Thematic case study No. 6
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Surface treatments in the construction sector

Surface treatments are a true science, and not... alchemy. A science that must take account of a whole series of parameters and constraints upon which the longevity, the appearance and the technical properties of the treated product will depend. Surface treatments for steel are legion and those that are employed in construction comprise only a very small proportion of them. However, there is no standard formula, no automatic answer to the question "what surface treatment should be chosen for a given application?". Hence the mission that Otua has assigned itself: to provide instruction on the subject, in particular by means of its website, compiled by a network of experts capable of answering any questions on the subject of surface treatments.

Whether you are a developer, an architect, a consulting engineer, a student of civil engineering..., here is what you should know about steel surface treatments:

- **Surface treatments** serve principally to protect steel from corrosion, and/or to modify its surface properties (to harden it, increase its roughness or its coefficient of friction, provide a suitable key for paint, increase its heat-resistance, etc.), and/or to alter its appearance (brightness, colour, texture...).

- **Surface treatments are a complex science** requiring the choice of treatment to be factored in at **as early a stage** as possible, at the product design stage, together with a **holistic vision** of their life cycle. The component designer can thus design it so as to facilitate subsequent treatments: without recesses or folds that would be difficult to access or would constitute liquid retention zones.

- How does one choose the right one from the profusion of treatments available? By drawing up a **functional performance specification,** an **indispensable tool** detailing a product's conditions of service.

- For a surface treatment to be effective, the ideal is that it should be the result of collaboration between steelmaker, processor, applier and user.

In need of information on surface treatments? Contact Otua or visit the website: www.otua.org /Tout sur l'acier/Traitements de surface.

By surface treatment, we mean here anything that modifies the steel's surface (as opposed to its body), whether it be a mechanical, chemical or thermal operation. We will limit ourselves here to surface treatments performed once the steel has been processed to its final thickness.

In construction, what are the requirements with regard to surface treatments?

- **Protection against corrosion**

In the presence of humidity and air, a hydrophilic layer of iron oxides (rust) forms naturally on the surface of steel.
One of the principal purposes of surface treatment is therefore to protect steel from corrosion, and the treatment will of course vary according to the harshness of the environment (the harshest environments being coastal zones, industrial atmospheres, urban areas...), to whether it is internal or external.

- **Provision of specific properties**:

- Heat-resistance: one can, for example, increase steel structures' fire-resistance by coating them with flocking (application or spraying of short textile fibres or a special coating onto a surface) or an intumescent paint that reacts to the rise in temperature by swelling strongly to form a protective layer, like a meringue.
- Absorption of humidity: in agricultural buildings, for example, flocking is employed to prevent condensation of the water vapour produced by the animals.
- Suitability for subsequent keying of the paint by sandblasting or phosphating (a chemical operation involving precipitation onto the surface of the steel of a relatively insoluble compound that improves adhesion).
- Etc.

- **Aesthetic finish**

Aesthetic appeal is an important aspect of surface treatments in the construction sector. An attractive finish, matt or bright, a wide variety of colours, textures and effects (opalescent, fluorescent, metallic...) constitute a powerful argument in favour of steel and stainless steel solutions. These choices of finish are an integral part of architectural design. Furthermore, the final coating provides effective additional protection and generally increases the product's durability. However, certain surface treatments have an essentially decorative function. This is the case with silvering or gilding, employed for example in the rehabilitation of monuments, such as the Pont Alexandre III.

The Millau viaduct visitor centre facade units are made of pre-painted steel in a colour that blends with the viaduct

Architects: AA Concept and J.B. Crouzet – Photo: M.C. Bordaz

As for stainless steel, it is also highly valued in the construction sector for its aesthetic appeal – and not only for its corrosion-resistance. There is a range of possible finishes, such as matt, mirror-bright, etched, etc.

The various solutions for combating corrosion in the construction sector

- **Paint systems**

These systems vary according to whether structures or building envelopes are being treated.

For structures, paint systems comprise:

- **surface preparation** so that it receives the treatment under the best possible conditions. This preparation has two purposes: cleaning of the surface and development of surface roughness to promote keying of the paint. It is generally performed by shotblasting and is often complemented by chemical cleaning, essentially intended to remove any trace of grease or scale from the surface of the steel.

- a coat of primer (iron oxide- or zinc particle-based), which serves as a key for organic coatings.

- an undercoat, which inhibits water ingress.

- a **finishing coat**, to enhance the appearance and protect the undercoat from UV radiation.

For building structures, in most instances the steel industry supplies bare steel and it is the constructor who then paints it. Here, the paint has several functions: protection against corrosion, aesthetic appeal and fire protection (intumescent paints that will inhibit overheating of the steel; widely used for car park structures in particular).

For thick sheet (employed particularly in bridges and railway and maritime applications, etc.), the steel industry is developing pre-painted shotblasted steels. These steels are shotblasted and receive a coat of primer. Shotblasting and painting thus protects the steel against corrosion and can constitute pre-treatment prior to final painting. But above all, it provides the steels with a surface finish that promotes more careful, more precise execution.
For sections manufactured in long lengths (up to 40 metres in a single length), hot-dip galvanising is impossible (see the chapter opposite on the subject of galvanising). They undergo finishing and surface treatment (shotblasting and three coats of paint) close to the rolling mills in order to minimise handling operations. And components ready for installation are delivered to site – usually by rail. It is also possible to spray on molten zinc (metallisation) following shotblasting in order to increase corrosion-resistance.

For sections in long lengths, hot-dip galvanising is impossible. They are finished and treated on leaving the rolling mill for delivery to the site – in this case the Yerres bridge – of components ready for installation.

For roofcoverings and facades, nine times out of ten, constructors employ pre-painted sheet. Indeed, steel producers offer product ranges incorporating a wide variety of grades, equating to turnkey construction solutions, incorporating the combination of protective galvanisation, a paint keying treatment (see the paragraph on painting after galvanisation, page 3) and paint. These grades are classified according to their resistance to solvents, light, heat, humidity, their suitability for curving, folding...

- **Galvanisation: the most widespread corrosion protection in construction and civil engineering**

Apart from its corrosion-resistant properties, bare galvanised steel is also employed for its attractive finish. Here for the structure and envelope of a business incubator in Cherbourg (left) and a motorway maintenance facility (below).

This involves depositing a layer of zinc on the surface of the steel. This operation can be performed by in-line hot dipping by the steelmaker or the processor.

By the steelmaker:
Here, the user purchases steel that is already galvanised, in the form of sheet, tubes, rod or wire. This is relatively rare, and not recommended if the steel has to undergo several subsequent machining operations because all the cut, sawn and drilled edges of the galvanised steel component will not be coated. If the sheet is thin, protection of the cut edges will occur of its own accord (by cathodic protection by the zinc); but on slightly thicker components, it will be necessary to apply a zinc-rich paint to the cut edges. This is what is done by manufacturers of greenhouses, for example.

By the processor:

Often, the processor purchases bare steel – suitable for galvanising - which he has dip-galvanised following manufacture of the component. In particular, this is the case when the components are thick or complex (see boxed article on the Eiffel Tower, page 5). Hence the large number of jobbing galvanisers.

In general, galvanising baths are 8 to 15 metres long, 2 metres wide and 1.50 metres deep. When the component exceeds these dimensions, there are several solutions. If it is 19 metres long, for example, it can be dipped in two operations; but it will not be possible to dip-galvanise a 30-metre component. Either it is cut into segments that are galvanised and subsequently reassembled, by bolting for example, or molten zinc is sprayed onto it (an operation known as "metallisation").

• Painting after galvanisation: an operation to be performed with care.

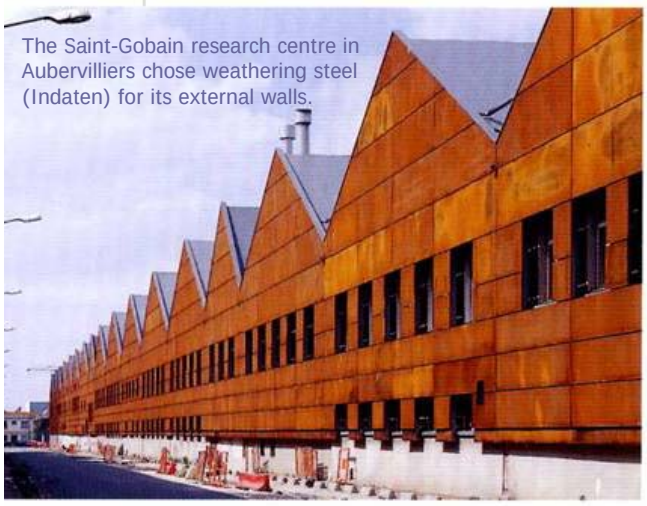
Galvanised steel can be used bare or painted, according to the desired effects. While one can paint directly onto bare steel, the same is not true of galvanised steel. For the paint to adhere to the zinc, the surface must first be treated painstakingly in order to inhibit the chemical reactions that induce the phenomenon of delamination (peeling of the paint).

The adhesion of the paint can also depend on the chemical composition of the galvanising bath, consisting of 95% zinc and some other metals (read the boxed article on the Eiffel Tower, page 5). Therefore, in this field, makeshift solutions are not acceptable.

One can also opt for a coating of zinc combined with aluminium or titanium. Aluminised zinc is very well suited to roofcoverings and resists corrosion while retaining an attractive finish.

• Techniques for preventing or inhibiting corrosion without surface treatment

- Steels with enhanced resistance to atmospheric corrosion ("weathering steels")



The Saint-Gobain research centre in Aubervilliers chose weathering steel (Indaten) for its external walls.

Architects: B. Cornette and O. Decq

Weathering steels (known principally by the brand names Indaten or Corten) are low-alloy steels containing chromium and copper. They have the characteristic, in humid environments and under certain conditions of exposure, of forming – over several months, or even years – a very dense protective layer of oxides, known as a "patina". Architects generally choose these steels for aesthetic but also economic reasons because they do not require any maintenance. However, weathering steels are problematic in use because their oxidation requires alternating periods of humidity and dryness and the absence of water retention zones. The choice of this grade therefore demands a very precise functional performance specification (see boxed article on page 4).

- Protection by design

The deck of the Millau viaduct was designed from the outset to be corrosion-resistant: no surface treatment internally, but a ventilation system to maintain a constant level of relative humidity.

Architect: N. Foster – Photo: D. Jamme – Millau for CEVM

One can cite the Millau viaduct, in respect of which engineers thought of corrosion protection at the design stage. The interior of the deck was fitted with humidity sensors, a system for the recovery of runoff water and a dry air ventilation system, in order to prevent the risks of corrosion without treating the surface of the steel.

- Protection by means of aluminium or zinc sacrificial anodes or impressed current

For offshore platforms or undersea pipelines, protection is provided by means of sacrificial anodes that can only fulfil their role when immersed. For land pipelines, on the other hand, impressed current or cathodic protection is employed, which can complement a paint system or other coatings.

• Sometimes, galvanising is not necessary: for interior use, for example.

It is not always necessary to galvanise the bare steel. If the risk of corrosion is minimal, as in the case of interior furniture (electrical cabinets, for example), simple phosphating can suffice beneath the coat of paint.

An essential tool for selecting the appropriate surface treatment: the functional performance specification

When Otua is asked to advise about surface treatment, the question can often be summed up: “can I use this paint on a given product?”. This is inadequate.

To know what surface treatment to use, one must ask oneself several questions about one’s product (whether it is a facade, a roofcovering or a structure...):

- In what environment will the product be used: externally? exposed to strong sunlight? in a damp environment? subject to abrasion, to impact?
- What method of assembly will be employed?
- What is the desired product life?
- What are the intended maintenance intervals?
- What finish is required (brightness, colour...)?
- What budget is available?

In order to determine the appropriate surface treatment, the design office needs the architect to define a precise functional performance specification. In other words, a document providing information on the product’s end use, specifying the conditions under which it will be used and requirements in terms of strength, finish, longevity.... It is the design office’s task to translate this requirement in terms of material and surface treatment.
Generally, there are always several possible surface treatment solutions. A choice must then be made, comparing costs, ease of execution...

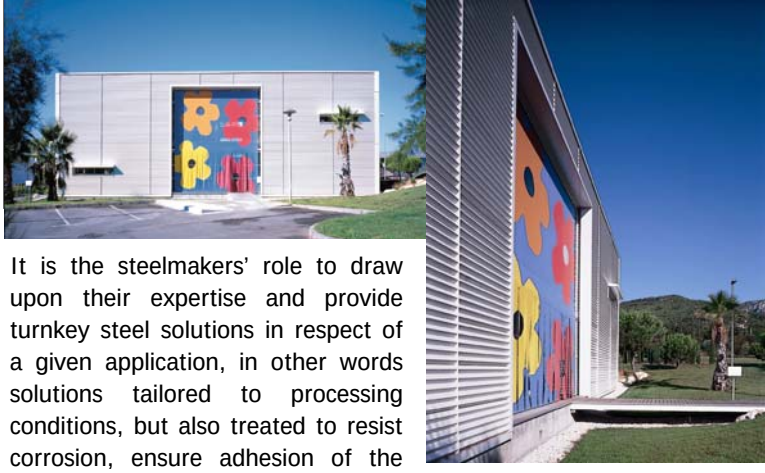
- **Enamelled and stainless steels: another option for longevity of structures**

Stainless steel is also widely employed in the construction sector, principally in the form of flat products (sheet), for roofs and facades, but also for interior partitions. Naturally resistant to corrosion, it can nevertheless be treated (detail of stainless steel surface treatments, page 5).
Together with stainless, enamelled steels are the best performing products in terms of durability. (See page 5).
But these two product categories are more expensive than most coated steels.

What defines a good surface treatment?

- **Assistance and support from steelmakers**

Construction professionals’ primary preoccupation with regard to the steel components that they choose, is the hue and the form. They do not usually ask the question “what type of sheet should I use to avoid corrosion?”. And even less “what surface treatment should I apply?”. For the most part, they are unaware of the importance of these treatments.



Pre-painted steel was chosen for the production of this cladding for the BBG architectural practice. Pre-painted steels supplied by steelmakers include galvanisation, a surface treatment that promotes keying of the paint and a finishing coat.

It is the steelmakers’ role to draw upon their expertise and provide turnkey steel solutions in respect of a given application, in other words solutions tailored to processing conditions, but also treated to resist corrosion, ensure adhesion of the paint, permit deformation without damage, etc. Either they supply products already treated and painted or they can advise the processor as to necessary and appropriate treatments. The ideal being to work in collaboration with all the participants in the product manufacturing chain. For example, the purchaser should always specify to the steelmaker if the component is going to be galvanised so that the steelmaker provides him with a compatible grade of steel (with, in particular, a controlled silicon content).

- **Good correlation between product and treatment process**

The effectiveness of the treatment depends, among other things, on a good match between the substrate, the type of paint or coating, and lastly the process for application of the treatment. There are treatments, such as galvanising, that require or preclude certain grades (chemical compositions) of steel. Silicon steels, for example, are incompatible with certain galvanising processes. Similarly, thermocoating is not possible on components that are too thin and would be deformed, nor on components that are too large, incompatible with the size of the ovens. If it is poorly applied, the best surface treatment becomes ineffective. Excellent control of the process is therefore imperative.

- **Compliance with standards and regulations**

Surface treatments must be performed in accordance with the rules of good practice and the standards in force. The location and the type of structure are determinant criteria in the choice of treatments and the method of application. In the case of a bridge, for example, the specialists refer to the requirements of "Folio 56" of the CCTG (handbook of general technical clauses for State procurement), "Protection of Metal Structures against Corrosion". Bodies such as ACQPA (French Association for the Certification and Qualification of Anticorrosion Paintwork) or OHGPI (French Certification Office for Industrial Paintwork Guarantees) provide information in this field.
Surface treatments are further regulated when effected in situ. For sandblasting, for example, the use of silica is forbidden; it must be replaced by aluminium oxides (corundum). Similarly, the climatic conditions under which the treatment is effected are closely monitored: the temperature/humidity ratio must be strictly controlled so as to ensure that there will not be any condensation on the components to be painted.

The Eiffel Tower light show: a specific surface treatment for the 20,000 lampholders

In 2000, for the first time, the Eiffel Tower glittered with light. At the time, the light show was intended to last for a year. When the Paris City Council decided to perpetuate the operation, that changed the parameters with regard to corrosion.

The new objective: to guarantee the installation a service life of 10 years.

Two experts were consulted for their advice on the quality of the corrosion protection system for the lampholders, which are cut from thick sheets of bare steel and coated with zinc by galvanising.

Two types of galvanisation were examined in a comparative study entrusted to Jean-Claude Catonné, an Otua surface treatment expert. On the one hand, conventional galvanising, employing a lead addition in the bath, traditionally employed in the construction sector; on the other, lead-free galvanising, developed in the offshore and automotive industries in particular.

In the opinion of Jean-Claude Catonné, lead-free galvanising, which contains aluminium, offered the project two major advantages compared with conventional galvanising: aluminium enrichment at the iron-zinc interface, enhancing the coating's cathodic potential in the event of damage; the existence of a zinc-iron alloy surface layer, conducive to adhesion of the keying primer.

The protection system for the lighting system components consists of a zinc coating, a keying primer and a two-coat finish. Following sandblasting of the galvanised steel, the primer and the first finishing coat were sprayed on prior to assembly. Following assembly and installation of the units on the monument, the second finishing coat was brushed on by abseiling painters.

A surface treatment offering exceptional aesthetic appeal and durability: enamelling

Enamelled steel has remarkable qualities in terms of durability, aesthetic appeal and cleanability.

But surface preparation prior to enamelling is complex, because enamel is a glass whose firing temperature is in the order of 850°C and it is difficult to achieve adhesion to the steel sheet.

By virtue of their durability and cleanability, enamelled steels are particularly suited to high-traffic areas such as stations (above). They are also excellently suited to screen printing.

The steel industry has developed enamelling steels, including one with an aluminium-silicon coating that promotes adhesion of the enamel.

Alliance is one of the world's few manufacturers of continuously enamelled sheet. In most cases, enamelling is performed on a jobbing basis.

For architecture, enamelled steels offer numerous advantages. Their durability makes them an ideal material for high-traffic areas such as underground and railway stations, airports... They permit screen printing and are very easy to clean and graffiti-resistant (on the enamel, graffiti are easily cleaned with a solvent).

Stainless steels

• Varying corrosion-resistance according to the composition of the stainless steel

Stainless steel does not mean "non-rusting steel". It naturally develops a so-called "passive" coating, whose corrosion-resistance depends on the composition of the steel.

In the construction industry, basically three grades of stainless steel are used. In increasing degree of corrosion-resistance, these are:

- X6Cr17 (European standard, numeric code 1.4016) or 430 (US standard), containing approximately 17% chromium. It is employed inside buildings, in non-corrosive atmospheres. It is found in partitions, false ceilings, interior cladding of lifts, reception desks...

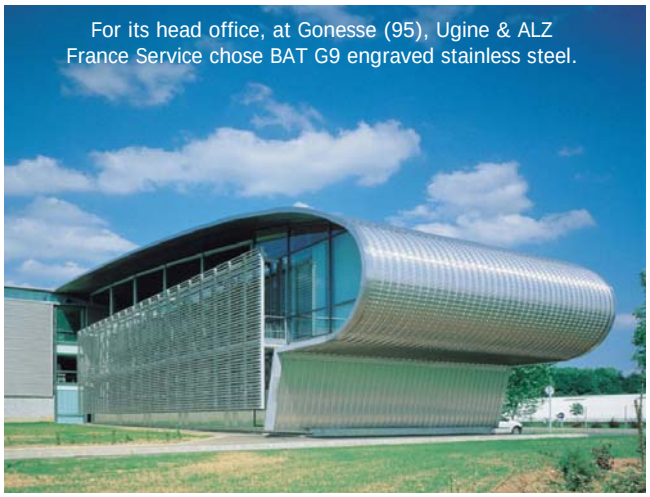
- X5CrNi18-10 (European standard, numeric code 1.4301) or 304 (US standard), containing approximately 18% chromium and 10% nickel. It is employed inside and outside buildings, but only in non-corrosive atmospheres; particularly for facades, in non-industrial rural or urban environments.

- X2CrNiMo17-12-2 (European standard, numeric code 1.4404) or 316L (US standard), containing approximately 17% chromium, 11% nickel and 2% molybdenum. It can

be used in virtually all atmospheres. It withstands corrosion on coastal sites or in corrosive industrial atmospheres, provided it is given an extremely smooth surface finish and cleaned frequently.

The smoother the finish, the better the corrosion-resistance.

- **Stainless steel in construction: principally flat products**



For its head office, at Gonesse (95), Ugine & ALZ France Service chose BAT G9 engraved stainless steel.

Architects: B. Pantz and C. Bapts – Photo: E.Avenel

In the construction sector, stainless steel is employed above all for finishing works, roofcoverings and facades, and very rarely for structures. In other words, very little in the way of long products. When beams (which are generally welded plate sections) are employed for structures, they do not undergo any special preparation. As for tubes, they are generally polished, micro-pellet blasted, shotblasted.

- **Surface treatments applied to stainless steel without application of another material**

These treatments consist of altering the surface texture, modulating the sheen, or even producing raised designs or motifs. One can thus easily "write" company logos on a stainless steel surface, by exploiting the contrast between matt and bright finishes, by polishing or shotblasting of bright surfaces.

These treatments can be performed by the steelmaker or downstream, by specialist companies.

Treatment by the steelmaker

In this case, it is the stainless steel production process that determines the finish:

- when annealed in an inert atmosphere, the stainless steel is said to be "bright annealed": you can see your reflection in it, even if the contours of images are somewhat blurred.
- when annealed in an oxidising atmosphere, followed by pickling and then a skin pass, stainless steel assumes a glazed finish. This is the most common finish, the surface is slightly milky, and one cannot see one's reflection in the sheet.
- the steelmakers can then, in a final operation, polish the coils or sheets, to increase or reduce the roughness of the finish. Or engrave them, by "imprinting" onto the sheet designs previously etched onto the surface of the roll. These designs have names such as leather grain, linen, rice grain...

Certain steelmakers have succeeded in developing engraved finishes with a very delicate motif, which is particularly suited to roofcoverings: these extremely dull finishes are employed here so as to avoid dazzling aeroplanes or simply neighbours living in taller houses or apartment buildings. These products are highly valued because the rainwater or snowmelt recovered from the roofs or gutters can be used with confidence; they are not polluted by particles of earthenware (in the case of tiled roofs), or copper oxides (in the case of copper roofs...). This is ideal, particularly for mountain refuges.

Treatment by specialist companies

These companies can perform various operations that alter the surface finish:

- combine several polishes to inscribe logos, messages (through the contrast between different degrees of shine);
- perform micro-pellet blasting or spark-erosion, which gives a very matt finish, highly sought-after by architects;
- perform mirror-polishing. By means of very fine non-directional polishing, one obtains an ultra-bright finish, in which one sees one's reflection perfectly, as if in a mirror. This finish is employed for reasons of safety (mirror effect without the risk of breakage) in psychiatric hospitals, prisons, dance halls...
- obtain burnished finishes by polishing or turning. This finish is highly appreciated in the food processing sector because it is easy to maintain and not prone to soiling.

- **Coated stainless steels**

Surface treatment of stainless steel by means of another material is generally intended to impart a different appearance to the surface, rarely to increase its corrosion-resistance. One can single out:

Terne-coated stainless steels

An alloy of tin is deposited on the surface of the stainless steel. The tin will weather over time and assume a very dull grey hue. This finish meets two requirements:
- To provide a very dull finish for roofcoverings in order to avoid inconveniencing neighbours or aeroplanes.
- To facilitate soldering when necessary, for example for gutters or drainpipes.

Stainless steel is increasingly used for roofcoverings because it has a considerably lower coefficient of expansion than zinc and thus enables manufacture of roofcovering or gutter units in greater lengths without expansion joints.

Electrolytically coloured stainless steels

This consists of electrochemical deposition of a thin layer of chromium oxides. The thickness of this coating is between 0.02 µm and 0.36 µm. Depending on the thickness of the coating, the eye sees different colours, ranging from the

"champagne" hue, through turquoise or fuchsia to dark violet, As these coatings are very thin, the sheet's initial finish (bright, matt, shotblasted) is retained and this makes it possible to increase the range of surface finishes. By polishing coloured areas, it is possible to produce motifs, designs, logos...

Varnishes

It is possible to varnish stainless steels, but this process is little used. The application of a coat of varnish generally impairs the surface finish, rendering it less bright or less luminous. As certain surface finishes are very susceptible to fingermarks, the only advantage of a varnish can be to counter this drawback.

Paints

The application of paint to stainless steel causes it to lose its original appearance and is therefore not a common operation. The most usual examples are:

- Tunnel walls. "Conventional" stainless steel cannot be used due to drivers being dazzled by other vehicles' headlights. Painted stainless steel is used, which resists corrosion better than a conventional steel in the event of gravel splatter or an accident.

- Partitions in the food processing industry. In order to brighten up these plants, architects employ coloured constructional systems. For reasons similar to those mentioned in the case of tunnels, they opt for painted stainless steels. If the walls are damaged by impact or abrasion from trucks, their resistance to cleaning products and saline atmospheres is not impaired.

- **Maintenance of stainless steels: simple but vital**

The cleaning of stainless steel is very important; it is this operation that will ensure the longevity of the structure or the installed component. In most cases, simple rinsing with fresh water (free from salt and chlorides) or with an alkaline detergent is sufficient.

Professionals, specialists in surface treatments

"Our idea is to make it clear that surface treatment is not alchemy, but science," explains Suzanne Mathieu, who, together with Jean-Claude Catonné, coordinates Otua's team of surface treatment experts.

A surface treatment is not deployed haphazardly, and its selection requires a good understanding of "how it works".

Answers to all your questions on surface treatments by contacting Otua's network of experts – Contact details and competencies on the website: www.otua.org / Tout sur l'acier / Traitements de surface.

Hence an educational exercise on the website. Selecting famous artefacts (the Eiffel Tower, the Pont Alexandre III, and soon the Millau viaduct ...), the experts provide a detailed (verbal and written) explanation as to how and why these objects were treated.

In response to recurring requests from steel processors, the site will soon provide a glossary and a directory of subcontractors. A requirement expressed in particular at surface treatment exhibitions (such as SITS): "Who can gild steel for me and where?". From now on, for the answers to these questions, one will only have to go as far as the website directory. There, it will be possible to sort by company, type of coating, or by a given French *département*.

Why a website and not a work of reference?

Because needs and treatments are changing very rapidly, and in order to promote questions and interactivity.

Useful links and addresses

- **ACQPA**: French Association for the Certification and Qualification of Anticorrosion Paintwork (www.acqpa.com).
- **Cefracor:** French Anticorrosion Centre, a non-profitmaking association, comprises representatives of industrial companies, research scientists in public and private laboratories, educators, suppliers of materials and services, involved with corrosion and corrosion prevention (www.cefracor.org).
- **Cetim:** French Engineering Industry Technical Centre (www.cetim.fr).
- **CSTB:** Construction Industry Scientific and Technical Centre, public body responsible for scientific and technical studies and research relating to construction and housing (www.cstb.fr).
- **CTICM:** French Steel Construction Industry Technical Centre. Its mission is to promote technical progress, contribute to productivity improvements and ensure quality in the steel construction industry (www.cticm.fr).
- **Galvazinc Association**: comprising galvanisers from several European countries, the association has a website (www.galvazinc.com) and publishes a review ("*Galvanisation à chaud*"). It features practical advice to users and numerous examples of applications.
- **IFETS**: French environment and surface treatments institute (www.ifets.org).
- **OHGPI**: French Certification Office for Industrial Paintwork Guarantees (www.ohgpi.com).
- **SITS**: French Surface Treatment Manufacturers and Suppliers Trade Association (www.sits.fr)
- **SATS**: French National Association of Surface Treatment and Plating Companies (www.sats-france.com).

See also the "Traitements de surface" chapter of the publication **"L'acier, sa fabrication, ses propriétés, sa mise en œuvre, ses emplois"**, by Louis Roesch.