

TECHNICAL NOTE

AEFAC
Australian Engineered
Fasteners and Anchors Council



POST-INSTALLED REBAR CONNECTIONS

Ver. 1.1
August, 2019

AEFAC Technical Note

on

Post-Installed Rebar Connections

1. Scope

This Technical Note provides recommendations on design of post-installed rebar using adhesives in drilled holes in concrete for tensile load. This Technical Note covers the design for development length to achieve the characteristic yield strength of rebar. It also covers the determination of tensile capacity of post installed rebars to develop a stress less than the characteristic yield strength of rebar.

The basis of this Technical Note are EAD 330499 [1], EAD 330087 [2] (which superseded EOTA TR 023 [3]) and AS 3600 [4]. EAD 330499 and EAD 330087 are used for the prequalification of post-installed rebar system and AS 3600 is used for the design for development length and tensile capacity.

The provisions of AS 3600 are for cast-in rebar and do not address the behavior of post-installed rebar. The purpose of this Technical Note is to ensure that post-installed rebar performs in a similar manner to cast-in rebar (in terms of load transfer and load-displacement behaviour). Since a layer of adhesive is present between the rebar and the substrate in the post-installed rebar application, the overall behavior of the system is also dependent on the properties of the adhesive. Thus, in order to use this Technical Note, the post-installed rebar adhesive system must be **prequalified according to EAD 330087** to ensure its suitability for this application. The ETA (European Technical Assessment) based on EAD 330087 is referred to herein as **ETA-Rebar**. This is to distinguish the additional prequalification for the ETA which is issued based on EAD 330499 and referred to herein as just ETA which is used for designs according to AS 5216:2018[4].

The product ETA-Rebar for post-installed rebar system based on EAD 330087 is different from the product ETA for adhesive anchors issued based on EAD 330499 testing and evaluation method. The ETA-Rebar specifically provides the design ultimate bond strength (also called bond resistance) values (f_{bd}) which are different from design bond strength values derived from

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the characteristic bond strength values (τ_{RK}) in the ETA for adhesive anchors. For post-installed rebar connections, the design ultimate bond strength (f_{bd}) as given in ETA-Rebar are used.

In general, the design ultimate bond strength value in the ETA-Rebar is lower than the bond strength in the ETA (based on EAD 330499). The lower value of bond strength must be considered to scale the development length obtained from equation (1) in Section 5 of this Technical Note. Please refer to Example 1 for f_{bd} of 2.5MPa.

The Technical Note covers straight deformed reinforcing bars with diameter greater than or equal to 10mm and concrete with minimum compressive strength of 20MPa with upper limits for concrete strength and rebar as defined by the relevant ETA-Rebar.

This Technical Note covers static loading and does not cover seismic, fatigue and fire actions. It covers post-installed rebars installed in dry and wet concrete (not in flooded holes).

The recommendations provided in this Technical Note are of general nature. For product specific detailed information, advice from the supplier/manufacturer should be sought.

For post-installed rebar connections, the required hole depth may be large and hence the installation quality is extremely important. The installation must be carried out in accordance with the manufacturer's installation instructions (MII). The installation should only be performed by **competent personnel**, either certified by AEFAC [6] or trained by anchor supplier for this specific application.

Note:

This Technical Notes can be used with the post-installed rebar adhesive systems pre-qualified according to EOTA TR-023.

2. Terminology

The following terminologies and definitions are used in this Technical Note. Please refer to AEFAC Anchor Dictionary [7] for additional terminologies and definitions.

Anchor: a type of device that is post-installed into matured concrete or cast into concrete.

Competent person: A person who has acquired thorough training, qualification or experience, or a combination of these, the knowledge and skills to enable that person to perform the required task.

Cover: Distance between the outside of rebar and the nearest surface of the substrate excluding

any applied surface finish.

Post-installed rebar: Reinforcement that is anchored into matured concrete using adhesives in drilled hole.

3. Notation

A_s	=	Cross-sectional area of rebar
c_d	=	Distance between rebar and edge (clear cover)
c_{min}	=	Minimum clear cover
d_b	=	Diameter of rebar
f_{bd}	=	Ultimate bond strength (also called bond resistance) of post-installed rebar (given in ETA-Rebar)
f'_c	=	Characteristic compressive (cylinder) strength of concrete
f_{sy}	=	Characteristic yield strength of rebar
k	=	Factor or coefficient (with numerical subscripts) to determine development length of rebars according to AS 3600
L_{st}	=	Reduced development length to develop a stress σ_{st} of deformed rebar in tension in accordance with AS3600
L_{syt}	=	Development length to develop a stress f_{sy} of deformed rebar in tension in accordance with AS3600
N_{st}	=	Nominal tensile capacity of post-installed rebar with embedment depth L_{st}
s_{min}	=	Minimum clear spacing between two post-installed rebars
σ_{st}	=	Tensile stress in the rebar, less than the yield strength (f_{sy})

4. General

Design of post-installed rebars is not covered in AS 3600. However, if the post-installed rebar system is prequalified according to EAD 330087 and installed based on the instructions reported in the product ETA-Rebar, the provisions given in AS 3600 can be used for post-installed rebar design within the scope describe in Section 1 of this Technical Note and the ETA-Rebar.

EAD 330087 is used in Europe for the prequalification and design of post-installed rebars and it refers to the concrete design code Eurocode 2 [8]. In this Technical Note, the design provisions of AS 3600 are adopted rather than Eurocode 2 to be used with ETA-Rebar.

The qualification process for post-installed rebar is included in EAD 330087 which also includes the intended application range of post installed rebar as reported in Figure 1.1 to 1.5 of EAD 330087 and also reproduced in the product ETA-Rebar.

5. Design of Post-installed Rebar Connection

Unlike Eurocode 2, AS 3600 does not explicitly use bond strength (f_{bd}) in the formula to obtain the development length. If the design ultimate bond strength (f_{bd}) in the relevant product ETA-Rebar is less than the values stated in EAD 330087 and shown in Table 1, then the calculated development length from equation (1) needs to be increased in proportion to the ratio of the value given in EAD 330087 and the value from the ETA-Rebar for the given strength of concrete (see Example 1).

Table 1: Design bond strength according to EAD 330087 without limitation.

S.N.	Compressive strength of concrete (MPa)	Design ultimate bond strength f_{bd} (MPa)
1	20	2.3
2	25	2.7
3	32	3.2
4	40	3.7
5	45	4.0
6	50	4.3

Note:
Design ultimate bond strength (f_{bd}) provided in this table are for rebar with diameter less than or equal to 32mm.

5.1. Determination of Development Length

The embedment length of post-installed rebars to develop characteristic yield strength of a rebar should not be less than the development length obtained from equation (1) which is in AS 3600.

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The development length ($L_{sy,t}$) to develop the characteristic yield strength of a rebar (f_{sy}) in tension is given by equation (1).

$$L_{sy,t} = \frac{(0.5k_1 k_3 f_{sy} d_b)}{k_2 \sqrt{f'_c}} \geq 0.058 f_{sy} k_1 d_b \quad \text{Eq (1)}$$

Where,

$k_1 = 1.3$ for a rebar with more than 300mm of concrete cover

$= 1.0$ otherwise

$k_2 = (132 - d_b) / 100$

$k_3 = 1 - \frac{0.15(c_d - d_b)}{d_b}$

(within the limits $0.7 \leq k_3 \leq 1.0$)

$c_d =$ Minimum of clear cover on each side and half of clear spacing between rebars

$f'_c \leq 65\text{MPa}$

Equation (1) is valid for cracked and un-cracked concrete if no additional requirement is provided for cracked concrete in product ETA-Rebar.

Notes:

- 1. The minimum limit of $0.058 f_{sy} k_1 d_b$ in equation (1) is intended for cast-in rebar applications. This requirement may lead to a conservative estimate (especially for higher strength concrete) for post-installed rebar connections.*
- 2. k_1 can be assumed to be 1 for post installed rebars in fully cured concrete.*
- 3. For the product specific applications, relevant product ETA-Rebar should be referred for concrete type and strength limit.*

Example 1:

Characteristic compressive strength of concrete, $f'_c = 25\text{MPa}$

Diameter of rebar, $d_b = 12\text{mm}$

Characteristic yield strength of rebar, $f_{sy} = 500\text{MPa}$

$$\frac{(0.5k_1 k_3 f_{sy} d_b)}{k_2 \sqrt{f'_c}} = 350\text{mm}$$

And

$$0.058f_{sy} k_1 d_b = 348\text{mm} < 350\text{mm}$$

- a) If the design bond strength, f_{bd} is 2.7MPa in the product ETA-Rebar (which is same as the value given in Table 1), the development length to yield the rebar is,

$$L_{syt} = 350\text{mm}.$$

- b) If the design bond strength, f_{bd} is 2.5MPa in the product ETA-Rebar (which is less than the value given in Table 1), the development length to yield the rebar should be,

$$L_{syt} = 350 \times 2.7 / 2.5 = 378\text{mm}.$$

Notes:

1. In this example the value of k_1 and k_3 are assumed as 1.0 and 0.7 respectively. According to Section 5.3, minimum cover for hammer drilled holes, c_{min} would be 51mm which is more than $3d_b$, resulting the value of k_3 to be 0.7, provided that the clear spacing, s_{min} is greater than or equal to $6d_b$.
2. Design ultimate bond strength for the same parameters and installation methods (e.g., drill type, drilling method and hole and concrete condition) as for the intended application should be taken from the product ETA-Rebar. Advice from supplier/manufacturer should be taken if any of the parameters are outside the scope of product ETA-Rebar.
3. The development length to yield the rebar was governed by $\frac{(0.5k_1 k_3 f_{sy} d_b)}{k_2 \sqrt{f'_c}}$

5.2 Determination of post-installed rebar capacity for $L_{st} < L_{sy,t}$

In some cases, it might not be possible or required to achieve the full development length of the rebar specified in Section 5.1 due to the structural dimensions or some other reasons.

The development length (L_{st}) for a post-installed rebar to develop a tensile stress (σ_{st}), which is less than the characteristic rebar yield strength is given in AS 3600 as -

$$L_{st} = L_{sy,t} \frac{\sigma_{st}}{f_{sy}} \quad \text{Eq (2)}$$

The development length (L_{st}) calculated from equation (2) should not be less than $12d_b$ or any other provisions specified in AS 3600.

Accordingly, the reduced nominal capacity of the post-installed rebar (N_{st}) can be calculated from equation (3) or (4). (See Example 2).

$$N_{st} = A_s \sigma_{st} \quad \text{Eq (3)}$$

$$N_{st} = A_s f_{sy} \frac{L_{st}}{L_{sy,t}} \quad \text{Eq (4)}$$

Where,

$$A_s = \frac{\pi d^2}{4} \quad \text{Eq (5)}$$

Note:

Alternative methods (e.g., anchor design as per AS 5216:2018) can be used to determine the capacity of post-installed rebar if the product has ETA based on EAD 330499. The design approach, scope and applicable factors as given in AS 5216:2018 should be followed.

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Example 2:

Characteristic compressive strength of concrete, $f'_c = 32\text{MPa}$

Diameter of rebar, $d_b = 12\text{mm}$

Characteristic yield strength of rebar, $f_{sy} = 500\text{MPa}$

$$\frac{(0.5k_1 k_3 f_{sy} d_b)}{k_2 \sqrt{f'_c}} = 310\text{mm}$$

And

$$0.058f_{sy} k_1 d_b = 348\text{mm} > 310\text{mm}$$

- a) If the design bond strength, f_{bd} is 3.2MPa in the product ETA-Rebar (which is same as the value given in Table 1), the development length to yield the rebar is,

The development length ($L_{sy,t}$) to develop the characteristic yield strength of a rebar (f_{sy}) = 348mm

The development length (L_{st}) for a post-installed rebar to develop a tensile stress ($\sigma_{st} = 300\text{MPa}$),

$$L_{st} = L_{sy,t} \frac{\sigma_{st}}{f_{sy}}$$

$$= 348 \times 300 / 500$$

$$= 209\text{mm}$$

The nominal capacity of the post-installed rebar (N_{st}) installed for a depth of 209mm,

$$N_{st} = A_s \sigma_{st} = 113.1 \times 300 = 34000\text{N} = 34\text{kN} \quad \text{OR}$$

$$N_{st} = A_s f_{sy} \frac{L_{st}}{L_{sy,t}} = 113.1 \times 500 \times 209 / 348 = 34000\text{N} = 34\text{kN}$$

- b) If the design bond strength, f_{bd} is 3.0MPa in the product ETA-Rebar (which is less

than the value given in Table 1), the development length to yield the rebar should be,

$$L_{sy,t} = 348 \times 3.2 / 3.0 = 372 \text{ mm.}$$

The development length (L_{st}) for a post-installed rebar to develop a tensile stress ($\sigma_{st} = 300 \text{ MPa}$),

$$L_{st} = L_{sy,t} \frac{\sigma_{st}}{f_{sy}}$$

$$= 372 \times 300 / 500$$

$$= 224 \text{ mm}$$

The nominal capacity of the post-installed rebar (N_{st}), installed for a depth of 224 mm,

$$N_{st} = A_s \sigma_{st} = 113.1 \times 300 = 34000 \text{ N} = 34 \text{ kN} \quad \text{OR}$$

$$N_{st} = A_s f_{sy} \frac{L_{st}}{L_{sy,t}} = 113.1 \times 500 \times 224 / 372 = 34000 \text{ N} = 34 \text{ kN}$$

Notes:

1. Value of k_3 is assumed to be 0.7 in this example.
2. The development length to yield the rebar was governed by $0.058 f_{sy} k_1 d_b$

5.3 Additional Design Provisions

Adequate concrete cover should be provided to prevent damage to the concrete during installation.

EAD 330087 provides minimum concrete cover (c_{min}) as -

$$c_{min} = 30 + 0.06 L_{st} \geq 2d_b \quad \text{for hammer drilled or diamond drilled holes with } d_b < 25 \text{ mm}$$

$$= 40 + 0.06 L_{st} \geq 2d_b \quad \text{for hammer drilled or diamond drilled holes with } d_b \geq 25 \text{ mm}$$

$$c_{min} = 50 + 0.08 L_{st} \geq 2d_b \quad \text{for compressed air drilled holes with } d_b < 25 \text{ mm}$$

$$= 60 + 0.08 L_{st} \geq 2d_b \quad \text{for compressed air drilled holes with } d_b \geq 25 \text{ mm}$$

Where, L_{st} is the actual embedment depth of the post-installed rebar.

If drilling aid is used, the factors 0.06 and 0.08 could be reduced. Relevant product ETA-Rebar should be followed for the actual requirements for the clear cover.

The minimum spacing between post-installed rebars (s_{min}) should be -

$$s_{min} = 40\text{mm} \geq 4 d_b$$

If drilling aid is used, the requirement of $4 d_b$ could be reduced. Relevant product ETA-Rebar should be followed for the actual requirements for the spacing.

6. References

- [1] EAD 330499-00-0601 "Bonded fasteners for use in concrete", European Organisation for Technical Assessment, July 2017.
- [2] EAD 330087-00-0601 "Systems for post-installed rebar connections with mortar", European Organisation for Technical Assessment, May 2018.
- [3] EOTA, "TR 023: Assessment of post-installed rebar connections," European Organization for Technical Approvals, 2006.
- [4] Standards Australia, "AS 3600: Concrete structures," Standards Australia, 2018.
- [5] Standards Australia, "AS 5216: Design of post-installed and cast-in fastenings in concrete," Standards Australia, Australia, 2018.
- [6] AEFAC, "AEFAC Anchor Installer Certification Program," Australian Engineered Fasteners and Anchors Council. www.aefac.org.au.
- [7] AEFAC, Technical Note, "AEFAC Anchor Dictionary," Australian Engineered Fasteners and Anchors Council. www.aefac.org.au.
- [8] CEN, "BS EN 1992-1 : Design of concrete structures," 2004.



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