DESIGN OF FASTENINGS IN CONCRETE

Understanding and integrating the new standard: Eurocode 2 Part 4 (EN 1992-4)

THE NEW EUROPEAN DESIGN STANDARD: EUROCODE 2 PART 4 (EN 1992-4):

Fix your fastenings to the future!

Hilti has already implemented Eurocode 2's new section for the design of concrete fastenings (Part 4) into our PROFIS Engineering software together with the updated ETAs (European Technical Approvals).

The purpose of this paper is to

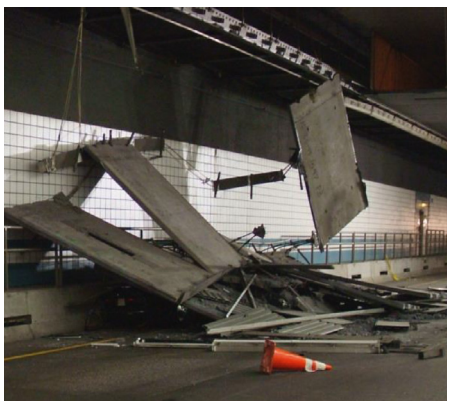
- elaborate on the changes in the new design standard
- enable the design of safer and more reliable fastenings for your projects
- show how you can increase productivity with simple software solutions that comply with the new standard

Enjoy reading!

SUMMARY

NEW EUROCODE STANDARD

Eurocodes are European standards for the design of buildings and civil engineering infrastructure. They enable structural engineers to design quality structures and monitor compliance in terms of safety and reliability. They have been published in CEN (European Committee for Standardization) accredited markets since 2009 and are already mandatory in many countries.



REMEMBER!

EUROCODE
European standards for the design of buildings and civil engineering structures

EOTA
European Organization for Technical Assessment

ETAG
European Technical Approval Guidelines

EAD
European Assessment Document

FASTENING TO CONCRETE

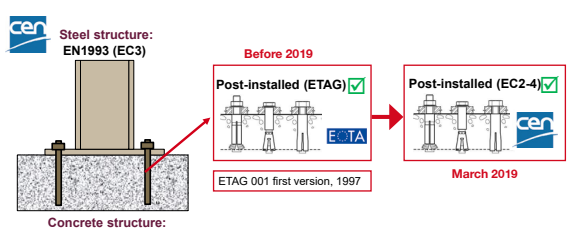
A new design standard to improve efficiency, consistency and safety in construction

They may be invisible, but they are everywhere. They are “concrete anchors”. They are used in both structural and non-structural applications to fasten one building element to another. A miscalculation during the design of fastenings or poor installation on the jobsite may have serious consequences, ranging from falling objects, failing handrails and even structural collapse.

The reason for designing according to Eurocode 2 Part 4 is to provide improved security, reliability and durability in your projects. Moreover, European design standard also helps to promote awareness among the engineering community on the importance of concrete fastening design.

From EOTA guideline to EN standard

Eurocodes have evolved over time to cover the design calculations for structures and only consider concrete fastenings. In the past, the design of concrete fastenings was linked to a series of recommendations which were formulated by European Organization of Technical Assessment (EOTA), in the form of technical approval guidelines such as ETAG 001. Since March 2019, the design of concrete fastenings has moved from the status of an EOTA guideline to an EN standard under the auspices of the CEN. In other words, the design of fastenings in concrete is now treated with the same importance as that of the concrete structure itself.



IN SUMMARY

What are the differences and similarities between Eurocode 2 Part 4 and ETAG 001?

Guidelines are used as a temporary solution in the absence of an official standard for a specific application or product. Standards supersede relevant guidelines and technical reports when they are officially published. Whereas standards are mandatory documents to be complied with, guidelines are treated more like a recommendation. However, they both have similar purposes, which is helping to avoid:

- Anchor failures that may lead to partial or total collapse of structures
- Possible casualties and economic loss due to improper anchor design

On the other hand, they also have certain differences:

ETAG 001

- Is a guideline and recommendation on howto design post-installed anchors
- Is only available in English
- Has limited updates
- Creates limited awareness as a non-mandatory document
- No definition for specification details and proper anchor selection on the jobsite

EUROCODE 2 PART 4

- Is a mandatory document when designing anchor channels, cast-in anchors and post-installed fastenings
- Will have local language versions in each CEN accredited country
- Will be supported with national annexes published by local governmental entities
- Creates high awareness for cracked concrete usage as a mandatory standard
- Defines how to specify anchors and which steps to follow on the jobsite enabling proper anchor selection and installation

TIMELINE

Concrete Fastenings: the development of technical documents

2019

Eurocode 2 Part 4 was published by CEN for the design of concrete fasteners
Eurocode 2 – Design of concrete structures – Part 4: Design of fastenings for use in concrete. A mandatory standard for concrete fastenings has major implications for the engineering community.

It has superseded previous design guidelines and technical reports such as: ETAG 001 Annex C, EOTA TR029, EOTA TR045, EOTA TR020 or also EOTA TR047
Official publication date: 31 March 2019.

2007

EOTA published the fifth part of ETAG 001 and TR029 technical report for bonded anchor design.

In 2013, EOTA published TR045 technical report for seismic design of post-installed anchors and ETAG 001 Annex E: metal anchors for use in concrete under seismic actions.

2004

EOTA published TR020, technical report for fire design of post-installed mechanical anchors.

1997

ETAG 001's first version was published. It was comprised of 4 parts with an annex for mechanical anchor design.
Part 1: General information on fastening bolts
Part 2: Torque controlled expansion anchors
Part 3: Undercut anchors
Part 4: Deformation controlled expansion anchors
Annex C: design of mechanical anchor calculations. Description of the design/calculation methods of metallic anchors in concrete

From 1990

First Eurocode launches:
Eurocode 2 (EC2) for the design of concrete structures
Eurocode 3 (EC3) for the design of structures in steel
As these standards do not cover concrete anchor design, there was a need for a new guideline.

REGULATORY PROCESS

Who defines the regulatory framework for construction products?

From 1989 to 2011, the CPD (Construction Product Directive) had been responsible for the regulatory framework for construction products. CPR (Construction Product Regulation) has since then replaced CPD to streamline regulations and increase transparency for construction products in Europe.

Development of technical documents: a regulatory process in 3 stages

1. A European organization defines the design requirements:

The CEN (European Committee for Standardization) develops the Eurocode Standards for specific applications and product types. CEN is the entity which oversees the European standards for the design, calculation and verification of building structures (e.g. Eurocode 2).

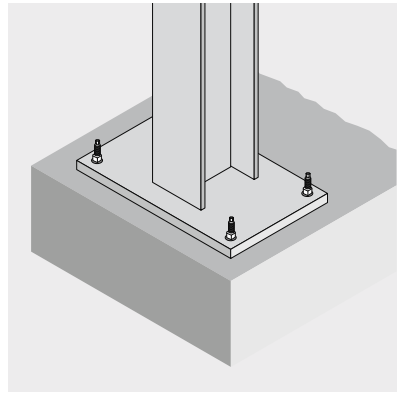
2. A European organization defines the assessment criteria:

EOTA (European Organization for Technical Assessment) formulates the European Assessment Documents (EAD) notably in the field of construction products. EAD defines the criteria to assess product performance. For example, when anchors are installed, different criteria are considered:

- Installation parameters (e.g. edge distance, spacing, required torque value, curing time etc.)
- Unpredictable effects of jobsite conditions (e.g. using old drill bits' effect on the performance)
- Concrete crack width effect
- Applied torque to tighten or install an anchor

3. Accredited entities publish European Technical Assessments based on these assessments:

Technical assessment centers such as the CSTB (Centre Scientifique et Technique du Bâtiment) in France, carry out European Technical Assessments (ETA) of construction products based on the criteria defined in the EAD.



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Transition from ETAG 001 to Eurocode 2 Part 4: What has changed?

Eurocode 2 Part 4 was published in March 2019 to replace the ETAG anchor calculation methods (Annex C of the ETAG 001 guide for metallic anchors and EOTA TR029 technical report for chemical anchors). The changes below in the design standard will have significant impact on the calculation:

- Concrete strength classes
- Anchor layout configurations
- Anchor failure modes
- Concrete strength class evaluation
- Performance evaluation criteria for various failure modes
- Tensile and shear combination evaluation

Here is the list of the main changes between the ETAG 001 and Eurocode 2 Part 4.

Eurocode 2 Part 4 provides a new layout plan for up to 9 anchors with 3x3 configuration, reassuring all those designers, who want to continue with a legitimate standard rather than engineering judgment method.

Concrete Strength Classes

Before: between C20/25 and C50/60 (ETAG).
Now: between C12/15 and C90/105 (Eurocode 2 Part 4).

The new EAD allows anchor producers to take ETA approvals beyond ETAG limits. It's now possible to make fastening design from C12/15 to C90/105.

As a structural designer, you can now feel more comfortable with renovation projects where concrete strength classes are lower than C20/25.

Anchor Layout Configurations

Eurocode 2 Part 4 covers 7 configurations:

The pre-requisite for using all these new configurations is that they need to be gap-filled unless;

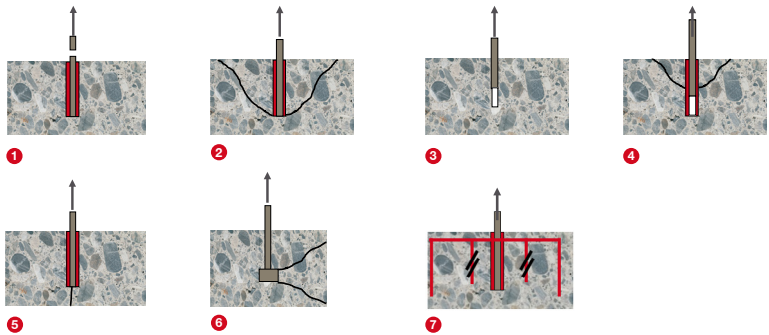
1. There is no shear force acting on the base plate

2. Shear load is acting on the base plate but anchors are located far from edge for all load directions: $c > 10h_{ef}$ or $c > 60d_{nom}$

IN PRACTICE 2/5

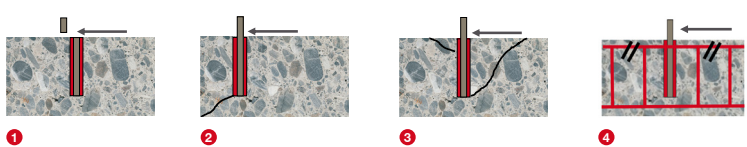
Anchor Failure Modes

Eurocode 2 part 4 states seven anchor failure modes for tension load:



1. Steel Failure
2. Concrete Cone Failure
3. Pull-out Failure (for mechanical anchors)
4. Combined Concrete Cone and Pull-out Failure (for chemical anchors)
5. Concrete Splitting Failure
6. Concrete Blowout Failure (valid for cast-in fasteners)
7. Steel and Anchorage Failures of Supplementary Reinforcement (new with Eurocode 2 Part 4)

Eurocode 2 part 4 states four anchor failure modes for shear load:



1. Steel Failure (with or without lever arm)
2. Concrete Edge Failure
3. Concrete Pry-out Failure
4. Steel and Anchorage Failures of Supplementary Reinforcement (new with Eurocode 2 Part 4)

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Concrete Strength Class Evaluation

Before: Under ETAG 001, concrete resistance was based on the strength of cubic samples

Now: Under Eurocode 2 Part 4, concrete resistance is based on the strength of cylindrical samples

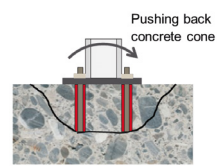
IN DETAIL

Equations to determine concrete-related failure loads, such as concrete cone failure and concrete edge failure, were originally determined by considering the concrete compressive strength measured on concrete cubes with an edge length of 200 mm. ETAG on the other hand considered a cubic strength with an edge length of 150 mm. Concrete strength factor "k" was also increased to compensate this strength loss. Therefore, an estimated 4% reduction in concrete strength can be expected.

Performance evaluation criteria for various failure modes

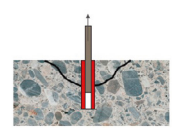
1. Concrete cone failure

When a base plate with minimum two anchors is subjected to a bending moment, a fastening system is set up consisting of a tensile force in the anchor and a compressive force beneath the fixture. In this design case, concrete cone failure load may be influenced by the adjacent compression stress block beneath the fixture. This effect is determined using the coefficient $\Psi_{M,N.}$ in Eurocode 2 Part 4.



2. Combined concrete cone and pull-out failure

Given that fastenings must ensure safe load transfer over many years, their long-term behavior is of greatest importance. When verifying the "combined pull-out and concrete cone failure" of chemical fasteners, Eurocode 2 Part 4 adds an additional coefficient Ψ_{sus} which is the effect of tension loads acting permanently on the fastening (sustained loading). Permanent dead loads decrease the bond strength of the chemical fastening over an extended period of sustained loading. This coefficient is product-specific and can be found in the product's European Technical Assessment (ETA) document. It is factored into the design by considering the ratio of the value of sustained loading related to the value of short-term loading. If no value is specified in the ETA, a default coefficient of Ψ_{sus} = 0.6 is applied. Hilti's PROFIS Engineering software simplifies post-installed anchor design based on each chemical anchor's unique Ψ_{sus} coefficient in its ETA.



Combined concrete cone and pull out resistance (bonding)

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

Important Note: The Ψ_{sus} figure is 0.6 by default unless the chemical anchor is retested to the new test standard and a new ETA with a higher value is published.

IN PRACTICE 4/5

3. Concrete Splitting Failure

Eurocode 2 Part 4 is more lenient than ETAG 001 when it comes to avoiding splitting failure:

- Edge distance (C_{cr}) must be greater than characteristic edge distance ($C_{cr,sp}$)
- Concrete thickness must be equal or greater than minimum value ($h_{,min}$)

Eurocode 2 Part 4 is more lenient than ETAG 001 when it comes to avoiding splitting failure:

Before **ETAG 001 Annex C**	**Now** **Eurocode 2 Part 4**
• In all directions c ≥ $1.2C_{cr,sp}$ • I• h ≥ $2h_{ef}$ for mechanical anchor • I• h ≥ $2h_{min}$ for chemical anchor or • Reinforcement in cracked concrete that limits crack width up to 0.3 mm	• In all directions c ≥$1.0C_{cr,sp}$ for a single anchor or c ≥ $1.2C_{cr,sp}$ for group anchors. • h ≥ h_{min} or • Reinforcement in cracked concrete that limits crack width up to 0.3 mm.

4. Steel Failure (with lever arm)

Eurocode 2 Part 4, allows the structural designer to take advantage of grout thickness between 0.5d <t <40 mm in uncracked concrete; and makes an improvement in the steel strength for base plate applications with stand-off.

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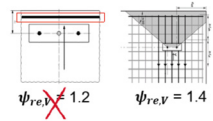
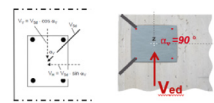
5. Concrete Edge Failure

ETAG 001 increased resistance against “concrete edge failure” in cracked concrete by 20% ($\Psi_{re,V}$ = 1.2), however in Eurocode 2 Part 4 straight edge reinforcement is ignored.

Eurocode 2 Part 4 has modified the Ψ_{α} coefficient which is used for shear forces acting parallel to the concrete edge. The new standard gives 20% lower shear resistance than ETAG 001 under prevailing shear load which is 90 ° perpendicular to the concrete edge failure direction with this update.



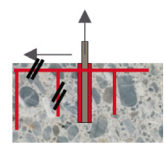


$$\Psi_{\alpha} = \sqrt{\frac{1}{(\cos\alpha_v)^2 + (\sin\alpha_v)^2}}$$

EC2-4: 0.5

6. Supplementary Reinforcement Failure

Both concrete edge breakout and cone failures can be avoided with supplementary reinforcement however, the steel and anchor failure mode of this element is also verified in the standard.



Tensile and shear combination evaluation

Before	Now
ETAG 001 considered two different equations to check the tension and shear load combination depending on whether there was governing steel failure or not.	On top of ETAG 001’s requirements, Eurocode 2 Part 4 also takes into consideration the effects of supplementary reinforcement during combined tension and shear load check and evaluates steel and concrete governing failures separately.

TOOLS AND SERVICES

How to enable you that your fastening designs comply with Eurocode 2 Part 4?

Fastening designs must comply with the updated code. This new standard is an opportunity for structural and civil engineers to design and install anchors in such a way that our buildings and infrastructure are safer and more reliable. Hilti has already updated our products with new ETA approvals and our PROFIS Engineering software already allows engineers to design according to the new standard making fastening design easier and safer.

PROFIS Engineering software using, Eurocode 2 Part 4 available now.

Anchor design has moved to a new era with PROFIS Engineering software! You will now be able to design your fastenings in total compliance with Eurocode 2 Part 4.

PROFIS Engineering software not only makes designing easier but also helps to increase productivity as you have the option of importing load combinations from structural design software (Dlubal RSTAB / RFEM) and exporting designs to your BIM modelling software (Tekla Structures).

8 reasons to use PROFIS Engineering

Time saving

Import load combinations: compatible with modelling software such as Dlubal RSTAB / RFEM – you can import load combinations from different software separately.

All-in-one software

Modelling your anchors with base plates: Reduce the number of software and tools to design the thickness, stiffeners and welding of your anchor base plate.

Automatic export to your numerical models

With just a few clicks, you can download dimensions of concrete slab, base plate, welding, stiffener and anchors to your modelling software (e.g. Tekla Structures)

Online version

Use the online software to work with the latest version.
Reducing contact with IT for softwareupdate requirement.

Technical assistance

Our engineering team is at your disposal for your questions related to PROFIS software!

Handrail and guardrail design module

Helping you to design your handrail and guardrail profiles, base plates and anchors in compliancewith the National Annexes

Easy order

PROFIS Engineering shows the item numbers needed for anchor installation.
Order all itemsfor anchor selection and installation on www.hilti.xxx

Designing according to Eurocode 2 Part 4 standard

PROFIS ENGINEERING

FREE TRIAL!

DID YOU KNOW?

Our range of software and construction services help you learn more about the new standard.

Video: the essentials in 60 seconds

Watch our video and discover all you need to know about the new European standard Eurocode 2 Part 4.

✓ Discover

Video: interview with François Régnier

Decode the European standard Eurocode 2 Part 4 with François Régnier, Technical Marketing Manager for Western Europe.

✓ Discover

A product guide for cracked concrete

Eurocode 2 Part 4 asks structural designers to verify if concrete is uncracked. There are many factors that exert stresses on concrete such as temperature changes, permanent live loads acting on the base material, tension force acting on steel base plate etc. It is nearly impossible to verify concrete stress except when you subject it to specific conditions. Make sure you select the cracked concrete option in PROFIS Engineering!

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