but may add useful insight.

1 BS 8539:2012 *Code of Practice for the selection and installation of post-installed anchors in concrete and masonry*. From BSI shop http://shop.bsigroup.com/

2 BS 5080-1:1974 *Methods of test for structural fixings in concrete and masonry. Tensile loading*
BS 5080-2:1996 *Structural fixings in concrete and masonry. Method for determination of resistance to loading in shear.*

3 European Technical Approval Guideline (ETAG). From July 2013, under the Construction Products Regulation, ETAGs will become European Assessment Documents, (EAD).
For a full list of all ETAGs go to www.eota.be/en-GB/content/endorsed-etag-s/9/
See also CFA Guidance Note: *ETAs and design methods for anchors used in construction*

4 European Technical Approval (ETA). From July 2013, under the CPR, ETAs will become European Technical Assessments, (ETA).
For a full list of all ETAs go to www.eota.be/pages/valideta/
See also CFA Guidance Note: *ETAs and design methods for anchors used in construction*

5 CFA Guidance Note: *Anchor terminology and notation*.

6 CFA Guidance Note: *ETAs and design methods for anchors used in construction*

7 Guidance Note: *Anchorage systems for seasonal decorations*

8 CFA Article: *Creep and construction fixings*

9 CFA Article: *Load relaxation and anchor testing*.

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Acknowledgement: Photos in figures 7, 8, 9, 10, 11, 15, 16 and 17 are reproduced courtesy of Hydrajaws Ltd.

Appendix 1 Procedure for testing anchors in shear.

Testing of anchors in shear is required very rarely and generally only for the purpose of determining the allowable resistance in applications for which there is no recommended load data available from the manufacturer. These tests would comply with Clause 9.2 of BS 8539.
Tests to check the quality of installation (proof tests) are not required to be carried out in shear as the quality of installation only affects the tensile performance of anchors.

Test regimes should follow those for tensile tests outlined in section 3.

Test procedures will also be similar except that in determining Allowable Resistance in shear frequently involves more detailed monitoring of displacement, which may be decisive, so the application of test loads will frequently be done in increments and displacement monitored by means of a remote mounted dial gauge.

Below is a diagram showing a test rig arrangements for applying shear test loads on a flat surface with means of monitoring the displacement.

Test rig description

The fixing to be tested is installed through a bush in a shear bracket designed to translate the test load (applied by the test meter or hydraulic ram at a distance from the surface) into a shear load. A reaction box to support the tester/ram is fixed (using 2 4 or 6 bolts – self taping concrete screws may be suitable) to the base material. As displacement is usually required to be measured a dial gauge must be mounted so as to record the movement of the anchor. The dial gauge must be remotely mounted so as not to be affected by the test.

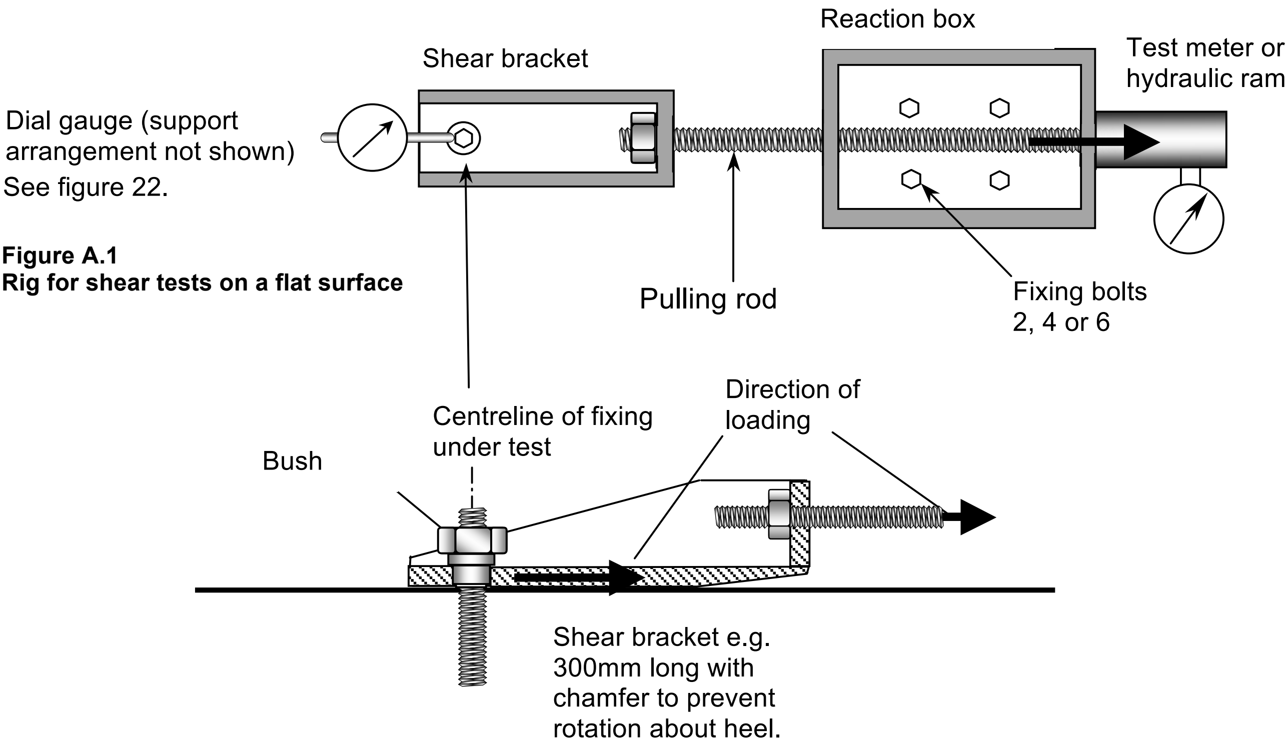

Figure A.1
Rig for shear tests on a flat surface

Shear tests across edges.
These are very rarely required as the specification of anchors should always be within the edge distance criteria specified by the manufacturer. They are sometimes requested when anchors have been set closer than these criteria but the usefulness of such tests is doubtful as tests to proof loads will not demonstrate the required safety margin and tests to ultimate load may damage the structure. Preliminary load tests would, under these circumstances be the best option if approved by the manufacturer who should always be consulted before such tests are undertaken. Tests across edges can be achieved with a rig that bears against the edge while not interfering with the anchor under test. See adjacent photo.

Appendix 2 Equipment check list. Tensile tests

Equipment to install fixings
Fixings
Drilling Machine
Transformer
Extension Cable
Drill bit
Hole cleaning equipment

Blow out bulb for small fixings i.e. hole diameter up to 10mm, or large volume pump for larger fixings, or oil free compressed air. (All hole cleaning systems should reach to the base of the hole.)

Brush – for resin anchors should be hole diameter + 1 – 2mm.

Setting equipment appropriate to fixing
Spanner
Calibrated torque wrench
Socket (Deep reach in the case of projecting studs)

Test Equipment
Loading frame or bridge
Hydraulic pump, ram & gauge combination or
Calibrated test meter
Test adaptor
Pulling frame
Bushes to suit fixing diameter
Pulling rod, washers and nuts
Threaded coupler

If movement is to be monitored
Dial gauge or feeler gauge, Stand with remote mounting arm

Safety Equipment
Site specific PPE including:
Helmet
Eye protection to BS 2092 Grade 1 (if drilling or if installing anchors overhead)
Gloves if handling resin systems
Ear protection if drilling in confined spaces or for prolonged periods
Dust mask if drilling overhead or in a confined space
Fixings, drill bit etc. to secure loading frame, ram and dial gauge etc. to base material in the case of testing under a soffit or against a vertical surface.

Administration
Report forms
Calibration chart / curve for load gauge or test meter.