AEFAC

Australian Engineered Fasteners and Anchor Council

Test and Evaluation Procedure for Concrete Screw Anchors

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Contents

Symbols and notations

c_1 = distance from screw anchor to edge of concrete

$d_{cut,m}$ = medium range diameter of drill bit

d_f = diameter of hole in fixture

d_{nom} = nominal diameter of screw anchor

f_{cm} = mean compressive strength of concrete at the relevant age

h_{et} = total embedment depth of screw anchor

t_{fix} = thickness of fixture

1. General

This document details the test procedure for testing concrete screws up to 12mm hole size with minimum edge distance that is smaller than the minimum allowable edge distance that is specified by the European Technical Approval Guidelines (ETAG). If the minimum edge distance required conforms to ETAG requirements, the ETAG 001, *Metal anchors for use in concrete* testing procedures applies. The pull-out capacity based on concrete cone failure published in an ETA is limited by a theoretical cap and could be conservative compared to values obtained from testing.

The test methods outlined in this document are for the assessment of a single anchor without the influence of a fixture element. If the fixture element is likely to affect the capacity of the anchor, then the fixture and anchor are to be tested as an assembly. The capacity of the fixture element must be checked for its intended use by engineering principles or testing.

Testing and reporting shall be carried out by an independent laboratory.

2. Test parameters

2.1 Concrete testing

Where concrete strength or other concrete properties are referred to in this document, these shall be determined in accordance with the requirements of the appropriate parts of AS 1012.

Concrete used to construct test elements shall comply with the requirements of AS 1379. Concrete test cylinders shall be prepared to AS 1379 and be cured under identical conditions as the test blocks. Verification tests of concrete strength shall be conducted upon completion of the respective tests. A minimum of 3 test cylinders shall be used to determine the concrete strength at the time of the tests, the mean value governs.

It is recommended to measure the concrete compressive strength on cylinders with diameter of 100mm and height of 200mm.

The concrete control specimens shall be tested on the same day as the screw anchor tests to which they relate. If a test series takes a number of days, the concrete specimens shall be tested at a time giving the best representation of the concrete strength at the time of the screw anchor tests.

2.2 Concrete properties

Concrete specimens used for this test program shall have mean compressive strength, f_{cm} in the range of 18-30MPa at 28days determined in accordance with AS 1379.

The concrete specimens for testing shall be in a non-cracked state. Reinforcement can be introduced for handling purposes provided that they do not influence the outcome of the test.

2.3 Dimensions of test members

The thickness of test members shall correspond to the minimum member thickness applied by the manufacturer's specifications; generally equal to at least twice the total embedment depth of the concrete screw anchor, $2h_{et}$ or a minimum of 100mm. The thickness of the concrete test member must be lesser than or equal to the thickness of the intended application on site.

2.4 Summary of test specimens

1. Mean compressive strength of concrete, f_{cm} in the range of 18-30MPa at 28 days.
2. Minimum number of tests: 5 tension tests and 5 shear tests
3. Specimen geometry:
    a. Min thickness = max($2h_{et}$, 100mm)
    b. Edge distance for testing = 35mm or 45mm
    c. Required embedment depth varies depending on size of screw anchor and thickness of base material.

3. Anchor Installation

The supplier shall ensure the concrete screw anchors supplied for the tests are statistically representative of the manufactured product and supply in the market place.

The screw anchors shall be installed in accordance with the Manufacturer's Installation Instructions (MII), including information about the required drill bit type, the drill bit diameter, the required hole depth, the maximum fixture thickness, the minimum embedment depth and the maximum tightening torque.

Screw anchors achieve their load capacity by threads undercutting the base material. It is not necessary to tighten the anchor to any specific torque value. However it is important not to over tighten the anchors.

3.1 Drilling

The test procedure described in this document is based on carbide-tipped bits used with rotary hammer drill to form the hole for the concrete screw anchors. The holes for the screw anchors shall be perpendicular to the surface of the concrete member unless specified otherwise by the manufacturer's installation instructions.

The holes shall be drilled with a drill bit having a medium diameter ($d_{cut,m}$) of the specified tolerance range given in Table 1. The diameter of the drill bit shall be checked every 10 drilling operations to ensure continued compliance.

Table 1: Tolerance on cutting diameter of hard metal hammer-drill bits (ETAG 001)

Nominal drill diameter mm	Drill bit medium diameter range ($d_{cut,m}$),mm	
	Min	Max
6	6.2	6.3
8	8.25	8.35
10	10.25	10.35
12	12.25	12.35

4. Test procedure

4.1 Tension test

4.1.1 Test Setup

The reaction frame shall be situated at a minimum distance of twice the total embedment depth from the screw anchor as shown in Figure 1. The test rig shall allow the formation of an unrestricted rupture cone.

4.1.2 Instrumentation

Direct measurement of the screw anchor displacement shall be made relative to the concrete surface at a distance of at least $2h_{et}$ from the center of the screw anchor (as close as possible to the supporting legs of the frame, measuring in the same plane as the supporting legs). This may be achieved by averaging two displacement transducers measuring a rigid bar directly attached to the head of the screw anchor, or by way of direct measurement by a simple displacement transducer located at the centre of the head of the screw anchor as shown in Figure 1.

The load and displacement measurements shall be recorded at a rate not less than 10 samples per second throughout the test. The measuring error shall not be greater than 0.02mm for displacement and 2% of the load throughout the entire measuring range.

The tensile load-displacement behaviour of screw anchors shall be predictable. The displacement of the specimens shall be monitored for any unreasonable scatter.

4.1.3 Load application

Tension tests shall be conducted in either load or displacement control. The load shall be applied concentrically to the screw anchor. The diameter of the clearance hole provided in the fixture shall be in accordance with the values given in Table 2.

The load shall increase in such a manner that the peak load occurs 1 to 3 minutes after the commencement of loading. The application of load shall increase until failure is achieved, denoted by a drop in the load carrying capacity of the screw anchor.

For test conducted in displacement control, the test shall be continued beyond the ultimate load until the load has reduced to at least 70% of the peak load (to allow the drop of the load-displacement curve).

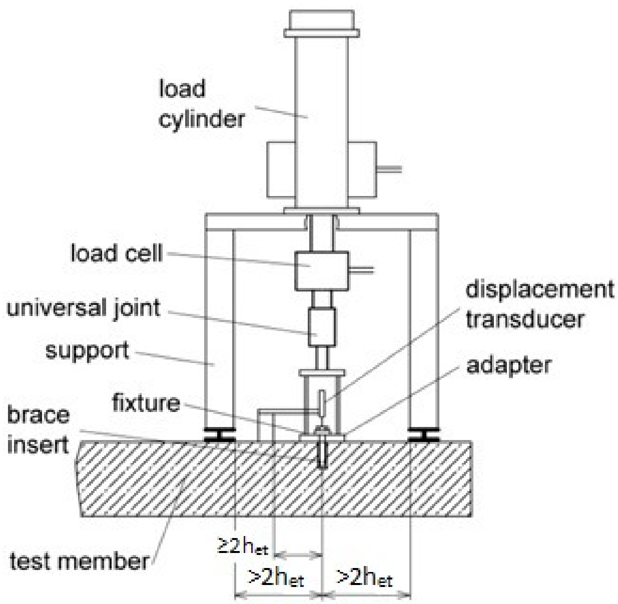

Figure 1: Typical tension test rig setup (DR2 AS3850.1)

4.2 Shear Test

4.2.1 Test Setup

The screw anchor is connected to the test rig as shown in Figure 2, without gap between the screw anchor and the fixture plate (refer to Figure 3). The interchangeable sleeves may be used in conjunction with the fixture plate to allow for different size anchors as shown in Figure 3. If sleeves are used they shall be made of quenched and tempered steel compatible with screw material and have radiused edges (0.4mm) where they are in contact with the screw anchor. If the fixture plate is used without sleeves, it shall also comply with the same requirements for the sleeves as stated earlier. The inner diameter of the sleeves or fixture plate assembly shall correspond to the sizes given in Table 2.

To reduce friction, a smooth sheet (e.g. PTFE) with a maximum thickness of 2mm shall be placed between the concrete specimen and the loading plate and sleeve (refer to Figure 3).

4.2.2 Instrumentation

The displacements of the screw anchor relative to the concrete shall be measured in the direction of the load application (refer Figure 2). Direct measurement of the screw anchor displacement shall be made relative to the concrete surface at a distance of at least $2h_{et}$ from the centre of the screw anchor. Load and displacement measurements shall be recorded as per section 4.1.2.

4.2.3 Load application

The shear tests shall be conducted in either load or displacement control. There are two types of shear tests, perpendicular to edge and parallel to edge. For the former, the load shall be applied parallel to the concrete surface towards the closest concrete edge whilst for the latter; the load shall be applied parallel to the closest concrete edge. Refer to section 4.1.3 for details on load application.

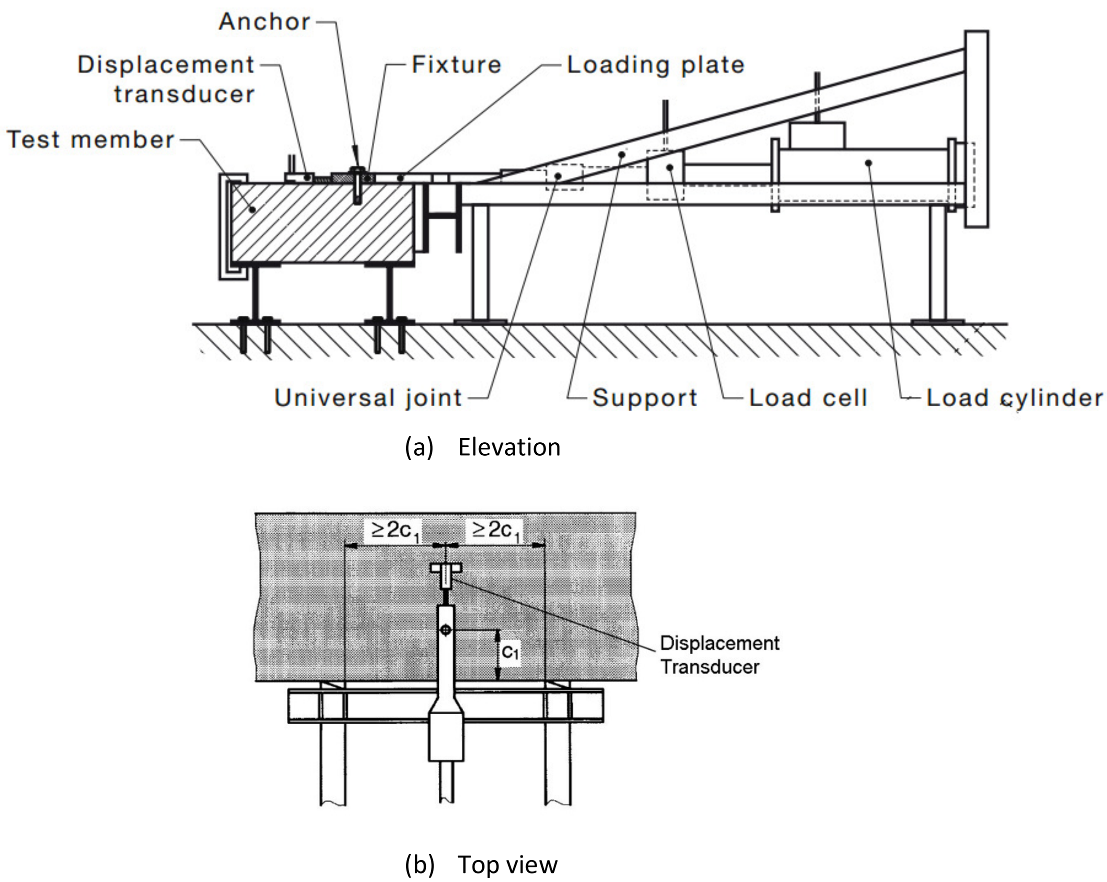

Figure 2: Typical shear test rig setup (ETAG 001)

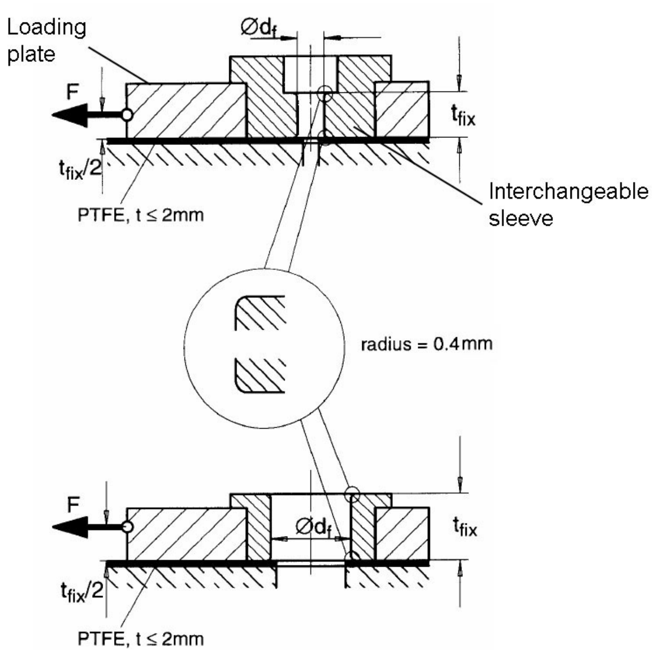

Figure 3: Examples of shear test sleeves with d_f according to Table 2 (ETAG 001).

Table 2: Diameter of clearance hole in the sleeve or fixture plate (ETAG 001)

External diameter d or d_{nom} mm	Diameter d_f of clearance hole in the fixture mm
6	7
8	9
10	12
12	14
14	16

5. Test report

Test records shall be provided for all tests. The test report shall include the following information as a minimum:

(a) Test details

- Purpose of the test
- Name and address of test facility
- Date, time and environmental conditions at the time of the test
- A detailed description of the screw anchor being tested, providing identification of the screw anchor where appropriate including any markings on the screw, the name and address of the manufacturer and supplier, batch number, etc.
- A detailed description of the geometry and material properties of the screw anchor including where appropriate, dimensions, materials, coating, yield stress (f_{sy}) and ultimate strength (f_{su}).

- A detailed description of the test arrangement, including instrumentation layout and fixture geometry, details of test rig, setup of test specimen and connection to test rig illustrated by sketches or photographs.
- Type of test performed (tension and shear)
- A detailed description of the test procedure
- Number of tests performed
- The names, positions and qualifications of the personnel carrying out or supervising the test
- The results of the test, covering the following, where relevant:
  - i. The direction of loading
  - ii. The load at failure
  - iii. The mode of failure for each test
  - iv. Any specific observations concerning the application of load
  - v. A description of the test progress, including the mode of failure and any permanent deformations
  - vi. The details of the load deformation curves, so proportioned that if there has been any discontinuity or considerable departure from linearity during the progress of increasing the loads the this will be clearly evident
  - vii. Any other relevant information such as signs of distress prior to failure

(b) Details of concrete elements

- Time of casting and testing of all specimens
- Compressive strengths of concrete as determined at the time of test
- Dimensions of test specimens
- Identification certificate in accordance with AS 1379

(c) Details of screw anchor installation

- Depth of anchorage
- Photographic evidence or sketch including illustrations of the distance to edges and spacing of anchors within a concrete member
- Tools employed for screw anchor installation, e.g. impact drilling tool
- Applied torque and copy of certificate for calibration of torque wrench (where applicable)
- Type of drill bit, manufacturer’s name and model and measured drill bit dimensions
- Procedure adopted for hole cleaning

6. Assessment of test results

6.1 5%-fractile of the ultimate loads

The test reports shall provide characteristic values based on statistical method to provide a 5% fractile of the ultimate loads at a 90% confidence level using a normal distribution.

Characteristic values are calculated from the ultimate loads determined by tests.

A normal distribution and an unknown standard deviation of the population are assumed unless an alternate probability distribution is justified. The 5%-fractile value of characteristic strength is calculated as follows:

Characteristic value = Mean value × (1 - k_sv)

where k_s = sampling factor listed in Table 3

v = coefficient of variation

Table 3: Sampling factor to establish characteristic strength

No. of tests	k_s	No. of tests	k_s	No. of 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		

6.2 Strength in tension

6.2.1 Failure modes

The failure mode for each specimen shall be identified from the following:

a) Steel failure
b) Concrete cone failure
c) Pull-out failure

If a test series yields different failure modes exhibiting similar capacities and one failure mode predominates, note the failure modes and corresponding failure loads in the test report. Report the average failure load, taking into account all results as the failure load associated with the predominant failure mode.

If no failure mode predominates in a test series, increase the sample size until at least five samples for each failure mode have been obtained. Conduct a significant difference test to see if the capacities for the different failure modes are statistically different. If they are statistically different, the lesser is adopted and characteristic strength calculated.

The mean strength determined from reference tests, N_{rm} and characteristic strength determined from reference tests, N_{rk} shall be calculated for each failure mode if more than one failure mode exists. The failure mode with the lowest characteristic value shall be decisive.

$N_{rm} = \min(N_{rm,us}, N_{rm,uc}, N_{rm,up})$

$N_{rk} = \min(N_{rk,us}, N_{rk,uc}, N_{rk,up})$

where

N_{rm}; N_{rk} = mean value or characteristic value of tensile strength

$N_{rm,us}$; $N_{rk,us}$ = mean value or characteristic value of ultimate load of steel failure

$N_{rm,uc}$; $N_{rk,uc}$ = mean value or characteristic value of ultimate load of concrete cone failure

$N_{rm,up}$; $N_{rk,up}$ = mean value or characteristic value of ultimate load of pull-out failure

6.2.2 Characteristic tensile strength

In order to identify the characteristic strength of the screw anchor, the following values shall be determined:

(i) *Mean ultimate loads:* The mean ultimate loads shall be obtained from test results.

(ii) *Coefficient of variation for ultimate loads:* The coefficient of variation of ultimate loads, **ν** shall be determined and if this value is greater than 15%, the sample size is permitted to be increased.

(iii) *Characteristic values calculated from the ultimate loads determined by tests:* The characteristic values shall be determined for the ultimate load

6.3 Strength in shear

6.3.1 Failure modes

The failure mode of each specimen shall be identified from the following:

a) Steel failure
b) Concrete failure

Similar to tension test, report the average failure load, taking into account all results as the failure load associated with the predominant failure mode.

If no failure mode predominates in a test, test additional screw anchors to obtain at least five samples for each failure mode and conduct a significant difference test to see if the capacities for the different failure modes are statistically different. If they are statistically different, the lesser is adopted and characteristic strength calculated.

6.3.2 Characteristic shear strength

The characteristic shear strength of the screw anchor shall be calculated for each failure mode. The failure mode with the lowest characteristic value shall be decisive.

In order to identify the shear strength of the screw anchor, the characteristic value shall be calculated from the ultimate loads determined by tests. The characteristic basic shear strength, V_{bk}, shall correspond to the 5%-fractile of the mean loads measured in the test series and is calculated according to statistical procedures for a confidence level of 90%. Values are calculated in a similar manner to characteristic tensile values (refer to Section 6.2.2).

7. Evaluation of results

7.1 Characteristic tensile strength of screw anchors

The characteristic strength, $R_{u,N}$ shall be given in the following equation:

$$R_{u,N} = \frac{N_{rk}}{\psi_c}$$

where

$R_{u,N}$ = characteristic ultimate tensile strength of screw anchors normalised to a concrete strength equal to 20MPa

ψ_c = factor to normalise strength according to a concrete compressive strength equal to 20MPa.

= $(f_{cm}/20)^{0.5}$

f_{cm} = mean compressive strength of concrete at the relevant age

The characteristic strength, $R_{u,N}$ shall be multiplied by Φ_N to obtain the design characteristic tensile strength where

Φ_N = capacity reduction factor for tensile loading

$$= \frac{1}{\gamma_c \gamma_2}$$

γ_c = partial safety factor for concrete, 1.5

γ_2 = partial safety factor representing installation safety

= 1.2 for systems with normal installation safety

7.2 Characteristic shear strength of screw anchors

The characteristic shear strength, $R_{u,V}$, shall be determined from the basic shear strength, V_{bk} and normalised to a concrete strength equal to 20MPa as follows:

$$R_{u,V} = V_{bk}/\psi_c$$

where

$R_{u,V}$ = characteristic ultimate shear strength of screw anchor normalised to a concrete strength of 20MPa

V_{bk} = basic characteristic ultimate shear strength of screw anchor for concrete mode of failure

ψ_c = factor to normalise strength according to a concrete compressive strength equal to 20 MPa (refer to Section 7.1)

The characteristic strength, $R_{u,V}$ shall be multiplied by Φ_V to obtain the design characteristic shear strength where

Φ_V = capacity reduction factor for shear loading

$$= \frac{1}{\gamma_c \gamma_2}$$

γ_c = partial safety factor for concrete, 1.5

γ_2 = 1.0 for Φ_V

8. References

AS1012 (set), “Methods for testing concrete”, Standards Australia

AS 1379-2007, “Specification and supply of concrete”, Standards Australia

DR2 AS 3850.1, “Prefabricated concrete elements, Part 1: General requirements”, Standards Australia

ETAG 001, “Guideline for European Technical Approval for Metal Anchors for Use in Concrete, Part 1: Anchors in General”, European Organisation for Technical Approvals, www.eota.eu

ETAG 001, “Guideline for European Technical Approval for Metal Anchors for Use in Concrete, Annex A: Details of Tests”, European Organisation for Technical Approvals, www.eota.eu