



Corrosion in the construction industry

Methods for preventing corrosion damage

Introduction

Corrosion processes cause costs amounting to several billion euros each year. In addition to the financial consequences, numerous dramatic damage events can also be attributed to corrosion. The risk of the occurrence and spread of corrosion can be significantly reduced by selecting suitable active and passive corrosion protection.

In particular, the selection of suitable corrosion protection plays an important role when designing

screw connections. Not only must the screw material be taken into consideration, the entire technical system, including the components in contact with it, and the environmental conditions must also be considered. The following paragraphs provide an overview of the most common types of corrosion on screw connections in the construction industry and describe the most important corrosion protection measures.



Corrosion on self-drilling screws



Types of corrosion

DIN EN ISO 8044 describes corrosion as a “physico-chemical interaction between a metal and its environment that results in changes in the properties of the

metal, and which may lead to significant impairment of the function of the metal, the environment, or the technical system, of which these form a part.”

Corrosion system

In a corrosion system, this leads to electron migration between the anodic and cathodic areas. The electrons released at the anode (oxidation) are absorbed at the cathode (reduction). This chemical process is also known as redox reaction. The prerequisite for this process is that the anode and cathode are connected to each other both directly and also via a conductive electrolyte such as water. During the corrosion process, the anodic area dissolves.

56 types of corrosion are detailed in DIN EN ISO 8044. The following types are most relevant for screw connections in the area of the building envelope and the technical building equipment:

- > Uniform corrosion
- > Bimetallic corrosion
- > Crevice corrosion
- > Stress corrosion cracking

Uniform corrosion

A characteristic feature of uniform corrosion is the consistent abrasion of the surface through the formation of anodic and cathodic sections. This type of corrosion mainly leads to an influence on the

surface properties and visual impairments; with regard to the load-carrying capacity of the screw connection, this type of corrosion is considered comparatively uncritical.

Bimetallic corrosion

Bimetallic corrosion occurs when two or more metallic materials with different voltage potentials come into contact. If a suitable electrolyte is present, the corrosion process occurs due to the different

potentials of the two materials. This type of corrosion, also known as galvanic corrosion, can be prevented by selecting the appropriate combination of materials.

Crevice corrosion

Crevice corrosion leads to a chemical decomposition of the material in narrow, unsealed crevices that are not adequately ventilated. The reactions that take place can also make the corrosion medium even more aggressive. Due to the lack of oxygen supply

in the area of the crevice, the formation of a passive protective layer is not possible. The lack of this protective layer means that even stainless steels can be attacked in the area of crevices.

Stress corrosion cracking

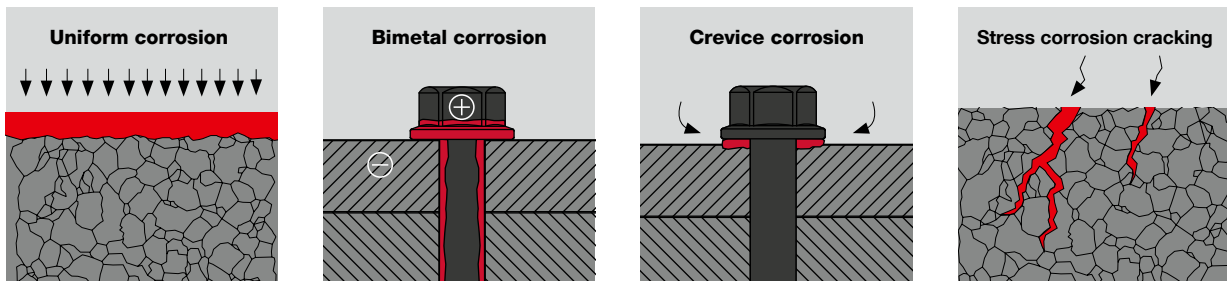
A particularly critical form of corrosion is stress corrosion cracking. The material is damaged by a combination of mechanical and chemical stress. It is possible for cracks in the material structure or complete screw fractures to occur without the appearance of visible corrosion products. Stress corrosion cracking can be divided in two different types:

Anodic stress cracking corrosion occurs primarily on a large number of stainless steels: If these are used in highly corrosive atmospheres, such as indoor swimming pools, cracks in the passive layer can

spread to the entire material structure. As a result, the load-carrying capacity of the screw is reduced to below the critical cross-section.

In contrast to this, cathodic stress-cracking corrosion can occur primarily in case-hardened screws.

Cathodic stress-cracking corrosion is also known in this context as hydrogen induced embrittlement (see the EJOT information sheet 01/2016). Through the accumulation of atomic hydrogen in the screw material, cracks develop in the screw under the effect of tensile loads, which reduce the load-carrying capacity and can lead to breakage of the fastener.



Preventing corrosion damage

Corrosion of fastening elements depends on many factors. Product geometry, environmental conditions and the combination of different materials are only some of the influencing factors to be mentioned here. Corrosion protection measures begin with product design and the selection of suitable materials. If no corrosion-resistant materials can be used, a range of coatings is available to improve corrosion protection. The goal of corrosion protection measures is to prevent damage caused by corrosion to metallic components.

In general, the terms “corrosion resistant” or “active corrosion protection” are used when suitable materials, e.g. rust- and acid-resistant steels or nonferrous metals, are utilised to prevent corrosion.

If a coating is applied to a steel surface for corrosion protection purposes, this is generally referred to as “protected against corrosion” or “passive corrosion protection” are used.

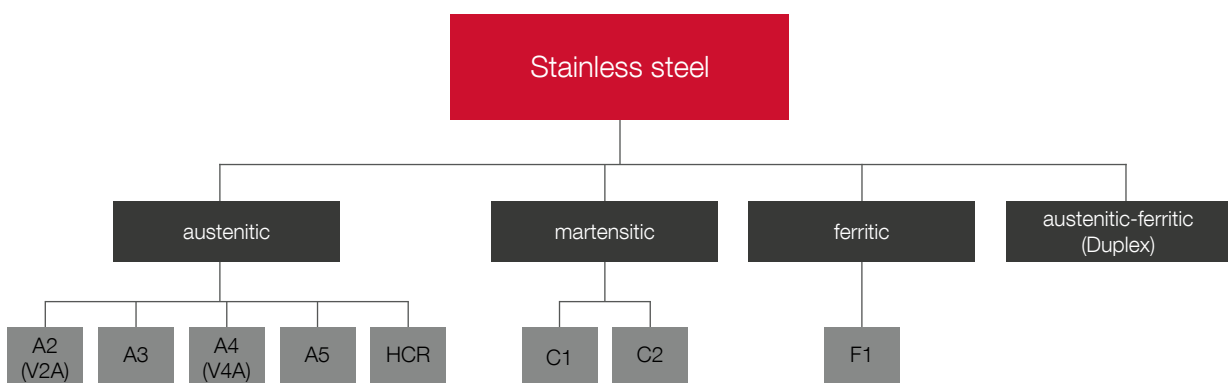
Corrosion resistant

Depending on the requirements of the connection, screws are manufactured from different metallic and non-metallic materials. Corrosion-resistant materials for screws include stainless steels in accordance with DIN EN 3506 and the national building authority approval Z-30.3-6. Stainless steels have a chromium content of at least 10.5%. Increasing the chromium content and adding other alloying elements, such as nickel or molybdenum, further improves the corrosion resistance.

The characteristic feature of stainless steels is the formation of a self-restoring surface layer, known as a passive coating, which protects the base material

against corrosion. The prerequisite for the formation of this passive coating is the presence of a sufficient oxygen concentration.

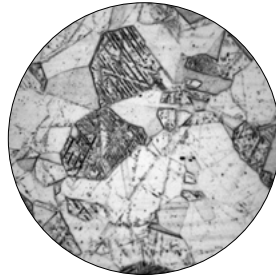
Stainless steels can be divided into four sub-groups: The majority of stainless steels are austenitic stainless steels. In addition, there are martensitic (hardenable) and ferritic stainless steels. Compared to austenitic stainless steels, these versions have a significantly lower corrosion resistance and are therefore only suitable under certain conditions as materials for screws. Special mechanical properties in combination with good corrosion resistance are achieved through using modern austenitic-ferritic steels.



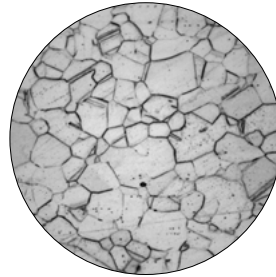
Stainless steel

Micrographs

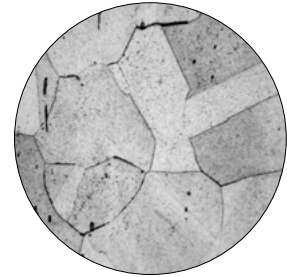
500 times magnification



Stainless steel A2 (V2A)
1.4301



Stainless steel A4 (V4A)
1.4401



Stainless steel HCR
1.4529

The fastening technology industry primarily uses austenitic stainless steels of type A2 (V2A) and A4 (V4A). The steels are characterised by good corrosion resistance in moderately aggressive atmospheres. For especially aggressive atmospheres, stainless steels

of type HCR (e.g. 1.4529) should be used, as these have the highest corrosion resistance among stainless steels. The most important materials for screws and the corresponding corrosion resistance classes can be found in Table I.

Trade name	DIN EN 10088-5	DIN EN 10088-3	AISI (American Iron and Steel Institute)	UNS (Unified Numbering System)
A2 (V2A)	X5CrNi18-10	1.4301	304	S30400
	X3CrNiCu18-9-4	1.4567	304Cu	S30430
A4 (V4A)	X5CrNiMo17-12-2	1.4401	316	S31600
	X3CrNiCuMo17-11-3-2	1.4578	-	-
HCR	X1NiCrMoCuN25-20-7	1.4529	-	-

Table I: Description of selected austenitic stainless steels

In particular, when using materials that are supposedly resistant to corrosion, special attention should be paid to bimetallic corrosion. Table II lists typical construction materials that can be combined with fasteners made of corrosion-resistant stainless steels. The surface ratio between screw and component

plays a key role in the process of galvanic corrosion. While aluminium components, for example, can be fastened with stainless steel screws under normal atmospheric conditions without risk of corrosion, the connection of stainless steel sheets with aluminium fasteners is not recommended.

Component material (larger area)	Screw material (smaller area)		
	Stainless steel A2 / A4 / HCR	Zinc-plated steel	Aluminum
Stainless steel A2 / A4 / HCR	✓	x	x
Aluminum	✓	0	✓
Cooper	✓	x	x
Zinc-plated steel	✓	✓	✓
Casting	0	x	x

Table II: Compatibility table for atmospheric attack

✓ good x uncertain 0 poor

Protection against corrosion / passive corrosion protection

Surface coatings for screws can be divided into non-metallic coatings and metallic coatings. The figure gives an overview of the different coatings.

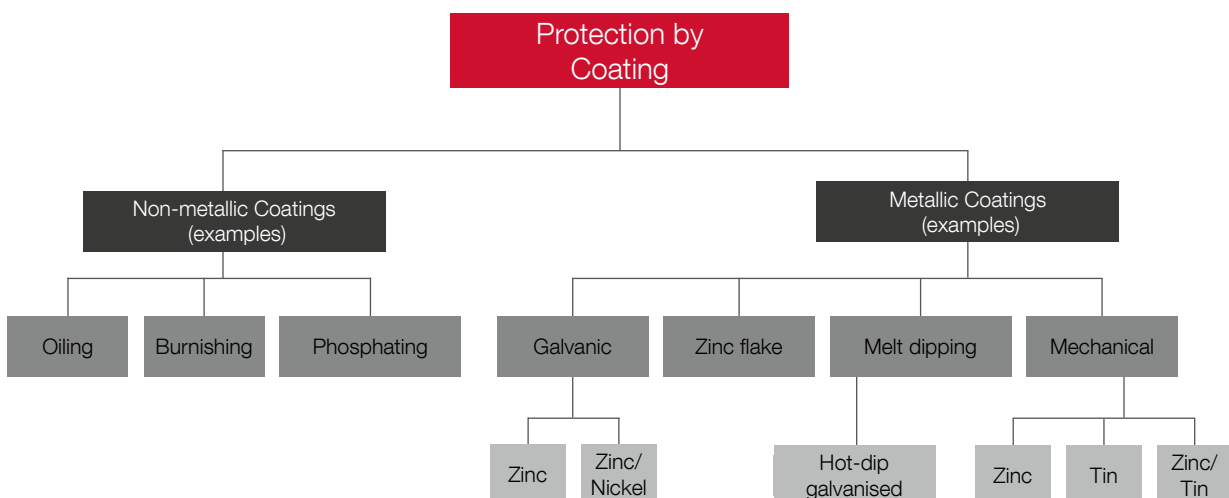
Non-metallic coatings (except for paint systems), such as burnishing, usually offer only limited corrosion protection. Galvanised coatings or zinc flake coatings are generally used for screws in the construction industry, especially self-drilling screws and self-tapping screws.

The most common metallic coating for fasteners is galvanic zinc plating (5–10µm) with subsequent passivation. Passivation is a conversion layer created by a post-immersion solution that improves corrosion resistance. Passivation is achieved by separating solutions that contain chromium. In accordance with the specifications of the REACH directive, EJOT uses only Cr(VI)-free coatings and passivations. During passivation, the term thick film passivation is used for a coating thickness from 0.5–3 µm. Passivations can be produced in different colours, depending on the requirements for the fasteners. In addition to transparent passivations, blue passivations are mainly used for screws in the construction industry.

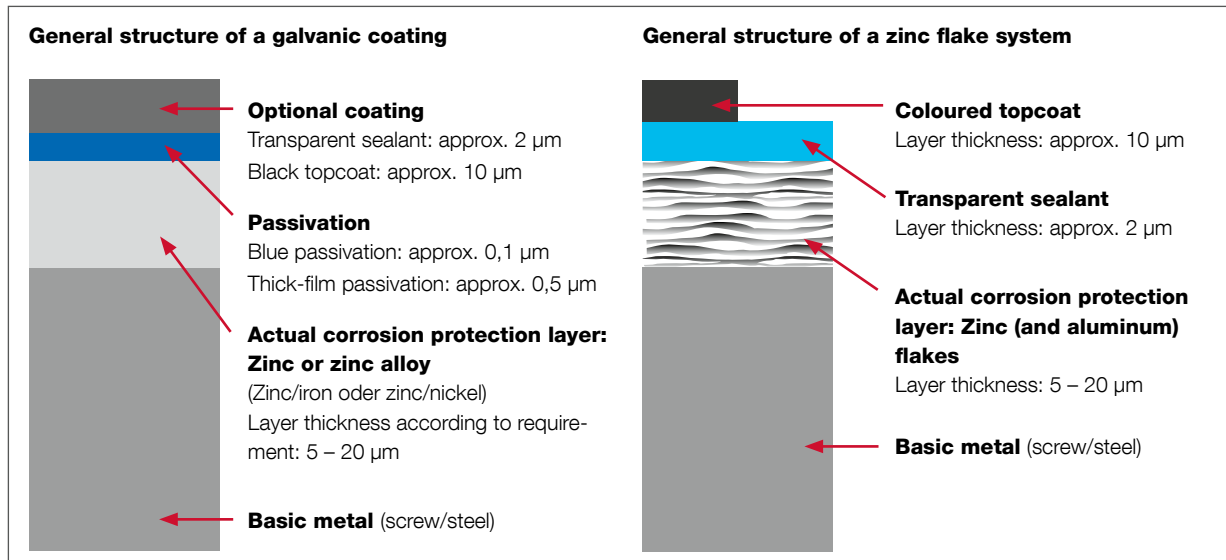
Applying sealants/top coats or organic coating is another way of improving the corrosion resistance of electroplated surfaces. The term sealant is used for coating thicknesses of 1 to 3 µm. Coatings that are thicker than 3 µm are called top coats.

Zinc flake coatings are also considered metallic coatings. In contrast to electroplated coatings, there is no risk of a manufacturing-related hydrogen induced embrittlement of the base material. Zinc flake coatings generally consist of an inorganic base coat, which is composed mainly of zinc and aluminium flakes, and a top coat/sealant. In addition, organic top coats can also be applied to improve corrosion protection.

The combination of a sealant/top coat and an electroplated coating or zinc flake coating is also known as duplex coating. The improved corrosion resistance is achieved through a combination of the final effect of the top coat and the cathodic corrosion protection of the base layer.



Indexing of surface coatings



Schematic layer composition

Hot-dip coatings, such as hot-dip galvanising and mechanical coatings, are less suitable for self-tapping and self-drilling screws in the construction industry due to the sometimes high layer thicknesses.

EJOT Baubefestigungen GmbH uses duplex coatings C 1000, CLIMADUR and EJOGUARD for its products, in addition to electroplated coatings in accordance with DIN EN 4042 and zinc flake coatings in accordance with DIN EN ISO 10683.

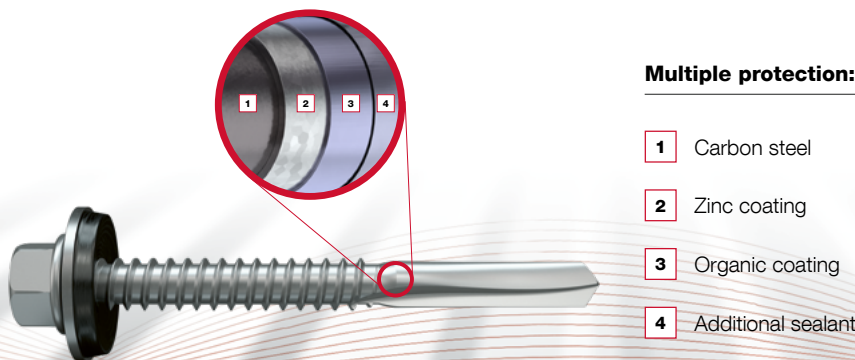
An overview of the resistance of various coatings is given in Table III.

Thanks to the combination of specifically concerted coatings, the EJOGUARD surface offers excellent corrosion properties. With a resistance of one thousand hours in the salt spray test in accordance with DIN EN ISO 9227 and 15 Kesternich cycles in accordance with DIN 50018, the application range of steel screws is significantly expanded depending on national regulations.

Coating	Corrosion resistance without base metal corrosion (red rust)
Zn8/Al/T0*	72 h NSS
Zinc flake	max. 720 h NSS
C 1000	1000 h NSS
CLIMADUR	15 Kesternich cycles (KWF 2.0 S)
EJOGUARD	1000 h NSS, 15 Kesternich cycles (KWF 2.0 S)

*galvanised, min. 8 µm blue passivated

Table III: EJOT surface coatings for construction products



Corrosion tests

The corrosion resistance of a surface coating generally cannot be tested in practice due to time constraints. Therefore, testing is often carried out in defined, accelerated laboratory tests. Common tests for fasteners are the neutral salt-spray test (NSS) in accordance with DIN EN ISO 9227 and the cyclic corrosion test in the presence of sulphur dioxide (Kesternich test) in accordance with DIN 50018. However, the neutral salt-spray test is mainly used for fasteners.

Due to the varying atmospheric conditions, the results of the above-mentioned tests cannot be compared with each other. This means that coatings with a high salt-spray resistance may not necessarily demonstrate high resistance in the Kesternich test, and vice versa. The tests are performed on undamaged parts. Points of impact or damage to the coating caused

by processing the parts is not taken into account. Therefore, only limited conclusions can be drawn from the laboratory tests about the practical applicability.

The assessment criterion in the construction industry is usually the initial occurrence of red rust (base metal corrosion). Depending on the test procedure used, the resistance is stated in cycles (Kesternich test, e.g. 3 cycles) or in hours (NSS test, e.g. 120 h). In general, the higher the stated value, the higher the corrosion resistance of the coating. The results of the short-term tests cannot be transferred to practical applications or outdoor weathering. They are primarily used for checking the quality of the coatings and identifying any manufacturing-related defects in the coating. Material testing with regard to corrosion resistance in short-term tests is not permitted in accordance with DIN EN ISO 14713.



Kesternich test

Testing the screws in the condensation tester



Normative basics

There are a number of European and international standards available to assist in material selection and assessment of the environmental conditions with regard to the corrosion stress to be expected. In addition, there are several other national regulations that supplement or define exceptions to the international standards.

One of the most important standards for assessing environmental conditions under corrosive aspects is DIN EN ISO 12944-2. This standard divides environmental conditions into six different corrosivity categories. An overview of the corrosivity categories

and examples of environments are given in Table IV. In accordance with DIN EN ISO 12944-2, statements are made on the use of stainless steels in the European Assessment Documents (EAD) 330046-01-0602 “Fastening Screws for Metal Members and Sheeting” and 330047-01-0602 “Fastening Screws for Sandwich Panels”, among others. Both assessment documents require the use of stainless steels for corrosivity categories \geq C2. The documents form the testing basis for all European Technical Assessments on the market in the area of industrial lightweight construction, such as ETA-10/0200 and ETA-13/0177.

According to DIN EN ISO 12944-2	Description	Corrosion class
C1	Internal, non exposed and dry environment	Very low
C2	Rural surroundings, as well as light industrial and urban areas, typically over 500 m away from heavy industry fall out and away from all environmental influences listed below.	Low
C3	Industrial areas characterised by pollution precipitation from adjacent designated industrial environments or where small industries lead to significant pollution. Also mild marine areas min. 1000 m away from marine environment, characterised by a noticeable salt smell.	Average
C4	Heavy industry characterised by high emissions. Perceptible chemical odour, e.g. sulphur and acid. Includes factory buildings and buildings with moderate internal humidity and/or expected moderate corrosion due to the technical and chemical conditions. Also includes the marine environment between 100 and 300 m from the shore in an inland direction.	High
C5 I	Heavy industrial areas or chemical industry, characterised by strong emissions from chimneys and strong chemical odours, e.g. sulphur and acids. Extremely high corrosion rates inside and outside the building can usually be expected here.	Very high
C5 M	Marine areas, including off shore applications, as well as any building less than 100 m from the coast or the surf line	Very high

Table IV: Corrosion classes according to EN ISO 12944-2

For the dimensioning and construction of steel structures in the construction industry, DIN EN 1993-1-4 can be used to determine the corrosion load. The standard can be used as an aid in determining the corrosion resistance factor CRF required for the application. This is calculated from the sum of the values for exposure to chlorides from saltwater and de-icing chemicals, exposure to sulphur dioxide and a

value for the cleaning concept or rain washing of the construction. Depending on the existing conditions, the CRF value can be between 1 and < -20 . In accordance with DIN EN 1993-1-4, a corrosion resistance class CRC can be assigned to the CRF. Table V lists the possible corrosion resistance classes and the assignment to the corrosion resistance factors.

Corrosion resistance factor CRF	Corrosion resistance class CRC	Material
1	I	1.4003; ...
$0 \geq \text{CRF} > -7$	II	1.4301; 1.4567, z. B. JT3 / JT4 / JZ3; ...
$-7 \geq \text{CRF} > -15$	III	1.4401; 1.4578, z. B. JT9 / JT6 / Dabo TKE; ...
$-15 \geq \text{CRF} \geq -20$	IV	1.4462; ...
< -20	V	1.4529, z. B. JZ1 / JA1; ...

Table V: CRF and CRC with example material designations

Material and coating selection in practice

It is essential to design the screw connection in accordance with the corrosion requirements for the practical application. In accordance with DIN EN ISO 1993-1-4, fasteners that are used in weathered outdoor areas must be made from a material of at least corrosion resistance class II (stainless steels A2). Depending on national regulations, screws with duplex coatings, such as the EJO GUARD, can also be used.

In addition to the environmental conditions, the cleaning concept of the construction and the materials of the components to be fastened also play a role in the selection of the screw material.

The following examples describe the material selection for a screw in different designs, taking into consideration the requirements of DIN EN ISO 1993-1-4.

Elements for determining the corrosion resistance factor (CRF)

F₁ the risk of exposure to chlorides from saltwater or de-icing chemicals (road salt)
 from 1 = Indoors
 to -15 = Very high risk of exposure

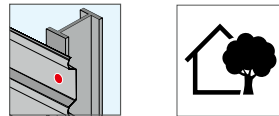
F₂ The risk of exposure to sulphur dioxide
 von 0 = Low risk of exposure
 bis -10 = High risk of exposure

F₃ the cleaning concept or the exposure to rain washing
 von 0 = Complete exposure to rain washing
 bis -7 = No rain washing or no specific cleaning

Example I: Fastening a galvanized steel trapezoidal profile to a steel substructure in a rural area. The risk of exposure to saltwater and chlorides is classified as low. Therefore a value of 0 is selected for F1. With regard to the sulphur dioxide concentration, a low value is also expected, which thus gives a value of 0. As the construction can be completely washed by rain, a value of 0 is also applied here.

$$CRF = F_1 + F_2 + F_3 = 0 + 0 + 0 = 0$$

For a CRF value of 0, a stainless steel of corrosion resistance class CRC II can be used, according to Table V. Therefore, the screw should be made of at least corrosion-resistant stainless steel A2. Due to the significantly smaller surface ratio of the stainless steel screw compared to the galvanized steel trapezoidal profile, no galvanic corrosion is to be expected for the connection.



Example II: Fastening a stainless steel attachment in concrete using through bolts in a road tunnel, in which de-icing chemicals are introduced by vehicles. The introduction of de-icing chemicals means there is a high risk of exposure to chlorides. According to DIN EN ISO 1993-1-4, a value of -10 must be selected for F1. At the same time, very high exposure to sulphur dioxide is to be expected in road tunnels, meaning that a value of -10 is also applied for F2. If there is a specific cleaning concept for the construction, then a value of -2 can be set for F3.

As the CRF value is -22, a material of corrosion resistance class CRC V must be selected for the through bolts. Through bolts made of austenitic stainless steel 1.4529 belong to this group. Since both the component to be fastened and the screw are made of stainless steel, no further measures need to be taken with regard to galvanic corrosion.



$$CRF = F_1 + F_2 + F_3 = -10 - 10 - 2 = -22$$

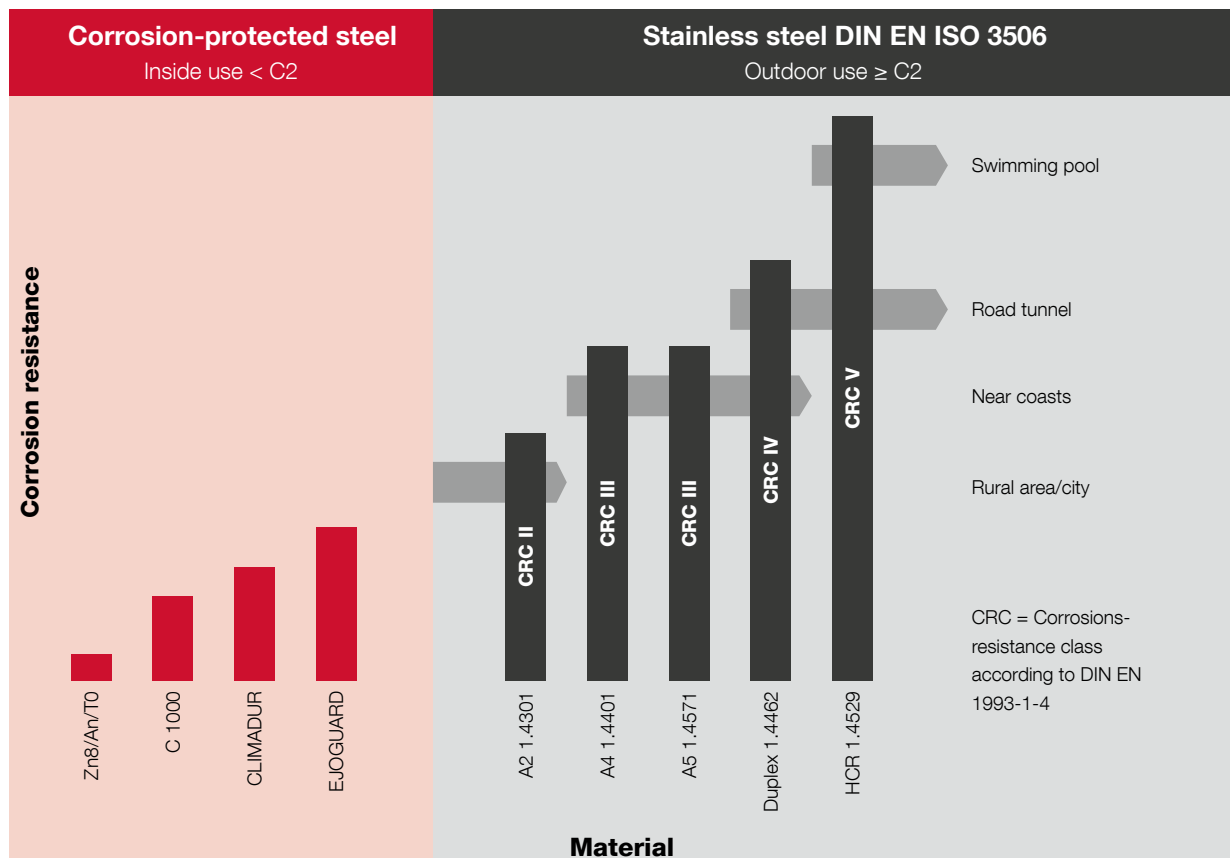


Diagram of material selection for different environmental conditions

List of standards

DIN 50018

DIN 50018:2013-05, DIN 50018:2013-05, Testing in a saturated atmosphere in the presence of sulfur dioxide

DIN EN 1993-1-4

DIN EN 1993-1-4:2015-10, Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels

DIN EN 4042

DIN EN 4042:2018-11: Fasteners – Electroplated coating systems

DIN EN ISO 3506

DIN EN ISO 3506-1:2010-04: Mechanical properties of corrosion-resistant stainless steel fasteners – Part 1: Bolts, screws and studs

DIN EN ISO 8044

DIN EN ISO 8044:2015-12: Corrosion of metals and alloys – Basic terms and definitions

DIN EN ISO 9227

DIN EN ISO 9227:2017-07: Corrosion tests in artificial atmospheres – Salt spray tests

DIN EN ISO 10683

DIN EN ISO 10683:2018-11: Fasteners – Non-electrolytically applied zinc flake coating systems

DIN EN ISO 12944-2

DIN EN ISO 12944-2:2018-04: Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments

DIN EN ISO 14713

DIN EN ISO 14713-1:2017-08: Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures – Part 1: General principles of design and corrosion resistance

EAD 330046-01-0602

EOTA, Fastening Screws for Metal Members and Sheeting, 2018

EAD 330047-01-0602

EOTA, Fastening Screws for Sandwich Panels, 2017

ETA-10/0200

EJOT Baubefestigungen GmbH: ETA-10/0200, Fasteners for metal components and sheet metal, 2018

ETA-13/0177

EJOT Baubefestigungen GmbH: ETA-13/0177, Fasteners for sandwich panels, 2018

Z-30.3-6

Informationsstelle Edelstahl Rostfrei (ISER) (Stainless Steel Information Centre): Z-30.3-6, Products, components and fasteners made of corrosion-resistant steels, 2018



Fastening solutions for the building industry

The EJOT Construction Division supplies to selected segments of the building industry. This includes professional applications on building facades as well as installation solutions for technical facilities inside the building.

Striving for high product quality is not an end in itself for EJOT. The customer really benefits from our screws and anchors. Therefore reliable installation also means low failure costs for the customer. Moreover, durable quality joints provide the best protection against expensive customer complaints. This is why our strategic product lines are manufactured according to highest quality standards.

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Other services include advice over the telephone, application advice on-site, initial sizing, component tests in the EJOT Test Centre and a comprehensive training programme for system providers, architects, specifiers, assemblymen and contractors with the EJOT TEC ACADEMY.

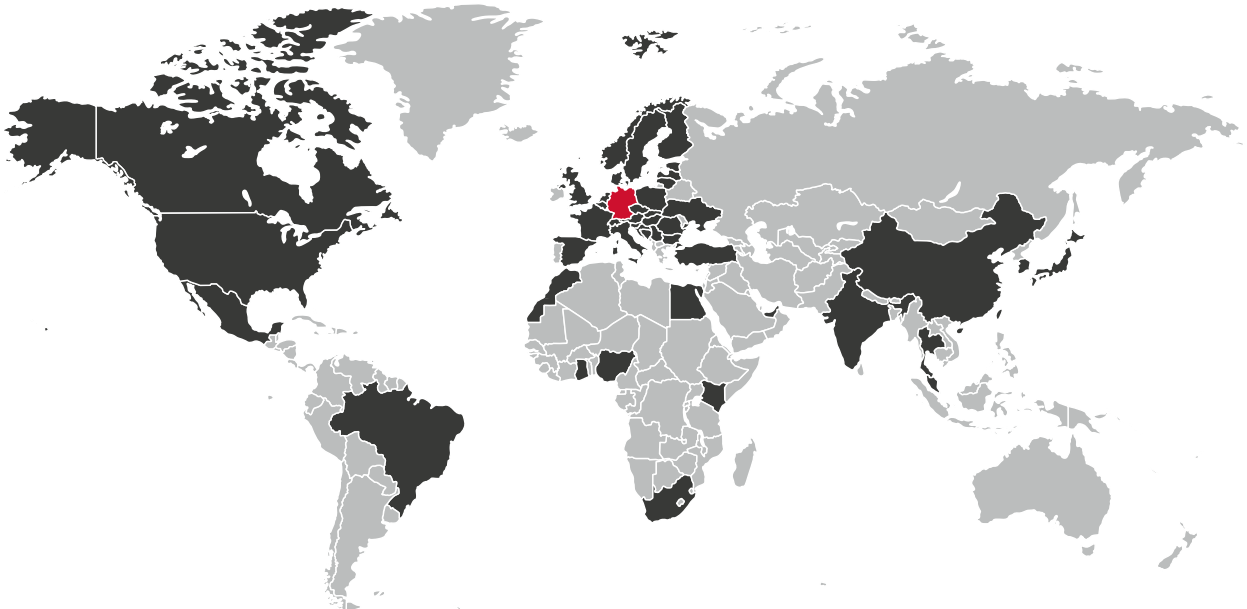
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We stand for sustainability

EJOT® products have Environmental Product Declarations

Environmental protection and the sustainable use of resources are amongst the most important future projects. Sustainability is becoming more and more important for the building and real estate industry, both today and in the future.

Buildings are assessed under ecological aspects such as energy efficiency and resource consumption. In particular public awarding authorities include these criteria into their contracts.

EJOT, as a leading company in the field of ETICS fasteners, has responded to these requirements several years ago and carried-out life cycle assessments.

The first Environmental Product Declaration (EPD) for anchor manufacturers was obtained by EJOT and we can now present a comprehensive and complete record for the sustainability and the balance of environmental influences of our products.

EPDs for anchors and fasteners from the areas of flat roof and rear-ventilated facade have followed. The extensive portfolio of industrial lightweight construction was also balanced with an EPD.



EJOT Sustainability on the Internet:

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EJOT® TEC ACADEMY

Our know-how for your building projects


With the EJOT TEC ACADEMY, we regularly offer training courses to inform you about current trends in the construction industry, our products and their applications.





EJOT® TEC ACADEMY:
www.ejot.com/tec-academy

Audio podcast

EJOT® TEC ACADEMY podcast




In our EJOT TEC ACADEMY podcast, you can find out more about current trends and topics in the construction industry and the associated fastening solutions – always up-to-date, technically sound and at the heart of the industry.



Listen now!

YouTube channel

EJOT® Construction Division



Our YouTube channel offers a large number of videos with product presentations, assembly instructions and tips from the world of fastening technology.

Watch now!

EJOT® TEC ACADEMY in detail

Expert seminars

We offer expert trainings in our seminar rooms for various topics. The expert seminars are aimed at architects, specifiers, distributors and technicians and are structured in different modules.

Benefits

- > Build up skills in fastening technology
- > Knowledge of conditions under the German building law
- > Safe product selection for the application case, based on guidelines in compliance with the approval
- > Safety in practical handling

Online trainings

As an addition to the face-to-face events in our seminar rooms, we offer you a wide range of digital options to further your education flexibly from your home office or office and to expand your expertise.

Technical requirements

- > We use the tool Microsoft Teams for our free online trainings.
- > You can ask questions at any time during the training via a chat function.

Content

- > Industrial Lightweight Construction
- > Flat Roofing
- > Anchoring Technology
- > Rear-Ventilated Facades
- > Solar
- > Timber Construction

Dates

The expert seminars are tailored to your individual requirements. Current training dates are announced in our newsletter as well as on our TEC ACADEMY page on the Internet.

Notes on registration

- > Current training dates are announced in our newsletter as well as on our TEC ACADEMY page on the Internet.
- > After you have registered, we will send you a confirmation email containing the login details for the respective online training.
- > If you have registered but are then unable to attend the online training due to scheduling reasons, a separate deregistration is not necessary.

Website guidebooks in the construction fasteners blog

Digital reading material - take advantage of the opportunity to further educate yourself on a wide variety of topics on our website at any time. From now on, the new corrosion guidebook will regularly give you useful tips and information on the topic of corrosion.

Comprehensive series of advice on heavy-duty anchoring, corrosion, the use of self-drilling screws and the planning and installation of flat roofs, as well as numerous blog posts

on a wide range of topics and problems relating to fastening technology – you can find all this in our construction blog on our website.

It's worth checking in regularly, because new, exciting articles are added every month.



To the Construction blog:
www.ejot.com/blog



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