TECHNICAL NOTE

AEFAC
Australian Engineered Fasteners and Anchors Council

AEFAC – TN11

POWER ACTUATED FASTENERS (PAF)

Vol 2: Prequalification, Selection and Design

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Revision Sheet

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0		Initial release	Dec 2023

1. Scope

This Technical Note is Volume 2 of a suite of AEFAC Technical Notes on power actuated fasteners (PAF). The various types of power actuated fasteners, including their features, benefits and applications are explained in the AEFAC technical note, TN 11 Vol 1 [1]. However, AS 5216, *Design of post-installed and cast-in fasteners in concrete* [2] does not cover the design and verification of PAF.

The aim of this Technical Note is to provide guidance on the prequalification, selection, and design of PAF for safety-critical applications in concrete base materials. It is a requirement that Volume 2 be used in conjunction with Volume 1.

A building component is deemed safety-critical, where the potential collapse or malfunction of the component may directly (or indirectly) endanger human lives or result in significant economic loss. In line with the principles of AS 5216, fasteners used in safety-critical applications shall be assessed and qualified as 'fit-for-purpose' and the relevant performance attributes shall be listed in the prequalification documents, such as an ETA (European Technical Assessment).

For the design of safety-critical building components with PAF, preference shall be made towards fastening systems with planned redundancy, where in case of the failure of one fastener (or fastening point), the load can be transferred to adjacent fasteners (or fastening points) without failure of the attached system. These applications are known as non-structural building parts fixed with "multiple-use" or "redundant" fasteners.

2. Terminology

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

The following additional terminologies and definitions are used in this Technical Note. Please refer to AS 5216 [2], AEFAC Anchor Dictionary [3] for further terminologies and definitions.

Reliability indices: Factor intended to quantify the required or available reliability of a system using a single numerical value, as defined in various building codes. A lower value indicates a lower reliability.

3. Design framework

Power actuated fasteners are used in safety-critical and non-safety-critical applications. Independent third-party assessments may be required to confirm fitness for intended use in line with applicable regulations.

3.1. Framework in EU

In Europe, the primary regulation governing construction applications and products are the Construction Products Regulation 305/2011 [4] and Eurocodes [5, 6].

Construction Products Regulation 305/2011, also referred to as "CPR", mainly defines the following:

- EU Regulation covering basic requirements for building products and essential characteristics,
- How to develop test and assessment criteria for products through harmonised EU Standards or European Assessment documents (EADs),
- How to declare performance in a European Assessment Document and/or Declaration of Performance, and
- Requirements for CE Marking to show compliance with the regulation.

For concrete construction and design, EN 1992 (EuroCode 2 or EC2) [5] and all of its parts govern the design for attachments to concrete.

While safety and reliability are subject to EU member states, often the values recommended by EN 1990 (EuroCode 0 or EC 0) [6] are utilized in practice, when no national requirements exist.

Resistance information for building products in Europe is often expressed as a 5% fractile of the test data considering different uncertainties. This is determined with a confidence interval of 75% in general or attachments to steel, and 90% specifically for anchorage to concrete.

Reliability indices (β) depend on Risk Categories. Table 1 shows the recommended minimum values of reliability indices.

Table 1: Recommended minimum values for reliability index from EN 1990

Reliability Class	Minimum values for β	
	1 year reference period	50 years reference period
RC3	5,2	4,3
RC2	4,7	3,8
RC1	4,2	3,3

In addition to the ultimate limit states covered by the reliability indices, serviceability and local failure may be considered as well, with lower β values of e.g. 1.5 for serviceability.

3.2. Framework in Australia

In Australia, all building work must meet specific legal and performance requirements. The legal framework is provided in the relevant Building Acts of each State and Territory of the Commonwealth. These legislations reference the National Construction Code (NCC) [7] for the performance requirements of various building components, as well as construction products used in Australia.

Therefore, the NCC is a legally binding document, including direct references to a series of Australian Standards, which specify the minimum requirements for the construction industry. Building professionals must ensure that the selected construction product has been qualified as “fit for purpose” (conformance) and its performance has been verified for the specific application in accordance with the relevant standards (compliance).

AS 5216 – Design of post-installed and cast-in fasteners in concrete is the primary referenced standard within the NCC for the purpose of qualification, selection and design of concrete fasteners in safety-critical applications. Appendix A of AS 5216 sets out the qualification requirements for various concrete fasteners, utilizing the same European Assessment Documents (EAD’s) described in section 3.1.

The demonstration of product suitability is covered in Appendix B of AS 5216. European Technical Assessments (ETA’s) are accepted as evidence of conformity for concrete fasteners. Furthermore, AS 5216 provides guidance to the specifier in carrying out the necessary design checks and verifications of the selected fastener in a given application.

Similar to Europe, product resistance information is expressed as a 5% fractile in Australia per the NCC. In NCC, the reliability index β is different from Europe. The reliability indices in NCC are shown in Table 2.

Table 2: Annual target reliability indices in NCC

Type of action	Target reliability index β
Permanent action	4.3
Imposed action	4.0
Wind, snow and earthquake action	3.7

In summary, annual target reliabilities for typical buildings of Risk Class 2 appear to be slightly higher in Eurocodes, compared to the requirements in the Australian NCC.

4. Power Actuated Fasteners - Requirements

4.1. Testing and assessment

EAD 330083 *Power-actuated fastener in concrete for redundant non-structural applications* [8] was developed for various intended uses or redundant applications and fastener types. Figure 1, Figure 2 and Table 3 show the examples and details of Fastener type 1, 2 and 3 PAF covered in EAD 330083.

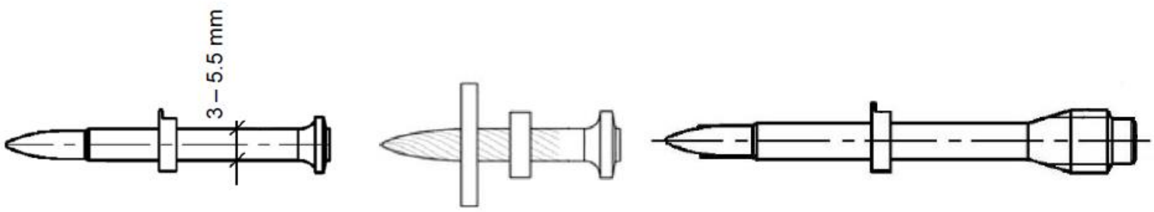

Figure 1: Power actuated fastener with washer (Type 1 and 2)

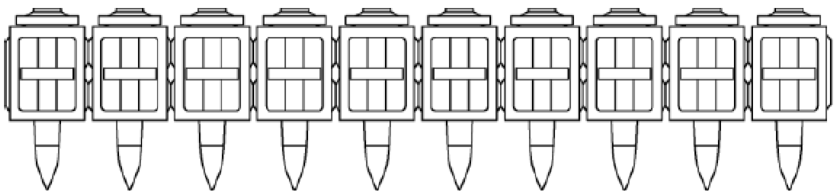

Figure 2: Power actuated fasteners (Type 3)

Table 3: Types of power actuated fastening systems

Fastener type	Minimum anchorage depth	Maximum anchorage depth	Definition of multiple fasteners
1	≥ 25 mm	-	According to ETAG 001-6:2013, Annex 1 [5]: $n_1 \geq 4$; $n_2 \geq 1$ and $n_3 \leq 3{,}00$ kN or $n_1 \geq 3$; $n_2 \geq 1$ and $n_3 \leq 2{,}00$ kN
2a	≥ 18 mm	-	$n_1 \geq 4$; $n_2 = 1$ and $n_3 \leq 0{,}60$ kN
2b	≥ 15 mm	-	$n_1 \geq 6$; $n_2 = 1$ and $n_3 \leq 0{,}30$ kN
3	11 mm	18 mm	Fastening of cables spanned in one direction $10 \leq n_1 \leq 100$; $n_2 = 1$ and $n_{3S} \leq 0{,}10$ kN maximum span 1000 mm

Static and quasi-static load resistances, as well as fire resistances can be determined in accordance EAD 330083. One of the latest developments in the EAD is the testing and evaluation of groups of 5 or more fasteners to attach partition wall tracks, to utilize system redundancy as well as application relevant loading conditions. In general, two different sets of tests are carried out per EAD 330083 to assess the performance related to the influence factors relevant for PAF in concrete as follows:

- Admissible Service Condition Tests (A tests): Performance of fasteners for intended use:
    - Tests at upper and lower concrete strength class
    - Tests in cracked (0.2 mm) and non-cracked concrete
    - Tests to consider load direction (shear & tension)
    - Tests at different service temperatures, if the fastener contains plastic parts (e.g. cable holders or conduit clips)

- Functional tests (F tests): Performance under expected job site variations and sensitivity of the product to adverse conditions:
    - Crack width sensitivity 0.35 mm
    - Sensitivity to large (32 mm) and hard (Mohs hardness ≥ 5) aggregate
    - Sensitivity to hydrogen embrittlement (PAF are typically hardened, and zinc plated)
    - Contact with reinforcement

4.2. Performance declaration

In Europe, the results of the tests are evaluated by a third party and submitted for review to a Technical Assessment Body (TAB) in a selected EU member state. After a circulation also in the European Organization for Technical Assessments (EOTA) for review, a European Technical Assessment (ETA) is published, and CE Marking and Declarations of Performance (DoP) can be provided for the product. These items contain:

- Intended use and quantified boundary conditions (e.g. concrete classes)
- Manufacturer information
- Product details and specifications
- Installation details and requirements
- Declared performance data
- Design provisions and safety factors

4.3. Quality assurance

In Europe, additional to the tests and assessments in accordance with EAD, products also required to be supported by product specifications and continuous quality assurance programs to ensure constancy of performance in serial production, when covered by an ETA.

4.4. Installer Training

The installation must be carried out by competent personnel. The requirements for such qualification vary strongly by country and are not covered by the EAD 330083. However, all manufacturers offer in person and virtual training courses, depending on the relevant national requirements.

Such training typically includes a general education on key applications, functioning of installation tools, safety instructions, as well as fastener selection, tool maintenance and trouble shooting.

5. Summary

In summary, performance data in ETA's is fully linked to EuroCode 2 design provisions, while covering a wide range of applications and critical relevant influence factors or construction site conditions.

Using design values in ETA can provide a high level of reliability and transparency for current and future applications. For example, there is a greatly increased need for seismic design data for PAF in concrete, related to damage sensitive non-structural elements, such as drywall partitions. Testing for seismic and fire performance related to redundant fastening systems is currently not covered in any guideline globally and must be developed.

In addition, EAD developments can help to further enhance qualification and design provisions for PAF in Australia, building on EADs and ETAs, including a potential coverage by AS 5216 in the future.

6. References

[1] AEFAC, Technical Note 11 Vol 1, "Power Actuated Fasteners," Australian Engineered Fasteners and Anchors Council. www.aefac.org.au.

[2] Standards Australia, AS 5216: Design of post-installed and cast-in fastenings in concrete, SAI Global, Sydney, 2021.

[3] AEFAC, Technical Note, "AEFAC Anchor Dictionary," Australian Engineered Fasteners and Anchors Council. www.aefac.org.au.

[4] "Regulation (EU) no. 305/2011 of the European Parliament and of the Council of 9 march 2011, Laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC", Official Journal of the European Union, Brussels, Belgium, 2011

[5] CEN (European Committee for Standardization). "EN 1992: Eurocode 2: Design of concrete structures". Brussels: CEN, 2004

[6] CEN (European Committee for Standardization). "EN 1990: Eurocode 0: Basis of structural design". Brussels: CEN, 2010

[7] ABCB, "National Construction Code (NCC)", Australian Building Codes Board, 2022

[8] EAD 330083, "Power-actuated fastener in concrete for redundant non-structural applications", EOTA, 2019

[9] Standards Australia, AS 1170.2: "Structural design actions, Part 2: Wind actions", SAI Global, Sydney, 2021.

[10] Standards Australia, AS 1170.4: "Structural design actions, Part 4: Earthquake actions in Australia", SAI Global, Sydney, 2007.

Appendix A: Design Examples

A.1 Fixing of internal partition wall tracks into concrete slab

This design example covers the required strength checks for the fixings of a typical internal partition wall in a two-story, 7-metre-high family villa located in Gold Coast, Australia. The building site is in a suburban area, 1.2 kilometres away from the shoreline. The partition wall in question comprises of a 2.7-metre high, single leaf construction of non-fire rated plasterboard wall supported by metal tracks and studs.

Calculation of design actions:

A. Wind actions:

The design wind load is calculated in accordance with the AS 1170.2 [9], Section 4 and 5.

- Wind region: B ("non-cyclonic")
- Building importance level: IL 2
- Terrain category: 3 ("suburban")
- Height of building component from ground: less than 10 metres
  - Design wind pressure in the Ultimate Limit State: P = 0.67 kPa
- Wall height: 2.7 m
- Default spacing of fasteners: 0.6 m
  - Design shear force on a single fastening point (bottom or top track):

$\mathbf{V_{wind}}$ = 0.5 * 1.25 * 2.7m * 0.6m * 0.67kN/m2 = **0.68kN**

B. Seismic actions:

The relevant Earthquake Design Category (EDC) is determined based on Table 2.1 of AS 1170.4 [10].

- Importance Level / Type of Structure: Domestic structure ("housing")
- Structure height: less than 8.5m
  - Seismic verification to be carried out in accordance with Appendix A of AS 1170.4:

The seismic risk is calculated as a combination of the probability factor "k_p" and hazard factor "Z":

- Probability factor: 1.0 (IL2 → Annual probability of exceedance: 1:500)
- Hazard factor: 0.08 ("Gold Coast, Australia")
  - Seismic risk: $k_p * Z = 1.0 * 0.08 = 0.08 < 0.11$

- The seismic risk (k_pZ) is smaller than the threshold given in "Appendix A" and the house is designed and detailed against lateral wind load, therefore "no specific earthquake design is required" in accordance with "Table A1" of AS 1170.4.

Required strength checks:

A. Wind load:

Requirements: $V_{wind} < V_{Rk} / \gamma_M$

Where:

V_{Rk} = 0.8kN, characteristic shear load of the PAF from product ETA
γ_M = 1.50, partial safety factor for fastener resistance from product ETA

Based on the relevant performance table in the product ETA:

$V_{Rk} / \gamma_M = 0.8kN / 1.5 = 0.53kN$
$V_{wind} = 0.68kN > 0.53kN$ – single fastener does not meet design criteria

Try reducing the distance of fasteners:
New fastener spacing = 0.4m
$V_{wind} = 0.5 * 1.25 * 2.7m * 0.4m * 0.67kN/m^2 = 0.45kN$
$V_{wind} = 0.45kN < 0.53kN$

The selected fastener meets the design criteria against the design wind load at 400mm spacing.

A.2 Fixing of electrical conduits into the underside of concrete slab

This worked example covers the design verifications for the fixings of a 32mm electrical conduit including lighting cables to the underside of a concrete slab in a six-story residential complex in Sydney, Australia.

Calculation of design actions:

A. Static actions:

- Self-weight of 32mm PVC conduit including insulated copper wires: 2.0 kg / metre
- Distance between conduit clip supports: 1.2 metres

- Factored vertical reaction force at the cable supports:

  F = 1.25 * 1.2m * 20 N/m = **30 N**

B. Seismic actions:
In accordance with AS 1170.4:2007, Clause 8.1.4., Section (b), Point (xviii), electrical conduits of less than 64mm inside diameter are not required to be designed against earthquake actions.

Required strength checks:

A. Static load:

Requirements: $F < N_{S,max}$

Where:

F	=	Vertical reaction force at the conduit support
$N_{S,max}$	=	Maximum service load in tension

Based on the relevant performance table in the product ETA:

$N_{S,max}$ = 45N
F = 30N < $N_{S,max}$ = 45N

The selected conduit clip and PAF meet the design criteria against the maximum service load.

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