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The European Stainless Steel Development Association

Stainless steel flat products for building – the grades in EN 10088-4 explained

Building Series, Vol. 18

Euro Inox

Euro Inox is the European market development association for stainless steel.
The members of Euro Inox include:

- European stainless steel producers
- National stainless steel development associations
- Development associations of the alloying element industries.

A prime objective of Euro Inox is to create awareness of the unique properties of stainless steels and to further their use in existing applications and in new markets. To this purpose, Euro Inox organises conferences and seminars and issues guidance in printed form and electronic format, to enable architects, designers, specifiers, fabricators and end users to become more familiar with the material. Euro Inox also supports technical and market research.

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Aperam, Luxembourg (L) (bottom left); Thomas Pauly (others)

Table of contents of EN 10088-4

Note: In this publication, the paragraphs marked in dark blue are specifically expanded on. The other paragraphs of the standard, in a lighter shade of blue, are mentioned for completeness' sake.

Introduction

The inclusion of building products into CE marking created the need for harmonized European standards for these products – including the materials they are made from. As the pre-existing EN 10088 parts 1, 2 and 3 are not application-specific and describe stainless steel grades and the delivery conditions of flat and long products in general terms, two new parts — 4 (for flat products) and 5 (for long products) — were written. Although their content is partly identical with parts 1, 2 and 3, parts 4 and 5 specifically encompass the stipulations that are relevant for building applications and that must be taken into account when giving a product the CE mark[1]. Awareness of these standards is therefore a must for anyone using stainless steel in the manufacture of products dedicated for use in building and construction. EN 10088-4 and -5 became valid throughout the EU in October 2009. Potentially conflicting national standards will have to be withdrawn by January 2012.

As EN 10088 parts 1 to 5 cover technical delivery conditions only, they do not provide:

- principles of grade selection; some basic guidance, however is given in EN 1993 (Eurocode 3), part 1–4, Supplementary rules for stainless steel
- advice on fabrication (though limited information is available in EN 1090, parts 1 and 2).

Practical guidance for the proper use of stainless steel is limited and dispersed. It is the purpose of the present brochure to combine information from the above-mentioned standards with relevant practical experience to give designers and fabricators basic orientation. For practical reasons, this publication focuses on flat products, i.e. EN 10088-4.

To make it easier for the reader to distinguish between what is said in EN 10088-4 as such and what is additional explanatory information, two different styles are used for either type of information:

- *The text in blue and italics paraphrases the content of EN 10088-4 as such.*
- The text in black contains comments and additional practical information.

Building products are subject to CE marking.

CE marking ensures the marketability of building products throughout Europe. Photo: Halfen, Langenfeld (D)

1 EN 10088 Stainless Steels,
Part 1:2005 – List of stainless steels
Part 2:2005 – Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes
Part 3:2005 – Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion-resisting steels for general purposes
Part 4:2009 – Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for construction purposes
Part 5:2009 – Technical delivery conditions for bars, rods, wire, sections and bright products of corrosion resisting steels for construction purposes

The table of contents of the standard (see text box) is taken as a guideline. The chapters of this publication have been numbered accordingly. This makes it easy for readers who want to know all the details to identify the respective chapter in the original standard EN 10088-4. As indicated by the numbering, not all items of the standard are addressed. Only those aspects will be covered that require the designer or fabricator to take explicit decisions.

On 4.1. Designation of steel grades

Specifiers and users of stainless steels often use colloquial terms such as "18/8", AISI/ASTM numbers like "304", common designations like "2205" or brand names. However, some of these terms may refer to groups of stainless steels rather than to specific grades. Additionally, the American AISI/ASTM grades may have analysis bands that are different from those of the nearest equivalent European EN grades. For instance, grade AISI/ASTM 316L falls within the definition of EN 1.4401, 1.4404 or 1.4432. In a European context, it is strongly advised to use the EN name (e.g. "X5CrNi18-10") or number designation ("1.4301") consistently and throughout, because these are unequivocal.

Further Reading:

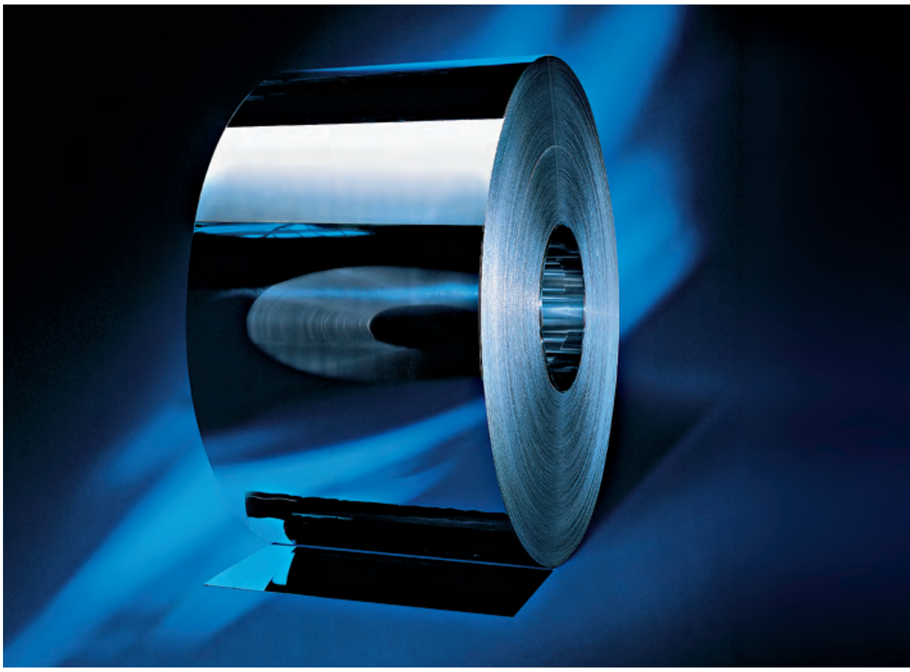
- About the correspondence between AISI/ASTM numbers on the one hand and EN name/number designations on the other:
  Table of Technical Properties, Luxembourg: Euro Inox 2007. Searchable online data base or downloadable pdf file: www.euro-inox.org/technical_tables/

On 4.2. Order designation

Lack of information provided on ordering is a common cause of misunderstanding between purchaser and supplier and often results in claims. The complete designation for ordering a product according to this European Standard should contain the following information:

a) the desired quantity
b) the product form (e.g. strip or sheet/plate)
c) the type of material (steel)

d) the nominal dimensions, the number of the appropriate European Standard plus any choice of requirements[2]
e) the number of this European Standard
f) the steel name or steel number
g) the symbol for the desired heat treatment or cold worked condition
h) the desired process route (see symbols)
i) verification of internal soundness, if required (flat products with thickness > 6 mm shall be tested in accordance with EN 10307)
j) type of inspection certificate (3.1 or 3.2) according to EN 10204
k) regulatory marking requirements



Reference to EN standards ensures error-free communication between customer and supplier. Photo: ThyssenKrupp Nirosta, Krefeld (D)

Example:
A customer wishes to order 10 plates of a steel grade with the name X5CrNi18-10 and the number 1.4301 as specified in EN 10088-4 with the nominal dimensions of thickness 8 mm, width 2000 mm, length 5000 mm, tolerances on dimensions, shape and mass as specified in EN 10029 with thickness class B and "normal'' flatness tolerance class, in process route 1D (see Table 6), inspection certificate 3.1 as specified in ISO EN 118286 and the declaration of conformity.

In this case, the request for quotations and the eventual order should mention:

10 plates EN ISO 18286 – 8B × 2000 × 5000
Steel EN 10088-4 – X5CrNi18-10 + 1D
Inspection certificate 3.1, CE
or
10 plates EN ISO 18286 – 8B × 2000 × 5000
Steel EN 10088-4 – 1.4301 + 1D
Inspection certificate 3.1, CE

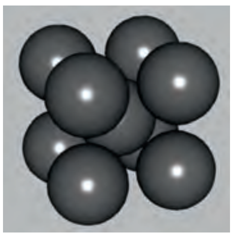
2 • EN ISO 18286:2010, Hot rolled steel plates – Tolerances on dimensions and shape
• EN ISO 9445-1:2010 Continuously cold-rolled stainless steel – Tolerances on dimensions and form – Part 1: Narrow strip and cut lengths
• EN ISO 9445-2:2010 Continuously cold-rolled stainless steel – Tolerances on dimensions and form – Part 2: Wide strip and plate/sheet

On 5. Classification of grades

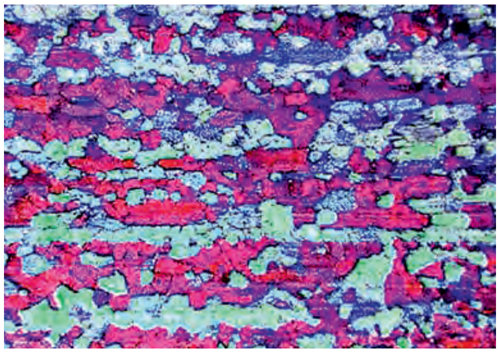
There are several families of stainless steel, which can broadly be distinguished by their main alloying constituents. Ranked by quantitative importance, they can briefly be described as follows:

- Chromium-nickel alloyed grades are particularly versatile and by far the most frequently used types of stainless steel in building and construction. Their cubic crystal structure features a face-centred atomic arrangement, called “austenitic” in metallurgy.
- A second group of stainless steels is essentially chromium-alloyed and contains no (or only very small amounts of) nickel. These have a body-centred, “ferritic” microstructure. They cost less than austenitic grades. Typical applications are in interior and mild exterior atmospheric conditions. However, molybdenum-alloyed ferritic grades like EN 1.4521 can have a level of pitting corrosion resistance similar to that of austenitic grade 1.4401.
- A third group has nearly equal proportions of ferritic and austenitic structure. Steels of this family are referred to as “duplex” grades. They combine high levels of corrosion resistance with high mechanical properties. In building and construction, they are mostly used in structural applications.
- Other stainless steels are of the “martensitic” and “precipitation-hardening” type. These are occasionally specified for special applications, usually in fasteners made from long products, which are not discussed in the present document.

Atoms in a face-centered austenitic structure



Atoms in a body-centered ferritic structure



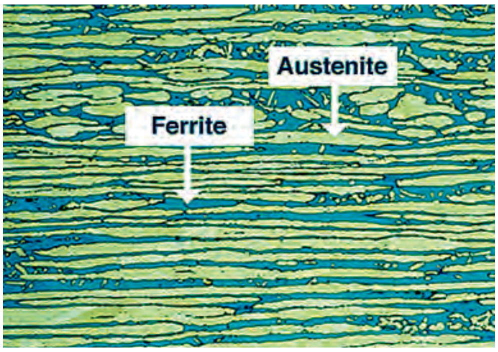
Micrographic view of the ferritic crystal structure of chromium stainless steels

EN 10088-4 does not address these families in the order of their relevance for the market, but in the more conventional order of alloying compositions and resulting metallurgical structures:

- Cr-alloyed:
  ferritic (a)
  martensitic (b) and
  precipitation hardening (c),
- CrNi-alloyed:
  austenitic (d) and
- mixed austenitic-ferritic:
  “duplex” (e)

This order will be maintained in the present publication.

Micrographic view of the austenitic crystal structure of chromium-nickel stainless steels



The austenitic-ferritic crystal structure of duplex stainless steels

a) Ferritic stainless steels

Ferritic stainless steels are iron-chromium alloys, sometimes containing additional elements, specifically

- titanium (Ti) and niobium (Nb) for stabilisation to improve weldability
- molybdenum (Mo) for enhanced pitting corrosion resistance.

Their hue is slightly colder than that of austenitic (nickel-containing) grades. In visually critical applications, it is therefore recommended not to mix (neutral to cool) ferritic with (slightly yellowish, warmer) austenitic stainless steels.

When the design involves crevices, care should be taken to select a grade of adequate general corrosion resistance (expressed as a PREN value). Narrow crevices, (e.g. under bolts or washers) should be avoided, for example by choosing welded instead of a mechanical connections.

Although the weldability of the ferritic grades suggested for building and construction is good, welding operations should be performed in controlled workshop or factory environments and the recommended welding parameters should be strictly respected. On-site welding as well as the welding of thicker sections should be avoided.

Also, the forming behaviour of ferritic stainless steels is different from that of austenitic grades, being closer to that of carbon steel. With the exception of grade 1.4003, the ductile-to-brittle transition temperature is around freezing point, which limits their usability for structural applications.

Standard grades

1.4003

This is a basic "chromium-only" grade at the low end of the spectrum of alloying compositions of stainless steels. The grade is suitable for environments with low corrosive influence, typically heated and unheated interiors with no relevant influence of chlorides. Still, it may develop discolourations if unprotected, which, however, does not normally lead to structurally relevant corrosion. It is the only ferritic stainless steel grade whose ductile-to-brittle transition temperature is at -40 °C, which makes it suitable for load-bearing applications where either a protective coating is applied or "cosmetic" corrosion is acceptable.

1.4016

This common 17 % Cr ferritic grade is frequently used for decorative interior cladding, such as lift cabins, where corrosive stress is usually low (except in coastal or industrial locations where chlorides and sulphur dioxide are also present in normally heated and aerated interior environments). This grade typically has excellent surface properties[3].

1.4510

This steel is a stabilised 17 % Cr grade, which has been used in metallic roofing (standing seam roofs) and rainwater goods (gutters, downpipes, accessories). It has a history of successful use in non-corrosive atmospheric environments, such as inland areas without noticeable sulphur dioxide and chloride content. It is commercially available in special coil formats for the roofing industry. As a roofing material, EN 1.4510 is also produced with an additional tin coating. Although the latter does not add to the corrosion resistance of the base material, it reduces reflectivity and facilitates soldering (e.g. in rainwater goods). Over time, the tin-coated sheet material develops a decorative patina, which makes it look similar to more traditional roofing metals.

Grade 1.4510 ferritic stainless steel with an additional tin coating develops a decorative non-reflective patina over time. Photo: Blum & Rossbacher/Aperam, Luxembourg (L)

3 Although this is outside the scope of the present publication, it may be interesting to note that this grade is typically used for the tubs of washing machines and tumble dryers, which is proof of its corrosion resistance in humid environments.

1.4509

In terms of pitting corrosion resistance, this grade is similar to the "classic" austenitic grades such as EN 1.4301 (AISI 304). It has been successfully used in building interiors and recently also for the building envelope, specifically as a tin-coated roofing material and an alternative to 1.4510.

1.4521

Due to its molybdenum content, this ferritic stainless steel has high corrosion resistance. Its pitting resistance equivalent is similar to that of austenitic grade EN 1.4401 (AISI 316). It has been introduced into the domestic plumbing market in several European countries.

Experimental use of bright annealed ferritic stainless steel grade 1.4526 in the façade of an industrial building. Photo: Aperam, Luxembourg (L)

Beyond these grades, other stainless steels less commonly used in building and construction are also mentioned in the standard: *1.4512*, *1.4513* and *1.4526.*

Further reading:

- About ferritics in general:
  The Ferritic Solution. Properties, Advantages, Applications, Brussels: International Stainless Steel Forum 2008, also downloadable from the Euro Inox website:
  www.euro-inox.org/fla_126_EN.html

- About building applications of ferritic stainless steels:
  The Ferritic Solution. Building Interiors, Brussels: International Stainless Steel Forum 2009, www.worldstainless.org

Mo-alloyed grade 1.4521 is also used for domestic plumbing. Photo: Nussbaum, Olten (CH)

b) Martensitic and c) precipitation hardening grades

EN 10088-4 also mentions 1.4006, 1.4021, 1.4418 and, as "special grades", 1.4542 and 1.4568.

These steels are occasionally found in, for example tensioning systems, where they are used for their mechanical properties. However, they are normally lower in corrosion resistance than the most common austenitic grades. Their weldability and formability are extremely limited.

d) Austenitic grades

Austenitic grades are the workhorses among the stainless steels commonly used in building and construction. The reason is their combination of excellent weldability (also on site), outstanding formability and the wide range of grades to match the most diverse corrosive conditions, from very mild environments such as normal building interiors to the most corrosive, in indoor swimming pool or tunnel atmospheres. The standard grades 1.4301/1.4307 (AISI 304/304L) and 1.4401/1.4404 (AISI 316/316L) are universally available and accessories in the same grade are easy to come by.

As demonstrated in these window sections, austenitic stainless is so formable that the sheet can be bent back on itself without cracking. Photo: Forster, Arbon (CH)

1.4301

This classic grade is also known in consumer goods as "18/8" or "18/10". Suitable for environments with medium-low corrosive conditions, it is commonly used for building interiors and exteriors in normal industrial atmospheres away from the coast (some technical documents say more than 1 km). Experience shows that slightly acidic conditions at the material surface are tolerated, such as would be typical of contact with wood. Its formability is outstanding, permitting minimal bending radii in sheet metal forming (bending radius = material thickness). On-site welding can be performed without difficulty.

Excellent weldability — also on site — and ease of post-fabrication finishing make austenitic grades the most commonly used stainless steels for building products. Photo: CIBO, Tildonk (B)

1.4307

As a low-carbon variant of grade 1.4301, this steel has improved weldability in thicker sections above 6 mm. It can be substituted for 1.4301 without any disadvantage.

1.4306

Similar to 1.4307, this is another low-carbon variant of 1.4301, however with higher nickel content for further improved formability. As the elevated alloying content makes it more expensive than 1.4307, this grade is reserved for special applications in which exceptionally complex forming operations are required.

1.4318

is a grade with particularly marked work-hardening behaviour. With corrosion resistance slightly below that of reference grade EN 1.4301 (AISI 304), this grade is found in transport rather than building applications.

1.4311

is also a variant of 1.4301, additionally alloyed with nitrogen, which increases the steel's mechanical properties, especially when work hardened. Although mentioned in the standard, it is less common. Its very low magnetic permeability allows it to be used in specialised buildings, e.g. those housing MRI scanners.

1.4541

Similar in corrosion resistance to grade EN 1.4301, this grade is titanium-stabilised to improve weldability in thicker sections. This stabilisation prevents chromium carbide precipitations forming. However, the titanium content leads to comet tails in mechanical polishing or electropolishing, which makes the grade less suitable for decorative applications. Over the last decades, it has been almost completely replaced by 1.4307 (above), which is as weldable as 1.4541 but can be polished with much better results.

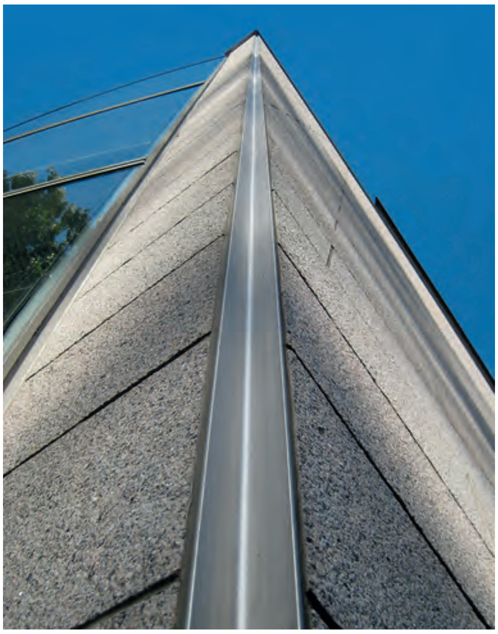
1.4401

This grade, also known as AISI 316, is molybdenum alloyed, which makes it suitable for medium-high corrosive environments, including permanently wet applications, locations in a coastal atmosphere (some technical documents say between 1 km and 100 m from the shore), polluted industrial atmospheres or near roads where de-icing salts can be an issue. It is also suitable for components that are not accessible for cleaning and inspection and must ensure long-term structural performance.

Nickel-containing stainless steels like EN 1.4301/1.4306 and EN 1.4401/1.4404 are by far the most commonly used grades in building and construction. Photo: Acerinox, Madrid (E)

1.4404

As a low-carbon variant of grade EN 1.4401, this has the same level of corrosion resistance as the latter and is used for the same types of environment. It corresponds to grade AISI 316L. The low carbon content strongly reduces the risks of chromium carbide formation in the weld and the heat-affected zone and gives the steel excellent weldability, even in thicker section. This steel can be substituted for 1.4401 without disadvantages. It is also a more modern alternative to grade 1.4571 (see below).



Edge profile in grade 1.4571

1.4571

Similar in corrosion resistance and mechanical properties to 1.4401 and therefore used for similar environments, this traditional grade (which is also known as AISI 316Ti) is titanium-stabilised to improve its weldability in thicker sections. Titanium has a greater affinity with carbon than chromium. The carbides that form during welding are therefore titanium, not chromium carbides and a chromium-depleted (i.e. less corrosion resistant) zone is prevented. The titanium content leads to comet tails in mechanical polishing and electropolishing, which makes this grade less suitable for decorative applications (see also "Further Reading" below). This is why in building and construction, grade 1.4571 has been almost completely replaced by low-carbon grade 1.4404, which is as weldable as 1.4571 but can be polished with much better results (see above).

CrNi stainless steels have demonstrated good corrosion resistance in contact with wood and concrete.

1.4432

Similar to 1.4404, i.e. also a low-carbon variant of 1.4401, but with somewhat higher corrosion resistance than 1.4404. Used, for instance, in external cladding or roofing in a coastal atmosphere, it is often found in roofing sheet.

1.4529, 1.4547

These super-austenitic stainless steels (i.e. grades with a PRE index above 25) have high enough an alloying content to avoid the SCC sensitivity of the more usual austenitic grades. They are the materials of choice in highly corrosive environments, typically:

- road tunnels, where the combined effect of sulphur dioxide (from exhaust gases), chlorides (from de-icing salt) and humidity (ingress water) form a highly corrosive atmospheric mix;
- indoor swimming pools, where the most severe conditions are found in suspended ceilings and even spaces remote from the

swimming pool. In such locations, repeated cycles of condensation and drying can lead to exceptionally high concentrations of chlorides on the stainless steel surface.

Further grades listed in the standard are: 1.4335, 1.4372, 1.4406, 1.4429, 1.4435, 1.4436, 1.4438, 1.4439, 1.4466, 1.4539, 1.4563 and 1.4565.

Further Reading:

- About austenitic stainless steels in general:
  CUTLER, Peter, "The Advantages Nickel Brings to Stainless Steels", paper given at the 3rd International Stainless Steel Symposium, Stresa, Italy, 8th October 2009; www.nickelinstitute.org

- About the selection of austenitic stainless steels according to environmental conditions:
  Which Stainless Steel Should Be Specified for Exterior Applications? Software, International Molybdenum Association 2006; www.imoa.info

- About structural design with austenitic stainless steels:
  Design Manual for Structural Stainless Steel, Luxembourg: Euro Inox, third edition 2006 (Building Series, Volume 11); www.euro-inox.org/fla_29_EN.html

- About the difference between stabilised and low-carbon variants of steels with improved weldability:
  VAN BENNEKOM, Andre / WILKE, Frank, "Comparison between Stabilised and Low Carbon Austenitic Stainless Steels", paper, Euro Inox 2009; www.euro-inox.org/fla_162_EN.html

- About stainless steel in interior swimming pool environments:
  BADDOO, Nancy / CUTLER, Peter, "Stainless steel in indoor swimming pool buildings", Structural Engineer, reprint downloadable from www.euro-inox.org/fla_25_EN.html

- About the welding of austenitic stainless steels:
  CUNAT, Pierre-Jean, The Welding of Stainless Steels, Luxembourg: Euro Inox, second edition 2007; www.euro-inox.org/fla_1_EN.html

  METTING, Günter, Guidelines on the Welded Fabrication of Stainless Steels, CD-ROM, Duisburg and Luxembourg: SLV and Euro Inox, second edition 2010; www.euro-inox.org/fla_122_EN.html

Footbridge in grade 1.4462 stainless steel Photo: SBi, Stockholm (S)

Fastening system for solar panels of grade 1.4362 stainless steel Photo: Modersohn, Spenge (D)

e) Austenitic-ferritic (duplex) grades

Generally, duplex stainless steels are specified for their combination of high strength and high corrosion resistance. They are also much more resistant to stress corrosion cracking (SSC) than the standard austenitic grades. However, their mechanical properties require stronger tools and may lead to high levels of wear in cutting and forming operations. Duplex grades do not polish as easily as austenitics, although very reflective surface finishes have been achieved.

1.4462

As the most common duplex grade, this material is high enough in corrosion resistance to be used in corrosive environments such as offshore structures and bridges in coastal locations. It is also known under the common designation “2205”.

1.4362

In contrast to 1.4462, this grade is not molybdenum-alloyed. Still, its corrosion resistance is similar to that of classic austenitic grade 1.4401 (AISI 316). However, it is not sensitive to SCC and is higher in mechanical strength.

Special grades

1.4162

This so-called “lean duplex” grade is beginning to make inroads into building and construction. It combines a corrosion resistance higher than that of the reference austenitic grade EN 1.4301 (AISI 304) with high mechanical properties.

Other special austenitic-ferritic grades mentioned in the standard but less commonly found in building applications include 1.4477, 1.4410, and 1.4424.

Façade of grade 1.4162 duplex stainless steel Photo: Montanstahl, Stabio (CH)

Further reading:

Practical Guidelines for the Fabrication of Duplex Stainless Steels, London: International Molybdenum Association, second edition 2009, also available from the Euro Inox website www.euro-inox.org/fla_173_EN.html

BADDOO, Nancy, Helix Pedestrian Bridge, Case Study, Team Stainless 2011, also downloadable from the Euro Inox website www.euro-inox.org/pdf/case/SCI/Helix_Bridge_EN.pdf

BADDOO, Nancy, Stonecutters Bridge Towers, Case Study, Team Stainless 2009, also downloadable from the Euro Inox website www.euro-inox.org/fla_181_EN.html

BADDOO, Nancy, Cala Galdana Bridge, Case Study, Team Stainless 2009, also downloadable on the Euro Inox website www.euro-inox.org/fla_180_EN.html (about structural aspects) and

HELZEL, Martina, Bridge in Cala Galdana on Menorca, www.euro-inox.org/fla_131_EN.html (about architectural aspects)

MIALET, Frédéric, The Grande Arche Panoramic Lifts at La Défense, Case Study, Euro Inox 2002, www.euro-inox.org/fla_33_EN.html

On 6.3. Chemical composition

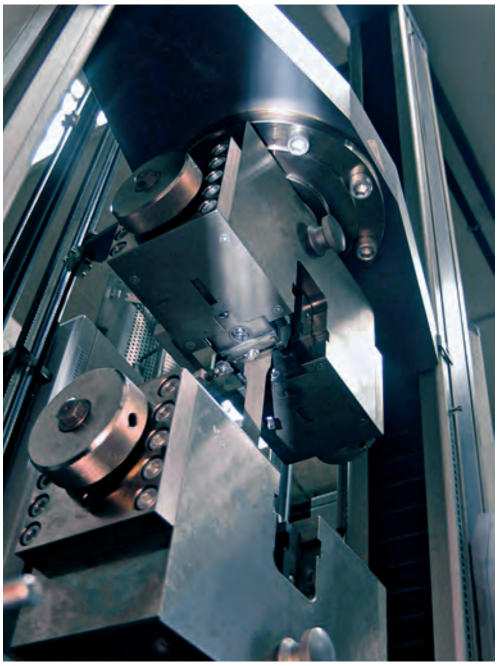
Chemical composition determines the relative corrosion resistance of stainless steels. A so-called "Pitting Resistance Equivalent Number" can be calculated by using the formula PREN = % Cr + 3.3 × % Mo [+ 16 × % N]. This makes it possible to rank different stainless steels within the same family in terms of general corrosion resistance.

Low carbon content and the presence of stabilising elements such as titanium and niobium are indicative of a material's weldability in greater thicknesses (above 6 mm).

While all the austenitic grades listed in EN 10088-4 are resistant to intergranular corrosion in delivery condition, grades with elevated levels of carbon such as 1.4301, 1.4401, 1.4305, 1.4372 are prone to intergranular corrosion when sensitised, for example through exposure to high temperatures in the heat affected zone near the weld. Low-carbon and stabilised grades avoid this problem.

On 6.5. Mechanical Properties

The mechanical strength is indicative of the load-bearing capacity of a part made from stainless steel. Two criteria can apply:



Mechanical testing of a stainless steel sample. Photo: Acroni, Jesenice (SLO)

(a) The load at which a standardised sample of defined size and shape shows a permanent plastic deformation of 0.2 %. *These proof strength ($R_{p0.2}$) values range (in the transverse direction), in the solution-annealed condition, from*
- *220 to 320 MPa for ferritic stainless steels*
- *200 to 420 MPa for austenitics*
- *400 to 650 MPa for austenitic-ferritic (duplex) stainless steel*

(b) The load at which such a sample breaks. This criterion is the ultimate tensile strength (R_m). *These values range, in the solution-annealed condition, from*
- *380 to 650 MPa for ferritic grades*
- *470 to 950 MPa for austenitic grades*
- *630 to 1050 MPa for austenitic-ferritic (duplex) grades*

Work-hardened stainless steel grade 1.4571 of the strength class +CP350 was used in the structure of this stainless steel and glass façade.

The elongation after fracture indicates by what percentage the sample has lengthened at the moment of rupture. This value is indicative of the formability of a material: the higher the value, in the solution-annealed condition, the better its formability. The values in EN 10088-4 range from

- *18 to 25 % for ferritic stainless steels*
- *30 to 45 % for austenitic stainless steels*
- *20 to 30 % for austenitic-ferritic (duplex) stainless steels.*

Austenitic stainless steels undergo work-hardening when they are deformed. Their mechanical strength increases with the degree and the speed of the deformation. This property can be used to give fabricated components, such as sections, extra strength. Work-hardened material can be ordered from the supplier as coil or sheet (process route 2H) in three strength classes.

If tensile strength (R_m) is the criterion, the strength classes are (according to Table 13)

- *+C700: (700–850 MPa)*
- *+C850 (850–1000 MPa)*
- *+C1000 (1000–1150 MPa)*

If 0.2 % proof strength ($R_{p0.2}$) is the criterion, the designations in Table 14 can be applied:

- *+CP350 (350–500 MPa)*
- *+CP500 (500–700 MPa)*
- *+CP700 (700–900 MPa)*

Work-hardening also inevitably occurs during forming and cutting operations. These should therefore be performed slowly and without applying higher than necessary pressure.

Further reading:

- About chemical composition, mechanical properties and physical properties of stainless steel according to EN 10088-2 (of which the grades in EN 10088-4 are a subset): *Tables of Technical Properties of Stainless Steels*, online data base or downloadable pdf file, www.euro-inox.org/fla_74_EN.html

- About the design of structures made from cold-worked stainless steel:
  Relevant information on grade selection in building and construction can be taken from Eurocode 3, Part 4, annex “Stainless Steel”

On 6.6. Surface quality

As stainless steel is usually selected in building and construction because of its attractive appearance, the selection of an appropriate surface finish is paramount. It has to be noted that the descriptions in EN 10088-4 alone are not sufficient to describe a surface completely. Products of the same EN denomination may differ from one supplier to another and even from one batch to another. It is therefore strongly recommended to exchange samples between supplier and purchaser as a reference. Appearance also varies depending on the installation direction of the fabricated component.

1D finish

Table 6 of the Standard describes process routes and surface finishes:

Among the ***hot rolled*** finishes,

1D

hot-rolled, heat treated and pickled

can be found in building products, e.g. sections. It is hot-rolled, heat treated to ensure good workability and pickled to ensure a clean metallic surface and allow stainless steel's natural self-passivation to take place. The surface, however, is not as smooth as the cold-rolled finishes mentioned below. Also, grinding marks may still be visible. Thicker-walled structural open sections are a typical application.

The other hot-rolled finishes mentioned in EN10088-4 apply to material for further processing and are not commonly found in final products for building and construction.

Hot rolled stainless steel with a 1D finish in an L profile on a glazed façade

2B finish

2R finish

Cold-rolled

For architectural applications, cold rolled surfaces are the usual option. The definitions in EN 10088-4 are identical to those in EN 10088-2, of which the most common are:

2D

cold-rolled, heat-treated and pickled

This somewhat duller mill finish is among the most cost-effective surfaces. However, it tends to show finger marks and should not be used in areas of the building where this could be a problem.

2B

cold-rolled heat-treated, pickled and skin passed, smoother than 2D

This has a slightly milky, glossy surface effect. It also tends to show finger marks and should not be used where this could be a problem.

2R

cold-rolled, bright annealed; smoother and brighter than 2B and a common finish for further processing

This surface comes close to mirror-like surface effect.

Other, less usual surfaces described in EN 10088-4 are:

2H

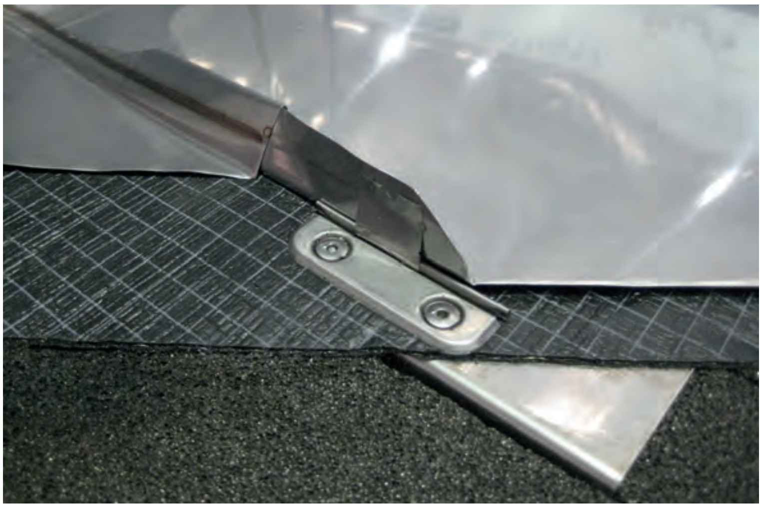
work-hardened, cold-worked to obtain a higher strength level, bright

2E

cold-rolled, heat treated, mechanically descaled

2Q

cold-rolled, hardened and tempered, scale-free



2B finish in the model of welded stainless steel roofing

Classic 2K satin polished stainless steel in an interior application

Special finishes

The following special hot rolled (1) and cold rolled (2) finishes are listed:

1G or 2G
ground, grade of grit or surface roughness can be specified;
unidirectional, low-reflectivity finish

1J or 2J
brushed or dull polished, smoother than ground, the grade of brush or polishing belt can be specified;
still not very reflective

1K or 2K
satin polished, with additional specific requirements compared to type "J" finishes to ensure good corrosion resistance in marine and exterior architectural applications, transverse $R_a \leq 0.5$ µm. Surface characteristics can be agreed more specifically between manufacturer and purchaser (e.g. surface roughness or grade of grit);
semi-reflective finish

1P or 2P
bright polished, mechanical polishing, non-directional finish, reflective with a high degree of image clarity;
process or surface roughness can be specified

2F
cold-rolled, heat treated, skin-passed on roughened rolls, uniform non-reflective matt surface, heat treatment by bright annealing or by annealing and pickling

1M
patterned (design to be agreed), chequer plate used for floors, second surface flat;
produced by hot rolling

2F matt-rolled finish in a façade application. Photo: Aperam, Luxembourg (L)

2M
patterned, a fine texture finish (design to be agreed) mainly used for architectural applications, second surface flat;
produced by cold rolling

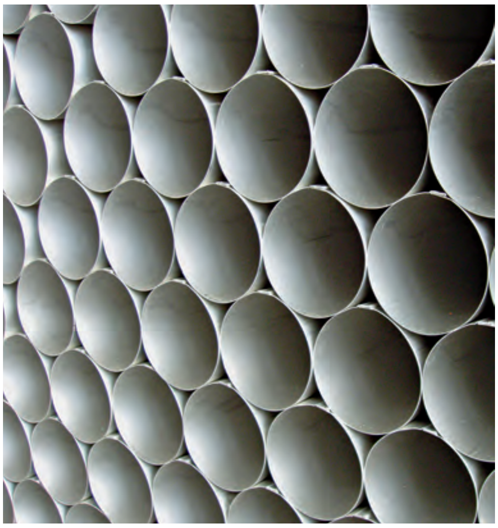
2W
corrugated (design to be agreed)

2L
coloured (colour to be agreed)

1S or 2S
surface coated e.g. with tin, aluminium, one side only unless agreed otherwise

Example of a 2W finish corrugated sheet metal used for a ticket booth (left) and a 2L electrolytically coloured surface used for a façade (right)

1M chequer plate as the flooring of a London Underground station



2S surface: stainless steel with a tin coating used for the manufacture of rainwater downpipes. The metallic coating facilitates soldering and forms a decorative patina. Photo: Brandt Edelstahldach, Cologne (D)

Further reading:

- About mill and special finishes:
  COCHRANE, David, Guide to Stainless Steel Finishes, Luxembourg: Euro Inox, third edition 2005 (Building Series, Volume 1); www.euro-inox.org/fla_12_EN.html; also available on a CD ROM with realistic animations of 20 usual finishes

- About "plastic" finishes obtained by forming of sheet and wire:
  HELZEL, Martina, Depth, Pattern and Texture – The Third Dimension in Stainless Steel Surfaces, Luxembourg: Euro Inox 2008 (Building Series, Volume 14); www.euro-inox.org/fla_193_EN.html

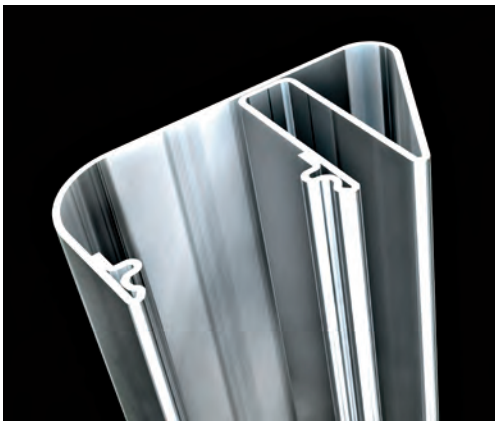
- About the selection of finish for cleaning-friendly design:
  BADDOO, Nancy, Cleaning Architectural Stainless Steel, Luxembourg: Euro Inox 2009 (Materials and Applications Series, Volume 15); www.euro-inox.org/fla_176_EN.html

  BADDOO, Nancy, Erection and Installation of Stainless Steel Components, Luxembourg: Euro Inox 2006 (Building Series, Volume 10); www.euro-inox.org/fla_112_EN.html

- About post-fabrication finishing:
  VAN HECKE, Benoît, The Mechanical Finishing of Decorative Stainless Steel Surfaces, Luxembourg: Euro Inox 2005 (Materials and Applications Series, Volume 5); www.euro-inox.org/fla_75_EN.html

On 6.8. Formability at room temperature

The outstanding formability of most stainless steels, specifically austenitic grades, makes it possible to create most complex shapes. Photo: Welser Profile, Ybbsitz (A)



Elongation after fracture expresses by how much a defined stainless steel sample can be stretched before its breaks (i.e. when its tensile strength is exceeded). As mentioned on p 17,

- *ferritic grades have elongation values of 18–25 % (Table 7 of the standard)*
- *austenitic grades between 30 % and 45 % (Table 9 of the standard)*
- *austenitic-ferritic (duplex) grades between 20 % and 30 %*

Although included in the standard, martensitic and precipitation-hardening grades are not discussed here because they are rarely found as flat products in building and construction. The higher the elongation the better the formability (e.g. in obtaining sharp edges in cassettes or in embossing the material).

Further reading:
VAN HECKE, Benoît, The Forming Potential of Stainless Steel, Luxembourg: Euro Inox 2006 (Materials and Applications Series, Volume 8), www.euro-inox.org/fla_113_EN.html

On 8. Evaluation of conformity and 9. Marking

When purchasing material for building applications, care should be taken to ensure that the material carries the CE mark, which is a prerequisite for the material being eligible for use in construction applications (for details see chapter 8 of the Standard).

On Annex ZA. 3 CE marking and labelling

If a product is covered by a so-called 'harmonised Standard', it must be CE marked ("Conformité Européenne") if it is to be used for construction within the European Economic Areas, i.e. the 27 member states of the European Union, EFTA countries Iceland, Liechtenstein and Norway as well as Turkey. EN 10088-4 is a harmonised Standard, and therefore stainless steel specified to this Standard must be CE marked. By CE marking the product, the manufacturer declares that it is fit for purpose for its intended use. The CE Mark indicates that the product conforms to the relevant Standard, meeting any specified threshold values required by that Standard (such as minimum thickness or minimum strength), and that the conformity assessment procedures have been complied with.

The CE mark …

… and how its graphic design is defined

The CE mark itself can be shown on the construction product, on the packaging, on an accompanying label or on accompanying commercial documents.

The process of CE Marking will generally involve initial type testing (ITT) and factory production control (FPC), to demonstrate that the product has the claimed characteristics and performance, and that all production achieves the declared performance. The responsibility for carrying out the conformity assessments depends on the Attestation of Conformity (AoC) level, which is specified in the relevant harmonised Standard and ranges from 1+ to 4. Responsibility will generally be shared between the manufacturer and a Notified Body. As a general rule, the more safety-critical products will be allocated an onerous AoC (e.g. 1 or 1+) and the less critical products will have a less onerous AoC (e.g. 3 or 4). Although the manufacturer remains entirely responsible for all aspects of production, the Notified Body may be required to certify the FPC systems, carry out regular surveillance of the FPC systems, and, for the more onerous AoC levels, undertake ITT. The responsibilities are indicated below.

EN 10088-4 is a harmonised Standard, and specifies that for structural metallic sections and profiles, the Attestation of Conformity level is 2+. EN 10088-4 also identifies the essential characteristics that are to be declared on the CE Mark, including tolerances, mechanical properties, weldability and durability.

Following a successful assessment, the manufacturer prepares a Declaration of Conformity and, if necessary, the Notified Body will prepare a FPC Certificate. The manufacturer is then in a position to CE Mark the product. The information to be provided on the CE Mark is specified in Annex ZA of the harmonised Standard.

Notified Bodies are listed in the New Approach Notified and Designated Organisations (NANDO) website, which is to be found at http://ec.europa.eu/enterprise/newapproach/nando.

Fabricated steelwork is covered by EN 1090, which is also a harmonised Standard. Therefore, construction products manufactured in accordance with EN 1090 must be CE Marked, if they are to be used in the European

	AoC Level					
	1+	1	2+	2	3	4
Tasks for the manufacturer						
Factory production control (FPC)	X	X	X	X	X	X
Testing of samples	X	X	X			
Initial type testing (ITT)			X	X		X
Tasks for the Notified Body						
Initial type testing	X	X			X	
Certification of FPC	X	X	X	X		
Surveillance of FPC	X	X	X			
Audit testing of samples	X					

Economic Area. All the basic material used in such fabricated products must be CE Marked. CE Marking in accordance with EN 1090 is mandatory from 1 July 2014, although manufacturers may wish to commence CE Marking before this date.

There is no requirement to CE Mark products if they are not covered by a harmonised Standard. If no harmonised Standard exists, CE Marking is still possible if a European Technical Approval Guideline (ETAG) has been prepared by the European Organisation for Technical Approvals (EOTA). A list of ETAGs is available at www.eota.be/pages/home/. It is also possible for a manufacturer to develop a Common Understanding of Assessment Procedure (CUAP), which is then endorsed by EOTA, and permits CE Marking – this option is appropriate for bespoke products not covered by a harmonised Standard or an ETAG.

Further information on CE Marking is given in ECCS Publication 128 Guide to the CE Marking of Structural Steelwork (ECCS, 2012)

Further reading:
A useful website, which compiles information about stainless steel in building and construction from authoritative sources across the European Union and beyond:
www.stainlessconstruction.com

euro inox
The European
Stainless Steel
Development Association

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