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The European Stainless Steel Development Association

# A Guide to Stainless Steel for Architects

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Presentation on the occasion of the conference
*Creative Architecture with Stainless Steel*
jointly organised by Euro Inox, Brussels, Belgium and
Cedinox, Madrid, Spain, on 12th March 2002 in Barcelona

## 1 Introduction

Today, stainless steel is a material commonly used in architecture; however, this is a comparatively recent phenomenon. It was first used for construction purposes in New York in 1929 in such iconic buildings as the Empire State Building and the Chrysler Building. Its use in architecture has developed rapidly ever since.

The development of the use of stainless steel in architecture is closely linked to the properties of the materials. The success of a project involves careful planning of the appropriate use of materials. The designer must take advantage of their performance profile while minimising risks rising from their limitations.

## 2 General comments on Types of stainless steel

Stainless steels are alloys of iron, chromium and carbon to which other elements, primarily nickel, can be added.
The addition of chromium gives the material corrosion resistance. In oxidising environments, such as the air, chromium forms a thin, tight oxide layer that shields the material from corrosive attacks. When using stainless steels, the objective should always be to keep this passive layer intact, thus guaranteeing the material's protection from corrosion. Stainless steel can be described in terms of the different elements and their respective concentration in the alloy. In general, there are three basic families:

· Martensitic stainless steels
· Ferritic stainless steels
· Austenitic stainless steels

Martensitic steels are alloys of iron, chromium and carbon with the following characteristic contents:
C ≤ 0.10% / Cr: 12-14%
A typical representative of this group is grade 1.4028 according to European standards (or 420 according to ASTM).
Ferritic steels are also alloys of iron, chromium and carbon with higher chromium content and lower carbon content than martensitic steels.
Typical values for this type are:
C < 0.10% / Cr: 16-18%
A common grade in this group is 1.4016 (430).
Austenitic steels are alloys of iron, chromium, nickel and carbon. The addition of nickel modifies the structure of these materials such that it remains austenitic regardless of temperature.
A typical austenitic steel is grade 1.4301 (304).
The most important general characteristics of these three families of stainless steels are as follows:

**Martensitic steels**
These undergo temperature-induced structural modifications, which is why they are usually subjected to thermal annealing and tempering treatments. With these processes, the materials obtain better mechanical properties and sufficient resistance to corrosion. Their most common application is in cutlery.

**Ferritic steels**
The mechanical properties of these steels are the reason of their limited formability. They weld well and are frequently used in applications in which aesthetic considerations are important. Due to their higher levels of chromium, they are more resistant to corrosion than martensitic steels.

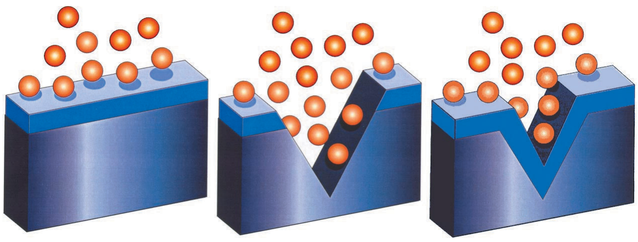
**Austenitic steels**
This is the group of steels that is most commonly used for manufactured goods and show excellent behaviour in practical use. Austenitic grades have outstanding shaping properties, are very suitable for welding and provide a high degree of resistance to different types of corrosion.

## 3 Parameters to bear in mind when using stainless steel in an architectural project

From a generic point of view, the parameters that an architect or other specifier should consider in order to use stainless steel correctly can be grouped into seven different but interrelated categories:
· Resistance to corrosion
· Mechanical properties
· Physical properties
· Manufacture and finishes
· Types of joints
· Costs
· Design
These categories are not listed in any particular order; all of them are interrelated and must be considered to use the material successfully.

### 3.1 Resistance to corrosion

Stainless steel is resistant to corrosion because it has the ability to remain passive in a wide variety of environments. In its passive state, the metallic surface has an extremely thin, invisible, and highly stable protective layer.
This layer has the essential ability to automatically and spontaneously regenerates after damage. This property distinguishes it from protective coatings such as paints, varnishes, enamels or metallic layers, in which damage remains permanent unless it is repaired.
It must be pointed out, however, that not all stainless steels have the same inherent resistance to corrosion; there are some steels that are more resistant to corrosion than others. Faced with the question of grade selection, the most important factor is the environment in which the product shall be used and whether this environment is polluted or not.
It is not always wise to be excessively prudent and choose a stainless steel with the highest alloying content; rather it is better to choose the material that best suits the requirements of the project. A valid albeit very general rule is that ferritic steels are best for interiors and austenitic steels are best for exteriors.



### 3.2 Mechanical properties

As has been demonstrated above, stainless steel is classified according to its structure and chemical composition:
· Martensitic steels: 12% Cr
· Ferritic steels: 17% Cr
· Austenitic steels: 18% Cr – 8% Ni
Each of these families has very different mechanical properties, which are also quite different from the mechanical properties of traditional building materials such as galvanised steel, aluminium, copper and zinc:

| MECHANICAL PROPERTIES | 1.4616 | 1.4301 | GALVANISED STEEL | Al | Cu | Zn |
|---|---|---|---|---|---|---|
| Tensile Strength (N/mm$^2$) | 540 | 600 | 420 | 90/130 | 160/300 | 220 |
| Proof Strength (N/mm$^2$) | 245 | 195 | 220 | 70/90 | 130/200 | 120 |
| Elongation after fraction (%) | 18 | 45 | 25 | 15 | 15 | 20 |

Table 1: Comparison of the mechanical properties of stainless steel and other traditional materials

According to Table 1, the values for tensile strength, proof strength and elongation after fraction, especially for grades 1.4301 (304), are far superior to those of other materials. This indicates that thinner materials gauges may be sufficient to obtain the requird degree of strength in the finished piece.

### 3.3 Physical properties

We will concentrate on three of these: thermal expansion, thermal conductivity and density, which we will again compare with other elements employed in the construction industry (table 2).
These properties are of vital importance since, as the coefficients for thermal expansion and thermal conductivity are often quite different from one stainless steel to another, the selection of grade influences the need for expansion joints, e.g. gutters, roofs and structural frames.

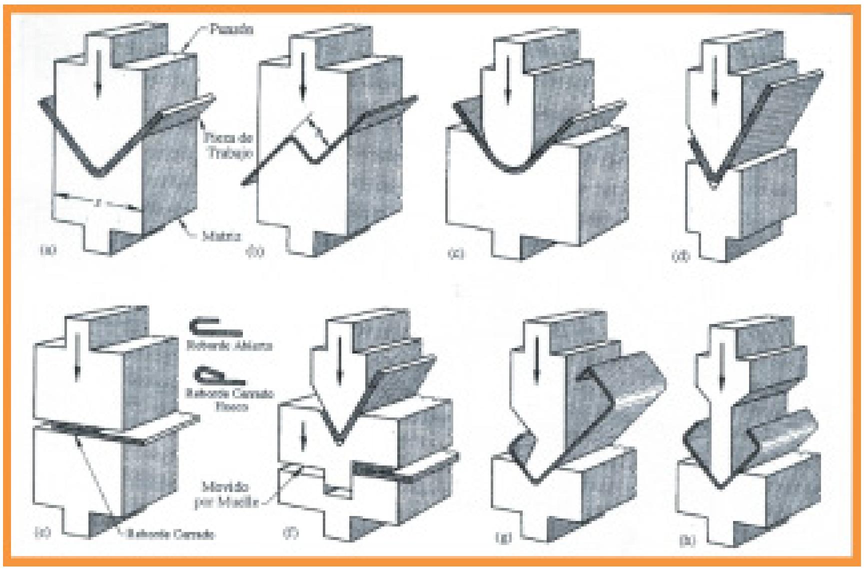
| PHYSICAL PROPERTIES | AISI 430 | AISI 304 | GALVANISED STEEL | Al | Cu | Zn |
|---|---|---|---|---|---|---|
| Density (Kg/dm$^3$) | 7.7 | 8.0 | 8.0 | 2.7 | 8.96 | 7.14 |
| Thermal Expansion (K 10/°C) | 10.2 | 16 | 12 | 24 | 16.5 | 29.3 |
| Thermal Conductivity (Kcal/hm°C) | 21 | 12 | 45 | 185 | 300 | 96 |

Table 2: Comparison of the physical properties of stainless steel and other traditional materials

### 3.4 Manufacture and finishes

#### 3.4.1 Manufacture

In this section we will refer to products made of cold formed stainless steel sheet.
The most common techniques for cold forming stainless steel are:
· Deep-drawing
· Brake-pressing
· Bending
· Profiling
· Punching



*Various folding tools*

Obviously, at the design stage, the specifier should take into account that the forming properties of a material are closely linked to the practical application of the techniques mentioned above, as well as to the technological properties of the different types of stainless steel.
During forming operations, precaution must be taken to prevent the surface of the stainless steel from becoming contaminated with tiny particles of iron or other materials, which can induce pitting. If contamination is suspected, the pieces should be treated in diluted nitric acid and rinsed off with water in order to clean the surface without damaging the stainless steel.

### 3.4.2 Finishes

The surface properties of stainless steel are not the result of an external coating such as paint, varnish, chrome or nickel-plating, but of an alloying process that does not require additional protective layers. Depending on their dimensions (width, length and thickness), commercial stainless steel products come in several different surface finishes which can be subdivided into two broad families:

· Standard mill finishes
· Finishes obtained by polishing

Within the standard finishes, we can define those that are most commonly used in construction and decoration:

**Finish 2B**

This is obtained by cold rolling, annealing, pickling and skin passing. This produces a shiny silvery grey finish. Its average roughness is about 0.08 microns.

**Finish BA**

This is obtained by cold rolling, annealing in an inert atmosphere and dry skimming. It has a shiny mirror-like finish and an average roughness of 0.04 microns.

However, in the majority of decorative applications, more complex finishes are required for aesthetic reasons. Designers generally prefer low-reflective satin finishes, and this usually means finishes obtained by abrasion, among which we can highlight the following:

**Finish No. 3**

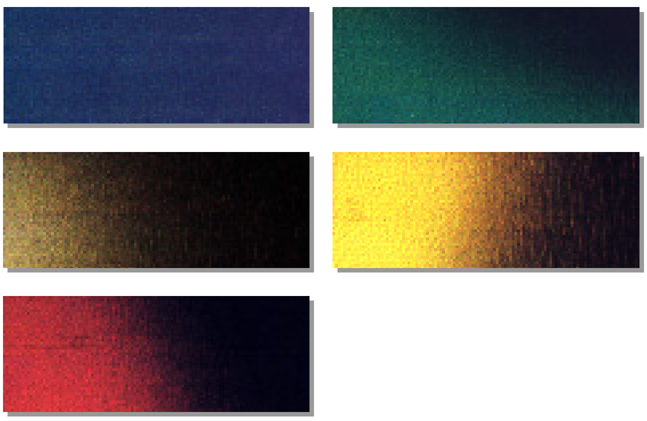
This is normally obtained from 2B by polishing with 80 – 100 grain abrasives. The result is a coarse satin finish.

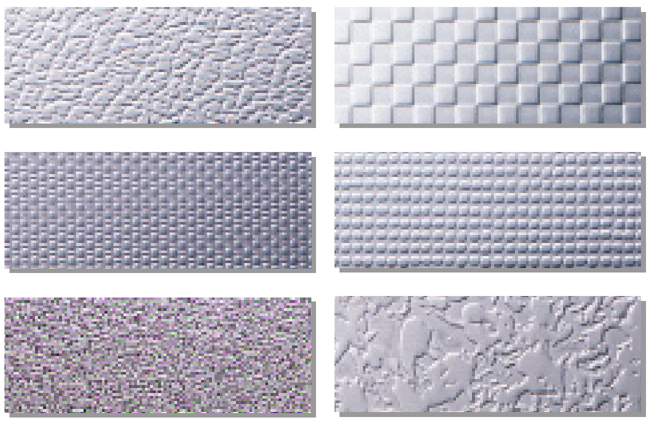
**Finish No. 4**

This is obtained from No. 3 by successive polishing with 120 -150 grain abrasives. The result is a shiny satin finish. This is mainly used when the finish will be visible, thus requiring an attractive surface for aesthetic reasons.

**Finish No. 6, 7 & 8**

This is obtained using 400 – 800 grain abrasives. The trend today is moving rapidly towards the use of coloured or embossed finishes. There is a wide range on the market (see “Guide to Stainless Steel Finishes,” Euro Inox Building Series, Vol.1).





### 3.5 Types of joints

One of the key points to bear in mind on all projects is the assembly and joining of the different parts with permanent joints.

### 3.5.1 Welding

Generally speaking, welding is the most commonly used technique for joining pieces of stainless steel, even those made of thin sheet. The following types of welding are commonly used for this purpose:

- Metal inert gas shield welding (MIG) and tungsten inert gas shield welding (TIG)
- Shielded metal arc welding
- Resistance welding (spot or seam welding)

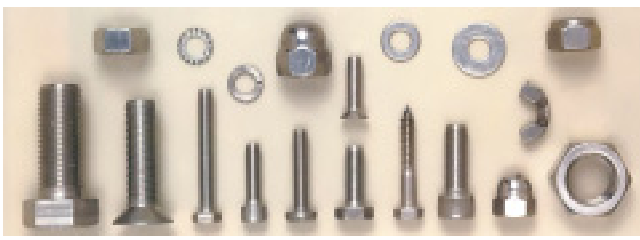
Austenitic products can be welded with or without filler of the same type. They produce satisfactory joints of optimum strength with either electric arc welding or resistance welding.
Ferritic products are normally welded using resistance welding, whether spot or seam welds are used. The same is true of martensitic products.

### 3.5.2 Mechanical joints

Mechanical joints (using bolts, rivets, etc.) are regularly used as long as the parts and the fasteners are galvanically compatible with each other. The fasteners must at least be as noble as the parts to be joined. This is particularly important if an electrolyte is present.
Stainless steel bolts are well suited to join other metallic materials without having to use special insulation techniques:

- Aluminium alloys
- Zinc and copper
- Galvanised steel

In more aggressive corrosive conditions, e.g. close to chemical plants and in marine environments where a danger of seawater spraying exists, it is best to insulate the bolts from other metallic elements. This can be achieved simply by greasing the bolt during assembly with a neutral acid-free grease, or by applying a lacquer which prevents direct contact with other metals. Another system consists of insulating the parts by separating them with plastic or rubber washers.



### 3.5.3 Adhesive bonding

The use of structural adhesives is one of the most advanced current techniques for joining steel. These are applied to the surfaces at ambient or slightly elevated temperatures. If the joint has the right design and size, it can have a mechanical resistance similar to that of the elements being joined.
Table 3 provides an overview of some types of adhesives employed in joining different types of stainless steel with each other and with other metallic and non-metallic materials, indicating the maximum and minimum temperatures.

| TYPE OF ADHESIVE | NO. OF COMPONENTS | STATE | DISSOLVENTS MECHANISM | GLUING | MIN. TEMP. | MAX. TEMP. |
|---|---|---|---|---|---|---|
| Anaerobic | 1 | Liquid | | Polymerisation | -60 | 200 |
| Polyamide Epoxy | 1 | Solid Powder | | Fusion + Chemical reaction | -60–-50 | 150–90 |
| Polyamid Epoxy | 2 | Viscous Liquid | | High Temp.Chemical reaction | -60 | 70 |
| Polyamide Epoxy | 2 | Viscous Liquid | | Chemical reaction | -60 | 150 |
| Epoxy Phenols | 1 | Tape | | Fusion + Chemical reaction | -60 | 150 |
| | 2 | Viscous Liquid | | Chemical reaction | -50 | |
| Epoxy-poly-sulphides | 2 | Viscous Liquid | | Chemical reaction | -40 | 70 |
| Nitrilic phenol | 1 | Tape | | Fusion + Chemical reaction | -55 | 150 |
| | 2 | Liquid and Powder | Ketonic solvents | Evaporation + Chemical reaction | -55 | 150 |

Table 3: Adhesives used in joining metals

## 3.6 Costs

The cost of stainless steel sheet is linked to the composition of the alloy, the thickness and the finish. Thickness, in particular, directly influences cost as the latter rises as the thickness is reduced.
On a scale from least to most expensive according to the type of alloy used, the cheapest steels are the martensitic types. Ferritic steels are in the medium price range and austenitic steels are the most expensive.
However, despite the higher initial cost, stainless steel compared with other materials, it should be borne in mind that subsequent savings on cleaning, painting and maintenance, which are required by other materials, more than compensate for the higher investment.

## 3.7 Design

Finally, design issues shall be addressed, which are closely related to the aspects mentioned above. Design, in the broadest sense of the term and not merely the aesthetic sense, must take into consideration, specifically the following aspects:

- The creation of suitable conditions allowing the material to withstand corrosive attacks
- The sequence of fabrication steps in the construction
- The requirement of an easy and precise assembly of parts
- The possibility of carrying out inspections as well as periodic maintenance during the working life of the part.
- The need that the part or assembly reflects its function.
- The cost of the part or assembly.

## 4 Types and forms of stainless steel used in the construction industry

Now that the factors behind the choice of stainless steel in so many architectural systems have been analysed, we can discuss the different types of steel commonly used: their formats, finishes and thicknesses. These will vary according to applications, uses, required properties and the importance that these properties have for different fields of architecture.
The most commonly used materials in construction are the grades 1.4301 (304), 1.4401 (316), 1.4016 (430), although in recent years duplex steel has become common as well.
Grade 1.4016 is best for interior decoration.
In coastal regions and highly polluted areas where corrosion is a common factor, grade 1.4401 is used.
Regarding the product forms, in the majority of cases steel strip and sheet is the basis. Stainless steel tube is also used, e.g. for decoration or for air conditioning. Sections, angles, corrugated sheet; wire or cables may serve structural purposes.
Specialised surface finishes are labour and cost intensive. Therefore the use of mill finishes is recommended wherever possible.
Generally speaking, the most commonly used finishes are 2B and 4, although coloured finishes are becoming increasingly popular in architectural applications.
Some examples of the most frequent steel types and gauges for different applications are presented in the following tables:

*Grade 1.4016 is best for interior decoration.*

| APPLICATION | TYPE OF STAINLESS STEEL | THICKNESS (mm) |
|---|---|---|
| Curtain walls | 1.4301 (304), 1.4401 (316) | 1.0-1.5 |
| Façade cladding | 1.4301 (304), 1.4401 (316) | 0.6-0.8 |
| Panels for industrial buildings | 1.4301 (304), 1.4401 (316) | 0.4-0.5 |
| Roofing | 1.4510 (430), 1.4301 (304), 1.4401 (316) | 0.4 |
| Structures | 1.4301 (304), 1.4401 (316) | 0.7 |
| Shop windows | 1.4301 (304) | 0.7-1.0 |
| Doors and entrancess | 1.4301 (304) | 0.8-1.2 |
| Chimneys | 1.4301, 1.4401 (304, 316) | 1.0 |
| Solar panels | 1.4301, 1.4401 (304, 316) | 0.5-0.6 |

Table 4: Exterior building applications

| APPLICATION | TYPE OF STAINLESS STEEL | THICKNESS (mm) |
|---|---|---|
| Plumbing | 1.4301, 1.4401 (304, 316) | 0.7 |
| Stairs | 1.4301, 1.4016 (304, 430) | 0.8-1.2 |
| Interior wall cladding | 1.4301, 1.4016 (304, 430) | 0.4-0.6 |
| Floor tiles | 1.4016, 1.4301 (304, 430) | 0.4-0.6 |
| Parapets | 1.4016, 1.4301 (304, 430) | 0.7-0.8 |
| Ceiling coverings | 1.4016 (430) | 0.4-0.5 |
| Handles and door knobs | 1.4301 (304) | 0.4-0.5 |
| Hinges | 1.4016, 1.4301 (304, 430) | 1.5-2.5 |
| Urinals | 1.4301 (304), 1.4401 (316) | 1.0 |

Table 5: Interior building applications

*In coastal regions and highly polluted areas where corrosion is a common factor, grade 1.4401 is used.*

## 5 Conclusions

It is obviously not possible to enumerate all of the quantitative data that needs to be taken into account on a given project, nor was it my intention to do so. I have merely addressed some of the most important factors, attempting to demonstrate the relationship between different parameters, which a designer must know and evaluate to use stainless steel successfully.