

Hot dip galvanizing and corrosion categories

In which corrosion categories could galvanized steel be used? This question is frequently asked, when corrosion protection only is specified to a certain corrosion category. Such a specification is not enough, since corrosion categories give quite wide ranges for the environmental exposure of the steel structure without specifying corrosion protection or life time. More information is needed as basis for a good decision.

Corrosion in different environments

Atmospheric exposure

The corrosion rate of a zinc coating is affected by the time for which it is exposed to wetness, air pollution and contamination of the surface, but the corrosion rates are much slower than for steel and often decrease with time. General information on the atmospheric corrosion rate for zinc is given in ISO 9224.

Table 1 gives basic groups of environments (related to ISO 9223). Where the relative humidity is below 60 %, the corrosion rate of iron and steel is negligible and they may not require zinc coating, e.g. inside many buildings. When the relative humidity is higher than 60 % or where they are exposed to wet or immersed conditions or prolonged condensation then, like most metals, iron and steel are subject to more serious corrosion. Contaminants deposited on the surface, notably chlorides and sulphates, accelerate the attack. Substances that deposit on the surface of the iron and steel increase corrosion if they absorb moisture or go into solution on the surface of the iron and steel. The temperature also influences the corrosion rate of unprotected iron and steel and temperature fluctuations have a stronger effect than the average temperature value.

The micro-environment, i.e. the conditions prevailing around the structure, is also important because it allows a more precise assessment of the likely conditions than study of the basic climate alone. It is not always known at the planning stage of a project. Every effort should be made to identify it accurately, however, because it is an important factor in the total environment against which corrosion protection is required. An example of a micro-climate is the underside of a bridge (particularly over water).

The corrosion of steelwork inside buildings is dependent upon the internal environment but in "normal" atmospheres, e.g. dry and heated, it is insignificant. Steelwork in the perimeter walls of buildings is influenced by the configuration within the perimeter wall, e.g. steelwork without direct contact with the outer leaf of a wall comprising two parts separated by an air space is at less risk of corrosion than steelwork in contact with or embedded in the outer leaf. Buildings containing industrial processes, chemical environments, wet or contaminated environments should be given special consideration. Steelwork which is partially sheltered, e.g. farm barns and aircraft hangars, should be considered as being subject to the exterior environment.

Table 1 sets out an indication of the likely range of corrosion rates which are applicable to zinc coatings exposed to the different types of corrosivity category dealt with in ISO 9223.

Table 2 indicates the life to first maintenance for hot galvanized steel exposed to the corrosivity categories C3 to CX. For C1 and C2 hot dip galvanizing normally gives very long life times, and could be used without further analyse.

Table 1 — Description of typical atmospheric environments related to the estimation of corrosivity categories (2).

Corrosivity category C Corrosion rate for zinc (based upon one year exposures), r_{corr} ($\mu\text{m}\cdot\text{a}^{-1}$) and corrosion level	Typical environments (examples)	
	Indoor	Outdoor
C1 $r_{\text{corr}} \leq 0,1$ Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, central Arctic/Antarctica
C2 $0,1 < r_{\text{corr}} \leq 0,7$ Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls	Temperate zone, atmospheric environment with low pollution ($\text{SO}_2 < 5 \mu\text{g}/\text{m}^3$), e.g.: rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas
C3 $0,7 < r_{\text{corr}} \leq 2$ Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution ($\text{SO}_2: 5 \mu\text{g}/\text{m}^3$ to $30 \mu\text{g}/\text{m}^3$) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides, subtropical and tropical zones with atmosphere with low pollution
C4 $2 < r_{\text{corr}} \leq 4$ High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution ($\text{SO}_2: 30 \mu\text{g}/\text{m}^3$ to $90 \mu\text{g}/\text{m}^3$) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water, exposure to strong effect of de-icing salts, subtropical and tropical zones with atmosphere with medium pollution
C5 $4 < r_{\text{corr}} \leq 8$ Very high	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones	Temperate and subtropical zones, atmospheric environment with very high pollution ($\text{SO}_2: 90 \mu\text{g}/\text{m}^3$ to $250 \mu\text{g}/\text{m}^3$) and/or important effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline
CX $8 < r_{\text{corr}} \leq 25$ Extreme	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter	Subtropical and tropical zones (very high time of wetness), atmospheric environment with very high pollution (SO_2 higher than $250 \mu\text{g}/\text{m}^3$), including accompanying and production pollution and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas with occasional contact with salt spray

NOTE 1 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea-salt, such as wind direction, wind velocity, local topography, wind sheltering islands beyond the coast, distance of the site from the sea, etc.

NOTE 2 Extreme influence of chlorides, which is typical of marine splashing or heavy salt spray, is beyond the scope of ISO 9223.

NOTE 3 Corrosivity classification of specific service atmospheres, e.g. in chemical industries, is beyond the scope of ISO 9223.

NOTE 4 Sheltered and not rain-washed surfaces, in a marine atmospheric environment where chlorides are deposited, can experience a higher corrosivity category due to the presence of hygroscopic salts.

NOTE 5 In environments with an expected "CX category", it is recommended to determine the atmospheric corrosivity classification from one year corrosion losses. ISO 9223 is currently under revision; category "CX" will be included in the revised document.

NOTE 6 The concentration of sulphur dioxide (SO_2) should be determined during at least 1 year and is expressed as the annual average.

NOTE 7 Detailed descriptions of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1. Indoor corrosivity categories IC1 to IC5 are defined and classified.

NOTE 8 The classification criterion is based on the methods of determination of corrosion rates of standard specimens for the evaluation of corrosivity (see ISO 9226).

NOTE 9 The thickness-loss values are identical to those given in ISO 9223, except that, for rates of $2 \mu\text{m}$ (per year) or more, the figures are rounded to whole numbers.

NOTE 10 The zinc reference material is characterized in ISO 9226.

NOTE 11 Corrosion rates exceeding the upper limits in category C5 are considered as extreme. Corrosivity category CX refers to specific marine and marine/industrial environments.

NOTE 12 To a first approximation, the corrosion of all metallic zinc surfaces is at the same rate in a particular environment. Iron and steel will normally corrode 10 to 40 times faster than zinc, the higher ratios usually being in high-chloride environments. The data is related to data on flat sheet given in ISO 9223 and ISO 9224.

NOTE 13 Change in atmospheric environments occurs with time. For many regions, the concentrations of pollutants (particularly SO_2) in the atmosphere have reduced with time. This has led to a lowering of the corrosivity category for these regions. This has, in turn, led to the zinc coatings experiencing lower corrosion rates compared to historical corrosion performance data. Other regions have experienced increasing pollution and industrial activity and therefore would be expected to develop environments more accurately described by higher corrosivity categories.

NOTE 14 The corrosion rate for zinc and for zinc-iron alloy layers are approximately the same.

Table 2 — Life in year to first maintenance for a range of corrosivity categories (2).

System	Reference standard	Minimum thickness μm	C3	C4	C5	CX
			Hot dip galvanizing	ISO 1461	85	40/>100
	140	67/>100	33/67		17/33	6/17
	200	95/>100	48/95		24/48	8/24
Hot dip galvanized sheet	EN 10346	20	10/29	5/10	2/5	1/2
		42	20/60	10/20	5/10	2/5
Hot dip galvanized tube	EN 10240	55	26/79	13/26	7/13	2/7

Exposure to soils

The wide range in physical and chemical properties of soils (e.g. the pH variation from 2,6 to 12 and resistivity from tens of ohms to approximately 100 k Ω) and the gross inhomogeneity of soils means that corrosion of zinc coatings in soils is rarely uniform in nature. Corrosion in soil is dependent on the mineral content, on the nature of these minerals and on the organic components, water content and oxygen content (aerobic and anaerobic corrosion). Corrosion rates in disturbed soil conditions are usually higher than in undisturbed soil. General guidance on the corrosion likelihood in soil can also be found in EN 12501-1.

Lime-containing soils and sandy soils (provided that they are chloride-free) are, in general, least corrosive, whilst clay soils and clay marl soils are corrosive to a limited extent. In bog and peat soils, the corrosiveness depends on the total acid content.

Where major iron and steel structures such as pipelines, tunnels, and tank installations, pass through different types of soil, increased corrosion (localized) can occur at isolated points (anodic areas) by the formation of differential aeration cells. For some uses, e.g. earth reinforcement, a controlled backfill is used in conjunction with a zinc coating.

Corrosion cells can also form at the soil/air and soil/ground-water level interfaces, leading possibly to increased corrosion, and these areas should be given special consideration. Conversely, the application of cathodic protection for structures in soil (or in water) can both modify the protective coating requirements and lengthen their life. Specialist advice should be sought for full guidance on all conditions involved.

While the average annual corrosion rates for zinc coatings in most soils are less than 10 μm per annum, the factors influencing corrosion in specific soil environments are complex and detailed expert advice should be sought regarding individual exposure conditions.

In some cases it is recommended to use galvanizing + paint, so called duplex system, to achieve long service lives. This is for example:

- In almost constant damp environments
- In highly acidic or basic environments
- In corrosive soils as clayey or peat soils

Exposure to water

The type of water — soft or hard fresh water/brackish water/salt water — has a major influence on the corrosion of iron and steel in water and the selection of protective zinc coatings. With zinc coatings, corrosion is affected primarily by the chemical composition of the water but temperature, pressure,

flow rate, agitation and oxygen availability are all important. For example, zinc should not be used in hot non-scale-forming waters; heavy corrosion of zinc can also occur in condensate, especially between about 55 °C and 80 °C (e.g. in saunas). Otherwise, barrier protection can occur at all temperatures; below about 60 °C, zinc can also provide cathodic protection. The duration of life of zinc surfaces in cold scale-forming waters is usually higher than in non-scale-forming waters (Ryznar's or Langelier's index should be used to calculate whether the water is scale-forming). Since the composition of non-saline waters can vary greatly, previous experience or expert advice should be sought.

For hot water, specialist advice should always be sought (see also for example EN 12502-3). Coatings used for all structures (including pipes, fittings, tanks and tank covers) in contact with potable water should be non-toxic and should not impart any taste or odour, colour or turbidity to the water, nor foster microbial attack. With tanks, if additional protection to hot dip galvanizing is necessary, sufficient coats of high-build bitumen paint should be applied.

Zones of fluctuating water level (i.e., the area in which the water level changes as a result of natural fluctuations — e.g. tidal movements, or artificial alteration of the water level in lock chambers or reservoirs) or splash zones should be given special consideration as, in addition to water attack, there can also be atmospheric attack and abrasion.

The many factors affecting corrosion in fresh water make it impracticable to present simple guidance. Some guidelines for seawater are set out below but it is emphasized that, for all water exposures, specialist advice should be sought for full guidance on all conditions involved.

In temperate sea water, the average zinc corrosion rate will usually lie between 10 µm per annum and 20 µm per annum. Hot dip galvanized tubes and sheets normally have additional protection when used in sea water (see ISO 12944-5 and ISO 12944-8 and EN 13438). Brackish water may be more or less corrosive than sea water and no general estimates of durability can be given.

References:

1. *Varmforzinkning og korrosionskategorier*, Nordic Galvanizers in cooperation with FORCE Institutets Korrosionsafdeling, Denmark.
2. *EN ISO 14713-1:2009 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*