TECHNICAL NOTE

AEFAC
Australian Engineered Fasteners and Anchors Council

AEFAC – TN11

POWER ACTUATED FASTENERS (PAF)

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1. Scope

Power actuated fasteners (PAFs) are used in connecting non-structural elements to steel and concrete substrates. Depending upon the power source, the power actuated fasteners can be divided into powder actuated, gas-actuated or battery actuated fasteners. This document focuses on attachments to concrete only. The behaviour of PAF is less known as compared to other fasteners such as cast-in fasteners, expansion fasteners or chemical fasteners. AS 5216 [1] does not cover the prequalification and design of these fasteners. The designers are depended on the proprietary information from the manufacturers and suppliers. This technical note provides the basic information on PAF, their working principles and installation tools commonly used to install PAF for redundant systems.

2. Terminology

The following terminologies and definitions are used in this Technical Note. Please refer to AS 5216[1], AS/NZS 1873 series [2] and AEFAC Anchor Dictionary [3] for additional terminologies and definitions.

Base material: material in which the PAF is installed.

Edge distance: distance between the free edge of the concrete member and the centre-line axis of PAF.

Fastening: assembly comprising fastener(s) to secure a fixture to the base material.

Fixing point: fastening or single fastener.

Fixture: element or system that is being secured to the base material via fasteners.

Guard: a device attached to the muzzle end of the power actuated tool, designed to prevent the escape of flying particles or material that could ricochet. Also called anti-spalling guard or splinter guard.

Misfire: the failure of the cartridge or charge to ignite when the power actuated tool is operated.

Non-structural element: element attached to and supported by the structure but not contributing to the load resisting system.

Post-installed fastener: fastener that is installed in concrete in the hardened state.

Power actuated fastening system: a fastening system comprising of fasteners (typically nails or threaded studs), power source and power-actuated tools.

Power actuated tool: a tool whereby a power actuated fastener is driven into substrate.

Power load: a cased cartridge or a caseless pellet of explosive, designed specifically for a powder actuated tool. Also called *charge* or *power charge* or *explosive charge*.

Redundant system: statically indeterminate system of at least three fixing points and attached non-structural element.

Statically indeterminate system: at least three supports or fixing points, so that the system can retain its static stability after the loss of any redundant support of fixing point by allowing alternative load paths.

3. General

3.1. Power actuated fasteners

A Power actuated fastener is typically a drive pin, threaded stud, or specialised fastener driven directly into a solid concrete using a power actuated tool.

There are two main categories of PAF: (i) drive pins and (ii) threaded studs.

Drive pins

Drive pins directly attach a fixture via the head of the fastener, whereas threaded studs allow the attached part to be bolted to the concrete substrate using a nut and washer. A typical example of a drive pin is shown in Figure 1. A rubber or plastic guide is used to hold the pin in the tool and serves to guide the pin during the driving operation while the head prevents the fasteners from being over driven. Collated fasteners are also available to increase speed of installation.

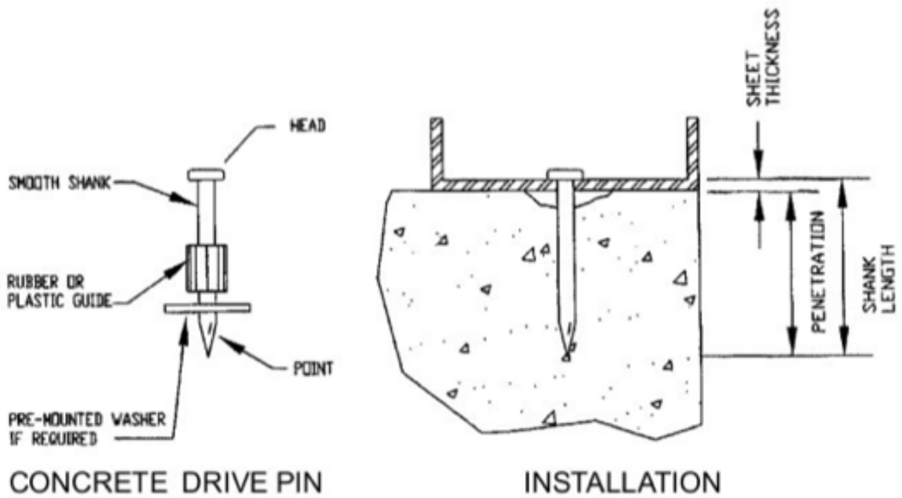


Figure 1: Power actuated drive pin connecting steel fixture to concrete

Threaded studs

For those applications where the adjustment or removability of the fixture is required, threaded studs are used. The threaded studs have external thread on the exposed part of the fasteners where fixtures are attached using removable nuts. Figure 2 shows the typical example of threaded stud from EAD 330083.

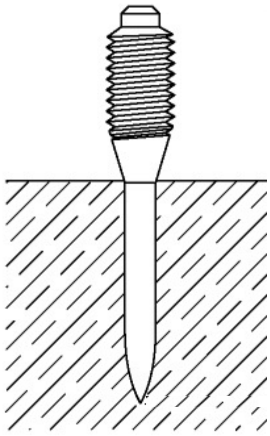


Figure 2: Power actuated threaded stud

3.2. Working Principle

The performance of a PAF depends on several factors including, but not limited to, strength of concrete, dimension of fastener (diameter and embedment depth), spacing and edge distance, and hardness or concentration of aggregates in concrete.

When a PAF is driven into concrete, the fastener displaces the volume of concrete around the fastener. This results the concrete surrounding the fastener is compressed and in turn presses back against the fastener as shown in Figure 3. In addition, heat generated during the driving action causes particles within the concrete to fuse to the fastener. The combined action of compression and fusion helps to hold the fastener in the concrete substrate.

The intense heat generated during driving causes concrete to be sintered onto the fasteners. This sintered material forms ridges on the fasteners surface which will help to increase the anchorage performance by keying mechanism.

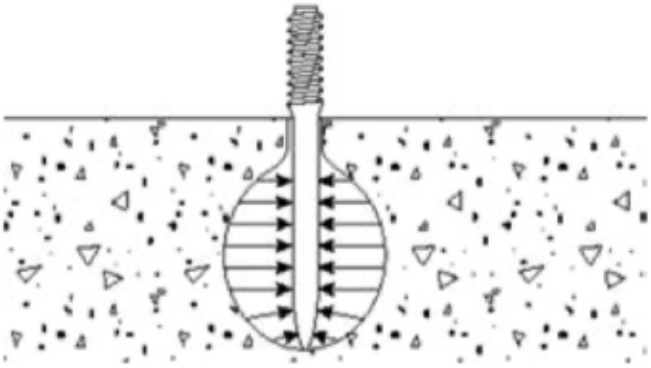


Figure 3: PAF working principle

Depending on aggregate size gradation and hardness, fasteners might get slightly or significantly deflect when installed directly into concrete. This can result in higher capacity variations or occasional no holds. It is recommended to use PAF in concrete for applications, where the failure or excessive deformation of an individual fastener can be compensated by neighbouring fasteners (redundancy). EAD 330083 contains a test series to validate the sensitivity of a PAF system to installations in hard and large aggregate.

3.3. Benefits of PAF

Power actuated fasteners have following advantages:

- The PAF can be installed quickly as compared to other fasteners. Consequently, less labour is required to install the fasteners.
- The predrilling is generally not required to install the power actuated fasteners.
- The installation and performance of power actuated fasteners is weather independent
- The installation process produces no dust or very less dust compared to other post-installed fasteners.

4. Fasteners in redundant non-structural applications (Multiple use fasteners)

The PAFs are intended for redundant non-structural applications in cracked or non-cracked concrete. The fasteners could be type 1, 2a, 2b or 3 depending on the number of fixing points, no of fasteners per fixing points and maximum design load on the fixing point. Table 1 shows the details of these fastening types.

Table 1: Types of power-actuated fastening systems (EAD 330083)

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

For the fasteners used in redundant non-structural applications, it is assumed that in case of failure or excessive displacement of one fastener the load can be transmitted to neighbouring fasteners without significantly violating the requirements on the fixture in the serviceability and ultimate limit state.

5. Applications/Usages of PAF

PAF are predominantly used in non-structural fastening applications, where the building parts and their fixings are not included in the structure's primary load resisting system. An occasional failure of a single fastener may not impact the integrity of an overall redundant system. However, depending on the use case and level of application redundancy, the consequences might be more severe. Therefore, for the purpose of this Technical Note, it is most practical to classify non-structural components and their fixings based on the potential consequences of failure. In case of safety-critical systems, a potential collapse or malfunction of the components may directly (or indirectly) endanger human lives or result in a considerable economic loss. Consequently, the failure of non-safety-critical building parts does not put human lives at risk or pose significant financial risk.

5.1. PAF in safety-critical applications

AS 5216 sets out the provisions for safety-critical fastening applications and calls upon prequalification documents (in accordance with Appendix A) to assess, if a fastener is 'fit for purpose'. Following comprehensive tests and a successful assessment, the fastener is awarded with a prequalification report. AS 5216 does not cover power actuated fasteners and general guidance are provided in this technical note.

When verifying PAF for safety-critical applications, the designer should therefore consider selecting a fastener that has a current pre-qualification document such as

ETA. For the design of safety-critical building components, a preference shall be made towards fastening systems with planned redundancy, where in case of the failure of one fastener the load is assumed to be transferred to adjacent fasteners without impairing the intended function of the attached element.

Typical examples of safety-critical applications with PAF are shown in Figure 4. This includes, but are not limited to, steel decking and cladding applications, floor gratings, fixing of safety barriers and the hanging of various building services and equipment. Some non-structural fit-out components, like the fixings of fire-rated partition walls and suspended ceilings may be regarded as safety-critical, too.


(a) metal decking


(b) grating fasteners


(c) safety barriers


(d) wall ties


(e) shear connectors in composite decks & beams


(f) air duct hangers


(g) fixing of steel frame to slab


(h) fixing of timber frame to slab


(i) ceiling application

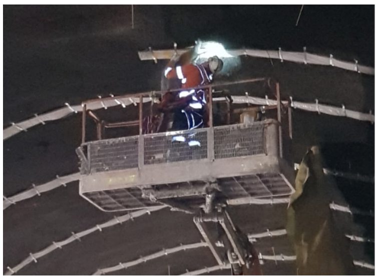
Figure 4: Examples for typical safety-critical applications with PAF.

5.2. PAF in non-safety-critical applications

The decision whether a fastening application falls in the critical or non-safety-critical category shall always be at the discretion of the responsible design engineer or project stakeholders. The examples provided under this section are typically considered as non-safety critical. However, this should be taken as a general guide only and may be overridden by the responsible engineer or specific project requirements (e.g., buildings of Importance Level 4). The verification of non-safety-critical connections with PAF is based on the application diagrams and available load data published by the relevant supplier.

Typical non-safety critical applications are shown in Figure 5. These include, but are not limited to, the fixing of small pipes, cables and conduits, electrical junction boxes, signages and insulation boards. PAF may also be used for temporary fixings during construction, such as the positioning of drain strips and membranes, reinforcing and wire meshes, as well as internal or external kickers for concrete form supports.

(a) small conduits



(b) strip drains

(c) insulation boards

(d) drain membranes

(e) fixing of steel frame to slab

(f) fixing of timber frame to slab

Figure 5: Examples for typical non-safety-critical applications with PAF.

6. Power actuated fastening tools

A power actuated fastening tool is used in order to install the fastener. The driving force of the fastening tool is provided by a power source like powder cartridges in case of powder actuated tools, expanding gases in case of gas driven tools, electric battery power in case of battery driven tools, or compressed air in case of pneumatic tools.

6.1. Types of power actuated tools

The power actuated fastening tools may be “indirect acting” or “direct acting”.

Indirect acting tools

By far the most common industry standard power actuated tools are indirect acting type tools. They are also called low velocity tools and the driving velocity is less than 100m/s. Indirect acting tools are designed to apply the driving energy to a captive piston which transfers the energy to the fastener.

Direct acting tools

Direct acting tools are only used today in special applications like underwater ship repairs. The driving energy contained within the power load is transferred directly to the fasteners. These tools are also called high velocity tools and the velocity of the pins is usually more than 150m/s. These types of tools are today not recommended anymore for construction applications.

Depending on the power source, the PAF can be divided into following 3 types:

1. Powder-actuated tools

In powder-actuated tools, the driving force of the fastening tool is provided by the power load of a cartridge. When ignited, the cartridge transfer energy to a piston which drives the fasteners into concrete.

Different power levels are required depending on the strength of the concrete and size of the fastener. AS/NZS 1873.3:2003 [3] has the requirement of the power actuated tool and classification of power-load (colour code) and is shown in Table 2. Most commonly available colours or power load levels are green, yellow and red.

Table 2: Power identification of power load (AS/NZS 1873.3:2003)

Colour	Power Level
Grey	Minimum
Brown	Very weak
Green	Weak
Yellow	Medium
Blue	Medium strong
Red	Strong
Purple	Very strong
White	Especially strong
Black	Maximum

All cartridges (charges) are colour coded and load level numbered. As the number increases, the power level increases. Always start with the lightest load. If the fastener does not set completely, use the next higher load, and repeat the process.

2. Gas-actuated tools

In gas-actuated tools, the driving force of the fastening tool is provided by combustible gas. An electrical spark is applied to ignite the gas inside the combustion chamber. The expanding gas acts as propellant and it transfers the energy to a piston which drives the fastener into the base material. Some gas tools employ battery power for the ignition of the propellant and the ventilation of the combustion chamber.

Gas-actuated devices generally apply smaller energy drive compared to powder-actuated tools and therefore are best utilized for light-duty fastening applications, such as fixings in interior finishing or installation of light-weight cables and conduits.

The overall benefit of gas technology is the increased productivity rate compared to conventional powder-actuated tools, as these tools can typically execute a large number of fastenings with the use of a single gas canister and battery charge.

3. Battery-actuated tools

The driving force of the battery-actuated fastening tool is provided by electrical power with the help of rechargeable batteries. These types of tools are completely propellant free. The battery powers an electro-mechanical system, which activates spring load to accelerate the piston and drive the fastener into the base material. The energy used to drive the fastener into the base material is comparable to that of gas-actuated tools and therefore the range of typical fastening applications is similar to the ones described in the previous section.

6.2. Tool safety

Most of the power actuated tools are trigger operated and are easy to handle and fire. These tools have safety features to prevent accidental firings. They only fire pins only when pressure is exerted on the work surface and do not fire when the tool is dropped.

Power actuated fasteners must be installed by properly trained and licensed operators where required. Only the fastener type (threaded stud or drive pin or application specific assemblies) and power loads recommended by the tool manufacturer for a particular tool shall be used.

Following safety features/measures are applied in power actuated tools

- **Energy control**
  There is no contact between power load (charge) and fastener in indirect-acting tools. The power load is applied to a piston which drives fastener. Most of the energy is retained in the piston.

- **Drop firing safety**
  This prevents the accidental firing if the tool is dropped or mishandled
- **Contact pressure safety**
  This requires some force in the tool against a base material before the tool can be fired.
- **Trigger safety**
  This prevents accidental activation of the power actuated tool. Trigger mechanism cannot be activated until the contact pressure has been taken off.
- **Unintentional firing mechanism**
  This ensures the tool cannot be fired unless the correct firing sequence is observed.

Note 1: Hitting of main reinforcement, pre-stressing rebar and cables or other important services should be avoided. Consultation with design engineer should be done if in confusion.

Note 2: In general, the capacity of a fastener increases with increase in embedment depth. If the embedment depth is larger, there is a possibility of the fastener bending which results decrease in the capacity of fastener.

7. References

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

[2] Standards Australia/New Zealand Standard, AS/NZS 1873 Series: Powder-actuated (PA) hand-held fastening tools, SAI Global, Sydney, 2003.

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

[4] EAD 330083, Power-actuated fastener for multiple use in concrete for non-structural applications, EOTA, 2018

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