Introduction

CHEMICAL ANCHORING - REINFORCING BAR TO AS3600 & AS5216

Chemical Anchoring Reinforcing Bar to AS3600 & AS5216

AS3600 – 2018 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 AS5216:2021 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:

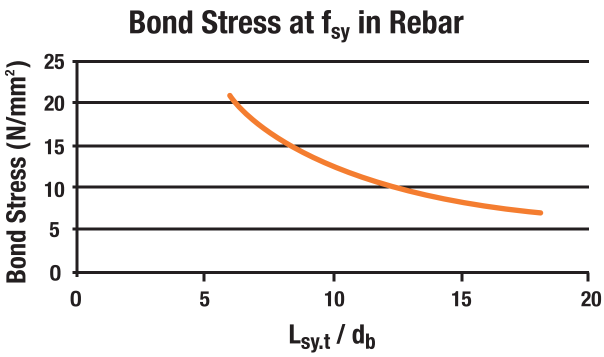
$$\sigma_b = \frac{A_b . f_{sy}}{L_{sy.t} . \pi . d_b} \quad \text{.....Equation 1}$$

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 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 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.



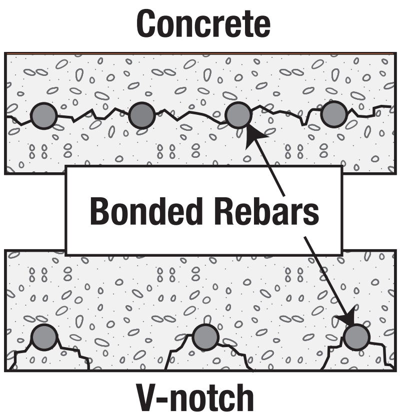


Figure 1.

Introduction

CHEMICAL ANCHORING - REINFORCING BAR TO AS3600 & AS5216

Therefore where there is shallow cover or close bar spacing, it is necessary to apply the splitting factor k_1,k_2 & k_3 listed in Section 13 of AS3600 – 2018. The splitting factors influence the development length to ensure there is sufficient embedment to reduce stress in concrete and prevent splitting failures.

Development lengths calculated from bond strength alone should NOT be used for bar anchorages designed to comply with AS3600 – 2018 as concrete splitting is not accounted for.

If splitting factors from AS3600 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%.

The development length tables in “Design Case 1” in the following section are calculated using Equation 3. This relationship applies to a single bar remote from an edge and does not account for concrete splitting affects.

For designs where there are multiple parallel reinforcing bars in structural elements such as walls, floors, beams and columns, concrete splitting factors from section 13.1 of AS3600 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 AS3600.

AS5216 - 2021 Appendix D covers development length of post-installed reinforcing bar

AS5216:2021 Appendix D Clause D.4.2 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 AS3600.’

Therefore, the basic development length of deformed bar according to AS3600-2018 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 AS3600-2018 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 AS3600 – 2018 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 AS3600 applies the splitting factors, k_1, k_2 and k_3 to influence the development length.

AS3600 allows for various depths of concrete cover to bars depending on environmental and other circumstances. The designer must refer to AS3600 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.

References

1. AS3600 – 2018 Concrete Structures, Standards Australia
2. AS/NZS4671 – 2001 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. AS5216 - 2021 Design of post-installed and Cast-in fastenings in concrete.

Design Process

CHEMICAL ANCHORING - REINFORCING BAR TO AS3600 & AS5216

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 AS3600 – 2018 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 AS3600 – 2018.

The document provides the steel yield development length $L_{sy.t}$, required by AS3600 – 2018, 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. Development Length of single bar remote from an edge
2. Development Length of multiple bars in concrete elements. (Large clear anchor spacing)
3. Development Length of multiple bars in concrete elements. (Medium clear anchor spacing)
4. Development Length of multiple bars in concrete elements. (Minimum clear anchor spacing)

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 AS3600 - 2018. 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.

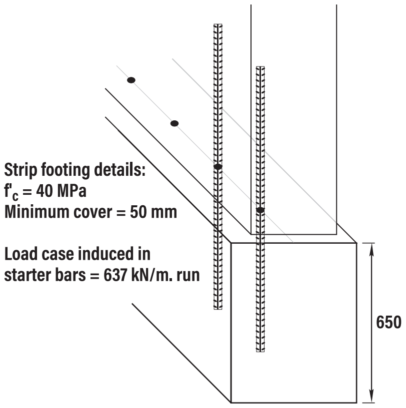
Design Process

WORKED EXAMPLE

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 mm^2/m. run

Which satisfies our steel sectional requirement.

As the project requires a post-installed solution, consider the use of ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC^2 or EPCON™ C8 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™ Plus, Chemset™ 801 Xtrem™ XC^2 or EPCON™ C8 Xtrem™ is:

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

Specify

N24 @ 275 mm. centres post-installed using Ramset™ ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC$_2$ or EPCON™ C8 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,

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

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 mm^2/m. run

Which satisfies our steel sectional requirement.

Specify

N24 @ 250 mm. centres post-installed using Ramset™ ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC^2 or EPCON™ C8 Xtrem™ @ 540 mm. deep

Reinforcing Bar

ENGINEERING PROPERTIES

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)	14*	16**	20	25	30	30	35	40	45	50
Stress area, A_b (mm^2)	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_{sy}, (kN)	39.3	56.5	100.5	157.0	226.0	245.5	308.0	402.0	510.0	630.0

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

*Note: For EPCON C8 Xtrem with 10mm Rebar Size, drill hole diameter dh = 12mm

**Note: For EPCON C8 Xtrem with 12mm Rebar Size, drill hole diameter dh = 15mm

ChemSet™ Reo 502™ PLUS

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

AVAILABLE IN AUSTRALIA ONLY

(New Zealand refer to EPCON™ C6 PLUS 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 AS5216:2021 Appendix D and AS3600-2018 clause 13.1.2.2 steel yield development length

- European Technical Assessment - tested to EAD 330087

Benefits, Advantages and Features

- 100 year working life

Greater productivity:

- Anchors in dry, damp, wet or flooded holes
- Easy dispensing even in cold weather

Greater security:

- Strong bond
- Rated for sustained loading

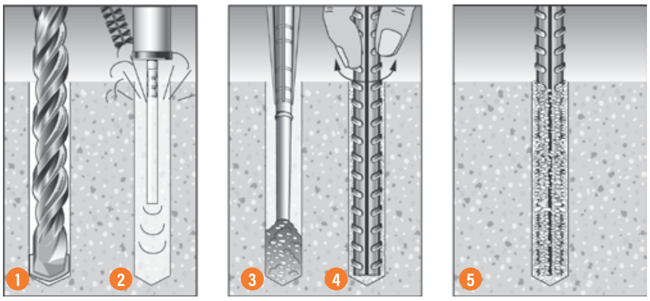
Versatile:

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

Greater safety:

- Low odour
- VOC Compliant

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, 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™ Reo 502™ PLUS to cure as per setting times.

Principal Applications

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

Recommended Installation Temperatures

	Minimum	Maximum
Substrate	5°C	40°C
Adhesive	10°C	40°C

Service Temperature Limits

-40°C to 70°C

Setting Times Reo 502™ Plus

Temperature of base material	Cartridge Temperature	Gel Time	Curing time in dry and wet concrete
5°C	Minimum 10°C	300 min	24 h
10°C	10°C	150 min	18 h
15°C	15°C	40 min	12 h
20°C	20°C	25 min	8 h
25°C	25°C	18 min	6 h
30°C	30°C	12 min	4 h
40°C	40°C	6 min	2 h
Note: Cartridge temperature minimum +10°C			

DESCRIPTION AND PART NUMBERS

Description	Cartridge Size	Part No.	Working Time at 20°C	Cure Time at 20°C
ChemSet™ Reo 502™ PLUS	600 ml	REO502P600	25 minutes	12 hours

ChemSet™ 801 Xtrem™ XC^2

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

GENERAL INFORMATION

Performance Related | Installation Related *

Product

Chemset™ 801 Xtrem™ XC^2 is a heavy duty Vinylester for anchoring threaded studs and reinforcing bar into cracked and uncracked concrete.

Compliance

Design according to AS5216:2021 Appendix D and AS3600-2018 clause 13.1.2.2 steel yield development length

- European Technical Assessment - tested to EAD 330087

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 @ 20ºC

Greater security:

- Strong bond
- Rated for sustained loading

Versatile:

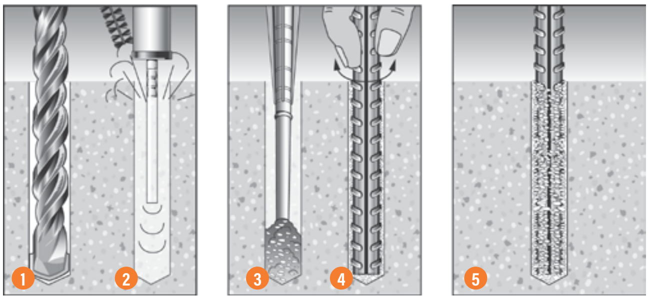
- Earthquake, Fire & Flooded Conditions
- Cold and temperate climates

Greater safety:

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

Made in Australia

Installation



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™ XC^2 to cure as per setting times.

Principal Applications

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

Recommended Installation Temperatures

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

Service Temperature Limits

-40°C to 80°C

Setting Times 801 Xtrem™ XC^2

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.

EPCON™ C8 Xtrem™

CHEMICAL INJECTION - NON-CRACKED & CRACKED CONCRETE

GENERAL INFORMATION

Performance Related	Installation Related

*

Product

EPCON™ C8 Xtrem™ is a High Performance Pure Epoxy Anchoring adhesive for use in Cracked and Non-Cracked concrete. For structures subject to external exposure, permanently damp or aggressive conditions.

Compliance

Design according to AS5216:2021 Appendix D and AS3600-2018 clause 13.1.2.2 steel yield development length

- European Technical Assessment - tested to EAD 330087

Benefits, Advantages and Features

- 100 year working life
- Approved for flooded holes
- Approved for floor, wall & overhead applications
- Data for 100 years sustained loading

Greater productivity:

- Anchors in dry, damp, wet or flooded holes
- No weather delays
- Fast, easy dispensing with high flow mixer

Greater security:

- Highest performance in cracked concrete

Versatile

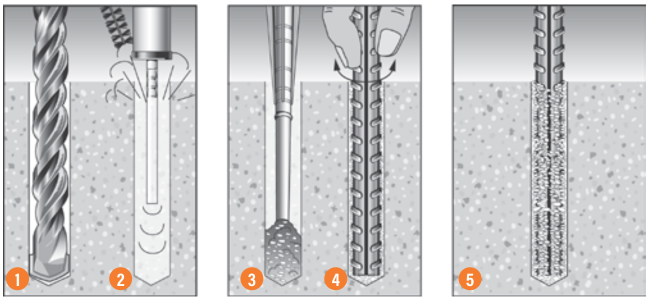
- Anchors all stud & bar diameters in all directions
- Oversized holes
- Anchors in carbide drilled and diamond cored holes
- For tropical and cold weather conditions

Greater safety:

- Low odour

Fire Rated : Refer Fire rated anchoring section

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 rebar to bottom of hole while turning.
5. Allow EPCON™ C8 Xtrem™ to cure as per setting times.

FIRE TESTED SEISMIC 100 YEAR WORKING LIFE ETA CRACKED CONCRETE CERTIFIED FLOODED HOLE APPROVED

Principal Applications

- Anchoring into cracked & non cracked concrete
- Road barrier hold down bolts
- Bridge refurbishment
- Road & Rail tunnel construction
- Reinforcing bar from 10 to 32mm
- Starter Bars
- Threaded Studs from M8 to M30
- Threaded Stud material: Zn, A4 316, HCR steels
- Threaded Stud material: 5.8, 8.8, 10.9 grade

Recommended Installation Temperatures

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

Load should not be applied to anchor until the chemical has sufficiently cured as specified.

Service Temperature Limits

-40°C to 80°C

Setting Times EPCON™ C8 Xtrem™

Temperature of base material	Gel Time	Curing time in dry concrete	Curing time in wet concrete
5°C - 9°C	20 min	30 h	60 h
10°C - 19°C	14 min	23 h	46 h
20°C - 24°C	11 min	16 h	32 h
25°C - 29°C	8 min	12 h	24 h
30°C - 39°C	5 min	8 h	16 h
40°C	5 min	6 h	12 h

Note

*Performance of cored & oversized holes was not included in the ETAG test program and therefore is based on testing conducted at Ramset™ Product Engineering Laboratory.

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 1

For Single Bar Remote from an Edge ($e > 4\ d_b$)

For designs intended to comply with AS5216-2021 and AS3600-2018, refer to Design cases 2, 3 and 4

Concrete Splitting Factors

k_1	1.0
k_2	1.0
k_3	1.0

Table 1 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™ Plus, Chemset™ 801 Xtrem™ XC² or EPCON™ C8 Xtrem™

Rebar size	10*	12	16	20	24	25	28	32	36*	40*
Minimum Cover, e (mm)	40	48	64	80	96	100	112	128	144	160
Min. Clear Spacing, a (mm)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
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, $L_{sy.t\ (nom)}$	**105**	**140**	**205**	**265**	**335**	**360**	**400**	**470**	**540**	**615**
Effective length, L_{st} (mm)	Stress developed in steel, $\sigma_{st\ (nom)}$ (MPa)									
50	238									
60	286									
70	333	250								
80	381	286								
90	429	321								
100	476	357	244					$\sigma_{st} < f_{sy}$		
105	500	375	256							
120		429	293	226						
140		500	341	264	209					
160			390	302	239	222				
190			463	358	284	264	238			
205			500	387	306	285	256			
220				415	328	306	275	234		
230				434	343	319	288	245	213	
265				500	396	368	331	282	245	
300					448	417	375	319	278	
335					500	465	419	356	310	272
360						500	450	383	333	293
380		$\sigma_{st} > f_{sy}$					475	404	352	309
400							500	426	370	325
430								457	398	350
450								479	417	366
470								500	435	382
540									500	439
615										500

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

*Note: 10, 36 & 40 mm Reinforcing bar diameter data only applies to ChemSet™ Reo 502™ Plus and EPCON™ C8 Xtrem™

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™

STRENGTH LIMIT STATE DESIGN

Checkpoint 1a

Table 1a Concrete compressive strength effect on development length, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc}	1.26	1.13	1.00	0.89	0.80

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 1b

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

Checkpoint 1b

Table 1b Concrete compressive strength effect on steel stress, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc}	0.79	0.88	1.00	1.12	1.25

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.

Strength Limit State Design

Design Case 2

Multiple Bars in Concrete Elements (Large clear anchor spacing)

Steel yield development length, $L_{sy.t}$ (AS5216-2021 Appendix D and AS3600 - 2018, clause 13.1.2.2)

Table 2 Nominal steel yield development length $L_{sy*t\ (nom)}$, of Grade 500 reinforcing bar in tension post-installed in 32 MPa concrete with ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC² or EPCON™ C8 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	377	325
915								462	394	340
990								500	427	368
1160									500	431
1345										500

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

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

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

*Note: 10, 36 & 40mm Reinforcing bar diameter data only applies to ChemSet™ Reo 502™ Plus and EPCON™ C8 Xtrem™

**Note: 1. ChemSet™ Reo 502™ Plus and ChemSet™ 801 Xtrem™ XC² development length data is based on Diamond Core drilled holes.
2. EPCON™ C8 Xtrem™ development data is based on hammer drilled holes. For Diamond Core drilled holes refer to Development Length multiplication factors below.
3. When using 36 & 40mm Reinforcing bar diameter apply Development Length multiplication factors below.

Development Length Multiplication Factors on $L_{sy.t(nom)}$		
Chemical Anchor Type	**Diamond Core Drill Factor**	**36mm and 40mm diameter factor**
EPCON™ C8 Xtrem™	Multiply $L_{sy.t\ (nom)}$ x 1.2	Not required
ChemSet™ Reo 502™ Plus	Not required	Multiply $L_{sy.t\ (nom)}$ x 1.4

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 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 10-25 bar diam.	1.26	1.13	1.00	0.89	0.80
X_{nc} - for 28-32 bar diam.	1.26	1.13	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	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 10-25 bar diam.	0.79	0.88	1.00	1.12	1.25
X_{nc} - for 28-32 bar diam.	0.79	0.88	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	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.

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 3

Multiple Bars in Concrete Elements (Medium clear anchor spacing)

Steel yield development length, $L_{sy.t}$ (AS5216-2021 Appendix D and AS3600 - 2018, clause 13.1.2.2)

Table 3 Nominal steel yield development length $L_{sy.t\ (nom)}$, of Grade 500 reinforcing bar in tension post-installed in 32 MPa concrete with ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC² or EPCON™ C8 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	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Minimum Cover, e (mm)	30	30	32	40	48	50	56	64	72	80
Min. Clear Spacing, a (mm)	60	60	70	80	100	100	120	130	150	150
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**	**520**	**675**	**835**	**880**	**1015**	**1205**	**1410**	**1670**
Effective length, L_{st} (mm)	Stress developed in steel, $\sigma_{st\ (nom)}$ (MPa)									
120	207									
180	310									
200	345	286								
250	431	357								
290	500	414	279							
300		429	288					$\sigma_{st} < f_{sy}$		
330		471	317							
350		500	337	259						
400			385	296						
445			428	330						
520			500	385	311	295				
550				407	329	313	271			
595				441	356	338	293	247		
675				500	404	384	332	280	239	
700					419	398	345	290	248	
775					464	440	382	322	275	232
835					500	474	411	346	296	250
880						500	433	365	312	263
945		$\sigma_{st} > f_{sy}$					465	392	335	283
1015							500	421	360	304
1050								436	372	314
1120								465	397	335
1205								500	427	361
1410									500	422
1670										500

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

*Note: 10, 36 & 40mm Reinforcing bar diameter data only applies to ChemSet™ Reo 502™ Plus and EPCON™ C8 Xtrem™

**Note:
1. ChemSet™ Reo 502™ Plus and ChemSet™ 801 Xtrem™ XC² development length data is based on Diamond Core drilled holes.
2. EPCON™ C8 Xtrem™ development data is based on hammer drilled holes. For Diamond Core drilled holes refer to Development Length multiplication factors below.
3. When using 36 & 40mm Reinforcing bar diameter apply Development Length multiplication factors below.

Development Length Multiplication Factors on $L_{sy.t(nom)}$		
Chemical Anchor Type	**Diamond Core Drill Factor**	**36mm and 40mm diameter factor**
EPCON™ C8 Xtrem™	Multiply $L_{sy.t\ (nom)}$ x 1.2	Not required
ChemSet™ Reo 502™ Plus	Not required	Multiply $L_{sy.t\ (nom)}$ x 1.4

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™
STRENGTH LIMIT STATE DESIGN

Checkpoint 3a

Table 3a Concrete compressive strength effect on development length, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-25 bar diam.	1.26	1.13	1.00	0.89	0.80
X_{nc} - for 28-32 bar diam.	1.26	1.13	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	1.00	1.00	1.00

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

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

If there is insufficient concrete depth to install bar to $L_{sy.t}$
go to Checkpoint 3b

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

Checkpoint 3b

Table 3b Concrete compressive strength effect on steel stress, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-25 bar diam.	0.79	0.88	1.00	1.12	1.25
X_{nc} - for 28-32 bar diam.	0.79	0.88	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	1.00	1.00	1.00

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

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

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

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™
STRENGTH LIMIT STATE DESIGN

Strength Limit State Design

Design Case 4

Multiple Bars in Concrete Elements (Minimum clear anchor spacing)

Steel yield development length, $L_{sy.t}$ (AS5216-2021 Appendix D and AS3600 - 2018, clause 13.1.2.2)

Table 4 Nominal steel yield development length $L_{sy.t\ (nom)}$, of Grade 500 reinforcing bar in tension post-installed in 32 MPa concrete with ChemSet™ Reo 502™ Plus, Chemset™ 801 Xtrem™ XC² or EPCON™ C8 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	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Minimum Cover, e (mm)	30	30	32	40	48	50	56	64	72	80
Min. Clear Spacing, a (mm)	30	36	48	60	72	75	84	96	108	120
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, $L_{sy.t\ (nom)}$**	**335**	**410**	**565**	**730**	**910**	**965**	**1105**	**1310**	**1535**	**1780**
Effective length, L_{st} (mm)	Stress developed in steel, $\sigma_{st\ (nom)}$ (MPa)									
150	224									
200	299									
250	373	305								
290	433	354								
335	500	409	296							
350		427	310					$\sigma_{st} < f_{sy}$		
390		476	345							
410		500	363	281						
450			398	308						
480			425	329						
565			500	387	310	293				
600				411	330	311	272			
650				445	357	337	294	248		
730				500	401	378	330	279	238	
780					428	404	353	298	254	
850					467	440	385	324	277	239
910					500	472	412	347	297	256
965						500	437	368	314	271
1030		$\sigma_{st} > f_{sy}$					466	393	336	289
1105							500	422	360	310
1200								458	391	337
1250								477	407	351
1310								500	427	368
1535									500	431
1780										500

500 Denotes adhesive tensile bond stress at Grade 500 steel yield development length, $L_{sy.t}$

Interpolation permitted. Do not extrapolate.

*Note: 10, 36 & 40mm Reinforcing bar diameter data only applies to ChemSet™ Reo 502™ Plus and EPCON™ C8 Xtrem™

**Note:
1. ChemSet™ Reo 502™ Plus and ChemSet™ 801 Xtrem™ XC² development length data is based on Diamond Core drilled holes.
2. EPCON™ C8 Xtrem™ development data is based on hammer drilled holes. For Diamond Core drilled holes refer to Development Length multiplication factors below.
3. When using 36 & 40mm Reinforcing bar diameter apply Development Length multiplication factors below.

Development Length Multiplication Factors on $L_{sy.t(nom)}$		
Chemical Anchor Type	**Diamond Core Drill Factor**	**36mm and 40mm diameter factor**
EPCON™ C8 Xtrem™	Multiply $L_{sy.t\ (nom)}$ x 1.2	Not required
ChemSet™ Reo 502™ Plus	Not required	Multiply $L_{sy.t\ (nom)}$ x 1.4

Chemset Reo 502™ Plus, Chemset 801 Xtrem™ XC² or EPCON™ C8 Xtrem™
STRENGTH LIMIT STATE DESIGN

Checkpoint 4a

Table 4a Concrete compressive strength effect on development length, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-25 bar diam.	1.26	1.13	1.00	0.89	0.80
X_{nc} - for 28-32 bar diam.	1.26	1.13	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	1.00	1.00	1.00

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

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

If there is insufficient concrete depth to install bar to $L_{sy.t}$ go to Checkpoint 4b

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

Checkpoint 4b

Table 4b Concrete compressive strength effect on steel stress, tension, X_{nc}

f'_c (MPa)	20	25	32	40	50
X_{nc} - for 10-25 bar diam.	0.79	0.88	1.00	1.12	1.25
X_{nc} - for 28-32 bar diam.	0.79	0.88	1.00	1.00	1.00
X_{nc} - for 36-40 bar diam.	1.00	1.00	1.00	1.00	1.00

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

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

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