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Guide to protection of steel against corrosion

Indoor and outdoor structures

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1 Introduction.

1.1 Foreword

This guide has been drawn up based on the following publications:

- ECCS – Technical Committee 4 – Surface Protection, Technical Note N°90, Surface Protection Guide for Steelwork in Building Interiors and Facades, First Edition (1997);
- ECCS – Technical Committee 4 – Surface Protection, Technical Note N°98, Surface Protection Guide for Steelwork exposed to Atmospheric Environments, First Edition (1998).

The information from the above publications has been updated taking into account the development of the standards and the state of technology currently applied in the Belgian and Luxembourg markets.

This guide describes solutions for protecting steel structures against corrosion, irrespective of whether these structures are located inside buildings or whether they are exposed to the outside air. The guide has been prepared by a working group consisting of experts in the field of protection of steel against corrosion and those working with the following organizations:

- Infosteel (www.infosteel.be);
- VOM vzw. the Belgian association for surface technologies of materials (www.vom.be);
- Stichting Zinkinfo Benelux (www.zinkinfobenelux.com);
- the 'Mobility and Public Works' department of the Flemish Region (www.vlaanderen.be).

1.2 General

The purpose of this guide is to provide guidance to all participants in the construction industry (clients, architects, consulting engineers etc.) involved in the design, the actual construction, the maintenance and the renovation of steel structures. There are a number of solutions recommended for corrosion protection, based mainly on the corrosivity class (C1 to C5).

The anticorrosive systems described in this document are based on reference standards or codes of practice.

This guide contains a non-exhaustive list of existing corrosion protection systems. Only the most frequently used and the most appropriate solutions are proposed. It is possible that other acceptable solutions exist for specific projects that are not described here.

1.3 Innovative systems

New corrosion protection systems are constantly being developed and put on the market. That those systems are not included in this guide says nothing about their performance. The explanation is that these systems are continuously under development or that there are no existing practical guidelines for them.

1.4 Environmental regulations

Attention is drawn to the fact that the environmental regulations on corrosion-resistant products are constantly becoming stricter and that they depend on the location where they are used. It is up to the different participants to determine whether the systems used comply with the environmental regulations.

1.5 Specific conditions

In order to choose the optimal protection system, for each project account must be taken of the specific conditions that apply to the structures (indoor or outdoor application, visible or hidden structure, accessibility, etc).

2. Atmospheric corrosion

Atmospheric corrosion plays a role in structures which are neither buried nor submerged in a liquid (usually water). The corrosion of buried or submerged structures is dealt with in § 3.2.

The risk of atmospheric corrosion and the rate at which this corrosion occurs are primarily dependent on the following parameters:

- the relative humidity of (inside or outside air) where the steel structure is located;
- the risk of condensation (depending on the relative humidity, the temperature of the steel and the speed at which the air is moving);
- the concentration of corrosive pollutants (gases, solids or liquids), such as sulphur dioxide, acids, alkalis or salts.

The solutions for protection against corrosion for the corrosivity class C2 to C5 (atmospheric corrosion) are described in the central table of this document.

3. Exceptional cases 3.1

Corrosivity class C1

Corrosivity class C1 corresponds to the neutral interior atmosphere of a dry and heated building. In this class non-visible elements (lowered ceilings, attics, etc.) require no anticorrosive treatment, except some constructions that are built into the masonry (see § 3.3, 2nd situation).

When elements in a class C1 interior atmosphere are visible, for aesthetic reasons and with a view to easy cleaning, it may however be desirable to provide a minimum level of protection, such as the 2/2-system.

It should be pointed out that a dry and heated building where no neutral atmosphere prevails (presence of corrosive gases or chlorides) falls under a higher corrosivity class.

3.2 Corrosion with buried or submerged structures

With buried or submerged structures, the choice of an anti-corrosion system depends on a large number of parameters. This is a complex choice wherein a specialist should be consulted. These special situations are therefore not dealt with in this guide.

COMMENTS:

- *The following parameters must be taken into account with buried structures: chemical composition, water content, degree of soil aeration and mechanical load.*
- *With submerged structures account must be taken of the salt content and the chemical composition of the water and any cycles of immersion and drying (which are determining for the submerged zone, the transition zone and the splash zone).*

3.3 Structures worked into the masonry

When steel structure elements are located in the outer wall of a building and they are not fully visible or accessible, the choice of the anticorrosion system can not always be based on the corrosivity class of the interior atmosphere of the building. There are two possible situations.

1st situation: the steel structure is protected against water from the outside

When the steel structure is protected against water from the outside, the choice of the anticorrosion system is based on the corrosivity class that corresponds to the interior atmosphere of the building.

This situation occurs in the following cases:

- when the outer cavity leaf of the building is water tight (Figure 1a)
- when the steel structure is protected against water infiltration: - either by a layer of air of at least 40 mm (Figure 1b) - or by a continuous, impermeable layer of material at least 25 mm thick (Figure 1c).

2nd situation: the structure is possibly exposed to water from the outside.

When there is a risk that the steel structure is exposed to water from the outside, hot-dip galvanizing is a suitable protection solution for an interior atmosphere of class C1 to C4.

This applies for the majority of cases where the steel structure directly (Figure 2a) or indirectly (Figure 2b) comes into contact with the non-watertight outer cavity leaf of the building.

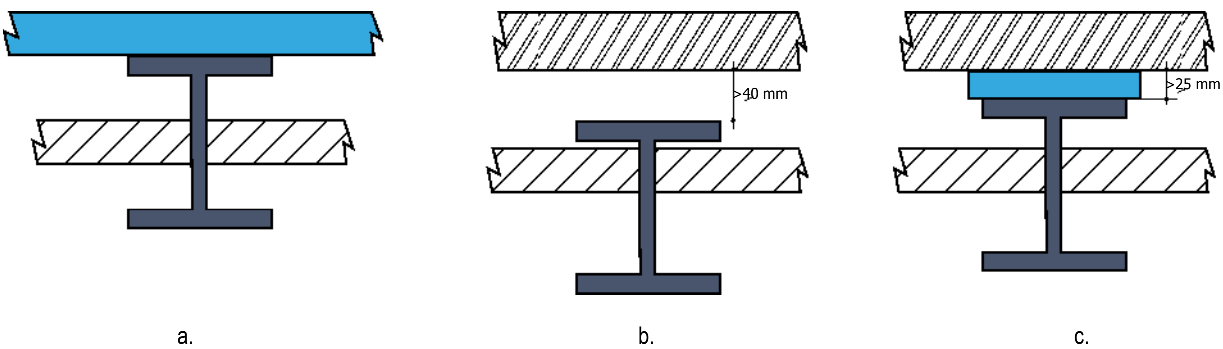

Figure 1: the steel structure is protected against water from the outside (horizontal cross-section)

a. Watertight outer cavity leaf
b. Non-watertight outer cavity leaf - Presence of a layer of air
c. Non-watertight outer cavity leaf - Presence of an intermediate layer in a watertight material

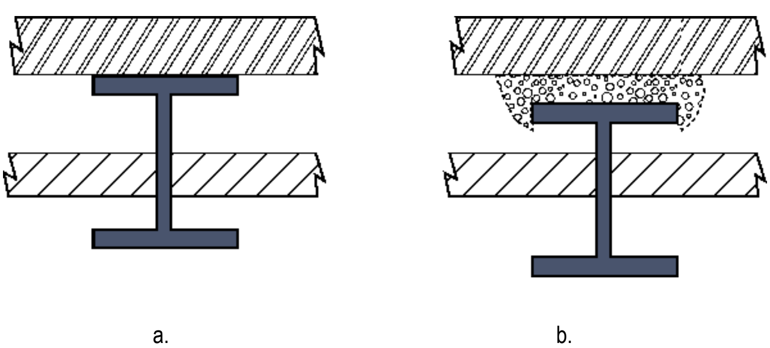

Figure 2: the steel structure is exposed to water from the outside (horizontal cross-section)

a. Non-watertight outer cavity leaf - Steel structure in contact with the outer cavity leaf
b. Non-watertight outer cavity leaf - Presence of an intermediate layer in a watertight material

4. Reference documents

EN ISO 1461 : 2009	Hot-dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
EN ISO 2063 : 2005	Thermal spraying – Metallic and other inorganic protective coatings - Zinc, aluminium and their alloys
EN ISO 4628-3 : 2003	Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance * Part 3: Assessment of degree of rusting (ISO 4628-3:2003)
ISO 8501-1 : 2007	Preparation of steel substrates before application of paints and related products. Visual assessment of surface cleanliness. * Part 1: rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
ISO 9223 : 1992	Corrosion of metals and alloys – Corrosivity of atmospheres - Classification
EN ISO 12944 Parts 1 to 4: 1998 Part 5: 2007 Parts 6 to 8: 1998	Paints and varnishes – Corrosion protection of steel structures by protective paint systems * Part 1: General information * Part 2: Classification of environments * Part 3: Design considerations * Part 4: Types of surface and surface preparation * Part 5: Protective paint systems * Part 6: Laboratory performance test methods * Part 7: Execution and supervision of paint work * Part 8: Development of specifications for new work and maintenance
EN ISO 14713 Parts 1 and 2: 2009	Protection against corrosion of iron and steel in structures -- Zinc and aluminium coatings - Guidelines * Part 1: General principles of design and corrosion resistance * Part 2: Hot-dip galvanizing
EN 15773: 2009	Industrial application of powder organic coatings to hot dip galvanized or sherardized steel articles [duplex systems]. Specifications, recommendations and guidelines
GSB ST 663 Edition May 2011	International Quality Regulations for the Piecework Coating of Steel and Galvanised Steel Building Components
Belgian code of practice BPR 1197 duplex 3rd revised edition - September 2004	Quality requirements for the industrial application of organic protective layers on intermittent hot-dip galvanized steel (duplex-system)
Evio code of practice December 2007	Code of practice for the application of thermally sprayed layers (metallisation) on steel followed by an organic protective layer

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	2/1	2/2	2/3	2/4	2/5
A. Outdoor climate Type of surroundings	Atmosphere with low degree of pollution. Rural areas in particular.				
B. Indoor climate Type of surroundings	Unheated buildings where condensation may occur. Examples: storage areas, sports centres ...				
C. Corrosivity classes (atmospheric corrosion)	C2				
D. System number	2/1	2/2	2/3	2/4	2/5
E. Type of protection system	paint	paint	paint	hot-dip galvanizing	duplex paint
F. Reference to standard or code of practice	EN ISO 12944-5 (system A2.03)	EN ISO 12944-5 (system A2.08)	EN ISO 12944-5 (system A2.07)	EN ISO 14713 EN ISO 1461	EN ISO 14713 EN ISO 1461 EN ISO 12944-5 (system A7.09)
G. Preparatory treatment	SA2½ blasting	SA2½ blasting	SA2½ blasting	hot-dip galvanizing 85 µm	hot-dip galvanizing 85 µm + light irradiation or chemical treatment
H. Priming coat	alkyd 80 µm	zinc rich epoxy primer 60 µm	epoxy 80 µm		
I. Intermediate layer					
J. Finishing layer	alkyd or acrylic 80 µm		polyurethane 80 µm		polyurethane 80 µm
K. Total nominal thickness of the dry layer	160 µm	60 µm	160 µm		80 µm (on zinc layer)
L. Expected working life for the first intervention	> 15 years	> 15 years	> 15 years	> 100 years	> 15 years

TABLE: recommended anticorrosion systems

The table above provides an overview of the anticorrosion systems that are best adapted to corrosivity classes C2 to C5 (atmospheric corrosion). The systems are applicable on both indoor and outdoor structures. This table does not deal with the corrosivity class C1 (see §3.1), nor buried or submerged structures (see §3.2).

In order to use this table, the corrosivity class of the indoor or outdoor climate to which the steel structure is exposed must first be determined, taking account of local conditions where appropriate.

Local conditions

In some cases, the conditions of the immediate environment of a structure are more demanding and a higher corrosivity class should be selected than that stated in the table. This concerns, for example, the presence of gritting salt on portal structures on motorways, the build-up of corrosive materials against the columns of an industrial building or the local emission of corrosive or damp gases inside a building. Sometimes the local conditions can be avoided from providing more stress by preventing water from remaining or from corrosive particles being deposited on the structure. Figures 3a to 3e show examples of recommended construction methods.

A. Outdoor climate: examples

These examples have been taken from the ISO 12944-2 standard and are provided for informational purposes. The choice of the corrosivity class is always dictated by the atmospheric conditions, local circumstances and personal experience.

B. Indoor climate: examples

Ditto (see § A above).

C. Corrosivity classes (atmospheric corrosion)

An international system for corrosion classes has been formalized in the EN ISO 9223 standard based on the corrosion rate which has been established for standard test samples of unprotected steel in a specific environment. This system has been incorporated in the EN ISO 12944-2 standard, where examples are given for each class of environment type in a temperate climate. These examples are included in the table.

These classes are based on an arbitrary format that does not correspond with the existence of a continuous gradation of the corrosivity in the real environment. The most relevant corrosivity class should be selected based on all available information about the environment in which the project is located and the personal experience.

The selected corrosivity class should be considered for its relevance and if necessary, expert advice should be sought in this respect.

2/6	2/7	2/8
duplex paint powder coating	metallisation + paint	metallisation + powder coating
EN ISO 14713 EN ISO 1461 EN 15773 GSB ST663	EN ISO 2063 + Evio code of practice	EN ISO 2063 + Evio code of practice
hot-dip galvanizing 85 µm + light irradiation or chemical treatment	SA2½ blasting + metallisation 50 µm	SA21/2 blasting + metallisation 50 µm
	mist coat	
	epoxy primer 40 µm	
polyester powder coating 80	polyurethane 40 µm	polyester powder coating 80
80 µm (on zinc layer)	80 µm (on metallisation)	80 µm (on metallisation)
> 15 years	> 15 years	> 15 years

Urban and industrial atmospheres, moderate sulphur dioxide pollution. Coastal areas with low salt content.

Production area with high humidity and some pollution. Examples: food industry, laundries, breweries, dairy plants etc.

C3					
3/1	3/2	3/3	3/4	3/5	3/6
paint	paint	paint	hot-dip galvanizing	duplex paint	duplex paint powder coating
EN ISO 12944-5 (system A3.09)	EN ISO 12944-5	EN ISO 12944-5 (system A3.03)	EN ISO 14713 EN ISO 1461	EN ISO 14713 EN ISO 1461 EN ISO 12944-5 (system A7.10)	EN ISO 14713 EN ISO 1461 EN 15773 GSB ST663
SA2½ blasting	SA2½ blasting	SA2½ blasting	hot-dip galvanizing 85 µm	hot-dip galvanizing 85 µm + light irradiation or chemical treatment	hot-dip galvanizing 85 µm + light irradiation or chemical treatment
epoxy 80 µm	zinc rich epoxy primer 60 µm	alkyd 80 µm		epoxy 60 µm	epoxy or epoxy-polyester powder coating 60 µm
epoxy 80 µm	epoxy 60 µm	alkyd 80 µm			
polyurethane 40 µm	polyurethane 40 µm	alkyd 40 µm		polyurethane 60 µm	polyester powder coating 70
200 µm	160 µm	200 µm		120 µm (on zinc layer)	130 µm (on zinc layer)
> 15 years	> 15 years	> 15 years	40-100 years	> 15 years	> 15 years

Figure 3a - Prevent water and dirt from accumulating

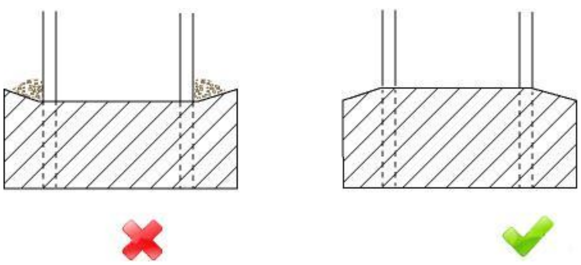

Figure 3b - Prevent water from remaining at the foot of a column

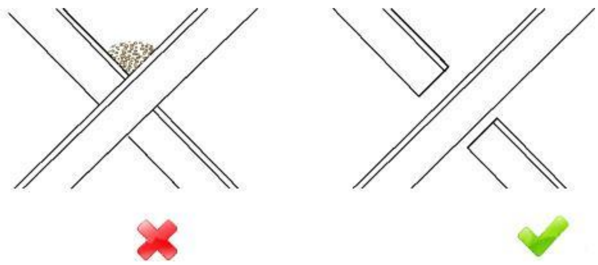

Figure 3c - Prevent water and dirt from remaining behind on joints by means of breaks

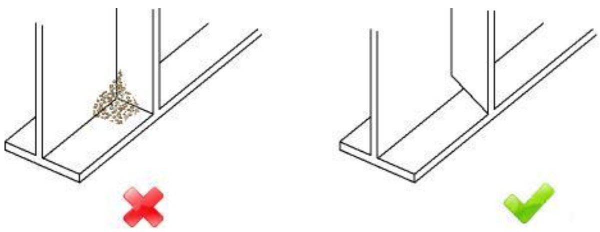

Figure 3d - Promote air circulation

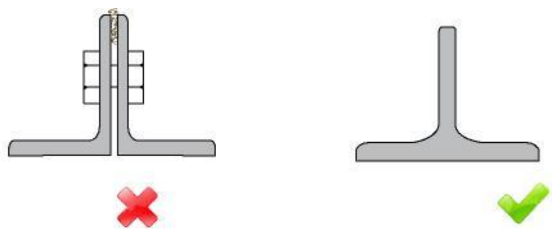

Figure 3e Prevent open clearances

Industrial and coastal areas with a moderate salt content

Examples: chemical factories, swimming baths, shipyards on the coast etc.

		C4						
3/7	3/8	4/1	4/2	4/3	4/4	4/5	4/6	4/7
metallisation + paint	metallisation + powder coating	paint	paint	hot-dip galvanizing	duplex paint	duplex paint powder coating	metallisation + paint	metallisation + powder coating
EN ISO 2063 + Evio code of practice	EN ISO 2063 + Evio code of practice	EN ISO 12944-5 (system A4.09)	EN ISO 12944-5 (system A4.15)	EN ISO 14713 EN ISO 1461	EN ISO 14713 EN ISO 1461 EN ISO 12944-5 (system A7.11)	EN ISO 14713 EN ISO 1461 EN 15773 GSB ST663	EN ISO 12944-5 (system A8.01)	EN ISO 2063 + Evio code of practice
SA2½ blasting + metallisation 80 µm	SA2½ blasting + metallisation 80 µm	SA2½ blasting	SA2½ blasting	hot-dip galvanizing 85 µm	hot-dip galvanizing 85 µm + light irradiation or chemical treatment	hot-dip galvanizing 85 µm + light irradiation or chemical treatment	SA3 blasting + metallisation 100 µm	SA3 blasting + metallisation 100 µm
mist coat	epoxy or epoxy-polyester powder coating 60 µm	epoxy 80 µm	zinc rich epoxy primer 60 µm		epoxy 80 µm	epoxy or epoxy-polyester powder coating 60 µm	mist coat	epoxy or epoxy-polyester powder coating 60 µm
epoxy sealer 40-60 µm		epoxy 140 µm	epoxy 140 µm				epoxy sealer 80 µm	
polyurethane 60 µm	polyester powder coating 70 µm	polyurethane 60 µm	polyurethane 40 µm		polyurethan e 80 µm	polyester powder coating 70	polyurethan e 80 µm	polyester powder coating 80
100-120 µm (on metallisation)	130 µm (on metallisation)	280 µm	240 µm		160 µm (on zinc layer)	130 µm (on zinc layer)	160 µm (on metallisation)	140 µm (on metallisation)
> 15 years	> 15 years	> 15 years	> 15 years	20-40 years	> 15 years	> 15 years	> 15 years	> 15 years

D. System number

The number in the table is specific to this guide.

E. Type of protection system

- **Paint:** Anticorrosion protection through the application of one or multiple layers of liquid paint.
- **Hot-dip galvanizing:** Anticorrosion protection through submerging of the steel elements in a bath of liquid zinc.

  NOTE: the hot-dip galvanizing referred to in this document is carried out according to EN ISO 1461 and EN ISO 14713 standards.

- **Duplex paint:** Anticorrosion protection through the application of a liquid paint on hot-dip galvanized steel elements that have been mechanically or chemical treated beforehand so that the paint adheres properly.
- **Duplex powder coating:** Anticorrosion protection through the application of a powder layer on hot-dip galvanized steel elements that have been mechanically or chemical treated beforehand so that the powder coating adheres properly.
- **Metallisation + paint** Anticorrosion protection consisting of the thermal spraying of zinc / aluminium, the sealing of the pores and the application of a finishing layer with liquid paint.

  NOTE: the metallisation referred to in this document consists of zinc-aluminium (85%-15%) and is carried out according to EN ISO 2063 standard.

- **Metallisation + powder coating** Anticorrosion protection consisting of the thermal spraying of zinc / aluminium, the sealing of the pores and the application of one or multiple layers of powder coating.

  NOTE: the metallisation referred to in this document consists of zinc-aluminium (85%-15%) and is carried out according to EN ISO 2063 standard.

F. Reference to standard or code of practice

The anticorrosion solutions described in this guide, are – where possible – based on the most relevant European (EN) or international reference standards (ISO). In other cases please refer to codes of practice that are common in the industry.

G. Preparatory treatment

Depending on the case, the preparatory treatment comprises a mechanical treatment (blasting), hot-dip galvanizing (for duplex-systems) and/or metallisation.

To obtain an efficient anticorrosive system, it is essential to remove any traces of grease, dirt, rust or old layers of paint.

SA21/2 and SA3 are degrees of purity of the steel surface defined in the ISO 8501 standard that are obtained through blasting the steel structures.

Industrial areas with an high humidity and an aggressive atmosphere.

Buildings or zones with permanent condensation and a high contamination.

C5I				
5/1	5/2	5/3	5/4	5/5
paint	paint	hot-dip galvanizing	duplex paint	metallisation + paint
EN ISO 12944-5 (system A5I.02)	EN ISO 12944-5 (system A5I.05)	EN ISO 14713 EN ISO 1461	EN ISO 14713 EN ISO 1461 EN ISO 12944-5	EN ISO 14713 EN ISO 1461 EN ISO 12944-5
SA2½ blasting	SA2½ blasting	hot-dip galvanizing 85 µm	hot-dip galvanizing 85 µm + light irradiation or chemical treatment	SA3 blasting + metallisation 120 µm
epoxy 80 µm	zinc rich epoxy primer 60 µm		epoxy 80 µm	mist coat
epoxy 180 µm	epoxy 200 µm		epoxy 100 µm	epoxy sealer 120 µm + epoxy 120
polyurethane 60 µm	polyurethane 60 µm		polyurethane 60 µm	polyurethane or epoxy 90 µm
320 µm	320 µm		240 µm (on zinc layer)	330 µm (on metallisation)
> 15 years	> 15 years	10-20 years	> 15 years	> 15 years

Coastal areas and maritime zones with a high salt content.

Buildings or zones with permanent condensation and a high contamination.

C5M			
5/6	5/7	5/8	5/9
paint	paint	duplex paint	metallisation + paint
EN ISO 12944-5 (system A5M.02)	EN ISO 12944-5	EN ISO 14713 EN ISO 1461 EN ISO 12944-5	EN ISO 12944-5 (system A8.02)
SA2½ blasting	SA2½ blasting	hot-dip galvanizing 85 µm + light irradiation or chemical treatment	SA3 blasting + metallisation 120 µm
epoxy 80 µm	zinc rich epoxy primer 80 µm	2 component epoxy 80 µm	mist coat
epoxy 180 µm	epoxy 180 µm	combination of epoxy 100 µm	epoxy 160 µm
polyurethane 60 µm	polyurethane 60 µm	polyurethane 60 µm	polyurethane 80 µm
320 µm	320 µm	240 µm (on zinc layer)	240 µm (on metallisation)
> 15 years	> 15 years	> 15 years	> 15 years

H. Priming coat

This concerns the first layer of an anticorrosion system. This first layer is always necessary, except with certain systems for corrosivity class C2 and protection through hot-dip galvanizing.

I. Intermediate layers

This concerns any layers between the primer and the finishing layer.

J. Finishing layer

This is the final layer of an anticorrosion system.

K. Total nominal thickness of the dry layer

This is the nominal thickness of the dry layer for the complete anticorrosion system, without taking into account any weldable priming coat, metallisation layer or hot-dip galvanized layer. It is the residual thickness after curing of the coating.

> *NOTE: (applicable on H., I. and J.):*
> the specified thickness for each layer is the minimum nominal thickness after curing of the relevant layer.

L. Expected working life for the first intervention

The terms listed in the table are based on the values specified in the relevant standards or codes of practice and experience acquired. It is therefore not about the duration of the guarantee, which is granted by the applicator and where appropriate, is confirmed by an insurance company.

These periods are valid under the following conditions:

- the protection systems are applied in accordance with the standards and the relevant codes of practice;
- the structures are suitably maintained (cleaning);
- the structures are used as originally intended (corrosivity class).

It concerns the period prior to an Ri3 degradation degree being determined according to ISO 4628-3 standard, which corresponds to the presence of rust across 1% of the surface.

With protection systems through hot-dip galvanizing, the life span prior to the first intervention depends on the speed with which the thickness of the hot-dip zinc-layer decreases. With this, an original galvanizing thickness of 85 µm is assumed (the minimum zinc layer thickness for elements of more than 6 mm thick) and the maximum (respectively minimum) speed at which the thickness decreases as listed for each corrosivity class in the ISO 14713 standard.

In duplex systems, the expected lifetime before the first intervention corresponds to the durability of the paint or powder coating. In this case, the durability of the hot-dip zinc layer is not taken into consideration.

With systems with a preparatory treatment by metallisation, the expected lifetime before the first intervention is determined by the durability of the paint or powder coating. In this case, the durability of the metallisation layer is not taken into consideration.