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Structural steels with improved atmospheric corrosion resistance

*Aciers de construction à résistance améliorée à la corrosion
atmosphérique*



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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 4952 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 3, *Steels for structural purposes*.

This third edition cancels and replaces the second edition (ISO 4952:2003), which has been technically revised.

Structural steels with improved atmospheric corrosion resistance

1 Scope

1.1 This International Standard specifies the chemical and mechanical characteristics, the methods of manufacture, the acceptance conditions and the marking of structural steel products with improved atmospheric corrosion resistance.

This International Standard applies to plates hot-rolled on reversing mills, having a thickness of 4 mm and over, wide flats, bars, and hot-rolled sections, generally used in the delivery condition and which, as a rule, form part of the bolted, riveted or welded structures in metal constructions¹⁾ and which have an improved atmospheric corrosion resistance.

1.2 This International Standard does not include the following steels, certain of which are covered by other International Standards:

- general-purpose structural steels (ISO 630);
- steels for boilers and pressure purposes (ISO 9328-2);
- steels for heat treatment;
- continuously hot-rolled steel sheet of structural quality with improved atmospheric corrosion resistance (ISO 5952);
- steel plates for forming and deep drawing.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 377, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 404:1992, *Steel and steel products — General technical delivery requirements*

ISO 2566-1, *Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels*

1) For precautions to be taken when welding, the guide for the welding and weldability of C-Mn and C-Mn micro-alloy steels published by Sub-commission IX-G of the International Welding Institute may be helpful (document IIS/IIW 843-87), as well as the notes given in Annex C of this International Standard.

ISO 4948-1, *Steels — Classification — Part 1: Classification of steels into unalloyed and alloy steels based on chemical composition*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO/TR 9769, *Steel and iron — Review of available methods of analysis*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

3 Terms and definitions

For the purposes of this document, the following term and definition apply.

3.1 steel with improved atmospheric corrosion resistance
steel in which a certain number of alloying elements, such as P, Cu, Cr, Ni, etc., have intentionally been added in order to increase its resistance to atmospheric corrosion, by forming an auto-protective oxide layer of the base metal

4 General requirements

4.1 Steelmaking process

Unless otherwise agreed at the time of order, the steelmaking method is left to the discretion of the manufacturer; however, it shall be stated to the purchaser if so requested at the time of delivery.

4.2 Method of deoxidation

With the exception of qualities A and B, the steels shall be from casts with the addition of elements capable of producing a fine grain.

Steel of qualities A and B shall be supplied as non-rimming steel.

4.3 Delivery condition

4.3.1 The products are usually delivered as-rolled, except for S415W and S460W, which are delivered in the thermomechanically rolled or quenched and tempered conditions. Other delivery conditions may be agreed at the time of the order.

4.3.2 Flat products of quality D are delivered as-rolled, normalized (normalizing rolling), in the thermomechanically rolled, quenched and tempered condition, or in an equivalent condition.

4.4 Surface condition

The products shall have a smooth surface corresponding to the rolling process used; they shall not have any defects that are prejudicial to their subsequent processing or appropriate use.

By agreement, alternative requirements may be specified such as ISO 7788 for plates and wide flats, ISO 20723 for sections and ISO 9443 for bars. Other and/or more requirements than those reported in International Standards may be specified as well.

5 Technical requirements

5.1 Chemical composition

5.1.1 General

The steels specified in this International Standard are alloyed steels in accordance with ISO 4948-1.

5.1.2 Cast (heat) analysis

The composition limits for the cast (heat) analysis are given in Table 1.

If agreed at the time of enquiry and order, rare earth elements may be added, with a maximum of 0,15 %.

5.1.3 Product analysis

Table 2 gives the limits of permissible deviations in the product analysis relative to the limits for the cast (heat) analysis given in Table 1.

Table 1 — Chemical composition of improved atmospheric corrosion resistance steels [cast (heat) analysis]

Grade	Quality ^a	C % max	Mn %	Si %	P %	S % max	Cr %	Cu %	Ni % max	Mo % max	Zr % max
S235W	A to D	0,13 ^b	0,20 – 0,60 ^b	0,10 – 0,40	≤ 0,040	0,035	0,40 – 0,80	0,25 – 0,55	0,65	—	—
S355WP	A to D	0,12	≤ 1,00	0,20 – 0,75	0,06 – 0,15	0,035	0,30 – 1,25	0,25 – 0,55	0,65	—	—
S355W	A to D	0,19	0,50 – 1,50	≤ 0,50	≤ 0,040	0,035	0,40 – 0,80	0,25 – 0,55	0,65	0,30	0,15
S390WP	A to D	0,12	≤ 1,40	0,15 – 0,65	0,07 – 0,12	0,035	0,30 – 1,25	0,25 – 0,55	0,65		
S415W	A to D	0,20	0,50 – 1,35	0,15 – 0,65	≤ 0,040	0,035	0,40 – 0,80	0,25 – 0,55	0,65		
S460W	A to D	0,20	≤ 1,40	0,15 – 0,65	≤ 0,040	0,035	0,40 – 0,80	0,25 – 0,55	0,65		

Any element other than those listed in this table, which is added intentionally, shall be indicated to the purchaser.

^a These steels shall contain at least one of the following grain-refining elements in the proportions indicated below:

- Al_{total} ≥ 0,020 %;
- Nb = 0,015 % to 0,060 %;
- V = 0,02 % to 0,15 %;
- Ti = 0,02 % to 0,10 %.

If these elements are used in combination, at least one of them shall be present in the steel in the minimum specified quantity.

^b If a minimum tensile strength requirement of 400 N/mm² is agreed, the limits for C and Mn can be increased to 0,15 and 1,00 respectively.

Table 2 — Permissible deviations for the product analysis relative to the specified cast (heat) analysis

Element	Specified limits %	Permissible deviation ^a
C	≤ 0,20	+ 0,03
Mn	≥ 0,20, ≤ 1,50	+ 0,10 – 0,05
Si	≥ 0,10, ≤ 0,75	+ 0,10 – 0,05
P	≤ 0,040 ≥ 0,06, ≤ 0,15	+ 0,005 ± 0,01
S	≤ 0,035	+ 0,005
Cr	≥ 0,30, ≤ 0,80 > 0,80, ≤ 1,25	± 0,05 ± 0,10
Ni	≤ 0,65	+ 0,05
Cu	≥ 0,20, ≤ 0,55	± 0,05
Nb	≥ 0,015, ≤ 0,060	± 0,005
V	≥ 0,02, ≤ 0,15	– 0,01 + 0,02
Ti	≥ 0,02, ≤ 0,10	– 0,01 + 0,02
Al	≥ 0,020	– 0,005
Mo	≤ 0,30	+ 0,05
Zr	≤ 0,15	+ 0,02

^a The deviations apply either above or below the specified limits of the range, but not simultaneously for one element from different samples taken from different products originating from the same cast.

When maxima only are specified, the deviations are positive only.

The values only apply to samples prepared under the conditions laid down in 7.3.1.

5.2 Mechanical properties

Steels in the delivery conditions defined in 4.3 shall comply with the mechanical characteristics specified in Table 3, when these are determined on test pieces selected in accordance with the specifications of Clause 7.

For products more than 63 mm thick, the mechanical properties shall be subject to an agreement between the parties involved.

Table 3 — Mechanical characteristics

Grade	Quality	Yield strength			Tensile strength R_m N/mm ^{2*}	Percentage elongation at fracture $A^{a,b}$ % min $L_0 = 5,65 \sqrt{S_0}$			Impact energy KV^c J min		
		R_{eH} N/mm ^{2*} min								+ 20 °C	0 °C
		$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$		$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$			
S235W	A	235	225	215	360 - 520 ^d	26	26	25			
	B	235	225	215	360 - 520 ^d	26	26	25	27		
	C	235	225	215	360 - 520 ^d	26	26	25		27	
	D	235	225	215	360 - 520 ^d	26	26	25			27
S355WP	A	355 ^e			470 - 630	21 ^e					
	D	355 ^e			470 - 630	21 ^e					27
S355W	A	355	345	335	470 - 630	22	22	21			
	B	355	345	335	470 - 630	22	22	21	27		
	C	355	345	335	470 - 630	22	22	21		27	
	D	355	345	335	470 - 630	22	22	21			27
S390WP	A	390 ^e			490 - 650	20 ^e					
	B	390 ^e			490 - 650	20 ^e			27		
	C	390 ^e			490 - 650	20 ^e				27	
	D	390 ^e			490 - 650	20 ^e					27
S415W	A	415	405	395	520 - 680	18	18	17			
	B	415	405	395	520 - 680	18	18	17	27		
	C	415	405	395	520 - 680	18	18	17		27	
	D	415	405	395	520 - 680	18	18	17			27
S460W	A	460	450	440	570 - 730	17	17	16			
	B	460	450	440	570 - 730	17	17	16	27		
	C	460	450	440	570 - 730	17	17	16		27	
	D	460	450	440	570 - 730	17	17	16			27

* 1 N/mm² = 1 MPa
a For transverse test pieces (plate and wide flats not less than 600 mm wide), these values are reduced by 2 points.
b Non-proportional test pieces may be used (see 7.1).
c Average of three tests; no individual result shall be less than 70 % of the specified minimum average value.
d If agreed at the time of enquiry and order, 400 - 560 N/mm² can be applied as the tensile strength requirement.
e This quality is only delivered for a product not more than 12 mm thick.

6 Inspection and testing

6.1 General

The product covered by this International Standard may be the subject of inspection and testing, in accordance with the conditions specified in Clause 8 of ISO 404:1992 relating to the chemical composition and mechanical properties of the product. Verification of the chemical composition of the product is also carried out if this is agreed and stated in the order.

If an inspection and testing is specified in the order, it shall be carried out in accordance with 6.2 to Clause 8, unless otherwise agreed at the time of order.

6.2 Test unit

6.2.1 General

The verification of product analysis and mechanical properties shall be per cast (heat).

6.2.2 Tensile tests

A test unit shall contain products of the same form, grade and delivery condition and be taken from the same thickness range, in accordance with Table 3, for the specified yield strength.

For a test unit not exceeding 50 t, one tensile test shall be carried out.

For a test unit exceeding 50 t, two tensile tests shall be carried out.

6.2.3 Impact tests

A test unit shall contain products of the same form, grade and delivery condition.

For a test unit not exceeding 50 t, one set of three impact tests shall be carried out at 0 °C for quality C or at – 20 °C for quality D or, if specified in the order, at + 20 °C for quality B.

For a test unit exceeding 50 t, two sets of three impact tests shall be carried out at 0 °C for quality C or at – 20 °C for quality D or, if specified in the order, at + 20 °C for quality B.

6.2.4 Product analysis

If specified in the order, one product analysis shall be carried out per cast.

6.2.5 Testing procedures

6.2.5.1 General

Unless otherwise stated by the purchaser, the procedure shall be as specified in 6.2.5.2 and 6.2.5.3.

6.2.5.2 Tensile test

A sample shall be taken for each specified thickness range specified in Table 3, with the additional requirement that, for $t \leq 16$ mm, the maximum thickness of the products of the batch shall be not greater than twice the minimum thickness.

6.2.5.3 Impact test

A sample shall be taken from the thickest product in each thickness range given in Table 3.

For flat products of quality D, if agreed at the time of enquiry and order, a test sample shall be taken from each rolled product (parent plate).

6.3 Position and orientation of sample (see ISO 377)

6.3.1 General

For product thicknesses between 6 mm and 40 mm, sub-surface specimens shall be used.

For product thicknesses exceeding 40 mm, samples shall be taken from the 1/4 thickness position.

6.3.2 Plates and wide flats of width equal to or greater than 600 mm

The test samples shall be taken midway between the axis in the direction of rolling and the edge of the rolled product.

- a) The longitudinal axes of tensile test pieces shall be perpendicular to the direction of rolling.
- b) The longitudinal axes of impact test pieces shall always be parallel to the direction of rolling.

6.3.3 Sections, girders and wide flats of width less than 600 mm

The longitudinal axes of the test pieces shall be parallel to the direction of rolling. However, if agreed, a transverse test piece may be used for widths between 450 mm and 600 mm.

For sections, the test samples shall be taken such that the axis of the test piece is 1/3 from the outer edge of the half-flange (for I-sections) or of the flange (for other sections) or, for small sections, as near as possible to this position (see Figure A.1). In the case of tapered flange sections, the test samples may be taken at the outer 1/4 position of the web.

6.3.4 Rounds, squares, flats, hexagons and other similar products

The longitudinal axis of the test pieces shall be parallel to the direction of rolling. For small sizes, the test piece consists of a section of the product.

In other cases, sampling shall be carried out as described in Figure A.1.

7 Test methods

7.1 Tensile test (see ISO 6892)

Normally, the test piece used shall be a proportional prismatic or cylindrical test piece and have an original gauge length L_0 given by the formula:

$$L_0 = 5,65\sqrt{S_0}$$

where S_0 is the original cross-sectional area of the gauge length of the test piece.

The prismatic test piece of rectangular cross-section shall have a maximum width on the gauge length portion of 40 mm, its thickness being that of product; however if the product thickness exceeds 30 mm, it may be reduced to 30 mm by planing or milling on one face only.

A cylindrical test piece may be used for products more than 40 mm thick; it shall be 10 mm to 30 mm in diameter and its original gauge length shall be determined by the above formula; the axis of the test piece shall be positioned at 1/4 of the thickness from the surface.

A non-proportional test piece with fixed original gauge length (for example 200 mm) may be used. In this case, reference shall be made to a conversion table (see ISO 2566-1). However, in case of dispute, only the results obtained on a proportional test piece shall be taken into consideration.

The yield strength specified in Table 3 is the upper yield stress, R_{eH} . If the yield phenomenon is not visible, either the 0,2 % proof stress, $R_{p0,2}$, or the 0,5 % total elongation, $R_{t0,5}$, may be used. The specification of the material is complied with, in this respect, if either value satisfies the specified value of yield strength.

7.2 Impact test

7.2.1 The impact test shall normally be carried out on products having a thickness greater than or equal to 12 mm. The test piece shall be machined so that the face nearest to the rolled surface is not more than 2 mm from it.

1/4 thickness machining may also be agreed.

The notch shall be perpendicular to the rolled surface.

If agreed at the time of enquiry and order, impact tests may be carried out on products having a thickness less than 12 mm; the dimensions of the test pieces shall be in accordance with the requirements of ISO 148-1, i.e. 10 mm × 7,5 mm or 10 mm × 5 mm, or they shall be 10 mm × t , t being the product thickness.

The minimum required energy value for the smaller test pieces shall be decreased proportionally to the test piece width.

7.2.2 The test shall be carried out using a V-notch test piece supported at both ends (see ISO 148-1), the value to be taken into account being the average of the results obtained from three test pieces adjacent to each other from the same product unless there are reasons for a retest (see 7.4).

7.3 Chemical analysis

7.3.1 If a product analysis is specified in the order, its frequency shall be as specified in 6.2.4.

The samples may be taken from the test pieces used to check the mechanical properties or from the full thickness of the product at the same place as the test pieces. In case of dispute, only the analysis of material from the full thickness of the product shall be taken into consideration.

For the selection and preparation of samples for chemical analysis, the requirements of ISO 14284 shall be applied.

7.3.2 In case of dispute about analytical methods, the chemical composition shall be determined in accordance with a reference method of International Standards listed in ISO/TR 9769. If no standard exists, the method to be used shall be agreed between the parties concerned.

7.4 Retests

7.4.1 General

If, during inspection, a test does not give the required result, additional tests in accordance with ISO 404:1992 shall be carried out as follows.

7.4.2 Tensile test

Procedures defined in 8.3.4.3.2 "Non-sequential tests" of ISO 404:1992 shall apply.

7.4.3 Impact test

The assessment of the impact test shall be made following the method described in 8.3.4.2 "Assessment of results of sequential tests" of ISO 404:1992 and, if retests are necessary, they shall be carried out following 8.3.4.3.3 "Sequential tests" of ISO 404:1992.

8 Inspection documents

The type of inspection documents, with respect to specific inspection and testing, shall be chosen from those defined in ISO 10474 and specified in the order.

In every case, the inspection document shall state the manufacturer's results for the cast analysis of all chemical elements specified for the steel grade concerned.

9 Sorting and reprocessing

The requirements of Clause 9 of ISO 404:1992 shall apply.

10 Non-destructive testing

If the purchaser requires non-destructive tests to check the soundness of the products by means of ultrasonic, magnetic or dye-penetrant methods, these tests shall be agreed at the time of enquiry and order. This agreement shall include details of the test methods and interpretation of results.

11 Marking

Unless otherwise agreed at the time of order, products shall be marked with the following:

- the identification symbols for the grade of the steel;
- the brand of the manufacturer;
- where necessary, symbols, letters and numbers which relate the inspection document, test pieces and products to each other.

In the case of products which are consigned in bundles, the above information may be marked on a tag securely attached to each bundle (or it may be marked on the topmost item in the bundle, if appropriate).

12 Information to be supplied by the purchaser

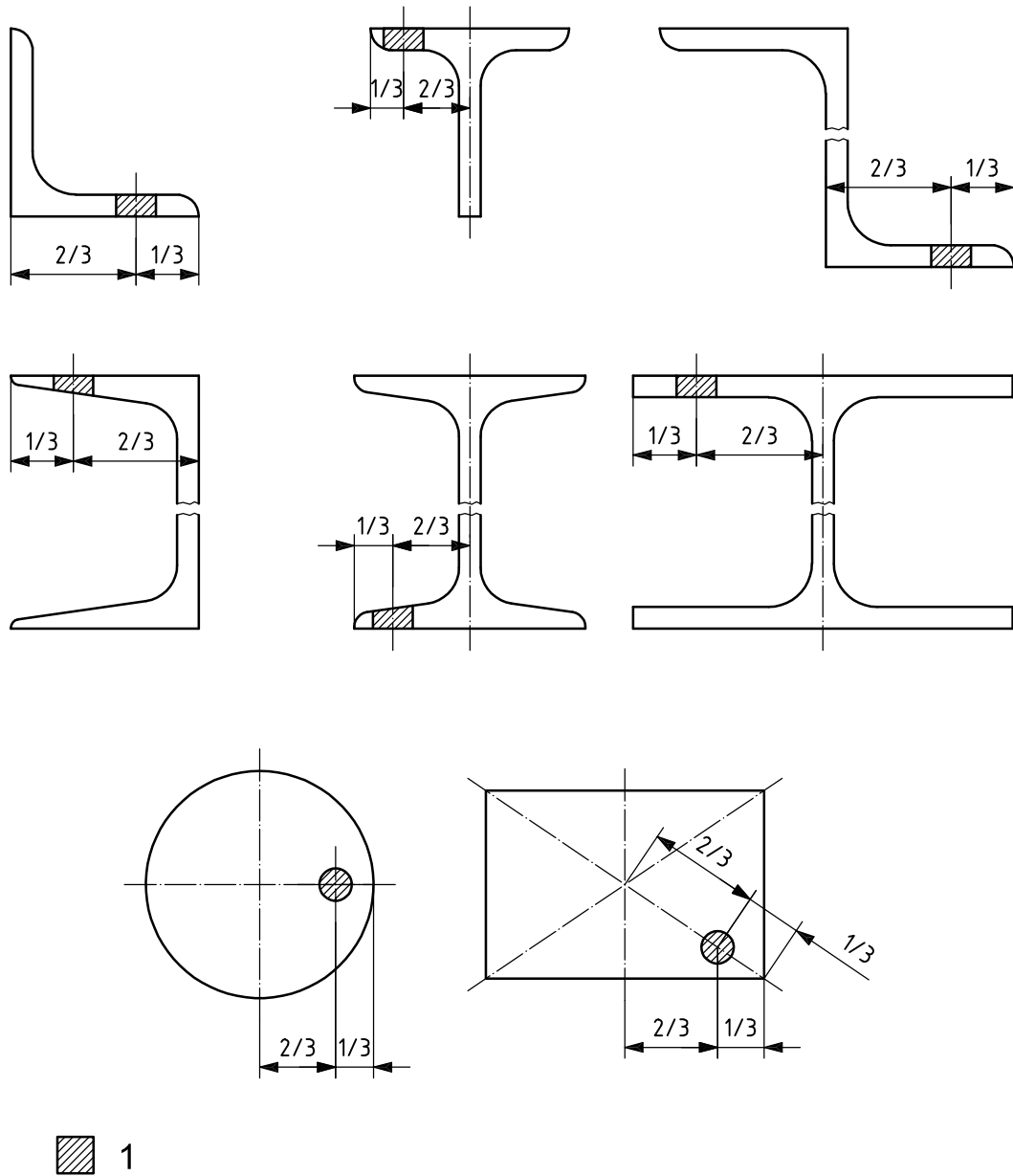
In addition to the information mentioned in ISO 404:1992, the following information shall also be given, if applicable:

- the particular steelmaking process required (4.1);
- the particular production process required (4.3);
- if product analysis is required (6.2.4) and the number of samples required (7.3.1);
- if impact tests for each rolled product are required for quality D (6.2.5.3);
- if impact tests are required for products of thickness less than 12 mm (6.2.3);
- if retests are not permitted (7.4);
- the type of inspection document required (Clause 8);
- if non-destructive tests are required (Clause 10);
- other type of marking required (Clause 11).

The non-supplied items shall not be taken into consideration by the manufacturer.

Annex A
(normative)

Position and orientation of test pieces



Key

1 Location of sample

Figure A.1 — Position and orientation of test pieces

See 6.3 (for the impact test, see also 6.2.5.3).

Annex B (informative)

Notes on weldability

The steels specified in this International Standard do not have unlimited suitability for the various welding processes, since the behaviour of a steel during and after welding depends not only on the material but also on the dimensions and shape, as well as on the manufacture and service conditions of the components.

The weldability increases for each grade from quality A to D.

Special precautions shall be taken when welding grades S355WPA to S355WPD and S390WPA to S390WPD with a high phosphorous content.

With increasing product thickness and increasing strength level, the occurrence of cold cracking in the welded zone forms the main risk. Cold cracking is caused by the following factors in combination:

- the amount of diffusible hydrogen in the weld metal;
- a brittle structure of the heat-affected zone;
- a significant tensile-stress concentration in the welded joint.

Annex C (informative)

Additional information for the use of steel with improved atmospheric corrosion resistance

The corrosion-inhibiting effect of the auto-protective oxide layer relates to the nature of its constituents and to the particular distribution and concentration of alloying elements in it. The resistance to atmospheric corrosion depends on weather conditions being successively dry and wet for the forming of the auto-protective oxide layer of the base metal. The protection afforded depends on the environmental and other conditions prevailing at the site of the structure.

Provisions should be made in the design and in the fabrication structure for the auto-protective oxide layer on the surface to form and regenerate itself unimpeded. It is the responsibility of the designer to include corrosion of unprotected steels in his/her calculation and, as far as is necessary, to compensate for this by increasing the thickness of the product.

A conventional surface protection is recommended when the content of particular chemical substances in the air is significant and absolutely necessary where the structure is in contact with water for long periods, is permanently exposed to moisture, or is to be used in a marine atmosphere. Before painting, the products should be descaled. Under comparable conditions, the susceptibility to corrosion of steel with improved atmospheric corrosion resistance under painting is less than that for conventional structural steels.

The surfaces of structures which are not exposed to the elements, but which may be subject to the build-up of condensation, should be appropriately ventilated. Otherwise, a suitable surface protection is necessary. The extent to which these factors depend on the prevailing climatic conditions in the widest sense, and on the details of the structure, do not permit any generally valid statements on the corrosion process. The user should therefore consult the manufacturer of the steel regarding the suitability of the products for each individual application.

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