TECHNICAL NOTE: PREQUALIFICATION OF POST-INSTALLED AND CAST-IN ANCHORS

1. SCOPE

The purpose of this document is to explain international prequalification of anchors and outline the benefits of selecting independently qualified anchor products. This document is intended for general advice only, to aid in the process of selection, design and installation of anchors to best-practice. The contents are based on anchors for construction having international prequalification that are used in safety-critical structural and non-structural applications.

A prequalification, based on harmonised assessment and design procedures, provides the highest level of certainty that a product is fit for its intended use. Many anchor products available in Australia have prequalification. AEFAC recognises prequalification as promoting best-practice, using products independently assessed to state-of-the-art standards. Products that are qualified according to the standards outlined in this document are compatible with European standards using the Concrete Capacity method for design.

2. TERMINOLOGY

AVCP - Assessment and Verification of Constancy of Performance is a high level quality control system that ensures the product continues to perform in accordance with its technical specification such as an ETA or harmonised European standard for the duration of its production. The procedure for conformity control was formerly conducted under the Attestation of Conformity.

CE Marking – Conformité Européene (European Conformity) Marking which is a symbol denoting a manufacturer has conformed to the Essential Requirements of the Construction Products Regulation. The CE is only applicable to products that have an ETA and an AVCP system in place.

CEN – European Committee for Standardisation that is responsible for the planning, drafting and adoption of European Standards.

DoP – the Declaration of Performance is a document published by the manufacturer that includes the essential characteristics of their product. The DoP is generated when a product is covered by a harmonised European standard or an ETA. The manufacturer therefore assumes the legal responsibility of the product conforming to the declared performance.

EAD – European Assessment Document is the replacement for an ETAG. An EAD provides the same framework for testing and assessment of anchors, except design methods have been removed and placed in European Standard EN 1992-4 *Design of fastenings for use in concrete*.

EOTA – European Organisation for Technical Assessments (formerly European Organisation for Technical Approvals) comprises Approval Bodies nominated to issue European Technical Assessments (ETAs) by EU Member States and European Free Trade Association States who have contracted to the European Economic Area Agreement. The EOTA monitors the drafting of ETAs and co-ordinates all activities relating to the issuance of ETAs.

ETAG – An ETAG is a document drafted by and for the EOTA Approval Bodies as a result of a mandate from the European Commission and EFTA. Its basic aim is to establish how Approval Bodies should evaluate the specific characteristics/requirements of a product or family of products. An ETAG is being replaced by a European Assessment Document.

ETA – European Technical Assessment (formerly European Technical Approval) is prequalification for a construction product that represents a favourable technical assessment of its fitness for an intended use. European Technical Approvals issued prior to 1st July, 2013 will remain relevant for their period of validity. The period of validity of a European Technical Assessment is unlimited provided an AVCP system is in place.

3. INTRODUCTION

In Australia, anchors for construction do not currently require prequalification to be legally placed in the market. Internationally, such as in Europe and USA, prequalification of structural anchors by manufacturers is mandatory, to ensure products meet minimum performance requirements for safety critical applications [1]. The European Organisation for Technical Assessment (EOTA) overseas all matters relating to the awarding of prequalification for construction products, or European Technical Assessment (ETAs). International Code Council Evaluation Service, Inc. (ICC-ES) does technical evaluations of building/construction products in the USA. Prequalification provides independent verification that a product will perform as intended under environmental conditions and applied loads listed by the manufacturer. For this reason, there is a clear benefit for the Australian construction industry to demand anchor products with an ETA or ICC-ES evaluation report. This document outlines the merits of requesting anchor products for construction with ETAs.

4. BACKGROUND TO THE EOTA

The EOTA was established on December 21, 1988 as a legal body under Belgian Law, which comprises Approval Bodies which issue ETAs by EU Member States and EFTA States, who have contracted to the European Economic Area Agreement. The goal of the EOTA is to remove technical barriers to trade in the construction products sector. The primary task of the EOTA is to monitor and progress the drafting of European Assessment Documents (EADs), valid throughout all European Union states. ETAs are intended to be sympathetic to national standards for a given country. EOTA states the failure of safety-critical anchors may “compromise the stability of the works, cause risk to human life and/or lead to considerable economic consequences.”

5. GUIDELINES FOR PREQUALIFICATION

AEFAC recommends EADs as the preferred guidelines for testing and assessment of safety-critical anchors for prequalification. A product complying with the requirements of an EAD receives a European Technical Assessment (ETA) demonstrating its fitness for purpose. Provided a product has been granted an ETA and the relevant conformity control measures are implemented by the manufacturer, the product may carry CE marking. In the past, ETAs were reviewed every five years. However, the period of validity of an ETA awarded after 1st July, 2013 is not limited provided the system for Assessment and Verification of

Constancy of Performance (AVCP) is in place. An ETA is awarded to a single product only and is non-transferable to any other product, made either by the same or different manufacturer. The first published Guideline for European Technical Approval (ETAG), now being replaced by an EAD, was ETAG 001 "Guideline for European Technical Approval of Metal Anchors for use in Concrete" [2].

If there is no ETAG for a particular product, it is possible to obtain an ETA under the EOTA Common Understanding of Assessment Procedure (CUAP). Guidelines for anchor prequalification outside the European Union also exist, such as those published by the American Concrete Institute Committee 355 for post-installed mechanical anchors [3] and post-installed bonded anchors [4].

6. PREQUALIFICATION OF ANCHORS FOR USE IN CONCRETE (ETAG 001)

The European prequalification currently valid for anchors used in construction is ETAG 001 "Metal Anchors for Use in Concrete" [2]. This Guideline is the very first ETAG, adopted in 1997, which was specifically written to be compatible with European Standards. The first five parts of ETAG 001 in addition to the Annexes, relate to structural anchors as follows:

- Part 1: Anchors in General
- Part 2: Torque-Controlled Expansion Anchors
- Part 3: Undercut Anchors
- Part 4: Deformation-Controlled Expansion Anchors
- Part 5: Bonded Anchors
- Part 6: Anchors for multiple use for non-structural applications
- Annex A: Details of tests
- Annex B: Tests for admissible service conditions – detailed information
- Annex C: Design methods for anchorages
- Annex E: Assessment of metal anchors under seismic action

Part 1 of ETAG 001 contains the essential requirements and assessment methods, while Parts 2 – 5 contain specific requirements, required tests and assessment methods for specific types of metal anchors. The design of anchorages has been incorporated into Annex C since prequalification, assessment and design is interdependent. EADs do not include design methods since these reside in European Standard 1992-4 *Design of fastenings for use in concrete* [5] which is presently published as CEN/TS 1994-4 parts 1 – 5 ([6], [7], [8], [9], [10]).

The contents of ETAG 001 may be further broken down to detail the rigour of the prequalification as outlined below. This Guideline may be used to evaluate almost all safety-critical metal anchors.

6.1 Types of anchors covered

The four main types of anchors covered in ETAG 001 are torque-controlled expansion anchors, undercut (including screw anchors), deformation-controlled expansion anchors, and bonded anchors.

6.2 Options

The Option number (refer to Table 1) determines the scope of the application for which the anchor performance has been independently verified. In total there are 12 possible combinations reflected in the Option number. The factors determining the Option number include the state of the concrete (cracked and non-cracked, or non-cracked only), concrete strength (C20/25 to C50/60), direction of loading (single value covering all directions, or separate for tension and shear), effect of reduced edge and spacing distances, and design method. Options 1 (cracked and non-cracked concrete) and 7 (non-cracked concrete) are the most demanding test regimens, while Options 6 and 12 have the least demanding test regimens. The selection of a product for a given application must therefore ensure the Option covers the required criteria.

Table 1**:** ETAG 001 Options for prequalification of metal anchors for use in concrete.

Option No.	Concrete		Requirements for Specification				Reduced edge & spacing	Design Method as per Annex C
	Cracked & non-cracked	Non-cracked only	C20/25*	C20/25 to C50/60	Single value (all directions)	Tension & shear values		
1	X			X		X	X	A
2	X		X			X	X	A
3	X			X	X		X	B
4	X		X		X		X	B
5	X			X	X			C
6	X		X		X			C
7		X		X		X	X	A
8		X	X			X	X	A
9		X		X	X		X	B
10		X	X		X		X	B
11		X		X	X			C
12		X	X		X			C

* Here ‘20’ represents 20 MPa concrete strength determined via cylinder tests, whereas ‘25’ represents 25 MPa concrete strength determined via cube tests.

6.3 Testing methods

A series of comprehensive tests are undertaken to measure the performance of the anchor against set criteria. The tests reflect factors that may be encountered during installation or during the expected service life of the anchor. However, it is important to note the scope of an ETA excludes gross installation errors. Correct installation is therefore critical.

6.3.1 Reference tests

Reference tests are performed as benchmarks of performance for later comparison during the assessment of performance. These tests are performed under 'ideal' conditions.

6.3.2 Suitability tests

The suitability tests are used to measure the performance of an anchor in adverse conditions. The required tests depend on the Option number and include a combination of the following:

- Installation safety tests
- Functioning in low or high strength concrete
- Functioning in crack movements
- Repeated loads
- Sustained loads
- Torque tests
- Functioning under freeze/thaw conditions
- Effect of installation direction

6.3.3 Admissible service condition tests

Tests for admissible service conditions include tests to examine the performance of an anchor against conditions likely to be experienced during service, such as elevated temperatures, performance in a corner, minimum edge and spacing distances, etc.

6.3.4 Tests for durability

Tests are conducted to ascertain durability performance involving either immersion in an alkaline solution or exposure to sulphurous atmosphere.

6.4 Assessment of tests

The assessment and judgement of an anchor's performance for its intended use includes an examination of load/displacement behaviour, as well as change in performance when certain factors are varied. If the requirements of test are met, the characteristic resistance of the product is determined. The published characteristic resistance is based upon the basic characteristic resistance determined from reference tests, modified according to environmental conditions then reduced according to partial safety factors determined from the results of the test regimen and installation safety.

6.5 Supplementary references for prequalification

A number of ETAGs relating to anchor prequalification besides ETAG 001 have been published and include:

- ETAG 014 "Guideline for European Technical Approval of Plastic anchors for fixing of external thermal insulation composite systems with rendering" [11]
- ETAG 020 "Guideline for European Technical Approval of Plastic anchors for multiple use in concrete or masonry for non-structural applications" [12]
- ETAG 029 "Guideline for European Technical Approval of Metal injection anchors for use in masonry" [13]

Technical Reports (TR) published by the EOTA are developed as supporting reference documents to ETAGs. Technical Reports are evolving documents, expressing the common understanding of existing knowledge and experience of the EOTA bodies at a particular point in time. A number of Technical Reports have been published relating to anchor prequalification that include:

TR 018 “Assessment of torque-controlled bonded anchors” [14]

TR 023 “Assessment of post-installed rebar connections” [15]

7. DESIGN METHODOLOGY FOR ANCHORS HAVING PREQUALIFICATION

A companion design methodology exists for anchors that have undergone rigorous testing and assessment and have been awarded prequalification via an ETA. Three different design methods are currently provided in ETAG 001 Annex C [1], with method ‘A’ being the most stringent, accounting for all failure modes and allowing the most efficient anchor design. Design methods ‘B’ and ‘C’ are simplified approaches that have reduced test requirements and consequently, reduced flexibility in design. The design method correlates with the Option number for the ETA (refer to Table 1). In the future, the design method will reside in European Standard EN 1992-4 *Design of fastenings for use in concrete* [5] and will not be available in the EAD that eventually replaces ETAG 001.

Supporting references such as the EOTA Technical Reports are also available to supplement ETAG 001.

7.1 Concrete Capacity design

The underlying theory of the design method adopted in ETAG 001 is accepted internationally including in the United States ([16], [17]). The theory is termed the Concrete Capacity Design (CCD) method and was originally presented in 1995 [18], although earlier more primitive versions had been developed. An inverted pyramid is used to predict concrete failure due to loading on the anchor and has been demonstrated to be very accurate. The design method permits a reduction in the failure load using modification factors to account for eccentricity of loading in tension, shear, bending, edge and spacing effects, reinforcement, state of the concrete (cracked or non-cracked), concrete member thickness and details of fixture including plate stiffness, plate thickness and hole clearance.

The safety concept is based on limit state design using the partial safety factor approach as follows:

$E_d \leq R_d$

where

E_d = Design load effect calculated in accordance with Eurocode 1.

R_d = Design resistance

$R_d = R_u/\gamma_M$

where

R_u = Characteristic resistance of the anchor

γ_M = partial safety factor for material published in ETA

The design resistance is determined from a combination of characteristic values and partial safety factors published in the ETA, and the design guidelines published in ETAG 001 Annex C. Each failure mode is examined independently as outlined in Table 2.

Table 2**:** Failure modes considered when establishing design resistance of anchor.

Tension (Characteristic resistance)	Shear (characteristic resistance)
Steel failure ($N_{u,s}$)	Steel failure ($V_{u,s}$)
Concrete cone failure ($N_{u,c}$)	Concrete edge failure ($V_{u,cp}$)
Pull-out failure ($N_{u,p}$)	Pry-out failure ($V_{u,c}$)
Splitting failure ($N_{u,sp}$)	

After establishing the decisive failure mode in the respective directions, the design actions are compared to the design resistance. Tension and shear loads are assessed independently. Where combined loading is present, an interaction equation is used to determine adequacy of the design.

The characteristic resistance for tension (N_u) and shear (V_u) are evaluated from the least favourable failure mode in the respective directions:

N_u = $\min(N_{u,s}, N_{u,c}, N_{u,p}, N_{u,sp})$, where $N_{u,s}$, $N_{u,c}$, $N_{u,p}$ and $N_{u,sp}$ are identified in Table 2
V_u = $\min(V_{u,s}, V_{u,cp}, V_{u,c})$, where $V_{u,s}$, $V_{u,cp}$, and $V_{u,c}$ are identified in Table 2

The design resistance for tension (N_d) and shear (V_d) are determined by dividing N_u and V_u by their partial safety factors determined from ETAG 001 Annex C and the issued ETA. The design tensile load (N^*) and design shear load (V^*) are then compared to N_d and V_d, such that

$N^* \leq N_d$, and
$V^* \leq V_d$

The final check requires examination of the interaction equation (simplified version included below):

$$N^*/N_d + V^*/V_d \leq 1.2$$

Due to the complexity of the process, many manufacturers offer software that performs this task.

7.2 Anchors for use in non-structural applications

Where an anchor is to be used in normal weight concrete for a non-structural application, it should be tested and assessed in accordance with ETAG 001 [2], Part 6. Appropriate prequalification is still imperative since the failure of such fixtures may represent an immediate risk to human life, even though they are categorised as non-structural.

Recommendations are provided for the minimum number of fixture points, as well as the minimum number of anchors per fixing point. A redundancy condition exists such that if an anchor experiences excessive slip or failure, the load may be redistributed to neighbouring anchors without compromising the requirements of the serviceability and ultimate limit states. Further, if certain strength and stiffness conditions are met in a fixture containing multiple anchors, then the design case of a single anchor experiencing excessive slip or failure need not be considered in the design of the fixture. Under these conditions the design meets redundancy requirements.

7.3 Supplementary References for design

Additional design publications available at the time of publication include:

- TR 020 "Evaluation of Anchorages in Concrete Concerning Resistance to Fire" [19], which outlines the characteristic resistance of anchorages to steel failure under fire, as well as the test to determine the fire resistance according to the "Standard Temperature/Time Curve".
- TR 029 "Design of bonded anchors" [20], which covers the design for bonded anchors based on Annex C with the necessary modifications.
- TR 045 "Design of metal anchors for use in concrete under seismic actions" [21], which covers the design for seismic conditions for anchors that have been awarded an ETA under ETAG 001 [2], Annex E.

8. SELECTING PREQUALIFIED ANCHORS

One of the most important design considerations when selecting an anchor is the state of the concrete. Concrete may crack due to a variety of reasons. Where no guidance is available to indicate the state of the concrete, the designer must demonstrate via analysis of stresses, that cracking will not be experienced during the service life of the anchor, if the anchor is to be designed for non-cracked concrete. For all other applications, cracked concrete should be assumed. Anchors designed for cracked concrete automatically qualify for use in non-cracked concrete. Where cracked concrete is expected, anchors with Options 1 – 6 in their ETA should be selected, whereas anchors qualified only in non-cracked concrete applications should be selected according to Options 7 – 12.

9. INSTALLING PREQUALIFIED ANCHORS

Structural capacity of anchors is sensitive to installation. While the prequalification includes provision for a 'reasonable' variation from ideal installation practice, gross errors are beyond the scope of the prequalification. The installer should ensure that proper training has been received and that adequate supervision of anchor installation is undertaken for the anchor to be considered fit for its intended use. The installation procedure as recommended by the manufacturer and given in the issued ETA must always be followed. General information may be found in the AEFAC Technical Note "Correct Installation of Bonded Anchors for Applications in Concrete" [22].

10. BENEFITS OF EUROPEAN TECHNICAL APPROVALS

Anchor products having prequalification most likely require a modest upfront investment. However, prequalification provides the designer and builder with the necessary confidence that the selected products are fit for purpose and independently verified.

There are clear advantages to selecting anchor products with ETAs, which include:

- Confidence for designers and installers knowing the product has qualified under a harmonised assessment and design procedure reflecting it is fit for its intended use.
- Confidence that the anchor will perform as intended for the duration of its design life that is currently 50 years. For longer design life periods, please contact AEFAC for guidance.
- ETAs reflect the required level of performance according to current state-of-the-art assessment techniques that have been independently verified.
- Quality assurance and safety standards are achieved.
- A safety margin exists for 'reasonable' variations from the manufacturer's installation instructions during installation.
- Traceability of the product from fabrication to packaging to on-site.
- Comprehensive installation instructions supplied by the manufacturer with all required information for installation.

11. REFERENCES

[1] Construction Fixings Association, "ETAs and design methods for Anchors used in Construction", Guidance note, www.fixingscfa.co.uk

[2] ETAG 001, "Guideline for European Technical Approval of Metal Anchors for Use in Concrete" European Organisation for Technical Assessments, www.eota.eu

[3] ACI 355.2-07, "Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary", Report by ACI Committee 355, American Concrete Institute, 2007

[4] ACI 355.4-11 "Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary", Report by ACI Committee 355, American Concrete Institute, 2011

[5] EN 1992-4:2014 Design of fastenings for use in concrete

[6] CEN/TS 1992-4-1:2009 Design of fastenings for use in concrete – Part 4-1: General

[7] CEN/TS 1992-4-2:2009 Design of fastenings for use in concrete – Part 4-2: Headed fasteners

[8] CEN/TS 1992-4-3:2009 Design of fastenings for use in concrete – Part 4-3: Anchor channels

[9] CEN/TS 1992-4-4:2009 Design of fastenings for use in concrete – Part 4-4: Post-installed fasteners – Mechanical systems

[10] CEN/TS 1992-4-5:2009 Design of fastenings for use in concrete – Part 4-5: Post-installed fasteners – Chemical systems

[11] ETAG 014 "Guideline for European Technical Approval of Plastic anchors for fixing of external thermal insulation composite systems with rendering"

[12] ETAG 020 “Guideline for European Technical Approval of Plastic anchors for multiple use in concrete or masonry for non-structural applications”

[13] ETAG 029 “Guideline for European Technical Approval of Metal injection anchors for use in masonry”

[14] TR 018 “Assessment of torque-controlled bonded anchors”

[15] TR 023 “Assessment of post-installed rebar connections”

[16] ACI 318-11 “Building Code Requirements for Structural Concrete and Commentary”, Report by ACI Committee, American Concrete Institute, 2011

[17] “2012 International Building Code 2012”, International Code Council, 2012

[18] Fuchs, W., R. Eligehausen, and J. E. Breen, 1995, Concrete Capacity Design (CCD) Approach for Fastening to Concrete, ACI Structural Journal, 92(1), pp. 73-93

[19] TR 020 “Evaluation of Anchorages in Concrete concerning Resistance to Fire”, European Organisation for Technical Assessments, www.eota.eu

[20] TR 029 “Design of bonded anchors”, European Organisation for Technical Assessments, www.eota.eu

[21] TR 045 “Design of metal anchors for use in concrete under seismic actions”, European Organisation for Technical Assessments, www.eota.eu

[22] AEFAC “Correct installation of Bonded Anchors for Applications in Concrete”, Australian Engineered Fasteners and Anchors Council, Technical Note, 2013