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AS 5216:2021 Webinar Series

POST-INSTALLED REBAR CONNECTIONS + FASTENINGS FOR REDUNDANT NON-STRUCTURAL SYSTEMS

MS Teams Webinar

Wed, 23 Mar 2022
12PM - 1PM

FREE
REGISTRATION

Presenters

Dr. Tilak Pokharel

Dr. Jessey Lee

3 Critical Elements to Achieve Quality Assurance

AEFAC
Australian Engineered
Fasteners and Anchors Council

01. Pre-qualification

Products independently tested and assessed to be "fit for purpose"

02. Design

Rigorous assessment to design for critical mode of failure

03. Installation

Informed and competent installer with appropriate supervision and experience

AEFAC - Introduction

AEFAC Australian Engineered Fasteners and Anchors Council

AEFAC Founding Board Members

AEFAC Supporting Members

The role of AEFAC....

AEFAC
Australian Engineered
Fasteners and Anchors Council

AEFAC
Australian Engineered
Fasteners and Anchors Council

For Designers
Guidelines for the specification and design of fasteners

For Contractors
Training and certification

For Field Engineers
Guidelines for field testing

For Manufacturers
Minimum performance and standard specifications

For fastener Industry
Research and development

AEFAC Installer Certification Program

"The best anchor product is only as good as its installation"

www.aefac.com/icp - Free online training

Standard Development

SA TS 101 - 2015

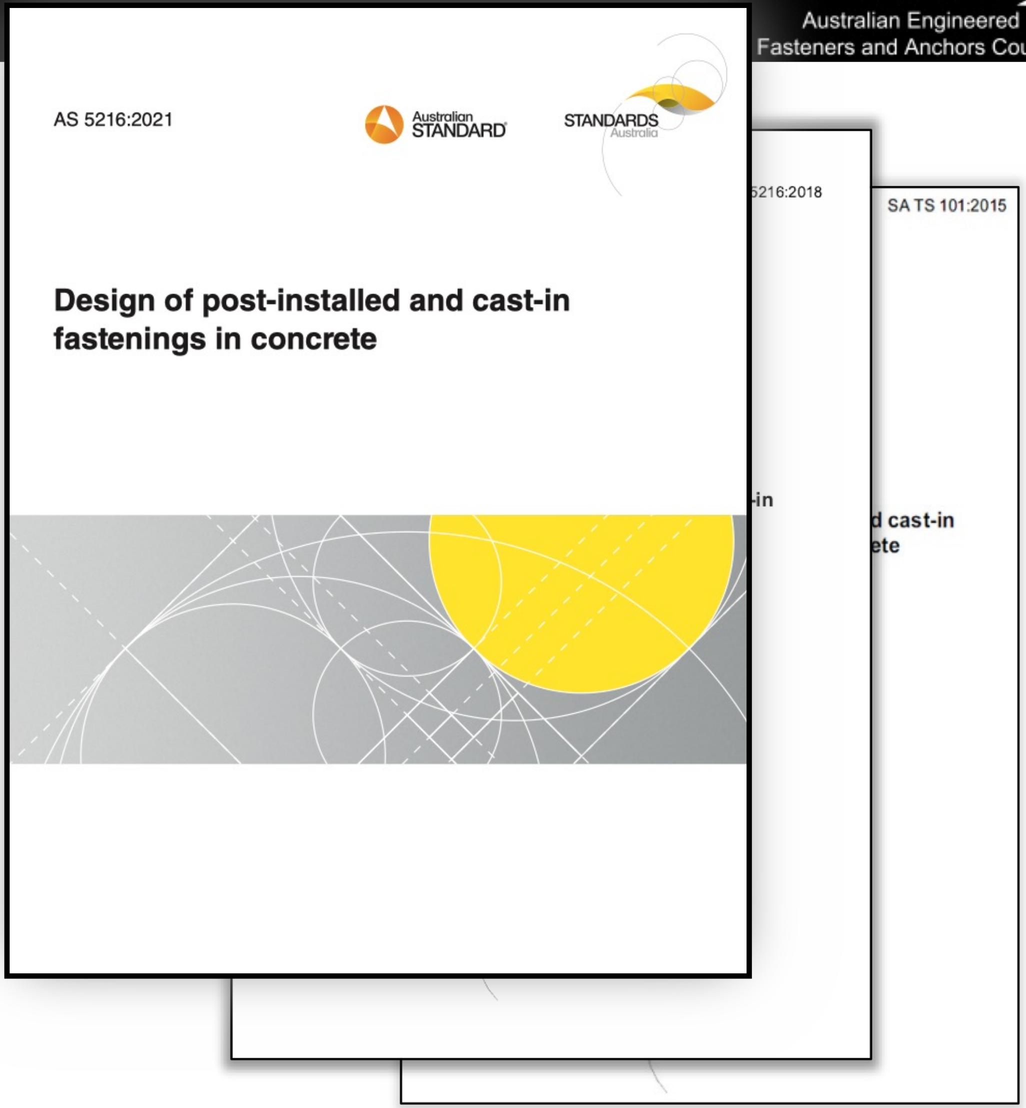
Design of post-installed and cast-in fastenings for use in concrete

AS 5216 - 2018

Design of post-installed and cast-in fastenings in concrete

AS 5216 - 2021

Design of post-installed and cast-in fastenings in concrete



Scope of AS 5216

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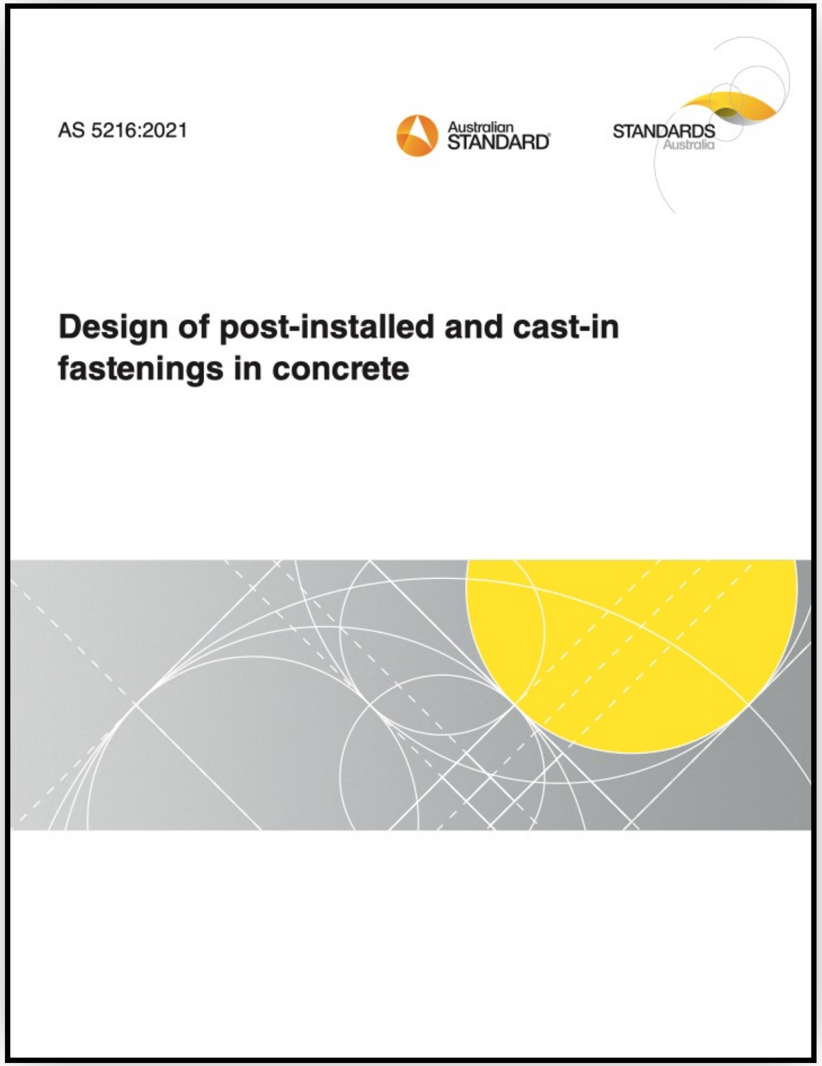
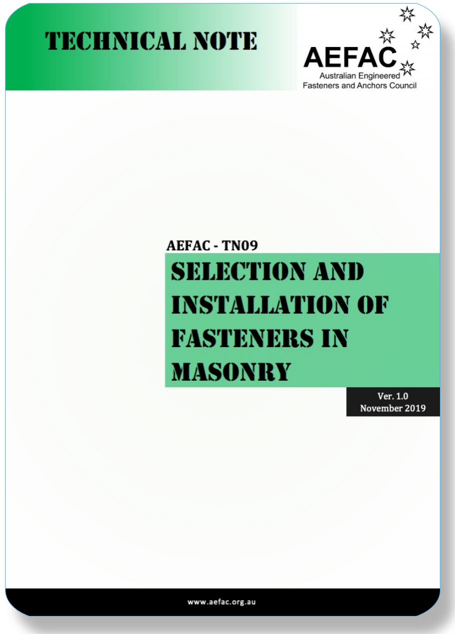
- ✅ Post-installed fasteners
- ✅ Cast-in fasteners

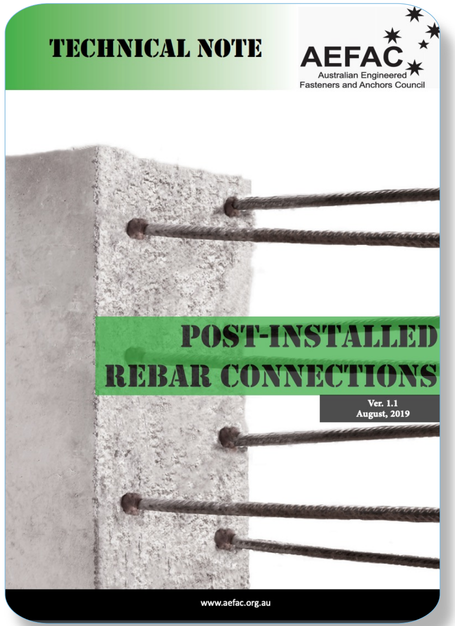
- ✅ Design for seismic actions
- ✅ Anchor channel with 3-D loading
- ✅ Post-installed rebar connections
- ✅ Redundant non-structural connections
- ⛔ Design for fire and durability
- ⛔ Design for fatigue

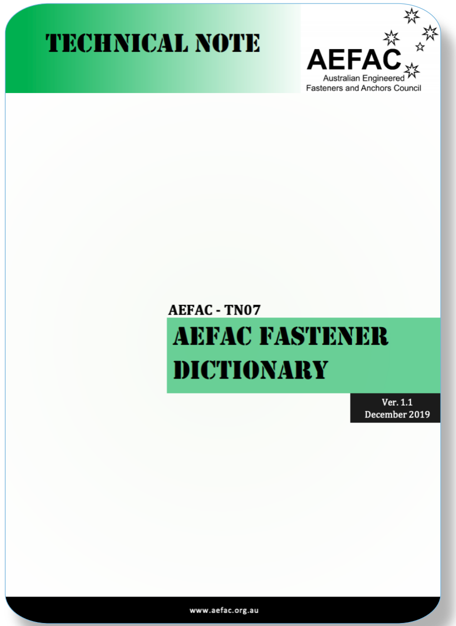


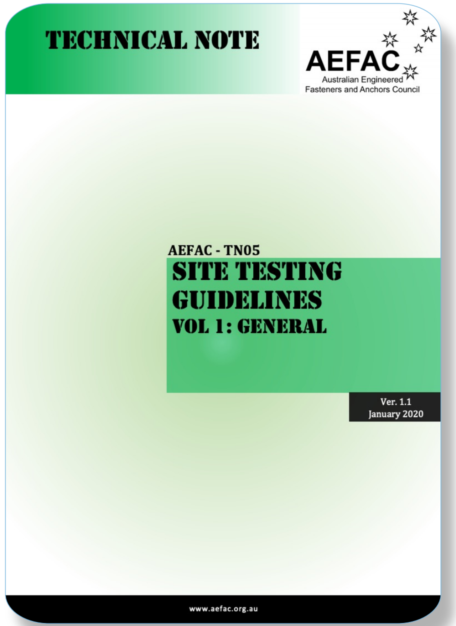
Technical Publications

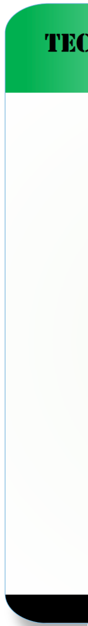
AEFAC
Australian Engineered Fasteners and Anchors Council











Vol 1: General
Vol 2: Proof Test
Vol 3: Ultimate Test
Vol 4: Masonry

All publications are available for free on
www.aefac.org.au

AEFAC Webinar Series on AS 5216:2021

SEMINAR #2

Post-Installed Reinforcing Bar Connections

AEFAC
Australian Engineered
Fasteners and Anchors Council

Dr. Tilak Pokharel MIEAust CPEng NER APEC Engineer IntPE(Aus)

23 March 2022

What is covered?

- What are Post-Installed Reinforcing Bar (PIR) connections and their application
- Similarities and differences of PIR and chemical anchors
- Pre-qualification and design method in AS 5216
    - Anchor model
    - Rebar model
- Guidelines/Suggestions
    - Selection of suitable design model

Standard Definitions

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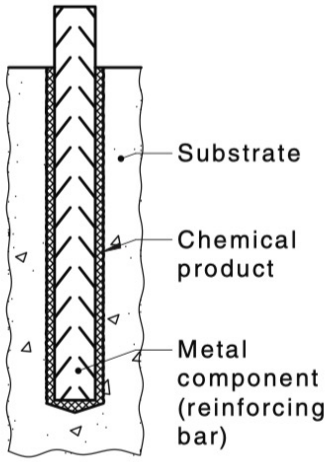
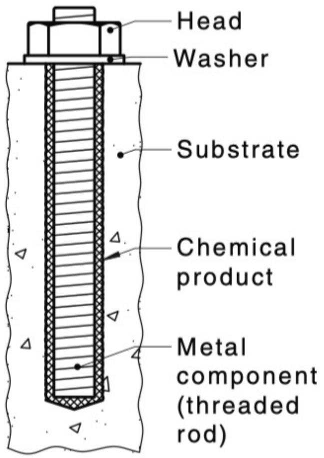
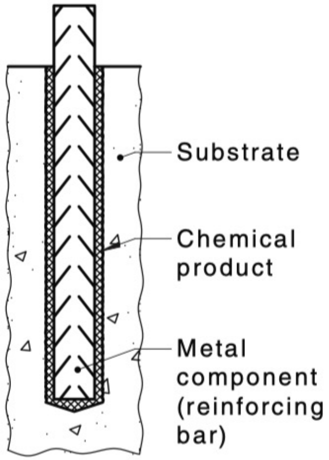
- Post-installed reinforcing bars
  - reinforcement that is anchored into matured concrete using adhesives in drilled hole
- Chemical fastener
  - post-installed fastener that includes a steel element (threaded rod or reinforcing bar) and a bonding compound that transmits loads from the embedded steel element into the base material
    - Also known as bonded fastener.







What is Post-Installed Rebar (PIR)?

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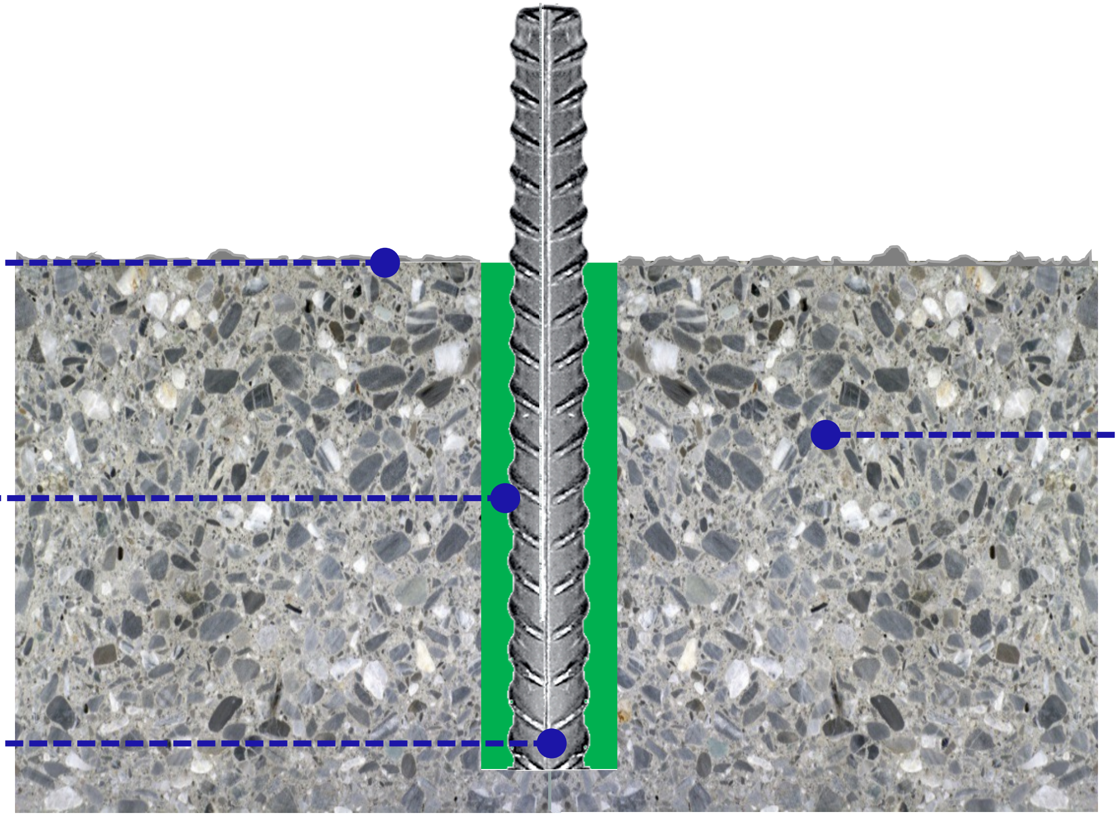

Applications of PIR Connections

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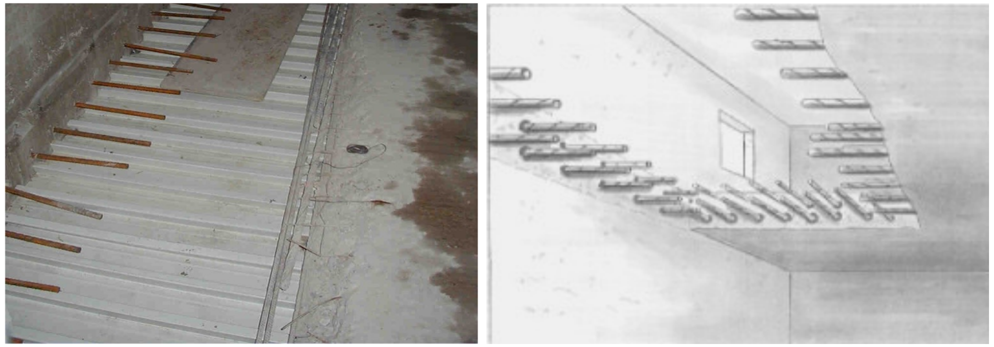
Australian Engineered Fasteners and Anchors Council

Connection of new slabs

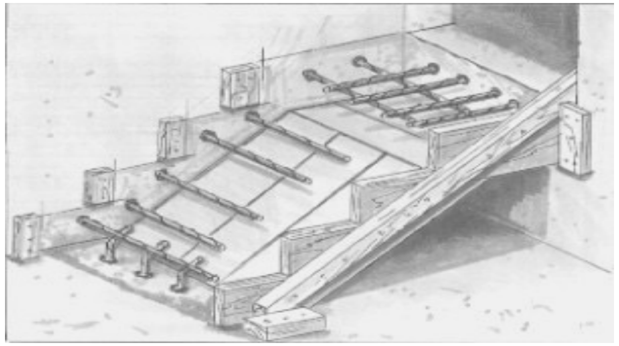
Balcony extensions

Bridge enlargement

Close openings / slab enlargement



Staircase connections



Wall extension

Courtesy: Hilti

Applications of PIR Connections

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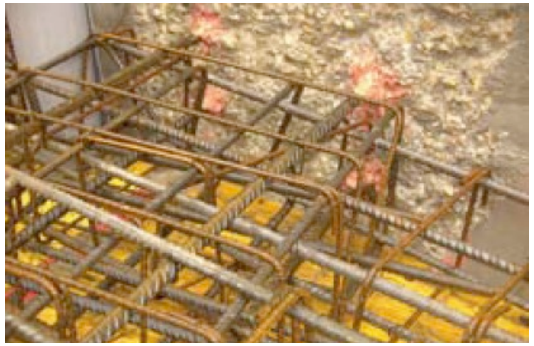
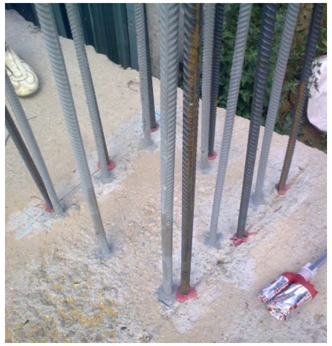
New columns / Columns extensions


Misplaced or missing rebars


Beam connections




Additional rebars

Courtesy: Hilti

Design of Chemical Fasteners

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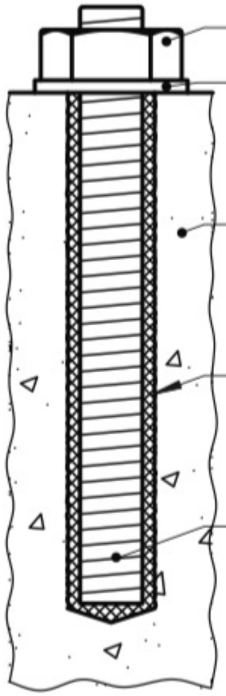
- Tension load – Failure modes in AS 5216
  - Steel failure
  - Concrete cone failure
  - Pull-out failure
  - Combined pull-out and concrete cone failure (chemical)
  - Concrete splitting failure
  - ~~Concrete blow-out failure (undercut)~~
  - Supplementary reinforcement failure



Anchor Design – AS 5216

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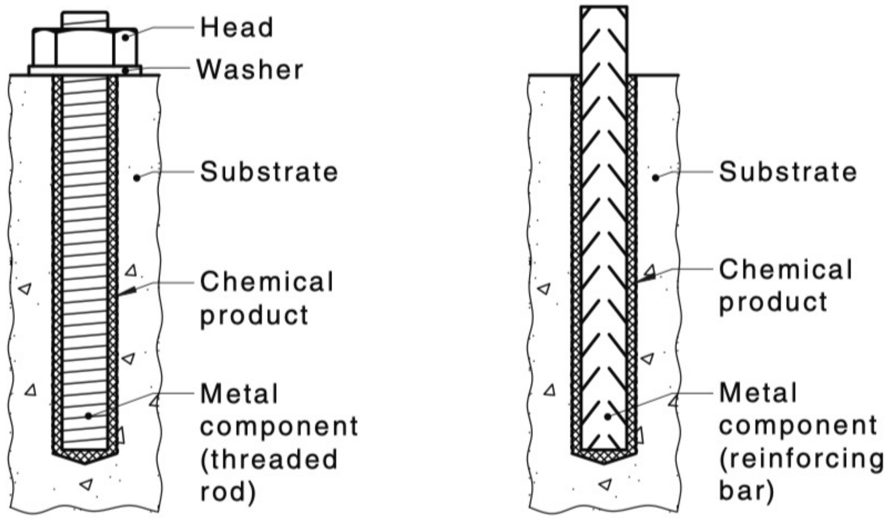
- Minimum Diameter ≥ 6mm
- Maximum diameter No limitation (tension)
  ≤ 60mm (shear)
- Effective embedment depth ≥ 40mm
  Effective embedment depth ≤ 20 d_{nom}

Concrete Capacity (CC) method from AS 5216 can be used for threaded rods and deformed reinforcing bars

ANCHOR MODEL



Pull-out Failure

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Australian Engineered Fasteners and Anchors Council

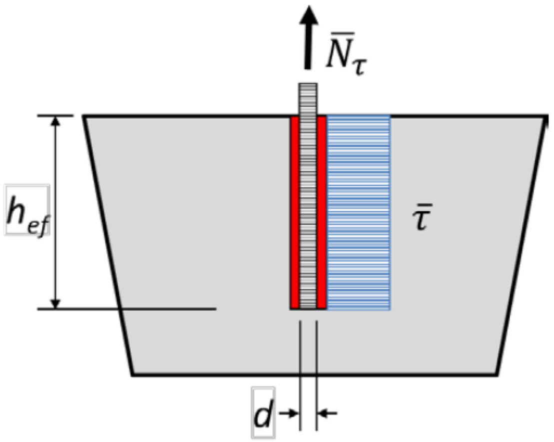
- Clause 6.2.5

$$N_{\mathrm{Rk,p}} = N^0_{\mathrm{Rk,p}} \left(\frac{A_{\mathrm{p,N}}}{A^0_{\mathrm{p,N}}} \right) \psi_{\mathrm{s,Np}}\, \psi_{\mathrm{g,Np}}\, \psi_{\mathrm{re,N}}\, \psi_{\mathrm{ec,Np}}$$

$$N^0_{\mathrm{Rk,p}} = \tau_{\mathrm{Rk}} \pi\, d\, h_{\mathrm{ef}} \psi_{\mathrm{sus}}$$

Contact area ($\pi\, d\, h_{\mathrm{ef}}$)

Bond strength (τ_{Rk})



Assumptions

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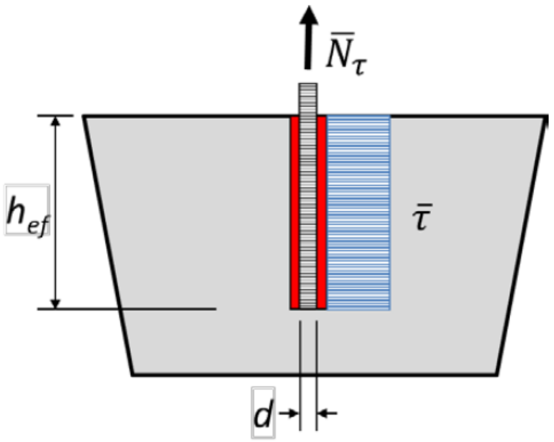
- Uniform distribution of bond stress along its length
  - True for shallow embedment
  - Tests were conducted for 8 – 10 d_{nom}
  - Works up to $h_{ef} \leq 20\ d_{nom}$
- For greater embedment depth
  - Stress VARIES with depth
  - Uniform bond stress model
    - Does not work

$$\bar{N}_\tau = \bar{\tau}\,\pi\,d\,h_{ef}$$

where:

$\bar{N}_\tau$	=	mean failure load
$\bar{\tau}$	=	mean bond strength
d	=	anchor diameter
h_{ef}	=	embedment depth



Deep anchors (rebars)

- Tension load – Possible failure modes
  - Steel failure
  - ~~Concrete cone failure~~
  - Pull-out failure ~~(CC Method does not work)~~
  - ~~Combined pull-out and concrete cone failure (chemical)~~
  - Concrete splitting failure
  - ~~Concrete blow-out failure (undercut)~~
  - ~~Supplementary reinforcement failure~~

DESIGN: Embedment depth to have steel failure

What next?

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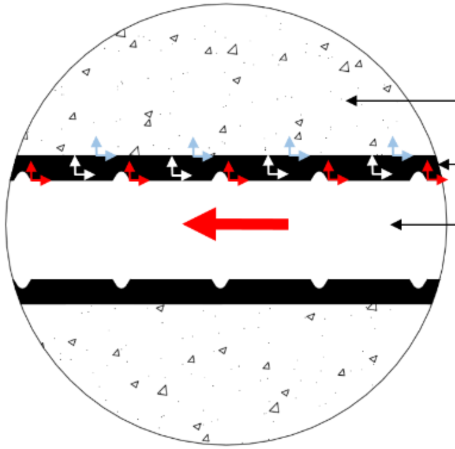
- ? Use AS 3600
  - Developed for cast-in reinforcing bars
  - Does not address the behaviour of PIR
- Extra layer of chemical between rebar and concrete in PIR
  - Connection behaviour is also dependent on the properties of the chemical
- To use AS 3600
  - Ensure PIR performs in a similar (or better) manner to cast-in rebar
    - Load transfer & Load displacement



PIR (AS 5216:2021)

- Appendix A (EAD 330087)
  - Intends to demonstrate comparable performance to cast-in solution
  - Tension loads only
  - Only steel, pull-out or splitting failure possible
    - concrete cone failure avoided by compressive strength and/or large embedment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EUROPEAN ASSESSMENT DOCUMENT

EAD 330087-00-0601

May 2018

SYSTEMS FOR POST-INSTALLED REBAR CONNECTIONS WITH MORTAR

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Pre-qualification of PIR

- Pass/Fail Criteria

Concrete Compressive Strength, f_{ck}	16	20	25	30	35	40	45	50
Required Bond Strength to have equivalent cast-in rebar, $f_{bm,req}$	8,6	10,0	11,6	13,1	14,5	15,9	17,2	18,4
Design Bond Strength of PIR, $f_{bd,PIR}$	2,0	2,3	2,7	3,0	3,4	3,7	4,0	4,3

Chapter 13 of AS 3600:2018

$$L_{sy.t} = k_4 \, k_5 \, L_{sy.tb}$$

$$L_{sy.t.lap} = k_7 \, L_{sy.t} \geq 0.058 f_{sy} k_1 d_b$$

$$L_{sy.tb} = \frac{0.5 k_1 k_3 f_{sy} d_b}{k_2 \sqrt{f'_c}} \geq 0.058 f_{sy} k_1 d_b$$

REBAR MODEL

Assessment Documents

AEFAC
Australian Engineered Fasteners and Anchors Council

Shallow embedment. $h_{ef} \le 20d_b$


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EUROPEAN ASSESSMENT DOCUMENT

EAD 330499-01-0601

December 2018

BONDED FASTENERS FOR USE IN CONCRETE

EAD 330499

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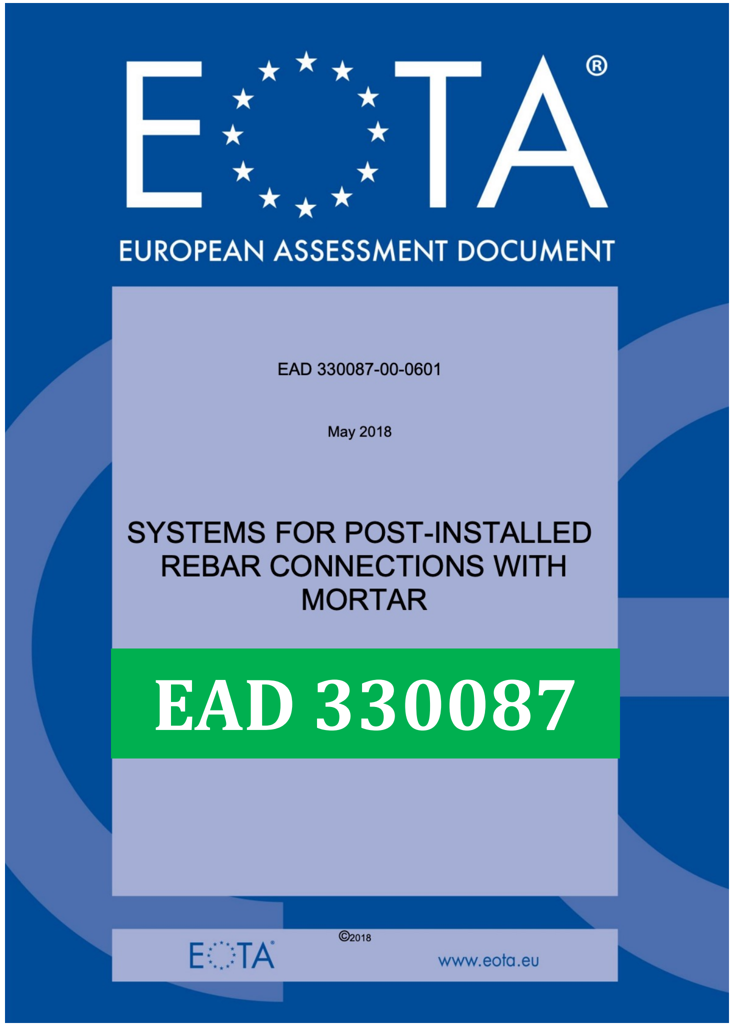
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May 2018

SYSTEMS FOR POST-INSTALLED REBAR CONNECTIONS WITH MORTAR

EAD 330087

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Deep embedment. $h_{ef} > 20d_b$

Pre-qualification Reports

AEFAC
Australian Engineered Fasteners and Anchors Council

EAD 330499

Chemical Fasteners

Shallow embedment. $h_{ef} \le 20d_b$

Deutsches Institut für Bautechnik DIBt

Member of EOTA www.eota.eu

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment ETA-19/0203 of 2 December 2020

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Mungo Injection system MIT700RE for concrete
Product family to which the construction product belongs	Bonded anchor for use in concrete
Manufacturer	Mungo Befestigungstechnik AG Bornfeldstrasse 2 4603 OLTEN SCHWEIZ
Manufacturing plant	Werk 13 / Plant 13
This European Technical Assessment contains	39 pages including 3 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 330499-01-0601, Edition 4/2020

EAD 330087

PIR Connections

Deep embedment. $h_{ef} > 20d_b$

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European Technical Assessment ETA-19/0204 of 2 December 2020

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Mungo Injection system MIT700RE for rebar connection
Product family to which the construction product belongs	Systems for post-installed rebar connections with mortar
Manufacturer	Mungo Befestigungstechnik AG Bornfeldstrasse 2 4603 OLTEN SCHWEIZ
Manufacturing plant	Werk 13 / Plant 13
This European Technical Assessment contains	22 pages including 3 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 330087-00-0601, Edition 05/2018

Pre-qualification Reports

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EAD 330499

Chemical Fasteners

Provides characteristic bond strength, τ_{Rk}

Table C3: Characteristic values of tension loads under static and quasi-static action for a working life of 50 years

Anchor size threaded rod					M8	M10	M12	M16	M20	M24	M27	M30
Combined pull-out and concrete failure												
Characteristic bond resistance in non-cracked concrete C20/25 in hammer drilled holes (HD) and compressed air drilled holes (CD)												
Temperature range	I: 40°C/24°C	Dry, wet concrete and flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	20	20	19	19	18	17	16	16
Temperature range	II: 72°C/50°C	Dry, wet concrete and flooded bore hole	$\tau_{Rk,ucr}$	[N/mm²]	15	15	15	14	13	13	12	12

Shallow embedment. $h_{ef} \leq 20d_b$

EAD 330087

PIR Connections

Provides design ultimate bond strength, $f_{bd,PIR}$

Table C3: Design values of the ultimate bond stress $f_{bd,PIR}$ in N/mm² for all drilling methods and for good conditions

Rebar	Concrete class								
ϕ	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
8 to 32 mm ZA-M12 to ZA-M24	1,6	2,0	2,3	2,7	3,0	3,4	3,7	4,0	4,3
34 mm	1,6	2,0	2,3	2,6	2,9	3,3	3,6	3,9	4,2
36 mm	1,5	1,9	2,2	2,6	2,9	3,3	3,6	3,8	4,1
40 mm	1,5	1,8	2,1	2,5	2,8	3,1	3,4	3,7	4,0

Deep embedment. $h_{ef} > 20d_b$

EAD 330087

- Essential characteristic assessed
  - Mechanical resistance and stability
    - Bond strength of post-installed rebar under static and quasi-static loading ($f_{bd,PIR}$)
    - Reduction factor (k_b)
    - Amplification factor for minimum anchorage length (α_{lb})
  - Safety in case of fire
    - Reaction to fire
    - Bond strength at increased temperature

EAD 330087 – Test Program

- Basic tension test – reference
  - uncracked concrete
  - Cracked concrete (0.3mm)
- Functioning under tension load
- Resistance to fire

Line	Purpose of test	Concrete strength class [1)]	Rebar size [2)] ϕ [mm]	Setting depth [3)] l_v [mm]	Minimum number of tests	Criteria	Test procedure / assessment
Basic tension tests							
1	Reference tension tests in uncracked concrete	C20/25	all[10)]	10 ϕ	5 each	$f_{bm} \geq 7,1$ [N/mm^2] [14)]	2.2.1.1
2		C50/60	ϕ_{max}	7 ϕ	5		
3	Reference tension tests in cracked concrete (Δw = 0,3 mm) [4)]	C20/25	12	10 ϕ	5	-	2.2.2
4			ϕ_{max}		5		
5		C50/60	12	7 ϕ	5		
6			ϕ_{max}		5		

Line	Purpose of test	Concrete strength class [1)]	Rebar size [2)] ϕ [mm]	Setting depth [3)] l_v [mm]	Minimum number of tests	Criteria	Test procedure / assessment
Functioning under tension load with respect to							
7	Robustness in dry concrete [5) 10)]	C20/25	s/m/l	10 ϕ	5 each	rqd. $\alpha \geq 0,8$	2.2.1.2
8	Robustness in wet concrete [6) 10)]	C20/25	s/m/l	10 ϕ	5 each	rqd. $\alpha \geq 0,75$	2.2.1.3
9	Installation at minimum installation temperature [15)]	C20/25	ϕ_{max}	max l_v	3		2.2.1.4
10	Installation at maximum installation temperature	C20/25	ϕ_{max}	max l_v	3		2.2.1.4
11	Correct injection	-	ϕ_{max}	max l_v	3		2.2.1.5
12	Vertical upwards installation direction [7) 13)]	C20/25	ϕ_{max}	10 ϕ	5	rqd.$\alpha \geq 0,9$	2.2.1.6
13	Horizontal installation direction [8)]	C20/25	ϕ_{max}	10 ϕ	5	rqd.$\alpha \geq 0,9$	
14	Sustained loads [9) 13)]	C20/25	12	10 ϕ	5	rqd.$\alpha \geq 0,9$	2.2.1.7
15	Freeze/thaw conditions [13)]	C50/60	12	7 ϕ	5	rqd.$\alpha \geq 0,9$	2.2.1.8
16	High alkalinity and sulphurous atmosphere [13)]	C20/25	12[11)]	-	3 x 10		2.2.1.9
17	Corrosion resistance of rebar [12)]	C20/25	12	70 mm	3		2.2.1.10
Resistance to fire							
18	Bond strength at increased temperature [4) 9)]	C20/25	12	10 ϕ	20		2.2.4

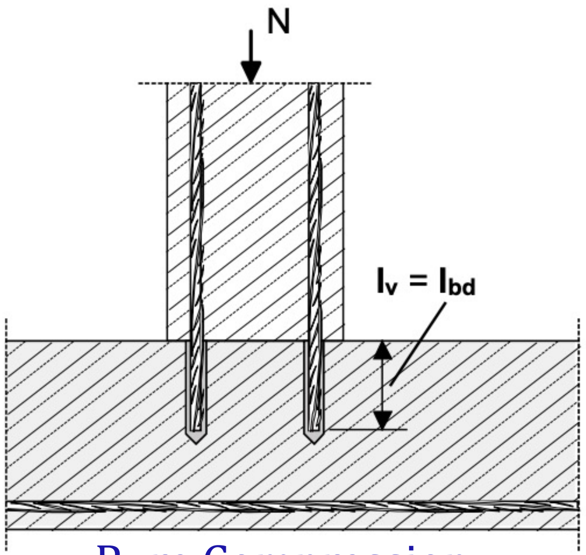
Design of PIR – AS 5216:2021

Appendix D covers the design of post-installed reinforcing bar connections

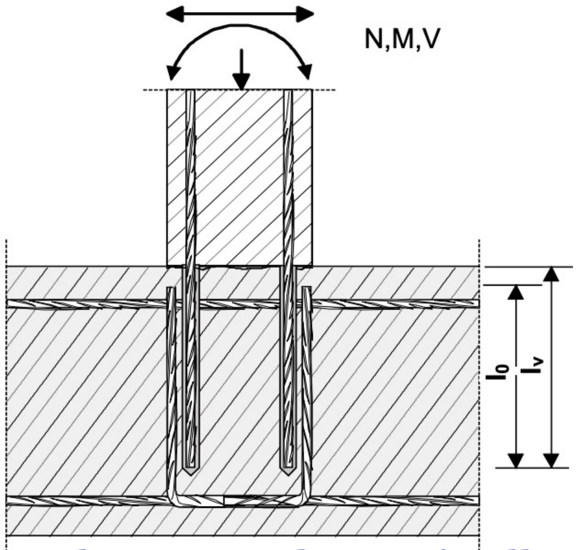
Scope of PIR

- Pre-qualified in accordance with EAD 330087
- Straight deformed bars with diameter ≥10mm and comply with AS/NZS 4670
- Normal weight concrete with char. compressive strength ≥ 20 MPa
- Static and quasi-static loadings
- PIR in dry and wet concrete only (no flooded holes)
- Within the intended application range specified in pre-qualification report

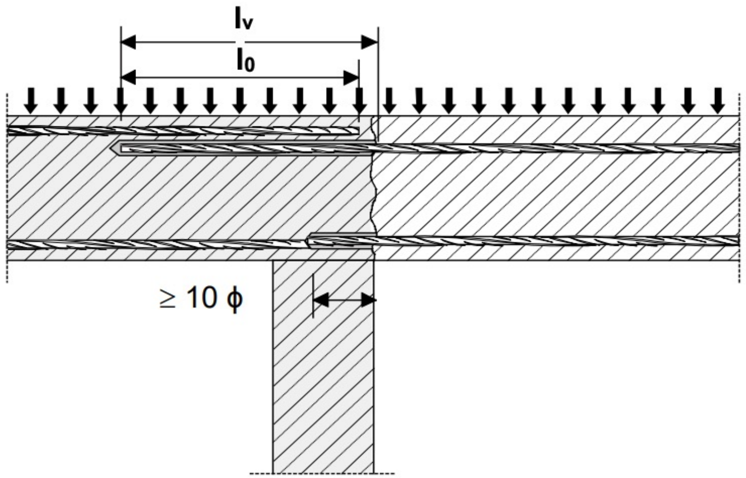
Intended Applications



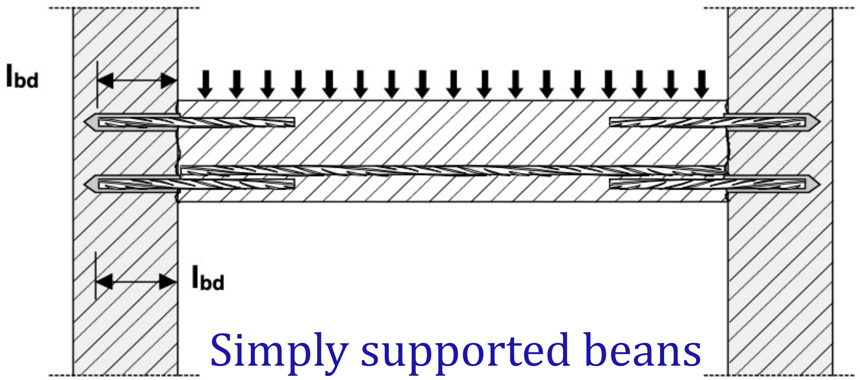
Pure Compression



Splicing in columns/walls



Splicing in beams/slab



Simply supported beans

Post-installed reinforcing bars intended for applications shall be qualified in accordance with EAD 330087

Summary (PIR vs Chemical Fasteners)

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- Chemical Fasteners (Anchor)
  - Transfer tension, shear or combination of two
    - Limited by the concrete's tensile resistance
  - Assumption of uniform stress distribution
    - Valid up to effective depth of $20d_{nom}$
  - Potential cone failure
    - Brittle behaviour
  - Presence of fixture

- PIR Connections (Rebar)
  - Transfer tension load only
    - Does not rely on concrete's tensile resistance
    - Shear transferred through the interface between old & new concrete
  - No uniform stress Distribution
    - Design using AS 3600 principle
  - No concrete failure –
    - Steel component can yield
    - ductile behaviour
  - Generally, no fixture

Anchor design or Rebar design method

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Possibility of Concrete cone

- YES: Anchor design method
- NO: Rebar design method

Shear loading in the fastener

- YES: Anchor design method
- NO: Rebar design method

Anchor embedment length

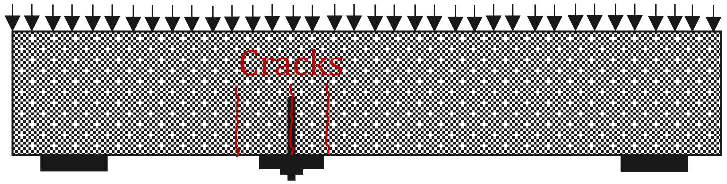
- $\leq 20\ d_b$: Anchor design method
- $> 20\ d_b$: Rebar design method

Presence of base plate

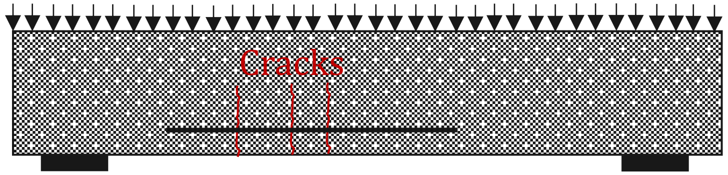
- YES: Anchor design method
- NO: Rebar design method

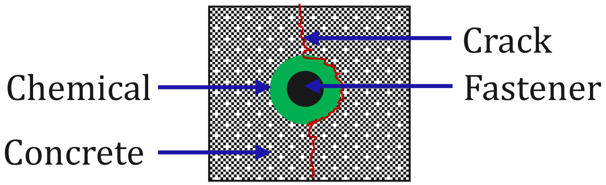
Cracked Concrete - PIR

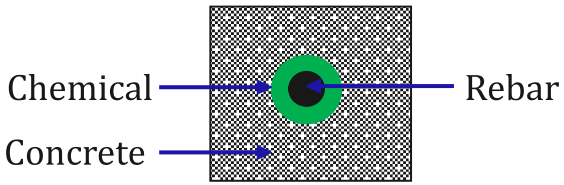
Anchor	PIR
Parallel crack	Perpendicular crack



Chemical Fastener







3 Critical Elements to Achieve Quality Assurance

AEFAC
Australian Engineered Fasteners and Anchors Council

01. Pre-qualification

Products independently tested and assessed to be "fit for purpose"

Appendix A EAD 330087

02. Design

Rigorous assessment to design for critical mode of failure

AS 5216:2021 Appendix D

03. Installation

Informed and competent installer with appropriate supervision and experience

AEFAC ICP Training

AEFAC Webinar Series on AS 5216:2021

SEMINAR #2
Fasteners for redundant non-structural systems

AEFAC
Australian Engineered Fasteners and Anchors Council

Dr. Jessey Lee
23 March 2022

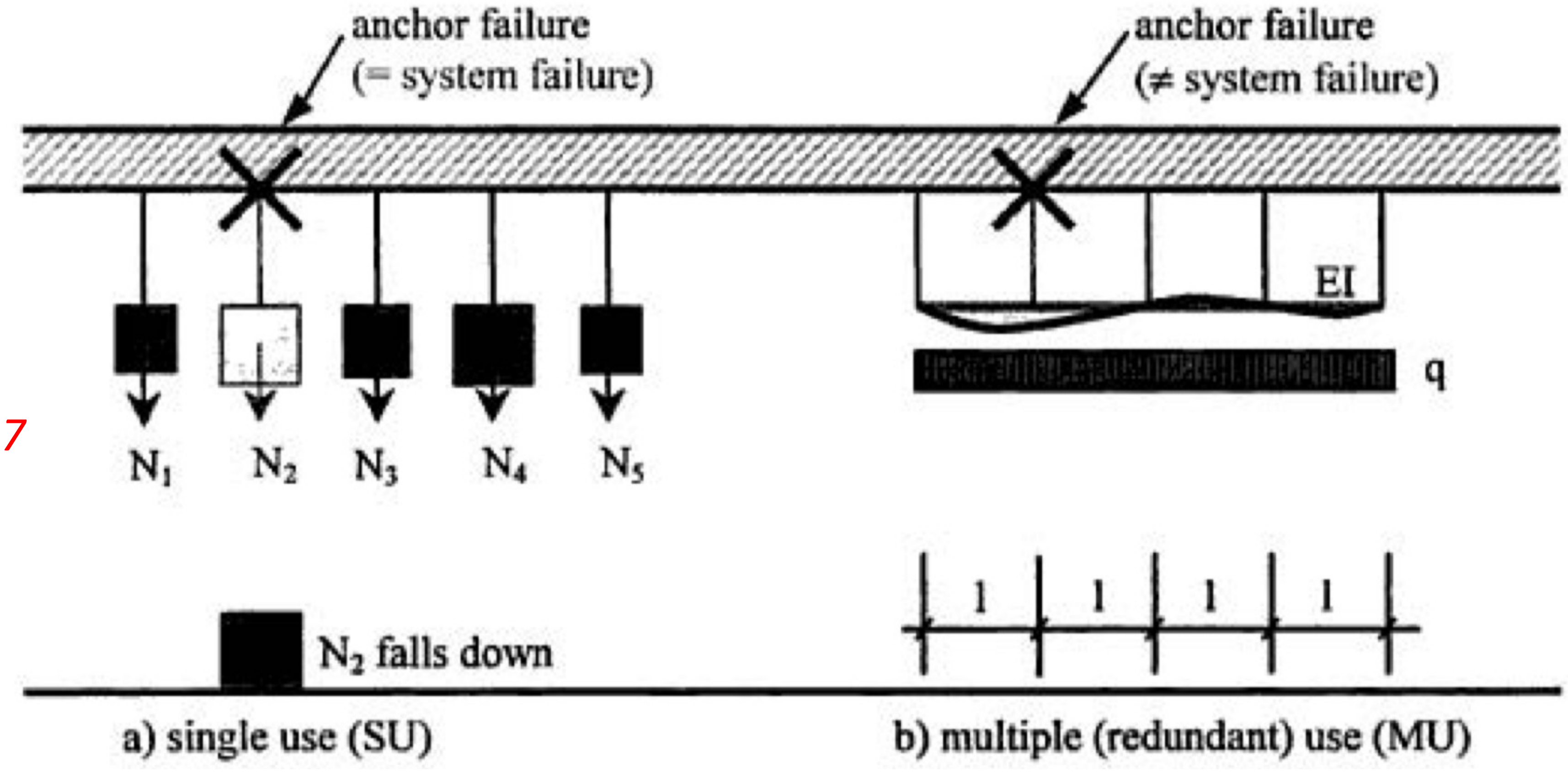
Introduction

AEFAC
Australian Engineered Fasteners and Anchors Council

Redundancy

- Single Use (SU) vs Multiple use/redundant (MU)

Design according to Sections 6 & 7 in AS 5216:2021



Design according to App. E in AS 5216:2021

Rößle and Eligehausen

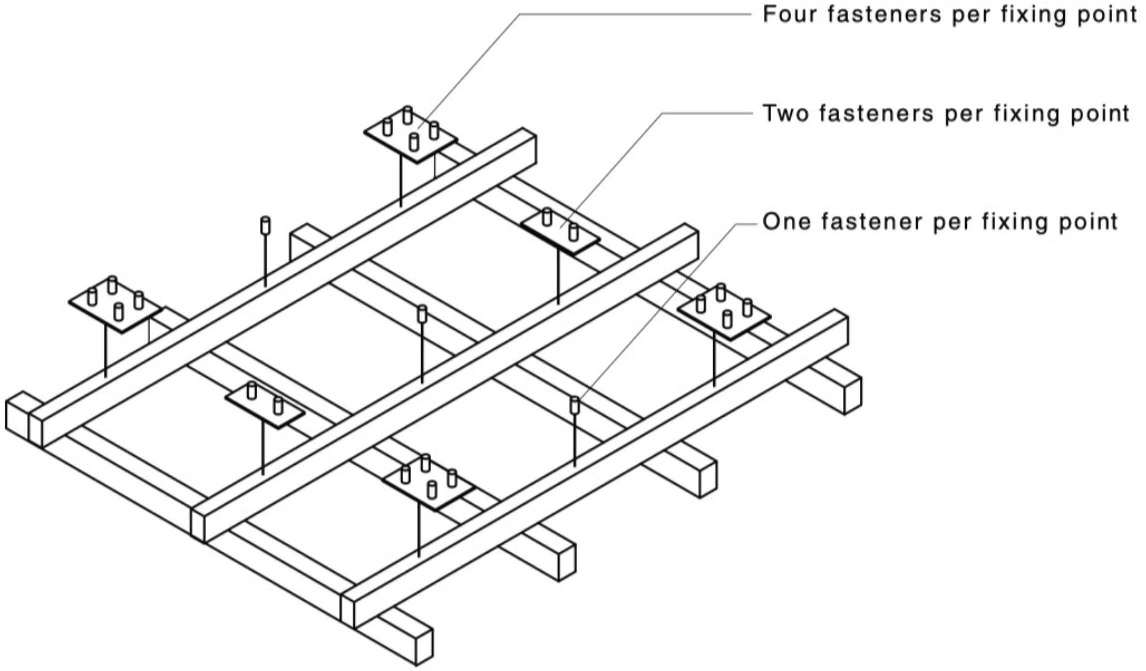
Introduction

AEFAC
Australian Engineered Fasteners and Anchors Council

- Less stringent prequalification requirements
- Probability of failure is same range as single use fasteners ($P_f \sim 1 \times 10^{-6}$)
- Redundancy = intentionally overspecification ->number of anchors
- Attachment should be sufficiently *stiff* to have effective load redistribution
  - Allowable bending stress and deflection of the attachment should be limited

Scope in AS5216 (Appendix E)

- Covers post-installed mechanical and chemical fasteners
- Only for safety-critical applications
- Minimum of 3 fixing points
- All fasteners in a fixing point is same
- Non-structural systems – *sufficient stiffness and strength*



Scope in AS5216 (App. E)

- Fasteners prequalified in accordance with Appendix A (EAD 330747)
  - 50 years working life
  - Min diam. 5mm, min h_{ef} 30mm
  - Normal concrete & precast prestressed hollow core slab
  - Static and quasi-static loading only
  - Cracked/uncracked concrete
  - Characteristic resistance to tension & shear loads
  - Fire resistance – mechanical fasteners only


EOTA®
EUROPEAN ASSESSMENT DOCUMENT

EAD 330747-00-0601

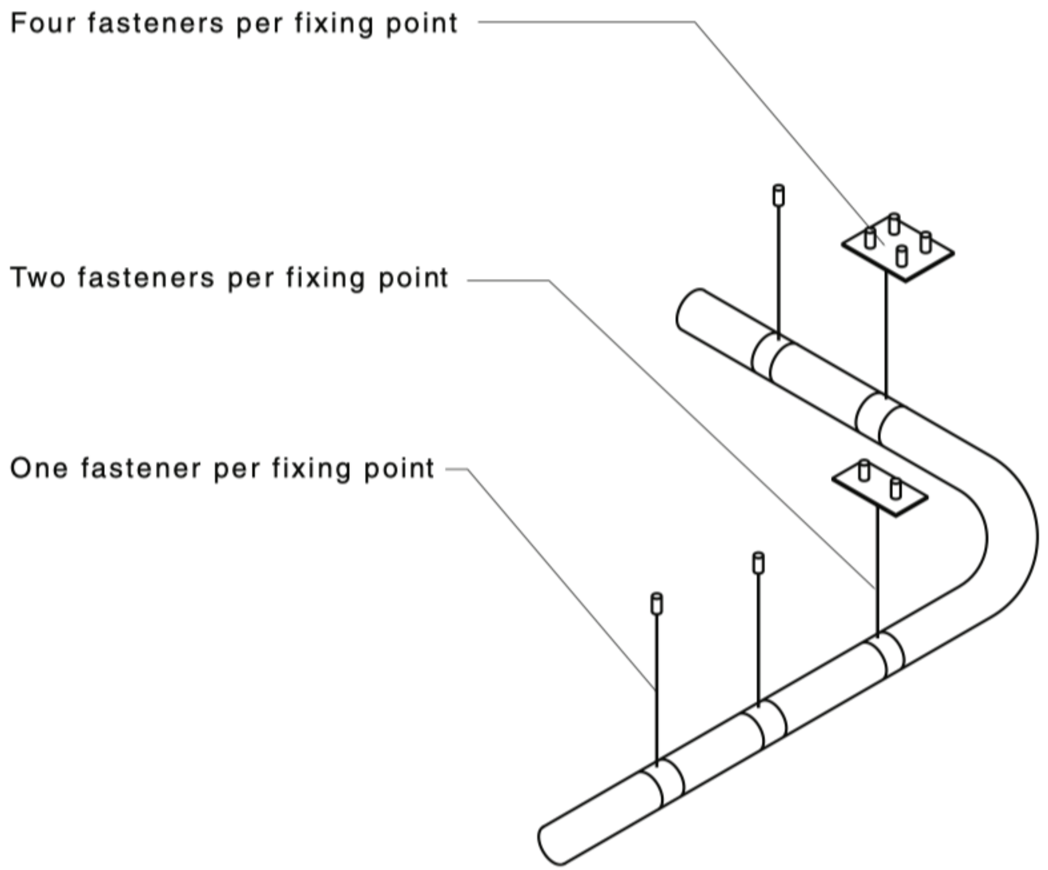
May 2018

FASTENERS FOR USE IN CONCRETE FOR REDUNDANT NON-STRUCTURAL SYSTEMS

EOTA www.eota.eu

Design

- Load calculation
  - Assume all fasteners are effective
  - Design load is limited on a fixing point
    - 2kN if number of fixing points are 3
    - 3kN if number of fixing points are more than 3
  - If the design load is greater than 3kN
    - Increase the number of fixing points
    - Consider single use fasteners



3 Critical Elements to Achieve Quality Assurance

AEFAC
Australian Engineered Fasteners and Anchors Council

01. **Pre-qualification**

Products independently tested and assessed to be "fit for purpose"

EAD 330747

02. **Design**

Rigorous assessment to design for critical mode of failure

AS 5216 - App. E

03. **Installation**

Informed and competent installer with appropriate supervision and experience

AEFAC ICP

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Fasteners and Anchors Council

Thank You!

Email: aefac@aefac.org.au