TECHNICAL NOTE

AEFAC
Australian Engineered Fasteners and Anchors Council

AEFAC - TN05

SITE TESTING GUIDELINES

VOL 4: TESTING IN MASONRY

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1. Scope

This Technical Note is Volume 4 of a suite of AEFAC technical Notes dedicated to providing recommendations for best practice for the site testing of fasteners. Volume 4 provides guidance specific to tests on fasteners installed in masonry substrates.

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 4 provides recommendations specific to testing in masonry that are supplementary to the recommendations provided in Volumes 1 – 3 ([1], [2], [3]). It is a requirement that Volume 4 be used in conjunction with Volume 1 [1].

It is assumed that site tests are to be performed on chemical fasteners in masonry that have been tested and assessed in accordance with EAD 330076 [4]. For procedures regarding the site testing of mechanical fasteners the engineer should seek advice from the product manufacturer's technical support service.

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

2. Notation

A full list of notations is provided in Section 2 of Volume 1.

3. Terminology

A full list of terminology is listed in Section 3 of Volume 1.

4. General

It is an underlying assumption of this Technical Note that the fastener has been approved – either through an ETA or a provisional approval by the manufacturer – for use in the type of masonry under consideration including –

i) characteristics of the unit: material (concrete/AAC/clay) and geometry (solid/hollow/perforated and dimensions), and

ii) characteristics of the mortar: material composition and dimensions

The location of fasteners in masonry in general should be situated away from the comparatively weaker joints and edge of masonry. Comprehensive guidance on good practice for the positioning of fasteners in masonry is published in BS 8539:2012 [5].

The scope of EAD 330076 [4] includes *injection fasteners consisting of a threaded rod, deformed reinforced bar, internal threaded socket, or other shapes and the mortar, placed into drilled holes in masonry and anchored by bonding the metal part to the sides of the drilled hole by means of mortar and by mechanical interlock*. Masonry units included under this prequalification include clay, calcium silicate, normal weight concrete and lightweight concrete (solid and hollow or perforated format blocks), autoclaved aerated concrete, and other similar materials. Injection fastener units for use in hollow masonry typically employ a sieve to promote mechanical interlock as illustrated in Figure 1.

***Note**: The fastener should be suitably prequalified for use in the type of masonry (solid/hollow/perforated).*

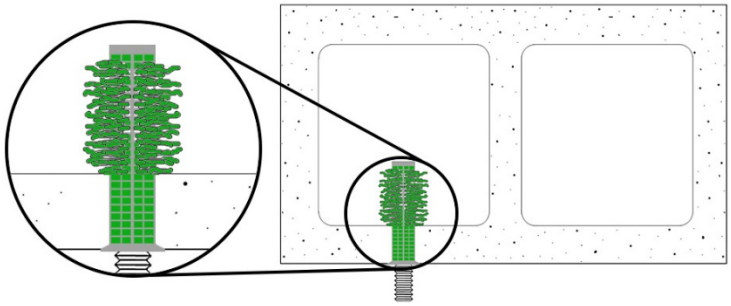

Figure 1: Injection fastener in hollow masonry employing a sieve.

EAD 330076 [4] covers the testing and assessment of injection fasteners for use in masonry. If an injection product for use in masonry is awarded an ETA and has been specified for use in a project, testing on site is not required provided all aspects of the application (e.g. injection fastener, type and strength of bricks and mortar, geometry of masonry, installation practice) conform to the requirements of the ETA. If the base material contains different bricks to those in the ETA that are of the same type (e.g. perforated), then job site tests may be conducted to establish the characteristic strength.

Although the scope of this Technical Note is restricted to chemical fasteners, other types of fasteners such as shield fasteners and stud fasteners may also be used in masonry [6].

AEFAC Technical Note 09 [10] provides information on selection and installation of post-installed fasteners in masonry.

5. Tests to determine suitability of fastener

5.1. Simplified tests

Simplified tests may be performed to a test load (N_{test}) and an estimation of characteristic strength of the fastening may be made. General guidance on the nature of a simplified test is provided in the AEFAC Technical Notes "Site Testing – Vol. 1: General" [1] and "Site Testing – Vol. 2: Proof Test" [2].

5.2. Ultimate tests

Ultimate tests may be performed to establish a more accurate estimation of the characteristic strength of the fastening. If the fastener is being installed in masonry and has been awarded an ETA applicable to masonry, ultimate tests are not required if the type of substrate and dimensions of the masonry conform to the ETA. However, if the characteristics of the substrate vary then ultimate tests are required to establish the characteristic strength.

The procedure to follow for the determination of the ultimate strength of a chemical fastener in masonry depends on the nature of the prequalification. Figure 2 illustrates the different paths that may be followed in order to establish the ultimate strength of a fastener in masonry.

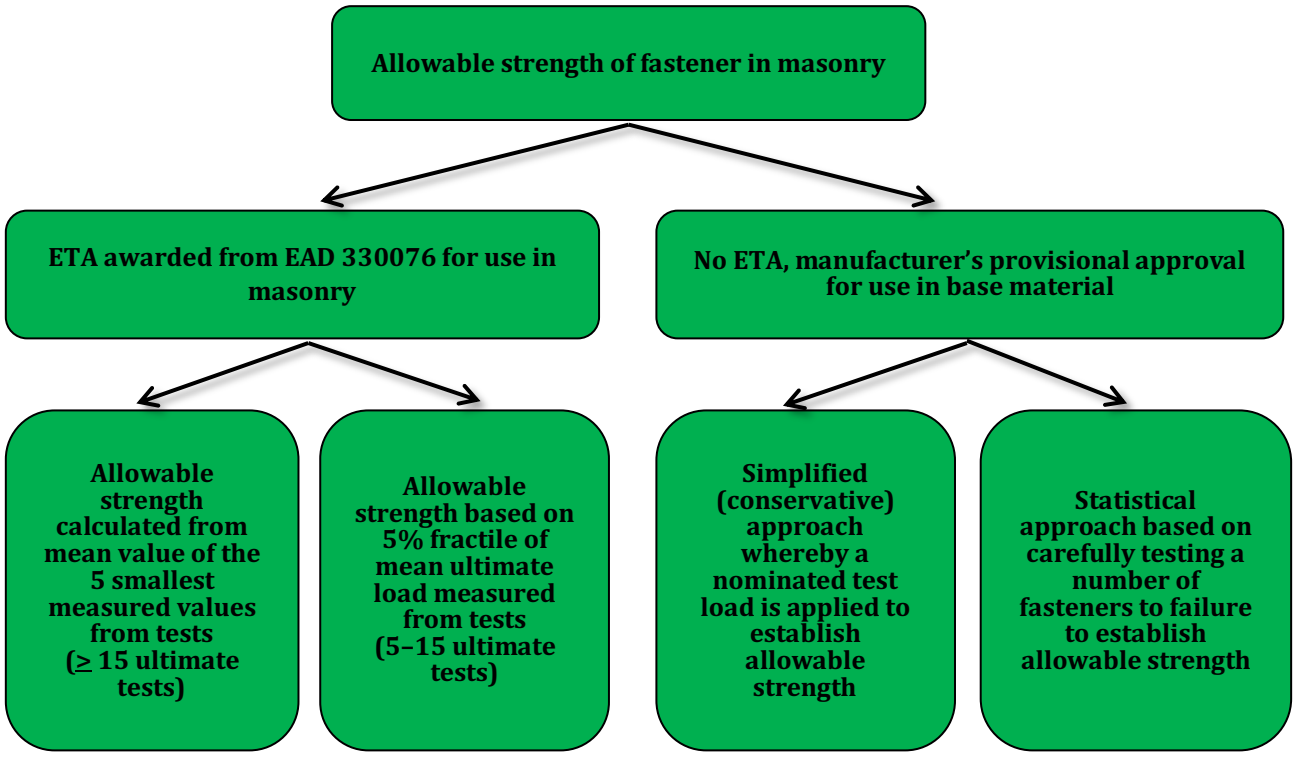

Figure 2: Paths to establishing allowable strength of fastener in base material.

There are a number of avenues that may be followed in order to determine the ultimate strength of a fastener in a given base material. The factors influencing the calculation of strength include fastener prequalification, nature of the base material, number of tests that have been conducted, and whether or not the base material may be damaged from testing to failure.

The following sections outline the procedure for calculating the allowable strength of a fastener in a base material depending on product prequalification, and the nature and number of tests conducted.

Additional guidance ultimate testing is provided in AEFAC Technical Notes "Site Testing – Vol. 1: General" [1] and "Site Testing Vol. 3: Ultimate tests" [3].

Note*: Site testing guidelines provided in EOTA TR053 note the use of "proof tests" to calculate the characteristic strength of the chemical fastener in masonry. The term "proof test" in the AEFAC Site Testing Guidelines Technical Notes is reserved exclusively for the verification of fastener installation.*

6. Test setup

The general requirements for the test equipment and configuration for testing in masonry are provided in AEFAC Technical Note "Site testing – Vol. 1: General" [1]. Specific guidance on proof tests and ultimate tests are provided in AEFAC Technical Notes "Site testing – Vol. 2: Proof tests" [2] and "Site testing – Vol. 3: Ultimate tests" [3], respectively.

Given the relatively weak nature of mortar joints in masonry it is important that the test rig legs are supported by different units than the one including the fastening under investigation. This test setup will ensure the brick break-out failure mode is not inhibited by the placement of the test rig supports.

7. Test regime

7.1. Application of load

7.1.1. Simplified method

As a guide, the test load (N_{test}) may be estimated based on the following:

$$N_{test} \geq \frac{0.8S^*}{\phi_M \beta} \qquad (1)$$

where

S^* = Design load (characteristic action applied to the fastener × load factor i.e. factored applied load)

ϕ_M = capacity reduction factor for masonry
= $1/\gamma_M$

γ_M = partial safety factor for masonry (published in ETA)
= 2.5 where no further guidance is available

β = factor considering influences of product – determined from prequalification (published in ETA)

7.1.2. Statistical method

The load is to be increased in accordance with the requirements of Vol. 3 [3], Cl. 7.1.

7.2. Test sequence

Details of the test sequence are provided in AEFAC Technical Note "Site testing – Vol. 1: General" [1].

7.3. Number of tests

The requirements for job site tests are outline in EOTA TR053 [7]. In order to establish the characteristic strength (5% fractile), at least 15 tests need to be performed. If fewer than 15 tests are conducted a statistical estimation of characteristic strength is determined, including an adjustment β-factor sourced from the prequalification document (e.g. ETA). Partial safety factors applicable to masonry substrate are also provided for the evaluation of tests.

Although there are guidelines for the minimum required number of tests to be performed, the requirements for each project should be considered on the basis of the fixing requirements. Projects with complex installation requirements or more variable substrate for instance, may require a greater number of tests to achieve the desired confidence in the fixing system.

7.4. Modes of failure

EOTA TR054 [8] outlines the design procedure for the fixture for the ultimate limit state based on an injection fastener prequalified in accordance with EAD 330076 [4], addressing potential failure modes occurring under tensile or shear loading outlined in Table 1.

The EOTA documents ([4], [7], [8]) and a list of inject products for use in masonry awarded ETAs may be found on the European Organisation for Technical Assessment (EOTA) website (www.eota.eu).

Note: Some potential masonry failure modes differ to those in concrete identified in AS 5216:2018 [9].

Table 1: Potential modes of failure of fastener in masonry under tensile or shear loading.

Mode of failure under tensile loading	Mode of failure under shear loading
• Metal fracture	• Failure of metal part without lever arm
• Pull-out failure of fastener	• Failure of metal part with lever arm
• Brick breakout failure	• Local brick failure
• Pull-out of one brick	• Brick edge failure
• Influence of joints	• Pushing out of one brick
	• Influence of joints

8. Evaluation of results of tests

8.1. Simplified tests

Using the results of the simplified tests an estimate of the characteristic strength ($N_{Rk,2}$) of the masonry may be made as follows, provided no visible movement or displacement of the injection fasteners occur in all tests:

$$N_{Rk2} = \frac{N_{test}\beta}{0.8} \leq N_{Rk,ETA} \quad (2)$$

where

N_{test} = test load

β = product-dependent influencing factor

$N_{Rk,ETA}$ = characteristic strength determined through prequalification and published in the ETA

The following simplifications may be made when estimating characteristic shear strength:

i) If $V_{Rk,ETA} \geq N_{Rk,ETA}$, $V_{Rk2} = N_{Rk2} \leq V_{Rk,ETA}$

ii) If $V_{Rk,ETA} < N_{Rk,ETA}$, $V_{Rk2} = N_{Rk2}(V_{RK,ETA}/N_{Rk,ETA}) \leq V_{Rk,ETA}$

8.2. Statistical tests

8.2.1. Anchors having an ETA

This evaluation is only applicable when a fastener has been awarded an ETA that covers the intended substrate (refer to Section 4).

8.2.2. Characteristic strength for less than 15 tests

Where less than 15 ultimate site tests are performed, the characteristic strength (N_{Rk1}) is determined in accordance with Equation (3) as follows:

$$N_{Rk1} = N_{Ru,m}(1-k_s.v)\beta \leq N_{Rk,ETA} \quad (3)$$

where

N_{Rk1} = characteristic ultimate strength determined from tests

$N_{Ru,m}$ = mean ultimate load calculated from test results

k_s = sample factor from Table 2

v = coefficient of variation of ultimate loads calculated from test results
= $s/N_{Ru,m}$

s = standard deviation of ultimate loads calculated from test results

β = influencing factor provided in the approval document for fasteners in masonry applications (ETA awarded in accordance with EAD 330076 [4])

$N_{Rk,ETA}$ = characteristic strength published in the approval document

Note: This procedure assumes the fastener has been prequalified in accordance with EAD 330076.

8.2.3. Characteristic strength for a minimum of 15 tests

In the event that at least 15 ultimate tests are conducted on site, the characteristic strength (N_{Rk1}) is determined in accordance with Equation (4):

$$N_{Rk1} = 0.5N_1 \leq N_{Rk,ETA} \quad (4)$$

where

N_{Rk1} = characteristic ultimate strength determined from tests

N_1 = mean value of the five smallest measured ultimate strengths

$N_{Rk,ETA}$ = characteristic strength N_{Rk} given in the ETA for the same category of masonry

For shear strength:

i) If $V_{Rk,ETA} \geq N_{Rk,ETA}$, $V_{Rk1} = N_{Rk1} \leq V_{Rk,ETA}$

ii) If $V_{Rk,ETA} < N_{Rk,ETA}$, $V_{Rk1} = N_{Rk1}(V_{RK,ETA}/N_{Rk,ETA}) \leq V_{Rk,ETA}$

8.2.4. Design strength

The design strength of the fastener (N_{Rd}) may be determined according with Equation (5):

$$N_{Rd} = \varphi_M N_{Rk1} \quad (5)$$

where

N_{Rd} = design strength of the fastener

φ_M = capacity factor for material

= $1/\gamma_M$, where the partial safety factor for material strength (γ_M) is obtained from the approval document (e.g. ETA). In the absence of further guidance it may be assumed that $\gamma_M = 2.5$.

N_{Rk1} = characteristic ultimate strength determined from tests

Note: *An ETA includes partial safety factors to account for uncertainties, whereas these uncertainties are accounted for in Australian design standards via capacity factors. Further guidance is provided in the AEFAC Technical Note "Design concepts for post-installed and cast-in fasteners" [7] and AEFAC Technical Note "Prequalification of post-installed and cast-in fasteners" [8].*

Table 2: Sampling factor for the 5% fractile of strength with a 90% confidence interval.

No. tests	k_s	No. tests	k_s	No. tests	k_s
5	3.400	10	2.568	40	2.010
6	3.091	15	2.329	50	1.965
7	2.894	20	2.208	∞	1.645
8	2.755	25	2.132		
9	2.649	30	2.080		

NOTE: *The greater the number of tests, the greater the confidence in the results and the lower the statistical penalty in the determination of characteristic strength, represented by a lower k_s-value.*

9. Additional requirements for tests

Further considerations required prior to testing in masonry are provided in AEFAC Technical Note "Site testing – Vol. 1: General" [1].

10. Report of results

Suggested information to be included in the report generated from site testing may be found in AEFAC Technical Note "Site testing – Vol. 1: General" Appendix A [1].

11. Summary

Volume 4 of the suite of site testing Technical Notes provides guidance for the testing of fasteners in masonry. The procedure to be followed depends on the nature of the fastener's prequalification and the objective of the test (proof load or ultimate test). Certain types of fasteners do not function correctly in masonry so it is imperative the fastener has as a minimum, a provisional approval granted by the manufacturer for use in masonry.

12. References

[1] "Site Testing Guidelines – Vol 1: General", AEFAC Technical Note 05, www.aefac.org.au

[2] "Site Testing Guidelines – Vol 2: Proof tests", AEFAC Technical Note 05, www.aefac.org.au

[3] "Site Testing Guidelines – Vol 3: Ultimate tests", AEFAC Technical Note 05, www.aefac.org.au

[4] EAD 330076 "Metal injection anchors for use in masonry", European Organisation for Technical Assessment, 2017, www.eota.eu

[5] British Standard 8539:2012, "Code of practice for the selection and installation of post-installed anchors in concrete and masonry", BSI Standards Limited

[6] "Fixings for brickwork", Article, Construction Fixings Association, www.the-cfa.co.uk

[7] EOTA TR053 "Recommendations for job-site tests of metal injection anchors for use in masonry", European Organisation for Technical Assessment, 2016, www.eota.eu

[8] EOTA TR054 "Design methods for anchorages with metal injection anchors for use in masonry", European Organisation for Technical Assessment, 2016, www.eota.eu

[9] AS 5216:2018 "Design of post-installed and cast-in fastenings in concrete", Standards Australia

[10] "Selection and Installation of fasteners in Masonry", AEFAC Technical Note 09, www.aefac.org.au

www.aefac.org.au