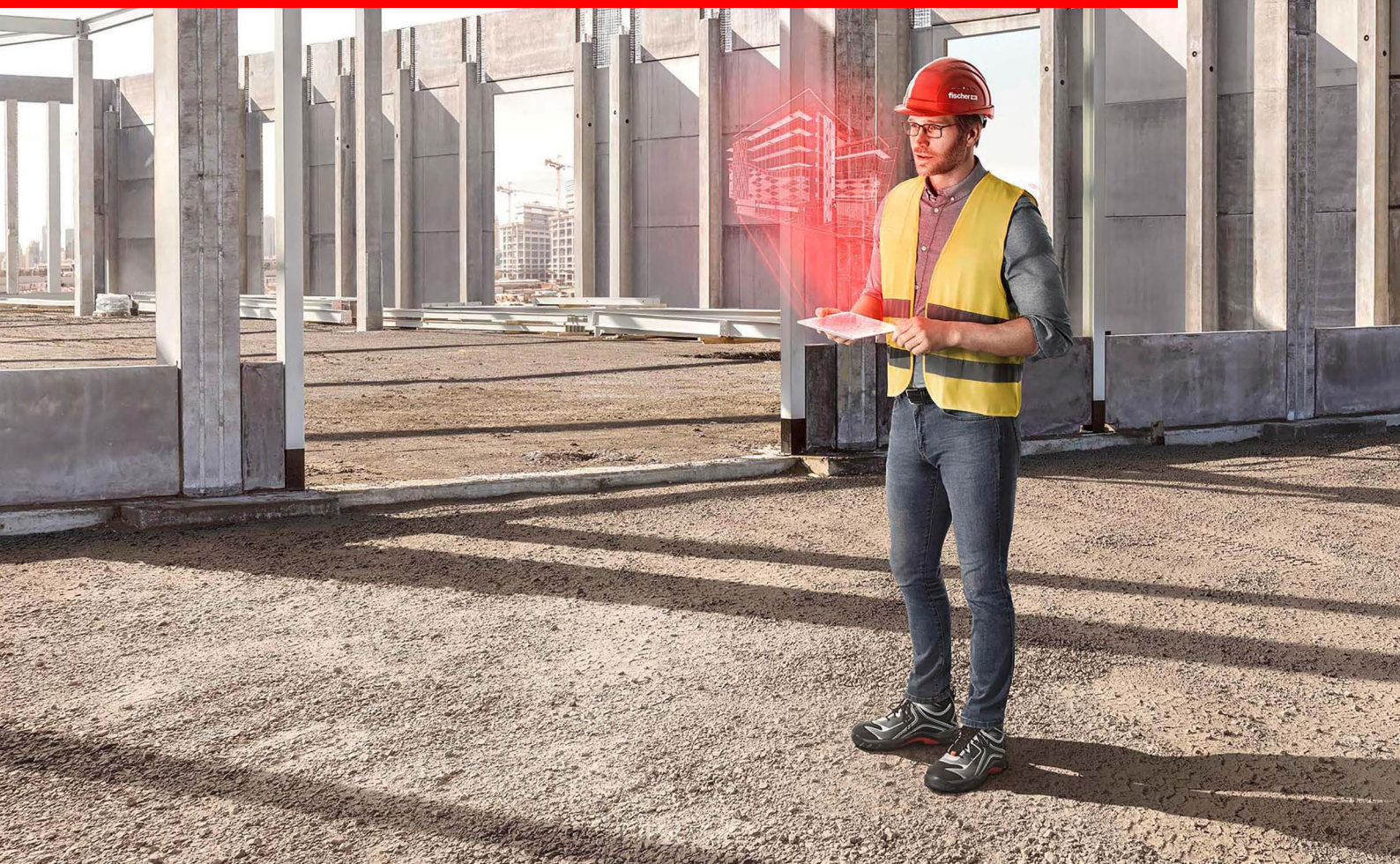


The importance of the new EN 1992-4 standard for the design of fastenings in concrete.

A white paper for structural
engineers, construction
engineers and planners.



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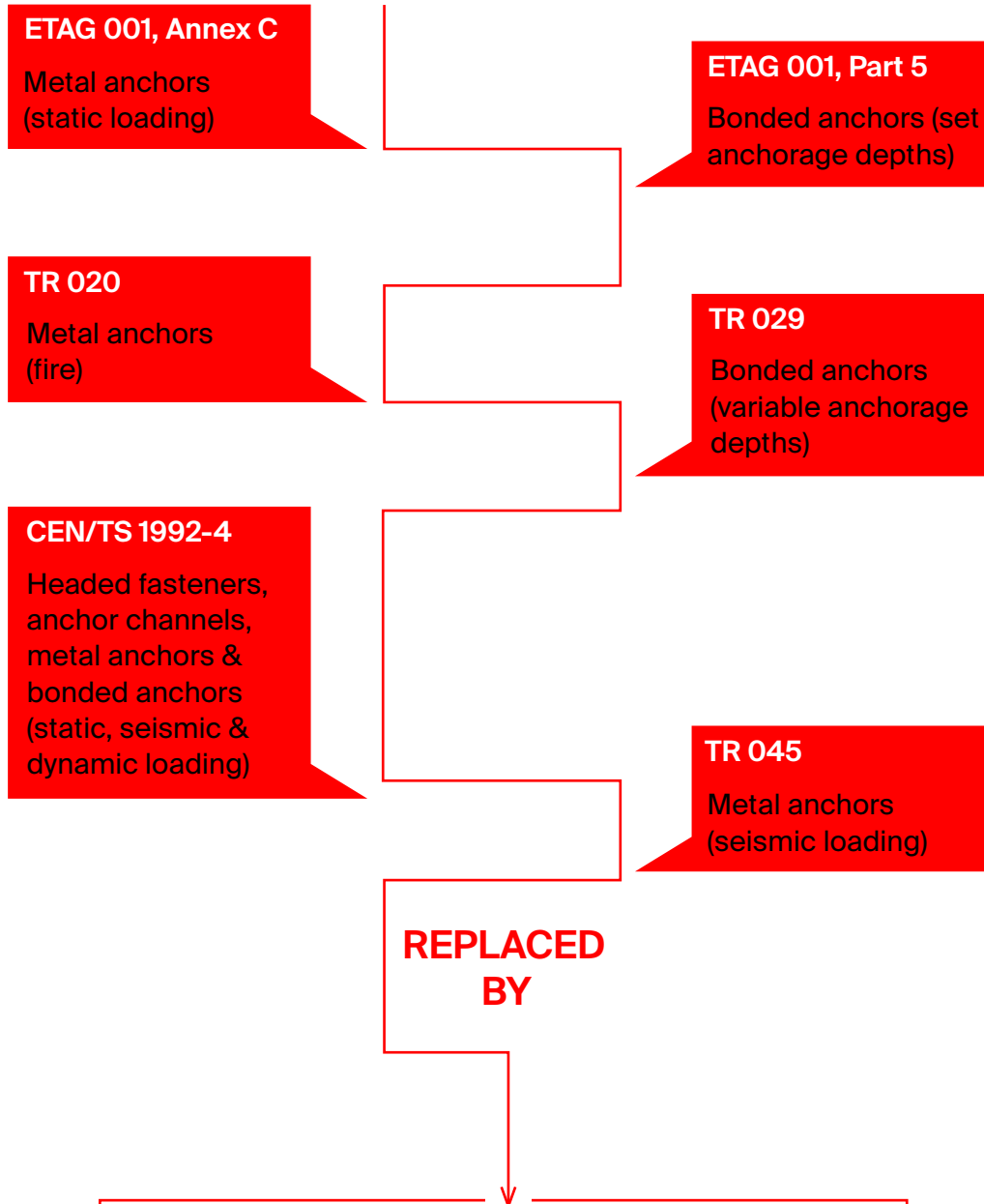
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Any further questions?

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Design guidelines

The path to EN 1992-4.



EN 1992-4 – in effect as of spring 2019

For the first time there is a uniform standard that regulates the design of fastenings in concrete across Europe. EN 1992-4 is a key document that supersedes all previous design guidelines for fastenings in concrete in Europe.

History

The first design guidelines for fastenings in concrete valid throughout Europe were published in 1997 by the European Organisation for Technical Approvals (EOTA) in Annex C of the ETAG 001 guideline. This was followed by several Technical Reports (TR) and the CEN/TS 1992-4 technical specification by the CEN, the European Committee for Standardisation, in 2009. This Committee also developed EN 1992-4.

EN 1992-4

A brief introduction

Has EN 1992-4 already been adopted by building authorities? And how do structural engineers approach calculations that were carried out before the new standard was introduced and which now provide a different result under the new standard? Dr. Thilo Pregartner is regularly confronted by practical questions such as these. The fischer expert is familiar with users' problems and the complex multitude of guidelines and technical reports that previously regulated the design of fixings in concrete (see diagram on p. 3). "This was always cause for confusion", says Thilo Pregartner, speaking from experience. The situation will be made significantly more transparent and clearer with the introduction of EN 1992-4.

An efficient procedure

EN 1992-4 was published in early 2019. As part 4 of Eurocode 2 ("design of concrete structures"), it comprehensively regulates the design of

fastenings in concrete in accordance with the latest standards in technology. It also provides planners, structural engineers and construction engineers with a significantly more efficient approach when it comes to design.

User advantages: They save time on creating the designs. The standard also provides added safety for construction projects.

This white paper provides a basic overview of the current state of the art:

- What are the most important changes to the design of fastenings in concrete?
- What do planners, structural engineers and construction engineers have to take into consideration in future?
- Which programmes offer design support in accordance with the new standard?

Eurocode 2 EN 1992 (EC2)

The Eurocode 2 standards apply to the design of buildings and civil engineering works in plain, reinforced and prestressed concrete in the European Union.



Everything in one document

The main advantage of the new standard is that it compiles the design of various fastening systems and action categories into one key document. The standard therefore applies to both the design of inserts (anchor channels and headed fasteners) as well as the design of post-installed fastenings (metal expansion anchors, undercut anchors, concrete anchors, bonded anchors and bonded expansion anchors).

EN 1992-4 furthermore covers designs for the following action categories:

- static and quasi-static
- dynamic
- seismic
- fire exposure

An important step

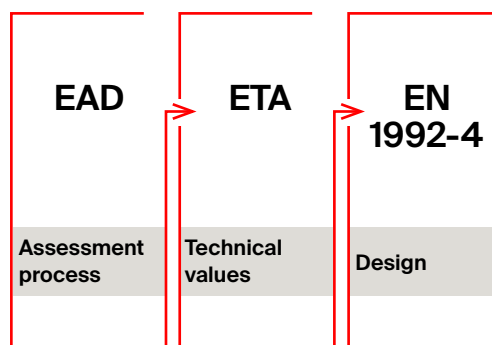
The publication of EN 1992-4 is an important step for the fastening technology industry. Prior to 2019, the design of fastenings in concrete was merely regulated by guidelines or Technical Reports (TR). Standard-based regulation gives the subject higher priority in the construction business. The safety concept for fastenings in concrete has now also been directly adapted to the Eurocode safety concept for reinforced concrete constructions.

Its introduction across Europe guarantees a uniform approach to design. National annexes offer the option to adapt the standard to country-specific conditions. The German national annex contains adaptations for the design of fastenings under seismic loads, for instance.

Introduction by German building authorities

EN 1992-4 had not yet been referenced as a design method in the

2019 Model Administrative Provisions – Technical Building Rules ("Muster-Verwaltungsvorschrift Technische Baubestimmungen" – abbreviated to MVV TB), but applied as the state of the art. It is expected to officially be introduced as the design standard in the new edition of the 2020 MVV TB, thereby becoming mandatory in Germany. Designs carried out prior to this complied with the national construction law at the time and shall continue to be valid. But planners, structural engineers and construction engineers must exercise caution when it comes to changes in the new standard compared to previous applicable guidelines. The state-of-the-art technology has changed for bonded anchors under permanent loads, for example: The new ψ_{sus} reduction factor can lead to significant differences during the design process (see p. 12).



System for valid designs

The basis of design

EN 1992-4 designs are based on a three-part system consisting of the design standard, European Technical Assessments (ETA) and the corresponding European Assessment Documents (EAD). Input parameters or specific characteristic resistance values from the ETAS form the fundamental prerequisite for the application of the new standard. Many ETAs have already been converted to designs in accordance with EN 1992-4.

MVV TB Model Administrative Provisions – Technical Building Rules

In Germany, the MVV TB is gradually being translated into national law. Construction products shall therefore exclusively be subject to the building regulation requirements of the state building code and the VV TB of the federal state.

i The **ETAs** define the methods and criteria for assessing the performance of the fastening elements.

Dr. Oliver Geibig has extensive experience with fixing systems training and marketing, including via digital media.



»We acknowledge our responsibility by professionally processing new regulations for our customers through presentations, our Fixperience software and via individual training sessions at the fischer Academy «

Dr. Oliver Geibig, Authorised Representative and Division Head Research, Development & Trend Scouting at fischer

The CC Method

The principles of designing fastenings in concrete.

The so-called concrete capacity method was published by the CEB (Comité Européen du Béton) in 1995 and is based on the performance capacity of concrete. The CC method allows planners and structural engineers to design fastenings in a safe and economic manner.

Accepted internationally

The CC method is a semi-empirical method based on partial safety factors. It was adopted into Annex C of the ETAG 001 guideline in 1997 by the EOTA (European Organisation for Technical Approvals). The method has undergone constant development ever since and is accepted internationally.

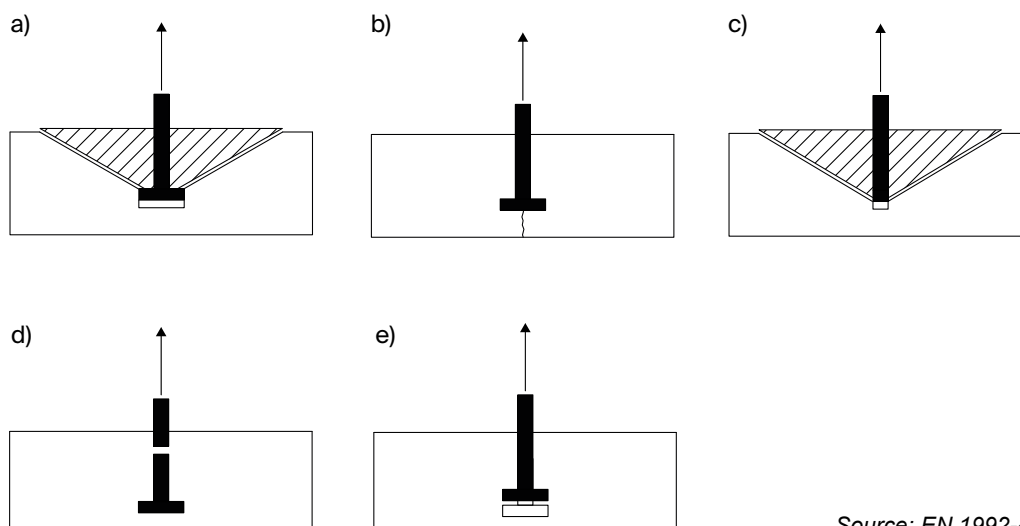
The CC method takes the following into account:

- various concrete conditions (cracked or non-cracked)
- various load directions (tensile, shear and interaction)
- various failure modes

Separate verification

During the CC method verification is carried out for the load-bearing capacity for all types of failure modes and every load direction (tensile and shear load). During the initial design step, the load distribution of the outer load must be determined for the individual fastenings of a group. The inner eccentricity of the load is also determined. Depending on the failure mode, the CC method requires verification with the loading of the most critically loaded anchor or with the group loading (with the corresponding inner eccentricity). It is assumed that the anchor plate remains level, meaning it is sufficiently rigid and lies flush with its entire surface against the concrete.

Verification under tensile load is always carried out on the most critically loaded anchor in the case of pull-out failure and steel failure, as the load-bearing capacity is not influenced by neighbouring fastenings during these failure modes.



Tensile loading can lead to the following failure modes:

- a) Concrete pryout failure
- b) Splitting
- c) Bonded anchors: Combined failure - concrete pryout and pull-out failure
- d) Steel failure
- e) Pull-out failure

Source: EN 1992-4

Group verification is always carried out for concrete failure modes, as neighbouring fastenings or edges affect the group load-bearing capacity. The following merely provides an explanation of the concrete pryout failure mode – the method can be applied in a similar manner to other failure modes.

Concrete failure

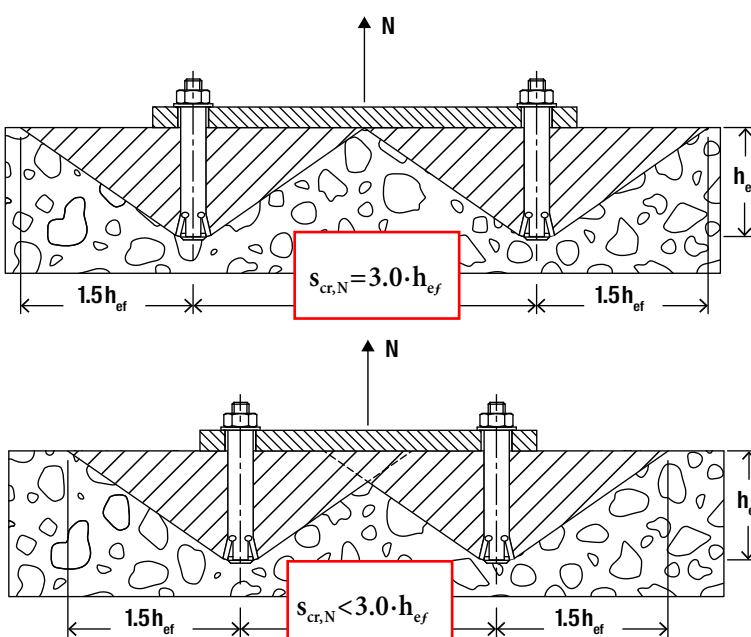
The breakout body of the individual anchor is the foundation for the group verification in case of concrete failure. The cone failure is idealised as a pyramid with a square base area. The base area of the pyramid is projected onto the upper side of the component.

The total load-bearing capacity is assessed by the surface ratio in order to be able to measure the action of several anchors (group load-bearing capacity). The surface required for full load-bearing capacity is used as the base surface. Anchors placed sufficiently far apart (distance greater than the characteristic spacing) each achieve the full load-bearing capacity of the individual anchor.

The characteristic edge distance $c_{cr,N}$ is crucial to the action of edges, as is the characteristic spacing distance $s_{cr,N}$ on group effects. The theoretical fracture surfaces overlap when anchors are placed in close proximity. The entire available fracture surface of the group is determined and put in relation to the base surface. The group load-bearing capacity is multiplied by the ratio of the projected surfaces and is smaller than or equal to the added load-bearing capacity of the individual anchors. When it comes to fastenings near an edge the projected surfaces are determined analogous by taking the characteristic edge distance into account.

Influencing factors ($\Psi_{i,N}$)

Further actions such as edges, eccentric load positions etc. are taken into account via additional influencing factors. Once all individual verification for tensile and shear loads has been carried out and fulfilled, the interaction between tensile and shear loads is examined. Specialist verification for combined failure was added to the CC method for bonded anchors in 2007.



Assessment of non-influenced anchor

Assessment of influenced anchor

Source: Eligehausen, Mällée, Silva

Concrete pryout failure under tensile load:

$$N_{Rk,c} = N_{Rk,c}^0 \cdot A_{c,N} / A_{i,N}^0 \cdot \Psi_{i,N}$$

Calculating the projected surfaces

Cone failure without overlap
(see upper left diagram)

Cone failure with overlap
(see lower left diagram)

The characteristic edge distance and the characteristic spacing are defined as follows:

$$c_{cr,N} = 1.5 \cdot h_{ef}$$

$$s_{cr,N} = 3.0 \cdot h_{ef}$$

The base area of the individual anchor without edge and spacing effect is calculated from:

$$A_{c,N}^0 = s_{cr,N}^2 = 9 \cdot h_{ef}^2$$

The base area of the existing groups is derived from the existing surface area of the projected areas taking into account the existing edge distances and spacing and the characteristic edge distances and spacing

The 5 most important changes.

1. Concrete strength classes

The new EN 1992-4 standard covers concrete strength classes C12/15 to C90/105 for the first time. However, ETAs currently only apply to concrete strength classes C20/25 to C50/60. The scope of the ETAs is expected to be expanded in future, however.

2. Shift to compressive cylinder strength

One of the fundamental changes of EN 1992-4 is the use of compressive **cylinder strength instead of the concrete's cube compressive strength**. The characteristic cylinder strength with a diameter of 150 mm and a height of 300 mm (f_{ck}) tested at 28 days was used for the Eurocode 2 classification.

Numerous CC method equations are determined empirically and are based on cube compressive strength. The shift affects all equations that have dimensional prefactors. This is demonstrated in the following points 2.1 Tensile load and 2.2 Shear load.

2.1 Tensile load

C12/15	C16/20	C20/25	to	C50/60	C55/67	to	C90/105
--------	--------	--------	----	--------	--------	----	---------

ETAG 001, Annex C etc.

EN 1992-4

EN 1992-4 covers many concrete strength classes

The action of the specimen geometry becomes evident when calculating the characteristic resistance for the cone-shaped **concrete breakout failure mode (right)**, for instance. The compressive cylinder strength f_{ck} is of a lower value than the cube compressive strength, which is why factor k_1 was adapted for designs according to EN 1992-4. This factor is increased to 7.7 for cracked concrete and to 11.0 for non-cracked concrete. As a result, the base value of the characteristic resistance is lower for all concrete failure modes than before

2.2 Shear load

Compressive cylinder strength is also applied for the **concrete edge breakout failure mode (right)** in accordance with EN 1992-4, but factor k_9 was not adapted due to re-evaluated test results and an extension of the equation's validity. Compared to previously applicable guidelines, the factor remains at 1.7 for cracked concrete and 2.4 for non-cracked concrete.

Concrete pryout failure:

ETAG 001/TR029

$$N_{Rk,c}^0 = k_1 \cdot h_{ef}^{1.5} \cdot \sqrt{f_{ck,cube}}$$

$$k_1 = 7.2 \quad \text{cracked concrete}$$

$$k_1 = 10.1 \quad \text{non-cracked concrete}$$

EN 1992-4

$$N_{Rk,c}^0 = k_1 \cdot h_{ef}^{1.5} \cdot \sqrt{f_{ck}}$$

$$k_1 = 7.7 \quad \text{cracked concrete}$$

$$k_1 = 11.0 \quad \text{non-cracked concrete}$$

Concrete edge failure:

ETAG 001/TR029

$$V_{Rk,c}^0 = k_1 \cdot d_{nom}^a \cdot l_f^b \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$$

$$k_1 = 1.7 \quad \text{cracked concrete}$$

$$k_1 = 2.4 \quad \text{non-cracked concrete}$$

EN 1992-4

$$V_{Rk,c}^0 = k_9 \cdot d_{nom}^a \cdot l_f^b \cdot \sqrt{f_{ck}} \cdot c_1^{1.5}$$

$$k_9 = 1.7 \quad \text{cracked concrete}$$

$$k_9 = 2.4 \quad \text{non-cracked concrete}$$

The 5 most important changes.

3. Layout of fastenings on anchor plates

In contrast to the guidelines of standards applicable thus far, EN 1992-4 provides significantly more permissible anchor layouts: Groups up to a maximum of 9 are now possible for

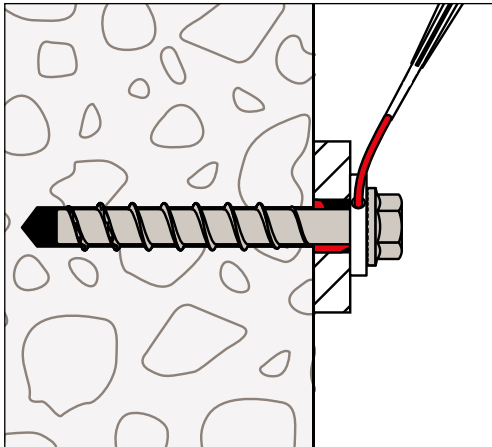
fastenings without hole clearance, which applies to all edge distances and load directions. Post-installed fastenings are considered fastenings without hole clearance if the annular gap is filled with suitable mortar.

New: Use a filling disc!

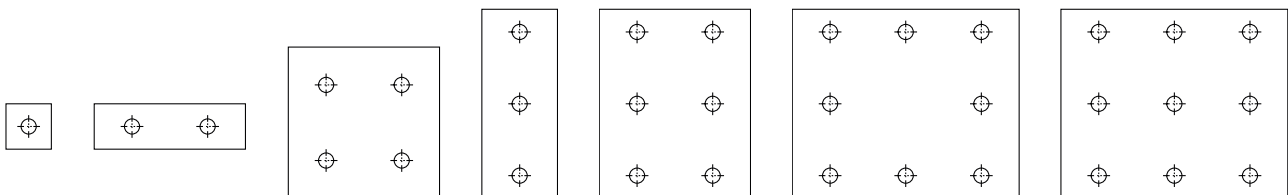
The gap between the fastening element and the component must be filled with a mortar with sufficient compressive strength ($\geq 40 \text{ N/mm}^2$). A **filling disc** is used for this purpose and allows the annular gap to be filled without the formation of bubbles. Rectangular groups of 4 are the maximum permitted layout for fastenings close to the edge without annular gap backfilling (see EN 1992-4 for details).

Filling disc

This is used for the subsequent filling of the annular gap when using metal and bonded anchors.



Filling the annular gap



Valid anchor layouts

The facade cladding of the thyssenkrupp elevator test tower in Rottweil is securely attached with heavy-duty anchors by fischer



Dr. Thilo Pregartner is familiar with the many new EN 1992-4 guidelines and knows what effect they have on day-to-day operations



»The new EN 1992-4 standard for the design of fastenings in concrete increases the level of safety and transparency when designing fastenings«

Dr. Thilo Pregartner, Head of Approvals and Technology Transfer at fischer

The 5 most important changes.

4. Bonded anchors under permanent load: Ψ_{sus}

Ceiling panels with a combined weight of 2.6 tonnes collapsed onto a moving vehicle in a road tunnel in Boston (USA) in July 2006. The passenger was killed while the driver was injured. A report by the US transportation agency NTSB found that the severe accident was caused by the use of a substandard epoxy resin that was unable to hold a constant load

Ψ_{sus} Reduction factor

As a result of this accident, in-depth research was carried out into the load-bearing capacity of fixings under creep strain, with the new findings being incorporated into the design of bonded anchors in concrete.

Creep tests carried out with bonded anchors in concrete under different temperatures came to the following result: The transferable bond stress

can be up to 40 per cent lower at the end of a product's working life (50 years) than at the beginning of it. The product-dependant reduction factor Ψ_{Osus} was therefore introduced with EN 1992-4.

Erhebliche Unterschiede

The new reduction factor can result in significant differences when comparing the design results according to the old EOTA TR 029 or CEN/TS 1992-4 regulations to designs according to the new EN 1992-4 standard. Because the reduction factor depends on the product, various mortars can also lead to various design results.

In principle, the value of Ψ_{Osus} is defined in the ETAs for the corresponding product. If the ETA does not indicate a value, EN 1992-4 recommends applying a reduction factor of 0.6.

Calculating the actual reduction:

$$N_{\text{Rk,p}}^0 = \Psi_{\text{sus}} \cdot \tau_{\text{Rk}} \cdot \pi \cdot d \cdot h_{\text{ef}}$$

$$\Psi_{\text{sus}} = 1.0$$

$$\text{for } \alpha_{\text{sus}} \leq \Psi_{\text{sus}}^0$$

$$\Psi_{\text{sus}} = \Psi_{\text{sus}}^0 + 1 - \alpha_{\text{sus}}$$

$$\text{for } \alpha_{\text{sus}} > \Psi_{\text{sus}}^0$$

See following page for details on α_{sus}

Many fastenings were implemented with fischer heavy-duty fixings inside the Brenner Base Tunnel

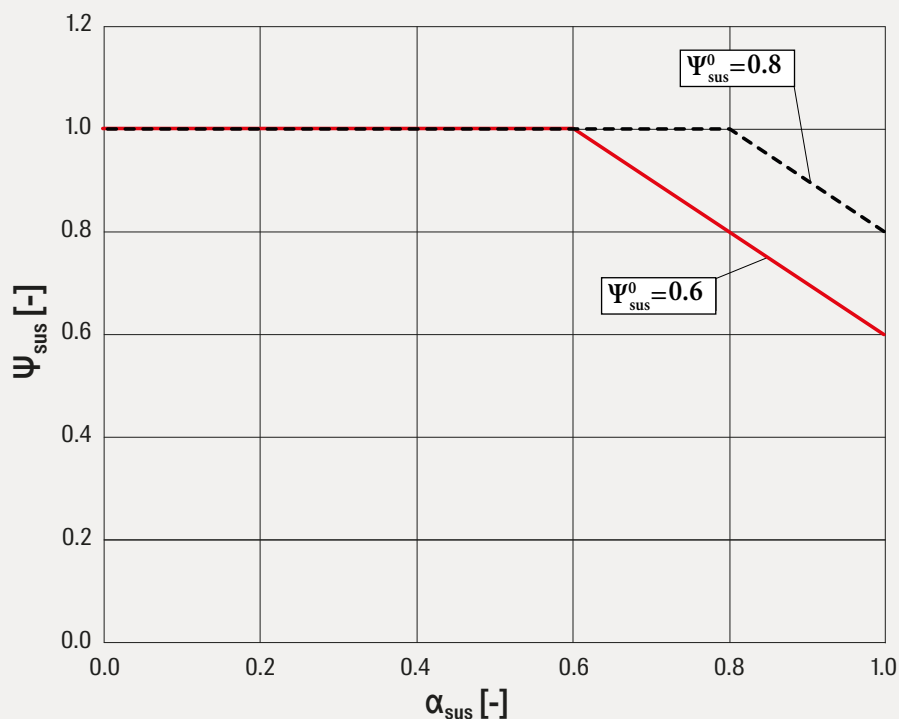
Calculating the reduction factor under constant load

The size of the actual reduction depends on the ratio of the creep-generating sustained tensile load to the sum of the applied total load (α_{sus}). Should this ratio exceed the value of $\psi_{0\text{sus}}$, the ψ_{sus} factor is linearly reduced starting from 1.0. The maximum reduction factor amounts to barely $\psi_{0\text{sus}}$ when the creep-generating sustained tensile loads correspond to the value of the sum of the total loads (tension). The ratio of the permanent load to the total load (tension) is therefore crucial to the efficient design of bonded anchors.



Combined failure of a bonded anchor

α_{sus} describes the ratio of the sustained load to the total load. Both permanent loads and the sustained proportion of variable loads are considered sustained loads.



The ψ_{sus} reduction factor is product-dependent. If the ETAs do not define a value for $\psi_{0\text{sus}}$ then EN 1992-4 assumes a maximum reduction of the transferrable bond stress of 40 per cent ($\psi_{\text{sus}} = 0.6$).

The 5 most important changes.

5. Interaction between tensile and shear loads

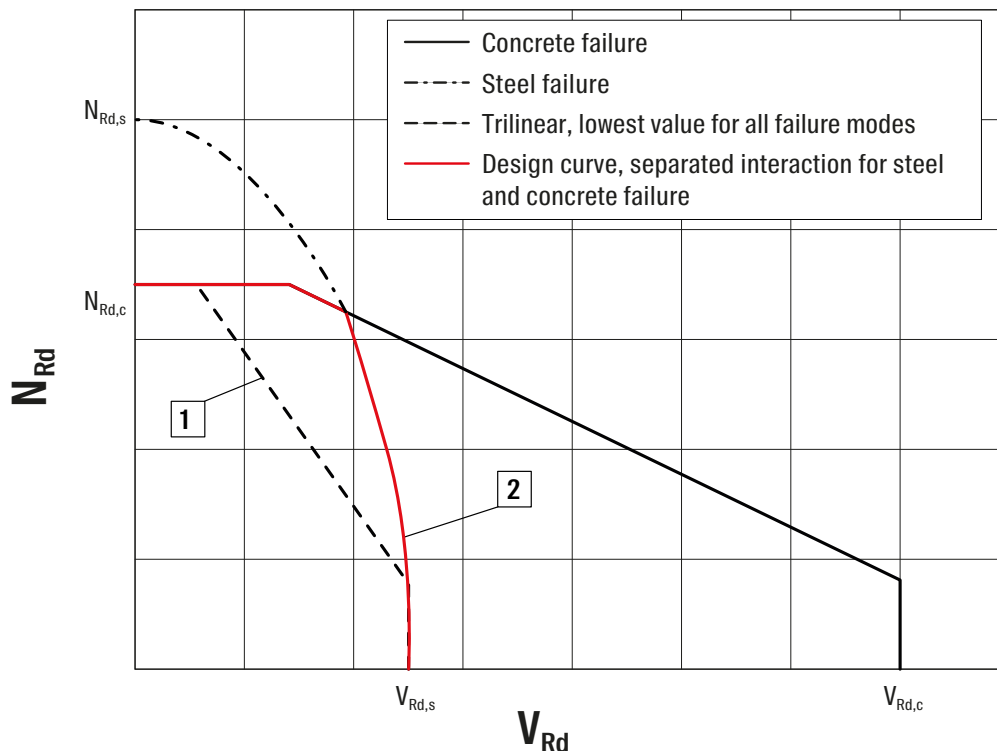
EN 1992-4 introduces a new approach to verification in case of interaction, for which the evaluation is carried out separately according to failure mode. Up until now, the maximum ratio of impact and resistance of all possible failure modes under tensile or shear load was applied in the interaction equation. This approach provides conservative results, as various failure modes and the resulting forces are superimposed. Furthermore, the stresses can appear in varying places and in differing materials, for example concrete failure under tensile load or steel failure under shear load.

Separated evaluation

The new approach introduced with EN 1992-4 initially provides evidence for steel failure before providing additional proof of interaction for other failure modes, resulting in separate verification of the utilisation of both interaction conditions. This represents the actual behaviour, ensuring the design approach complies with other regulations.

Improved performance

One of the major advantages of separate evaluation of interactions is that it enables better fastening performance. This applies to all fastening systems covered by EN 1992-4, including headed fasteners, anchor channels as well as anchors.



i Comparison of design curves
Curve 1 depicts the previous approach, curve 2 shows the improved EN 1992-4 approach.

Diagram: Sippel, Ignatiadis

fischer Fixperience

Safety becomes calculable with the planning software's C-Fix module.

Verification is required to prove that a selected product is suitable for the required load in order to prevent an anchor from failing. This makes simple design software for planners, structural engineers and construction engineers an essential.

Design with C-Fix

fischer's free Fixperience software comprises engineering software in addition to seven specialist application modules. The C-Fix module is the right choice for the design of steel and bonded anchors in concrete. The programme follows the logical approach of manual verification and is mostly self-explanatory. Users can immediately commence planning their projects after downloading the software. Anchor plates can be modelled according to requirements before adding the structural steel section and inserting the applicable loads. Next, the user selects the anchors of

their choice. The programme ideally confirms a valid design before generating a verifiable printout. If this isn't the case, then multiple designs can be carried out. The programme calculates all applicable products before recommending suitable products.

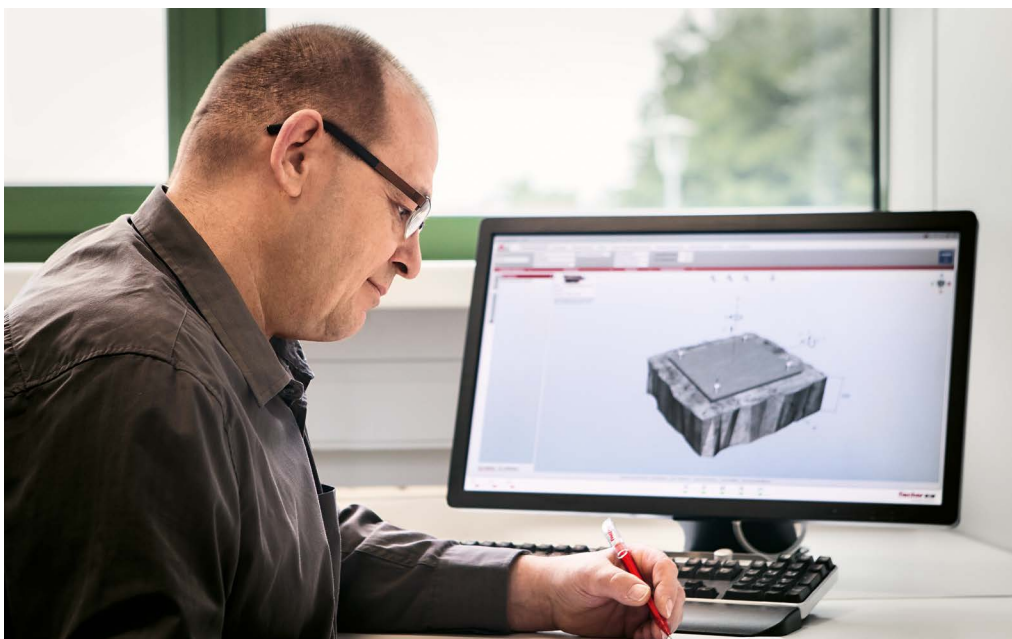
Integrated EN 1992-4

The Fixperience software by fischer undergoes continuous development to meet the design standards and requirements of planners, structural engineers and construction engineers. The new EN 1992-4 standard has already been fully integrated into the Fixperience software. The advantage: The user is on the safe side and does not have to worry about whether the right design standard has been selected for the corresponding product. fischer Fixperience contains all the necessary information from the ETAs.



Download and try out fischer Fixperience free of charge now!

Go to the Fixperience Suite



i The C-Fix module provides standardised designs for steel and bonded anchors in reinforced concrete.

Johannes Braun is in
charge of developing
fischer Fixperience



» Our Fixperience software contains
design standards for 120 countries
and is available in 20 languages «

Johannes Braun, Head of International Application
Engineering at fischer

Building Information Modeling fischer's all-round BIM service.

Whether it's an architectural model, a structural model or a building services model: Building Information Modelling (BIM) is being used with increasing frequency in the construction industry. To begin with, a digital building model is designed that serves as the basis for the real construction. These precise models reduce potential errors in addition to costs. Further benefits include simpler collaboration with other companies via cloud solutions as well as the constant and immediate availability of planning data on the construction site.

Integrated BIM Attributes

BIM-ready product data are a prerequisite to virtual planning. All relevant fischer products are therefore equipped with fundamental BIM attributes that enable the conceptual and digital display of the products.

This data can be downloaded free of charge and the fischer solutions can be added to the building model in just a few clicks.

A wide range of services

fischer provides a wide range of additional support services, such as 3D scanning including point cloud analysis and as-built documentation for renovation and extension projects. The fischer fixings specialist offers **BIM engineering** from the conceptual design stage to the maximum level of detail (LOD 500), allowing you to quickly find the right solutions for fastenings, installation systems and facade substructures. On-site BIM support allows you to precisely project the components from the 3D model onto the construction site while making any adjustments directly on the spot.



i The fischer experts provide advice on how to speed up your construction project using BIM: BIM@fischer.de

fischer's BIM-ready product data provides all the essentials on the construction site.



fischer Academy

Experience live fixing technology.

Structural engineers, civil engineers, designers or installers – anyone working in planning and construction using safe and efficient fastenings must participate in continuous



Experienced seminar instructors share their knowledge

professional development. The Academy by the fixings specialist fischer is one of the leading choices for high-quality and practical training.

35 years of the fischer Academy

The company has been offering targeted seminars for professionals in the construction industry for over three decades. The fischer Academy works in cooperation with trainers who understand their “trade”. All state-of-the-art training sessions provide information on current national and European standards

and guidelines as well as statutory provisions and their implementation during planning and processing. Our trainers complete theoretical and practical training and development sessions year after year to guarantee the high standard of quality.

Training on demand!

The seminar rooms of the fischer Academy in Tumlingen in the Black Forest are perfectly equipped for specialist training sessions of any kind. To make things easier for those interested, the specialist seminars are also offered at selected educational facilities and professional associations across Germany or directly on company premises.

Technical advice

fischer supports its customers with comprehensive and personal technical advice and fastening know-how from the planning stage to the project's completion. The company helps structural engineers, planners and civil engineers efficiently optimise anchor constructions and design specialist constructions and designs, for instance.

Training for planners and structural engineers:
Book the training session of your choice now!

www.fischer.co.uk/en-gb/training



First-hand expert know-how



Which product suits which project?

Summary.

White paper summary EN 1992-4.

Published in early 2019, the EN 1992-4 standard comprehensively regulates the design of fastenings in concrete as Part 4 of Eurocode 2, replacing a multitude of old guidelines and technical reports. EN 1992-4 represents the latest standards in technology and increases the level of safety for the user in addition to the transparency of anchor design.

The 5 most important changes

The following is a summary of the key changes introduced with EN 1992-4:

1. Concrete strength classes

The standard covers the concrete strength classes C12/15 to C90/105.

2. Shift to compressive cylinder strength

Unlike previous guidelines, EN 1992-4 is based on compressive cylinder strength rather than cube compressive strength. This affects all CC method equations that have dimensional prefactors.

3. Layout of fastenings on anchor plates

According to EN 1992-4, groups up to a maximum of 9 are now possible for fastenings without hole clearance. This applies to all edge distances and load directions.

4. Bonded anchors under permanent load

Bonded anchors under creep-generating sustained (tensile) load lead to a reduction in the transferable bond stress over time. The product-dependent reduction factor ψ_{0sus} was therefore introduced with EN 1992-4.

5. Interaction between tensile and shear loads

The new standard takes separate account of the interaction of tensile and shear loads by failure mode and location, enabling improved performance.

Selecting the design rule

The new EN 1992-4 standard applies across Europe to both the design of inserts and the design of post-installed fastenings while covering a wide range of action categories. European Technical Assessments (ETA) remain the key document for design.

Simple design software that features the new standard and automatically selects the right design rules for each product is an essential for structural engineers, planners and construction engineers.

Any further questions?

We're happy to help!

Get comprehensive anchor design support from fischer's Technical Advice department:

Telephone: +49 7443 12 - 4000

(Mon – Thu: 7:30 – 17:30 CET,

Fri: 7:30 – 17:00 CET)

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The fixings specialist fischer

The product range of the long-established family-owned business includes chemical systems, steel anchors and plastic plugs. Whether it's heavy-duty fixings for professional tunnel, bridge or power plant constructions or wall and cavity plugs for do-it-yourselfers – fischer offers the right solution to any fixing problem.

- The headquarters of the fischer Group of Companies is located in Waldachtal. The company is represented in 37 countries with 49 subsidiaries worldwide and exports to more than 100 countries.
- fischer fixing systems is the technological market leader in key fields of fixing technology.
- Number of employees in the Group of Companies: approx. 5,200
- Owner: Prof. Klaus Fischer
- Year of establishment: 1948