AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

AEFAC
Australian Engineered Fasteners and Anchors Council

TECHNICAL NOTE: SITE TESTING GUIDELINES – VOL 3: ULTIMATE TESTS

VERSION 1.0

1 SCOPE

This Technical Note is Volume 3 of a suite of AEFAC Technical Notes dedicated to providing recommendations for best-practice for the site testing of anchors. Volume 3 provides details specific to ultimate tests.

The purpose of ultimate load tests is to identify the strength of an anchor in a substrate for which the anchor manufacturer intends the anchor to be used in. The recommendations are intended to assist design engineers formulate appropriate site testing procedures, and to assist field testers conducting tests on site.

The scope of Volume 3 provides recommendations specific to ultimate tests that are supplementary to the recommendations provided in Volume 1. It is a requirement that Volume 3 be used in conjunction with Volume 1.

This document provides technical advice on site testing techniques to determine the strength of anchors and does not address all safety precautions needing to be followed during site testing of fastenings to concrete.

2 TERMINOLOGY

A full list of terminology has been provided in Section 2 of Volume 1.

3 NOTATION

A full list of notation has been provided in Section 3 of Volume 1.

4 GENERAL

Ultimate tests are carried out in a representative substrate using anchors that will be used in the project and installed by the same work crew. Anchors tested in ultimate tests are used exclusively for the purpose of testing and must not be used in the project. Anchors should not be located closer than $3h_{ef}$ to working anchors so as not to damage the substrate of the working anchors.

The objective of ultimate tests is to determine the ultimate strength of the fastening when not all of the required design parameters are known, or the application is beyond the scope of the fastener's prequalification such as an ETA (subject to certain criteria being met).

Ultimate tests are not required if the anchor has an ETA and is to be used in an application that conforms to the ETA. Importantly, in order to be eligible for ultimate tests, the fastener manufacturer should provide advice for the use of the anchor in the chosen substrate, subject to performing site testing to identify key performance parameters. Further guidance is available for anchors installed in concrete applications in ETAG 001 [4] and for injection anchors installed in masonry applications in ETAG 029 [6].

A more comprehensive discussion is provided in Section 4 of Volume 1.

For testing of anchors in masonry substrate, please refer to AEFAC Technical Note: Site Testing Guidelines - Vol 4: Testing in Masonry.

Note: *There are many factors influencing fastener performance that relate to substrate characteristics, installation and product characteristics. These need to be investigated in a robust manner for the preapproval*

for use of an anchor in a given application. The scope of testing and assessment required for preapproval is beyond the scope of site testing practice, but may be found in references such as ETAG 001 [4], EOTA Technical Report 029 [6], etc. This site testing guideline is unsuitable for suitability testing for the compatibility of an anchor with a substrate.

5 TYPE OF TEST

Clause 5.2 of Volume 1 provides guidance on when ultimate tests may be required and factors to consider when proposing ultimate tests.

There are two test regimes that may be adopted to determine the ultimate strength of a fastening. The first is the simplified test (refer to Clause 5.1) and the second is the statistical test (refer to Clause 5.2).

A flowchart summarising the selection process and test procedure for the ultimate test regimes is provided in Appendix A.

Note: *These guidelines to determine the characteristic strength are a recommendation; the responsible engineer may elect a more conservative approach depending on project-specific requirements.*

5.1 Simplified test

The test load (N_{test}) for the simplified tests may be calculated according to Equation (1) –

$$N_{test} = N_{Sk}\, k_{test} \quad (1)$$

where

N_{test} = test load applied to anchor

N_{Sk} = characteristic action applied to anchor

k_{test} = factor for simplified test that depends on the type of anchor and intended application as identified in Table 1

There are three possible outcomes from the test as follows:

i) All anchors resist the test load (N_{test}): The allowable resistance ($N_{R,all}$) may be taken as being equal to the characteristic action as per Equation (2) –

$$N_{R,all} = N_{Sk} \quad (2)$$

where

$N_{R,all}$ = allowable resistance of the fastening

ii) Any anchor fails to resist the test load (N_{test}) and the number of anchors in the project *may be* increased: The designer should be consulted to determine how the specification may be modified to include additional anchors of the same type to make up the shortfall in strength. This approach is only recommended when all measured failure loads were at least equal to $0.8N_{test}$.

The revised test regime becomes –

a. Load all test anchors to failure

b. Calculate the average ultimate strength ($N_{u,ave}$) and identify the lowest ultimate strength ($N_{u,low}$) from the test results

c. Calculate the allowable strength and ensure it is no greater than the average load at 1.0 mm displacement as per Equation (3) –

$$N_{R,all} = \min(N_{u,ave}/k_{ave}, N_{u,low}/k_{low}) \text{ where } k_{ave} \text{ and } k_{low} \text{ are identified from Table 1.} \quad (3)$$
$$\leq N_{1mm,ave}$$

Note: *If it is possible to increase the number of anchors in the project, the (revised) total number of anchors required may be estimated using a pro-rata approach of comparing the allowable resistance ($N_{R,all}$) to the original characteristic action (N_{Sk}).*

iii) Any anchor fails to resist the test load (N_{test}) and the number of anchors in the project *cannot* be increased: The design engineer needs to modify the specification to develop an alternate fastening solution, investigating ways to increase strength such as increased diameter, increased embedment depth, different anchor type, etc. The simplified test procedure should be repeated for the new anchor in the revised specification.

Table 1: Factors used to establish test load (N_{test}) and allowable resistance in preliminary tests (adapted from BS 8539:2012).

Application	Anchor material	Factors to give test load (N_{test})	Factors to determine allowable resistance ($N_{R,all}$)	
		K_{test}	K_{ave}	K_{low}
Long-term loading for general purpose	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

5.2 Statistical approach test

The statistical approach requires a minimum of five tests and calculates the statistical estimation of characteristic strength based on the ultimate strength determined from each test. The test regime becomes –

i) Load a minimum of five test anchors to failure

ii) For each anchor test note the load at 1.0 mm displacement (N_{1mm}), the ultimate load (N_u) and the mode of failure

iii) Calculate the average load at 1.0 mm displacement ($N_{1mm,ave}$), the average ultimate load ($N_{R,ave}$) and the coefficient of variation of the ultimate loads (v)

iv) Calculate the characteristic strength in accordance with Equation (4) using the sample factor (k_s) sourced from Table 2 as follows –

$$N_{Rk} = N_{R,ave}(1 - k_s v) \leq N_{Rk,ETA} \quad (4)$$

where

N_{Rk} = characteristic strength calculated from the results of testing

$N_{R,ave}$ = average ultimate strength determined from tests

k_s = sampling factor determined from Table 2

v = coefficient of variation of ultimate loads determined from tests

$\leq$ 0.3

$N_{Rk,ETA}$ = characteristic strength N_{Rk} given in the ETA

Note: *If an anchor has an ETA, the characteristic strength obtained from testing should not exceed capacities given in the ETA*

v) Calculate the allowable strength ($N_{R,all}$) based on a factor of safety (FOS) determined by the designer, ensuring that $N_{R,all}$ does not exceed the average load at 1.0 mm displacement –

$$N_{R,all} = N_{Rk}/\text{FOS} \leq N_{1mm,ave} \quad (5)$$

where

N_{Rk} = Characteristic strength determined from tests

FOS = Factor of safety specified by the engineer. Further guidance may be found in AEFAC Technical Note "Design Concepts for Post-installed and Cast-in Anchors" [7].

$N_{1mm,ave}$ = Average load at 1.0 mm movement determined from tests

Table 2**:** Values of the sample factor (k_s) for the 5% fractile of strength with a 90% confidence interval.

Number of tests	k_s	Number of tests	k_s
5	3.400	20	2.208
6	3.091	25	2.132
7	2.894	30	2.080
8	2.755	40	2.010
9	2.649	50	1.965
10	2.568	∞	1.645
15	2.329		

Note: The statistical test produces more accurate results than the simplified test. However, it is more likely to cause some local damage to the structure.

6 TESTS TO DETERMINE PERFORMANCE OF FASTENING

6.1 Test setup

The test equipment should be prepared in accordance with Cl. 6.1 of Volume 1.

6.2 Configuration of test rig

The configuration of the test rig should be in accordance with the requirements of Cl. 6.2 of Volume 1. Care should be given when selecting the appropriate positions of fixings for ultimate tests to ensure that the conditions are representative of the intended application, including the condition of the substrate, distance

to any edges and spacing with other fixings. Any deviation from the manufacturer's recommendations or project-specific requirements should be noted in the test report.

The potential for the structure to sustain damage as a result of the test and the requirement for subsequent remedial work should also be considered.

Additional considerations for ultimate tests are provided in Cl. 6.2 of Volume 1.

7 TEST REGIME

7.1 Application of load

Recommendations for the application of load are provided in Cl. 7.1 of Volume 1.

Where an ultimate load test is requested that requires the recording of first movement, the following procedure should be undertaken:

1. The load should be progressively applied until the first movement becomes visible, or the manufacturer's recommended load or design load has been achieved.
2. If visible deformation becomes apparent, loading should be paused and the load at which this occurred should be recorded.
3. Loading should resume until the maximum load is achieved, terminating the test when no further increase in load is possible and to avoid further damage to the substrate.
4. The maximum load is recorded as well as the failure mode observed and any damage sustained by the structure.

7.2 Number of tests

7.2.1 Minimum number of tests

The number of required tests must be assessed on a case-by-case basis by the engineer requesting the tests. However, the following serves as a guide:

- Ultimate tests: Minimum of 5 tests

The above guidelines are applicable to a sample population having the same type of anchor, the same base material that has not experienced different environmental exposure, and one crew was responsible for anchor installation. Where any of these variables change, this group of anchors shall be considered a separate anchor population.

7.2.2 Increased sample size using the simplified approach

In the event that the simplified approach is adopted to identify the allowable resistance of the fastening ($N_{R,all}$) and the test results and fastening configuration are unable to meet the project requirements, the designer will need to modify the specification. In the event that the revised specification requires a different anchor, the simplified approach should be repeated for the new anchor.

8 ADDITIONAL REQUIREMENTS FOR TESTS

Appendix A provides the procedure to evaluate the characteristic strength of the fastening depending on whether or not the fastener has an ETA for the given application.

Additional requirements for ultimate tests are listed in Section 8 of Volume 1.

9 REPORT OF RESULTS

A list of the information to be included in the test report is provided in Volume 1 Appendix A.

10 SUMMARY

Volume 3 of the suite of site testing Technical Notes provides information specific to ultimate tests intended to identify the allowable strength ($N_{R,all}$) of the fastening for the purpose of design. The two test regimes available to identify $N_{R,all}$ are:

i) Simplified method: sample fasteners are loaded only to a test load (N_{test}) determined by the design engineer, allowing calculation of $N_{R,all}$ based on N_{test}.

ii) Statistical method: all fasteners in the sample population are loaded to failure and $N_{R,all}$ is calculated based on a statistical procedure.

Samples used for ultimate tests are sacrificial and should not be used in the project.

11 REFERENCES

A list of references is provided in Cl. 11 of Volume 1.

APPENDIX A: SUMMARY OF ULTIMATE TEST REGIMES

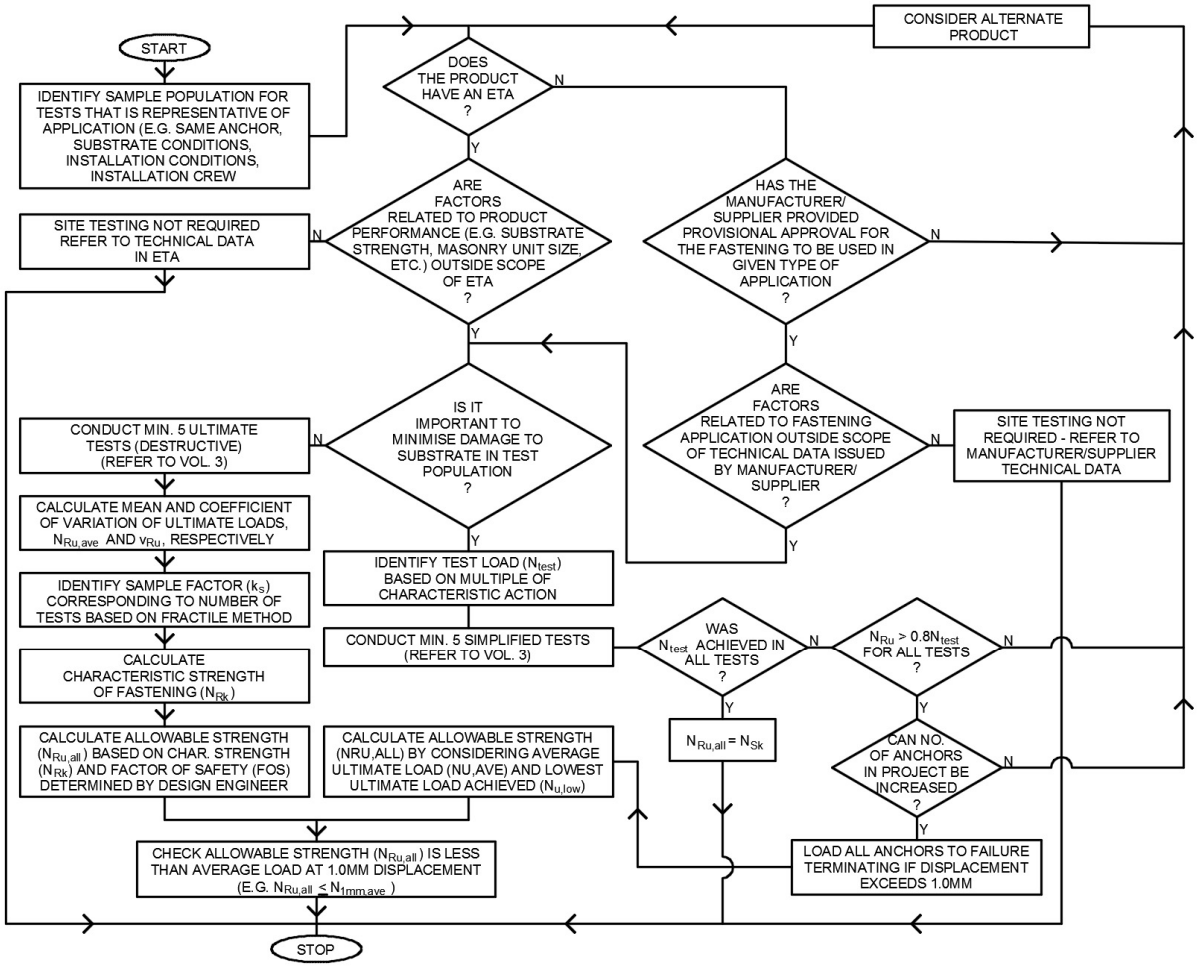

Figure A1: Flowchart of ultimate test regimes adopted to determine performance parameters for fastener design when the fastener manufacturer has issued a provisional approval for the intended application.