Safe anchoring in Earthquake zones: Fastenings under seismic actions.

White Paper for planners, structural and civil engineers.

Contents.

White Paper „Safe anchoring in Earthquake zones: Fastenings under seismic actions“.

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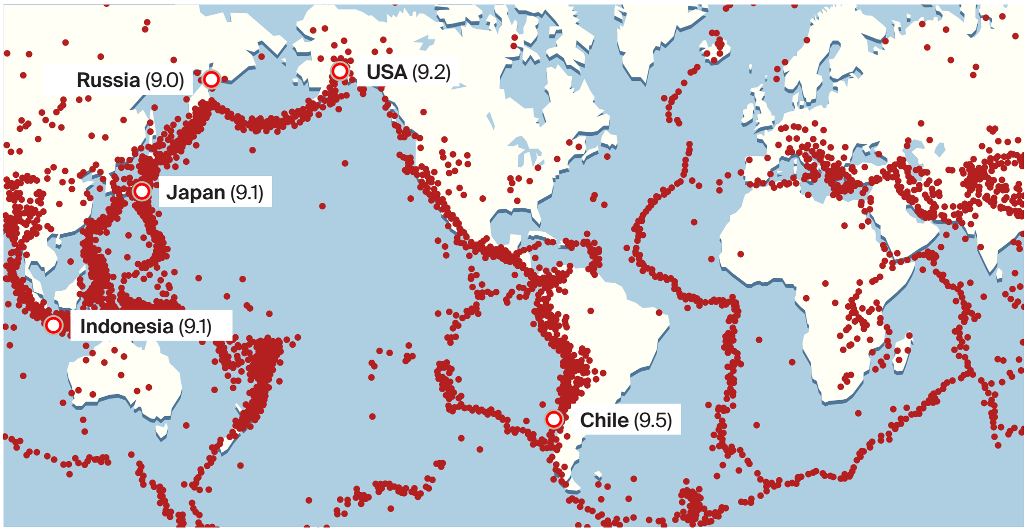
Earthquakes – Danger from the deep.
Facts & Figures at a glance.



Earthquakes usually occur along the boundaries of tectonic plates: This can be seen clearly by the epicentres marked in Red, shown on the map above. Earthquakes can be observed frequently along the Pacific Ring of Fire, which surrounds the Pacific Ocean at a length of roughly 40,000 kilometres. The five earthquakes since 1900 with the highest magnitude also occurred there (see map above).

The five strongest earthquakes worldwide since 1900 (Ranked by magnitude on the Richter scale):

1. **Chile:** Valdivia-Region (1960), Magnitude: 9.5
2. **USA:** Prinz-William-Sund/Alaska (1964) Magnitude: 9.2
3. **Indonesia:** Sumatra (2004), Magnitude: 9.1
4. **Japan:** Tōhoku-Region/Fukushima, (2011), Magnitude: 9.1
5. **Russia:** Kamchatka (1952), Magnitude: 9.0

Severe Damage

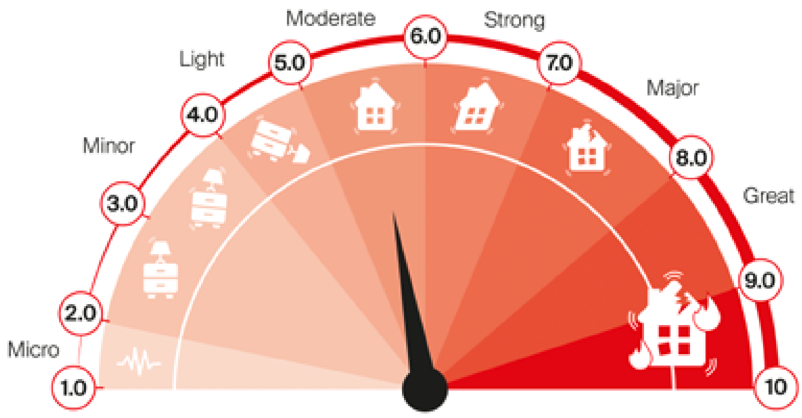
Approximately 1 million buildings were destroyed or damaged by the 2011 Tōhoku earthquake and the associated tsunami, including the nuclear power plant in Fukushima.

Ca. 130,000

Earthquakes with a magnitude of 3.0 to 4.0 occur about 130,000 times a year worldwide. Devastating earthquakes with a magnitude between 7.0 and 8.0 occur on average 15 times a year.

San Andreas Fault

1,400 km long continental transform fault in California (USA), where tens of thousands of smaller earthquakes occur every year. In 1906 the San Andreas fault triggered an earthquake in San Francisco with a magnitude of 8.6.



Richter scale: The Californian seismologist Charles F. Richter introduced the magnitude scale for earthquakes in 1935 that was named after him. An earthquake with a magnitude of 6.0 causes ten times stronger ground movements than at a magnitude of 5.0.

How do earthquakes evolve?
Destructive effects on buildings.

On August 24, 2016, a massive earthquake struck central Italy. The earthquake (magnitude 5.9 on the Richter scale) destroyed almost completely the town of Amatrice, east of Rome. In total, more than 130 municipalities were affected by the main and numerous aftershocks, and around 300 people died. Centuries-old churches suddenly lay in ruins – homes, schools and hospitals were unusable. Earlier in 2009, the L'Aquila earthquake had already caused severe damage in the same region.

Tectonic shifts

The fact that central Italy is so frequently affected by earthquakes is no coincidence. The region is situated on **complex tectonic** faults created by the collision of the African plate and the Eurasian plate. Additional movement is caused by the subduction of the Adriatic plate under the Apennines and the opening of the Tyrrhenian Basin. In Europe, other regions along the **eastern Mediterranean** are particularly prone to earthquakes, especially the Balkan states and Greece. In addition to tectonic earthquakes, there are induced earthquakes triggered, for example, by oil production or geothermal energy.

Danger for people and buildings

Depending on the magnitude of the earthquake, the **vibrations** in buildings lead to cracks in the walls, displacement of the foundation and bursting of pipes. In severe earthquakes, building components and even entire building can collapse.

Earthquakes also frequently trigger landslides, soil liquefaction, floods and tsunamis. Damaged power or gas lines can lead to devastating fires and cause additional damage.

Subduction: Term from plate tectonics. It refers to the dipping at the edge of a tectonic plate, while this edge is simultaneously "overrun" by another plate.

Adriatic Plate: Part of the African Plate whose collision with the Eurasian Plate caused the formation of the Alpine and Apennine Mountain ranges.

Induced earthquake: Earthquake caused by human activity.

Tyrrhenian Basin: Part of the Mediterranean Sea between Corsica, Sardinia and Sicily.

Earthquakes can have devastating consequences: Buildings and infrastructure in a region – such as here in Italy – are often destroyed for years.

An earthquake evolves: Sudden displacements along the fracture surfaces of the earth's crust release accumulated elastic energy. The earthquake waves propagate to the earth's surface starting from the epicentre.

Theoretical principles for design and the practical application of fixings in seismic zones are among Enrico Crivellaro's main tasks. He has been working for fischer for many years in the field of competence transfer and as a trainer in the academy.

»Anyone who lives in an earthquake area knows what it means to wake up at night to the shaking of the building. The use of earthquake-proof anchorages increases safety. And everyone can sleep peacefully.«

Dipl.-Ing. Enrico Crivellaro

Transfer of competence, standards and approvals at fischer Italy

Structural and non-structural constructional elements.
Differences & risks.

An earthquake does not only affect the stability of a building, components attached to the building also pose a risk. Therefore there is an important distinction between load bearing and non-load -bearing structural components.

Structural elements

During an earthquake, the ground acceleration is transferred to the structure of the building, which starts to vibrate. The prying effect amplifies this oscillation through the floors. Failure of structural components can lead to the failure of the entire structure or parts of it.

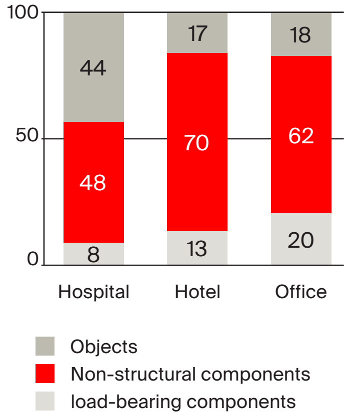
Non-structural elements

An additional interaction takes place between the action produced by an earthquake and the components attached to the structure. Pipes, cable trays, etc. also start to vibrate and experience acceleration. Since an earthquake usually lasts only a few minutes, **high load values** are achieved (non-dynamic loads). Non-structural components include:

- pipelines and cables
- suspended ceilings
- cable trays, air conditioning units
- facades

These non-structural components can fall down on people or block escape routes during an earthquake. If a building is destroyed, **it may be unusable for a long time,** even if the structure itself is still intact. Earthquake research shows that failure of non-structural components cause considerable financial damage. In a residential building, about 40 percent of repair costs are for non-structural components, 40 percent for load-bearing components and 20 percent for movable items such as furniture. For hospitals, office buildings and hotels, the cost of damage to non-structural components is significantly higher (see chart on the right side). In case of the design for seismic loading, structural engineers and planners should therefore always provide earthquake-resistant fasteners, even for non-load-bearing components.

Repair costs in %



Source: Taghavi & Miranda (2003)

In 2012, an earthquake damaged this Factory in Cavezzo (northern Italy).

Earthquake resistant anchoring.
3 important documents.

The most important aim of EN 1998-1 is to protect human life in the event of an earthquake, to limit damage and to ensure that important structures remain functional to protect human life. Fasteners must be able to withstand crack movements, alternating loads and larger cracks under seismic loading than under static loading. The following three documents are necessary for the design of anchorages under seismic loading:

- EN 1992-4 (EC2-4)
- ETA of the fastener
- EN 1998-1 (EC8-1)

EN 1992-4

The basis for calculation is EN 1992-4 (EC2-4), which applies to the design of anchors in concrete (published in 2019). EN 1992-4 stipulates the method for **calculation of the resistance** of the fastener. It is exclusively valid for anchorages in concrete.

ETA

The requirement for the application of EN 1992-4 are the European Technical Assessments (ETA). ETAs document the **seismic qualification of the fastener** and help in the selection of a suitable product.

EN 1998-1

The loads to be applied depend on the ground acceleration in the seismic region **(see page 8)**. **Important for all users:** For seismic loads, the load values can be found in EN 1998-1 instead of EN 1991-1.

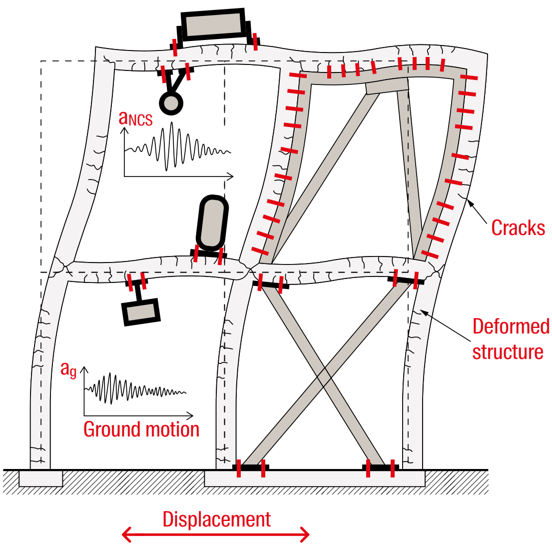
The following pages provide a step-by-step explanation of how designers and structural engineers can use the three documents mentioned above to perform a **valid design for anchorages under seismic actions:**

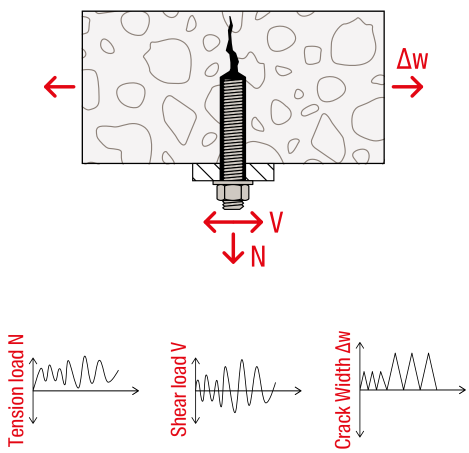
- **page 8:** Determination of the loads according to EN 1998-1
- **page 9:** Qualification of fasteners according to the categories C1 and C2
- **page 12 pp:** Description of three design methods according to EN 1992-4 and calculation of the resistance of the fastener

The significance of the EN 1992-4 standard for the design of fasteners in concrete

Click here for the White Paper

i The **European Technical Assessment (ETA)** defines the performance of a fastener.





During earthquakes, the concrete component and the anchors are subjected to cyclic loading with varying crack widths as well as varying tensile and shear forces in the concrete.

Sources: Mahrenholtz, P.: „Experimental Performance and Recommendations for Qualification of Post-installed Anchors for Seismic Applications", Dissertation, Institute for Materials in Civil Engineering, University of Stuttgart, 2012 (left).
Hoehler, M.: „Behavior and Testing of Fastenings to Concrete for Use in Seismic Applications", Dissertation, Institute for Materials in Civil Engineering, University of Stuttgart, 2006 (right).

Seismic loads according to EN 1998-1. Determination of the load on the anchorage.

The effects of seismic loading on non-structural components are determined according to the provisions of EN 1998-1. F_a is the **horizontal seismic force** acting at the centre of gravity of the non-structural element in the most unfavourable direction. In addition, the calculation of the **vertical seismic force F_{va}** must be considered. Two equations (see box on the right) make it easy to determine the forces.

Calculation of the loads

The magnitude of the seismic load depends on the ground acceleration a_g acting on a building in a particular region (see map below). This is included in the calculation of the earthquake coefficient S_a. EN 1992-4, however, provides a simplified calculation of the seismic coefficient and introduces the parameter A_a (seismic amplification factor). This is taken from Table C.2 in EN 1992-4, as is the behaviour factor for non-structural elements q_a. The importance factor γ_a is generally taken as 1.0. For anchorages of machine elements, equipment for safety systems or of containers containing toxic or explosive substances the factor must not be less than 1.5 (compare EN 1998-1). The equation for determining the vertical actions differs only in the factor S_{va}. Both A_a, γ_a and q_a are set equal to the values applicable to horizontal forces.

Specifics by different countries

The simplified approach described above is replaced in some **national regulations** (e.g. the Italian building regulation) by a more sophisticated approach that takes into account all vibration modes of the primary structure (modal analysis). A future revision of EN 1998 will probably adopt this approach.

Horizontal (static equivalent) effects of seismic action for non-strucrual elements:

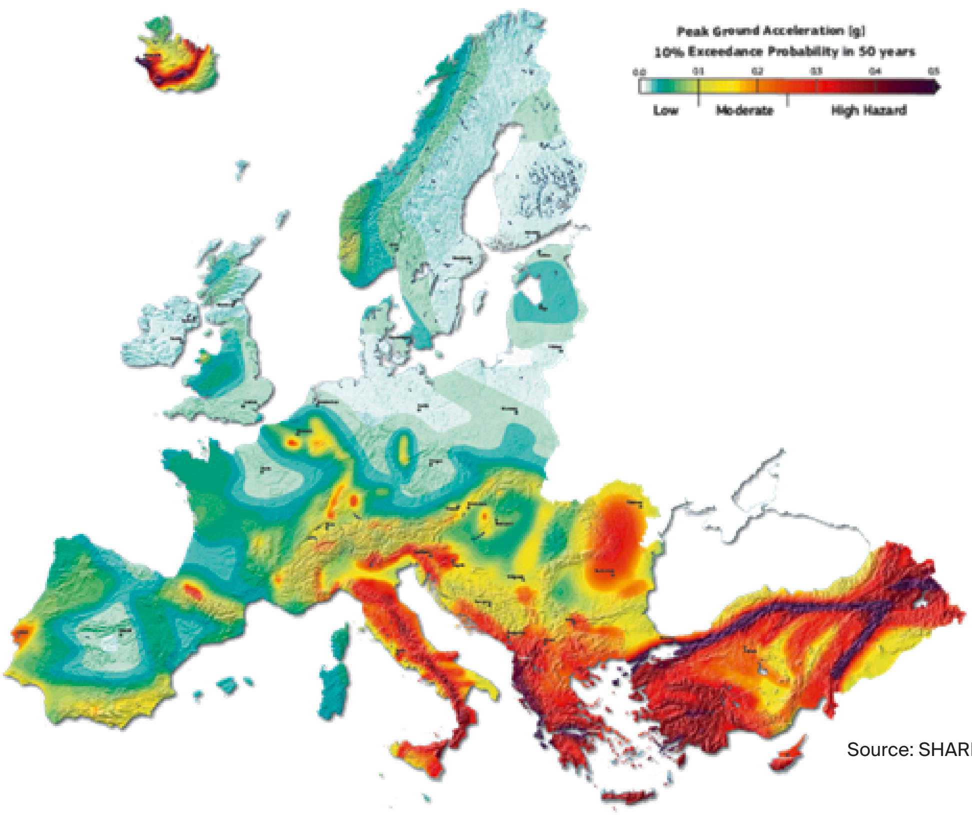
$$F_a = \frac{(S_a \cdot W_a \cdot \gamma_a)}{q_a}$$

- S_a: Horizontal seismic coefficient applicable to non-structural elements; Calculation see equation C.3 in EN 1992-4
- W_a: Weight of the non-structural element
- γ_a: Importance factor of the non-structural element from EN 1998-1
- q_a: Behaviour factor for non-structural elements according to Table C.2 in EN 1992-4

Vertical (static equivalent) effects of seismic action for non-structural elements:

$$F_{va} = \frac{(S_{va} \cdot W_a \cdot \gamma_a)}{q_a}$$

- S_{va}: Vertical seismic coefficient applicable to non-structural elements; Calculation see equation C.6 in EN 1992-4
- W_a: Weight of the non-structural element
- γ_a: Importance factor of the non-structural element from EN 1998-1
- q_a: Behaviour factor for non-structural elements according to Table C.2 in EN 1992-4



Source: SHARE

For the European research project SHARE, earthquakes from 1000 AD onwards were recorded and a ground acceleration map was created on this basis.

Seismic qualification of fasteners.
Seismic performance categories C1 and C2.

For seismic loading, fasteners are distinguished by two different performance categories. The category that must be selected for the fastening depends on three criteria:

- ground acceleration in the region (see p. 8)
- structural or non-structural component (see p. 6)
- significance category of the building

Accordingly, the correct fastener can be selected.

Categories C1 and C2

The basic requirement for the seismic qualification of a fastener is an **ETA** for cracked concrete. For certification according to performance category C1 or C2, the fasteners undergo extensive testing.

Performance category C1: The fastener must resist tests with pulsating tension load and alternating shear load up to a crack width of 0.5 mm. For category C1, the resistance is limited only to the specification of loads.

Performance category C2: For the qualification, crack opening tests with a crack width of 0.8 mm are carried out. In addition, the fasteners must be able to withstand crack changes. According to category C2, deformations play a significant role in addition to loads. **Category C2 anchors** are thus designed for the **highest seismic loads**.

Classification of the importance class of the building

Eurocode 0 defines four different importance classes for building structures. Category I buildings have a low importance for public safety. These are for example agricultural buildings. **In this importance class, a C1 qualified fastener is always sufficient.** Residential buildings are in category II, schools and cultural facilities in category III. The highest importance class IV includes structures whose integrity is particularly important for the population during an earthquake: for example, hospitals, fire stations and power plants.

For importance categories II-IV, always a C2 certified fastener must be used.

i **Eurocode 0** (EC 0) is the denomination for the European standard EN 1990. The standard defines the basic principles of structural design.

For further reading:

- Stehle, E.J.; Sharma, A. Review of Testing and Qualification of Post-Installed Anchors under Seismic Actions for Structural Applications. CivilEng 2021, 2, 406-420. https://doi.org/10.3390/civileng2020023.

<table>
<tr><th rowspan="2">Seismicity level [1]</th><th rowspan="2">Components</th><th colspan="4">Importance class according to EN 1992-4: 2018, 4.2.5</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>IV</th></tr>
<tr><td rowspan="2">< 0.05 g</td><td>Structural</td><td colspan="4" rowspan="2">ETA, static load</td></tr>
<tr><td>Non-structural</td></tr>
<tr><td rowspan="2">0.05 g – 0.1 g</td><td>Structural</td><td></td><td colspan="3">ETA, Seismic, Cat. C2</td></tr>
<tr><td>Non-structural</td><td colspan="3">ETA, Seismic, Cat. C1</td><td></td></tr>
<tr><td rowspan="2">> 0.1 g</td><td>Structural</td><td rowspan="2">ETA, Seismic, Cat. C1</td><td colspan="3" rowspan="2">ETA, Seismic, Cat. C2</td></tr>
<tr><td>Non-structural</td></tr>
</table>

The table shows how the ground acceleration, component type, and building importance class criteria are related to each other.

[1] Seismicity level = $a_g \cdot S$

Design according to EN 1992-4. Three design criteria.

Based on EN 1992-4, there are three different design methods, which are explained in detail on this and the following page. An essential difference between the methods is whether **ductility requirements** are set for the fastening systems. In the commonly used design methods **a_1** and **a_2** (see figure below), it is assumed that fasteners cannot absorb energy through ductile hysteretic behaviour. On the contrary, method **b** (see page 11) sets requirements for the ductility of the fastening, but has so far not been investigated extensively for seismic loading.

a_1: Capacity design

The anchorage (fasteners, base plate and attached profile) is designed for the maximum tensile or shear load that can occur in the event of an earthquake. The tensile and shear loads occurring on the fastener are reduced, for example, by a yield mechanism. There are three options for the capacity design:

- ductile yield mechanism of the component to be anchored, taking into account work hardening and overstrength of the material
- ductile yield mechanism of the baseplate, i.e. plastic deformation of the baseplate is allowed (*Only this option is shown in the diagram below.*)
- Utilizing the capacity of a non-yielding baseplate or fixture, i.e. allowing the fixture to fail

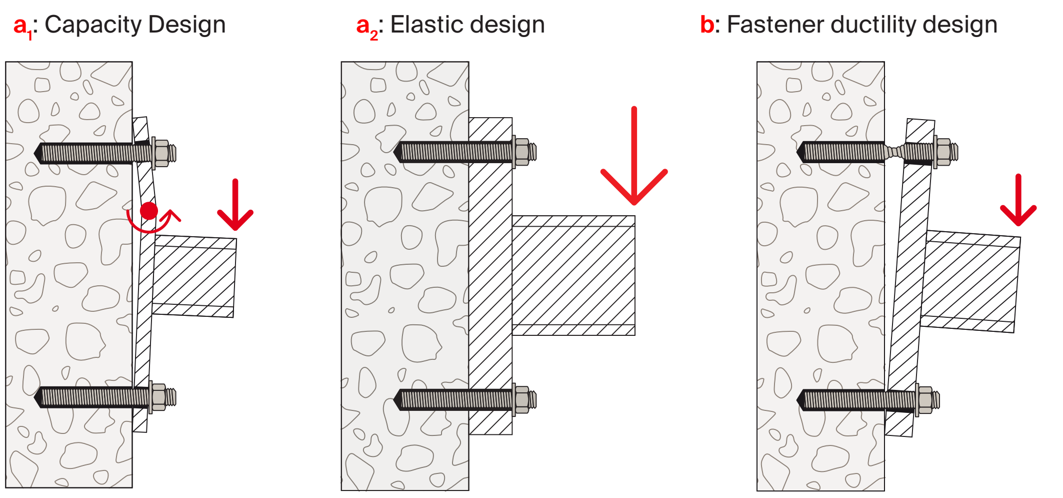
This way, the load on the fastener remains limited and the fastener is "protected". No requirements are set for the fastener in terms of ductility. The fastener is over-dimensioned in order to avoid brittle failure in all cases.

a_2: Elastic design

The anchor group is designed for the maximum load that results in case of an earthquake according to the load combinations from EN 1998-1. The baseplate or fixture is

i Ductility is a mechanical property of a material, and is defined by the degree to which a material can sustain plastic deformation under tensile stress before failure.

i Hysteresis is the dependence of the state (e.g. strain) of a system not only on the stress, but also on its stress history. In seismic systems, stresses and strains therefore run in loops and not in straight lines.



Three methods of performing a valid design of anchorages in case of seismic loading.

assumed to be sufficiently rigid (linear strain distribution). For the design, elastic behaviour of both the baseplate and the structure is assumed according to the **theory of elasticity**. Therefore, the behaviour factor q (structural components) or q_a (non-structural components) is assumed to be 1.0 when calculating the seismic loads.

b: Fastener ductility design

This design method calculates using the maximum ductility of the fastener. Ductile deformations of the fastener are targeted. The yield strength of the fastener under tensile load is decisive. The fastener therefore needs sufficient ductility (EC2-4: e.g. fracture strain > 12%, for further details see standard).

Note: There is **hardly any application experience** for seismic loading when following fastener ductility design. Therefore, this method is limited to non-structural members and the fastener must be qualified for category C2. This method is only applicable to components loaded in Tension. Shear loads must be transferred by additional aids or fasteners designed following option a_1 or a_2. An example can be a piping where the transverse loads are transferred by diagonal braces.

i Elasticity theory is used to describe the elastic and thus reversible deformation of a component.

Further literature:

Roeser W., Schlüter F.-H.: Fasteners in European Earthquake Regions, in "Commentary to EN 1992-4. Design of fastenings for use in concrete"; German committee for Structural Concrete, Heft 615, Beuth Verlag, 2019.

A ductile fastener requires adequate elongation length and elongation at break.

Design according to EN 1992-4.
Calculation of the anchorage resistance.

The design value of the seismic resistance of fastenings $R_{d,eq}$ is calculated according to EN 1992-4 (Equation C.7, see box on the right). The partial safety factor $\gamma_{M,eq}$ for seismic applications is the same as the value for quasi-static loading and is determined in accordance with section 4.4.2.2 of EN 1992-4. Additionally, the characteristic resistance for seismic loading $R_{k,eq}$ is to be calculated for the design of anchorages (equation C.8 in EN 1992-4, see box on the right). It should be determined for each failure mode for tensile and shear loading and any interaction between them.

The failure mode with the lowest resistance is decisive for the design. To calculate $R_{k,eq}$, users need the basic characteristic seismic resistance $R^0_{k,eq}$. For steel failure as well as for pull-out failure under tension load and steel failure under shear load, it can be easily taken from the European technical Assessment (ETA). For all other failure modes, $R^0_{k,eq}$ is determined according to Section 7 of EN 1992-4, analogous to the calculation procedure for quasi-static loading. An **important difference** compared to the design for static loading is that the reduction factors α_{gap} and α_{eq} must be considered for seismic design.

Reduction factor α_{gap}

The **annular gap** between the fastener and the baseplate or fixture can have an unfavourable effect on the load distribution of the anchorage under seismic loading. Therefore, the resistance of the anchorage must be reduced by the reduction factor α_{gap}.

In the case of **rapid cyclic loading** (see figure below) – as it can occur in an earthquake – the fixture repeatedly hits against the fastener and this hammering action reduces the resistance of the fastener. In the case of anchor groups, it is to be assumed that the shear forces are not equally distributed among the fasteners due to the arbitrary hole clearance pattern.

Seismic design resistance:

$$R_{d,eq} = \frac{R_{k,eq}}{\gamma_{M,eq}}$$

$R_{k,eq}$: Characteristic resistance under seismic loading; see equation below

$\gamma_{M,eq}$: Partial safety factor; see Section 4.4.2 in EN-1992-4

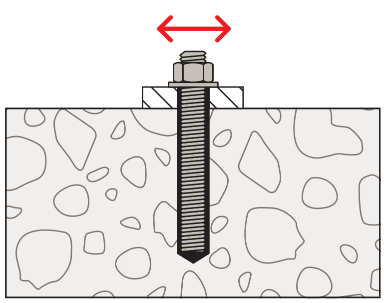
Characteristic resistance under seismic loading:

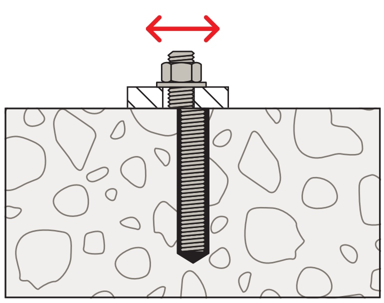
$$R_{k,eq} = \alpha_{gap} \cdot \alpha_{eq} \cdot R^0_{k,eq}$$

α_{gap}: Reduction factor; see ETA

α_{eq}: Reduction factor; see Table C.3 in EN 1992-4

$R^0_{k,eq}$: Basic value of the characteristic resistance under seismic loading; see ETA or EN 1992-4





The baseplate or fixture may slide on the concrete surface under seismic loading and hit the anchor with hammering action if the annular gap is not filled. As a result, premature failure of the fasteners is to be expected.

Prof. Akanshu Sharma has vast experience in structural engineering with a focus on strengthening methods with fastenings.

» In structural strengthening, seismic behaviour of anchors often governs the performance of structure under earthquakes. A safe and reliable anchorage is essential for the seismic safety of structures. «

Prof. Akanshu Sharma

Associate Professor Lyles School of Civil Engineering at Purdue University, USA

Therefore, for **anchorages with hole clearance**,the reduction factor α_{gap} must take the value of 0.5. This means that the fastener may only be loaded up to a maximum of 50 percent. For seismic loading, it is therefore recommended to fill the annular gap by means of a **filling disc** (see picture below; further information on p. 16). This significantly increases the load-bearing capacity: **If the annular gap is filled, α_{gap} can take the value of 1.0.**

Reduction factor α_{eq}

The reduction factor α_{eq} is assumed to account for different phenomena associated with seismic loading of anchors:

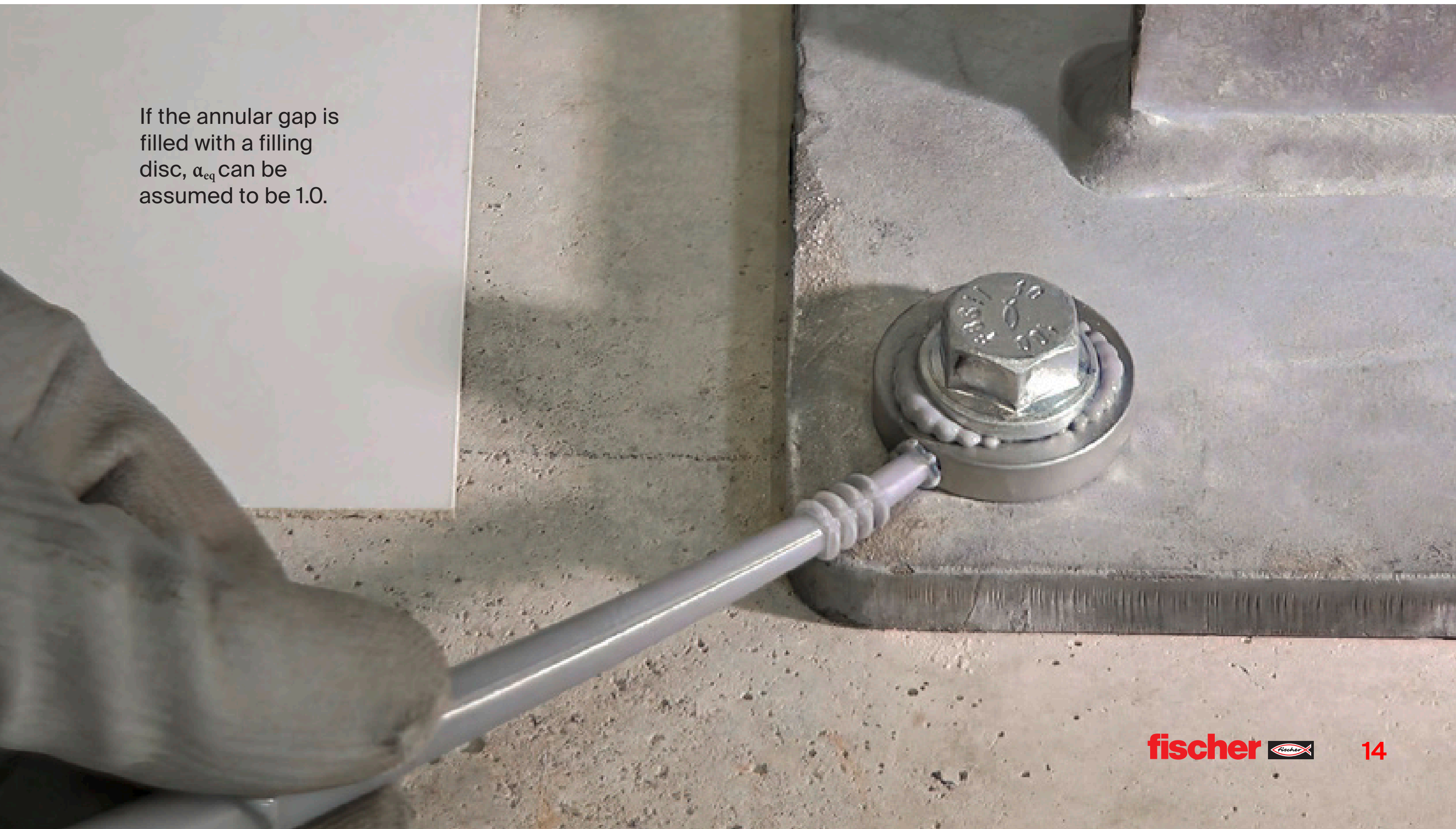
- In case of earthquakes, relatively wide cracks may develop compared to static loading.
- Simultaneous load and crack opening occurs. Due to the opening and closing of the cracks, the concrete surfaces do not exactly match at the same locations. As a result, both the concrete surface along the fastener and the fastener are damaged during earthquakes.
- In anchor groups, uneven load distributions can occur because certain anchors are in cracked concrete and other anchors in non-cracked concrete.
- Due to seismic actions, the scatter associated with the displacements is large.

The **reduction factor α_{eq} varies from 0.75 to 1.0, depending on the failure mode and loading direction.** The highest reduction must be applied to concrete failure, where α_{eq} is 0.75. Steel failure is less problematic because it is a ductile failure mode. The required values for α_{eq} can be taken from Table C.3 in EN 1992-4 (see table below).

Interaction of tension and shear loads

The design proof for the interaction between tensile and shear loads is performed analogously to Sections 7.2.3.1 and 7.2.3.2 of EN 1992-4 (Equa-

i The maximum **crack width** is 0.5 mm for fasteners according to seismic performance category C1 and 0.8 mm for category C2.



If the annular gap is filled with a filling disc, α_{eq} can be assumed to be 1.0.

tion C.9 in EN 1992-4, see text box on the right). It is to be performed for the **steel failure mode** and **for failure modes other than steel failure**.

N_{Ed} and V_{Ed} are the design actions on the fasteners (including seismic actions) for the corresponding failure modes. k_{15} can take different values: For steel failure, k_{15} is assumed to be 1. For fasteners with supplementary reinforcement that takes up only tension or shear loads, k_{15} is 2/3. In all other cases, k_{15} has a value of 1.

For the calculation of the anchorage resistance, the following values are used: for steel failure, the values $N_{Rd,i,eq}$ and $V_{Rd,i,eq}$ are identical to $N_{Rd,s,eq}$ and $V_{Rd,s,eq}$. For all other failure modes, the largest ratio of $N_{Ed}/N_{Rd,i,eq}$ and $V_{Ed}/V_{Rd,i,eq}$ becomes decisive.

Interaction for seismic design:

$$\left(\frac{N_{Ed}}{N_{Rd,i,eq}}\right)^{k_{15}} + \left(\frac{V_{Ed}}{V_{Rd,i,eq}}\right)^{k_{15}} \leq 1$$

N_{Ed}: Acting tension load

$N_{Rd,i,eq}$: Resistance tension load

V_{Ed}: Acting shear load

$V_{Rd,i,eq}$: Resistance shear load

k_{15}: see text on the left

Loading	Failure mode	Single anchor	Anchor group
Tension load	Steel failure	1.0	1.0
	Pull out & Combined failure		0.85
	Concrete failure modes[2]	0.85 (1.0)[1]	0.75 (0.85)[1]
Shear load	Steel failure	1.0	0.85
	Concrete edge break		
	Pryout failure	0.85 (1.0)[1]	0.75 (0.85)[1]

[1] Values in brackets only for headed fasteners and undercut fasteners (not for concrete screws)

[2] Concrete failure modes = concrete cone failure, splitting and local concrete cone failure.

The α_{eq} values are given in the table. The table contains the values for the reduction factor eq according to EN 1992-4 (based on Table C.3).

Prof. Akanshu Sharma: *"Displacement-based approaches are essential"*

Seismic strengthening solutions such as steel bracing, haunch retrofit solution, addition of shear walls, steel plating, concrete jacketing and even FRP (fiber reinforced polymer) wrapping need anchorages to make a good connection between the strengthening element and the existing structure.

Post-installed anchors offer attractive solutions to form the connection between the strengthening elements and the structure, thereby reducing the invasiveness of the strengthening systems. In such cases, the seismic performance of the strengthened structure is largely governed by the seismic performance of the post-installed anchors. Here, more than the load-carrying capacity, the displacement and hysteretic behavior of anchorages become important.

Displacement-based approaches for design, testing and qualification of anchorages are therefore essential to ensure safe, reliable, and efficient seismic strengthening solutions.

Prof. Akanshu Sharma

fischer solutions.
Products for seismic applications.

According to the German Federal Institute for Geosciences and Natural Resources (BGR), an average of more than 150 earthquakes with a magnitude of 6.0 and higher occur worldwide every year. In order to prevent serious consequences for the population and buildings in the affected areas, non-structural components must also be fastened in case of an earthquake. For this purpose, the fastening specialist fischer offers a variety of products that are suitable for anchoring under seismic loads.

Adhesive anchors

The **FIS EM Plus injection mortar** is approved for seismic applications in seismic performance categories C1 and C2. It provides a secure hold even under extreme conditions. A very high bond strength and thus a very high load level is also available by using **Superbond resin system FIS SB/RSB**. The ETA for cracked and non-cracked concrete and for seismic loads offers an additional benefit in terms of safety. With **FIS V Plus** fischer has established a universally applicable **injection mortar** that guarantees a service life according to the ETA rating of 100 years and is also suitable for seismic applications. The fischer **anchor rods FIS A and RGM** are also suitable as a system component for use with the chemical fastening solutions from fischer.

Mechanical anchors

The fischer **UltraCut FBS II concrete screw** is ideally suited for cracked and non-cracked concrete as well as for the highest seismic loads. This is guaranteed by the ETA assessment, which also includes fire rating for fire resistance class R 120. Also approved for use in earthquake zones are the fasteners **FAZ II bolt anchor**, the **FH II high performance anchor** and the **FZA Zykon undercut anchor**.

Filling disc FFD:
Suitable for subsequent filling of the annular gap between base plate or fixture and steel fastener to significantly increase the load-bearing capacity under seismic load. Application with fischer injection mortar.

Click here for the **filling disc FFD**

Reliable: These fischer products withstand even high seismic actions.

Prof. Giovanni Muciaccia has been working for many years on the challenges of earthquake-resistant anchorages in buildings.

» Southern Europe is almost entirely seismic-prone and with a prominent building inventory to be retrofitted in the upcoming decades through techniques which strongly require reliable fastening solutions. «

Prof. Giovanni Muciaccia

Senior Assistant Professor for Structural design and fastening technology, Department of Civil and Environmental Engineering (DICA) at Politecnico Milano, Italy

fischer services.
Everything from a single source.

The experts from fischer, support **planners and structural engineers** in many different ways. For example, the specialists from the **technical consulting department** are available from Monday to Friday by telephone, e-mail and chat and provide advice on all aspects of earthquake-resistant anchorages and the selection of adequate fastening solutions.

Design with FiXperience

To prevent failure of an anchorage under seismic loading, a proof must be provided that the selected products are suitable for the applied loading. In general, structural engineers and planners can design the fastening solutions of complete projects and individual applications with the **fischer software FiXperience Suite** in a particularly convenient, flexible and reliable way.

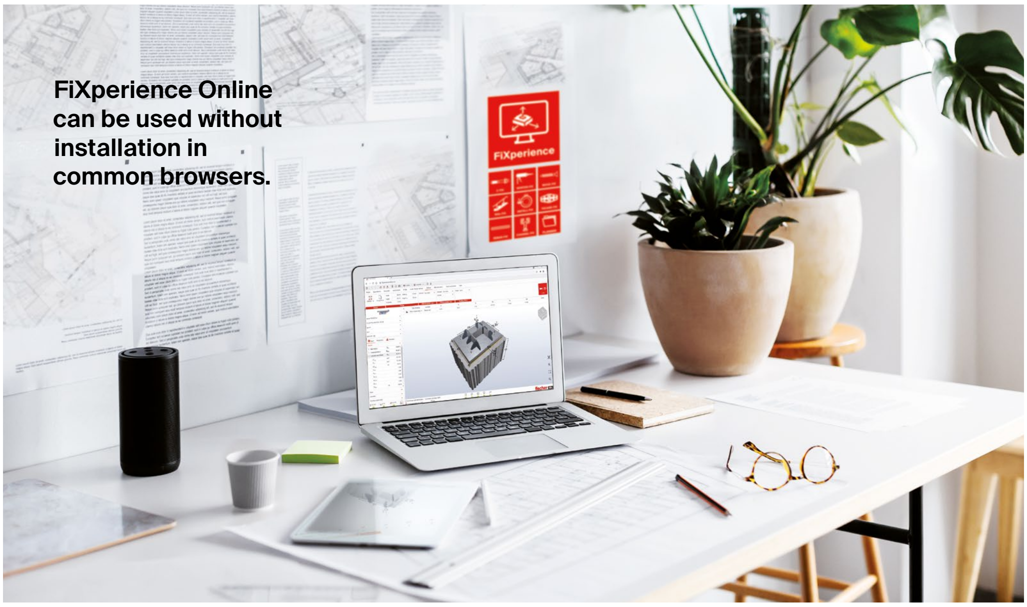
In addition to the offline FiXperience Suite, the design software is now offered as a browser version **FiXperience Online**. With the included **C-FIX online module** for the design of mechanical and chemical fasteners in concrete, users can assess the stiffness of the base plate with a linear spring model in combination with the FE Method and calculate realistic anchor forces in a time-saving way. **All three design criterias according to EN 1992-4** are available in the C-FIX online module. In the best case, the program confirms a valid design and generates a verifiable printout. For the optimization of fastener selection, multiple design is also possible.

fischer Academy

For more than 30 years, fischer has been offering target group-specific seminars for professionals in the construction industry. All training courses are state of the art and provide information on current national and European standards and guidelines as well as legal regulations and their implementation. Click here for the **online seminars offered by the fischer Academy**.

Try the design software FiXperience Online for free now!

Click here for **FiXperience**



FiXperience Online can be used without installation in common browsers.

Our technical consulting experts will be happy to help you!
Contact fischer now.

T +49 7443 12 - 4000
(Mon. - Thu.:
7:30 a.m. - 5:30 p.m.;
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Summary.

Summary White Paper. Earthquake-proof anchoring.

Earthquakes can develop a destructive force on buildings. Due to shifts in the tectonic plates, regions in Europe along the eastern Mediterranean are particularly at risk of earthquakes: Italy, Greece and the Balkan states, among others. An earthquake not only affects the stability of a building – all structural components attached to the building can also pose a hazard.

Hazards due to non-structural components
Non-structural components, such as pipes, conduits, suspended ceilings, cable trays and air-conditioning units, can fall down on people or block escape routes during an earthquake. Non-structural components can also cause a significant amount of financial damage. In the event of seismic loading, therefore, earthquake-resistant fixings must always be provided, even for non-structural components.

Three basic documents for the design
EN 1992-4, Annex C, forms the basis for the design of fastenings under seismic loading. The basic requirement for the application of EN 1992-4 are the ETAs documenting the seismic qualification of the anchor. The specifications for the calculation of the actions for seismic loading can be found in EN 1998-1.

Determination of the load according to EN 1998-1
The horizontal seismic force F_a and the vertical seismic force F_{va} are calculated according to EN 1998-1.

Seismic performance categories C1 and C2
For seismic loading, fasteners are distinguished by two different performance categories: C1 and C2. The selection of the correct fastener depends on the ground acceleration in the corresponding region and the importance category of the building. Another decisive factor is whether the component is a load-bearing or non-load-bearing component.

Design according to EN 1992-4: 3 criteria
Based on EN 1992-4, there are 3 design criteria: capacity design, elastic design and design with consideration of the ductility of the fastening. The three methods are described in the corresponding section of the white paper.

Design: Resistance of the fastener
The seismic design resistance of a fastener $R_{d,eq}$ is calculated according to EN 1992-4. An important difference compared to the design for static loads is that the reduction factors α_{gap} and α_{eq} must be taken into account.

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