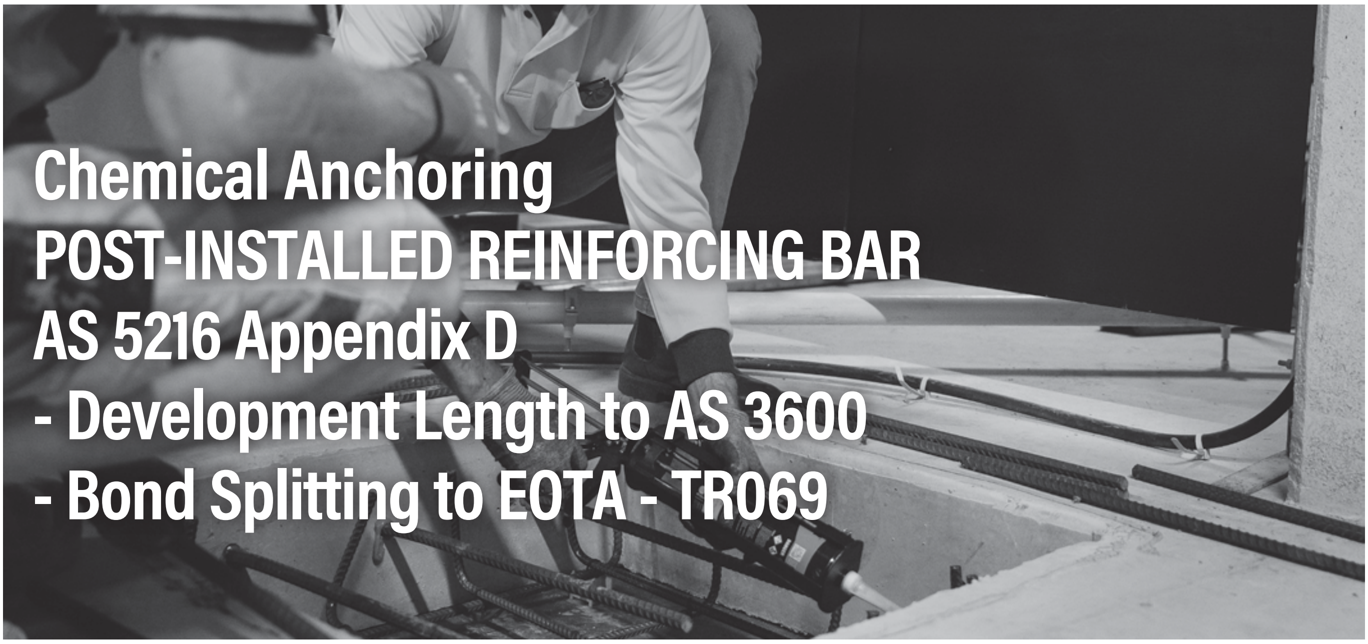
Introduction

POST-INSTALLED REINFORCING BAR TO AS 5216 Appendix D

Development Length to AS 3600 & Bond Splitting to EOTA - TR069



AS 3600 Section 13 covers development of stress in cast-in reinforcement.

In order to obtain full steel yield stress in a reinforcing bar it must be embedded in concrete to a length where the bond stress and steel stress are balanced and the bar does not displace within the concrete. The embedded length of bar is termed the Development Length ($L_{sy.t}$).

Furthermore, in accordance with AS 5216 Appendix D, the Chemical Adhesive when used with post-installed reinforcing bar requires a pre-qualification document demonstrating testing in accordance with EAD 330087

Stress Development in Post-installed Adhesive Bonded Reinforcement in Solid Concrete

Polymer adhesives like epoxy, generally bond significantly better to steel reinforcement than concrete to steel reinforcement. Consequently the development lengths of reinforcing bars bonded in concrete with adhesives are often significantly shorter than development lengths of cast-in bars.

As with cast-in bars, loads on adhesive bonded reinforcing bars are transmitted to and cause stress in the surrounding concrete.

The stress around a single reinforcing bar in tension remote from a concrete edge is given by:

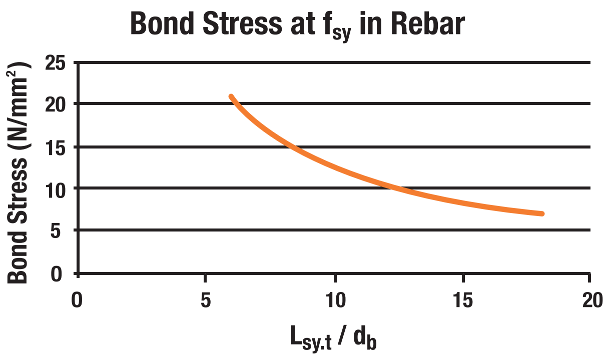
$$\sigma_b = \frac{A_b . f_{sy}}{L_{sy.t} . \pi . d_b} \quad \text{.....Equation 1}$$

σ_b	=	Bond Stress to the Concrete (MPa)
A_b	=	Cross-sectional Area of the Bar (mm^2)
f_{sy}	=	Steel Yield Stress (MPa)
$L_{sy.t}$	=	Minimum embedment length of rebar to develop steel yield stress (mm)
π	=	pi
d_b	=	nominal bar diameter (mm)

In the case where spacing and edge distances are remote, there is enough concrete cover to the bar and adhesive to dissipate the stresses in the concrete and avoid concrete splitting failures.

However, the situation changes when another bar or bars is/are introduced and or the concrete edge is no longer remote. Close bar spacing or insufficient concrete cover may result in concrete splitting failures such as those illustrated in figure 1.

From equation 1 above, stress (σ_b) in the concrete surrounding the bar decreases with increasing embedded length ($L_{sy.t}$). See graph below of bond stress developed in concrete when steel yield stress is applied to a reinforcing bar as a function of embedded length.



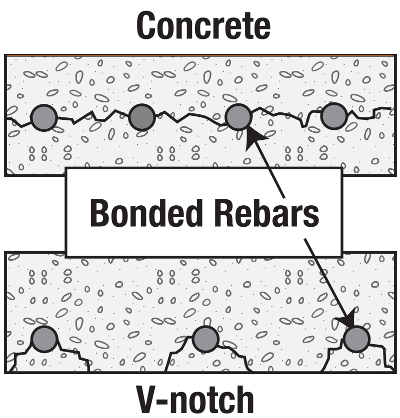


Figure 1.

Introduction
POST-INSTALLED REINFORCING BAR TO AS 5216 Appendix D
Development Length to AS 3600 & Bond Splitting to EOTA - TR069

Therefore where there is shallow cover or close bar spacing, it is necessary to apply the factor coefficients k_1,k_2 & k_3 listed in Section 13 of AS 3600.
These factors influence the development length to ensure there is sufficient embedment to reduce stress in concrete and prevent concrete splitting failures.

Development lengths calculated from bond strength alone should NOT be used for bar anchorages designed to comply with AS 3600 as concrete splitting is not accounted for.

If the factor coefficients from AS 3600 are not applied to development lengths of post-installed reinforcing bars in structural concrete elements, there may be a significant reduction in safety resulting in concrete failure and collapse due to concrete splitting. Concrete splitting is a function of edge distance and spacing and is independent of adhesive bond strength.

Derivation of Development Length for Adhesive Bonded Bars
Development lengths are predicted from bond stress, determined from pull out tests, according to equation 2. The predicted lengths are verified according to the current revision of AS/NZS 4671, Appendix C4, where a load equal to N_{sy} is applied and a displacement of the bar less than 0.2 mm recorded.

$$L_{sy.t} = \frac{A_b.f_{sy}}{\sigma_b.\pi.d_b} \quad \text{.....Equation 2}$$

The development length is a function of adhesive bond stress so a limit state factor of 0.6 is applied:

$$\frac{L_{sy.t}}{\text{Ø}} = \frac{A_b.f_{sy}}{0.6.\sigma_b.\pi.d_b} \quad \text{.....Equation 3}$$

Effectively the limit state factor increases development length by 67%.

For designs where there are multiple parallel reinforcing bars in structural elements such as walls, floors, beams and columns, the factor coefficients from section 13.1 of AS 3600 should be used. Concrete splitting is independent of adhesive bond strength and should be applied to all adhesive bonded bars where the design is intended to comply with AS 3600.

AS 5216 Appendix D covers development length of post-installed reinforcing bar
AS 5216 Appendix D states 'The embedment length of post-installed reinforcing bars to develop characteristic yield strength of a reinforcing bar shall not be less than the development length obtained in accordance with AS 3600.'
Therefore, the basic development length of deformed bar according to AS 3600 Clause 13.1.2.2 can be calculated as follows,

$$L_{sy.t} = \frac{0.5.k_1.k_3.f_{sy}.d_b}{k_2\,\sqrt{(f'c)}} \geq 0.058.f_{sy}.k_1.d_b \quad \text{.....Equation 4}$$

Furthermore, where the full yield strength is not required, the development length can be calculated in accordance with AS 3600 Clause 13.1.2.4 which prohibits development lengths less than 12db as follows,

$$L_{st} = L_{sy.t}.\frac{\sigma_{st}}{f_{sy}} \geq 12d_b \quad \text{.....Equation 5}$$

where σ_{st} = Required tensile stress

The development length tables in "Design Case 2, 3 and 4" in the following section are calculated using equation 4.
k_1 = 1.0 for adhesive bonded bars. In section 13.1 of AS 3600 k_1 = 1.3 for all horizontal bars with > 300 mm of concrete below them. According to Warner et al[3] (pg391), a zone of weak, air and water rich concrete forms on the lower surface of 'top' bars, which reduces the bond characteristics of bars in this position. Since the weakened zone of concrete is specific to cast-in bars it is not relevant to bonded bars and therefore k_1 = 1 in all cases.
k_2 is the direction function of the bar diameter (d_b).
The value of k_3 is influenced by the anchor spacing (a), edge distance/cover (e) and the bar diameter (d_b).

Edge Distance and Spacing
Edge distance and spacing of reinforcing bars are independent of adhesive bond strength. They are related to the stress transferred from the bars under tension, through the adhesive and into the concrete. As shown in equation 1 stress transferred to concrete by bars under tension is reduced by increasing embedded length. Hence AS 3600 applies the factor coefficients, k_1, k_2 and k_3 to influence the development length.
AS 3600 allows for various depths of concrete cover to bars depending on environmental and other circumstances. The designer must refer to AS 3600 to determine required cover.
In the following tables a minimum cover of 30 mm or 2 x d_b (2.5 x d_b edge distance) is adopted.

AS 5216 Appendix D also covers design considering bond-splitting behaviour of post-installed reinforcing bar (equivalent to EOTA TR069)
AS 5216 Appendix D considers that when designing post-installed reinforcing bars in groups which are subjected to a tensile load, verification of capacity is by adopting the mode of failure producing the lowest design strength between steel, concrete cone and bond-splitting failure. However, for a single post-installed reinforcing bar, the most unfavourable mode of failure is bond-splitting and therefore the most likely verified capacity. To use this method, the adhesive used needs to be pre qualified in accordance with EAD 332402. The table below provides the verification required for this design method.

Mode of Failure	Required Verification	
	Post-installed reinforcing group	Single post-installed reinforcing bar
Steel	$N^*_{group} = \phi_s{}^*N_{us}$	
Concrete cone	$N^*_{group} = \phi_c{}^*N_{urc}$	
Bond-splitting	$N^*_{group} = \phi^*N_{ursp}$	$N^*_{single} = \phi^*N_{usp}$ (most unfavourable)

References
1. AS 3600 Concrete Structures, Standards Australia
2. AS/NZS 4671 Steel Reinforcing Materials, Standards Australia
3. Warner, R.F. Rangan B.V. Hall A.S. Faulkes K.A. 1998, 'Concrete Structures', Addison Wesley Longman Australia
4. AS 5216 Design of post-installed and Cast-in fastenings in concrete.

Design Process
POST-INSTALLED REINFORCING BAR TO AS 5216 Appendix D
Development Length to AS 3600 & Bond Splitting to EOTA - TR069

This information is intended for use by qualified engineers or other suitably skilled persons. It is the designer's responsibility to ensure compliance with the relevant standards, codes of practice, building regulations, workplace regulations and statutes as applicable.

This section must be used in conjunction with AS 5216 Clause D.4 & AS 3600 and is intended to assist in design of reinforcing bar connections where they are post-installed using ChemSet™ Anchoring adhesives rather than being cast into the concrete.

For selection of the appropriate reinforcing bar diameter, reference should be made to the manufacturer's design tables and AS 3600.

The document provides the steel yield development length $L_{sy.t}$, required by AS 3600, clause 13.1.2.2 for Grade 500 reinforcing bars post-installed with ChemSet™ Anchoring adhesives into concrete.

The design process begins with the Designer choosing the relevant Design Case:

The Design Cases are:

1. Design considering Bond splitting behaviour to EOTA-TR069. (Single and multiple bars)
2. Development Length of multiple bars in concrete elements to AS 3600. (Large clear anchor spacing)
3. Development Length of multiple bars in concrete elements to AS 3600. (Medium clear anchor spacing)
4. Development Length of multiple bars in concrete elements to AS 3600. (Minimum clear anchor spacing)

For Design cases 1
Single and multiple bar assessments can be made using this method. For multiple bar assessment, the governing tensile capacity will be the minimum of steel, concrete cone and bond splitting failure. For single bar assessment, the most unfavourable mode of failure will be bond splitting.

For Design cases 2, 3 and 4
Having obtained the nominal development length for the design case, adjustment is made for the influence of concrete compressive strength to yield the value $L_{sy.t}$.

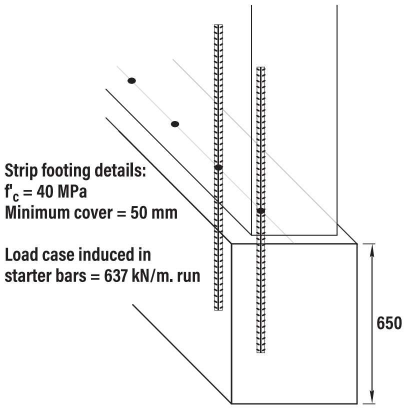
In the case where there is not sufficient depth of concrete for the reinforcing bar to be installed to $L_{sy.t}$, or the stress area of tensile steel exceeds design requirements, the stress (σ_{st}) less than the yield strength (f_{sy}) developed in the bar is provided for a variety of lengths (L_{st}), per clause 13.1.2.4 of AS 3600. Having obtained the stress developed in the bar for a nominated installed length, adjustment is made to the developed stress for the influence of concrete compressive strength.

Design Process
POST-INSTALLED REINFORCING BAR TO AS 5216 Appendix D
Development Length to AS 3600 & Bond Splitting to EOTA - TR069

DESIGN EXAMPLE 1

Using the AS1170 family of Australian Standards, the design action effect causing tension in reinforcing bars is calculated to be:

$N^* = 637$ kN/m. run



Consider design of Grade 500 reinforcement bar, fully developed.

To satisfy Strength Limit State Design criteria,

$$N^* \leq \phi f_{sy} * A_b$$

therefore, $637 * 10^3 \text{ N} \leq 0.8 * 500 * A_b$

transposing gives us, $A_b \geq 1593 \text{ mm}^2$

From reinforcement bar manufacturers tables,

Rebar Size 24 @ 275 mm. centres provides 1636 mm²/m. run

Which satisfies our steel sectional requirement.

As the project requires a post-installed solution, consider the use of ChemSet™ Reo 502™ Xtrem™, ChemSet™ 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™

Design is a wall with multiple longitudinal bars at 275 mm centres so Design Case 2 applies.

From Table 2, $L_{sy.t\,(nom)} = 700$ mm

From Table 2a, $X_{nc} = 0.89$ @ $f'_c = 40$ MPa

The tensile development length for Rebar Size 24 using ChemSet™ Reo 502™ Xtrem™, ChemSet™ 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™ is:

$$L_{sy.t} = L_{sy.t\,(nom)} * X_{nc}$$
$$= 700 * 0.89$$
$$= 623 \text{ mm}$$

Specify

N24 @ 275 mm. centres post-installed using Ramset™ ChemSet™ Reo 502™ Xtrem™, Chemset™ 801 Xtrem™ XC² or EPCON™ G5 Xtrem™ @ 623 mm. deep

DESIGN EXAMPLE 2

Consider the previous case; however the footing depth is 590 mm. Given minimum cover is 50 mm, the maximum bar length is 540 mm.

Use stress developed in the bar to determine the centre spacings required to achieve the design load case at shorter bar lengths.

From Table 2, Using $L_{st} = 540$ mm

Rebar Size = 24

gives, $\sigma_{st\,(nom)} = 386$ MPa

From Table 2b, $X_{nc} = 1.12$ @ 40 MPa

The stress developed in the bar at this depth is,

$$\sigma_{st} = \sigma_{st\,(nom)} * X_{nc}$$
$$= 430 \text{ MPa}$$

hence, $N^* \leq \phi \sigma_{st} * A_b$

therefore, $637 * 10^3 \text{ N} \leq 0.8 * 430 * A_b$

transposing gives us, $A_b \geq 1852 \text{ mm}^2$

From reinforcement bar manufacturers tables,

Rebar Size 24 @ 250 mm. centres provides 1850 mm²/m. run

Which satisfies our steel sectional requirement.

Specify

N24 @ 250 mm. centres post-installed using Ramset™ ChemSet™ Reo 502™ Xtrem™, Chemset™ 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™ @ 540 mm. deep

Grade 500 Reinforcing Bar

ENGINEERING PROPERTIES

Typical Engineering Properties of Grade 500 Reinforcing Bar

Rebar size	10	12	16	20	24	25	28	32	36	40
Drilled hole dia., d_h (mm)	12	15	20	25	30	30	35	40	45	50
Stress area, A_b (mm2)	78.5	113	201	314	452	491	616	804	1020	1260
Yield stress, f_{sy} (MPa)	500	500	500	500	500	500	500	500	500	500
Tensile steel yield capacity $N_{us} = N_{sy}$, (kN)	39.3	56.5	100.5	157.0	226.0	245.5	308.0	402.0	510.0	630.0
Design Tensile steel resistance ϕN_{us} (kN)	31.4	45.2	80.4	125.6	180.8	196.4	246.4	321.6	408.0	504.0

For further information refer to reinforcing bar manufacturer's published information and current revision of **AS/NZS 4671.**

Chemset™ Reo502™ Xtrem™

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

AVAILABLE IN AUSTRALIA ONLY

(New Zealand refer to G5 Xtrem™ range)

GENERAL INFORMATION

Performance Related | Installation Related

Product

ChemSet™ Reo 502™ PLUS is a heavy duty pure Epoxy for anchoring threaded studs and reinforcing bar into cracked and uncracked concrete.

Compliance

Design according to AS 5216 Appendix D and AS 3600 clause 13.1.2.2 steel yield development length

- D.4.1 - Design considering development Length (AS 3600 clause 13.1.2.2)
- D.4.2 - Design considering Bond splitting behaviour (EOTA TR069)
- European Technical Assessment - tested to EAD 330087 and EAD 332402

Use Ramset™ iExpert Anchor Software for optimised calculation or where a greater range of anchor layout detail is needed.

Principal Applications

- Threaded Studs
- Starter Bars
- Threaded Inserts
- Over-head installation
- Steel Columns
- Hand Rails
- Road Stitching

Benefits, Advantages and Features

- 100 year working life

Greater productivity:

- Anchors in dry, damp, wet or flooded holes

Greater security:

- Strong bond
- Rated for sustained loading

Versatile:

- Anchors in carbide drilled and diamond drilled holes
- Cold and temperate climates

Greater safety:

- Low odour
- VOC Compliant
- Suitable for contact with drinking water

Fire Rated: Refer Fire rated anchoring section.

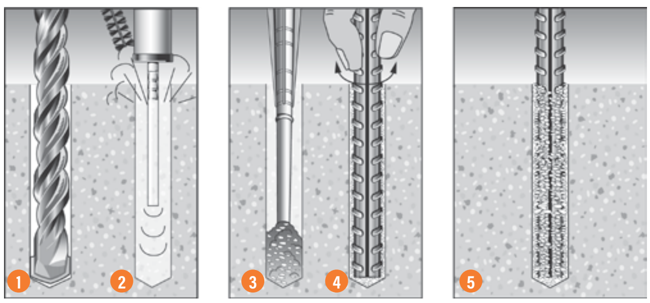
Installation & Substrate Temperature Range

Minimum	Maximum
5°C	40°C

Service Temperature Limits

-40°C to +75°C

Installation



1. Drill recommended diameter and depth hole.
2. **Important:** For hammer drilling technique clean dust and debris from hole with stiff wire brush and blower in the following sequence: blow x 2, brush x 2, blow x 2, brush x 2, blow x 2.
3. Screw mixing nozzle onto cartridge and dispense adhesive to waste until colour is orange. Insert mixing nozzle to bottom of hole.
   Fill hole to 2/3 the hole depth slowly, ensuring no air pockets form.
4. Insert **Ramset™** ChemSet™ Anchor Stud/rebar to bottom of hole while turning.
5. Allow ChemSet™ Reo 502™ XTREM™ to cure as per setting times.

Setting Times

Temperature of base material	Gel Time	Curing time in dry concrete	Curing time in wet and flooded concrete
5°C	75 min	30h	60 h
10°C	45 min	22h	44 h
15°C	35 min	14h	28 h
20°C	22 min	7h	14 h
25°C	14 min	5h	10 h
30°C	8 min	4h	8 h
35°C	6 min	3h	6h
40°C	4 min	2h 45min	5h 30min

Description and Part Numbers

Description	Cartridge Size	Part No.	Working Time at 20°C	Cure Time at 20°C
ChemSet™ Reo 502™ Xtrem™	600 ml	CRE0502X	22 min	7 hours

ChemSet™ 801 Xtrem™ XC²

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

GENERAL INFORMATION

Performance Related	Installation Related

*

Product

Chemset™ 801 Xtrem™ XC² is a heavy duty Vinylester for anchoring threaded studs and reinforcing bar into cracked and uncracked concrete.

SEISMIC C1 | 100 YEAR WORKING LIFE | ETA | CRACKED CONCRETE CERTIFIED | FLOODED HOLE APPROVED

Compliance

Design according to AS 5216 Appendix D and AS 3600 clause 13.1.2.2 steel yield development length

- European Technical Assessment - tested to EAD 330087

Use Ramset™ iExpert Anchor Software for optimised calculation or where a greater range of anchor layout detail is needed.

Principal Applications

- Threaded Studs
- Starter Bars
- Threaded Inserts
- Over-head installation
- Steel Columns
- Hand Rails
- Road Stitching

Benefits, Advantages and Features

- 100 year working life
- Flooded Holes
- Fire rated

Greater productivity:

- Easy dispensing even in cold weather
- Apply torque in 2 hours @ 20°C

Greater security:

- Strong bond
- Rated for sustained loading

Versatile:

- Earthquake, Fire & Flooded Conditions
- Cold and temperate climates

Greater safety:

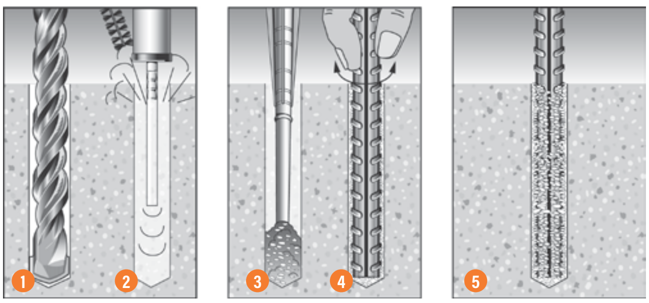
- Low odour
- VOC Compliant
- Suitable for contact with drinking water

Made in Australia

Installation & Substrate Temperature Range

	Minimum	Maximum
Substrate	5°C	40°C
Adhesive	5°C	40°C

Installation



1. Drill recommended diameter and depth hole.
2. **Important:** Use **Ramset™** Dustless Drilling System to ensure holes are clean. Alternatively, clean dust and debris from hole with stiff wire or nylon brush and blower in the following sequence: blow x 2, brush x 2, blow x 2.
3. Dispense adhesive to waste until colour is uniform light grey (2-3 trigger pulls). Insert mixing nozzle to bottom of hole. Fill hole to 3/4 the hole depth slowly, ensuring no air pockets form.
4. Insert **Ramset™** ChemSet™ Anchor Stud/rebar to bottom of hole while turning.
5. Allow ChemSet™ 801 Xtrem™ XC² to cure as per setting times.

Service Temperature Limits

-40°C to 80°C

Setting Times 801 Xtrem™ XC²

Temperature of base material	Gel Time	Curing time in dry concrete	Curing time in wet concrete
+5°C	60 min	240 min	480 min
6°C - 10°C	40 min	180 min	360 min
11°C - 20°C	15 min	120 min	240 min
21°C - 30°C	8 min	90 min	180 min
31°C - 40°C	4 min	60 min	120 min
Note: Cartridge temperature minimum +5°C			

Note:
* Diamond Core drilling only applicable for 50 years working life.

Description and Part Numbers

Description	Cartridge Size	Part No.	Working Time at 20°C	Cure Time at 20°C
ChemSet™ 801 Xtrem™ XC2	600 ml	C801X600	15 min	2 hours

Chemset™ EPCON™ G5 Xtrem™

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

AVAILABLE IN NEW ZEALAND ONLY

(Australia refer to ChemSet™ Reo502™ Xtrem™ range)

GENERAL INFORMATION

Performance Related	Installation Related

Product

ChemSet™ EPCON™ G5 Xtrem™ is a heavy duty pure Epoxy for anchoring threaded studs and reinforcing bar into cracked and uncracked concrete.

Compliance

Design according to AS 5216 Appendix D and AS 3600 clause 13.1.2.2 steel yield development length

- D.4.1 - Design considering development Length (AS 3600 clause 13.1.2.2)
- D.4.2 - Design considering Bond splitting behaviour (EOTA TR069)
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Use Ramset™ iExpert Anchor Software for optimised calculation or where a greater range of anchor layout detail is needed.

Benefits, Advantages and Features

- 100 year working life

Greater productivity:

- Anchors in dry, damp, wet or flooded holes

Greater security:

- Strong bond
- Rated for sustained loading

Versatile:

- Anchors in carbide drilled and diamond drilled holes
- Cold and temperate climates

Greater safety:

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- VOC Compliant
- Suitable for contact with drinking water

Fire Rated: Refer Fire rated anchoring section.

Principal Applications

- Threaded Studs
- Starter Bars
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- Steel Columns
- Hand Rails
- Road Stitching

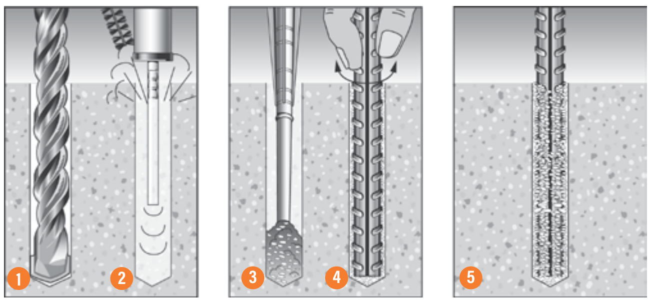
Installation & Substrate Temperature Range

Minimum	Maximum
5°C	40°C

Service Temperature Limits

-40°C to +75°C

Installation



1. Drill recommended diameter and depth hole.
2. **Important:** For hammer drilling technique clean dust and debris from hole with stiff wire brush and blower in the following sequence: blow x 2, brush x 2, blow x 2, brush x 2, blow x 2.
3. Screw mixing nozzle onto cartridge and dispense adhesive to waste until colour is orange. Insert mixing nozzle to bottom of hole.
   Fill hole to 2/3 the hole depth slowly, ensuring no air pockets form.
4. Insert **Ramset™** ChemSet™ Anchor Stud/rebar to bottom of hole while turning.
5. Allow Chemset™ EPCON™ G5 Xtrem™ to cure as per setting times.

Setting Times

Temperature of base material	Gel Time	Curing time in dry concrete	Curing time in wet and flooded concrete
5°C	75 min	30h	60 h
10°C	45 min	22h	44 h
15°C	35 min	14h	28 h
20°C	22 min	7h	14 h
25°C	14 min	5h	10 h
30°C	8 min	4h	8 h
35°C	6 min	3h	6h
40°C	4 min	2h 45min	5h 30min

Description and Part Numbers

Description	Cartridge Size	Part No.	Working Time at 20°C	Cure Time at 20°C
ChemSet™ EPCON™ G5 Xtrem™	600 ml	CEG5X600	22 min	7 hours

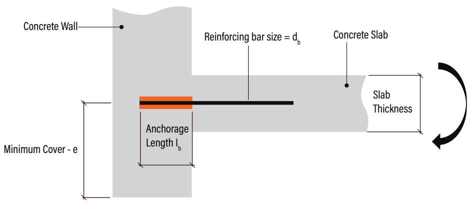
Chemset Reo 502™ Xtrem™ or ChemSet™ EPCON™ G5 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 1

For Single and Multiple Bars in concrete elements (bond splitting behaviour to EOTA-TR069)

For compliance with AS 5216 Appendix D.4.2 design considering bond splitting behaviour



Concrete Splitting Factors

A_k	4.48
sp1	0.19
sp2	0.44
sp3	0.60
sp4	0.33
lb1	0.55

Table 1a Bond-splitting tensile capacity utilising Grade 500 reinforcing bar post-installed in 32 MPa concrete with ChemSet™ Reo 502 Xtrem™ or ChemSet™ EPCON™ G5 Xtrem™

Rebar size	10	12	16	20	24	25	32	40
Minimum Cover, e (mm)	176	300	475	615	850	975	1665	2775
Min. Clear Spacing, a (mm)	90	90	130	180	220	220	270	320
Slab Thickness (mm)	100	100	150	200	250	250	300	320
Nominal embedment length of bar in tension, $L_{sy.t\ (nom)}$*	118	200	315	410	565	650	1110	1500
Effective length, $L_{st\ (m)}$	Bond-Splitting Design Tensile Resistance , ϕN_{usp} (kN)							
100	22							
118	26							
120		32						
140		38						
160		40	57					
200		45	65	88**				
240			70	95	118**			
250			71	97	120**	123**		
315			79	108	134	136		
320				109	134	137	176**	
410				121	150	154	197	244**
500					164	168	215	267
565					174	177	227	282
600						182	234	289
650						189	242	300
700							250	310
800							266	330
900							280	348
1110							308	382
1300								411
1500								437

Note: Bond Splitting design tensile resistance = ϕN_{usp} (kN), ϕ = 1/1.5 = 0.67 and data based on temperature range T1 : -40°C to +40°C
*Note: Moment loading assumed with central rebar placement **Note: Values only apply to compressive strengths of 32 MPa or higher
Note: Data assumes no transverse reinforcement is intercepted (K_m =0), no transverse pressure (P_{tr} = 0) and 100% of actions are considered to be sustained (α_{sus} = 1)

Checkpoint 1a

Table 1a-2 Concrete compressive strength effect on bond-splitting design resistance, tension, X_{nsp}

	Bond-Splitting Design Resistance - X_{nsp}							
Anchor size, d_b	10	12	16	20	24	25	32	40
f'_c (MPa)								
20	0.98	0.91	0.91	0.91	0.91	0.91	0.91	0.91
25	0.99	0.95	0.95	0.95	0.95	0.95	0.95	0.95
32	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	1.00	1.01	1.02	1.04	1.04	1.04	1.04	1.04
50	1.01	1.02	1.03	1.07	1.09	1.09	1.09	1.09

Table 1a-3 Cracked Concrete effect, X_{ncr}

	Cracked Concrete Effect - X_{ncr}							
Anchor size, d_b	10	12	16	20	24	25	32	40
f'_c (MPa)								
20 to 50	0.78	0.78	0.77	0.76	0.80	0.83	0.95	0.92

For Non-cracked concrete X_{ncr} = 1.0

Design reduced bond-splitting tensile resistance, ϕN_{ursp}

$$\phi N_{ursp} = \phi N_{usp} * X_{nsp} * X_{ncr}$$

Use Ramset™ iExpert Anchor Software for optimised calculation or where a greater range of anchor layout detail is needed.

Chemset Reo 502™ Xtrem™ or ChemSet™ EPCON™ G5 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 1

For Single and Multiple Bars in concrete elements (bond splitting behaviour to EOTA-TR069)

For compliance with AS 5216 Appendix D.4.2 design considering bond splitting behaviour

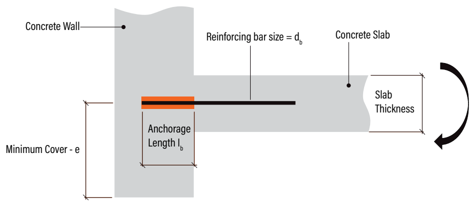


Table 1b Concrete cone break-out tensile capacity utilising Grade 500 reinforcing bar post-installed in 32 MPa concrete with ChemSet™ Reo 502 Xtrem™ or ChemSet™ EPCON™ G5 Xtrem™

Rebar size	10	12	16	20	24	25	32	40
Minimum Cover, e (mm)	176	300	475	615	850	975	1665	2775
Min. Clear Spacing, a (mm)	90	90	130	180	220	220	270	320
Slab Thickness (mm)	100	100	150	200	250	250	300	320
Nominal embedment length of bar in tension, $L_{sy.t\ (nom)}$*	118	200	315	410	565	650	1110	1500
Effective length, $L_{st\ (m)}$	Concrete cone break-out Design Tensile Resistance , ϕN_{uc} (kN) *							
100	24							
118	27							
120		28						
140		30						
160		33	45					
200		37	52	68**				
240			57	76	90**			
250			59	78	92**	93**		
315			67	90	107	107		
320				91	108	108	131**	
410				105	125	126	153	182**
500					141	141	172	205
565					151	151	185	220
600						157	191	227
650						164	200	238
700							209	248
800							225	267
900							240	285
1110							268	320
1300								348
1500								375

Note: Concrete cone design tensile resistance = ϕN_{uc} (kN), ϕ = 1/1.5 = 0.67 and data based on temperature range T1 : -40°C to +40°C
*Note: Moment loading assumed with central rebar placement **Note: Values only apply to compressive strengths of 32 MPa or higher

Checkpoint 1b

Table 1b-2 Concrete compressive strength effect on Concrete cone break-out Resistance, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc}	0.79	0.88	1.00	1.11	1.23

Table 1b-3 Cracked Concrete effect, X_{ncr}

	Cracked Concrete Effect - X_{ncr}							
Anchor size, d_b	10	12	16	20	24	25	32	40
f'_c (MPa)								
20 to 50	0.70							

For Non-cracked concrete X_{ncr} = 1.0

Design reduced concrete cone break-out tensile resistance, ϕN_{urc}

$\phi N_{urc} = \phi N_{uc} * X_{nc} * X_{ncr}$

Checkpoint 1c

Design tensile resistance, ϕN_{ur}

ϕN_{ur} = minimum of ϕN_{ursp}, ϕN_{urc}, ϕN_{us}

Check $N^*/\phi N_{ur} \leq 1$

Use Ramset™ iExpert Anchor Software for optimised calculation or where a greater range of anchor layout detail is needed.

Chemset Reo 502™ Xtrem™, Chemset 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 2

Multiple Bars in Concrete Elements (Large clear anchor spacing)

Steel yield development length, $L_{sy.t}$ (AS 5216 Appendix D.4.1 and AS 3600 clause 13.1.2.2)

Table 2 Nominal steel yield development length $L_{sy\cdot t\ (nom)}$, of Grade 500 reinforcing bar in tension post-installed in 32 MPa concrete with ChemSet™ Reo 502™ Xtrem™, Chemset™ 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™

Rebar size	10*	12	16	20	24	25	28	32	36#	40#
Concrete Splitting Factor, k_1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Concrete Splitting Factor, k_2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9
Concrete Splitting Factor, k_3	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Minimum Cover, e (mm)	40	40	45	60	75	75	95	110	130	150
Min. Clear Spacing, a (mm)	80	80	90	125	150	150	190	220	260	300
Adhesive reduced ultimate tensile bond capacity ϕN_{ub}, (kN), $\phi_c = 0.6$	39.3	56.5	100.5	157.0	226.0	245.5	308.0	402.0	510.0	630.0
Nominal development length of bar in tension, $L_{sy.t\ (nom)}$**	**290**	**350**	**465**	**580**	**700**	**725**	**835**	**990**	**1160**	**1345**
Effective length, L_{st} (mm)	Stress developed in steel, $\sigma_{st\ (nom)}$ (MPa)									
140	241									
160	276									
180	310	257								
240	414	343								
290	500	414	312							
310		443	333							
330		471	355							
350		500	376	302						
370			398	319						
410			441	353						
465			500	401	332	321				
490				422	350	338	293			
540				466	386	372	323	273		
580				500	414	400	347	293	250	
615					439	424	368	311	265	
650					464	448	389	328	280	242
700					500	483	419	354	302	260
725						500	434	366	312	270
780							467	394	336	290
835							500	422	360	310
875								442	360	310
915								462	394	340
990								500	427	368
1160									500	431
1345										500

$\sigma_{st} < f_{sy}$

$\sigma_{st} < f_{sy}$

500 Denotes adhesive tensile bond stress at Grade 500 steel yield development length, $L_{sy.t}$ Interpolation permitted. Do not extrapolate.

*Note: 10mm Reinforcing bar diameter data only applies to ChemSet™ Reo 502™ Xtrem™ and ChemSet™ EPCON™ G5 Xtrem™ for hammer drilling technique.

**Note: For Reinforcing bar diameters 12mm to 40mm, both hammer drilling technique and diamond core drilling technique can be used.

#Note: 36mm and 40mm Reinforcing bar diameter data only applies to ChemSet™ Reo502™ Xtrem™ and ChemSet™ EPCON G5™ Xtrem™ .

Chemset Reo 502™ Xtrem™, Chemset 801 Xtrem™ XC² or ChemSet™ EPCON™ G5 Xtrem™
STRENGTH LIMIT STATE DESIGN

Checkpoint 2a

Table 2a Concrete compressive strength effect on development length, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-40 bar diam.	1.26	1.13	1.00	0.89	0.80
X_{nc} - for 32 bar diam. C801X600 only	1.26	1.13	1.00	1.00	1.00

Design reinforcing bar steel development length, $L_{sy.t}$ (mm)

$$L_{sy.t} = L_{sy.t}\,(nom) * X_{nc}$$

If there is insufficient concrete depth to install bar to $L_{sy.t}$ go to Checkpoint 2b

Note: Effect of water in hole, multiply $L_{sy.t}$ by 1.4.

Checkpoint 2b

Table 2b Concrete compressive strength effect on steel stress, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-40 bar diam.	0.79	0.88	1.00	1.12	1.25
X_{nc} - for 32 bar diam. C801X600 only	0.79	0.88	1.00	1.00	1.00

Design tensile steel stress, σ_{st} (MPa)

$$\sigma_{st} = \sigma_{st}\,(nom) * X_{nc}$$

Note: Effect of water in hole, multiply σ_{st} by 0.7.