Stainless Steel in Architecture, Building & Construction

A Compendium of National and International Articles

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Contents

Particulars	Page No.
Preface	03
Indian Stainless Steel Industry - An Overview	04
About Indian Stainless Steel Development Association (ISSDA)	10
About Nickel Institute	12
Stainless Steel as a Material	13
Stainless Steel Finishes	13
Guidelines For Roof, Floors and Handrails	13
Cleaning & Maintaining Stainless Steel	13
Guidelines For Corrosion Prevention	13
Architecture Building & Construction Applications In India	13
Use of Stainless Steel in	13
Proving Its Long Term Mettle: Longevity, Whole Building LCAs and Stainless Steel	13
Duplex Stainless Steel Revolutionizes Structural Design	13

"This booklet also contains a flash drive having article & useful information on Stainless Steels, it's properties & multiple end-use application."

PREFACE

The pace of urbanization in India has accelerated over last 20 years, fueled by rapid economic growth. This has received further impetus by focused government initiatives on building smart cities and revamping urban infrastructure. The growth in high quality construction like Airports, Metro-Rails, IT Parks, Hotels Shopping Malls, Multiplexes, commercial and residential complexes has been unprecedented in last decade or so. There has been a total transformation in the way modern buildings and structures are now designed and built in India, with consumers demanding best of aesthetics and facilities, leading to search for superior construction solutions.

Stainless steel as a building material of choice is a natural corollary to the changing design and construction philosophy. We have seen a complete transformation in the end use of stainless steel during last two decades. From dominant consumption in kitchenware and stainless steel is now all pervasive across wide range of applications. However, the stainless-steel usage in Architecture, Building & Construction segment remains slow at about 8% of total, against global average of about 15%. Several enabling factors for stainless-steel usage in construction remains weak, such as lower awareness, lack of standards and design manuals, inadequate fabrication practices and few total solution providers. Indian stainless-Steel Development Association (ISSDA) has been trying to fill this gap by spreading awareness and education in Government, Policy makers, Architects, Builders and Urban Planners on the versatility of stainless steel in finding sustainable solutions for nation building, which can serve as important input for Indian stainless steel industry. For example, one such area is conservation of potable water in urban water supply management, where stainless steel-based distribution and storage systems can reduce water leakages from present 30-40% to 2-3%. This can be a boon for our water stressed cities and similar examples are available from other parts of the world where shifting to stainless steel resulted in averting urban water crisis. This book covers many such cases, which can enhance our urban landscape and quality of life for the citizens.

As part of its mission, ISSDA, with Nickel Institute, has brought this compendium of articles on Stainless Steel applications for urban infrastructure. We are grateful to Nickel Institute (NI) and International Molybdenum Association (IMOA) for sharing their immense research work on stainless steel applications with Indian users. Credits have been given for technical literature and photographs taken from different sources. We are specially grateful to Cathrine Houska for sharing her own articles and some wonderful photographs. The compilation has been well edited by Mr. Rohit Kumar, Executive Director, ISSDA and Mr. Nagendra Vijayavargia. Consultant, ISSDA. We hope the information will be useful to all stakeholders and serve as a ready reckoner on the subject.

K K Pahuja
President, ISSDA

Indian Stainless Steel Industry -An Overview

Indian Stainless Steel Industry - An Overview

In recent years, Asia has strongly emerged as both the world's largest stainless steel producer and user. Although this growth is driven primarily by China, India has been a part of this impressive growth with its production reaching 3.5 million tonne in 2017 as reported by International Stainless Steel Forum. The average growth in India recorded a CAGR of over 8-9 % over the last 10 years, double the world average growth during the period.

The main Stainless Steel consuming segments can be classified into 6 to 7 broad categories e.g. Metal products, Process and Engineering industries products; Electro mechanical and electronics; Construction, Transportation and others including medical, blades, coins etc. Out of these Metal products, Process Industries and Engineering goods are relatively mature application areas whereas construction and automobile are still growing in the country and have great future potential for growth.

The automotive, railway and transport (ART) sector is now emerging as the fastest consumption segment of Stainless steel in the country. This segment has grown the fastest around 30% over the last 8 years propelled by large requirements from railway wagon, passenger coaches and automotive exhausts. This procurement cycle is expected to continue for next several years as the railways have plans to switch over to stainless steel for all its coaches for all long distance trains.

Over the years there always has been a demand for "crashworthy" lighter coaches made with superior material and structural design and has been the focus of discussion after few unfortunate accidents.

Indian railways has understood the importance of stainless steel for coach manufacturing as far as passenger safety is concerned and for the same reason they introduced the LHB (Linke Hofmann Busch) coaches from Germany in 2000 and are currently being used in Rajdhani, Shatabdi and other premium trains. According to a senior Rail Ministry official "LHB coaches made of stainless steel have more inbuilt safety features, as they can absorb shock and impact of derailment more effectively and as a result do not topple and crush into eachother, thus reducing the loss of lives in case of accident." In 2016, the Indian Railways planned to roll out 4,000 LHB coaches in India, and as stated by Mr. P. K. Agarwal (Additional Member Mechanical, Engg, Railway Board) in his speech at the Rail India Conference 2016, "the Indian Railways will make a complete switch over to LHB coaches in future". Railways decision to fast track a complete replacement of steel coaches into stainless steel to ensure safety of its passengers will definitely increase the stainless steel consumption in a big way. Besides this, there has been rapid growth in demand for metro coaches in the country and is expected to grow manifolds.

One of the new emerging segments for stainless steel consumption is the Architecture, Building and Construction (ABC) sector. The ABC sector is mostly driven by growth in Indian real estate sector consisting of residential real estate, commercial real estate, retail space, entertainment space, hospitality projects and SEZs. In all these construction, stainless steel is finding space along with conventional materials like steel, glass, plastics, aluminum composites etc. The Architecture Building and Construction sector in India has become very much aware of the benefits of stainless steel. Stainless steel consumption in this sector (includes sinks, elevators, architectural products like hand rails, gates, roofing & cladding etc, street furniture and builders' hardware) has seen a tremendous growth in last few years

Transit buildings such as airports and metro rapid mass transport systems has been extensively using stainless steels in many areas such as bollards, column claddings, ticketing counters, benches, escalators, lifts, handrails, canopies etc. Indian Railways decision to redevelop and modernize 400 stations in a phased manner will generate good demand for stainless steels in coming future. There are fifty new airports planned and likely to come up in next 10 years. Not only that Airport Authority of India limited is also planning to open up portions of 50,000 acres of urban airport land under its territory for building multiplexes, shopping centers and convention centers where stainless steels in various applications will generate good demand.

Indian Cities are going through a phase of rapid urbanization and construction activities, both at the level of private and government, has picked up and likely to speed up the stainless steel demand in this sector. Apart from traditional use of building hardware there has been a noticeable shift in the use of stainless steel as a preferred choice of material for gates and handrails. Today, even a moderate size residential flat in a high rise apartment or an individual houses, big or small, would prefer to have a designer stainless steel gate in the front. The increase in demand of such gates can be gauged from the fact that several pipes and tubes mills has come up in recent past in the country. Availability and

Industry Sector	Potential Application/ Area	Industry Sector	Potential Application/ Area
Effluent and Water Treatment systems	Effluent treatment, Municipal waste& sewage treatment plants, Water treatment (with Desalination plants)	Oil and gas	Refineries,Petrochemicals, Oil and Gas exploration, LNG Re gasification, CNG Application
Architecture, Building & Construction (ABC)	Sinks, Elevators and escalators, Street furniture: Builder hardware, Architectural Products/Fabrication, Plumbing	Process Industry	Fertilizers, Chemicals, Dairy Industry Brewery and Distillery, Sugar Food Processing, Drugs and Pharma Paper and Pulp
Electronic and Electro Mechanical Industries	Washing Machines, Electrical Appliances, Optical Fiber Cables, Micro wave ovens	Power Sector	Thermal Power Plants, Nuclear
Engineering Industry:	Pumps, Valves, Welding wires and Electrodes, Fasteners, Solar Heaters, Watches, Pipe fittings, Machine tools/machined parts	Metal Goods	Utensil and Kitchenware, pressure cookers, Cutlery/ Kitchen tools and gadgets, Commercial kitchen equipment Gas stoves, Life Style products, Induction cookware, Kitchen chimney
Automobile, Railways & Transportation (ART)	Automobiles, Railways, Metro Rail, Bus body	Other areas	Surgical Instruments, Hospital Furniture Household, Office and garden furniture Coinage

acceptability of Structural hollow sections for building load bearing structures is gaining pace slowly.

In Urban Infrastructure development stainless steel find its rightful presence in many areas. In Delhi all bus shelters has been converted into stainless steel and this has resulted into a domino effect and now all over country, even in remote places, one can see stainless steel bus queue shelters. Foot over bridges with escalators are also swiftly adopting stainless steels for aesthetic and maintenance free life. Recently ministry of steel, Government of India, has created a task force to increase steel/stainless steel demand in the country and to fulfill this dream one of the prime focus of this task force is to explain the importance of life cycle cost analysis in selection of material to various other ministries in the government for their projects such as in ministry of urban development, ministry of road transport and highways, ministry of railways and others. Such initiatives are likely to help stainless steel becoming a material of choice in many urban development initiatives taken by the prime minister of the country such as creation of 100 smart cities, access to clean drinking water and clean India (Swachh Bharat) campaigns.

Process industry historically has been consistent consumer of Stainless steel. Stainless steel is used in wide ranging process industries including Refineries, Petrochemical, Chemicals, Dairy, Power, Textile, Sugar, Food processing, Distilleries, Fertilizer, Cement, Drugs, Paper and Pulp and others. This sector mainly consumes 300 series grade of stainless steel. The process and engineering industry requirement has increased over the years and is tied with the health of the general economy and investment in projects. Major share of the consumption within process industry is accounted by Heat exchangers, pressure vessels, reactors and columns etc.

New Government Initiatives and Indian Stainless Industry

National and International community is keenly looking at the reforms and various economic decisions being taken by this government to place India back on a trajectory of high economic

growth. India is likely to improve upon its GDP figures. The per capita consumption of stainless steel has strong co-relation with GDP growth. Using India's new GDP series, the IMF expects Indian economy growth to pick up in next two years making India the fastest growing large economy in the world.

The new initiative of Government of India on building 100 smart cities, focus on improving sanitation & waste management facilities is likely to give a strong push to the stainless steel industry which is struggling with low capacity utilization. The potential growth of stainless steel in India is enormous considering the fact that the per capita consumption at 2.1 Kgs is still much lower than world average of 6 Kg. Some future Stainless Steel Growth Sectors in India have been enumerated in the table above.

ISSDA Role in Stainless Steel Industry

It all started twenty Nine years ago when leading stainless steel producers formed the Indian Stainless Steel Development Association as a technical and market development arm of stainless steel industry. ISSDA's soon became a common forum for stainless steel and allied manufacturers, processors, fabricators and users to protect, promote, develop and propagate the use of stainless steel in the country. Through the focused efforts of ISSDA and its member companies, the widespread and visible use of stainless steel in different walks of life is all too evident, especially in the Architecture, Building & Construction (ABC) and the Automotive, Railway and Transportation (ART) sectors. Even during the period of 1994-95 Stainless steel production in India was merely 0.5 million tones that too mostly in kitchen utensils accounting to almost 90% of total consumption. Consistent efforts by ISSDA and its member companies helped in diversifying the end use applications over the years has resulted in Indian becoming second largest user of stainless steel in the world. Also,Indian Stainless Steel Development Association (ISSDA) has been constantly working with BIS as a neutral body to formulate various standards of Stainless Steel products to ensure quality in stainless steel related products. ISSDA will continue to promote stainless steels and spread education about the benefits in various end use sectors and find newer application areas for the growth of the industry in the country.

About Indian Stainless Steel Development Association (ISSDA)

The Indian Stainless Steel Development Association (ISSDA) is the unifying point for the growth and development of stainless steel usage in India. Founded in 1989 by leading stainless steel producers, it was formed with the explicit objective of diversifying the applications of stainless steel in India and increasing usage volumes in the country. At the point of formation of ISSDA, the main visible application in daily life was essentially household kitchenware. It currently has a membership of about 200 companies engaged in the stainless steel business.

Through the focused efforts of ISSDA and its member companies, the widespread and visible use of stainless steel in different walks of life is all too evident, especially in the Architecture, Building & Construction (ABC) and the Automotive, Railway and Transportation (ART) sectors. All-stainless steel railway coaches, Metro coaches, Railway wagons for carrying coal & minerals, airports, corporate buildings, retail shops & shopping malls, the ever-wider use by the hospitality industry, even bus stands, railway platform roofs, building hardware - you name it and stainless steel is making its presence felt there. It has become the most aspired material of construction for thousands of small and big things, apart from the chemical and food processing industry where the use of stainless steel is mandatory. With the economy booming, there is increasing demand for a wider range of products and services in stainless steel.

Such a change of fortunes for this material has been made possible through creation of awareness about the benefits of stainless steel amongst engineers, architects, designers, railway men, government bodies and a host of professionals responsible for specification of materials of construction and at the same time providing help to fabricators to fabricate and finish stainless steels in technically correct manner. Stainless steel production in India has increased from 0.5 million tonnes in 1994-95 to 3.5 million tonnes in 2017-18.

We firmly believe that in the ABC and ART sectors, we have only initiated the curiosity for stainless steel. There are several hundred cities looking forward for this aspirational product to reach them.

Newer sectors like household plumbing in thin-walled stainless steel and the water industry as a whole (potable water treatment, waste water treatment plants, large-dia pipes for carrying water), reinforce-ment bar for concrete, auto-mobile exhausts for two & four wheelers and commercial vehicles, bus bodies etc., wait to be explored and exploited seriously.

Our website www.stainlessindia.org is an important tool for easy availability of information on stainless steel to the users.

The various activities to increase market opportunity for stainless steel are given as under:

Stainless India

Stainless India magazine highlights and catalogues applications of stainless steel in India and is published quarterly. Anybody interested in the applications of stainless steels can write to ISSDA for a free copy of the magazine.

Free Technical Services

ISSDA has access to vast technical resources in the selection of proper grade of stainless steel for various service environments, as well as matters related to fabrication. This service is provided free of charge. Similarly up-to-date information on material selection of stainless steel for various industrial service environments and fabrication is available in the form of technical publications. Technical queries and matters relating to sourcing of stainless steel products & services are answered free of charge.

Programmes

ISSDA organizes workshops for specific end-use applications of stainless steel targeted at designers, material specifiers, engineers, architects, maintenance personnel; workshops for improving the quality of welding & fabrication; international conferences for increasing the awareness of applications in the stainless steel industry.

Affiliations

ISSDA has close relations with the Nickel Institute (NI), stainless steel development associations (SSDAs) in other countries, the International Stainless Steel Forum (ISSF), the International Chromium Development Association (ICDA) and the International Molybdenum Association (IMOA). This helps ISSDA to learn from their experience to introduce stainless steel for new applications. ISSDA is a member of ISSF which is the apex body for coordinating world-wide market development activities and other interests of stainless steel producers and SSDA's around the world.

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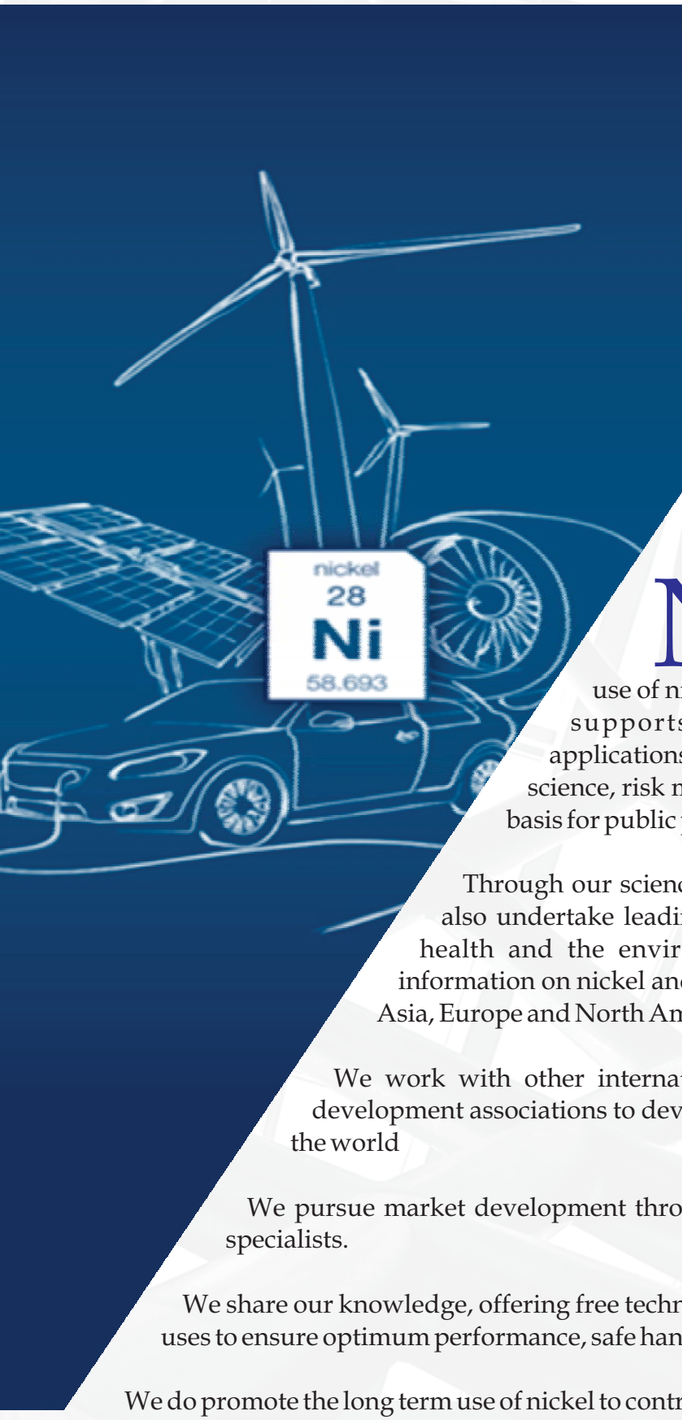


About

Nickel INSTITUTE

knowledge for a brighter future

Nickel Institute is the global association of leading primary nickel producers. Our mission is to promote and support the use of nickel in appropriate applications. NI grows and supports markets for new and existing nickel applications including stainless steel; and promotes sound science, risk management, and socio-economic benefit as the basis for public policy and regulation.

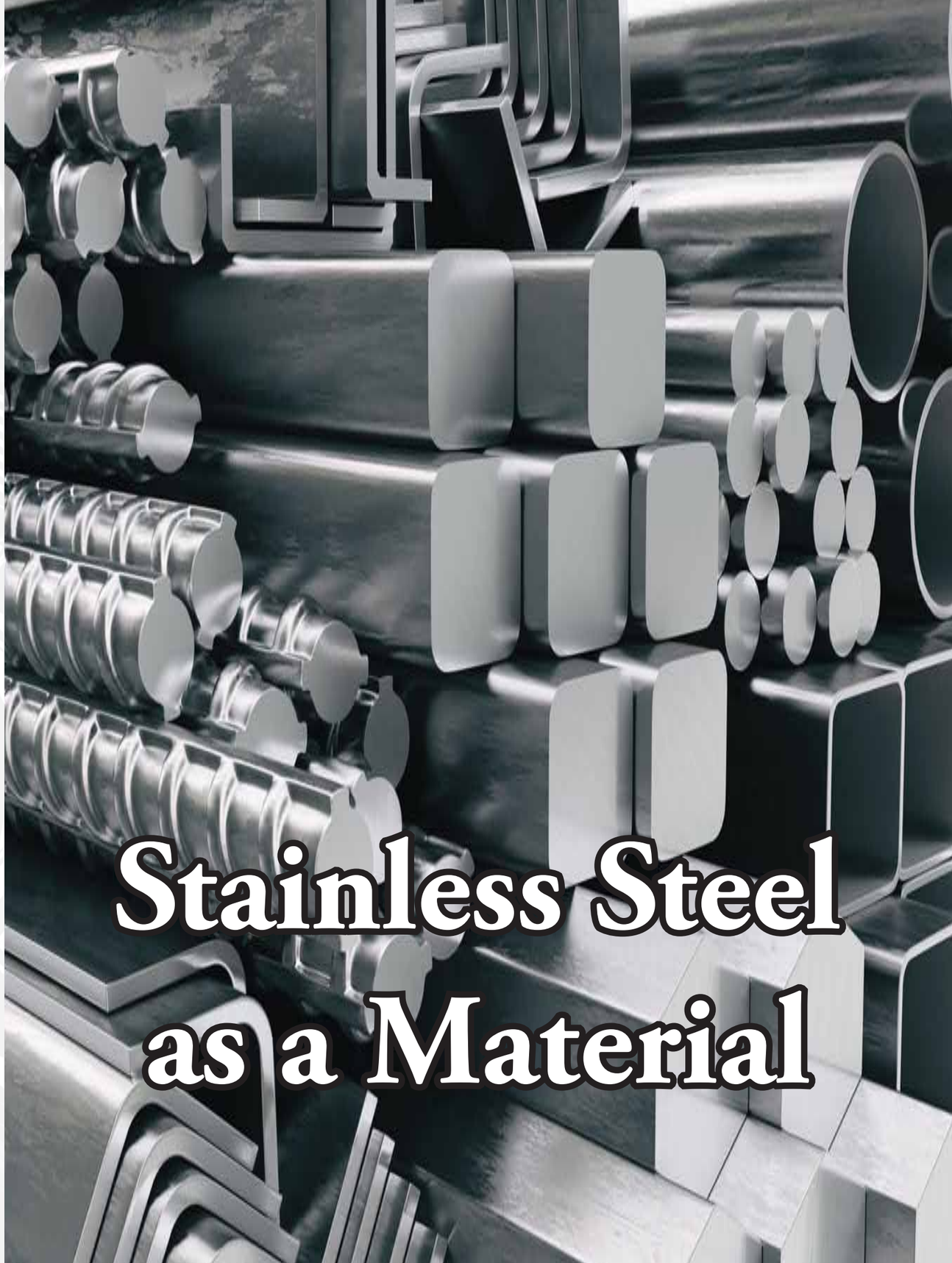
Through our science division NiPERAInc. (www.nipera.org), we also undertake leading edge scientific research relevant to human health and the environment. NI is the centre of excellence for information on nickel and nickel-containing materials and has offices in Asia, Europe and North America.

We work with other international metals associations and stainless steel development associations to develop and promote the safe use of nickel around the world

We pursue market development through a worldwide network of highly qualified specialists.

We share our knowledge, offering free technical knowledge about nickel, its properties and uses to ensure optimum performance, safe handling and use.

We do promote the long term use of nickel to contribute to a sustainable future.

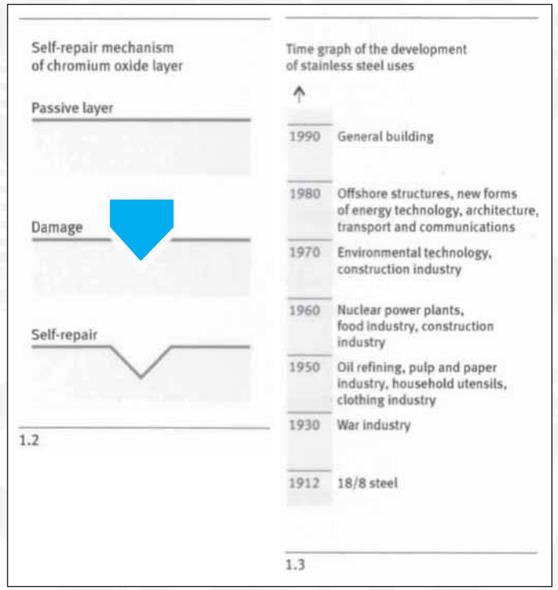


Stainless Steel as a Material

Stainless steel is the common name for all steel grades containing at least 10.5% chromium. Chromium improves the corrosion resistance of stainless steels. In addition to iron and chromium, stainless steels contain other alloying metals, of which the most important are nickel and molybdenum. The combination of chromium and oxygen leads to the formation of a chromium-rich passive layer on the surface of the steel. This layer protects the steel, and re-forms over time if damaged. On the basis of their microstructure, stainless steels are divided into austenitic, ferritic and martensitic basic types. More than 100 different stainless steel grades have been developed for various applications. The contents of the alloying metals influence the corrosion resistance, durability, strength and formability of the steel. Ferritic steels, such as iron-chromium alloys are mainly used for indoor applications. Some grades are also used for roofing. Austenitic grades represent about 70% of the world market for stainless steels. These are iron chromium-nickel alloys - some with additional alloying elements like molybdenum, which increases corrosion resistance even further. The most popular grades for building applications, like the classic "18/10" grade 1.4301(304), (about 18% chromium and up to 10% nickel) or the particularly corrosion resistant grade 1.4401 (316), (with additional molybdenum content), belong to this family. For extremely demanding conditions, austenitic ferritic steels, the so-called duplex steels, are the best choice. Their microstructure guarantees excellent strength and corrosion resistance. Stainless steel is a preferred material for applications where the structure must have a long service life and be easy to maintain, or where a metal surface is desirable for aesthetic reasons. In addition to corrosion resistance, the use of stainless steel in construction is based on its mechanical durability, the fact that it is easy to clean, and on factors related to image and appearance. The increase in the use of stainless steel is closely related to the rise in the standard of living. As standard of living and technical development are interdependent, the popularity of stainless steel can be assessed on the basis of technical development. A rising standard of living increases the quality awareness of individual consumers, which then increases the use of high-quality consumer durables, among them stainless steel products. Investment decisions are increasingly based on estimated total life-cycle cost.

Development

The first stainless steel grades were developed between 1910 and 1920. Krupp, the German, family steel company, patented the first austenitic (so-called 18/8) steel, containing both chromium and nickel. At about the same time, Harry Brearley in Sheffield, England, developed stainless steel grades used in the manufacture of cutlery. Thus, the first austenitic and martensitic stainless steels were developed just before the First World War. Industrial manufacture of stainless steel started in the 1920s.



Most of the standard stainless steel alloys in use today were developed between 1913 and 1935, in Britain, Germany, The United States and France. With the introduction of standard alloys, it was possible to concentrate on more economical production methods and on promoting the use of stainless steel. The use of stainless steels in the chemical, process and food industries started towards the end of the 1940s and in the 1950s. Stainless steel products have been used in the home since the 1950s. However, it was not until the 1960s and 1970s that the use of stainless steel increased significantly, when it was adopted in vehicles, energy generation and the construction industry. The extremely strong and corrosion - resistant molybdenum-atloyed stainless steel grades became popular in the 1970s.

Applications

The most important applications of stainless steel include: the process and chemical industry the wood processing industry the food industry household utensils energy generation plants environmental technology transport and vehicles architecture and construction furniture medical equipment and instruments

Materials

Steel grades and their properties Austenitic stainless steels are more commonly used than other steel grades, owing to the broad scope of their application. Austenitic stainless steels contain 17-18% chromium and 8-11% nickel. This high nickel content makes them easy to form, without compromising strength. Their corrosion resistance is also very good. The strength of austenitic steels can be further improved by alloying them with nitrogen, or by cold-forming. Austenitic steels are easy to weld and are also tough at low temperatures. Another sub-group of austenitic steels contains molybdenum. Their excellent corrosion resistance in very severe conditions is based on a 2-6% molybdenum content. Ferritic stainless steels contain chromium and, possibly, other alloying elements, but no nickel. They range from low-cost grades, near the lower end of the stainless steels spectrum, to stabilised grades used for household appliances. Typically, they are also used for interior cladding or with an additional matt tin layer for roofing. Austenitic-ferritic (Duplex) stainless steels contain 22-23% chromium and 4-5% nickel, and often molybdenum (an important additional alloying element). These steels have excellent corrosion resistance and strength properties. However, they are only used in special applications and for extremely aggressive conditions. Martensitic steels have the highest carbon content of all stainless steels, and are magnetic. The main applications of martensitic steels are in various small utilities, such as instruments, cutting tools, scissors, springs, etc. They are sometimes used for fasteners. Stainless steel grades can be manufactured with alloying metal contents of up to 50%, which gives almost unlimited possibilities for regulating the steels' properties. So, for instance, extremely corrosion resistant grades are even available for suspended ceilings

of indoor swimming pools - one of the most demanding and complex corrosive conditions to be found in building applications. If the content of alloying metals added to iron exceeds 50%, the steels are called "super alloys." The most common composition of austenitic stainless steel, and also that which has been used longest, is 18% chromium and 8.5-10% nickel, referred to as " 18/8" or " 18/10" steel. These steels account for about two thirds of the total market. The most common stainless steel grade, EN 1.4301, is of this composition. Steel designations specified in European Standard EN 10088 are commonly used in Europe, whereas the AISI in the United States, for instance, has its own designation system. The longer Euro norm-based designations indicate the steel's composition.Forexample,X5CrNi18-10 designates the steel grade and its most important alloying metal contents, while the shorter numerical designation for the same steel is 1.4301.

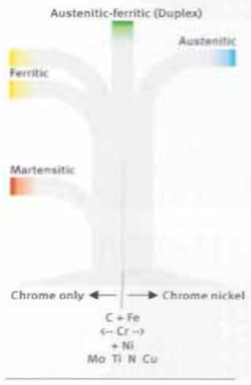
Composition of most common stainless steel grades

number	C	Cr	Mo	Ni
1.4301	<0.07	17.00...19.50	-	8.00... 10.50
1.4401	<0.07	16.50...18.50	2.00...2.50	10.00... 13.00
1.4404	<0.030	16.50...18.50	2.00...2.50	10.00... 13.00
1.4311	<0.030	17.00...19.50	-	8.50... 11.50
1.4318	<0.030	16.50...18.50	-	6.00... 8.00
1.4462	<0.030	21.00...23.00	2.50...3.50	4.50... 6.50

Designation of stainless steel grades in compliance with EN 10088-1

Example

Number designation 1.4404		
1.	44	04
Steel	Stainless steel group	Steel grade
Name designation X2CrNiMo17-12-2		
X	2	CrNiMo17-12-2
High-alloy steel	100 x % carbon	Content of alloying metals (Cr 17%, Ni 12%, Mo 2%)



Manufacturing Process

Stainless Steel is manufactured largely from recycled steel scrap. The scrap and required alloying metals are melted in an electrical furnace and the molten steel is then transferred into an AOD (Argon Oxygen Decarburization) converter for further refining. In the convertor the molten steel is decarbonised to a sufficiently low level, and all impurities that would impair the properties of the steel are removed . Once composition and temperature reach the desired level, the steel is cast. The steel's composition is finally regulated, at ladle stage. By adding any required alloying elements and by verifying correct temperature and uniform quality. The molten steel is then cast, cooled down and. finally cut into slabs of suitable size in a continuous casting machine. In hot rolling, the steel slabs are preheated to a temperature of about 1,250°C, to be hot rolled into a wide coil of 2-13 mm thickness. After the hot rolled coil has been cooled down it is heat treated and pickled. The steel grade and manufacturing lot is marked on the steel, and the hot rolled steel is then ready for use or for further processing. In the building industry, hot rolled stainless steel is used for fasteners, such as brick support systems. Most steel coils are cold rolled. Cold rolled steel is also heat-treated and pickled, and surface quality is improved, by dressing. to reach the standard required for high-quality consumer goods or architectural finishes. The finished coil is cut into plates or strips for delivery. In addition to sheets and plates, stainless steel is delivered as rods and other long products such as reinforcement bars and rod wire, also produced by rolling. From these stainless steel, wires of less than 5 mm diameter, are produced by drawing. These are typically found in architectural cables or woven metal fabric.

Surface finishes

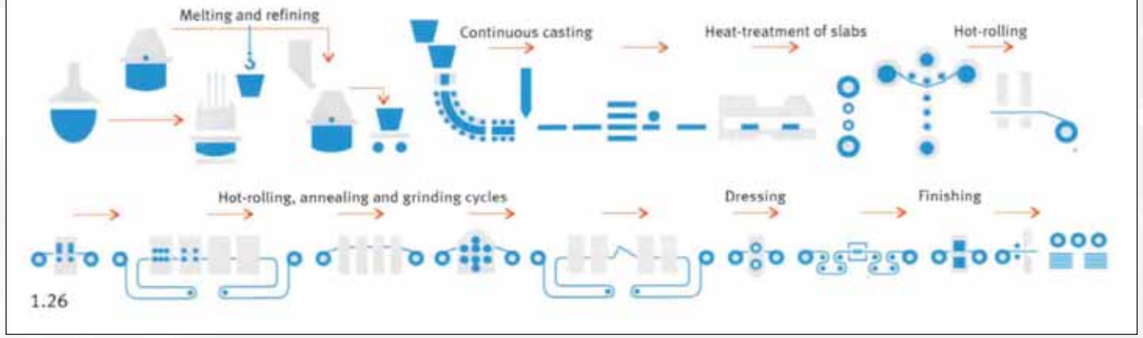
In the steel mill, the steel is finished to a certain surface grade. These pre-production finishes are sufficient for most applications. The best way of assessing a surface finish is to ask the mill for a sample. Factory finishes can also be further treated for various uses. The same criteria of "no visible faults" and "rated corrosion resistance," are applied to all steel finishes. This means that oxides created by the heat, as well as metal residues, have to be removed from the surface. This is usually done by treating the steel in an acid solution or by pickling. The designation for a hot rolled and pickled stainless steel surface finish is 1D. as specified in Standard EN 10088. The corresponding designation for a cold rolled and pickled steel surface finish is 2D. This smooth, matt surface finish is often used in industrial applications and, increasingly, in architecture, for example. Cold rolled steels can be further treated to increase surface polish and smoothness. For example, surface finish 2B is not only pickled but also lightly rolled in the skin pass mill. The most common of all surface finishes is 2B. Bright annealing can be used to produce an extremely glossy surface.

Surface treatment methods

After the steel sheet has been delivered from the mill, its surface can be treated before the sheet is sent for further processing, or post-production finishing can be carried out at the manufacturing stage of the actual product. If surface treatment is carried out before manufacturing stage, there is a risk of the surface being scratched or damaged in some way during the manufacturing process, or of the joints and corners requiring yet another treatment after manufacture. On the other hand, postproduction finishing carried out before manufacturing stage usually gives a more uniform surface quality than does treatment carried out afterwards. This is particularly advantageous if there are extensive visible surfaces on the finished product. Post-manufacture surface finishes are applied both to

Designations of common finishes

Finish	Surface finish (EN 10088-2)
1D	Hot-rolled, annealed, pickled
2D	Cold-rolled, annealed, pickled
2B	Cold-rolled, annealed, pickled, skin passed
2G	Cold-rolled, annealed, pickled, ground
2J	Cold-rolled, annealed, pickled, brushed
2F	Cold-rolled, annealed, pickled, dressed using roughened rolls
2H	Temper-rolled



products made of untreated steel and to the repair of pre-finished surfaces after manufacture. However, the pre-finished surface may differ from the surface treated after manufacture, so it is advisable to apply post-manufacture surface finishing to all surfaces to be joined together. Pickling is a surface finishing method also applied after delivery from the mill. Pickling maybe used to remove heat tint from welding, for example, or contamination from carbon steel particles, which would affect a stainless steel's corrosion resistance. The entire product can be pickled, or just local points, such as a joint. An additional rolling operation can be carried out to produce patterns on one or both sides of the steel sheet, using patterned rolls. A patterned surface hides scratches and minor surface defects, which makes this treatment suitable for contact surfaces. Pressing is also used. Certain symmetrical patterns can also be applied, to stiffen the structure and thus allow the material thickness of the steel to be reduced. Brushed and polished surfaces are produced, in one or several stages, using grinding 'belts, rolls or brushes. Several options are available, and the appearance, corrosion resistance and soil repellence of the surface may vary considerably, depending on the tools and methods used. Sand and glass-bead blasting can be used to produce a matt finish on stainless steel. Surface texture is regulated by changing the roughness and quality of the blasting agent. For example, sand produces a dark and rough surface, while glass beads produce a smooth, light coloured surface. Glass is preferable since it does not contain iron, which could be deposited on the stainless steel and affect its corrosion resistance. Electrolytic polishing, or electropolishing, is used to produce technically smooth surfaces. The process is based on an electrochemical reaction, whereby a suitable electrolyte causes a thin layer to escape from the surface of the steel, which acts as an anode. Maximum use is made of the "natural" corrosion resistance of the respective grade. However, electropolishing is not used for decorative purposes and does not produce mirror-like finishes. For such finishes, bright annealed and mechanically polished material is available. Stainless steel can also be coloured by means of an electrolytic process. This does not involve colour pigments, but is based on the optical effect of light interference. By building up different thicknesses of passive layer, a wide range of colours can be obtained. The layer is totally resistant to UV radiation. To achieve a good result, the surface must be smooth. There is, however, no possibility of repair if the colouring is locally destroyed through mechanical damage or welding. Painted steel sheets are mainly used on roofs and as cladding elements. Etching, bead blasting and laser technology can be used to produce patterns on stainless steel surfaces. This extremely accurate method offers unlimited patterning possibilities.

Stainless Steel products

Most stainless steel is used in cold rolled form. The roughness and unevenness of the surface of hot rolled stainless steel restricts its applications to non decorative applications, such as fasteners. Stainless steel is delivered from the mill as hot or cold rolled coils or plates. The material thickness may vary from 0.1 mm up to 13 mm, depending on the rolling method. The plates and coils are delivered either to the end-user or to further processing plants, for finishing or for use in the manufacture of finished and semi-finished products. These are then delivered to wholesalers or end-users. Stainless steel products include various hollow sections and profiles, rods and rolled wires, screws, bolts, concrete reinforcement bars and steel plates with different surface finishes. The diameter of steel rods and bars ranges from a few millimetres up to some 200 mm. Stainless steel

Plate, sheet, coil and strip products

Product	thickness	width	length
Hot-rolled coil and strip	1.5 – 13 mm	35 – 2,032 mm	-
Cold-rolled coil and strip	0.2 – 8 mm	5 – 2,000 mm	-
Hot-rolled plate and sheet	2.0 – 13 mm	400 – 2,032 mm	500 – 13,500 mm
Cold-rolled plate and sheet	0.25 – 8 mm	50 – 2,000 mm	500 – 12,000 mm

Structural hollow sections

Structural hollow section	
Square hollow sections	
dimensions	10 – 600 mm
thickness	0.5 – 16 mm
Rectangular hollow sections	
dimensions	10 – 600 mm
thickness	0.5 – 16 mm
Circular hollow sections	
diameter	4 to 3,000 mm
thickness	0.4 to 60 mm

1.34
Finished products.

1.35
Stainless square and rectangular hollow sections.

1.36
Stainless concrete reinforcement bars.

reinforcement bars are available in the same stock sizes as carbon steel reinforcement bars, with a thickness of 4-25 mm. Stainless steel reinforcement bars are typically used in the reinforcement of tunnel walls and bridges and in marine applications. The use of stainless steel reinforcement bars has increased significantly in recent years, especially in countries where road de-icing salt is applied. In special applications such as bridge structures, which are subject to high stress from both humid and chloridic atmospheres and mechanical and chloridic stress, reinforcement bars are made of highly corrosion resistant steels, containing molybdenum.

Use of stainless steel in construction

The construction industry mainly uses austenitic stainless steels, as their corrosion resistance, strength and formability are best suited to building applications. Ferritic grades are used for interior cladding, and specialist products are available for roofing. In applications subject to severe atmospheric stress, and in structures for which lightweight architectural solutions are sought, stainless steel is often the only alternative. The main selection criteria favouring stainless steel are its ease of use and low need of maintenance. Structures can be left visible and, with stainless steel, contemporary and highly effective designs can be achieved. Environmental values and the protection of the environment have made long-term durability and total life cycle cost, as well as the environmental impact of structures, important material selection criteria. Life cycle philosophy (LCA, LCC) favours the use of structural materials, such as stainless steel, which resist both mechanical and atmospheric stress and are easy to maintain.

In buildings, stainless steel is most commonly used on facades and interior surfaces, in stair structures, balconies, doors and lifts, as well as in

various supplementary structures such as canopies, hatches and balustrades. The use of stainless steel in load bearing structures is fast increasing. The construction industry uses about 12% of the total global production volume of cold rolled stainless steel and about 5% of that of hot rolled stainless steel. The amount of stainless steel used for building purposes varies from one country to another. The use of stainless steel is rapidly increasing in European countries. In some Asian countries, such as Taiwan and Japan, building and construction may account for more than 20% of total stainless steel consumption.

Load-bearing structures

Austenitic steel possesses better strength properties, both at room temperature and in a fire, than structural carbon steels. There is currently much research being carried out into stainless steel's load-bearing and fire-resistance properties. Some European countries approve stainless steel structures corresponding to fire resistance class R30, without any separate fireproofing.The development and renewal of standards concerning the use of stainless steels in structures has focused on the use of high-strength materials when preparing dimensioning codesfor both room temperature and fire situations. The development of dimensioning standards for stainless steel has also involved extensive European cooperation. Hollow sections for construction applications are made of stainless steel with rectangular and square cross-sections, using both hot and cold rolled steel. Usually, the most common austenitic steel grades are used. Typical applications include not only load-bearing frame structures for buildings, but also frame structures for canopies and balconies, glass facade frames and various supplementary structures. Rectangular hollow sections for frame structures are available in wide variety of exterior dimensions and wall thicknesses. In column structures or visible horizontal girders and lattices that must be particularly strong, maximum dimensions are used. In lightweight structures, stainless steel rectangular hollow sections make it possible to achieve high load bearing capacities.

Surface structures In the building trade, light-gauge stainless steel sheet products are mainly used as cladding sheets, cassettes, mouldings and roofing. Choice of stainless steel will centre on issues related to appearance and cleaning. The surface of light-gauge sheet can be polished in various ways, or patterned, and sheet can be straight, perforated or profiled. The steel can also be coloured or painted. The use of stain less steel nets, of varying thickness, in supplementary structures and balustrades, for example, has increased. Stainless steel's excellent corrosion resistance also makes it ideal for applications subject to severe atmospheric stress.

Supplementary structures and building components

Factors such as ease of cleaning and maintenance, as well as the excellent strength and rigidity required of slim structures, argue for the use of stainless steel in entrances and glass structures. Fasteners used in glazing are also often made of stainless steel. With no need for coatings, costly painting is eliminated, as is repainting, with its attendant disruption and protective measures. Where stainless steel is used in entrances, the doors, balustrades and fixtures are often also made of the same material. Stainless steel fixtures, already very popular, are constantly gaining popularity. Fasteners made of stainless steel are often used as masonry and concreteties, and as fasteners in facade cladding systems and glass facades. Stainless nails and fasteners are also commonly used in wooden

structures. Stainless steel concrete reinforcement bars are used in structures highly susceptible to corrosion, such as bridges, tunnels and foundations. The use of stainless steel reinforcement bars has also become quite common in external wall elements.

Bridges and urban structures

Bridges have a long required service life. Typical applications of stainless steel in bridges include various composite structures, supplementary structures and wires, as well as slab reinforcement bars. When stainless steel reinforcement bars are used, the estimated service life of the deck of a reinforced concrete bridge is up to 75-100 years. Stainless steel can also be used in the fixing points of other road structures. Besides mechanical wear and atmospheric influences, factors contributing to corrosion included also road salting. In road maintenance, corrosion generates not only repair costs, but also traffic disturbances and delays, due to repair activities. These represent a significant cost. It is therefore advantageous to use stainless steel reinforcement bars, since tests show they resist high chloride content over several decades. Normal carbon steel reinforcement bars are known to require replacement much more frequently, because of corrosion. Various harbour structures and piers are subject to stress levels similar to those of bridges. This not only applies to structures in direct contact with seawater, but also to shore structures susceptible to stress caused by chloride and humidity. Stainless steel is commonly used in various street furniture, such as kiosks, bus stop structures and canopies, benches, flagpoles and street lighting units, as well as children's play grounds and litter bins. The soiling and graffiti risks to which urban structures are subject also point to the use of stainless steel. Cleaning costs for stain less steel surfaces are relatively low. No special tools or detergents are needed and all cleaning can be carried out using ordinary methods.

Fixtures

Another main area of application for stainless steel is in the supply and treatment of water. Stainless steel is used to manufacture taps, water pipes and various fixings, battens and fittings. The fixtures and supplementary structures of wet areas, such as sinks, cabinets and battens are also often made of stainless steel. Designers of kitchen and bathroom fixtures and furniture have both increased their use of stainless steel in recent years and come up with new applications, beyond just taps and sink units.

Stainless steel has found applications in buildings intended for leisure and sports activities, such as in the pool structures of swimming baths. It is also often used as a cladding material. Swimming pool accessories, such as railings, stairs, partition walls and children's fixtures are, in practice, always made of stainless steel. Because high chloride content and humidity create extremely severe atmospheric conditions, steel used in swimming baths should mainly be of the molybdenum-containing type. In other sports facilities, stainless steel is used to some extent as a structural and cladding material, for reasons of ease of maintenance and durability. Steel equipment and surfaces are widely used in hospitals and other healthcare facilities. In electromagnetic medical applications, stainless steel is used as a protective material. In public premises involving no special requirements, owing to the nature of their purpose, steel surfaces and fixtures are often favoured for the same reasons that apply to street furniture. By using a material that is resistant to damage and can be easily cleaned, vandalism can be minimised and the results of any damage readily repaired.

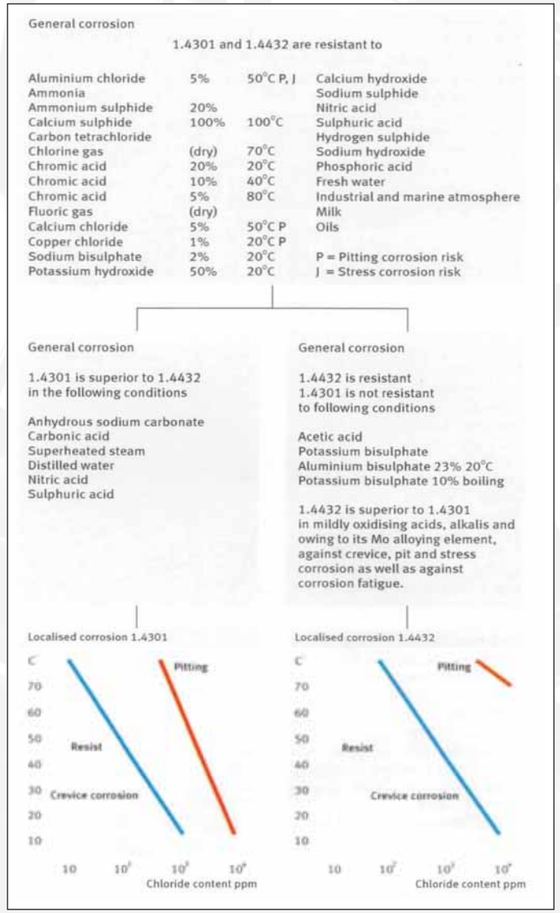
Material Properties

The austenitic steels used in the construction industry possess certain special properties that need to be considered when designing stainless steel structures. Benefit can be gained from cold forming, which increases the strength of thesteels. Austenitic steels are non-magnetic, although cold forming may cause slight magnetism. The heat conductivity of stainless steels is lower than that of other structural steels. Their higher heat expansion coefficient is a major consideration, particularly in the case of joints. The excellent strength properties of the material at high temperatures can be utilised in fire design.

Material Selection

Factors influencing the selection of a suitable stainless steel grade for an application include the ambient conditions, the manufacturing process, the possible need for machining, and requirements concerning surface appearance and maintenance of the structure. During its service life, a structure will be subject to various forms of corrosion that can be controlled by correct material selection. Experience previously gained in the corrosion resistance of the different steel grades is regularly considered in structural design. The initial investment costs associated with certain stainless steel grades, however, may be quite significant, and the price of the steel relates directly to its corrosion resistance. The availability of stainless steel grades, and structural parts made of different stainless steel grades, must also be borne in mind. A designer should therefore know the grades available, and their properties. When selecting stainless steel for a particular application, it is necessary to define the conditions, choose the grade suitable for those applications and verify the correct processing and manufacturing methods. The most relevant ambient factor is the possible concentration of halides (especially chlorides) and sulphur dioxide. The effect of the surround ings - for example the influence of the structural parts and materials in contact with the steel- must also be noted. Mechanical properties, requirements affecting the finished structure, ease of manufacture, product forms and surface quality are other factors to be considered.

A surface finish selected on the basis of the environment and the structure's intended use will ensure long-term durability and good service properties. It will take into account such factors as ease of cleaning, scratch-proof properties or choice of matt or reflective surface. The selection of surface finish deserves special



attention, as practical differences between various finishes are considerable. There are clear instructions available for the selection of screws used in the fixing of different stainless steel grades. The screws' corrosion resistance must be at least equal to that of the steel itself. After the most suitable steel grade has been selected for the application in question, selecting the fabrication processing methods ensures its long-term durability. The designer should also draw up instructions with regard to the equipment, materials and work methods used in the processing of the stainless steel. These are discussed in Chapter 4, under "Construction site techniques." Steel producers' inspection procedures involve verification of product analysis, testing of mechanical values, verification of product dimensions and inspection of surface quality. When delivered, the steel is normally accompanied by a material certificate containing the analysis of the batch, the dimensions, the results of mechanical tests and the identification data. The manufacturer's name, steel grade code, melting batch number and identification number are marked on every stainless steel item delivered. The manufacturer may also mark the dressing status of the sheet or coil, the rolling direction (if necessary), the nominal dimensions and the customer's order number. More detailed instructions are available for the marking of prefabricated steel products.

Long-term durability

Provided stainless steel structures are carefully designed and the steel is correctly selected, treated and maintained, the theoretical service life of stainless steel structures can stretch into hundreds of years. A rough estimate of the success of the design and the durability of a structure can be made after a few years. A rule of thumb is that if there are no rust stains, indicating corrosion, in the first few years, there is little risk of corrosion later. Stainless steel may be attacked by pitting corrosion, crevice corrosion, galvanic corrosion, stress corrosion cracking, general corrosion and intergranular corrosion. These corrosion types may occur either separately or in various combinations, depending on ambient conditions. Corrosion risks can be roughly divided in to three levels, which depend on the materials, the type of corrosion and the ambient conditions. General instructions for material selection can be provided at risk levels 1 and 2. At risk level 3, structural design must be carried out under expert supervision. At risk level 1, no significant corrosion defects will occur over a 50-year design service life. No structural repair is needed, although aesthetic aspects may require some maintenance. In normal corrosion conditions, most stainless steels meet the requirements well. Risk level 2 involves a risk of pitting or crevice corrosion that may require some repair during a 50-year design service life. This risk level applies to atmospheric conditions involving either a marine environment or

Normal surface finishes of rectangular hollow sections

Surface finish	
Ground surface grit 80-500 grit 220, grit 320	Possible surface finish of rectangular hollow sections Standard grit sizes
Pickled surface	Acid pickling
Polished surface	Electrolytic grinding, restrictions of hollow section dimensions

Types of corrosion

General corrosion	Not related to certain conditions, rarely affects stainless steel. Corrosion rate equal all over the metal.
Pitting corrosion, crevice corrosion	Localised corrosion, in aggressive water solutions. Geometry and deposits contribute to attack.
Galvanic corrosion	A conductive joint between two metals creates a galvanic couple where corrosion occurs on the anodic metal. A typical phenomenon on contact surfaces between stainless steel and carbon steel, particularly in wet conditions.
Stress corrosion	Occurs in a structures subjected to tensile stress, causing fractures. Internal stress in the metal, high temperatures and chloridic environment contribute to attack.
Intergranular corrosion	At high temperatures, chromium carbides form in austenitic steel. As the chromium content decreases, the steel becomes susceptible to corrosion. Causes corrosion on welded points.

1.8. Environment-related corrosion risks

EN 10088	Type of environment, corrosion risk class											
	Rural			Urban			Industrial			Marine		
	L	M	H	L	M	H	L	M	H	L	M	H
1.4301 1.4311 1.4541 1.4318	X	X	X	X	X	(X)	(X)	(X)	!	X	(X)	!
1.4401 1.4404 1.4406 1.4571	0	0	0	0	X	X	X	X	(X)	X	X	(X)
1.4439 1.4462 1.4529 1.4539	0	0	0	0	0	0	0	0	X	0	0	X

0 = no risk of corrosion
X = corrosion manageable by using correct planning solutions
(X) = fairly high risk of corrosion, use to be considered separately in each case
! = high risk of corrosion, not recommended for use
L: low environmental stress, M: medium environmental stress, H: high environmental stress

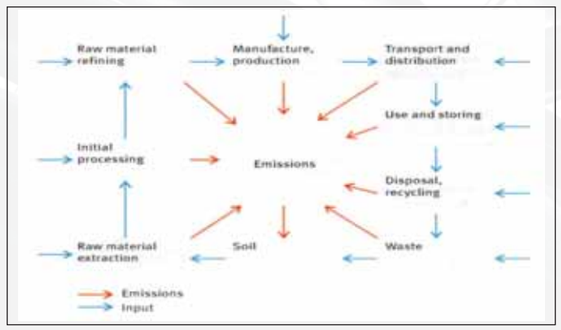
Table 1.9. Selection guide on the basis of atmospheric corrosion risk

Risk class	Degree of corrosion risk	Environment	Steel grades
M0	No corrosion risk	Indoors, dry, heated	Austenitic CrNi
M1	Slight corrosion risk	Indoors, humid, unheated	Austenitic CrNi
M2	Moderate corrosion risk	Rural, indoors, condensation risk	Austenitic CrNi
M3	High corrosion risk	Urban, industrial and marine environment	Austenitic CrNiMo
M4	Special corrosion risk	Vicinity of industrial plants	Requires special studies in each case and expert planning

chemical emissions from industrial processes. Risk level 3 involves various aggressive media, such as acidic chloride layers, which may cause structural deterioration as a result of cracking due to local stress corrosion. Service life, at this level, is determined by the choice of material and the probability of exposure to, and influence from, harmful media. Structures belonging to risk level 3 are found in, for example, indoor swimming pool atmospheres and applications susceptible to fire.

Environmental properties

The environmental impact of the manufacture and use of materials and products can be measured in terms of the amount and toxic effect of the emissions involved, as well as in terms of energy demand. The values and decision-making processes of consumers and companies today are based not only on traditional values, but also on environmental impact considerations. Environment-friendly products tend to be valued highly in selection situations. Legislation in recent years has also increasingly emphasised environmental values. Stainless steel is mainly manufactured from recycled carbon steel and stainless steel. Using recycled raw material reduces the energy required for the manufacturing process, as well as reducing waste and emissions. Depending on the process route, 60-70% of the raw material used in the manufacture of stainless steel consists of scrap metal. The remaining 30-40% consists mainly of alloying metals. Stainless steel itself is 100% recyclable. Thanks to the excellent durability of the material, however, product service life is extremely long. This reduces the consumption of natural resources and energy during the service life of stainless steel products, in comparison with hat of products made from materials that wear out faster and need to be replaced. Today's stainless steel mills pay particular attention to emissions. All particles released during the manufacturing process, or example, are filtered and colected. Advanced environmental technologyisan essential part of ' he state-of-the-art stainless s eel manufacturing process. The environmental impact of products and processes is often assessed using Life Cycle Assessment (LCA) methods, in which the environmental impact resulting from the manufacture, processing, use, logistics and final disposal of a product is assessed using specific default vales in each case. From a Life Cycle Assessment point of view, stainless steel's strengths include: its recyclability; its use of

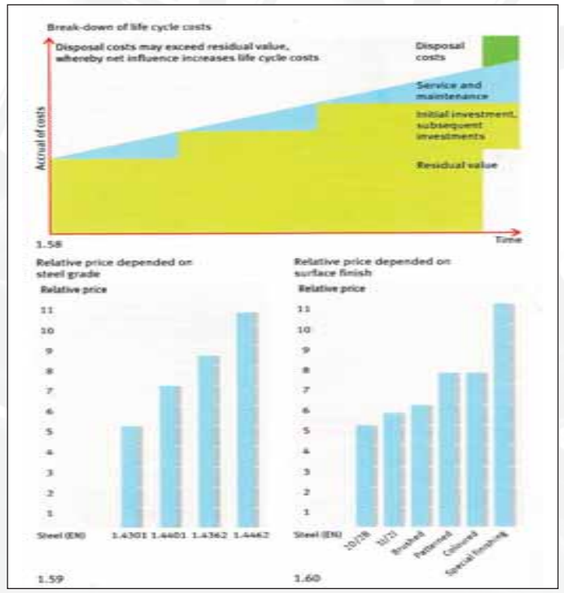


recycled raw materials; - the relatively low energy consumption of the manufacturing process.

Life cycle costs

Life Cycle Costing (LCC) takes into account the costs of manufacture, use and possible re-use, and final disposal. Cost items are divided differently depending on the product. Often, the cost of manufacture represents only a very small part, yet decisions are often based just on such initial costs. From the end-user's viewpoint, the correct approach would be to consider total life cycle costs. The investment costs of structures can be divided into: design cost material cost production cost surface treatment and finishing cost inspection and testing cost.

The manufacturing cost of stainless steel structural elements can be significantly influenced at design stage. The most dominant factor in the market price of stainless steel is the steel's grade. Another factor is the cost of the chosen finishing method. In frame structures, however, the material or surface finish selected does not usually make a great difference since, in most cases, it is not necessary to opt for the best grade. Noticeably more expensive grades are normally chosen because they possess high-strength and corrosion-resistance properties that will generate savings elsewhere. While material cost may be quite high in the case of stainless steel structures, costs generated by the installation, joining and handling of the finished structure correspond to those generated by other building materials. Since no separate surface treatment is needed, the costs incurred at the construction site consist only of mechanical installation expenses. Inspection costs are low, because stainless steel surfaces do not require regular inspection, to determine the need for renewal. The maintenance costs of stainless steel structures are very low. All materials require regular cleaning and occasional maintenance measures, but stainless steel is definitely one of the most durable and easy-to clean. As no surface treatment is needed, nor therefore, any renewal of surface treatment, maintenance is also easy. Stainless steel parts in concealed structures can go without maintenance for hundreds of years, in some cases. Provided the surface finishes are correctly selected and processed, and subsequently correctly maintained, the surface structures will last for an extremely long time, in present climatic conditions. As a recyclable material, with an existing market, stainless steel scrap has a high residual value, after the service life of the building has expired. This residual value, however, has only a minor influence on total life cycle cost, due to the exceptional length of service. Life cycle cost is usually calculated, over the estimated service lifetime, either by valuing partial costs at their present value or by converting them into annuities



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Stainless Steel Finishes

Stainless Steel Finishes

The finish on the surface of stainless steel sheet as produced by a mill or supplied by a steel service center is generally the result of processing to bring the sheet product to a final dimension. The resulting finish is usually a "rolled" (or unpolished) finish, either dull or bright. Several creative "rolled" finishes have been developed for aesthetic applications. They add texture or simulate other finishes, for example, polishing or abrasive blasting. Subsequent operations, such as grinding, polishing, buffing, blasting, colorizing and etching can be utilized to create a wide variety of special finishes.

Surface finish is an important factor in any specification or purchase order for stainless steel regardless of the intended end use. For those applications where appearance is important, finish is a design element and must be specified. The choice of finish should never be left to the supplier, but should be properly identified by either the standard industry designation, by the trade name or designation for proprietary finishes

Some of the important Finishes are :

Rolled finishes are created when a stainless steel coil is passed through a set of rolls. The finish on the rolls is transferred to the surface of the coil. They are directional and, if panels are not installed in the same rolling direction, a checkerboard appearance can result. To prevent this problem, the rolling direction should be marked on the back of the panel. Dirt and debris accumulation is greater when directional finishes are installed with a horizontal grain orientation.

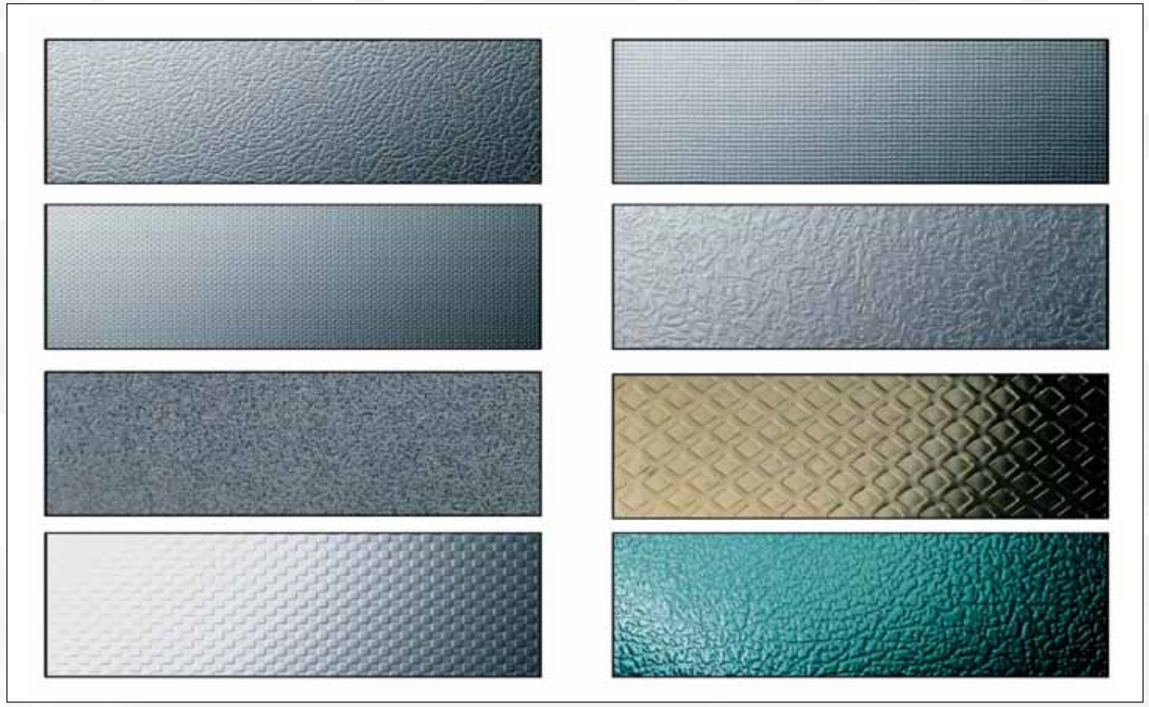

Image Courtesy: ISSF

COINING- In coining, one roll is smooth and the other is textured. The process creates a light, raised, one-sided pattern and strengthens the stainless steel through work hardening. This increases its impact resistance, reduces the depth of scratches, and often makes it possible to use a thinner gauge. Numerous patterns exist but the most popular mimic fabrics like linen. Coined finishes are used frequently on building exteriors to reduce gauge requirements and provide improved visual flatness. They are also popular in high traffic areas because they minimize scratches and provide improved impact resistance. Other applications include roofing, furniture, elevator panels, and kitchen refrigerator doors, cabinets, and back splashes. Coining can be combined with electrochemical color and paint. When the raised areas are buffed to remove color, the remaining color is protected from scratching and the resulting finish can perform well in high traffic areas.

EMBOSSING - Embossing is similar to coining except that both rolls have raised interlocking patterns. When the stainless steel coil is passed through the rolls, a deeper, two sided pattern is created. Because more metal is displaced, there is a higher level of work hardening and a greater increase in strength. The pattern depth determines the increase in strength, impact, and scratch resistance. With deep patterns, it is sometimes possible to make more substantial decreases in thickness requirements or sustain higher levels of impact. Like coined patterns, embossed finishes can be combined with color.

ABRASIVE BLASTED APPEARANCE- Several companies have developed non-directional rolled finishes that mimic the appearance of abrasive blasting. These finishes generally provide better flatness and uniformity and are more cost effective than abrasive blasting sheet or strip. They are applied in the same manner as coined or embossed finishes and can be either one or twosided. Because they do not have as much cold work or the raised patterns of the coined and embossed finishes, they do not hide scratches. Their impact resistance is similar to other flat finishes. They have been used for roofing, wall panels and other applications but are generally not used in high traffic areas. Some are susceptible to fingerprinting problems.

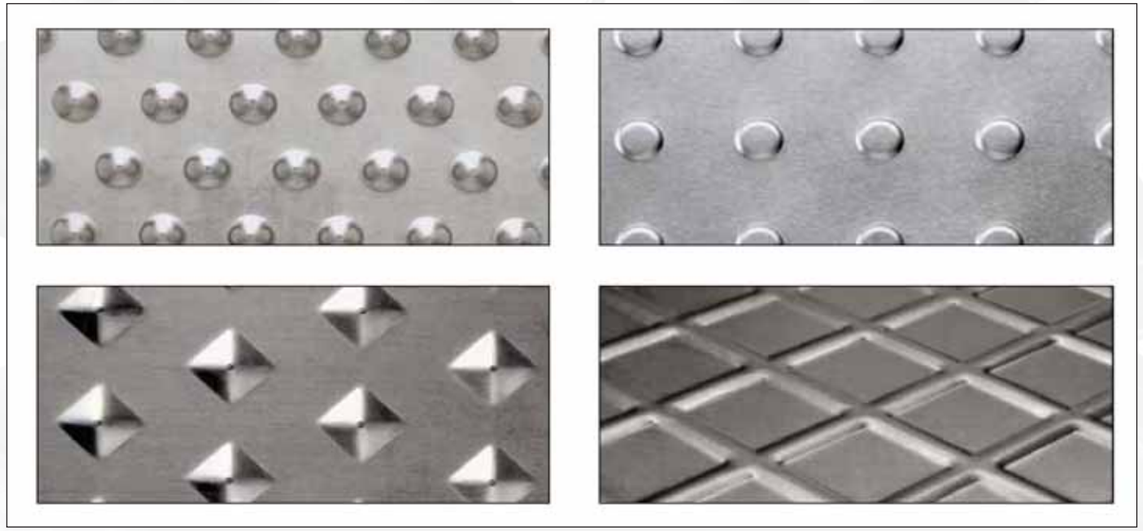

Image Courtesy : ISSF

POLISHED APPEARANCE - Several stainless steel producers have developed rolled finishes that mimic the look of a No. 3 or No. 4 polish or a hairline finish. Because these finishes are applied to the coil in the mill, they are less expensive than polished finishes. They can be one or two-sided. Their impact resistance is similar to that of other flat finishes. They will hide minor scratching that is in the same direction as the polish pattern. Blending and repair of minor damage is possible for some of these finishes.

Stainless steel can be colored by electrochemical coloring, sputtering, plating, and resin-based paints. The scratch resistance, appearance, and color stability of these processes varies considerably and should be taken into consideration during selection. Although some of these processes improve corrosion resistance, this should not be considered a substitute for selecting an appropriate grade of stainless steel for the environment.

ELECTROCHEMICAL COLORING- Electrochemical coloring (also called light interference or INCO coloring) is achieved by immersing pieces in a hot acid solution and applying an electrical current. This thickens the transparent chromium oxide film, which makes stainless steel corrosion resistant and changes the way light is reflected by the surface. A full spectrum of colors is available including gold, bronze, purple, blue, red, black, and green. The color will not fade and can be applied uniformly or varied for a rainbow effect. There will be slight variations in coloration. Since the color is transparent, the finish beneath it is visible. Different color and finish combinations create unique effects. Color can be removed selectively by etching, polishing or engraving. Fingerprints are visible but can be removed from smoother finishes. They may become permanent when rough finishes are used. The color can be damaged by scratching and is not repairable. When the color is applied over a coined or embossed finish and the raised areas are buffed, the remaining color is recessed and protected and has performed well in high traffic areas.

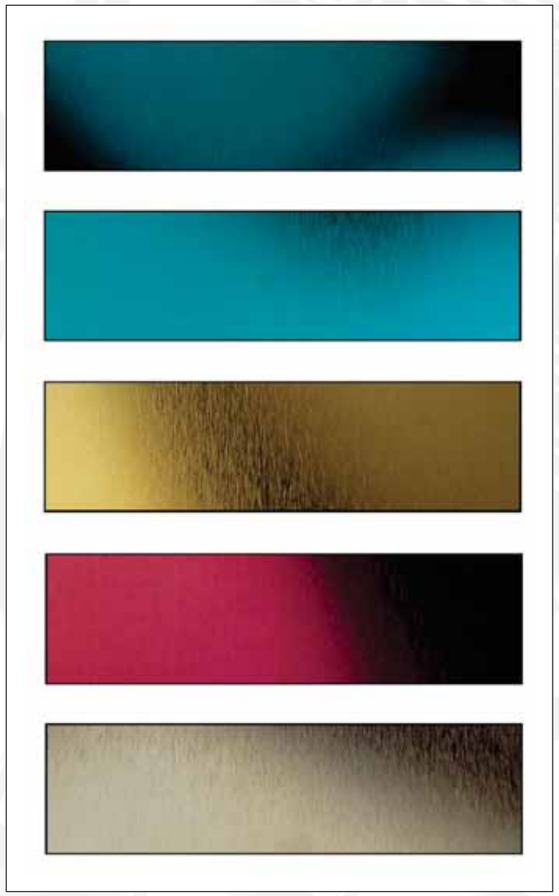

Image Courtsey : ISSF

SPUTTERED COLOR - Sputtering is sometimes referred to as plasma vapor deposition (PVD). The process applies a very thin, colored ceramic coating to the surface. A variety of colors can be obtained including: gold, black, blue, wine red, rose gold, silver gold, and brass. The color is stable, very uniform and significantly more abrasion resistant than electrochemical coloring. Although it has been used for aggressive applications like door hardware, it is important to note that the color

can be damaged and is not repairable. The pattern of the underlying finish is visible after color is applied and color can be removed selectively by etching or engraving

COLORED FINISHESPAINT - Painting stainless steel is similar to painting other metals except that it is done for aesthetic reasons rather than corrosion protection. The repainting schedule will be dependent on the paint's performance. The surface finish must be clean, dry, and rough enough for adherence. An appropriate primer and paint system should be selected with the assistance of a paint system supplier. The No. 2B or No. 2D mill finishes and rougher polished finishes, such as a No. 4, have been painted successfully.

TERNE, TIN AND TIN/ZINC COATINGS- Terne metal (80% lead, 20% tin), tin, and a zinc/tin coatings are primarily used for roofing but have also been used for exterior wall panels. They weather to a medium to dark gray tone and can be damaged by scratching or abrasion. The final color is dependent on the service environment. They can be applied to Type 304 or Type 316 and provide some additional corrosion protection. These coatings should not be considered a substitute for using an appropriate stainless steel in more aggressive environments. They can be painted using manufacturer recommended primers and paints

PLATING WITH OTHER METALS- Stainless steel can be plated with gold, copper alloys, and other metals. Copper plated stainless has had limited use in roofing applications when the strength of stainless and color of copper were desired. Gold plating is soft and easily abraded and is sometimes hard coated, but it should be noted that the hard coating might discolor and deteriorate over time.

GRAPHICS FINISHES - Etched patterns are created by selectively applying a protective acid resistant film to a highly polished surface and acid etching the unprotected areas. The film can be applied by hand painting, silk screening or other methods. Incorrect etching can undercut the protective film and result in rough edges. The etching removes a thin layer of stainless steel, changes the color to a dull silver gray, and roughens the surface. The etched pattern can be left as is or made more reflective. The finish is often electro polished after completion. Very elaborate patterns can be achieved. Both custom and stock patterns are available.

SELECTIVE POLISHING - When a polished finish is selectively coated with protective film and the unprotected areas are polished, buffed, or abrasive blasted to create a pattern, the process is called selective polishing. Like etching, the protective film can be hand cut rubber, plastisols applied by silk screening or a photo resist technique. The film is removed after processing. Fine detail can be achieved and the difference in reflectivity of the finishes creates the pattern. Some have a three dimensional appearance.

ENGRAVED - Like other metals, letters or lines can be cut into stainless steel by engraving. This is most commonly used for signage. Engraved patterns can be electrochemically colored or sputtered and engraving can be done after both of these coloring processes.

MECHANICAL FINISHES - A wide variety of very different and remarkable finishes can be achieved by a number of mechanical treatments to the surface of stainless steel. Other interesting textures and patterns can be created with perforation; knitting, weaving or welding cloth; and cutting and expanding the metal.

HAIRLINE POLISH - Seemingly endless polishing lines applied with Scotch Brite® pads give the hairline, long-grain, or fine-line finish its unique appearance and make it more reflective

than a No. 4 polish. Small scratches can be repaired in the field with Scotch Brite pads of equivalent grit or roughness. The Hairline finish is sometimes inaccurately sold as either a No. 5 or No. 6 polish. The No. 6 polish defined by ASTM A 480 and the Hairline finish have no visual similarity and are created by different methods.

NO. 9 OR SUPER NO. 8 POLISH - The No. 8 polish defined by ASTM A 480 is buffed to a mirror-like appearance but very fine polishing lines are still visible. A Super No. 8 or No. 9 polish isbuffed to a true mirror polish. Because it is not defined by ASTM and supplier terminology varies, it is important to determine that the supplier is providing a highly polished mirror finish. Applications range from decorative panels to bathroom mirrors.

ANGEL HAIR- A very fine, non-directional scratch pattern created with a stainless steel wire wheel is referred to as Angel Hair. The scratches can be long or short and the finish can be applied by hand or with CNC-operated equipment programmed to move the brush in a multi-directional pattern. Angel Hair was designed to hide light random scratching in hightraffic areas. Because there can be considerable variations in scratch length and other aspects of appearance, control samples are important.

DISTRESSED FINISHES - Distressed finishes have coarser scratches than Angel Hair finishes and are applied using a small grinding wheel or coarse stainless steel wire brushes. They can be applied by hand or with CNC-operated equipment programmed to move the wheels or brushes to give the appearance of random scratching. This pattern hides heavier random scratching in high traffic areas. Because there can be considerable differences in scratch length and other aspects of appearance, control samples are important.

SWIRL PATTERNS- Like the Angel Hair and Distressed finishes, grinding wheels or stainless steel wire brushes are used to create Swirl Patterns. The swirls can range in size and be either smooth or choppy. The grinding wheel grit or wire brush coarseness can be varied to create different effects. The finish can be applied by hand or CNC-operated equipment can be used to move grinding wheels or wire brushes in preset patterns. Swirl patterns can be applied to flat or curved pieces and small or large areas. Because a wide range of patterns can be created, it is important to have control samples to maintain consistency. Swirl patterns hide accidental scratching and are very decorative.

ENGINE-TURNED PATTERNS Engine-Turned patterns are created with CNC-controlled equipment, which grind circles into a flat surface that has been highly polished or bright annealed to a mirror-like appearance. The circles can range in size, overlap, and form decorative patterns. When the ground circles cover the entire surface, they are effective in hiding light random scratching.

ABRASIVE BLASTED - Stainless steel can be abrasive blasted with a variety of media to create a non-directional, repairable finish. As shown in Table 3, the choice of media will determine the appearance. It is important to clean the surface before and after blasting and to use clean media to avoid surface contamination. Fingerprinting can be a problem, particularly on rougher finishes where it may become permanent if it is not removed promptly. Abrasive blasting is ideal for large structural pieces, sculptures and other heavier sections. Even with appropriate fixturing, distortion can occur when abrasive blasting thin, flat sheets.Experienced suppliers blast both sides and either laminate pieces to a rigid backer or use fixturing to reduce distortion. If thin sheet or strip is required, it may be more

cost effective to consider one of the rolled finishes that simulate abrasive blasting.

WOVEN, WELDED AND KNITTED STAINLESS STEEL CLOTH - Cloth is produced by weaving, knitting, or welding stainless steel wire. It is used for security screens, baskets, fencing, shelving, partitions, and decorative applications. The wire thickness determines the weight, flexibility, and strength of the cloth. Weaving provides the greatest flexibility and can produce simple screens or more complex decorative patterns. The percentage of open area, wire diameter, and opening size should be specified.

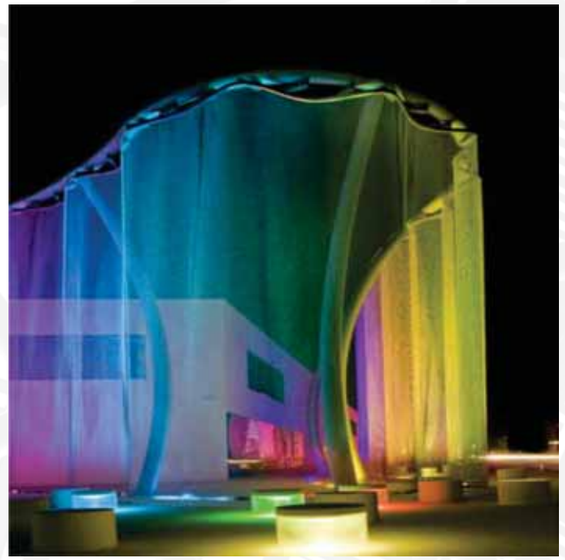

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Photo coutesy : ISSF

Guidelines for Roof, Floors and Handrails

Image Courtesy : Catherine Houska

Stainless Steel – *the modern material with a 60 year track record.*

The term "stainless steel" is used to describe over one hundred different stainless steels, with each one tailor-made to give outstanding performance in specific applications. The key to successful use is understanding the application and then specifying the correct type from the six generally associated with Architectural and Building products.

Grade Typical Chemical Composition

430	17% Cr		0.07% C	
304L	18% Cr	10.0% Ni	0.03% C	
304	18% Cr	10.0% Ni	0.06% C	
316L	17% Cr	12.0% Ni	0.03% C	2.5% Mo
316	17% Cr	12.0% Ni	0.06% C	2.5% Mo
2205	22% Cr	5.5% Ni	0.03% C	3.0% Mo

Why do stainless steels resist corrosion?

All metals react with oxygen in the air to form a film of oxide on the surface. The oxide formed on ordinary steel allows the oxidation to continue producing the typical rusty appearance. However, because stainless steels contain more than 11% chromium, the characteristics of the oxide are changed. Further oxidation is prevented and if the film is accidentally removed, a new one forms to continue the protection.

In practice, stainless steel contain at least 18% chromium. The most frequently used grades also contain at least 8% nickel.

Typical Uses

Type 430 stainless steel performs reasonably well indoors, but steels containing nickel are required for satisfactory service outdoors. Type 304 is widely used for curtain walling, side walling, roofing etc. but Type 316 stainless steel is preferable for coastal regions and locations where atmospheric pollution is a problem. Guidance on selection can be obtained from the companion brochure "Advantages for Architects".

The European specification Eurocode 3 Part 1.4, will include Grades 304L, 316L and 2205 for structural applications.

Product forms

Stainless steel is produced in virtually all standard metal forms and sizes, plus many special shapes and castings. The most commonly used products are made from thin sheet and strip.

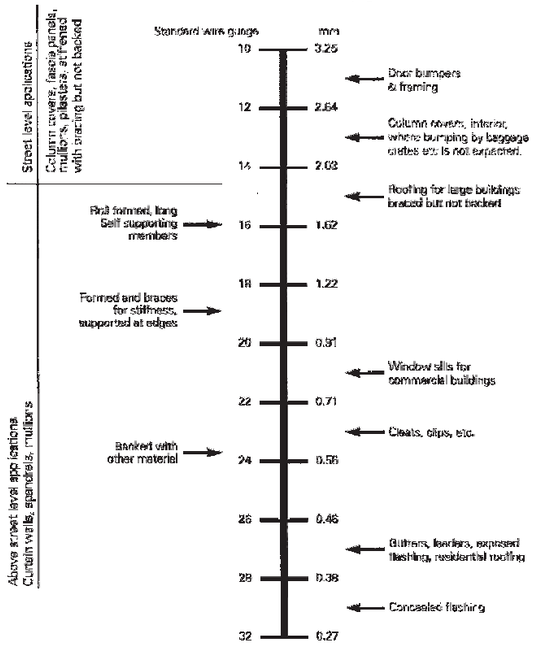
Surface appearance

A wide range of commercial surface finishes is available. The surface can be highly reflective or matt; smooth, brushed or embossed; painted, coloured or even coated with terne alloy to produce an appearance similar to lead.

Fabrication

Techniques used for welding, forming and cutting ordinary carbon steel can be used for stainless steel, but adjustments in equipment settings and recognition of the higher strength of stainless steel will be required. When these differences are accommodated, stainless steel can be readily fabricated.

Thickness of Stainless Steel used in Architectural applications



Design

For over 60 years, architects have used stainless steel to produce permanent expressions of their design concepts. Some, such as the Chrysler Building in New York City, are highly visible, but there are many other external and interior applications where stainless steel plays a less dramatic but vital role in the aesthetics and performance of a building.

Stainless steel's role as a long life, high integrity structural material is recognised by design codes such as the American Society of Civil Engineers standard ANSI/ASCE - 8 - 90 "Specification for the Design of Cold Formed Stainless Steel Structural Members" and the "Design Manual for Structural Stainless Steel" published by the Nickel Development Institute in conjunction with Euro Inox.

Future

Stainless steel already has many ideal characteristics required for an architectural material - but its development continues.

Existing types have been improved to give even better performance and new steels are being marketed to meet the demands of advanced architectural applications.

Roofs

Introduction

The unique properties of stainless steel are ideally suited for roofing, whether flat, pitched, arched or curved.

Stainless steel is a highly durable long lasting material, of high strength and ductility, and totally impervious to water. It requires little or no maintenance and is readily formable and weldable.

It can be coloured, by resin coating, as widely used for roofing in Japan for example, or used as a bare metal roof covering in hand built or standard profiled form.

Domestic, commercial, municipal and industrial buildings, sports stadia and Churches, have all been fitted with stainless steel roofs.

Many of these applications have been curved.

Courtesy of Nippon Metal Industry

Fig.1 Coloured Japanese roof

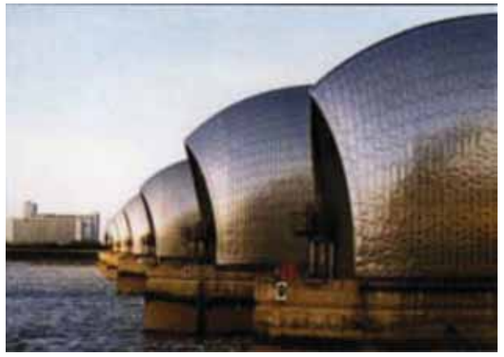


Photo D J Cochrane

Fig.2 Thames Barrier An example of a curved standing seam roof

Advantages of stainless steel

Roofing with stainless steel offers many advantages:

(a) it is highly resistant to corrosion and totally impervious to water
(b) it requires no maintenance other than the removal of leaves and debris as with all roofs
(c) it will last the lifetime of the structure(1)
(d) it is light, around 3kg/m^2 (Hand Built)
(e) it has a high degree of safety in the event of fire
(f) it is simple to lay
(g) it is cost competitive
(h) it has high strength and high ductility for forming
(j) it can safely be used with other building materials and is not attacked by cement, mortars, or timber preservatives
(k) is aesthetically pleasing
(l) it can be coloured
(m) it can be soldered and welded
(n) it can be shaped

Types of Roofing

Stainless steel can be used in the following ways:

(a) as Profiled sheeting
(b) as profiled sheeting with a Secret Fix system
(c) Standing Seam method, seam welded or folded
(d) Batten Roll method

The material can also be given a proprietary finish, used plain or terne coated, or be coloured.

(a) Profiled sheeting

In the same way that carbon steel may be profiled, stainless steel may also be used.

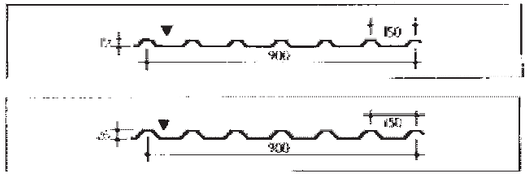


Fig.3 Typical roof profiles (dimensions in mm)

Due to its work hardening characteristics, stainless steel requires around 50% more pressure to produce the profile than is required for carbon steel, and austenitic grades of material are also subject to 'springback' during the roll forming process.

For these reasons manufacturers tend to offer a limited range of profiles.

An alternative process is brake pressing. The Waterloo Terminal roof was manufactured by this route and the panels were specifically designed to accommodate the long span required by the architect.

Photo D J Cochrane

Fig.4 Waterloo International rail terminal

The method of construction, however, is the same, in that the decking is supported on purlins, generally at about 1.8m centres, although the spacing is dependent upon the depth of profile and the design loading.

With stainless steel roofing, it is important that primary and secondary fixing screws are also made from stainless steel. Austenitic fasteners must be used with austenitic roofing sheets,

As Youngs Modulus for stainless steel is similar to that of carbon steel, deflections for identical profiles will be similar.

(b) Secret Fix System

The secret fix system is similar to profiled decking in appearance but uses a hidden clip fastening to connect adjacent sheets.

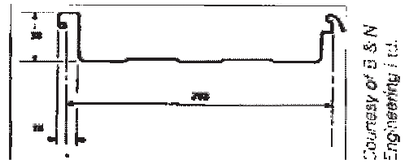
The advantage of this method is that the roof is not perforated by fixing screws, therefore, a potential source of leakage is eliminated.

There are different proprietary methods and profiles of secret fix systems available but the concept is the same for most of them.

The roof shown in Fig.7 illustrates one system. A Post Office Sorting Office in London used this particular system for which a proprietary pearl finish was given to the stainless steel.

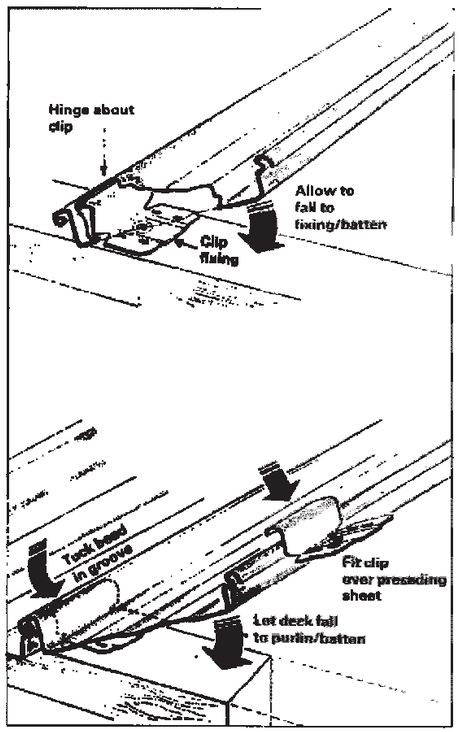
This system uses roll formed profiles which have male and female sides designed to clip over one another and thus provide a strong interlocking watertight roof membrane.

In between the interlocking members are specially designed clips which are fixed to the purlins and hold the roof down.



Courtesy of B & N Engineering Ltd.

Fig.5 Interlocking panel

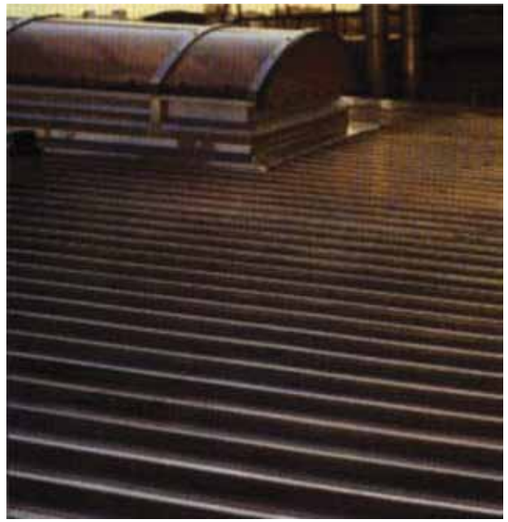


Courtesy of B & N Engineering Ltd.

Fig.6 Fixing clip

The interlocking panel principle may also be used for wall cladding either external or internal.

This type of system allows thermal movement, either expansion or contraction, to take place.



Courtesy of Avesta Sheffield Ltd.

Fig.7 Example of a Secret Fix roof

Minimum Slope

As with most roof structures a minimum 1 degree slope is necessary to avoid ponding and the creation of permanent water pools.

While this is the absolute minimum recommended, steeper pitches will allow a faster water run off and improved washing action by rainwater.

It is more usual to deploy a roof slope of between 3 and 6 degrees however, to simplify flashings and gutter details.

Thickness of Sheet

Profiles are usually rolled in thicknesses of 0.5, 0.6, and 0.7mm and are designed for a multiple span condition over the purlins which may be from 1.5m to 2.25m centres depending upon the load to be carried.

Pressed panels may be of thicker material and account should be taken of the increased pressure required for stainless steel sheets as indicated in Types of Roofing (a).

Load/Span Tables

These are available from roofing manufacturers.

Accessories

As with any stainless roof structure accessories such as clips and screws should also be manufactured in stainless steel.

Installation

The installation of this type of roof begins by marking out and fixing the first row of clips.

The first profile is hinged over the row of clips and lowered on to the purlins.

The next row of clips are installed by fitting them over the sheet that has been laid and secured as before to the purlins.

It is necessary to use crawler boards during installation, and that applies to most metal roof structures, to avoid permanent deflections and surface damage.

Footwear should also be selective for this reason, and, to avoid grease contamination, it is recommended that clean gloves should be worn for handling the material.

It is normal practice at ridge joints to turn up the sheeting, using a special tool, to prevent the passage of water, and conversely turn down the sheeting at drips and sheet ends to facilitate water run off.

Preformed stop ends are usually driven in at the rib ends to provide a neat finish and prevent their use by small birds insects etc.

Details of Ridge capping, gutters, verges, fascias and drips will be available from the roofing manufacturer.

Hand Built Types of Roof

Hand built types of metal roofing require a substrate for support, and stainless steel is no exception.

Within this category of roofing there are basically two systems used, commonly known as:

Standing seam

Batten roll

Preferably, the stainless steel used for hand built roofs should be in the softened condition for ease of forming.

It is recommended that for roof pitches up to 7°, the batten roll method be used but above this roof pitch either method may be used.

Aesthetically, the standing seam system provides a less conspicuous profile than the batten roll system which gives visually bold lines at the batten joints.

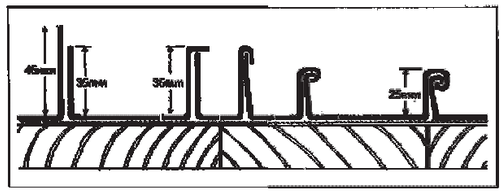
Both systems may be used together if the architect so chooses.

Care should be taken in manipulation, forming of seams, and dressing, as the stainless will rapidly harden when cold worked.

(c) Standing Seam

The standing seam system comprises a series of bays formed by the sheeting trays which are laid down the slope adjacent to the clips which have already been fixed to the substrate at 375mm centres. Clip size 45mm high x 25mm x 50mm long. Expansion clip 40mm high x 85mm long, 50mm slot for 30mm clip.

The clips are secured to the substrate or battens by screws or helical twist nails. The clips are folded with the upturn of the sheeting to form the longitudinal standing seam which will be approximately 25mm in height.



Courtesy of Steelex

Fig.8 Forming the standing seam

Plain clips are used to secure lengths up to 3m and when this length is exceeded, a mixture of 1/3rd plain clips and 2/3rds expansion clips should be used to take account of expansion, or thermal movement.

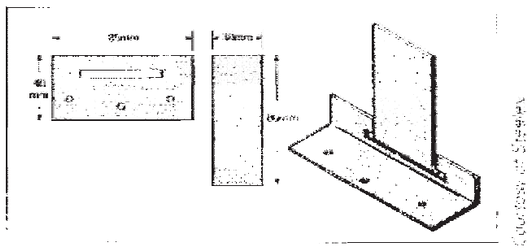
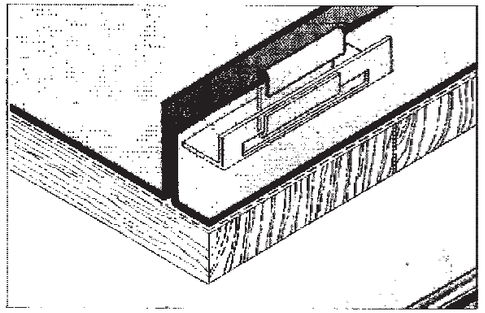


Fig.9 Expansion clip

When lengths in excess of 9m are required, sheets may be joined across the fall by a single welt, where the roof pitch exceeds 45°. Joints should be flattened to allow water to flow freely over the sheets. Where the roof pitch is less than 45° then it is recommended that a drip be formed. To avoid the difficulty of welting multiple thicknesses of stainless steel in the standing seam, cross joints should be staggered.

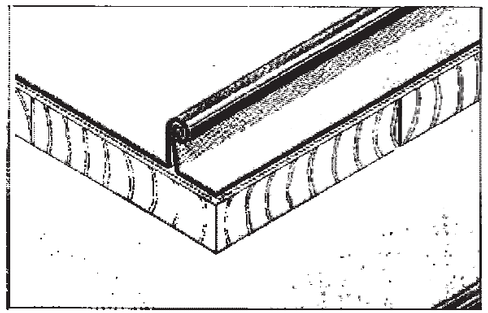
Standing seam

Method of Forming



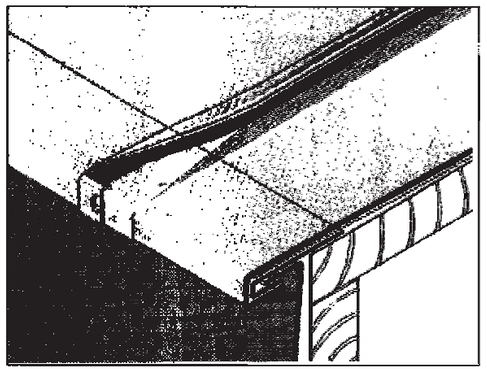
Courtesy of Steelex

Fig.10 Securing the tray



Courtesy of Steelex

Fig.11 Seam formed securing adjacent trays

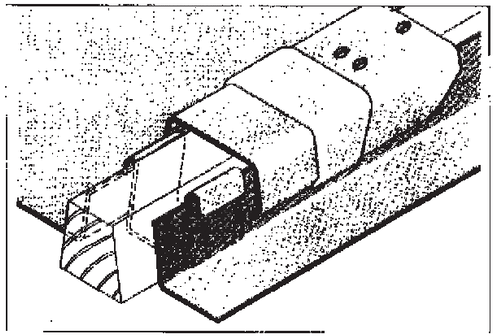


Courtesy of Steelex

Fig.12 Folding the standing seams at drips and eaves

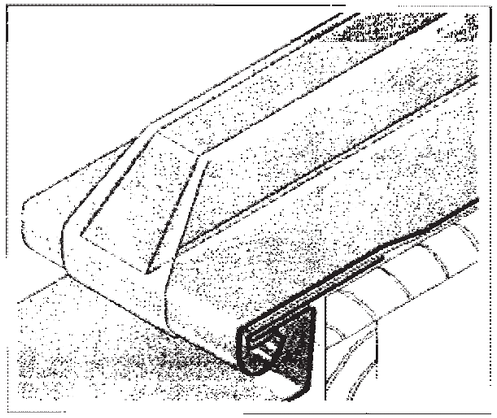
(d) Batten Roll System

In this system longitudinal timber battens are securely fixed to the substrate at 450mm centres using stainless steel number 10 size screws (3.5mm).It is important that the battens are securely fixed to avoid any displacement when dressing the metal into position and they will also be fitted with the sheeting clips prior to fitting to the substrate. Spacing of the battens is normally 425mm centres.



Courtesy of Steelex

Fig.13 Batten roll arrangement



Courtesy of Steelex

Fig.14 Forming at Drip and Eaves

At eaves and drip positions battens are usually splayed at 45° to facilitate dressing of the stainless steel capping. The main sheeting trays are formed from a coil width of 455mm with 45mm upstands along the longitudinal edges which are dressed up to the sides of the battens. The sheeting clips are folded over to secure or hold the sheet in position. Size 55mm high x 50mm long. Separate roll caps, generally 1 m long should be provided for the batten rolls. The capping covers locate and lock at one end and are fixed by 3, number 10 screws at the other.

Materials

All materials associated with stainless roofing should also be made from stainless including batten covers, flashings, drop aprons, and clips and nails. Flashings may also be in lead. Austenitic grades of stainless steel are generally used for roofing purposes, and these are typically as shown in Table 1. The higher alloyed Type 316 is recommended for aggressive coastal or industrial areas and further guidance can be obtained in ref.1.

Table 1. Materials suitable for Batten Roll, Standing Seam and Seam Welded roofing

Stainless Steel Grade			Min. Tensile Strength N/mm²	Condition	Min. 0.2% Stress N/mm²	Typical Hness Vickers
UNS	BS1449: Part 2	ASTM A240				
530403	304511	304L	480	Softened	180	150
530400	304531	304	500	Softened	195	150
531603	316511	316L	490	Softened	190	150
531600	316531	316	510	Softened	205	150

Table 2. Physical properties of stainless steel in the softened condition.

Stainless Grade	304511	304531	316S11	316531
Density kg/m²	7905	7910	7970	7970
Specific Heat KJ/KgK (20-200c)	0.52	0.52	0.52	0.52
Coefficient of linear expansion (20-200c)	8.0 x 10^{-6}c	18.0 x 10^{-6}c	17.x 310^{-6}c	17.3 x 10^{-6}c
Thermal Conductivity W/mk1000	16.0	16.0	16.0	16.0
Melting Point°c	1415	1415	1380	1380

Substructure

The design of the substructure for stainless will be identical to that used for other metal roofing.

Timber in the form of tongued and grooved boards 25mm in thickness or exterior grade plywood 19 or 25mm in thickness will provide a suitable substrate for stainless. Alternatively a concrete sub-structure will suffice. With a concrete substructure, provision must be made for securing clips or rolls by wooden dovetailed battens or plugs set into the concrete and set flush with the finished level of concrete.

It is suggested that timber battens be 75mm x 25mm deep. All timber should be preferably pressure treated or impregnated with a preservative to prevent decay.

The substructure should incorporate an even fall to facilitate drainage with the minimum slope being 1 in 40.

An underlay should be laid on top of the substructure to provide a smooth and even surface for the roof sheeting. The underlay is not a vapour barrier and ventilation should be provided by othermeans unless the underlay comprises a composite layer impervious to water.

This is important when concrete or screeds are used as they may retain moisture for long periods.

Material Thickness and Finish

A softened material generally with a hardness value less than 150 Vickers, and only 28 SWG (0.375mm) is generally preferred for hand built roofs.

A dull matt finish similar to a 2D finish, or Terne coated material (see under Terne Coating) is the usual type of finish preferred, to avoid reflection.

Precautions

Storage and protection of stainless steel. The stainless steel should be kept dry whilst in transit and in the store on site.

At all times care should be taken to avoid marking or scoring the material by for example nailed boots or heavy tools. Stainless steel should never be cleaned by wire wool made from carbon steel as this will inevitably lead to deposits of carbon steel and result in rust staining.

Stainless steel must always be kept apart from carbon steel especially where these are being machined.

The sheeting trays formed to fit the bays of the roof should contain an allowance for expansion and contraction as appropriate.

Checks

It is worthwhile for a construction that is to last as long as a stainless one to carry out a few checks and ensure that a good job has been done.

These should take the form of the following check list:

1. ensure that the substructure surface is of satisfactory finish, flat and firm, and with no projections such as screw heads.
2. ensure that the underlay is dry and free from dirt and extraneous matter and joints are butted and not lapped.
3. ensure that the main roof covering is laid true with the substructure and secured against wind uplift
4. ensure that all welted seams are correctly formed and in the proper direction
5. ensure that aprons and flashings are secured against wind uplift and main roof coverings adequately weathered
6. ensure that all pointings and flashings are completed and and adequately dressed or weathered
7. finally, ensure that the surface of the stainless steel has been properly cleared of all debris.

Terne Coated Stainless Steel

Whilst a dull flat finish is normally recommended for roofing, in order to reduce glare, terne coated material is frequently specified for roofing because of it's appearance which is similar to that of lead.

This type of coating weathers, and in time, closely resembles a lead roof.

Terne coating is a material with an alloy coating comprising 80-85% lead and 15-20% tin, depending upon the plating company, and the coating thickness is in the order of 20 microns per side.

It was developed by Follansbee in the USA from whom details of the way in which this coating is achieved, may be obtained.

It is important to note with this type of coating that it can be worked in the same way that ordinary sheeting in stainless steel can be worked and it is the appearance that is the main difference.

It is popular for this reason.

Resin Coated Stainless Steel

Resin coated stainless steel, i.e. PVF2, has met with spectacular success in Japan where it was introduced in the mid 1980's.

Over 22,000 tonnes/annum is currently used for roofing in Japan.

Resin coated stainless steel has been developed to give a long life coating and the process involves a tempering of the skin of the stainless steel by holding the final annealing process for a little longer than normal.

To ensure good adhesion, the steel passes through shotblasted skin pass rolls. An epoxy resin layer is applied as a primer prior to the application of the resin coating.

A high weathering coat of Vinylidene fluoride resin has been developed although the general purpose coating is a Silicone acryl resin.

Because seam welding is the fast growing market in Japan, a weldable resin coating has been developed.

The coating differs to the normal resin coating by the addition of 20% in weight of stainless powder and this ensures the electrical conductivity necessary for the seam welding equipment. Profiled sheeting can be used in the usual way or installed using a 'Secret Fix' type of concealed fitting.

Seam Welding

Seam welded roofs are basically the standing seam mentioned earlier except that the seams are welded to form a watertight join.

This is achieved with the aid of automatic portable machinery initially developed for the purpose by the Rostfria Tak Corporation of Sweden.

The principle of this method is that the sheeting clips are first spot welded to the sheeting.
The second is to seam weld 15mm up from the roof deck with the automatic seam welder which is self propelled.

The final operation is the folding over of the seam which again is a process carried out by a self propelled seam bending machine.

The seam welder requires a 3 phase power supply of 380V or a generator for 27 kVA and it's self propelling speed is 4 metres/ minute.

Courtesy of Rostifria Tak AB, Sweden

Fig.15 Seam welding

Gutters and Downpipes

With hand built roofing, that is batten roll or standing seam methods, gutters are generally laid on a substrate of hard board and valley gutters are generally of the preformed type also hand built. They may also be thin gauge rolled products. This is an area where the soldering of stainless may be used, not specifically for it's joint strength, but in order to seal a particular junction.

Stainless can be used uncoated or terne coated and in both cases are readily soldered.

Soldering of uncoated stainless

Soldering as a process is generally suitable for materials up to 1.25mm in thickness and it is recommended that a flux be used that suits stainless. For uncoated stainless a phosphoric based flux, which is only active at soldering temperatures, may be used. Either a 50/50 or 60/40 tin/lead solder is suited to stainless and the 2D surface finish to the roofing material means that no surface treatment other than perhaps a degrease is necessary before soldering.

Post soldering treatment

All flux residues and vapours must be removed following completion of the soldered joint.

Terne Coated Sheet

Because the coating already contains lead and tin, the soldering operation is generally simpler than the uncoated stainless, and again a Tinmens solder of 60/40 is very suitable.

Technical information on roofing is available in a well illustrated NiDI publication entitled: 'Technical Manual for the Design & Construction of Roofs of Stainless Steel Sheet'

Floor

Introduction

Stainless steel teardrop patterned floorplate was first produced in the UK in the mid-eighties in response to market demand, as an alternative to corrosion protected carbon steel.

Stainless flooring has since found applications in many different industries, for a variety of reasons, appearance, cleanliness, ease and frequency of cleaning - sometimes with chemicals - hygiene, hostility of the environment, and cost effectiveness.

Food processing plants, dairies, breweries, abattoirs, industrial and chemical plants, hospitals, motor plants, have all installed stainless flooring.

Commercial buildings, offices, and railway stations have also fitted stainless steel floorplate.

Electro-polished, floorplate is visually attractive and provides a surface finish that is least likely to harbour bacteria and dust - a requirement in Hi-tech plants and food processing areas for example - while security underfoot is provided by it's pattern which may be rolled, pressed, or etched.

It is an ideal material for applications where corrosive conditions place demands upon materials and protective finishes that require regular inspection, and often costly maintenance or replacement.

Basic Forms of Flooring

The following types of stainless steel flooring is produced:

1. Raised pattern solid floorplate.
2. Etched pattern solid floorplate
3. Grid
4. Plank

1. Raised Pattern Solid Floorplate

This is a hot rolled product produced by the rolling mills at the steelworks.

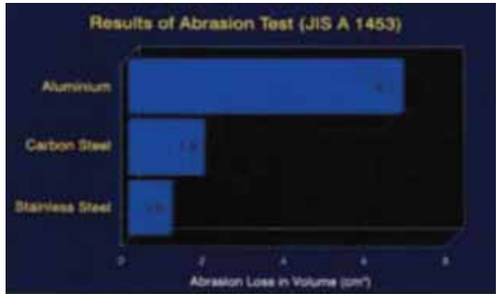
Floorplate is usually supplied in coil up to a weight of 23 tonnes, or in plate form which is already cut to size. With a maximum width of 1830mm the rolled product is produced in thicknesses of 3, 4.5, 6, 8, and 10 mm with a raised teardrop pattern at a cross centre pitch of 27mm. Typically the height of the studs or teardrops will be in the range 1.5 - 2.2mm and the teardrops themselves are 27mm long and a maximum width of 9mm.

This pattern facilitates the removal of surface water which can readily be swept away.

It has been shown by tests, that stainless steel floorplate of this pattern has considerably higher resistance to abrasion than materials such as carbon steel and aluminium.

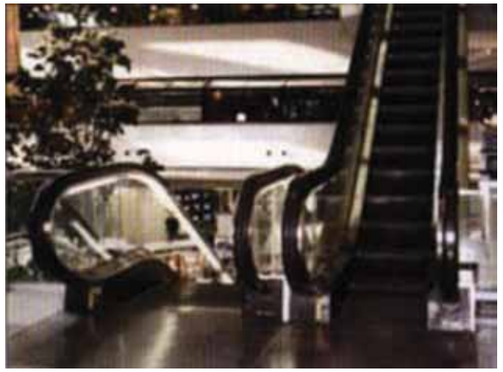
Photo D J Cochrane

Fig.1 Waterloo International rail terminal teardrop raised pattern floorplate



Courtesy of Nippon Yakkin Kogyo

Fig.2 Abrasion resistance of floorplate



Courtesy of Nisshin Steel Co., Japan

Fig.3 Etched patterned floorplate

Thin gauge floorplate, a recent development, is available as a pressed product in thicknesses of 1, 1.5, 2, and 3mm.

This product is finding application as wall liner and floors of transport vehicles such as refrigerated lorries, and floors of fire service vehicles, and milk lorries.

Adjacent sheets may be joined by the lock seam method to provide the necessary width, and the sheet may also be bonded in position using epoxy resin.

It can also be bonded to carbon steel floorplate where the pattern has worn flat - on steps for instance - where the bonding effectively acts as a barrier between the dissimilar metals and prevents galvanic corrosion.

2. Etched Patterned Solid Floorplate

Architectural floorplate is available in a variety of patterns and is principally produced in Japan.

Patterns are etched to a depth of around 800 microns and the bottom of the etching is coated to prevent contamination and corrosion.

Proprietary patterns are available, however, any pattern can be applied.

This product is commonly found at the bottom of escalators.

Plate thickness is in the range 3 to 8mm and the maximum width available is 1.5m.

Loading

Unless laid on a flat surface, floorplate will require support and the load carrying capacity will depend upon whether this is in the simply supported condition or encastre (fixed) on all four edges.

Load tables are provided by the manufacturers of the stainless floorplate for given width and breadth spans and are based either on deflection or a maximum skin stress of 180 N/m m^2. This value for bending stress was derived from load tests.

Fixing

Floorplate may be bolted to a suitable subframe or welded depending upon the application.

Countersunk headed bolts can be used provided that the material has sufficient thickness to prevent protruding boltheads.

The subframe may be either of stainless or carbon steel and bolts should be stainless to prevent corrosion between the dissimilar materials. If the subframe is carbon steel and the environment a corrosive one, then a suitable barrier should be used to separate the metals - a coat of bitumen would suffice, or a non-metallic barrier such as Teflon or a rubber strip.

If the floorplate is welded in position, and this may be necessary between floorplates to seal the floor for washing purposes, thermal movement should be taken into consideration. The welds should be cleaned up to restore the surface to prevent rust staining occurring due to the oxidised or weld heat tinted surface.

This may be achieved using proprietary pickle pastes which are available for this purpose. Manufacturers full instructions should be followed when using this method which involves brushing on the paste followed by a thorough water rinse.

When welding material less than 4.5mm thick, some distortion may occur due to the heat input and the solution is to adopt a stitch and gap technique where small runs are welded, a gap left, followed by another weld run and gap and so on. The gaps are filled when the metal has cooled.

Forming

Not all applications require flat square plates and floorplate is readily formed and cut in the fabrication shop. Upstands may be formed to facilitate washing to prevent the water from going over the edge.

Finishes

Floorplate is generally supplied in the rolled condition or is descaled to provide a dull matt appearance.

Where appearance or exceptional cleanability is concerned, it can be electro-polished to provide a superb finish. This type of finish leaves a smooth surface which is not susceptible to collection or harbouring of contaminants.

Stairtreads

The formability of floorplate readily allows its application for stairtreads. A fully stainless stairway, with stairtreads in floorplate as well as the handrail support frame, makes an attractive, practical installation.

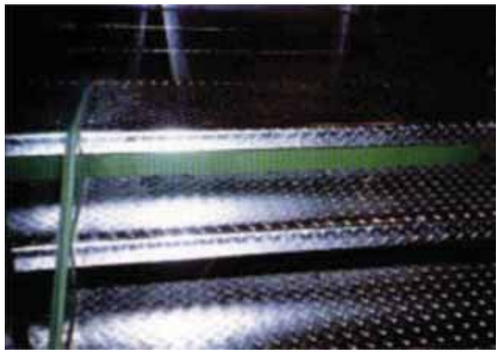


Photo D J Cochrane

Fig.4 Stairtreads, Science Museum London

Aesthetics

Floorplate with a raised pattern, if not in stainless, is subject to wear particularly at the high points in well used areas. Stainless steel has a good surface which will not become readily worn in the way that softer material such as aluminium will.

Painted surfaces, often found on carbon steel flooring, tend to become unsightly where the surface becomes worn at its high points and the same applies to galvanised surfaces. With any surface protection and raised projections, there is inevitably going to be wear exposing the substrate and leaving it bare and susceptible to attack and corrosion. Periodic recoating to restore the protection may be necessary for painted and galvanised steel.

In ship engine rooms, for example, it has been found necessary to remove floorplates and return for regalvanising before refitting. The cost of this exercise is such that stainless steel has become the standard material used by one of the UK major shipbuilders.

Stainless steel does not show the effects of abraded surfaces as protected surfaces do, and this is a clear advantage.

3. Grid Flooring

Grid flooring is often used as walkways, frequently elevated, or mezzanine floors, where the transmission of light and ventilation are required. In certain industries they may be subject to a highly aggressive working environment.

Grids are formed from bars welded or held in position and carbon steel grids can lose load carrying capacity if corrosion occurs, therefore, regular inspection and maintenance is essential.

It is an ongoing cost.

Stainless steel can be cost effective in this type of environment. Likely disruption and possible shut down for maintenance/replacement can be avoided by using stainless steel.

Photo J Fletcher

Fig.5 Corroded grid in carbon steel

As shown in Fig.5 the structural capacity of a carbon steel grid may not be evident simply by visual inspection. Clearly any elevated walkway in this type of environment is unlikely to tolerate this degree of attack without impairing its safety.

On a typical walkway with 5mm bearer bars, the thickness of a galvanised coating is approximately 65 microns i.e. a coating mass of 460 gm/m^2. This, by itself, is unlikely to provide a long service life in aggressive conditions because the surface will wear underfoot and reduce the life to first maintenance.

In addition to industrial applications, stainless steel grids have also been installed as an architectural feature on the outside of a building, where it was used to break up the monotony of the glass facade and serve as access for window cleaning purposes.

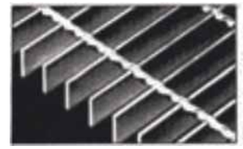
Weight for weight grids have a higher load carrying capacity than solid floorplate and load tables are available from the manufacturers.

There is more fabrication involved with the manufacture of grid flooring than with solid floorplate, but cut-outs and special shapes can be accommodated in the workshop so that site work is simply an assembly process.

Site modifications are difficult with grid flooring and involve cutting, rewelding, and clean-up of the weld areas to restore the surface to full corrosion resistance.

Because grids are made up from a number of components, welding of the individual bars could be a time consuming process and automated processes are a cost effective production method.

An example of an automated process is the forge weld process where the bearer bars and the transverse bars are fused in one press.



Courtesy of Redman Fisher Engineering Ltd.

Fig.6 Grid Floor, Plain

Fig.7 Grid Floor, Serrated

The bars are placed in position and subjected to a pressure of 100 tons and a 2000 k.V.A. electrical charge simultaneously. The transverse bars are pressed into the bearer bars under this welding process and fused together.

The twisted top transverse bars provide for grip underfoot and the bearer bars can be serrated to provide improved grip.

The principle of bearer bars with transverse bars which stiffen the frame and provide support to the compression part of the bearer bars can be achieved in different ways.

Small grids or gulley cover plates are commonplace in many commercial areas particularly in kitchens, food processing areas, and abbatoirs that are washed frequently.

Courtesy of ACO Technologies plc

Fig.8 Kitchen grid floor

From a hygiene standpoint, the use of stainless for the gulleys as well as the grid covers has become popular. It is worth noting that the smooth surface of stainless facilitates the removal of food particles and other droppings that occur in food processing and preparatory areas, that are washed into the drainage gulleys.

The smoothness of stainless means that particles are less likely to cling to the sides of the gulley walls where they can store bacteria and lead to unpleasant odours if not cleaned completely.

Plastic and other materials do not have the same high quality, durable surface to facilitate this removal.

It has been demonstrated by independent tests that the cleanability of stainless, i.e. the removal of bacteria, is comparable with glass and ceramics.

About 98% of bacteria is removed on these surfaces and this is one of the reasons why stainless is so widely used in the food processing industries and in the kitchens of the world's leading hotels.

Grid flooring can take different forms but basically transverse members are installed for rigidity to the frame as a whole and for the support of the compression part of the bearer bars.

Interlocking bars can be used to stabilise the frame while reducing the welding needed and generally this type of frame would have serrations at the top to provide grip underfoot.

Courtesy of ACO Technologies plc

Fig.9 Grid floor and drainage system

Member Sizes

Grid flooring has the advantage that the size of the bars can be selected as appropriate for the load and span required, and typical sizes for the main bearer bars range from 20 x 3mm for a clear span up to 900mm, to 60 x 5mm for spans up to 3m.

This will support a load slightly higher than 5kN/m^2 when in a uniformly loaded condition and with the bearer bars at a pitch of 30mm.

Deflection under this condition would be a little over 8mm or span/360 which is acceptable.

4. Plank Flooring

Typically this is formed from 2mm thick sheet which may be of the teardrop patterned type. Alternatively, it may incorporate punched holes that also form small upstands for underfoot grip.

Generally this type of floor is produced in a range of widths from 63mm to 333mm to accommodate different sizes of end uses. Depths can be as necessary but are usually around 35 to 50mm. Spans are up to 2m generally but may be more if required provided that the thickness and depth can take the design loading.

Photo D J Cochrane

Fig.10 Formed Plank

This type of floor is literally laid like wooden planks, side by side, requiring only end supports, and it has the capacity to carry very high loads and remain light in weight by bolting the planks together through the webs, effectively forming an I beam.

Should a plank be badly damaged for any reason it can be replaced quite readily.

Plank flooring is produced by pierce and blank tooling and press brake forming.

This type of flooring may be produced with any type of punched pattern to provide the strength required, generally punched round and slotted holes are used to reduce the product weight, allow the passage of air and light, and provide a surety underfoot.

Whereas with grid flooring items which may be dropped onto it could fall through, bolts for example on a site, the plank form will not be susceptible to this, hence it's usefulness over the other 2 forms.

Life Cycle Cost Analysis

A typical life cycle cost analysis was instigated by NiDI on the walkways for an offshore oil platform operating in the North Sea.

Contractor's normal maintenance practice is to use galvanised walkways, and in this type of environment, platforms are subject to aggressive salt water conditions.

Normally walkways last between 8 and 10 years before they are stripped out and new walkways shipped out and installed. In process areas this means cutting and welding equipment will be required and the rig may be shut down whilst the refit takes place.

The life cycle cost study showed that the use of stainless steel obviates the need for any replacement during the life of the platform which may be 30 or 40 years.

For a 30 year platform, there would be 2 replacements at years 10 and 20 of the carbon steel walkways and stainless would become cost effective at the time of the first replacement. The second results in very significant savings.

This study emphatically proved that it is not only the first cost that should be taken into consideration when specifying materials but the total ongoing related cost including operational and maintenance costs.

Stainless steel has the added benefit of increased safety in a fire situation, as it retains a higher level of strength at elevated temperatures, than carbon steel. In a separate study in which stainless steel and other materials were subjected to direct and radiated heat, structural integrity was maintained, whilst under load, at temperatures over 1,000°c.

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Handrails

Introduction

Whether for interior or exterior use, stainless steel can be seen in most countries in the world, in the form of handrails, balustrades, and staircases.

There are a great many variations in design for these components using tubular or oval sections, square or rectangular, flat plate, or drawn section (thin gauge stainless drawn onto a hardwood core).[1]
Drawn sections permit variations is section shape whilst providing a solid rail with a thin skin of stainless steel.

Infill panels may be safety glass, stainless wire mesh, or simple sections.

Key features in the use of stainless steel are aesthetics, strength, corrosion resistance, formability, weldability, and ease of maintenance.

In densely populated areas such as shopping malls and airports where rails may be subject to accidental damage from trolleys, cases etc, the high impact resistance of stainless steel and the fact that it has no added surface protection such as paint that will show damage, reduces the need for ongoing maintenance.

In roadside areas, or as bridge rails and parapets, stainless steel provides a maintenance free security barrier that will not be adversely affected by road de-icing salts.

Stainless steel provides the designer with a wide choice of end product to suit the location.

Surface Finish

Satin finish and bright polished (number 4) are the types of finish popularly specified. Sections may also be electro-polished.

Material Specification

The readily weldable austenitic grades 304 (for interior use) and 316 (for exterior use) are usually specified. A ferritic grade type 430 may also be used for interior dry atmospheres.

Design & Fabrication

GTIG and argon arc welding are the most common processes used and provide a neat weld that can be ground smooth and polished.

Courtesy of Krupp, Germany

Fig.1 Handrail with stainless steel infill wire

Care must be taken in design and manufacture to ensure that the welds can be ground and polished particularly with uni- directional finishes where polishing must be carried out in the direction of the pattern or grain.

All end plates, ball joints, screws and fixings must be in stainless steel of similar grade to avoid galvanic corrosion or staining. All manufacture should be carried out in a separate part of the workshop to carbon steel fabrications, and all tools and grinding wheels used should be dedicated to stainless production to avoid contamination by iron particles.

Austenitic stainless steel has high ductility, around 40%, and is, therefore, readily formable. Account must, however, be taken of the work hardening characteristics of the material and springback. Approximately 50% more load or force is required to form stainless steel than for carbon steel and about 5% should be allowed for springback.

Bending

Tubular handrail sections can be bent to a tight radius on specialist equipment.

2 x diameter is the minimum inside radius for tubular sections and the use of core bars are often used to prevent surface wrinkling.

Plate sections can be bent to a radius equal to the thickness of the material.

Joining

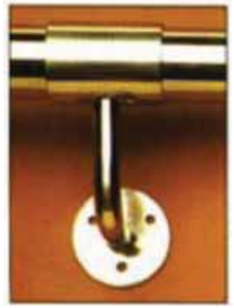
Tube lengths may be joined by a variety of methods. Welded joints, sleeved joints (which may incorporate a socket set screw on the underside to secure the connection), or the use of a spigot pressed into the tube end, are all popular types of handrail connection.

Care must be taken to ensure that socket set screws do not protrude from the tube surface. The use of square or rectangular section stanchions will alleviate the need for profile cutting and simplify weld clean up.

Welding can be avoided, or concealed, by the use of ball joints or sleeved ends.[2]

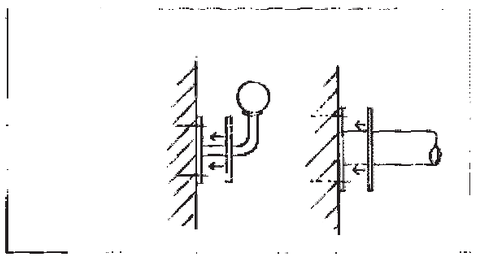
Courtesy of Racco Products Ltd.

Fig.3 Welded Joint



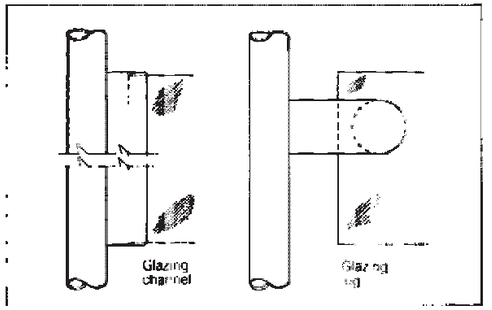
Courtesy of Racco Products Ltd.

Fig.3 Sleeved joint



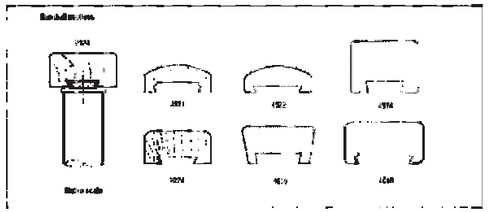
Courtesy of Racco Products Ltd.

Fig.4 Wall fixings



Courtesy of Racco Products Ltd.

Fig.5 Glass fixings



Courtesy of Drawn Metal Ltd.

Fig.6 Handrail sections using thin gauge stainless steel drawn onto a timber core

Photo D J Cochrane

Fig.7 Flat bar handrail

Couresy of Malcom Cole Group

Fig.8 Joining with a spigot[4]

Cleaning

Generally, an occasional wipe with a damp cloth followed by a dry duster will retain the pristine surface of stainless steel.

Proprietary stainless steel cleaning agents are available which will remove finger marking and other light contaminants. Wire wool must never be used unless made from stainless steel. In swimming pools, modern pool atmospheres are highly aggressive due to the use of chlorine, hypochlorite, and other chemicals in the water.

Under these conditions it is advisable to clean the stainless steel weekly to avoid the build up of contaminants on the surface which could lead to staining.[4]

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Cleaning & Maintaining Stainless Steel

Cleaning and Maintaining Stainless Steel

by Catherine Houska, CSI

With appropriate specification, stainless steel can last the life of a building. However, as with any other material, unsightly surface deposits can accumulate after many years of service. Accidents, vandalism, use of inappropriate cleaning procedures, and installation issues can make surfaces unsightly, cause damage, or even lead to rapid surface corrosion. Surface restoration is often possible with the right remediation approach.

Since its invention over a century ago, stainless steel's durable beauty has been repeatedly demonstrated. In the mid-1990s, more than 30 years of dirt, hydrocarbons, and other deposits had blackened the iconic upper floors of New York's Chrysler (left) and Empire State buildings, but simple cleaning with products commonly found in household kitchens returned them to their original appearance

The inherent corrosion resistance of stainless steel often makes it possible to restore surfaces after years of neglect when other materials may have suffered too much deterioration to make that feasible. This assumes an appropriately corrosion-resistant stainless steel and durable finish have been selected for the project, which have been the subject of this author's previous articles. (Previous articles by this author for The Construction Specifier include “Proving its Long-term Mettle” [August 2016], “Avoiding De-icing Salt Corrosion” [January 2015], “Designing on the Waterfront” [November 2007], “Stainless Steel for Severe Coastal Environments” [September 2011], “Architectural Metal Corrosion: The De-icing Salt Threat” [December 2006], “Preventing Corrosion in Soil” [April 2006], and [co-authored with James Fritz], “Swimmingly Stainless Pool Design” [December 2005]. Visit www.constructionspecifier.com. See also this author's articles for the International Molybdenum Association (IMOA) e-newsletter, Stainless Solutions, along with Architectural Metal magazine.)

General guidance

Environmental factors influencing the frequency of the routine cleaning required to retain a pristine appearance include:

- the owner's aesthetic standards;
- surface finish roughness;
- airborne particulate concentrations;
- pedestrian traffic levels; and
- exposure to regular heavy rain.

In 1995, the exterior of New York's 150 East 42nd Street (formerly Socony Mobil Building) was cleaned for the first time in 40 years, removing dirt and hydrocarbon accumulations. Photo courtesy ATI Allegheny Ludlum

This Chinese museum has a fountain along one side, which sprays water on to the surface. The water's high total dissolved solids (TDS) content is causing staining on both the stainless steel panels and the stone. While this staining can be removed, avoiding the problem by installing a reverse-osmosis (RO) system is best. Photos courtesy Catherine Houska

Dirt and grime are easily removed with simple cleaning of the stainless steel.

In exterior environments, sheltered areas (e.g. balconies or the lower floors on high-rises) can face more aggressive environments because rainwater cannot wash off corrosive surface deposits. A more corrosion-resistant stainless steel, smoother finish, and increased maintenance may be necessary to retain an attractive appearance.

One should always request the cleaning product's Globally Harmonized System of Classification and Labelling of Chemicals (GHS) information or material safety and data sheet (MSDS), and avoid chemicals containing 'chlor' (i.e. chlorides), acids, particulate, and anything potentially corrosive or abrasive. When there are

A maintenance worker 'cleaned' the hinges in this natatorium room with a household carbon steel wool pad. The corrosion is from the resultant embedded iron particles.

This stainless steel surface has been badly damaged by a maintenance worker's attempt to remove a poster with a metal scraper instead of an appropriate solvent.

concerns, a stainless steel supplier, industry association, or consultant can review the product chemistry before it is used. (A cleaning company, blogger, or random website does not necessarily understand metal corrosion or specialized finishes.)

Proprietary detergent and water solutions, including those used for automotive or dishwashing, and 'environmentally friendly' cleaning products containing hydrogen peroxide, vinegar, or similar chemicals are also used. The detergent should contain both a surfacent and degreaser, not leave a coating on the surface, and preferably be chloride-free and pH-neutral (i.e. non-acidic). Many cleaning products and wipes contain chloride compounds, such as bleach (sodium hypochlorite). If such products are used, the chloride or bleach content should be less than three percent, and thorough rinsing to remove the chlorides is critical. Bleach concentrations of five percent or higher cause corrosion of commonly used stainless steels like Type 304/304L at room temperature, so it is critical not to let solutions dry and concentrate.

Wash water

Clean, potable water is used for rinsing surfaces after most cleaning procedures, but it is important to check the water's chemistry. The U.S. Environmental Protection Agency (EPA) suggests no more than 250 ppm for chlorides and 500 ppm for total dissolved solids (TDS) for human consumption, but there are no hard maximums. In some areas, these levels are much higher, which could add to both corrosion and hard water staining problems.

Suitable water may need to be purchased or a reverse-osmosis (RO) system installed. It is important never to use natural untreated, industrial, or swimming pool water. When acidic cleaning products are used, the rinse water should have a maximum TDS content of 200 ppm or be de-ionized, distilled, or RO water—otherwise, hard water staining occurs. While it can be removed, opting for avoidance is far more cost-effective.

Applying cleaning products

Even durable finishes can be damaged with inappropriate cleaning methods—this is a particular concern for fragile mirror and colored finishes. Too often, 'cleaning' is attempted with abrasives only appropriate for refinishing. One should use a new or clean, soft, lint-free cloth or a clean sponge reserved for exclusive use on stainless steel. It is critical to avoid cleaning products used on other materials, such as carbon steel.

Products that can potentially change the finish appearance, or contaminate the surface with iron, include:

- coarse abrasives pads (e.g. sandpaper or non-metallic abrasives);
- metal scrapers, brushes, or wool pads;
- coarse abrasive powders; and
- abrasive blast media.

A soft nylon brush or plastic scraper can be used to help loosen adherent surface deposits, but should be tested first to ensure against surface damage. When cleaning directional finishes, one should always rub along the grain.

Light dirt, urine, and fingerprint removal
The choice of cleaning method for removing surface deposits, fingerprints, and other light discoloration depends on the application. Hand cleaning is common, but hot-water power-washing is appropriate for exterior applications where water infiltration is not a concern and a fast, low-cost cleaning option is desired.

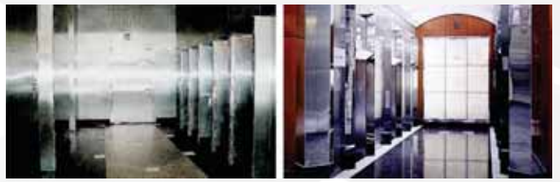
Light fingerprints and dirt accumulations are also easily removed with common window cleaning products, such as ammonia and water or vinegar and water solutions. This makes it easy to clean adjoining stainless steel surfaces as windows are cleaned. These products are also suitable for other light cleaning requirements, but they will not remove heavier fingerprinting.

Mild detergent and degreaser solutions will increase cleaning effectiveness. If there are chlorides (coastal or de-icing salts) on the surface, cleaning effectiveness is increased by a proprietary additive specially formulated to improve removal.

Heavy fingerprints, grease, and oil

Heavy grease and oil deposits can be removed with vapor or steam de-greasing, high-pressure water jets, or alkaline or emulsion cleaners. Hot-water power-washing with a mild detergent or oil-free citric acid solution can also be effective. Some household oil-free citric acid cleaners and degreasers effectively remove many heavier fingerprint, oil, and lighter grease deposits.

Proprietary industrial strength degreasers, such as alkaline formulations with surfactant additions, are effective on heavier oil and grease deposits. Any new product should be tested on a small stainless steel surface before use to ensure it does not cause color change. Manufacturer instructions for application and surface rinsing must also be followed.



After 50 years of oil and wax 'cleaning,' the stainless steel in this lobby was dark from dirt and grime accumulation and had some scratching (left). The panels were taken down, cleaned with dishwashing detergent, refinished with non-metallic abrasive pads, reshaped and reused in the new design (right). Any unused metal was recycled after the reshaping. Photo at right courtesy of IKM

Clear coatings, oil and wax

Stainless steel provides the best corrosion resistance when the surface is clean and exposed to oxygen. Clear coatings prevent oxygen exposure and can potentially cause corrosion problems and increase maintenance costs. The most problematic coatings are those that peel or delaminate; they create crevices as they fail, increasing corrosion problems.

Coatings increase surface reflectivity and can yellow over time. When applied in the field, service life is typically relatively short; repeated removal and replacement can be more expensive than simple cleaning. Further, some require such hazardous chemicals for removal that contractors frequently remove them by abrasion, destroying the initial surface.

If a coating must be applied to hide fingerprints or improve corrosion performance, one should select products that naturally dissipate or are easily removed to avoid finish damage—examples include oil, wax, and silicon mixtures. With the exception of lanolin polishes that dry hard and add natural corrosion protection, oils should not be used in exterior applications, swimming pool environments, or any other location with airborne dust or corrosive substances (e.g. salt or pollution), as they increase surface accumulations and can cause corrosion. Carnauba wax and similar automotive waxes that dry hard are also acceptable, but do not provide a corrosion-inhibitor.

Oil, wax, and silicon coatings can be helpful in indoor locations where fingerprinting is a concern. It is important to select products carefully since some do not harden and accumulate dirt.

Hydrochloric acid

Hydrochloric acid (i.e. muriatic acid) is very corrosive to construction materials; it should never be used for cleaning tile, concrete, or masonry near stainless steel. Concentrations of as little as 0.1 percent can cause room temperature corrosion of Type 304/304L (UNS S30400/S30403).

If there is accidental exposure, the surface should be immediately and thoroughly rinsed with clean water and the acid should be neutralized. Alternative cleaning products are available.

Adherent deposits

Degreasers can be very helpful in loosening some adherent deposits not involving adhesives. If the finish is not mirror-like, colored, or coated, then very fine abrasive powders suitable for cleaning glass can be effective when made into a paste and gently rubbed on the surface. (They should first be tested on a small area to make certain no surface damage occurs.)

The surface must be rinsed thoroughly to remove the white powder residue. A soft cloth or nylon brush can be used to loosen the powder. Calcium carbonate, which is used in toothpaste, is preferred because it does not scratch most finishes and is environmentally neutral. Fine crystalline silica, pumice powders, and baking soda (sodium bicarbonate) are also used. Coarse scouring powders should be avoided as they can contain bleach and can scratch surfaces.

Adhesive removal

Removal of residual adhesive deposits from protective strippable films, posters, and other sources can usually be accomplished without damaging the stainless steel surface. If the supplier can be identified, it should be contacted for removal advice. Several different adhesives are used in construction, and the appropriate removal products vary.

When recently applied, some can be removed with an eraser, mild detergent, vinegar (or ammonia), and water mixture. Plastic bristle brushes and scrapers may assist in removal, but anything that could scratch the surface should be avoided. Non-toxic household adhesive removers are also often very effective. If the finish is not mirror-polished or colored, fine abrasive cleaners suitable for glass can be made into a paste and then gently rubbed on with the grain to assist in removal. A strong solvent may be required, but it should be tested on a small area in advance and washed off completely afterward.

Sealant failure

'Rundown' occurs when fluids are released from sealant, producing dark areas or streaks below the joints as dirt, hydrocarbons, and other substances in the air collect on the tacky surface. The causes can range from poor installation to chemical exposure to normal end-of-service-life deterioration. (See the Failures article from the April 1997 issue of The Construction Specifier, “Premature Sealant Failure,” written by David H. Nicastro and Joseph P. Solinski.)

Discoloration color is determined by the type of particulate adhering to the sealant. This aesthetic problem is different in appearance from the normal rain/dirt runoff patterns occurring at window corners or directly under a joint. The appropriate removal product depends on the sealant type.

Paint and marker pens

Paint and marker pen stains can be removed using proprietary alkaline or solvent paint-strippers after testing the product on a stainless steel sample or in a low-visibility area to ensure

it does not cause any surface discoloration. A soft, nylon bristle brush can be helpful in loosening residue. Some proprietary chemical cleaners can damage sealant—care should be used to prevent inadvertent damage.

Cement and mortar

If cement or mortar is accidentally spilled onto stainless steel, it should be washed off immediately with adequate water before it can set. Otherwise, removing solidified material can be difficult without causing surface damage. If the surface is smooth, it may fall off as it dries. Low-power-washing can also be tried, with the water stream angled to loosen the deposit edge.

If the cement or mortar has been allowed to dry on the surface, dark multi-color alkaline staining may be apparent on the stainless steel surface after the deposit is removed. This can be removed by rubbing a paste of fine abrasive powders and water on the surface. However, if the stainless steel surface is colored or coated with metal, permanent surface damage may occur.

Conclusion

Appropriate cleaning of stainless steel can frequently restore the original appearance of stainless steel. There is generally no reason to use products damaging to the environment or hazardous to workers. Cleaning frequency is determined by the owner's expectations, site conditions, and appropriateness of the stainless steel and finish.

Generally, only occasional cleaning is required to remove surface deposits. However, care should be taken in applying coatings since some can adversely affect corrosion performance. With appropriate procedures and products, stainless steel can stand the test of time.

Guidelines for Corrosion Prevention

Guidelines for Corrosion Prevention

DESIGN, FABRICATION, MAINTENANCE AND SURFACE FINISH

PRACTICAL GUIDELINES FOR DESIGN AND FABRICATION

This section provides an overview of general design considerations. Examples of designs that can cause corrosion and alternate designs that help prevent corrosion are illustrated. Qualified, experienced stainless steel fabricators and contractors will be familiar with these guidelines, but it is important for the designer to know them as well. When designing and fabricating in stainless steel:

- Evaluate the environment and probable cleaning regime to determine the likelihood of accumulated deposits and air pollutants such as soot, iron oxide particles, sulphur dioxide, and salt exposure before selecting the stainless steel grade.
- Use a design that allows rain to rinse away surface deposits.
- Specify a higher grade of stainless steel in sheltered areas that are not washed regularly.
- Seal crevices in areas exposed to moisture and/or aggressive corrodants.
- Use a stainless steel fastener with equivalent or higher corrosion resistance than the component being fastened.
- Never use carbon steel brushes or steel wool on stainless steel. Use stainless steel brushes or soft-bristle brushes made of an inert material.
- Never use hydrochloric or muriatic acid on or around stainless steels. If muriatic acid is accidentally splashed on stainless, it should be washed immediately with large quantities of water before the acid severely damages the stainless steel.
- Dissimilar metals should be electrically isolated from each other in applications where they may get wet. This can be achieved using inert washers, protective coatings like paint, and other physical barriers that prevent direct contact. Dissimilar metals should be avoided in applications where standing water is likely and it is not possible to insulate the metals.
- If the design requires welding sections heavier than about 0.125 inches (3 mm) and the weld area will be exposed to a corrosive environment, use low carbon versions of the stainless steels (e.g., 304L or 316L) to reduce the risk of sensitization and improve weld corrosion resistance.
- If a filler metal is used in welding, its corrosion resistance should be equivalent to or greater than the corrosion resistance of the base metal.
- Weld imperfections, such as blowholes, cracks, slag or weld spatter, are potential sites for corrosion and should be repaired or removed.
- Visible welds should be ground smooth and polished to match the parent metal surface finish, taking care to remove any traces of spatter and heat tint.
- Do not use abrasive polishing or blasting materials that have been used previously on carbon steel. This will embed carbon steel in the surface.
- Clean tools and work areas previously used for carbon steel to remove iron particles and prevent their transfer to the stainless steel surface.
- Protect the stainless steel during fabrication, shipping, and installation with paper or strippable plastic film.
- Clean grease, oil, lubricants, paint, and crayon markings from the surface prior to welding to prevent weld contamination. Surface chromium depletion and a subsequent reduction of corrosion resistance may be caused by inadequate gas shielding during welding or insufficient heat tint removal.

Stainless steel is specified for its corrosion resistance and long service life. Even with appropriate grade selection, corrosion problems can occur in crevices and areas where water collects. The design rules for other architectural metals are also important for stainless steel. Examples of design details that can lead to corrosion problems and alternatives that minimize the potential for corrosion are shown in Figure 1.

Surface finish

Surface roughness is an important factor in corrosion performance in exterior applications. Table 1 provides an international cross-reference to common finishes and Table 2 and Figure 2 show the range of surface roughnesses associated with those finishes. Typical surface roughness ranges vary with the supplier. Polished finishes produced specifically for architecture are usually smoother, and lighter gauge sheet and strip generally have smoother finishes than heavier gauges.

Research has shown a direct correlation between surface finish roughness and the likelihood of corrosion.2 Smoother surface finishes typically retain less dirt and debris, and provide better corrosion performance than rougher finishes. For that reason, European Standard EN 10088 recommends a surface roughness of Ra 20 micro-inches or 0.5 microns or less for polished finishes used in environments with high levels of particulate, corrosive pollution, and/or salt exposure and in applications where regular maintenance is unlikely. Similar guidelines should be followed for finishes produced by means other than polishing.

For most coined or embossed finishes, the roughness of the finish should be measured prior to pressing the pattern into the metal. There are two exceptions. If the coined or embossed finish simulates another finish such as abrasive blasting or polishing, or if the pattern is likely to retain dirt and debris, the roughness of the final finish should be measured.

Table 1 International cross-reference to mill and polished finishes

Finish Type	USA (ASTM A 480)	Japan (JSSA)	European Standard EN 10088
Mill	2D	2D	2D
	2B	2B	2B
	Bright annealed (BA)	BA	2R
Polished	No. 3	No. 3	1G or 2G
	No. 4	No. 4	1J or 2J
	–	No. 240	1K or 2K
	No. 7	No. 7	1P or 2P
	No. 8		1P or 2P

Note: In the European Standard, 1 indicates a hot rolled product and 2 a cold rolled product.

Dirt accumulations are greater on horizontal or semi-horizontal surfaces and in sheltered locations. If the location tends to collect dirt and/ or a rougher surface finish is selected, it may be necessary to use a more corrosion-resistant stainless steel to achieve the desired long-term corrosion performance.

Electropolishing is sometimes used to make components with a No. 3 or No. 4 polish brighter and more reflective. It also smoothes the surface,

typically reducing the original surface roughness by about half, which can improve corrosion performance.

Some finishes have obvious directionality. These include the rougher polished (No. 3 and No. 4) and embossed finishes. The surface will collect less dirt and rain washing will be more effective if the finish grain orientation is vertical rather than horizontal.

Maintenance

Stainless steel looks best and provides maximum corrosion resistance when it is cleaned regularly. Corrosion may occur if dirt, grime and surface stains containing corrosive substances are left on the stainless steel surface. Routine cleaning preserves stainless steel's appearance. The frequency of cleaning will depend on aesthetic requirements, severity of the environment, suitability of the stainless steel grade and finish for that environment, the presence or lack of heavy rains to clean the surface, and the design.

When possible, designs should take advantage of natural rain washing and include building washing systems. Designing for rain cleaning and stainless steel grade and finish selection are particularly important in structures that will

Figure 1 Unsuitable metal design details for locations with potential corrosion problems and typical solutions[1, 21]

Problem	Typical Solution	Problem	Typical Solution
Backs of double angle create a crevice where dirt and moisture can accumulate	Design as single angle truss, or use T-section	Dirt accumulates and moisture penetrates into crevices created by bolted joints	Consider using welded or butt-welded joints or sealing with mastic
Potential corrosion due to angles creating a crevice	Close crevice by sealing or welding	Lapped joint creates ledge exposed to weather	Arrange joint so that ledge is not on the weather side
Sharp corners and discontinuous welding	Round corners and continuous welding	Gussets create pockets for dirt and moisture	Design without gussets or allow drainage
Channels or I-beams could collect dirt and moisture	Invert section or design to avoid retention of moisture and dirt		

Figure 1 (cont'd) Unsuitable metal design details for locations with potential corrosion problems and typical solutions[1, 21]

Problem	Typical Solution	Problem	Typical Solution
Possible crevice corrosion where stainless steel enters concrete	Avoid crevice corrosion with sealant	Angle collects dirt and moisture	Invert angle
Base and bolts at ground level result in water retention and corrosion	Column baseplate above ground level. Holding-down bolts not exposed to corrosion. Stalk of column well clear of ground level. Slope for drainage.	Welding only the bottom of the joint creates a crevice	Weld the top of the joint
		Reinforcement prevents drainage	Leave gap to allow drainage
		A crevice is created by welding a curved member at one end	Use a straight member and weld both sides

Table 2 Typical surface roughness ranges for cold rolled sheet and strip from North American stainless steel suppliers

ASTM A 480 Finish Descriptions	R_a and RMS Surface Roughness Equivalents			
	R_a, micro-inches	R_a, microns	RMS, micro-inches	RMS, microns
2D	5.0–39.0	0.13–1.0	6.4–49.2	0.16–1.25
2B	2.4–20.0	0.06–0.51	3.0–25.1	0.08–0.64
BA	0.5–4.0	0.01–0.10	0.49–4.9	0.01–0.13
#3	10.0–43.0	0.25–1.10	12.3–54.1	0.31–1.37
#4	7.0–25.0	0.18–0.64	8.9–31.5	0.23–0.80
6	12.0–18.0	0.30–0.46	14.8–22.6	0.37–0.57
7	2.4–8.0	0.06–0.20	3.0–9.8	0.07–0.25
8	0.74–4.0	0.019–0.10	0.9–4.9	0.02–0.13
Super No. 8	0.4–0.8	0.01–0.02	0.5–1.0	0.01–0.03
Hairline	5.5–8.0	0.14–0.20	6.9–9.8	0.18–0.25
Electropolished	4.0–16.0	0.10–0.41	4.9–20.2	0.13–0.50

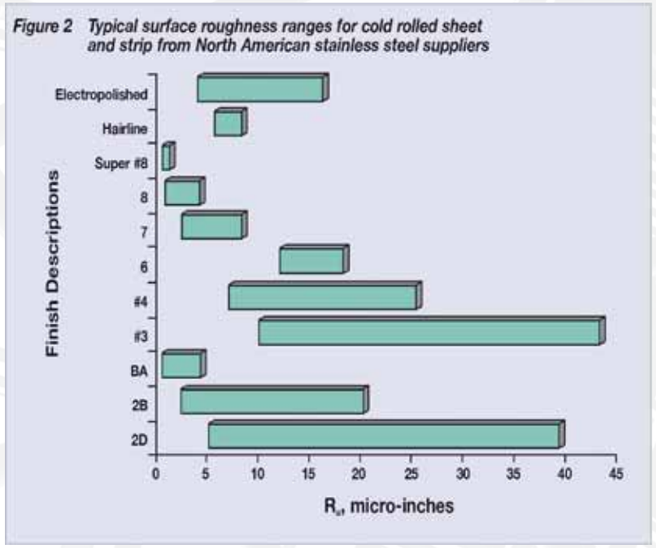
Note: Data for sheet and strip were obtained from North American suppliers. The highest and lowest values were used to create the surface roughness range and include both light and heavy gauges. Lighter gauges generally have smoother finishes than heavier gauges and would be at the bottom end of the range. Surface roughness will vary across sheet width and length.

never or rarely be cleaned, like industrial buildings and monumental structures such as the Gateway Arch.

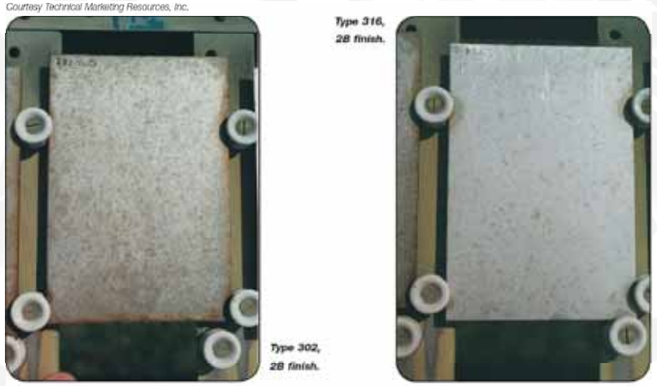
Stainless steel is easy to clean and regular cleaning with appropriate products will not change the appearance of the finish over time. Loose dirt is rinsed off with clean water. A mild detergent or 5% ammonia and water solution is applied with a soft clean cloth. This is rinsed off with clean water and then wiped or squeezed dry. A soft-bristle brush can be used to loosen dirt and a degreaser to remove oil stains. Cleaning products should not contain chlorides or harsh abrasives.

If the surface has been neglected or there are stubborn deposits, a mild, non-acidic, non-scratching, abrasive powder that does not contain chlorides can be used on bare stainless steel. More aggressive cleaning can damage the finish and the supplier should be consulted before proceeding. It is best to test cleaning products on a stainless steel sample or inconspicuous location before use. Although buildings can often be restored to their original appearance after many years of neglect, remedial cleaning is more costly and can have uncertain results. Cleaning guidelines can be found in the NI publication 11 014, Guidelines for Maintenance and Cleaning.

Figure 2 Typical surface roughness ranges for cold rolled sheet and strip from North American stainless steel suppliers



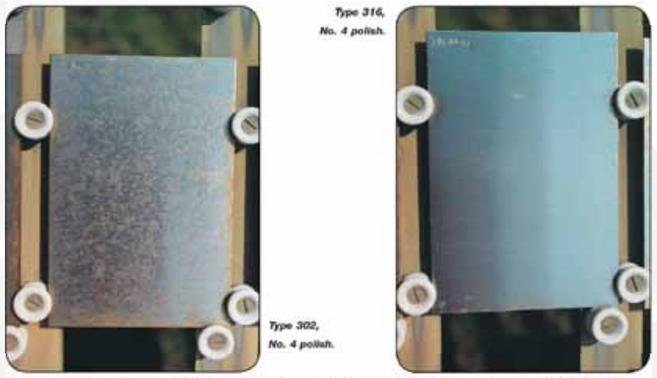
Courtesy Technical Marketing Resources, Inc.



Type 302, 2B finish.

Type 316, 2B finish.

Courtesy Technical Marketing Resources, Inc.



Type 302, No. 4 polish.

Type 316, No. 4 polish.

These Type 316 and 302 samples were exposed 800 feet (250 metres) from the ocean for forty years at Kure Beach, North Carolina with only natural rain cleaning.

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Architecture Building & Construction Applications in India

Image Courtesy: Catherine Housea

Architecture Building & Construction Applications in India

Indian Examples of SS in Smart cities and Sustainable Buildings and Infrastructure

National Museum of Indian Cinema

Stainless Steel has been the pre-eminent material for projecting a progressive, modern image of architecture and building for over last many years where long-term durability is the primary consideration.

Stainless Steel has yet again found its way in a new building in Mumbai, a coastal city where it has been used as a façade to counter the effects of corrosion and giving it a modern look.

First national museum for Indian cinemawill be housed in a heritage Building called Gulshan Mahal at Peddar Road Mumbai. A new swanky modern building,recently made of Glass and Stainless Steel, is also going to become a part of National museum. This will be the first museum dedicated to films in India. Both the building will be displaying the chronology of India's cinematic journey. The Phase I of the museum in the heritage Building will be mostly displaying static artefacts and telling the story of Indian cinema in a chronological form whereas Phase II of the Museum, being housed in the modern building will sport over 40 interactive galleries devoted to cinema across India, journey of Indian cinema from silent era to talkies,

technology and creativity in cinema as well as a Children's activity gallery.

Since the Part II of the project is to show the modern cinema and technology, the project authority wanted to build something modern and sustainable reflecting the agility, vibrancy and aesthetic of Indian Cinema. A part of Phase II building, a NBCC project done by M/s Shapoorji Pallonji & Company Private Limited, is having Stainless Steel on the façade of the building. Being in coastal region selelction of grade and surface finish is utmost important and keeping this in mind stainless steel grade 316L was selected. Steel authority of India Limited (SSP) supplied 45 MT of 1.6 mm thick sheets.

When asked why stainless steels were preferred, one of the field experts informed us that environments with higher pollution levels or coastal salt exposure causes accelerated deterioration of the most common type of materials. For example, the corrosion rates of copper and aluminum are typically 10 to 100 times more than that of stainless steels in such environments. When stainless steel properly selected and maintained it can remain attractive for centuries.

The ability to wrap buildings in relatively lightweight skins and the simultaneous introduction of new finishes introduced a broad range of design possibilities. Interest in sustainable design design has grown significantly around the world. Stainless steel illustrates expectional performance, cost effectiveness as an architectural design material and its appeal for sustainable design where long-term performance is expected.

Smart Poles in Stainless Steels for a Smart City

The concept of smart city has brought a great opportunity for increasing the usage of stainless steel in the country. Stainless steels are known

for its aesthetics, corrosion resistance and strength. If there is one product which needs combination of all these properties it is these smart poles. These day normal electric poles are getting a lot of attention from cities around the world and are getting transformed into smart poles. These new transformed streetlights are now improved to work as smart poles having environmental monitoring station, a wi-fi hotspot, a cctv camera apart from the normal lightings

Recently new delhi municipal council has come up with smart pole project. A normal electric pole is being transmuted in to a smart pole with smart led lights air sensors, wi-fi connectivity and cctv cameras. Air sensors are to monitor pollution parameters and will send live feed to central command. Wi-fi installed at these poles

are to provide connectivity nearby and CCTV cameras on these poles will also help to upgrade security infrastructure in central Delhi areas. These poles will have hydraulically operated underground cabinet for hosting telecom equipment.

These equipments both on the top as well as in the enclosure below required a material with good strength, suitable for extended service life and maintenance free. Stainless steel was selected by NDMC for the construction of these poles to full and achieve all these requirements. These poles are 9 to 12 meters height and made in 316l grade stainless steel

In the first phase 55 smart poles have been installed in areas of Connaught Place, Baba Kharag Singh Marg, Janpath, Kasturba Gandhi Marg, Sansad Marg, Barakhamba Road, Tolstoy Marg.

Similar smart poles are being erected in Indore, Bhopal, Kalaburagi, Dharwad and Vizag. At vizag, these poles will be integrated with command control centre of disaster management system. Most of these cities are implementing this project on dbfo basis in ppp model.

Smart poles are all about increasing urban efficiency, while at the same time keeping the clutter of street infrastructure item to minimum. Because they can incorporate software controls, and sensors that can receive and transmit information, they support all kinds of smart city applications. It is believed that in times to come these smart poles will be installed in every city considering the compact usefulness and stainless steels will always remain the first choice for material of construction.

Afghanistan Parliament Building- Load Bearing Stainless Steel

The Afghan parliament building will be the most prominent symbol of Indian efforts to help Afghanistan. One of the highlights of the under construction parliament building would be its DUPLEX stainless steel dome of 15 meter diameter and 4.5 meter height, which would cover the main assembly hall. In the picture shown above is under construction parliament building which has been made purely from

square and rectangular hollow sections of size 125 X 125 X 6 mm, 92 X 92 X 6 mm and 125 X 60 X 6 mm of duplex 2205 grade, this dome weighs approximately 20 tonnes. Duplex 2205 is a nitrogen enhanced duplex stainless steel that was developed to combat common corrosion problems encountered with the 300 series stainless steel.

Stainless Steel Support Structures for durability and longevity

Stainless Steel structural elements have become increasingly important and popular in cutting-edge design of structures. Stainless Steels corrosion resistance and its unique properties such as high strength to weight ratio, ability to make light weight structures and enhanced safety has enabled it in becoming a popular choice of material giving durability and longevity to structures.

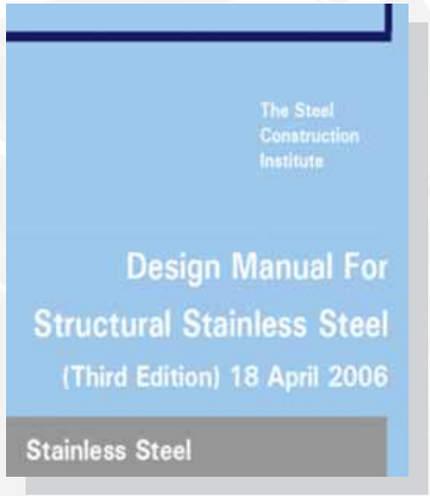
Today various industries are in need of a structure which has minimum problem of maintenance and a better campaign life. Load bearing Structures made in steel have to face severe problems of corrosion and therefore it needs protective coatings (e.g; paint) to prevent structural deterioration. This requires regular maintenance of structures resulting in loss of productivity and increaser in maintenance costs. In any industry productivity and safety remains a major focus area and both need to go hand in hand. Therefore, it becomes essential that you select a material which ensures safety as well as long service life.

Recognizing these needs and subsequent needs of the project, Reliance India Ltd., the largest private sector corporation in India, hired a team of structural engineers to design a carbonate tank made and supported by structures of stainless steels to ensure good campaign life crucial for their production chain.

For a new facility development on site, reliance India ltd. joined hands with RaajRatnaTubes for making structural section support for the tank. The structure supports the weight of the tank during top to bottom type of erection. This roof structure is a typical truss structure in a radial arrangement. It spans a diameter of 16500mm weighing almost 15 tons.

Different grades of Stainless steels are selected in different combinations of strength and corrosion resistance depending upon the severity of location, temperature, pressure and cyclic loading requirements. For this project dual grade 304 austenitic stainless steel was selected for its ability to have high strength and ductility together with excellent corrosion resistance. High strength of dual 304 stainless steel enabled designer to design lighter structures. RaajRatna tubes fabricated this whole structure with rectangular hollow section and other stainless steel products like flat bars and plate. The final structure was made and shipped in ready condition and it required only to assemble the sub-assemblies by fastening and other joining methods.

Stainless steel sections for load bearing critical structures are fast gaining popularity. Apart



from its longevity and maintenance free service life it offers added advantages of safety such as ability to retain its structural strength even at elevated temperatures such as in case of an accidental fire. In seismic zones designers consider higher strain levels and this stainless

steels,having the ability to work harden, offers higher levels of strength along with required ductility.

To know more about how to design with stainless steel you can download the publication "Design Manual for Structural Stainless Steel' third edition from http://www.steel-stainless.org/DesignManual

Stainless Steel – Expanding Horizons

Over the last year SAIL has come up with some of the most inspiring public installations made in stainless steel representing the versatility of this wonder metal. These various public installations truly highlight the excellent engineering properties in combination with beauty of stainless steels.

"TREE OF PROSPERITY"

"Tree of Prosperity" carved out of Stainless Steel has been erected by Salem Steel Plant, a unit of Steel Authority of India Limited.

They have named it "Tree of Prosperity" because they feel that it symbolizes the perpetual growth and prosperity that is envisioned for Salem Steel Plant. Its trunk symbolises the infrastructure of the plant & equipment and the branches represent various departments. The leaves symbolise the Salem Steel Collective who photosynthesize the sunlight (resources) and fructify them into fruits, ie,the output.

The Tree of Prosperity has been crafted aptly in Stainless Steel which manifests beauty, permanence and eco-friendliness. To have conceived a gleaming Coconut Tree, also known as MAHAVRIKSHA, in stainless steel, may be first of its kind in India and is indeed a unique effort.

This Stainless Tree measures about 5 metres in height, with a varying diameter of 200 to 350 mm through its trunk. Its leaves have been crafted out of stainless steel of grade 430 while its stem is made of grade 304. The outer cladding is of grade 430 and the inside SS pipe is made of grade 304.

CHARKHA – Symbol of Swadeshi Kranti by Mahatma Gandhi – Picture will be brought here

Continuing the zeal of bringing Stainless Steel in the public art and monuments, Steel Authority

of India Ltd. along with Khadi & Village Industries Commission and New Delhi Municipal Corporation haveput up a giant CHARKHA – a symbol of Swadeshi Kranti by our Father of Nation Mahatma Gandhi, near Khadi Gramodhyog Bhawan over Palika Bazar at Rajeev Chowk, New Delhi. It is part of Charkha Heritage Museum and is 25 ft long and 13 ft high. It has been fabricated out of Stainless Steel of Grade 316L supplied by Salem Steel Plant of SAIL.

Lion – Symbol of Make in India Initiative

To inculcate the spirit of "Make in India" amongst the people at large and visitors and employees of SAIL, a collage of SAIL PRODUCTS AND APPLICATIONS in the form of Lion was displayed at Pragati Maidan, New Delhi during IITF 2017. Now it is getting installed at Ispat Bhavan, corporate office of Steel Authority of India Ltd., New Delhi.

Lion – Logo of Make in India initiative of Honourable Prime Minister of India Shri Narendra Modi, has been made of Stainless Steel of Grade 316L. This artifact is Hollow and 8ft long x 4 ft tall and 21/2 feet widein the torso.

Surya Kanti – Solar Tree

New Delhi Municipal Corporation has installed a Solar Tree of 6.8 meter height with 9 petals at PalikaVatika near the Palika Bazaar at Rajeev Chowk, New Delhi. It generates 1.26 KW of

power, having mobile charging stations and interactive panel, in addition to LED lights. The stainless steel Solar tree fabricated by Steel Authority of India Ltd. is crafted out of 304 grade stainless

Gangaben Kutir

Gangaben Kutir – Weavers Chamber is a part of the CHARKHA heritage museum. It is an air-conditioned chamber where weavers are engaged in spinning continuously. This all-stainless steel air-conditioned cubicle and the adjacent stainless steel information kiosk have been fabricated and supplied by SAIL. These are all crafted with 304 grade stainless steel produced by Salem Steel Plant. In the same

garden leading to the Heritage CHARKHA museum as well as other popular public convergence spots in the Connaught place as well as the Defence Colony market, SS BOLLARDS supplied by SAIL have been installed by NDMC and SDMC. These LED lit bollards crafted with 304 grade stainless steel add light to lusture.

A 'Bat of Honour'

Such is the craze for the game of cricket in India that it is said "if cricket is a religion then Sachin is the God". The legendary batsman Sachin Tendulkar is one of the most successful batsman in international cricket with a statistics like 100 international centuries and over 15000 Test runs.

The Master Blaster always had this unmatched ability to adapt to format, physical conditions and the situation the team is in. He was selected to play for the Indian side in the year 1989. Readers of this magazine can recall and derive pleasure from the fact that it was exactly 25 years back that ISSDA was formed and started its journey parallel to Sachin.

To pay a rich tribute to retired batting legend Sachin Tendulkar a monument in the form of a large stainless steel bat was unveiled in Mumbai. Sachin's emotional farewell speech- has also been etched on a plaque below the installation.

This monument has been installed on the Carter Road Promenade - close to Tendulkar's residence. It is the largest stainless steel bat in the world - standing more than 25 feet high and weighing over two tonnes.

The core idea behind the concept was to make it timeless and iconic like Sachin, his 'magic wand' bat is sculpted in a scale to capture true weight of his bat which with each shot connected millions of hearts across India.The installation is intentionally created for human interaction, giving viewer a broader sensory experience and also to be enjoyed from a distant view. The bat is angled to give the fun illusion that the fan is holding Sachin's bat.

According to the designer Mr. Abhijit Bansod "We chose toughest, yet most beautiful material stainless steel, because of its strength, toughness, corrosion resistance and flawless finish. It also symbolize the flawless cricketing career of India's master blaster"

This project was sponsored by TV Network-18 and KBS Foundation.

Modern and Maintenance Free Car Parking in Stainless Steel

M/s Jindal Architecture Ltd has designed, fabricated and installed the first of its kind elegant made in stainless steel car park structure at the office premises of Central Vigilance Commission (CVC), an autonomous body under the Government of India.

Car Park Shades made in stainless steel have gained appreciation for high strength and durability. The high strength of stainless steel help the designer to use lighter and thinner structures in designing it to have more access to driveway with easily accessible entrance. High corrosion resistance material like stainless steel reduces the requirement of regular maintenance and painting.

This car parking has been made of quality stainless steel grade AISI 304. Approximately, 8.5 tons of Stainless Steel has been used. The total length of the car parking is 68 MTR. The Arch design of the parking is a contemporary design which blends perfectly with the architectural beauty of the building.

The use of stainless steel in car park structures is becoming increasingly popular as it proves to be economically advantageous and aesthetically pleasing. We are likely to see more of such beautiful designs coming up in places such as malls, hospitals, apartments, stadiums, even in homes etc.

Stainless Steel at Chennai Arignar Anna Zoological Park : For Animal Safety

Arignar Anna Zoological Park is one of the modern and scientifically managed zoos of the Country. It is also the first zoo in India, which was started during the year 1855.

Recently zoo authorities have taken the initiative to replace the existing steel enclosures with stainless steel for its carnivorous animals like Tiger, Leopard, lions, Jackals etc.

Animals urinate and do it often to advertise their territory. A carnivore's urine is acidic in nature and can speed up the corrosion process of material prone to form rust. The living enclosure of such animals made of steel has shown heavy rusting in past. Zoo authorities informed that replacing an enclosure and fitting new one is very stressful not only to them but to the animals too. With time rusting not only weakens the enclosure but broken or sharp edges create safety hazards for both animals and their keepers. Animals has tendency to rub their body against the enclosures which can result into injury and if it's from rusted steel then can cause septic. Many such cases of septic can lead to death.

So zoo authority has chosen stainless steel which fulfilled their criteria a material having high

strength, good corrosion resistance, long life and minimal maintenance. The long service life offered by stainless steel will prove to be cost saver.

First few enclosures have already used approximately 5 tonnes of Stainless Steel of grade 304. It was informed that they have planned to convert other enclosures in stainless steel in a phased manner.

Other than this Zoo authority also realized the aesthetic and long lasting values of stainless steel and has used it for the ticketing areas, railings and other guarding purposes.

The Softer Side of Stainless Steel:

An Installation at Bangalore International Airport

Next time when you walk through the arrival section at Bangalore International Airport you will pause for a moment to appreciate a 20 feet by 10 feet art installation named 'Flight'.

This stainless steel artwork is an ideal reflection of the modernity of airport and represents the city's heritage as the aerospace hub of India.

The creator of this art, Mr. Yusuf Arakkal is a Bangalore based internationally acclaimed artist. He is engaged in creating site-specific large sculptures, installations and murals. His creations are in a wide variety of material including stainless steel.

Quote: He says “I love to work with stainless steel for its aesthetics, long life, ability to be formed into intricate shapes and freedom to experiment in combination with other metals”

Mr. Arakkal drew inspiration from his twenty year old association with Hindustan Aeronautics Limited (HAL), Bangalore, where he designed aircraft components as a machinist. This stainless steel and copper art work, mounted on synthetic granite has fifty-five separate pieces joined together to bring alive the 'Flight'.

Stainless Steel Bus Shelters Reaching 2-Tier Cities – A Dominos Effect

Readers of this magazine can recall that very first group of stainless steel made Bus Shelters were installed in the National Capital, Delhi, more than a decade ago. Stainless Steel on account of its corrosion resistant, light weight structure, Aesthetics and cleanliness quickly became the first choice. Over the years, it remained maintenance free and did not require any regular paintings. Apart from this, these swanky Bus shelters became a popular place to put advertisements thereby neutralizing additional initial costs just over a period of few years. Now this story has already been replicated into other metro and big cities in India.

The good news is that stainless steel bus shelters have now started gaining acceptance in tier II cities in the country.

Keeping pace with changing face of developing cities under the "city operational plan" mandated by ministry of urban development for running city service buses under Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Bihar Urban Infrastructure Development Corporation (BUIDCo) has to develop stainless steel bus shelters.

A Newly Built Stainless Steel Bus Queue Shelter at Patna

Commencement of Stainless Steel Bus Shelters in Gurgaon

Since the public bus services started in Gurgaon, the city finally has bus queue shelters made of stainless steel. Being built at a cost of Rs 98 lakh, these shelters are probably the first ever that have come up in the city.

These bus shelters are similar to the stainless steel ones that are already there in Delhi. Initially these shelters have come up in seven different locations in Gurgaon and the final count will go up to around 70.

M/s Ozone Overseas Limited offering architectural hardware solutions have bagged this project and successfully completed seven stainless steel bus shelters in Gurgaon, Haryana.

Each bus shelter uses about 1.5 tonnes of 304 grade stainless steel.

The unique stainless steel bus-q-shelters are an eclectic mix of modern design, aesthetics and environment friendly structure. These bus shelters provide a comfortable seating arrangement along with litter bins.

In the second phase, the MCG will construct seven more bus shelters and these once will come up in new Gurgaon.

Ozone Overseas Private Limited has already started installing 216 swanky queue shelters at 108 locations across the city. 82 Bus shelters have already been installed in various parts of the city. Each bus shelter uses about 1.5 tonnes of 304 grade stainless steel.

We believe this success story will keep on multiplying considering the fact that present Government of India has committed to building 100 smart cities in future.

Modern Stainless Steel Bus Queue Shelters with Solar panels

Continuing its contribution towards Smart City initiative, SAIL has fabricated and installed two solar powered bus shelters at Shanti Path, New Delhi on behalf of NDMC. Crafted with 304 grade stainless steel, these bus shelters are designed to generate approx. 5kw power. Besides being self-reliant in generating electricity for bus shelter requirement, it will help government in generating electricity through solar power. NDMC is planning to build more such solar powered stainless steel bus shelters.

Infrastructure - Stainless Steel enters Rural India

Probably for the first time, Stainless Steel is being used for bus queue shelters in Rural coastal areas of Karnataka- Karwar. Under CSR, PepsiCo was convinced to use Stainless Steel as they were made to understand lifecycle costing and longevity advantages connected with this material. As the life increases multifold in comparison to other material they can advertise for a much longer period.

The designing was done by Stallion to keep the cost very economical and still be structurally strong to take various load factors involved in that geographical area. To ascertain this finite element analysis for structural integrity was done. The whole process was rooted through an NGO - Habitat for Humanity India. 10 Bus Shelters, each weighing 450kgs in 304 grade mirror finish was used.

This could become a role model project for Rural India, if perused systematically.

Stainless Steel Addressing Sanitation Challenges

Thiruvananthapuram-based Eram Scientific Solutions, a R&D social enterprise in the water and sanitation sector, has come up with a revolutionary electronic toilet models made in stainless steel which are durable, vandalism proof and hygienic. Understanding the usefulness after a successful installation and operation of these smart toilets at many places in the country, Madurai City Corporation has launched two such e-toilets in Meenakshi Park adjacent to Meenakashi Amman Temple.

The temple town of Madurai had long been affected by lack of proper toilet facilities. Providing toilets to the vast number of tourists and pilgrims was indeed a Herculean task. And it was not just prudent to go back to the same old traditional models of toilets for addressing the dire challenges of sanitation. What was needed is revolutionary solutions that can solve the grave issues of sanitation.

Alternative models like bio-toilets and portable toilets had many challenges, which include, among others, emptying the sludge and the issue of the lack of water in many places. Here, the ideal solution was automatic toilets or eToilets. Fully-automated, electronic-operated and sustainable e-toilets ideal built in stainless steels for Indian situations.

Eram's pre-fabricated public eToilets made of stainless steel are integrated with user-friendly electronic interfaces, to ensure cleanliness and hygiene to every user. Fitted with solar panels, the eToilet is programmed to turn on the lights and fan when a user enters, flush 1.5 litres of

water after the first three minutes and 4.5 litres after a little longer and clean the floor after every ten users.

Already, Eram has installed around 2,000 eToilets and 400 sewage treatments across 20 Indian states, showing the acceptability and ideal nature of the model in the Indian scenario. While Chennai installed 200 Eram e-toilets, Bangalore have installed 100 of them.

eToilets features self-cleaning mechanism, such as automatic pre-flush, automatic after-flush, automatic platform cleaning, automatic lights and exhaust fans. It has LED indications, overhead water tank, GPRS connectivity for online tracking, sensor-based electricity and water conservations, coin-validated entry, voice guidance, etc. They are completely automated and unmanned with remote monitoring capabilities with electrical, mechanical and web-mobile technologies incorporated. The entry, usage, and cleaning of e-toilets are remote-controlled and monitored. They are defining futuristic solutions in public sanitation by providing a network of connected eToilet infrastructure. Apart from this, it specifically focuses on the school sanitation sector, where students, especially girls, have a safe and hygienic place to go.

The e-toilet facilities of Eram are well-connected and users can easily identify the presence of the nearest unit through a free downloadable app from Google play store. It provides a host of real-time data on the performance of eToilets like number of usages, timestamp of usages, number of coins collected, water low indication, flush counts, complaint registration and report generation along with graphical representation of these data.

Stainless Steel not only helps in maintaining cleanliness but its light weight yet robust design helps in installing it faster and offers better protection against vandalism. It is more likely that this product will keep gaining acceptance in fulfilling 'Swatch Bharat Mission'.

One More Step Towards Clean and Green India

On October 2, 2014 Prime minister of India launched 'Swachh Bharat Abhiyan' (Clean India Campaign) and urged citizens of the country from all walks of life to help in successful implementation of this mission. The mission includes building public toilets with waste disposal systems.

India is home to 1.2 billion people, one sixth of world population. The sanitation coverage in the country in public places in urban areas and household rural areas has always been a challenge. Even bigger challenge is to have access to clean, hygienic and liquid and solid waste managed facilities.

Stainless steel modular toilets provide an appropriate solution for this long-standing problem. In terms of structural strength, product life, maintenance, hygiene, eco-friendliness and scrap value, stainless steel toilets have proved to be better than fibre, mild steel or brick-and-mortar toilets. Due to the modular design, the toilets can be assembled on site, saving time and transportation costs.

Taking on the challenge posed in front of the country, stainless steel industry has come with easy to install individual, cluster and

community toilet facilities built in stainless steel. Recently, Jindal Stainless Arc division has come up with some innovative solution.

These toilets are available in a range of single units and as community toilets of six and eight units, respectively. These toilets have the option of being upgraded to automated bio-toilets (similar technology for Indian Railways retention tanks fitted in coaches developed by DRDE & RDSO) which can convert human waste into gases and water with the help of special bacteria.

These toilets are considered to have a natural life of 25 years. Longer life and lower maintenance cost compensates the higher initial cost within

few years of its use and turns out to be a cheaper alternative compared to other materials.

Stainless Steel can be easily cleaned with non-acidic, mild, chlorine free household cleaning products. Stainless Steels are world wide preferred for public bathroom surfaces exposed to urine, partitions, dispensers, sinks and other fittings because, unlike painted or plastic surfaces, it can be cleaned and sanitized using chemical free steam cleaning also.

Public installations are often prone to vandalism. Stainless Steel is known for its high impact resistance and is very much vandalism proof. Very recently a such modular toilet was installed at Maruti Factory in Delhi NCR region. One of the users has this to say "These Modular toilets are very user friendly and stainless steel helps us to keep it clean 24X7. We are extremely happy and feel lucky to be the first few users of this wonderful innovation".

Stainless Steel Water Storage Tanks: The Right Choice

Stainless Steel Water Storage Tanks: The Right Choice

Potable water is a very serious problem not only in India, but the world over. Water quality has been drastically deteriorating over the years due to pollution and environmental degradation. Water is one of the most essential requirements for all of us. The purity of water significantly depends upon the characteristics of material in which it is stored and used.

The property of Stainless Steel in maintaining the purity and hygiene of food and drinks is well known to everyone. We are already using Stainless Steel in a big way, for milk and food processing, cooking, serving and eating purposes in the form of utensils, containers and various household appliances.

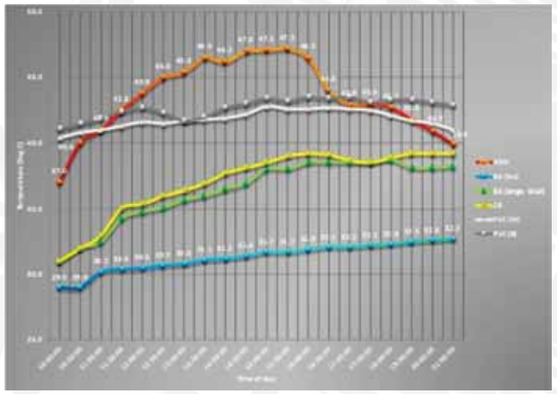
Stainless steel does not absorb pollutants, chemical, pesticides or other contaminants into its surface. If any of these substances find their way into a SS Water Tank one can just wash it out of the tank and re-fill. Depending on the contaminant, a plastic or plastic lined tank may have to be professionally cleaned or in a worst case, thrown away.

The advantages of Stainless Steel water tanks are Hygienic – Water remains in its natural form and 100% microbiological safe.

Reduces risk of water borne diseases Compact and aesthetic design

No algae/fungus formation Value for money for years Easy to clean and practically maintenance free Total drain out provision provided at bottom of tank for easy cleaning.

Available in 100, 250, 400, 500, 1000, 2000, 3000 plus liters in capacity



*Water Heats less in SS water tank*Graph**

There is a misconception that water will heat up more if stored in a SS tank exposed to sunlight compared to conventional plastic water tanks. ISSDA has regularly been disseminating information on why water in a SS tank is cooler compared to that stored in plastics and galvanized tanks. In a study done by a group of technical experts it was found that the water heats less compared to that stored in plastic made tanks. The experiment was done by recording temperature of the water at regular interval stored in tanks made of different materials. On account of its high reflectivity, stainless steel surface rejects almost 50% of sunlight preventing the water to be heated up during the day and it cools faster during evenings and night because of high thermal conductivity. The detailed results can be analyzed from the graph.

Today double walled Stainless steel tanks are available in market which can guarantee minimum variation in temperature of the water over the day.

An independent assessment of market size of popular plastic (High-density polyethylene - HDPE) tanks estimates it at ~15,00,000 tanks per annum are used for the pusrpose of storing water and is adding to the environmental burden rapidly. With the rapid urbanization, decreasing resources and erratic supply of water will force the citizens to depend more on stored water. Today mostly plastic tanks are being used because of low initial cost even with some inherent disadvantages such as fastwear and tear, less environment friendly, poor hygiene and many cases result in life threatening diseases. But over the years of knowledge sharing has empowered people to understand the benefits of using the right kind of material based on Life Cycle Costing of a product a long with taking care of their serious concerns to hygiene.

Certain areas of the country with minimal rain and abundant water shortage, the accumulation of rainwater becomes a necessity and these tanks would prove to be the best alternative for storing of rain water even for drinking purposes with certain precautions during collection.

Although the price of stainless steel water tank of quality AISI 304 is initially higher than the plastic water tank but you are assured of a very long and maintenance free service life. Stainless Steel is fully recyclable and has a good scrap value where as plastic tanks has no scrap value. The life of stainless steel water tank is considered to be 5 times more than any plastic tank.

Stainless Steel: An Ideal Solutions for Leak Proof Maintenance Free Plumbing

Modern Plumbing Systems in Stainless Steel Gaining Popularity

Plumbing systems have a huge impact on our modern lives, though we rarely ever think about them until something goes wrong. Plumbing systems distribute water throughout the building as pipes fitted in or around walls run from a water source into and throughout your building to valves and knobs that control water flow to your sinks, tubs, washing machine, and toilets.

A good water piping system increases the life and safety of the building. The most commonly used material for water piping is carbon steel but it tends to corrode heavily over a period of time and can cause leakages and subsequent damages to structure.

With increasing awareness Indian Architects, designers and plumbing consultants have started looking for alternatives to galvanized iron, PVC or copper to meet the demanding performance requirements from customer going for state-of-the art buildings.

Stainless Steel plumbing is often seen as expensive and crafty to work with but the new and innovative "Press Fit Technology" has made stainless steel to be cost effective and easy to install alternative to most systems.

Apart from the material benefits on account of very low corrosion rate in water, its hygienic, high flow rates and high strength there are some direct economic benefits of it such as

**PIC* - Front of whole Building, Pipe fitted to wall, Press fitting tool old,*

- Expected lifetime of stainless steel system is more than 50 years way ahead of many competing materials
- It requires no additional coating
- No maintenance and replacement results in cost saving
- Lower thickness of pipe on account of high strength thus lower material cost
- High flow velocity allows to use lower diameter pipes thus reducing cost
- With press fit technology (75% less installation time) savings in labor cost
- Savings in installation time results in saving in project overruns.

There has been several projects where benefits of stainless steel has been realized. Central Public Works Department under the Ministry of Urban Development, Government of India has gone for fully state-of-art stainless steel plumbing in one of their residential projects in New Delhi. It wasvery first time when CPWD used SS plumbing system in their projects. In three multi story towers AISI 304 grade stainless pipe system with press fit technology was used.

Indian Institute of Technology, Delhiis building a five storylecture hall in their campus in which SS plumbing system is being used.AISI 304 grade stainless pipe system with press fit technology has been used.

**PIC* - Front of building and Images.*

In a recent project done at Central University of Jammu, District Samba, Jammu stainless steel has been preferred for plumbing at high altitude cold region area.

Stainless Steel Plumbing: Guaranteed supply at minus 40 °C

The Indian "Bharati" research station in the eastern Antarctic, with an area of approximately 2000 m2 and up to 50 inhabitants, has been commissioned in March 2012. This "New Indian Research Station Bharati" was commissioned by the National Centre of Antarctic and Ocean Research (NCAOR), which belongs to the Indian Ministry for Geoscience. IMS Ingenieurgesellschaft mbH (Hamburg) were responsible for the basic design. KAEFER Construction GmbH, with its headquarters in Bremen, was entrusted with the task of the detailed planning and completion of the building. Viega GmbH & Co. KG was responsible for installation of piping system for heating and drinking water.

The year-round provision of heat and drinking water to the 134 containers of the "Bharati" research station is essential in the extreme Antarctic conditions.

This eastern part of Antarctic has to face extreme weather conditions where temperature can fall as low as minus 40°C. This posed a great challenge in maintaining water supply used for heating and drinking and required a proper selection of piping system and material of construction.

Hygienically reliable drinking water installation

When it comes to the drinking water system, hygiene requirements play a decisive role in material selection. Stainless steel is an ideally suited material for potable water applications. Apart from hygiene, stainless steel offers maintenance free life, corrosion protection, low resistance to flow, light weight and ease in installation. The demands were all met by the high grade piping system "Sanpress Inox" made of stainless steel 1.4521 (AISI 444). Grade 1.4521 (AISI 444) is a dual stabilized Molybdenum alloyed ferritic stainless steel. This grade offers excellent corrosion resistance coupled with resistance to stress corrosion cracking making it an ideal material for hot water systems. This grade is also approved worldwide for drinking water applications.

Viega is one of the leading companies in the field of plumbing and heating systems. Viega offers their expert solution in all fields of building services:

drinking water and heating installations, prewall and drainage facilities, gas, solar and compressed-air installations for buildings, industrial plants and shipbuilding.

Indian "Bharati" research station was officially commissioned at the Larsemann Hills on the eastern Antarctic coast. (Photo: KAEFER)

Openings for the drinking water installation realised with the Viega "Sanpress Inox" system made of stainless steel 1.4521. (Photo: Viega)

Proving Its Long-Term Mettle: Longevity, Whole-Building LCAs, and Stainless Steel

Proving its Long-term Mettle: Longevity, whole-building LCAs, and stainless steel

by Catherine Houska, CSI

Whether the project is a new building or major renovation, sustainability is an increasingly important factor in decision-making. Whole-building life cycle assessment (LCA) makes it possible to look at all phases of a building, from material extraction through construction to decommissioning and, when possible, recycling into a 'new' useful material. When it comes to comparing materials, increasingly available data, an ASTM standard procedure, and LCA analysis software are helping design professionals make better choices to reduce the building's carbon footprint.

Service life prediction is necessary for LCA; it makes corrosion-resistant, long-life, high-recycled-content materials like stainless steel an obvious choice, particularly for corrosive exterior applications. This article explains the fundamentals of whole-building LCA, along with the importance of site assessment and using available corrosion data. It provides examples of the stainless steel's long-term performance in demanding environments. (The author would like to acknowledge the support of the Nickel Institute and International Molybdenum Association (IMOA) in the preparation of this article).

Whole-building LCA

Sustainable design focuses on environmentally responsible and resource-efficient construction throughout the project's life. Historically, however, the primary focus has been on the post-construction aspects, including energy and water reduction, maintenance, healthy work environments, renovation, and demolition. While specifiers have long understood materials' environmental impacts can be significantly different, and that premature replacement affects the building's carbon footprint, resources have only recently been available to do a thorough LCA.

The environmental impacts associated with material choices are significant—from extraction (e.g. harvesting, mining) through production, use, and finally, its end-of-life. Those impacts include not only energy and emissions, but also water consumption, pollution, and waste. The International Green Construction Code (IgCC) and the most recent versions of the most widely used voluntary rating systems—Leadership in Energy and Environmental Design (LEED), Green Star, and Building Research Establishment Environmental Assessment Method (BREEAM)—include whole-building LCA as an option, while organizations like American Institute of Architects (AIA) and large owners like the U.S. General Services Administration (GSA) encourage it.

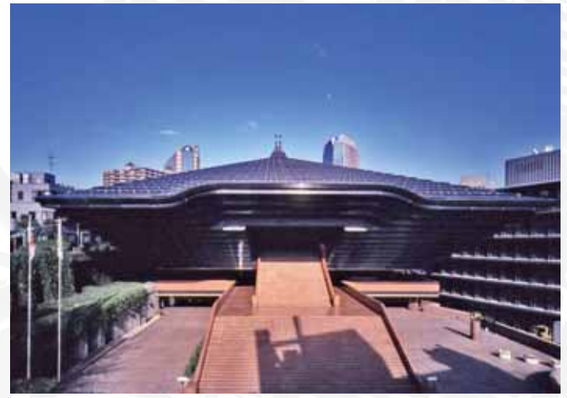
The availability of the product-specific life cycle inventory (LCI) data necessary for LCA has grown rapidly. Europe, Australia, and the United States have created databases, and additional international resources exist. (To use the databases for these three regions, see "European Platform on Life Cycle Assessment," "Australian Life Cycle Inventory Database" and "National Renewable Energy Laboratory life cycle inventory database"). If a product comes from a part of the world that does not have an LCI database, the producer may have Environmental Product Declarations (EPDs) containing the necessary information. Stainless steel is in these databases and many producers have EPDs. LCI data for a specific product varies with different regions of the world because of differences in energy sources and emission levels (among other factors, like recycled scrap availability) so producer- or country-specific data must be used.

LCA requires not only initial LCI data for a material, but also a determination of whether there will be replacements during the expected service life. The LCI of a product must be multiplied by the number of expected replacements during the desired service to determine the total environmental impact of a material choice. A material with lower initial LCI values may actually have a far greater negative impact on a building's total carbon footprint if it is unsuitable for the specific service environment and needs multiple replacements.

There are two International Organization for Standardization (ISO) standards defining LCA principles:

- ISO 14040:2006, Environmental Management: Life Cycle Assessment–Principles and Framework; and
- ISO 14044:2006, Environmental Management: Life Cycle Assessment–Requirements and Guidelines.

ASTM E2921, Standard Practice for Minimum Criteria for Comparing Whole Building Life Cycle Assessments for Use with Building Codes, Standards, and Rating Systems, is compliant with these standards. It was developed specifically to provide the minimum criteria for LCAs of buildings and to support codes and rating systems like LEED and IgCC. Unless it is otherwise specified by the applicable code or rating system, ASTM E2921 requires a building service life of no less than 75 years, which is the average lifespan of a U.S. building.



The electrochemically colored shingles on Tokyo's ReiyukaiShakedon Temple have not faded since they were installed in 1975.Photo courtesy JSSA

Avoiding material replacement

Corrosion or deterioration can lead to aesthetic or structural failure necessitating premature replacement. The first step in determining an appropriate material involves assessing the site environment to determine whether it would be corrosive. The specific environmental conditions that cause deterioration vary with the material, but include temperature, humidity, coastal or deicing salt exposure and pollution. This author developed the International Molybdenum Association (IMOA) stainless steel site evaluation, which is used globally.

One should also look at nearby buildings and structures to see how materials are performing, and ask questions about maintenance and replacement history. A material may look good because it is cleaned quarterly, but, if this level of maintenance is unlikely on your project, the product may fail. Applying the understanding of the environment, it is also important to determine whether material suppliers, industry associations, or consultants specializing in that

product have long-term atmospheric corrosion testing data for a similar environment, since known corrosion rates are the best way to predict failure.

This author has written articles providing specific guidance on comparative metal selection in coastal and deicing salt, soil, and swimming pool environments. (Previous articles by this author for The Construction Specifier include "Designing on the Waterfront" [November 2007], "Stainless Steel for Severe Coastal Environments" [September 2011], "Architectural Metal Corrosion: The De-icing Salt Threat" [December 2006], "Preventing Corrosion in Soil" [April 2006], and a piece co-authored with James Fritz, "Swimmingly Stainless Pool Design" [December 2005]). Further, industry association website resources provide significant additional stainless steel selection resources. (Visit www.imoa.info/molybdenum-uses/molybdenum-grade-stainless-steels/architecture/stainless-steel-selection-system.php or www.nickelinstitute.org/en/NickelUseInSociety/MaterialsSelectionAndUse/ArchitectureBuildingAndConstruction/SpecificationSelectionAndFabrication.aspx for examples).

The stainless steels most commonly used in architecture are:

- Types 304/304L (UNS S30400/S30403, EN 1.4301/1.4307, SUS 304); and
- 316/316L (UNS S31600/S31603, EN 1.4401/1.4404, SUS 316).

Duplex stainless steels are growing in popularity for structural applications. They include lean duplexes and UNS S32205 (which provides substantially more corrosion resistance than Type 316). There is a growing number of aesthetic finishes available for 2205 sheet. (See this author's May 2015 The Construction Specifier article, "Duplex Stainless Steel Revolutionizes Structural Design." Visit www.constructionspecifier.com).

With 60 percent of the world's population living in coastal zones, increased use of deicing salts, and high pollution levels in developing countries, the corrosion resistance of Type 316/316L or comparable stainless steels is typically necessary unless there will be regular maintenance cleaning. In more-corrosive environments like the Middle East, high deicing salt exposures, coastal splash zones, and near volcanic areas, UNS S32205 and other higher-alloyed stainless steels should be considered.

Once the tallest building in the world, New York City's Chrysler Building retains its elegant, glittering, stainless steel Art Deco styling more than 80 years after it was built. Photo courtesy Catherine Houska

Long-term performance

Stainless steel provides documented long-term performance with minimal or no maintenance in a wide range of service environments. The first known architectural applications for stainless steel date from the mid-1920s—they were relatively small or low-profile projects such as entrances and industrial roofs. Many of these early installations are still in service today, including the entrance canopy of London's Savoy hotel (1929). (See this author's co-written (with P.G. Stone, and D. J. Cochrane) Nickel Development Institute reference book, Timeless Stainless Architecture, from October 2001). This illustrates the durability and longevity of stainless steel. When properly specified and maintained, it can last the life of the project. When demolition finally occurs, an average of 92 percent of the stainless steel used in construction is recycled back into new metal—an indefinitely recyclable resource—without deterioration of properties. (For more, read Barbara Reck and T.E. Graedel's May 2013 internal report for the Center for Industrial Ecology Yale University, "Comprehensive Multilevel Cycles of Stainless Steel in 2010 Final Report to the International Stainless Steel Forum (ISSF) and Team Stainless").

Early skyscrapers

People have always built large structures as a means of expressing power and wealth, frequently pushing the limits of technology. Fittingly, the first large architectural applications for stainless steel were in the tallest buildings in the world: New York City's Chrysler (1930) and Empire State (1931) buildings. Although the former was only the tallest building in the world for a few months, its elegant, glittering stainless steel art deco styling has made it an enduring, internationally recognized, example of elegant skyscraper design. Both buildings have been awarded LEED Existing Buildings (EB) Gold status by the U.S. Green Building Council (USGBC). The two structures' minimal stainless steel replacement has been the result of modifications, hurricane damage, and other issues unrelated to the material's performance.

The introduction of metal and glass curtain wall design in the early 1950s revolutionized tall building design. Stainless steel was used for many of the early prominent building designs including the Socony Mobil Building (1954) and Chicago's Inland Steel Building (1958). By the 1960s, stainless steel was regularly being used for high-profile architectural applications around the world, so there are many project examples with longer than 50 years of service.

Japanese temple

The first coloring methods for stainless steel were introduced in the 1970s, and were developed for durability. For example, the electrochemically colored shingles on ReiyukaiShakeden Temple (Tokyo) have had no change in appearance since they were installed in 1975.

French museum

La Géode, which opened in 1985, is a geodesic dome with an exterior covered in 6433 mirror-finished Type 316 panels that holds an Omnimax theatre in Parc de la Villette at the Cité des Sciences et de l'Industrie in Paris, France. The largest science museum in Europe, it was designed by architect Adrien Fainsilber and engineer Gérard Chamayou. It is 36 m (118 ft) in diameter and reflects the sky.

Singapore racetrack

The Singapore Racecourse in Kranji was completed in August 1999. The design architect, Philadelphia-based Ewing Cole, wanted the

curved, 400-m (1312-ft) long grandstand roof to remind visitors of the graceful movement of a powerful racehorse in motion. Its undulating curves were achieved with a standing seam roof made of Type 316 (UNS S31600, EN 1.4401, SUS 316) stainless steel. Heavy year-round rainfalls are common in Singapore. The owners wanted a durable, long-lasting roof that would remain attractive with minimal maintenance.

"We did not think twice about using stainless steel, because it is a corrosive, tropical island environment," explained the design firm's John Chase. "Stainless steel roofing is widely used in Singapore for that reason."

The architect of record was Indeco, a Singapore firm.

One example, Via (625 West 57th St) is the first building designed by the Danish Architecture firm BIG (Bjarke Ingels Group) in North America. Nearing completion, the 709-unit building faces the Hudson River. The Durst Organization carefully vetted the materials and all aspects of construction with consideration of their impact on the environment. Type 316L was selected for both the façade and the custom structural sections supporting the cleaning system because of the building's deicing salt exposure adjoining the Joe DiMaggio Highway.

There are also many interesting new Type 316L-clad office towers in New York, including the LEED Gold-rated 7 Bryant Park and International Gem Tower, but the largest concentration of stainless steel façades is around the World Trade Center, where Type 316L visually connects the buildings' diverse design styles while making them more sustainable and resilient.

Although it is the smallest building in the complex, the National September 11 Memorial Museum Entry pavilion needed a very special finish for the Type 316L rainscreen.

"We created a subtle rhythm by alternating #4, #3, #4 with glass bead, #3 with glass bead and a custom Main Steel satin finish," said Bill Zahner (of the eponymous architectural metal and glass engineering firm, Zahner). "Gloss readings were taken of each and we worked with Snøhetta (architect) to arrive at the combinations that are now on the building."

The LEED Gold-rated One World Trade Center opened in 2014. Its 1776-ft (i.e. 541-m) height coincides with the year the Declaration of Independence was signed, making it the tallest building in the Western Hemisphere. Type 316L supports the podium's glass fins, accents the glass tower's façade corners (a proprietary 'laser' finish), and also forms the 6-ton spire (6.35-mm [1/4-in.] plate).

The grandstand for the Singapore Racecourse in Kranji boasts a standing seam roof comprising undulating curves achieved with Type 316 stainless steel. Photo © Erhard Pfeiffer. Photo courtesy Ewing Cole

Recent projects

The world's leading architects have continued to use stainless steel for relatively traditional curtain wall, sunscreens, elegant store interiors and transit buildings around the world. Type 316/316L is the preferred exterior stainless steel because of the corrosiveness of the typical service environment with 2010's One Canada Square in London, England (Cambric finish), being an excellent example of durability.

Some have had regular maintenance and others had none, but they look unchanged in appearance. All illustrate the exceptional performance and cost-effectiveness of stainless steel as an architectural design material and its appeal for sustainable designs where long-term performance is expected.

Home to more LEED-rated buildings than any other city, New York is in the midst of a construction boom. Sustainable residential buildings of all sizes are using Type 316L stainless steel on their exteriors, including 245 10th Ave, HL23, Beekman Tower, 50 West Street, 56 Leonard, American Copper Buildings, and Central Park Tower.

Rogers Stirk Harbour + Partners' Three World Trade Center will be completed in 2018. The 80-story, 329-m (1079-ft) building will be clad with Type 316L in a proprietary 'linen' finish, and has been pre-certified to LEED Gold.

Type 316 stainless steel was chosen for Via 57 West – a 709-unit New York City tower facing the Hudson, designed by Bjarke Ingels. Photo © Nic Lehoux

Restoration and reuse

New York City's Chrysler and Empire State Buildings are both excellent examples of the ability to restore stainless steel to its former glory. Both structures have been cleaned approximately every 30 years, with considerable surface accumulation of dirt and grime between restorations. A similar case is New York City's Socony Mobil Building (150 East 42ndStreet), constructed in 1954 and adjoining the Chrysler Building. It was cleaned for the first time in 1995 after over 40 years of service.

All three buildings were cleaned with a mild detergent/water solution containing a degreaser to remove hydrocarbon deposits and a fine abrasive where necessary to remove more adherent surface deposits. No aggressive or environmentally hazardous materials were required, nor any products emitting hazardous fumes. Similar solutions are used on buildings with more frequent cleaning regimes. These buildings exteriors have corrosion resistance equivalent to Type 304. With increased deicing salt use, New York has become more corrosive and the lower levels of these buildings must be cleaned regularly or coated. Today, Type 316 or an equivalent stainless is being used in new projects in New York for added corrosion resistance.

Conclusion

Whole-building life cycle analysis tools and databases finally make it possible to fully assess building performance and achieve more sustainable designs. To minimize the building footprint, the materials should be capable of lasting the life of the project with minimal maintenance. This can make stainless steel a suitable candidate.

With many examples of stainless steel projects exemplifying long service life, Type 316/316L is the primary alloy being selected for long service life applications in the corrosive exterior environments that exist in much of the world, though more corrosion-resistant stainless steels like 2205 are also available.

Duplex Stainless Steel Revolutionizes Structural Design

Duplex Stainless Steel Revolutionizes Structural design

by Catherine Houska, CSI

Architectural and engineering firms are increasingly exploring stainless steel's possibilities as a structural material as new research, structural codes, and design guides become available. Most designs have used the familiar Types 304L or 316L alloys from the austenitic family of stainless steels, but for all but the lightest sections, the duplex stainless steel family presents a much greater potential for innovation. Many architects and engineers are unaware of this interesting stainless steel alloy family.

The alloys in the duplex stainless steel family combine a wide range of corrosion resistance (similar to austenitics) with significantly higher strength levels than both common carbon steels and austenitics. This can allow designers to reduce structural section sizes, which can dramatically change design, or use a more corrosion-resistant stainless steel without a significant raw material cost differential. Cutting edge lightweight pedestrian bridges have been the most common duplex stainless steel application to date, but they are also being used for glass curtain wall supports, sunscreens, railings, concrete reinforcement, sculpture, and other structural applications.

What is duplex?

It is common for architects and designers to simply specify "stainless steel," not realizing there are five distinct alloy families—austenitic, ferritic, duplex, martensitic, and precipitation hardening—and hundreds of individual alloys. The most commonly used stainless steels for building and construction are the austenitics (e.g. 304/304L, 316/316L), which combine corrosion resistance with formability. They are used for a wide range of aesthetic, practical and structural applications. Small sections can be cold-worked to increase strength levels.

Stainless steel family names are derived from their characteristic microstructures. For example, austenite gives austenitic stainless steels their name and makes them non-magnetic, very formable, and weldable. The ferrite in the microstructure of mild steel, cast iron, and ferritic stainless steels (e.g. 430, 444) makes them magnetic. Ferritic stainless steels are less formable and weldable then austenitics.

First introduced in 1930, duplex stainless steels have mainly been used for corrosive industrial applications. Their name refers to the combined austenite and ferrite microstructure. The formability and weldability of these alloys are between those of the austenitic and ferritic stainless steels. Designers familiar with precipitation hardened (PH) stainless steel bolts (e.g. 17-4 PH) know duplexes are not the strongest stainless steels, but the PH alloys are less corrosion-resistant then Type 304 and not suitable for more severe environments unless they are protected. Duplexes are the only alloy family to provide both exceptional corrosion resistance and high strength.

Figure 1 provides the relevant ASTM and American Welding Society (AWS) standards

and specifications for duplex stainless steel; Figure 2 compares the mechanical properties of the stainless and carbon steels used for structural shapes. Figure 3 compares the impact toughness of austenitic, duplex, and carbon steel at different temperatures—important for safety and security applications.

STANDARD	SPECIFICATION NO.	DESCRIPTION
ASTM		
Plate, sheet, strip	A240/A240M	Chemical composition and mechanical properties
	A480/A480M	Finishes, dimensional tolerance, flatness, and shipping requirements
Hollow sections*	ASTM A554	Round, square, and rectangular stainless steel mechanical and structural tubing chemical composition, mechanical property, and dimensional tolerance requirements
Bars and shapes	A1069/A1069M	Laser-fused (laser-welded) stainless steel structural shapes
	A276**	Hot and cold rolled or extruded rounds, squares, hexagons, angles, tees, channels, and other structural shapes chemistry and mechanical properties
	A484/A484M	Dimensional tolerance, straightness, and finish descriptions for the products in A276
Bolts	A1082/ A1082M	High-strength duplex stainless steel bolts
Concrete reinforcement	A955	Round and deformed concrete reinforcement
	A1022	Deformed and plain stainless steel wire and welded wire mesh
American Welding Society (AWS)		
Structural*	D1.6	Structural welding code for stainless steel

* Duplex stainless steel hollow sections are also covered byA789 (tube), along with A790 and A928 (pipe), but those standards are for American Society of Mechanical Engineers (ASME) pressure vessel code products that carry liquids under pressure and require additional pressure testing that is not needed for a structural application. A554 includes large diameters and heavier walls; it is a more cost effective choice then 'pipe' for structural applications like bollards.
** Carbon steel welding codes should never be used for stainless steel, as there are important differences. A1069 only covers laser-welded structural shapes; all other welded structural shapes should be specified using AWS D1.6 in combination with ASTM A240 and A480.

Figure 1: Specifications for duplex stainless steel structural products

	UNS	COMMON NAME	TENSILE STRENGTH	MIN. YIELD STRENGTH	MINIMUM ELONGATION IN 50 MM (2 IN.)
A240A240M-15 Stainless steel					
Austenitic	S30400	304	515 MPa (75 ksi)	205 MPa (30 ksi)	40%
	S30403	304L	485 MPa (70 ksi)	170 MPa (25 ksi)	40%
	S31600	316	515 MPa (75 ksi)	205 MPa (30 ksi)	40%
	S31603	316L	485 MPa (70 ksi)	170 MPa (25 ksi)	40%
	S31703	317L	515 MPa (75 ksi)	205 MPa (30 ksi)	40%
Duplex	S32101		650 MPa (94 ksi)*	450 MPa (65 ksi)*	30%
	S32304	2304	600 MPa (87 ksi)	400 MPa (58 ksi)	25%
	S32003		655 MPa (95 ksi)**	450 MPa (65 ksi)*	25%
	S32205	2205	655 MPa (95 ksi)	450 MPa (65 ksi)	25%
A1043/A1043M-14 Carbon steel					
Grade 36			400 MPa (58 ksi)	250 MPa (36 ksi)	23%
Grade 50			450 MPa (65 ksi)	345 MPa (50 ksi)	21%

* These values apply to material of thickness less than 5 mm (0.187 in.). For thicker material, the minimum tensile strength is 700 MPa (101 ksi) and yield strength is 530 MPa (77 ksi).
** These values apply to material of thickness less than 5 mm (0.187 in.). For thicker material, the minimum tensile strength is 690 MPa (100 ksi) and yield strength is 485 MPa (70 ksi).

Figure 2: Minimum mechanical properties of the stainless and carbon steels used for structural sections.

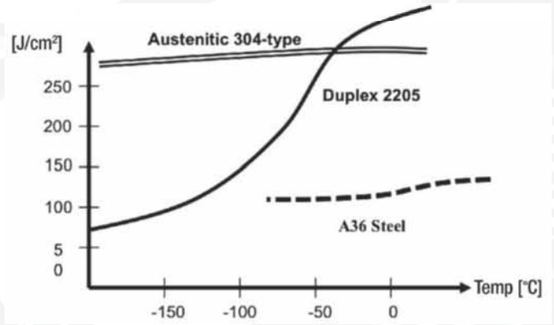


Figure 3: The relationship between impact toughness and temperature for austenitic and duplex stainless versus carbon steel.Image courtesy Steel Construction Institute

Design codes and guides

Stainless steel has been used selectively since the 1940s for bridges and other structural applications. Formal stainless steel structural design guidance first became available in 1968 when research prompted by the design of the Gateway Arch in St. Louis was published as an American Iron and Steel Institute (AISI) specification.

The current version of this standard, Structural Engineering Institute/American Society of Civil Engineering (SEI/ASCE) 8, Specification for the Design of Stainless Steel Cold-formed Structural Members, covers light-gauge austenitic and ferritic stainless steels. It was the basis for cold-formed stainless steel structural design standards in Europe, Australia, New Zealand, South Africa, and Japan.

The first large structural stainless steel non-industrial projects to use this research were the 1964 Unisphere sculpture (appearing at the World's Fair, New York City) and the following year's Gateway Arch, which were both Type 304. The 1986 restoration of the Statue of Liberty used Type 316L and UNS 32550 duplex stainless steel to replace much of the original iron support framing and is the first known large non-

industrial duplex structural application. The more recent 7 World Trade Center used both Type 316L and 2205 duplex for structural applications. By far, the largest construction-related structural application for duplexes (not including industrial buildings) has been bridges.

There has been substantial international structural design research done on stainless steel since the 1960s, including design for seismic, fire, and blast wall applications. In 1993, work began to add heavier stainless steel sections to the European standards. EuroCode 3, Design of Steel Structures, Supplementary Rules for Stainless Steels, Part 1–4, includes both light and heavy austenitic and duplex stainless steel structural sections. China is adding stainless steel to their structural design codes as well. Stainless steel-framed European and Japanese buildings were built to justify code additions. In 1995, EuroCode 3 was used in the design of the Canadian National Archives (Types 304L and 316L structural framing) to avoid coating VOCs.

Until recently, there was no North American guidance on the design of heavier structural sections. American National Standards Institute/American Institute of Steel Construction (ANSI/AISC) 360, Specification for Structural Steel Buildings, only covers heavier carbon steel structural sections. In September 2013, AISC Steel Design Guide 27, Structural Stainless Steel, was issued to provide design advice for sections 3.2 mm (0.125 in.) or greater. Capitalizing on new research that will be incorporated into EuroCode 3, it includes welded plate fabrications, extruded and rolled shapes, hollow sections, tensile bars, and fasteners.

The AISC design guide includes three duplex stainless steels (e.g. UNS S32101, S32304 [2304], S32205 [2205]) and can be applied to other stainless steels within this family—such as UNS 32003, which was used for subway canopies in Washington, D.C.

Alloy selection

Stainless steel alloy specification for corrosion resistance has been discussed in greater detail in previous articles. While there are common names (e.g. 304, 316) for many stainless steels, alloy chemistry should be specified using the international Unified Numbering System (UNS) and internationally recognized specification (e.g. ASTM, EN, JIS) to avoid miscommunication.

Figure 4 provides the chemistries and Pitting Resistance Equivalent Numbers (PREn) for the austenitic and duplex stainless steels in the AISC design guide and UNS 32003. PREn is a calculation based on the alloying elements that determine the corrosion resistance of stainless steel (e.g. chromium, molybdenum, and nitrogen) to pitting corrosion. Surface finishes, welding, environmental exposures, and other factors can be as important, so PREn should not be used exclusively for specification.

	UNS	CARBON	MANGANESE	CHROMIUM	NICKEL	MOLYBDENUM	NITROGEN	COPPER	PREn
Austenitic	S30400	0.03		17.5–19.5	8.0–10.5				18–19
	S30403	0.03		17.5–19.5	8.0–12.0				18–19
	S31600	0.03		16.0–18.0	10.0–14.0	2.00–3.00			24–25
	S31603	0.03		16.0–18.0	10.0–14.0	2.00–3.00			24–25
	S31703	0.03		18.0–20.0	11.0–16.0	3.00–4.00			30–33
Duplex	S32101	0.03	4.00–6.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	0.10–0.80	25–27
	S32304	0.03		21.5–24.5	3.0–5.5	0.05–0.60	0.05–0.20	0.05–0.60	25–28
	S32003	0.03		19.5–22.5	3.0–4.0	1.50–2.00	0.14–0.20		30–31
	S32205	0.03		22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20		35–36

Note: Remainder iron, PREn = Cr + 3.3(Mo +0.5W) + 16N. Carbon is the maximum allowed.

Figure 4: Primary chemical composition and pitting resistance equivalent number (PREn).

Based on the assumption corrosion staining is undesirable and there will be little or no maintenance cleaning, UNS S32101, S32304, and proprietary stainless steels with similar corrosion resistance to Type 316/316L are generally suitable for low to moderate salt exposure or polluted environments where there is regular heavy rain to clean surfaces.

UNS S32205 provides substantially more corrosion resistance and is suitable for higher levels of industrial pollution and salt exposure, when rougher finishes are specified, or where natural heavy rain cleaning is less frequent. Even more corrosion-resistant stainless steels are available for saltwater immersion and other particularly aggressive environments.

This article examines various new construction and restoration projects in both the United States and from around the world to help illustrate the reasons why certain stainless steels are specified.

Statue of Liberty restoration

Since its installation in New York in 1886, theStatue of Liberty has become one of the most well-known sculptures in the world. However, many people are not aware galvanic corrosion caused structural deterioration, making a significant restoration necessary in 1986.

The 1986 restoration of the Statue of Liberty used duplex stainless steel to replace much of the original iron support framing. Photo © Mike Renlund and Erik Cleves Kristensen (inset)

The original structure of the 46-m (151-ft) statue had a framework of puddled iron consisting of three distinct components—a central pylon, 1850 secondary framing beams, and armature bars. A double-helix staircase rises through the pylon's center. About 1500 U-shaped copper saddles connected the armature to the outer copper envelope sheets.

Designers Auguste Bartholdi and Gustave Eiffel anticipated the galvanic corrosion problem and tried to electrically isolate the materials. Unfortunately, the envelope design and subsequent modifications allowed rain containing coastal salt and acid from pollution to seep behind the copper. Condensation from temperature and humidity changes also adds the moisture necessary for corrosion.

Severe corrosion of the iron armature had occurred by 1981 and caused copper damage. Type 316L stainless steel replaced the iron armature except for a few bars in the right sole of the foot. No galvanic corrosion problem would be expected between copper and stainless steel in this type of environment and their coefficients of thermal expansion are the same. A high-strength, highly corrosion-resistant duplex stainless steel UNS S32550 secondary framework was used to support the new Type 316L armature.

Buildings

Duplex stainless steel's inherent corrosion resistance and opportunities for unique structural designs have made it a desirable material for both form and function in many buildings around the world.

Boston-area research building

The strength and corrosion resistance of duplex 2205 and Type 316L stainless steels are being used to support a unique façade in Boston. The building reflects its environment by using the light-gray New England granite found in many of the city's historic buildings. Unlike traditional heavier buildings, the airy modern design uses the stone as a secondary façade in front of a glass curtain wall. The stone will appear to come out

of the landscape and gently float up the glass exterior.

The stone will sit on a Type 316 framing and shelving system, which is held off the building by large 2205 struts and cleat plates. This design takes advantage of the corrosion resistance of both stainless steels and uses the much higher strength duplex 2205 to carry the primary structural load.

The higher corrosion resistance of the 2205 is important because it will be visible to building occupants. Its location behind the stone means it will be exposed to coastal and de-icing salt, but not readily rain-washed—this means resistance to corrosion is critical. Completion is expected later this year.

Located in Qatar, the Jahn-designed Doha Convention Center uses cable-net-supported glass walls to create a floating roof plane. Due to its structural properties and corrosion resistance, duplex stainless steel was specified for the façade. Photo courtesy Jahn

Doha Convention Center

Located in Qatar and adjoining the harbor, the Doha Convention Center is still under construction. International architectural firm Jahn's design uses cable-net-supported glass walls to create a floating roof plane. Its strong horizontal expression complements the verticality of the surrounding towers.

Due to its structural properties and corrosion

resistance, duplex 2205 was used for the façade cross-bars. Most of the other façade components are Type 316/316L. Type 317L, which is more corrosion-resistant then Type 316, was employed for many of the stainless steel landscape components (e.g. dot lights, semi-recessed planters) and exterior handrails. The interior decorative metal panels are Type 316.

The high strength of duplex stainless steels makes them ideal for tension bars when designers want to minimize structural section size and maximize the view through large glass curtain walls. The first large glass curtain wall application to use the strength of 2205 duplex to minimize the size of the structural support sections was SOM's New Poly Plaza, completed in Beijing in 2007.

Fondation Louis Vuitton Museum

Frank Gehry's design for this new Parisian museum is reminiscent of billowing transparent sails and was influenced by the iconic 19th century Parisian glass pavilions. The building consists of three primary components—the inner-core display areas (iceberg) with its concrete exterior, a secondary exterior structure of steel beams and wooden tripods, and a tertiary structure of billowing glass sails supported by a duplex grid.

Image 1 of 2 - Frank Gehry's design for Paris' Fondation Louis Vuitton Museum takes its cues from billowing transparent sails and 19th century glass pavilions. Photo © Iwan Baan

The glass sails on the secondary structure consist of painted steel columns, wooden beam 'tripods,' and a large 2205 duplex stainless steel grid that support glass sails weighing between 200 and 350 tonnes (220 and 386 tons). Three large sails serve as an umbrella for the building while nine others sweep around it creating the appearance of a 'ghost ship,' sailing above the treetops of Bois de Boulogne. To recover rainwater, 2205 gutters are used.

Duplex 2205 stainless steel plates were also inserted into the wooden beams at their connection points with the steel beams to strength the connections. Each of these connection points also used a complex 100-mm (3.9-in.) thick carbon steel/2205 duplex hybrid plate node to connect the wood and metal elements. These nodes ensure structural stability while permitting movement. About 1500 tonnes (1654 tons) of 2205 were used for this project.

Middle East cultural center

Construction will be completed this year on a cultural center near where Saudi Arabia's first oil was discovered. The geology and rock formations influenced the design's four visible rounded above-ground components—the library, keystone, tower, and auditorium.

A tower soars above the rest of the complex and is surrounded by smaller 'mountainous' forms. These shapes are clad in high-strength duplex 2205 stainless steel sunscreen façade composed of 250 km (155 mi) of 76.1-mm (3-in.) tubing. Duplex 2205 was selected because of corrosion research conducted on various stainless steels and architectural metals at a Dubai test site by stainless steel and high-performance alloy producers Outokumpu, with the assumption there will be no manual cleaning.

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The project's engineering design firm had to consider the corrosiveness of the coastal environment, wind loading from sand storms, durability requirements, and the unique curving shape of the sunscreen façade. The curves of tubular screen resemble the loops of a fingerprint and also snuggly wrap around the exterior curves of each building shape. Where the sunscreen façade extends across solid walls, it is 88 percent closed—this prevents the sun from reaching the surface and heating it. As it reaches windows, the sunscreen transitions gradually to a flattened tube 12 mm (0.47 in.) in height, creating an 84 percent open area. The angle of the flattened tubes prevents sun from reaching the windows and transferring heat into the building while giving visitors a minimally obstructed view.

The world's first duplex stainless steel sunscreen was the Stockholm Congress Centre, which used Z-shaped 2205 stainless steel beams with a semi-reflective matte finish because of its corrosive harbor-side location.

Pedestrian bridges

High-profile pedestrian bridges can change the urban landscape, creating new city gateways or connections highlighting and increasing the use of new or redeveloped areas. Rather than being purely utilitarian, stainless steel pedestrian bridges are often sculptural—inviting active public interaction. They are an evolving means of expression giving the architects and engineers the opportunity to develop and test cutting-edge concepts. The inherent corrosion resistance of stainless steel and ability to eliminate coatings makes design elements and connections into artistic details.

The first stainless steel bridge to garner international attention and become a significant tourist attraction was London, England's Millennium Bridge (2001) designed by Foster and Partners, Anthony Caro, and Ove Arup and Partners using duplex 2205. Figure 5 provides a listing of some of the completed duplex stainless steel bridges and their locations.

DATE	NAME	LOCATION	TYPE OF BRIDGE	DUPLEX STAINLESS STEEL
1999	Suransuns Bridge	Switzerland	Stress ribbon, 40 m (131 ft)	S32205
2001	Millennium Bridge	London, England	Tilted box girder arch, 80 m (262.5 ft)	S32205
2002	Apalis Bridge	Stockholm, Sweden	Tied beam pedestrian bridge	S32205
2004	Likholefossen Bridge	Norway	Lightweight pedestrian, 24-m (79-ft) span	S32101
2006	Siena Bridge	Ruffolo, Italy	Cable stayed pedestrian, 60 m (197 ft)	S32101
2006	Celtic Gateway Bridge	Holyhead, Wales	Load bearing arch, 160 m (525 ft)	S32304
2008	Zumaia Bridge	Spain	Composite FRP duplex	S32205
2009	The Helix	Marina Bay, Singapore	Tubular, 280 m (918.6 ft)	S32205
2009	Meads Reach	Bristol, England	Stressed skin arch	S32205
2009	Sant Fruitos Bridge	Spain	Arch	S32101
2011	Harbor Drive Bridge	San Diego, United States	Cable stay, 162 m (531.5 ft)	S32205

Figure 5: Some completed pedestrian duplex stainless steel footbridges, as found in Sustainable Duplex Stainless Steel Bridges, a U.K. Steel Construction Institute publication by Nancy Baddoo and A. Kosma.

In addition to providing the corrosion resistance necessary to offer the longevity expected of iconic bridges, their high strength and other design characteristics can make it possible to reduce structural component size, making these beautiful bridges more cost competitive. Currently, the longest duplex stainless steel pedestrian bridges in the world are The Helix in Marina Bay, Singapore (280 m [920 ft]) and the Harbor Drive Pedestrian Bridge in San Diego, California (168 m [550 ft]). Both used UNS S32205 duplex stainless steel as a primary structural material in their innovative, cutting-edge designs.

The Helix

Completed in 2010, the Helix Bridge, previously known as the Double Helix or DNA Bridge, is a new landmark linking Singapore's Marina Centre with Marina South. The world's first double-helix bridge is part of a high-profile development project and completes a 3.5-km (2.2-mi) pedestrian walkway around Marina Bay. The design consortium included architects COX Group Pte. (Australia), Architects 61 (Singapore), and the engineering firm Arup.

Completed in 2010, the Helix Bridge is a new landmark for Singapore. Photo © Kinsman

Two delicate helix duplex 2205 stainless steel structures surround the walkway and act as a tubular truss to resist design loads. That same material was also used for the cantilevered viewing 'pods' that extend out from the bridge and the slender concrete-filled support columns. The high strength of the duplex stainless steel pipes made much lighter sections possible for a total bridge weight of 1700 tonnes (1873 tons). It is estimated a conventional box girder bridge would have used five times as much carbon or weathering steel. When maintenance painting and other costs were considered, the 100-year design life analysis showed 2205 was a lower cost option than carbon steel.

Harbor Drive Bridge

Opening in 2011, San Diego's Harbor Drive Pedestrian Bridge is one of the longest self-anchored pedestrian bridges in the world. Designed to last at least a century, the elegantly simple lines of this horizontally curved structure mimic the look of the sailboats on the adjoining harbor.

The streamlined design is different from traditional suspension bridges, using a design that hides the main tension cables inside welded pipes. The main cable is enclosed within a 203-mm (8-in.) stainless steel pipe, and extends from the ground to the top of a single 40-m (131-ft) inclined pylon along the inside of the curve. Thirty-four suspender cables connect the inside

edge of the curved deck to the main cable pipe. A second longitudinal post-tensioned cable is hidden inside the 203-mm stainless pipe above the inside railing and provides horizontal force to stabilize the bridge.

Designers chose high-strength corrosion-resistant duplex 2205 stainless steel because of the alloy's strength and the site's regular salt fog exposure and longevity requirements. The designers fully utilized the high strength of this alloy. Type 316 austenitic steel was used for the suspender cables and safety mesh. The connectors for the cable system are 2205.

New Middle East bridge

A spectacular new pedestrian bridge project is nearing completion in the Middle East. Taking full advantage of the unique characteristics of the specified materials, it consists of two cable-stayed bridges that repeatedly curve apart and then intersect, creating a graceful series of figure eights. The design concept was a necklace being draped along the ring of the island marina. The open areas between the curving bridges are glass-floored for evening activities. Each bridge is approximately 200 m (656 ft) long and spans 90 m (295 ft) over the water from one quay to the other.

Opening is 2011, San Diego's Harbor Drive Pedestrian Bridge is one of the longest self-anchored pedestrian bridges in the world. Photo © Fred Kaplan

As the Middle East coast is a corrosive environment, duplex 2205 stainless steel was used for all the visible steel structural elements, including the supports for the cantilevered glass floors and concrete decks, along with canopy structures and bridge balustrade posts. The bridge pylons are also clad in duplex 2205 plate, which is structural, offers corrosion protection, and applies compression to the pylons.

Composite footbridges

Exceptionally lightweight smaller footbridges using high-strength duplex stainless steel structural frame sections to support fiberglass panel decks and side panels were pioneered by the engineering design firm Pedelta. They are light enough to be easily lifted in place by cranes.

Image 1 of 3 - This bridge, for the small Basque city of Zumaia, needed to withstand the maritime climate, achieve a long service life, and be lightweight. Duplex stainless steel fit the bill. Photo © Ricardo Ferraz

The small Basque city of Zumaia is located on the Bay of Biscay in Spain. Rivers slice through this small city, so a footbridge to improve accessibility was a crucial part of an urban development program. The bridge, pictured above, had to be able to withstand Zumaia's maritime climate, achieve the desired 120-year service life, and be lightweight. Completed in November 2008, the bridge design combines duplex 2205 stainless steel and fiberglass. Substantial steel section thickness and weight reduction was obtained relative to traditional materials.

This Spanish bridge in Vilafant provides a pedestrian crossing over high-speed and traditional rail tracks.

A more recent Spanish bridge in Vilafant (at left) provides a pedestrian crossing over high-speed and traditional rail tracks. It was lifted into place by crane in 2011 without disturbing rail service. Since the location was coastal, but not immediately adjoining salt water, UNS S32101 was specified.

Pedestrian arch bridges

The 2006 Celtic Gateway footbridge is a dramatic structure linking the center of the Welsh town of Holyhead with the inner harbor's ferry terminal and railway station. Two tubular load-bearing arches are the dominant visual feature. All the structural components are duplex 2304 stainless steel.

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Another example is the San Fruitos Bridge (2009) in Spain (below), which crosses a highway to connect residential and a commercial areas.

Spain's San Fruitos Bridge (2009) employs duplex 2304 stainless steel to cross a highway.Photo © Jasper Hermsen

Vehicular and rail bridges

Structural engineering firms have also been using welded stainless steel plate fabrications in vehicular and railroad bridges as primary structural components. The first was Pedelta'sCala Galdana Bridge in Menorca, Spain (right), which used duplex 2205 stainless steel structural components. The 2005 project replaced a mild steel-reinforced concrete bridge, which had severely deteriorated in the marine atmosphere.

Pedelta's Cala Galdana Bridge in Menorca, Spain, uses duplex 2205 stainless steel structural components. Photo © Juan Sobrino

The first stainless railway bridge was the Añorga Bridge in San Sebastian, Spain, which used a UNS 32101 truss structure and replaces a carbon steel structure that had required intensive maintenance over its lifespan. Other vehicular bridges that have used large stainless steel structural components include Arup's 2009 'Stonecutters Bridge in Hong Kong, which used 2205 plate on the exterior of the bridge pylons.

Many of these bridges were designed using EuroCode 3, which is overly conservative based on recent research. Design firm Ove Arup & Partners conducted a study for Outokumpu—"Outokumpu Stainless Steel Composite Bridge Study: Life Cycle Cost for Maintenance Study" (2012) and "Outokumpu Stainless Steel Composite Bridge Study: Study Report" (2011)—comparing 355 N/mm2 (51 ksi) minimum yield carbon and weathering steel with various stainless steels. The comparison used a two-span 28-m (92-ft) long bridge carrying a two-lane highway. EuroCode 3 was used for the initial analysis; then, an optimized design was developed using research incorporated into American Institute of Steel Construction (AISC) Steel Design Guide 27, Structural Stainless Steel.

The Arup study found duplexes to be the most cost-effective stainless steel alloy family for bridge design. (UNS S32101 and S32205 were included in the study.) With design optimization using stainless steel, 12 percent less tonnage was required then carbon or weathering steel. The initial cost of the lean duplex bridge was only 7.4 percent greater than that of the carbon steel bridge and five percent more than weathering steel.

A full lifecycle cost analysis was done based on 60 years of service. The model assumed maintenance repainting of the carbon steel every 10 years without removal of previous paint layers. Several scenarios were considered and a 30 to 40 percent cost savings could be achieved over 60 years by using duplex stainless steel.

Conclusion

The high strength and corrosion resistance of duplex stainless steels make them suitable choices for building/construction structural applications including bridges, railings, glass support structures, and sunscreens where strength and corrosion resistance is important. The new AISC design guidance has made it much easier for North American firms to design with structural stainless steel.

Alloy specification guidance is available from articles, industry associations, and producers. In more corrosive locations, however, the assistance of an expert in stainless steel atmospheric corrosion should be obtained to verify appropriate alloy specification.