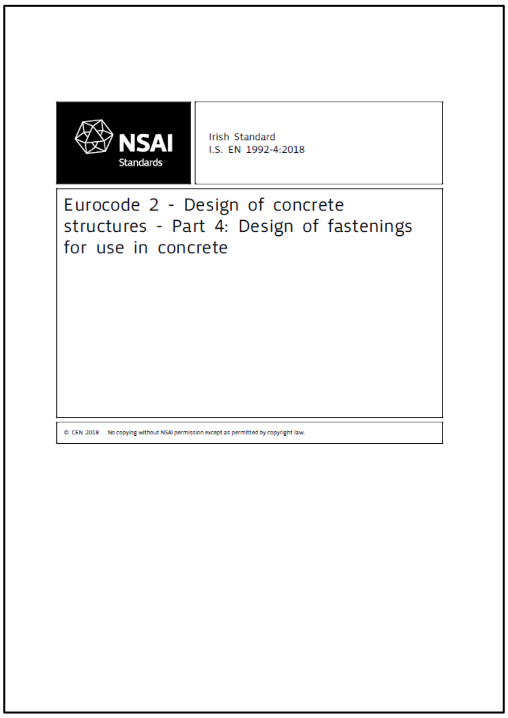
Anchor watch 06 –

Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete.

This is the sixth of my Anchor Watch articles, if you have missed any of the previous five you can access then on https://www.masonryfixings.ie/articles

My last article was published in April 2018, since then, in September 2018 the long awaited and much talked about code EN 1992-4 was finally published.

In light of the upcoming Irish Concrete Society technical seminar (webinar) on *The design and installation of anchors,* I though it appropriate to discuss the document again.



NSAI Standards

Irish Standard
I.S. EN 1992-4:2018

Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete

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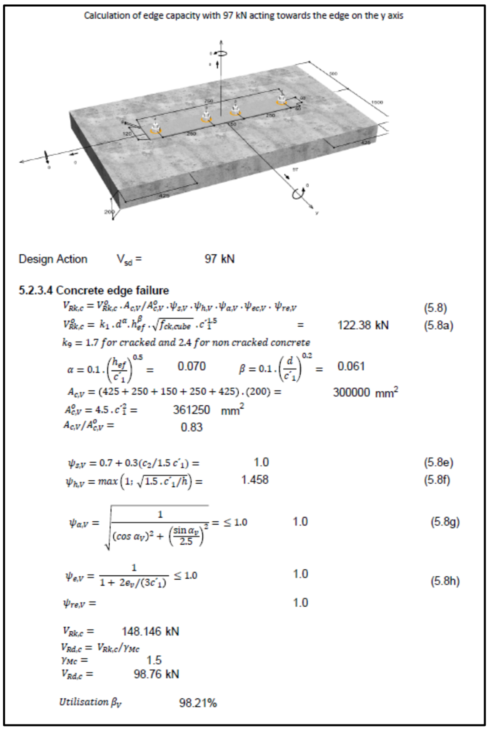
Use of connections employing fasteners for the transfer of heavy and concentrated loads in concrete structures is routine practice for designers. A myriad of different types of cast-in and post-installed fasteners are available to cover the wide range of structural fastening applications both safely and economically. The correct use of fasteners is beneficial in the construction process and improves productivity on the construction site. Their safe performance in their field of application is verified by means of prequalification and assessment procedures issued by approval bodies and stated in corresponding European Technical Product Specifications such as European Technical Assessments (ETAs) presuming proper installation.

The understanding of the behaviour of structural fastening systems, the range of the fields of applications and the design methods and installation procedures have made significant advances in the past three decades. Although a large number of fasteners are installed every day, understanding in the engineering community about their working principles and design is very limited even though study programmes and in-service training modules exist. Therefore, fasteners are not always best used in daily practice.

In my daily work I still encounter installers who don't fully understand the correct method of installing anchors and design engineers who don't fully understand the content of EN 1992-4.

Many of the anchor suppliers offer installation training via "toolbox talks" and "lunch and learn" sessions to help installers better understand how to correctly install cast-in and post-installed fasteners. They also offer CPD seminars to enable design engineers to better understand the prequalification and assessment procedures as outlined in EN 1992-4.



Calculation of edge capacity with 97 kN acting towards the edge on the y axis

Design Action V_{sd} = 97 kN

5.2.3.4 Concrete edge failure

$V_{Rk,c} = V^{0}_{Rk,c} \cdot A_{c,V}/A^{0}_{c,V} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{\alpha,V} \cdot \psi_{ec,V} \cdot \psi_{re,V}$ (5.8)

$V^{0}_{Rk,c} = k_1 . d^{\alpha} . h^{\beta}_{ef} . \sqrt{f_{ck,cube}} . c'^{1.5}_{1}$ = 122.38 kN (5.8a)

$k_9 = 1.7$ *for cracked and* 2.4 *for non cracked concrete*

$\alpha = 0.1 . \left(\frac{h_{ef}}{c'_1}\right)^{0.5} =$ 0.070 $\beta = 0.1 . \left(\frac{d}{c'_1}\right)^{0.2} =$ 0.061

$A_{c,V} = (425 + 250 + 150 + 250 + 425) . (200) =$ 300000 mm^2

$A^{0}_{c,V} = 4.5 . c'^{2}_{1} =$ 361250 mm^2

$A_{c,V}/A^{0}_{c,V} =$ 0.83

$\psi_{s,V} = 0.7 + 0.3(c_2/1.5\, c'_1) =$ 1.0 (5.8e)

$\psi_{h,V} = max\left(1;\ \sqrt{1.5 . c'_1/h}\right) =$ 1.458 (5.8f)

$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos \alpha_V)^2 + \left(\frac{\sin \alpha_V}{2.5}\right)^2}} = \leq 1.0$ 1.0 (5.8g)

$\psi_{e,V} = \frac{1}{1 + 2e_V/(3c'_1)} \leq 1.0$ 1.0 (5.8h)

$\psi_{re,V} =$ 1.0

$V_{Rk,c} =$ 148.146 kN

$V_{Rd,c} = V_{Rk,c}/\gamma_{Mc}$

$\gamma_{Mc} =$ 1.5

$V_{Rd,c} =$ 98.76 kN

Utilisation β_V 98.21%

Many suppliers offer software to verify that the proposed anchor system can safely satisfy the design requirements provided by the design engineer in the intended conditions, presuming proper installation.

These software packages generate reports for the designer following the prequalification and assessment procedures as outlined in EN 1992-4. The reports will look similar to the illustration shown here. Unfortunately, in many cases the designer cannot follow the content of the report as they have little knowledge of the content of EN 1992-4.

This of course makes it impossible for the designer to have any degree of confidence in the content of the report leaving many having to put their confidence in the integrity of the software.

The purpose of the webinar will be to further explain the prequalification and assessment procedures as outlined in EN 1992-4 so that the designer can have a greater understanding and be totally confident with the content of any such report. They may even learn to generate their own reports.

When any steel to concrete connection covered by the scope of EN 1992-4 is loaded in **tension** to the point of failure, the failure mode could be any of a number of possible failure modes. Mostly it will fail by way of concrete failure. Table 7.1 of EN 1992-4 outlines all the possible failure modes in tension and the required verification for each.

Table 7.1 — Required verifications for headed and post-installed fasteners in tension

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
1	Steel failure of fastener	$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	$N^{h}_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	
2	Concrete cone failure	$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$		$N^{g}_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$
3	Pull-out failure of fastener [a]	$N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	$N^{h}_{Ed} < N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	
4	Combined pull-out and concrete failure [b]	$N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$		$N^{g}_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$
5	Concrete splitting failure	$N_{Ed} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$		$N^{g}_{Ed} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$
6	Concrete blow-out failure [c]	$N_{Ed} \leq N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$		$N^{g}_{Ed} \leq N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$
7	Steel failure of reinforcement	$N_{Ed,re} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	$N^{h}_{Ed,re} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	
8	Anchorage failure of reinforcement	$N_{Ed,re} \leq N_{Rd,a}$	$N^{h}_{Ed,re} \leq N_{Rd,a}$	

[a] Not required for post-installed bonded fasteners.
[b] Not required for headed and post-installed mechanical fasteners.
[c] For cases which require verification see 7.2.1.8 (1).

In the pages following table 7.1 the code explains in detail how to calculate for each mode of failure. After checking the possible failure modes relevant to your application, the one with the least capacity becomes decisive. It determines the design resistance in tension of the connection in that application.

Changing things like the concrete strength or condition (tension or compression) can greatly influence the design resistance of the connection.

When any steel to concrete connection covered by the scope of EN 1992-4 is loaded in **Shear** to the point of failure, the failure mode could be any of a number of possible failure modes. Mostly it will fail by way of concrete failure. Table 7.2 of EN 1992-4 outlines all the possible failure modes in shear and the required verification for each.

Table 7.2 — Required verifications for headed and post-installed fasteners in shear

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
1	Steel failure of fastener without lever arm	$V_{Ed} \le V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	$V_{Ed}^{h} \le V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	
2	Steel failure of fastener with lever arm	$V_{Ed} \le V_{Rd,s,M} = \frac{V_{Rk,s,M}}{\gamma_{Ms}}$	$V_{Ed}^{h} \le V_{Rd,s,M} = \frac{V_{Rk,s,M}}{\gamma_{Ms}}$	
3	Concrete pry-out failure	$V_{Ed} \le V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$		$V_{Ed}^{g} \le V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$ [a]
4	Concrete edge failure	$V_{Ed} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$		$V_{Ed}^{g} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$
5	Steel failure of supplementary reinforcement [b]	$N_{Ed,re} \le N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	$N_{Ed,re}^{h} \le N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	
6	Anchorage failure of supplementary reinforcement [b]	$N_{Ed,re} \le N_{Rd,a}$	$N_{Ed,re}^{h} \le N_{Rd,a}$	

[a] Exception see 7.2.2.4 (4).

[b] The tension force acting on the reinforcement is calculated from V_{Ed} according to Formula (6.6).

In the pages following table 7.2 the code explains in detail how to calculate for each mode of failure. After checking the possible failure modes relevant to your application, the one with the least capacity becomes decisive. It determines the design resistance in shear of the connection in that application.

Changing things like the concrete strength or condition (tension or compression) can greatly influence the design resistance of the application.

A better understanding of the correct design and installation of anchors by all duty holders will ensure successful connections and a higher level of confidence and safety.

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