



Extended working life for fastenings in concrete

Assessment and design framework for fastenings with 120-years' working life

Version 1.0
February 2026



Table of contents

1. A brief overview of durability & working life in reinforced concrete structures	2
1.1 Threats to the durability of reinforced concrete	2
1.2 Impact of durability on design working life	3
2. Design working life requirements for the design of post-installed fastenings.....	5
2.1 EN 1990 & EN 1992(-4) design requirements for Design Working Life	5
2.2 Requirements for fastenings per EN 1992-4:2018	6
3. The behavior and assessment of post-installed fastenings in concrete	7
3.1 Steel-to-concrete fastenings with post-installed bonded anchors	7
3.1.1 Creep in bonded anchors	7
3.1.2 Evaluation in the European Assessment Document (EAD) 330499	9
3.2 Concrete-to-concrete connections with post-installed rebars	9
3.2.1 Behavior of post-installed rebar connections	9
3.2.2 EAD 330087 for post-installed rebar connections equivalent to cast-in	10
3.2.3 EAD 332402 for post-installed rebar connections with improved bond-splitting behavior	10
3.3 Steel-to-concrete fastenings with post-installed mechanical anchors	10
3.3.1 Durability of mechanical anchors	10
4. Design of cast-in and post-installed fastenings and connections beyond 50years' working life.....	12
4.1 Design overview of post-installed bonded and mechanical anchors with EN 1992-4 & EOTA TR 086	12
4.2 Design overview of post-installed rebar connections with EN 1992-1-1	13
4.3 Design overview of post-installed rebar connections with EOTA TR 069	13
5. Hilti solutions for design to an extended working life	14
5.1 Fastenings in concrete with mechanical anchors	14
5.2 Fastenings in concrete with bonded anchors	15
5.3 Connections in concrete with post-installed rebar assessed to EAD 330087	15
5.4 Connections in concrete with post-installed rebar assessed to EAD 332402	15
6. Design options in PROFIS Engineering.....	16
7. Summary.....	17
8. References	18

1. A brief overview of durability & working life in reinforced concrete structures

The durability of reinforced concrete (RC) structures is considered as its ability to withstand degradation caused by the design environment over the design life without undue loss of serviceability or need for major repair. However, unlike its intrinsic material properties, durability is contextual: depending on project-specific design, execution quality, and maintenance, concrete that performs adequately in one environment may deteriorate rapidly in another. As a large contributor to the lifecycle cost of any structure, premature degradation caused by environmental, chemical, physical, and mechanical factors may lead to a loss of serviceability and material integrity, increased operation and maintenance cost, and a premature end of design working life, which represents the period during which the structure maintains the required performance characteristics under anticipated exposure conditions, with 50 years being a traditional benchmark.

However, modern construction projects typically target design working lives of 100 years or more for critical infrastructure, particularly for major bridges, tunnels, and nuclear containment facilities in which partial or full replacement of the structure is exceptionally difficult or costly. The extension of the design working life necessitates more sophisticated approaches to durability design and assessment, moving beyond traditional prescriptive methods to performance-based methodologies that can help quantitatively predict long-term behavior [1].

1.1 Threats to the durability of reinforced concrete

The predominant threat to RC durability is corrosion of the reinforcing steel, which leads to cracking, staining, and spalling of the concrete cover. This degradation process compromises structural serviceability in terms of occupant safety, structural stability, and aesthetics while creating significant economic liabilities for owners and managers. The design working life of RC structures depends upon their ability to withstand dominant deterioration mechanisms such as corrosion over predictable periods.

Two primary mechanisms initiate corrosion of reinforcement:

1. **Carbonation-induced corrosion** – occurs when atmospheric carbon dioxide penetrates the concrete, neutralizing its natural alkalinity and degrading the protective passive layer on the steel reinforcement.
2. **Chloride-induced corrosion** – occurring often in marine environments or where de-icing salts are used, chlorides locally break down the passive layer even in alkaline conditions, leading to highly localized form of corrosion known as “pitting”.

Table 1 summarizes the primary and additional mechanisms that threaten the durability of reinforced concrete and their effects.

Threats to RC durability	Primary Causes	Key Effects on the Structure
Chloride-induced corrosion	Ingress of chloride ions from de-icing salts or marine environments	Localized pitting corrosion of steel reinforcement, leading to cracking, spalling, and loss of cross-sectional area
Carbonation-induced corrosion	Reaction of atmospheric CO ₂ with concrete, lowering its alkalinity (pH)	Loss of protective passive layer on steel, leading to generalized corrosion, cracking, and spalling
Sulphate attack	Exposure to sulphates in soil or groundwater	Expansion, cracking, and disintegration of the concrete
Freeze-thaw cycles	Repeated freezing and thawing of water in concrete pores	Internal expansive stresses that crack and create scaling on the concrete surface

Alkali-Silica reaction (ASR)	Reaction between alkalis in cement and reactive silica in certain aggregates	Formation of a swelling gel that causes expansive cracking throughout the concrete
-------------------------------------	--	--

Table 1: Threats to RC durability, their primary causes, and the consequent impact on the structure

1.2 Impact of durability on design working life

Note: Fasteners installed in concrete where deterioration-induced cracks have already propagated will have a significantly reduced effectiveness.

The most common model for understanding the relationship between durability and structural performance defined by the design working life, proposed by Tuutti [2], conceptualizes reinforced concrete's design working life into two distinct phases, illustrated in Figure 1:

1. **Initiation period:** Time required for aggressive agents (like chlorides or carbon dioxide) to penetrate the concrete cover and reach the steel reinforcement, breaking down its protective passive layer. This period is heavily influenced by the concrete's quality, permeability, and cover thickness.
2. **Propagation period:** Begins after the initiation of corrosion and continues until the structure reaches a predefined limit state (e.g., extensive cracking, spalling, or loss of load capacity). The rate of deterioration during this phase depends on factors such as the corrosion rate and the environment.

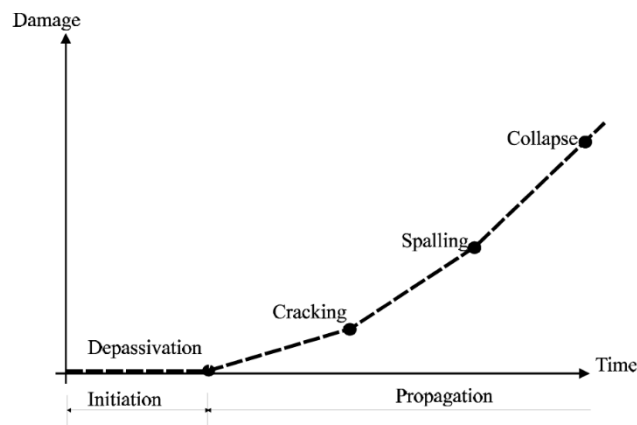


Figure 1: Determining working life and limit state with respect to corrosion, reproduced from Fig. 2 [3]

The relationship between these phases can be modelled mathematically, with the carbonation depth typically proportional to the square root of time, and chloride penetration often described by solutions to Fick's second law of diffusion, with the assumption of no initial chloride content [4]. The core principle behind enhancing durability of RC structures is to help extend the initiation period to last as long as the entire design working life, or at least to ensure that the propagation period is reduced significantly so that the limit state is not reached within the required working life.

Enhancing durability is possible through two main approaches. Traditional “**deem-to-satisfy**” approaches, such as those found in the Eurocodes, provide prescriptive rules for mix design and concrete cover that suffice for a typical structure designed for a 50-year working life. **Performance-based** approaches, such as those incorporated in the *fib* Bulletin 34 [5] and Model Codes [6], use mathematical models simulating degradation that allow for a probabilistic design accounting for the natural variability materials and environment. The latter approach is better suited for structures requiring a design working life beyond 50 years or structures built in extremely aggressive environments [7]. An illustrative example of a performance-based design working life model based on a probabilistic approach, as found in Figure 2, where environmental factors are considered as loads, $S(t)$, while material properties such as chloride penetration resistance are considered as resistances, $R(t)$.

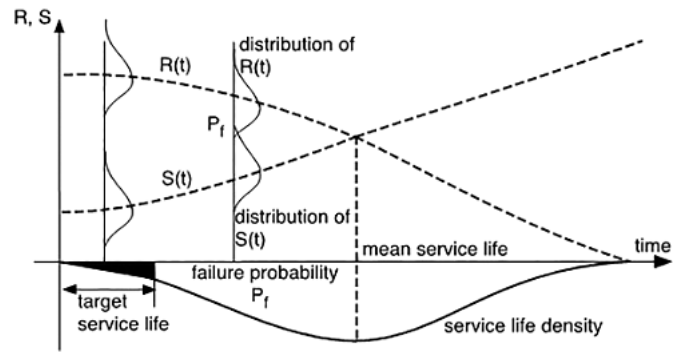


Figure 2: Illustrative representation of failure probability and target working life, reproduced from Fig. 1 [3]

2. Design working life requirements for the design of post-installed fastenings

Modern design standards based on limit state principles, such as EN 1990:2023 [8], specify a design working life of 50-years for typical structures and 100- or 120-years for selected categories of structures where replacement may be exceptionally difficult or economically disproportionate (e. g., major bridges, tunnels, nuclear containment structures, among others). For projects with a design working life exceeding 50 years, structural design is typically expected to address the associated working-life and durability assumptions and to adopt appropriate measures in accordance with the applicable standards and the relevant product documentation. Accordingly, structural engineers are often required to:

- Integrate several building components, including non-structural elements, into the overall design scheme,
- Mitigate risks from changing exposure environments from short-term extreme weather events to long-term climate change,
- Introduce new construction materials that reduce environmental impact,
- Understand current limits of knowledge and in models for design working life prediction,
- Define “design working life” in an “end of working life” criteria,
- Mitigate risks from the ubiquitous issue of inconsistent construction quality,
- Acknowledge the physical impossibility of verifying the structural design for a structure built for 100- or 120-years [1].

2.1 EN 1990 & EN 1992(-4) requirements for design working life

In EN 1990, durability is addressed an integral aspect of structural **reliability**, recognizing that structural performance is time-dependent and may be influenced by deterioration mechanisms acting over the intended design working life. Thus, performance can be achieved by including in design the fundamental principles for durability, safety, and serviceability together with a limit state approach based on partial factor methods. Reliability is dependent on the combined application of durability, safety, and serviceability principles within a limit-state design framework using partial safety factors. For structural verification, reliability is expressed by a target reliability index in the Eurocodes (β), which is selected in relation to the assumed design working life and the consequences of failure, and influences the applied partial factors for actions and resistances.

Reliability features in all parts of EN 1992, in which the design working life is addressed primarily through prescriptive rules for mix design, concrete cover, and Serviceability Limit State (SLS) design requirements, the latter becoming the critical design criterion when the design working life of a structure reaches or exceeds 100 years, as durability-related failures frequently precede strength-related failures, which are covered by Ultimate Limit State (ULS) requirements.

In both standards, durability does not explicitly translate into design working life in the form of an equation but instead comprises of several considerations that help achieve the specified design working life:

- The intended use and functional requirements of the structure,
- The required design criteria and reliability class,
- Expected environmental exposure conditions,
- Material properties and performance characteristics,
- Soil properties at site,
- Choice of structural system, shape of the concrete member, and reinforcement detailing,
- The assumed quality of workmanship and the level of execution control,
- Implementation of protective measures and planned maintenance during the design life.

2.2 Requirements for fastenings per EN 1992-4:2018

In line with “deem-to-satisfy” approach of EN 1992, Section 4.1 of EN 1992-4 requires that fasteners are fit for purpose (durable) and deform within specified limits of serviceability. Designing with the partial factors in EN 1992-4 and EN 1990 leads to the target reliability index, β , is 3.8 for a 50-year design working life (Reliability Class RC2). The “informative” Annex B correlates the required level of corrosion protection in fasteners exposed to dry, wet, and chemically aggressive environments. Durability for the **assumed*** working life must also be ensured through the proper installation of the fastener, requirements of which are covered in the “normative” Annex F [9].

***Note:** in the European Technical Assessments (ETAs) used in conjunction with the design provisions of EN 1992-4, the term “design” working life is replaced by “assumed” working life to distinguish between the (assumed) working life of the fastening or connections in concrete and the (design) working life of concrete member to which it is attached. In certain scenarios, both working lives may coincide but should be distinct from one another.

3. The behavior and assessment of post-installed fastenings in concrete

3.1 Steel-to-concrete fastenings with post-installed bonded anchors

3.1.1 Creep in bonded anchors

Post-installed bonded anchors transfer loads into concrete primarily through a bonded connection, typically using mortars such as epoxy, polyester, or vinyl ester resins. When subject to sustained tensile loading, the long-term behavior of these systems exhibits an inherently viscoelastic material behavior – i.e., characteristics of both an elastic solid and viscous fluid – which manifests as time-dependent deformation known as creep. Illustrated in Figure 3, **creep** in any natural or synthetic material will progress through three distinct stages: **primary** (instantaneous deformation that slows with time), **secondary** (mostly uniform steady-state deformation), and **tertiary** (accelerating deformation terminating at rupture). As with most materials, the creep behavior of bonded anchors is fundamentally non-linear, with deformation rates dependent on applied stress levels, the applied duration of the stress, adhesive material properties, age, material composition, and environmental conditions such as temperature [10].

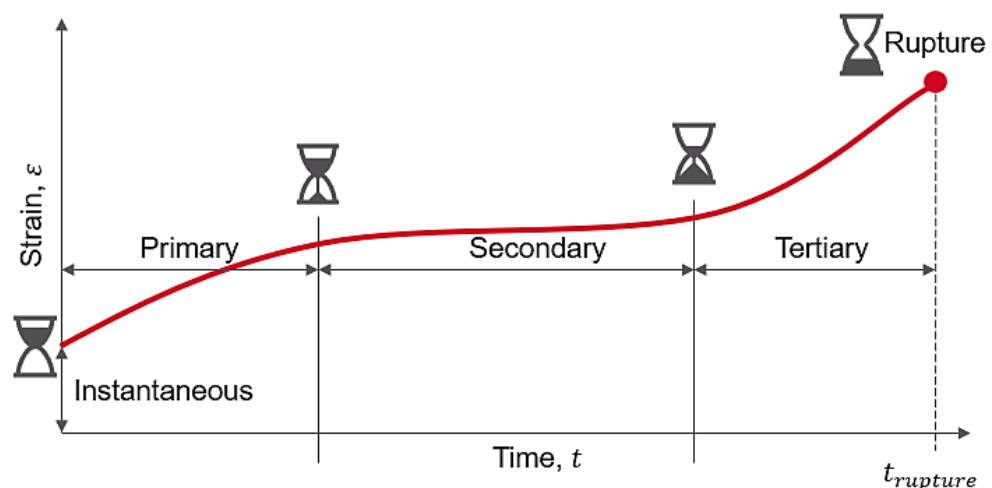


Figure 3: The different stages of creep (illustrative)

The significance of creep in epoxy anchors was demonstrated tragically in the 2006 ceiling collapse in the interstate 90 connector tunnel in Boston, where insufficient consideration of creep in epoxy anchor adhesives led to progressive failure under sustained loading. Investigation revealed that the failed anchors utilized “an epoxy anchor adhesive with poor creep resistance, that is, an epoxy formulation that was not capable of sustaining long-term loads” [11]. Over time, the epoxy resin lost adhesion and deformed beyond allowable limits, ultimately fracturing and resulting in the failure of several ceiling support anchors, which led to the collapse of several concrete panels. Although not unique, this incident starkly emphasized the importance of understanding and accounting for creep when designing and specifying bonded anchor systems, especially for overhead applications where such anchors are subject to sustained tension loads.

The consequences of creep in bonded anchors extend beyond the mere increase in displacement. As creep progresses, it initiates a detrimental cycle of stress redistribution within the bond zone, potentially leading to localized overstress and the accumulation of microdamage. This process can culminate in the onset of tertiary creep, which is characterized by an accelerating deformation rate that inevitably leads to failure. The transition from secondary to tertiary creep is a critical threshold beyond which a typically used anchor system cannot recover and failure becomes imminent [10].

To assess the long-term creep performance of bonded anchors, qualification extrapolates displacement behavior under constant tension load over the fastener's design working life and compares it to a target maximum limit. While several methods are available, a practical approach is the power-law extrapolation method based on Findley's Law. This helps to project the short-term test data onto a design working life of 50-year, which can be extended to 100- and 120-years, employing the expression $\delta(t) = \delta_0 + a \cdot t^b$, in which:

- $\delta(t)$ represents the total displacement at a specific time t ,
- δ_0 is the initial displacement, and
- a and b are parameters determined through regression analysis of the experimental data.

This approach helps to achieve a reliable prediction of long-term anchor displacements based on accelerated testing, typically conducted over much shorter durations than the actual design life, typically ranging from several weeks to months depending on the adhesive formulation and applied load [12]. In qualifying bonded anchors, tests for sustained load are conducted at multiple stress levels and temperatures to characterize the creep behavior under various conditions, and the resulting assessment employs a pass-fail criterion based on displacement limits [13]. As an example, the extrapolated 50-year displacement must not exceed a critical displacement value derived from static tension (pull-out) tests, as shown in Figure 4.

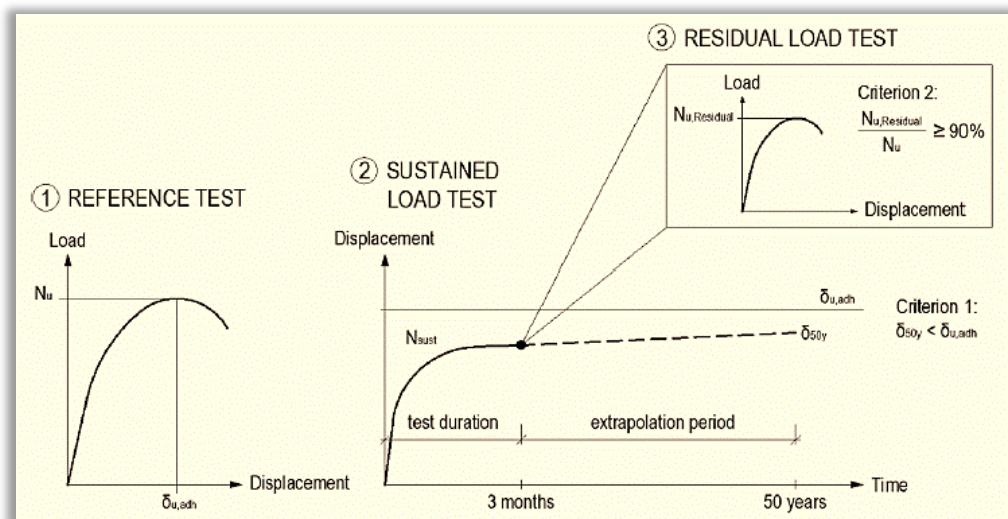


Figure 4: Schematic representation of the load tests for evaluating creep in bonded anchors, reproduced from Fig. 1 [12]

When comparing to Figure 3, Figure 4 also highlights both the initial, primary creep and, once the mortar stabilizes, secondary creep, with the power-law then used to extrapolate the displacement to a specific period (e.g., 50 years).

3.1.2 Evaluation in the European Assessment Document (EAD) 330499

EAD 330499 establishes the framework for assessing the long-term behavior of bonded anchors under sustained loading [14], accounting for factors such as material ageing, environmental exposure, and long-term loading. Summarized in Table 2, [14] specifies several tests that are dependent and independent of time or cycles; of those dependent on time or cycles, only two are explicitly linked to a specific design working life and employ the approach shown in Figure 4.

Table 2: Tests in EAD 330499 [14] dependent and independent of time or cycles

Tests independent of time or cycles	Tests dependent on time or cycles	
Reference to establish baseline performance	Freeze / thaw	Sustained tension loads
Robustness to check variations in imperfect conditions	Mortar durability in alkaline or sulphureous environments	Crack movement (repetitive opening & closing of cracks to 0.3 mm)
Maximum long-/short-term temperatures		
Maximum torque moment		
Installation direction		
Service condition tests		
Seismic tests		
Not applicable to design working life	Not linked to a specific design working life	Linked to a specific design working life

The two key tests linked to a design working life of 50, 100, and 120 years are summarized in Table 3.

Table 3: Tests in EAD 330499 [14] linked to a specific design working life for bonded anchors

Test		Design working life		
		50-year	100-year	120-year
Sustained tension load	Minimum test duration:	3 months	6 months	7.2 months
	Displacements extrapolated to:	50 years	100 years	120 years
	Displacement increase factor	No	Yes	Yes
	Residual loads compared to reference tests			
Minimum 3 months of stabilized displacements				
Crack movement	Cycles:	1000	2000	2400
	Displacements must be less than 2 mm in the first 20 cycles, less than 3 mm throughout all cycles			

3.2 Concrete-to-concrete connections with post-installed rebars

3.2.1 Behavior of post-installed rebar connections

As with bonded anchors covered in Section 3.1, post-installed reinforcing bars installed with a mortar also are subject to sustained loads. However, since rebars in a concrete member are permanently subjected to tension forces once built, the ratio of sustained-to-total loads are higher than bonded anchors in steel-to-concrete fastenings. This difference derives from the type of load transfer mechanism in concrete-to-concrete connections and steel-to-concrete fastenings; namely, the truss action in the former for lap splices or end anchorages, and the lack of such a truss action in the latter that allows the development of a combined concrete cone and pull-out failure.

3.2.2 EAD 330087 for post-installed rebar connections equivalent to cast-in

Due to the high sustained loads, chemical mortars used for post-installed rebar connections require an assessment along the same principles as bonded anchors for extended design working lives. However, as the behavior of post-installed bars differs from bonded anchors, minor variations are required to determine the long-term displacement behavior under constant load to prevent creep failure. These are:

1. The required **embedment depth**, which is longer for assessing post-installed rebar to EAD 330087 [15] to reflect that embedment of such bars typically exceeds 20ϕ (where ϕ is the bar diameter), and
2. The **sustained load** applied during testing, which is higher for assessing post-installed bonded anchors to EAD 330499 due to less redundancy in such fastenings.

3.2.3 EAD 332402 for post-installed rebar connections with improved bond-splitting behavior

For post-installed rebar and with improved bond-splitting behavior, many of the time- / cycle-dependent tests follow tests no different than those already prescribed by EAD 330499 & 330232 for an extended design working life. Note that this EAD [16] currently does not contain provisions for a 120-year design working life and assessment for such periods is handled presently by independent third-party evaluation reports.

3.3 Steel-to-concrete fastenings with post-installed mechanical anchors

3.3.1 Durability of mechanical anchors

Similar to bonded anchors, mechanical anchors too must be sufficiently durable to resist repeated loads from varied in-service loads imposed on the fastening over its design working life. Unlike bonded anchors, however, creep in the steel constituting the anchor leads to reduced pullout resistances over a longer design working life and, therefore, must be assessed. Within the European framework, the EAD 330232 requires a series of tests to address durability and long-term performance. Table 4 outlines tests specifically dependent on time or number of cycles.

Table 4: Tests in EAD 330232 [17] dependent and independent of time or cycles

Tests independent of time or cycles	Tests dependent on time or cycles	
Reference to establish baseline performance	Crack cycling & hole diameter	Repeated tension loads
Robustness to check variations in imperfect conditions	Durability (corrosion & coating)	Crack movement under load (repetitive opening & closing of cracks to 0.3 mm)
Maximum long-/short-term temperatures		
Maximum torque moment		
Installation direction		
Service condition tests		
Seismic tests		
Not applicable to design working life	Not linked to a specific design working life	Linked to a specific design working life

Apart from determining its resistance to repeated loads, the anchor must be sufficiently durable against adverse environmental conditions where high alkalinity, moisture, pollution, or others are prevalent. Resistance to corrosion is crucial to help ensure that the movement expected from specific parts of the fastener during installation and in service is not obstructed and does not lead to a loss of functionality; examples usually include the nut on the anchor's thread or the cone on the sleeve of expansion anchors. Consequently, this requires that the coating applied on the anchor is sufficiently durable for the designed movement over time, which typically is the entire design working life of the anchor, and

that the material composition of the anchor (carbon or stainless steel) is suited to the **in-service environmental conditions**. Table 5 summarizes the changes to the assessment for the regular 50-year and extended 100- and 120-year assumed working lives.

Table 5: Tests in EAD 330232 [17] linked to a specific design working life for mechanical anchors

Test		Design working life:		
		50-year	100-year	120-year
Repeated tension loads	Load cycles:	100000	200000	240000
	Residual loads compared to reference tests			
Crack movement under load	Movement cycles:	1000	2000	2400
	Displacements	< 2 mm in the first 20 cycles; < 3 mm for all	< 2 mm in the first 20 cycles; < 4 mm for all cycles	

4. Design of cast-in and post-installed fastenings and connections beyond 50-years' working life

4.1 Design overview of post-installed bonded and mechanical anchors with EN 1992-4 & EOTA TR 086

As mentioned in Section 2.2 of this document, the design of fastenings in concrete covered in EN 1992-4 targets a design working life of 50 years, but lacks specific mention of a design working life to either 100 or 120 years. In scenarios where a design working life of the fastening exceeding the 50-year reference period is required, the EOTA Technical Report (TR) 086 provides a framework to apply the EN 1992-4 design provisions beyond this reference period, while maintaining the same target reliability index ($\beta = 3.8$), loading conditions, assumptions, boundary conditions, and limitations described in EN 1992-4. The performance data relevant for design are published in anchor's respective ETA, derived subsequently from assessment to EAD 330232 for mechanical or EAD 330499 for bonded anchors.

In EN 1992-4, determining the fastening's overall resistance consists of verifying several failure modes in tension and shear, chief among them being the resistance to **pullout failure** (in tension) for mechanical anchors and the resistance to **combined cone and pullout failure** (in tension) for bonded anchors, which are affected by changes to the data published in the anchor's ETA for a 50 year design working life and highlighted in red in Figure 5.

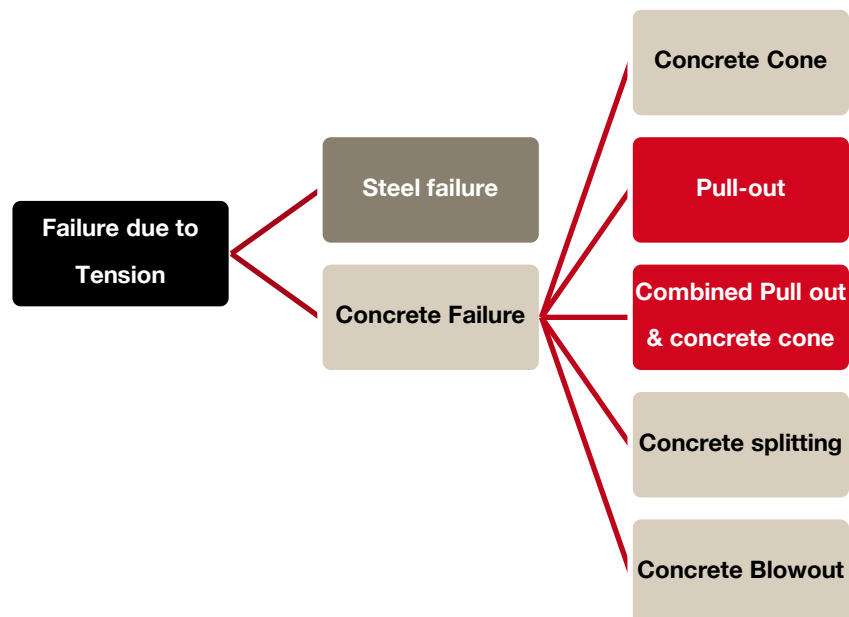


Figure 5: Tension failure modes in fastenings in concrete, with those affected by working life highlighted in red

Note: The possibility of carbonation of the concrete should be considered while designing fasteners for an extended design working life.

When using EOTA TR 086 for design of fastenings subject to **static** conditions beyond 50 years, the resistance to each of these two failure modes will be adversely affected by changes to the data published in the fastener's ETA. As an example, the value of $\tau_{Rk,100,cr}$ or $\tau_{Rk,120,cr}$ found in a bonded fastener's ETA is used in verifying failure to combined pullout and concrete cone in EOTA TR 086 for a 100-year or 120-year design working life, respectively. A similar approach applies to mechanical anchors, where the value of $N_{Rk,p,cr}$ (for 50 years) or $N_{Rk,p,120,cr}$ (120 years) from the fastener's ETA is used to verify pullout failure in EN 1992-4 or EOTA TR 086, respectively.

When using EOTA TR 086 for design of fastenings subject to **seismic** conditions for an extended design working life, the performance parameters $\tau_{Rk,C2}$ and $N_{Rk,p,C2}$ from the relevant tables of the respective ETA-assessed bonded or mechanical anchor are replaced by the relevant values from the ETA.

Design of bonded anchors for an extended working life subject to **fire** conditions according to EOTA TR 082 [19] requires the relevant performance parameter, $\tau_{Rk,fi,p,100y}(\theta) = k_{fi,p}(\theta) \cdot \tau_{Rk,100,cr}$, where $k_{fi,p}(\theta)$ is the reduction factor for bond resistance under fire exposure independent of the design working life. For mechanical anchors, performance under fire loads, considered as an accidental design situation according to EN 1990, for extended working lives is unaffected and design according to EN 1992-4 for any working life is sufficient.

4.2 Design overview of post-installed rebar connections with EN 1992-1-1

Covering lap splices and simply supported anchorages (where no moments are applied), mortars assessed by EAD 330087 and granted an ETA for use with post-installed rebar can be designed for **static** loading with the same design provisions of EN 1992-1-1 [20] for cast-in bars to either a normal 50 year or an extended working life of 100 years. To preclude failures such as those shown in Figure 6, with those affected by the design working life highlighted in red, the anchorage length, l_{bd} , evaluated using Eq. 8.4 and Eq. 8.10 of EN 1992-1-1 is the main design outcome and uses the bond strength applicable to the required design working life – $f_{bd,PIR}$, or $f_{bd,PIR,100y}$. EOTA TR 086 extends the validity of the EN 1992-1-1 design provisions to 120 years, using the bond strength, $f_{bd,PIR,120y}$, found in the ETA of the relevant mortar.

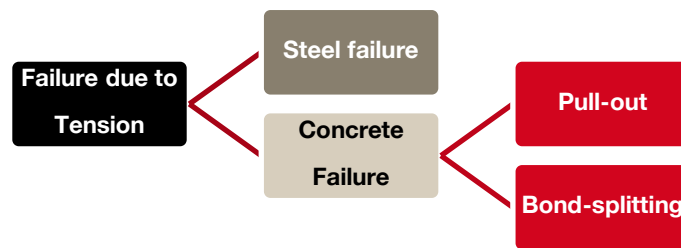


Figure 6: Failures in concrete connections using post-installed rebars assessed to EAD 330087, with those affected by working life highlighted in red

For **seismic** loading, design of the anchorage length accounts for additional provisions found in EN 1998-1 [21] and the bond strength from the ETA for the relevant design working life –

$f_{bd,PIR,seis}$, $f_{bd,PIR,seis,100y}$, or $f_{bd,PIR,seis,120y}$ – with all other design provisions unaffected.

Under **fire** conditions, additional provisions from EN 1992-1-2 [22] are combined with the relevant bond strength from the ETA for the relevant design working life – $f_{bd,fi}$, $f_{bd,fi,100y}$, or $f_{bd,fi,120y}$ – with all other provisions unaffected.

4.3 Design overview of post-installed rebar connections with EOTA TR 069

For post-installed rebars used in transferring moments at end anchorages using the improved bond-splitting model described in EOTA TR 069 [23], which permits formation of the concrete cone within verifiable limits and leverages the higher bond strength of the mortar, several parameters assessed by EAD 332402 are affected when designing for either a 50-year or a 100-year working life, including the bond strength, $\tau_{Rk,uCR}$, and the sustained load parameter, ψ_{sus}^0 , that are published in a separate ETA.

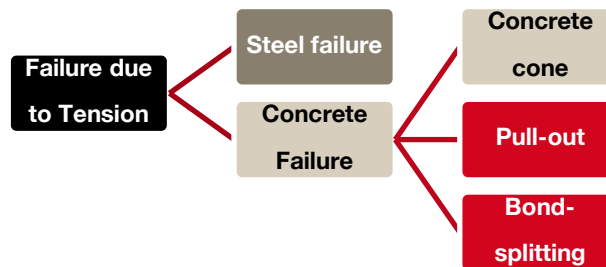


Figure 7: Failures in concrete connections using post-installed rebars assessed to EAD 332402, with those affected by working life highlighted in red

Apart from verifying resistance to steel failure and, additionally, concrete cone breakout that are unaffected by the design working life, design according to EOTA TR 069, 4.4 (3) requires verification of the minimum resistance between the pull-out and bond-splitting failures, $N_{Rk,sp}$, highlighted in red in Figure 7, provided by the mortar. The performance characteristics required in the verification are affected by the design working life and published in the ETA.


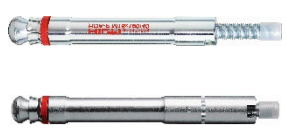
Note: for a design working life of 120-years, the time- and cycle-dependent mortar characteristics are not published in the ETA since EAD 332402 does not presently include assessment provisions for such a design working life. Instead, Hilti provides designers and engineers with Technical Data based on independent third-party evaluation reports for the design of post-installed rebar connections to EOTA TR 069.

5. Hilti solutions for design to an extended working life

Detailed in Tables 6-9, Hilti offers designers and contractors solutions assessed and qualified within the European regulatory framework for fastenings and connections in reinforced concrete structures for design working lives including and beyond 50 years, with the design outcome conditional on use of the correct ETA, EN 1992-1-1, EOTA TR 069 or EN 1992-4 together with EOTA TR 086, as well as the defined exposure and installation conditions expected over the structure's working life.




5.1 Fastenings in concrete with mechanical anchors

Table 6: Mechanical anchor solutions for fastening in concrete for different design working lives

Solution	HST4-R	HDA-P/-T (-R)
		
Assessed to:	EAD 330232	
Loading conditions:	Static, seismic, and fire	
Technical Data (50- or 100-years)	ETA-21/0878	ETA-99/0009
Technical Data (120-years)	ETA-25/1042	ETA-25/1043
Design method (50-years)	EN 1992-4	
Design method (100- or 120-years)	EN 1992-4 + EOTA TR 086	



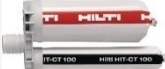

5.2 Fastenings in concrete with bonded anchors

Table 7: Bonded anchor solutions for fastening in concrete for different design working lives

Solution:	HIT-RE 500 V4	HIT-HY 200-A/-R V3	HVU2
			
Assessed to:	EAD 330499		
Loading conditions:	Static, seismic, and fire		
Technical Data (50- or 100-years)	ETA-20/0541	ETA-19/0601	ETA-16/0515 (only 50-years)
Technical Data (120-years)	ETA-25/0752	ETA-25/0584	-
Design method (50-years)	EN 1992-4		
Design method (100- or 120-years)	EN 1992-4 + EOTA TR 086		



5.3 Connections in concrete with post-installed rebar assessed to EAD 330087

Table 8: Post-installed rebar solutions for connections in concrete for different design working lives, assessed to EAD 330087

Solution	HIT-RE 500 V4	HIT-HY 200-A/-R V3	HIT-CT 100	HIT-FP 700-R
				
Assessed to:	EAD 330087			
Loading conditions:	Static, seismic, and fire			
Technical Data (50- or 100-years)	ETA-20/0540	ETA-19/0600	ETA-24/0147	ETA-21/0624
Technical Data (120-years)	ETA-25/0752	ETA-25/0534	ETA-25/1035	-
Design method (50-years)	EN 1992-1-1			
Design method (100- or 120-years)	EN 1992-1-1+ EOTA TR 086			

5.4 Connections in concrete with post-installed rebar assessed to EAD 332402

Table 9: Post-installed rebar solutions for connections in concrete for different design working lives, assessed to EAD 332402

Solution	HIT-RE 500 V4	HIT-HY 200-A/-R V3
		
Assessed to:	EAD 332402	
Loading conditions:	Static and seismic	
Technical Data (50- or 100-years)	ETA-20/0539	ETA-19/0665
Design method (50- or 100-years)	EOTA TR 069	

Design options in PROFIS Engineering

Hilti's cloud-based design software PROFIS Engineering contains design options that allow designers to select and design the resistance of post-installed fastenings and connections in concrete using solutions with the relevant ETA for an extended design working life. As highlighted in Figure 9 for post-installed fastenings in concrete, a dropdown option to select the relevant design working life is integrated in the "Loads" tab in the **Anchoring to Concrete** PROFIS module, in which the various fastening solutions presented in Table 6 and Table 7 can be used.

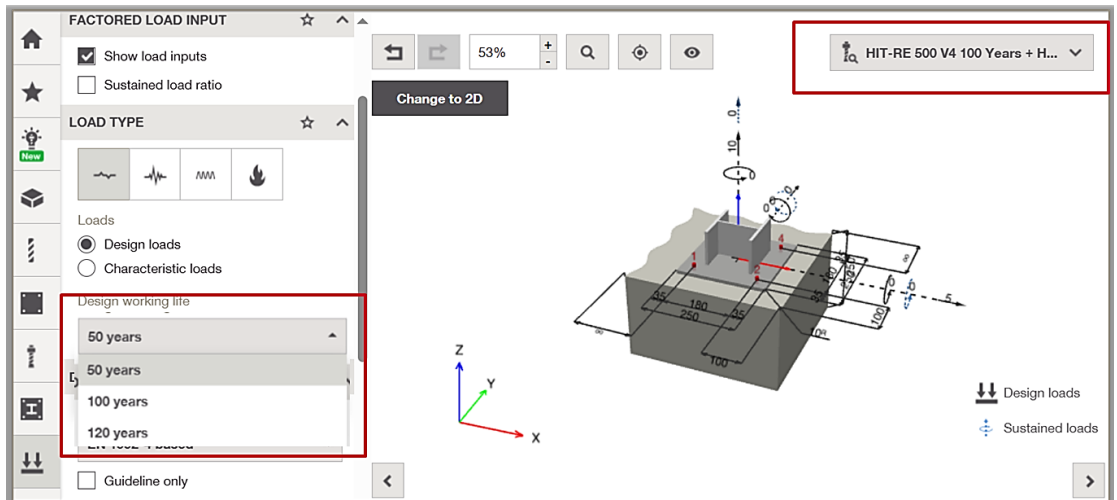


Figure 8: Dropdown with selection options for extended design working life in PROFIS Engineering's Concrete module

A similar option is available in the **Post-installed Rebar** module for design of rebar equivalent to cast-in rebars or with improved bond-splitting behavior, illustrated in Figure 10, where the post-installed rebar solutions described in Table 8 and Table 9 can be found.

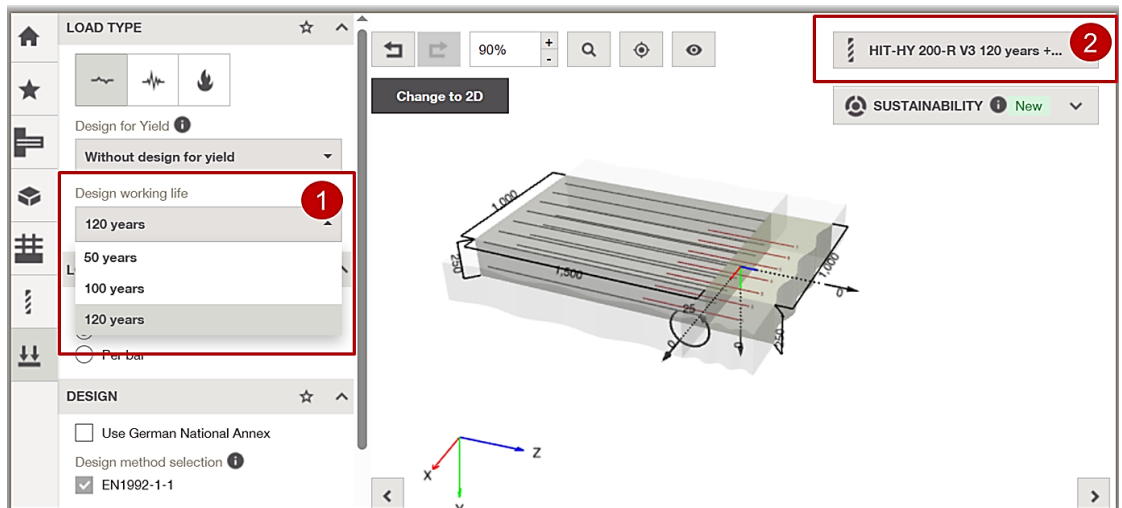


Figure 9: Dropdown with selection options for extended design working life in PROFIS Engineering's Post-installed Rebar module, available for design with EN 1992-1-1 and EOTA TR 069

6. Summary

Durability is a central pillar of structural engineering practice, particularly as demands to design crucial buildings and other civil infrastructure for extended working lives from clients and owners continue to grow. In certain projects such as rail and road tunnels, this impacts not just the design of structural components, but also non-structural components, creating additional challenges for engineers and contractors when accounting for and resolving issues related to durability. Amongst other standards, the Eurocode framework provides a systematic basis to help address the design of concrete to a 50-year working life and beyond through Serviceability Limit State design and probabilistic methods.

For post-installed mechanical or bonded anchors and post-installed rebar used in fastenings and connections in concrete, solutions assessed according to the state-of-the-art European Assessment Documents (EADs) 330232, 330499, 330087, and 332402 represent an important and evolving step in evaluating long-term performance. The ETAs published on their basis provide engineers with the relevant technical data for design according to EN 1992-4 (for steel fastenings into concrete) and EN 1992-1-1 and EOTA TR 069 (for post-installed rebar used in concrete connections). By integrating the relevant design methods and technical data from the ETAs for Hilti's different anchor solutions, PROFIS Engineering supports engineers and contractors in applying the relevant design provisions for fastenings and connections for the relevant design working life.

7. References

- [1] M. Alexander and H. Beushausen, "Durability, working life prediction, and modelling for reinforced concrete structures - review and critique," *Cement and Concrete Research*, vol. 122, pp. 17-29, 2019.
- [2] K. Tuutti, "Corrosion of steel in concrete," Swedish Cement and Concrete Research Institute, Stockholm, 1982.
- [3] T. Siemes and C. Edvardsen, "Duracrete: Working life Design for Concrete Structures," *Durability of Building Materials and Components*, vol. 8, pp. 1343-1356, 1999.
- [4] M. Collepardi, A. Marcialis and R. Turriziani, "Penetration of Chloride Ions into Cement Pastes and Concretes," *Journal of the American Ceramic Society*, vol. 55, no. 10, 1972.
- [5] Fédération Internationale du Béton, "Bulletin 34: Model Code for Working life Design," fib, Lausanne, Switzerland, 2006.
- [6] Fédération Internationale du Béton (fib), "Model Code for Concrete Structures 2010," Ernst & Sohn, Lausanne, Switzerland, 2013.
- [7] L. Bertolini, B. Eisener, P. Pedferri, E. Redaelli and R. B. Pldier, *Corrosion of Steel in Concrete: Prevention, Diagnosis, Repair*, 2nd ed., Wiley-VCH, 2013.
- [8] European Committee for Standardisation, "Eurocode - Basis of structural and geotechnical design (EN 1990)," CEN, Brussels, 2023.
- [9] CEN/TC 250, "Eurocode2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete (EN 1992-4)," CEN, Brussels, 2018.
- [10] T. Kränkel, D. Lowke and C. Gehlen, "Prediction of the creep behaviour of bonded anchors until failure - A rheological approach," *Construction and Building materials*, vol. 75, pp. 458-464, 2015.
- [11] National Transportation Safety Board, "Ceiling Collapse in the Interstate 90 Connector Tunnel (Accident Report NSTB/HAR-07/02)," NTSB, Boston, 2006.
- [12] E. Stierschneider, A. E. Tamparopoulos, K. E. McBride and K. Bergmeister, "Influencing factors on creep displacement assessment of bonded fasteners in concrete," *Engineering Structures*, 2021.
- [13] E. Stierschneider, O. Zeman and K. Bergmeister, "Long-term displacement behavior under sustained load for post-installed rebar connections and bonded anchors," *Structural Concrete*, vol. 26, no. 6, pp. 8741-54, 2025.
- [14] EOTA, "EAD 330499-02-0601-v02: Bonded fasteners and bonded expansion fasteners for use in concrete," EOTA, Brussels, 2024.
- [15] EOTA, "EAD 330087-02-0601-v01: Variant: Systems for post-installed rebar connections with mortar - 120 years working life," EOTA, Brussels, 2021.
- [16] EOTA, "EAD 332402-00-0601-v02: Post-installed reinforcing bar (rebar) connections with improved bond-splitting behaviour," EOTA, Brussels, 2024.

- [17] EOTA, “EAD 330232-02-0601-v01: Mechanical Fasteners for use in Concrete, working life of 120 years,” EOTA, Brussels, 2019.
- [18] EOTA, “TR 086 - Design of Post-installed rebar connections, bonded fasteners, and mechanical fasteners for use in concrete for a working life up to 120 years,” Brussels, 2025.
- [19] EOTA, “TR 082 - Design of bonded fasteners in concrete under fire conditions,” Brussels, 2024.
- [20] CEN/TC 250, “EN 1992-1-1: Eurocode 2 - Design of concrete structures - Part 1-1: General rules and rules for buildings,” CEN, Brussels, 2004.
- [21] CEN/TC 250, “EN 1998-1:2004 - Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings,” CEN, Brussels, 2004.
- [22] CEN/TC 250, “EN 1992-1-2: Eurocode 2 - Design of concrete structures - Part 1-2: Structural fire design,” CEN, Brussels, 2004.
- [23] EOTA, “TR 069 - Design method for anchorage of post-installed reinforcing bars (rebars) with improved bond-splitting behavior as compared to EN 1992-1-1,” EOTA, Brussels, 2019.



Hilti Aktiengesellschaft
9494 Schaan, Liechtenstein
P +423-234 2965

www.facebook.com/hiltigroup
www.hilti.group