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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

Revêtements de zinc — Lignes directrices et recommandations pour la protection contre la corrosion du fer et de l'acier dans les constructions —

Partie 1: Principes généraux de conception et résistance à la corrosion

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 4, *Hot dip coatings (galvanized, etc.)*.

This second edition cancels and replaces the first edition (ISO 14713-1:2009), of which it constitutes a minor revision following the publication of ISO 17668:2016 and ISO 9223:2012, with the following changes:

— ISO 17668 has replaced EN 13811;

— revisions to Table 1 to align with corresponding descriptions of typical environments in ISO 9223:2012, Table C.1 and to make clearer that the corrosion rates presented are for the first year of exposure.

A list of all parts in the ISO 14713 series can be found on the ISO website.

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

1 Scope

This document provides guidelines and recommendations regarding the general principles of design which are appropriate for articles to be zinc coated for corrosion protection and the level of corrosion resistance provided by zinc coatings applied to iron or steel articles, exposed to a variety of environments. Initial protection is covered in relation to

— available standard processes,

— design considerations, and

— environments for use.

This document applies to zinc coatings applied by the following processes:

a) hot dip galvanized coatings (applied after fabrication);

b) hot dip galvanized coatings (applied onto continuous sheet);

c) sherardized coatings;

d) thermal sprayed coatings;

e) mechanically plated coatings;

f) electrodeposited coatings.

These guidelines and recommendations do not deal with the maintenance of corrosion protection in service for steel with zinc coatings. Guidance on this subject can be found in ISO 12944-5 and ISO 12944-8.

NOTE There are a variety of product-related standards (e.g. for nails, fasteners, ductile iron pipes, etc.) which provide specific requirements for the applied zinc coating systems which go beyond any general guidance presented in this document. These specific product-related requirements will take precedence over these general recommendations.

2 Normative references

ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 2063, *Thermal spraying — Metallic and other inorganic coatings — Zinc, aluminium and their alloys*

ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness*

ISO 8044:2015, *Corrosion of metals and alloys — Basic terms and definitions*

ISO 12683, *Mechanically deposited coatings of zinc — Specification and test methods*

ISO 17668, *Zinc diffusion coatings on ferrous products — Sherardizing — Specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1461, ISO 2063, ISO 2064, ISO 8044, ISO 12683 and ISO 17668 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
atmospheric corrosion
corrosion with the earth's atmosphere at ambient temperature as the corrosive environment

[SOURCE: ISO 8044:2015, 3.4]

3.2
elevated temperatures
temperatures between +60 °C and +200 °C

3.3
exceptional exposure
special cases such as exposure that substantially intensifies the corrosive exposure and/or places increased demands on the corrosion protection system

3.4
life to first maintenance
time interval that can elapse after initial coating before coating deterioration reaches the point when maintenance is necessary to restore protection of the basis metal

4 Materials

4.1 Iron and steel substrates

In hot dip galvanizing, the reactivity of the steel is modified by its chemical composition, particularly by the silicon plus phosphorus contents (see ISO 14713-2). The metallurgical and chemical nature of the steel is irrelevant to protection by thermally sprayed or sherardized coatings.

The broad range of steels likely to be subject to zinc coating will commonly fall into the following categories:

— carbon steel, composed simply of iron and carbon, accounts for 90 % of steel production [e.g. EN 10025-2 and EN 10080 (steel reinforcement)];

— high-strength, low-alloy (HSLA) steels have small additions (usually <2 % by weight) of other elements, typically 1,5 % manganese, to provide additional strength for a modest price increase (e.g. EN 10025-6);

— low-alloy steel is alloyed with other elements, usually molybdenum, manganese, chromium, or nickel, in amounts of up to 10 % by weight to improve the hardenability of thick sections (e.g. EN 10083-1).

Steel can be hot rolled or cold formed. Hot rolling is used to produce angle, "I", "H" and other structural sections. Some structural sections, e.g. safety barriers, cladding rails and cladding panels, are cold formed.

Cast and wrought irons are of various metallurgical and chemical compositions. This is irrelevant to protection by thermally sprayed or sherardized coatings but special consideration is needed regarding the cast irons most suitable for hot dip galvanizing (see ISO 14713-2).

4.2 Zinc coatings

The application of zinc coatings provides an effective method of retarding or preventing corrosion of ferrous materials (see Clause 1 for the range of zinc coatings/processes covered by this document). Zinc coatings are used in this regard because they protect iron and steel both by barrier action and by galvanic action.

5 Selection of zinc coating

The zinc coating system to be used should be selected by taking the following items into account:

a) the general environment (macro-climate) in which it is to be applied;

b) local variations in the environment (micro-climate), including anticipated future changes and any exceptional exposure;

c) the required life to first maintenance of the zinc coating system;

d) the need for ancillary components;

e) the need for post-treatment for temporary protection;

f) the need for painting, either initially (duplex system) or when the zinc coating is approaching the end of its life to first maintenance to achieve minimal maintenance cost;

g) the availability and cost;

h) if the life to first maintenance of the system is less than that required for the structure, its ease of maintenance.

NOTE The life for a zinc coating in any particular atmospheric exposure condition is approximately proportional to the thickness of the coating.

The operational sequence for applying the selected system should be determined in consultation with the steel fabricator and the applier of the zinc coating system.

6 Design requirements

6.1 General principles of design to avoid corrosion

Design of structures and products should influence the choice of protective system. It may be appropriate and economic to modify the design to suit the preferred protective system.

The items in a) to j) should be considered.

a) Safe and easy access for cleaning and maintenance should be provided.

b) Pockets and recesses in which water and dirt can collect should be avoided; a design with smooth contours facilitates application of a protective coating and helps to improve corrosion resistance. Corrosive chemicals should be directed away from structural components, e.g. drainage tubes should be used to control de-icing salts.

c) Areas which are inaccessible after erection should be given a coating system designed to last the required life of the structure.

d) If bimetallic corrosion (corrosion due to contact between dissimilar materials: metals and/or alloys) is possible, additional protective measures should be considered (see ISO 14713-2).

e) Where the coated iron and steel are likely to be in contact with other building materials, special consideration should be given to the contact area; e.g. the use of paint, tapes or plastic foils should be considered.

f) Hot dip galvanizing, sherardizing, mechanical coating, zinc flake coating or electroplating can be provided only in works; thermal spraying can be applied in works or on site. When paint is to be applied to a zinc coating, the application is more readily controlled in works but, where there is a likelihood of substantial damage occurring during transportation and erection, specifiers may prefer to apply the final paint coat on site. The application of a powder coating on metal-coated steel can only be done in works.

   Where the total system is applied offsite, the specification has to cover the need for care at all stages to prevent damage to the finished iron and steel and set out repair procedures to the coating once the steelwork is erected.

g) Hot dip galvanizing (in accordance with ISO 1461), sherardizing (in accordance with ISO 17668) or thermal spraying (in accordance with ISO 2063) should take place after bending and other forms of fabrication.

h) Methods of marking parts should not have an influence on the quality of the pre-treatment operations prior to coating.

i) Precautions may be required to minimize the likelihood of deformation during processing or subsequently.

j) The conditions experienced by the articles during coating application may also need to be considered.

6.2 Design for application of different zinc coating processes

The design practice for hot dip coating differs from that for other zinc coating systems. ISO 14713-2 provides guidance on the design for hot dip coatings. This supplements the general principles of good design for steel structures.

The design practice for sherardized coatings can be found in ISO 14713-3.

The design for zinc thermal spraying should be discussed with the thermal sprayer at an early stage so that adequate provision is made for access to all areas of the article (see EN 15520).

The design for electroplating with zinc follows the general design principles for electroplating and these are not given here. The design for mechanical coating is best discussed with specialist applicators; in general, these processes are most suitable for small parts which can be tumbled in a barrel but specialist plants may be available for other shapes.

6.3 Tubes and hollow sections

6.3.1 General

If they are dry and hermetically sealed, the internal surfaces of tubes and hollow sections will not need protection. Where hollow sections are fully exposed to the weather, or interior environments that might give rise to condensation, and are not hermetically sealed, consideration should be given to the need for both internal and external protection.

6.3.2 Corrosion protection of internal and external surfaces

Hot dip galvanizing gives equal thickness internally and externally. There are some special products where the thickness of the coating is different on internal and external surfaces, e.g. tubes for water distribution systems (see EN 10240). When tubes and hollow sections are hot dip galvanized after assembly into structures, drainage/venting holes should be provided for processing purposes (see ISO 14713-2).

Sherardizing gives equal thickness internally and externally. No precautions are needed for hollow sections. When tubes are sherardized, the zinc dust and sand mixture should be loaded into the tubes before starting the thermal diffusion process (see ISO 14713-3).

6.4 Connections

6.4.1 Fastenings to be used with hot dip galvanized, sherardized or thermally sprayed coatings

The protective treatment of bolts, nuts and other parts of the structural connections should be given careful consideration. Ideally, their protective treatment should provide a similar performance to that specified for the general surfaces. Specific requirements are given in the appropriate product International Standards (e.g. ISO 10684) and in a series of International Standards for coatings on fasteners which are in the course of preparation/publication.

Hot dip galvanized (see, for example, ISO 1461 which covers specified minimum coating thicknesses up to 55 µm), sherardized or other coatings on steel fasteners should be considered. Alternatively, stainless steel fasteners can be used; for precautions, to take in order to minimize the potential for bimetallic corrosion, see 7.9.

The mating surfaces of connections made with high-strength friction-grip bolts should be given special treatment. It is not necessary to remove thermally sprayed, sherardized or hot dip coatings from such areas to obtain an adequate coefficient of friction. However, consideration has to be given to any long-term slip or creep-avoidance requirements and to any necessary adjustments to the assembly dimensions.

6.4.2 Welding considerations related to coatings

It is recommended to weld prior to hot dip galvanizing, sherardizing or thermal spraying. The use of welding anti-spatter sprays that cannot be removed in the pretreatment process at the galvanizers' works should be avoided. For this reason, where welding sprays are used, low silicone, water-soluble sprays are recommended. After welding, the surface should be prepared to the standard specified for preparing the steelwork overall before applying the protective coating process. Welding should be balanced (i.e. equal amounts on each side of the main axis) to avoid introducing unbalanced stresses in a structure. Welding residues have to be removed before coating. The normal pretreatments for thermal spraying are usually sufficient for this purpose but extra pretreatment may be needed for hot dip galvanizing; in particular, weld slag should be removed separately. Some forms of welding leave alkaline deposits behind. These have to be removed by blast-cleaning followed by washing with clean water before applying thermally sprayed coatings. (This does not apply to hot dip galvanizing and sherardizing where the pretreatment process removes alkaline deposits.)

It is desirable that fabrication takes place without the use of a blast primer, as this has to be removed before hot dipping, sherardizing or thermal spraying.

Where welding takes place after hot dip galvanizing, sherardizing or thermal spraying, it is preferable, before welding, to remove the coating locally in the area of the weld to ensure the highest-quality weld. After welding, protection should be appropriately restored locally by thermal spraying, “solder sticks” and/or zinc dust paints.

It is not recommended to weld sherardized articles, but spot-welding may be possible in certain applications.

After welding of coated steels, the surface should be prepared to the standard specified for preparing the steelwork overall before applying paint or fusion-bonded powder coatings.

Assemblies comprising different metals needing different pre-treatments should be discussed with the processor.

Welding of zinc-coated parts must be done with appropriate local air ventilation in accordance with health and safety regulations.

6.4.3 Brazing or soldering

Soft-soldered assemblies cannot be hot dip galvanized or sherardized and brazing should be avoided if possible — many types of brazing are unsuitable for hot dip galvanizing or sherardizing. The galvanizer or sherardizer should be consulted if brazing is being considered.

Since corrosive fluxes may be used in these processes, removal of flux residues after the coating process is essential to avoid corrosion of the coated parts; the design of these parts should facilitate this.

6.5 Duplex systems

ISO 12944-5 and EN 13438 give information on organic coatings which are applied to hot dip galvanized or sherardized coatings. When such an organic coating has been applied, the term “duplex system” is used to describe the combination of coatings — historically, this term was most commonly used to describe organic coatings on hot dip galvanized articles.

NOTE EN 15773 deals with quality and communications requirements in the supply chain when specifying the supply of duplex systems.

The life of a zinc-coated steel structure is longer than the life of the zinc coating system that is initially applied to it, as some steel can be lost by corrosion before a structure becomes unserviceable. If it is necessary to prolong the life of the zinc coating, maintenance has to take place before any steel rusting occurs and preferably while at least 20 µm to 30 µm of zinc coating remains. This gives a maintained zinc coating plus organic coating system a longer total life than a simple organic coating.

The total life of a zinc coating plus organic coating system is usually significantly greater than the sum of the lives of the zinc coating and protective organic coating. There is a synergistic effect, i.e. the presence of zinc coatings reduces under-rusting of the paint film; the paint preserves the zinc coating from early corrosion. Where it is desired to retain a reasonably intact layer of paint as a basis for maintenance, the initially applied paint system should have extra thickness.

Maintenance usually takes place when the zinc coating loses its appearance or becomes degraded. Zinc coatings usually take longer to degrade than paint. Hence, a zinc coating may be recommended for 20 years or more up to first maintenance, whereas the same coating when covered by paint is, for reasons of appearance of the paint, recommended for only 10 years up to first maintenance. It should also be noted that an area of degraded paint can retain moisture and hence hasten the corrosion of metal, particularly on a surface not washed by rain.

If maintenance is delayed until the zinc coating has been consumed and rusting has started, the iron and steel have to be maintained in the same way as rusted painted steel.

6.6 Maintenance

Zinc coatings may be left unmaintained if the corrosion rate of the coating is insufficient to affect the performance of the structure in its designed period of use. If a longer life span is required, maintenance of the coating should be carried out by stripping and re-galvanizing (part of) the structure or by painting while some original coating remains.

7 Corrosion in different environments

7.1 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. Zinc coating with or without painting may, however, be required for appearance or for reasons of hygiene, e.g. in a food factory. 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 sulfates, accelerate 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 also 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 1 — Description of typical atmospheric environments related to the estimation of corrosivity categories

Corrosivity category C Corrosion rate for zinc (based upon first year of exposure), r_{corr} in µm·a^{-1} and corrosion level	Typical environments (examples)	
	Indoor	Outdoor
C1 $r_{corr} \le 0,1$ 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 $0,1 < r_{corr} \le 0,7$ 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 (SO_2 < 5 µg/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 $0,7 < r_{corr} \le 2,1$ 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 (SO_2: 5 µg/m^3 to 30 µg/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 $2,1 < r_{corr} \le 4,2$ 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 (SO_2: 30 µg/m^3 to 90 µg/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