RebarinoX

Acerinox Stainless Steel reinforcement bar

cedinox

ACERINOX, S.A.

1957

ROLDAN,
long
products.
Ponferrada,
Spain

1970

ACERINOX
EUROPA,
flat products.
Algeciras,
Spain

1989

INOXFIL,
wire - long
products.
Barcelona,
Spain

1990

NORTH AMERICAN
STAINLESS,
USA
1990: flat products
2002: long products

2001

COLUMBUS
STAINLESS,
flat products.
South Africa

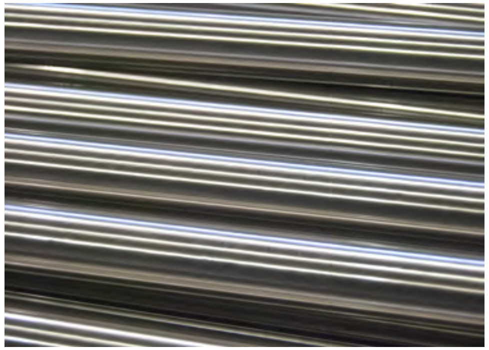
2009

BAHRU
STAINLESS,
flat products.
Malaysia

RebarinoX Stainless steel

ROLDAN
STAINLESS STEEL LONG PRODUCTS

Black bar
Ø16-115 mm



Bright bar
Ø2-110.3 mm

Round wire rod
Ø5.5-41.5 mm

Hexagonal bar
ø11-30 mm

Angle
legs: 20-100 mm

Hexagonal wire rod
ø14.5-31.5 mm

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ROLDAN
STAINLESS STEEL LONG PRODUCTS

Reinforced material

DELIVERY	Ø (mm)	Length (mm)
Bar	3 -14	3,000 - 8,000
	16 -50	3,000 - 12,000
Coil	3 - 32	

Other possibilities of shorter lengths on request

DIMENSIONS				
Ø (mm)	Section (mm)	Weight (kg/m)	Cold Rolled	Hot Rolled
3	7.1	0.06	x	
4	12.6	0.1	x	
5	19.6	0.155	x	
6	28.3	0.224	x	x
8	50.3	0.397	x	x
10	78.5	0.62	x	x
12	113.1	0.893	x	x
14	153.9	1.216	x	x
16	201.1	1.589		x
20	314.2	2.482		x
25	490.9	3.878		x
28	615.8	4.864		x
32	804.2	6.353		x
40	1256.6	9.927		x
50	1963.5	15.512		x

Approximate values
Other dimensions on request

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Projects with Roldan's STAINLESS STEEL REBAR

NORTH AMERICA & EUROPE

Connection ramp between Garden State Parkway and I-80. New Jersey (USA)

Glacier National Park of Flathead River. Southeast Essex, Montana (USA)

Reinforced concrete structures by Arminox | Photograph courtesy of Arminox

Parking at Boston airport (USA)

Blackpool (IRELAND)

Copenhagen Metro (DENMARK)

Projects with Roldan's STAINLESS STEEL REBAR

Extension of Monaco to the sea

Projects with Roldan's STAINLESS STEEL REBAR

Modern Art Museum. Vitoria (SPAIN)
Palace of Justice. Guernica (SPAIN)
High Speed Train León – Palencia (SPAIN)

Source Acero Inoxidable magazine 68

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Projects with Roldan’s STAINLESS STEEL REBAR

Eiffel Bridge rehabilitation (PORTUGAL)

Source: Acero Inoxidable magazine 62

Mediterranean highway (SPAIN)

Source: Acero Inoxidable magazine 74

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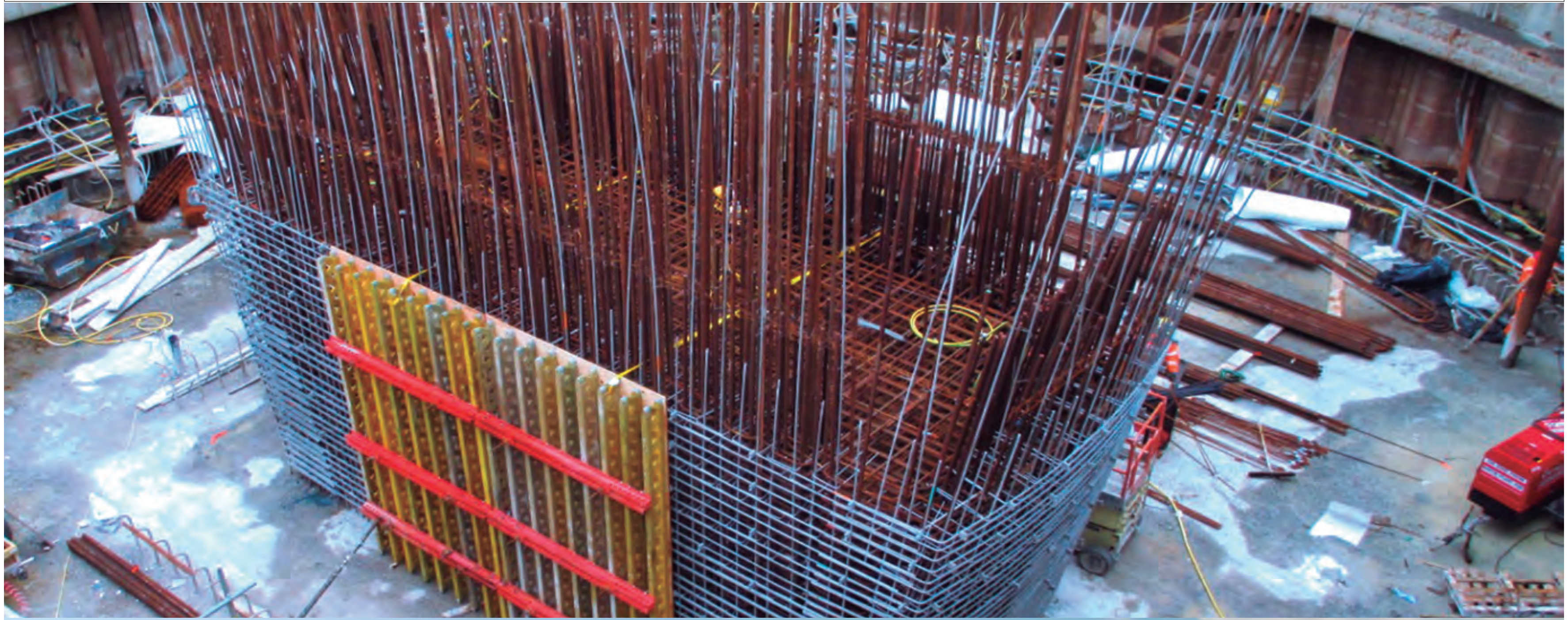
Projects with Roldan's STAINLESS STEEL REBAR

Queensferry Crossing (SCOTLAND)



Reinforced concrete structures by Fixing Center | Photographs courtesy of Fixing Center

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Projects with Roldan's STAINLESS STEEL REBAR

ASIA & MIDDLE EAST
Qasr al Alam Guest Palace, Muscat (Sultanate of Oman)

Reinforced concrete structures by Arminox | Photographs courtesy of Arminox

Jebel Ali Free Zone Extension (United Arab Emirates)
Sohar Port (Sultanate of Oman)
Sheikh Zayed Bridge, Abu Dhabi (United Arab Emirates)
Islamic Arts Museum, Doha (Qatar)
Ras Laffan Gas Loading Piers (Qatar)
Pearl Island, Doha (Qatar)

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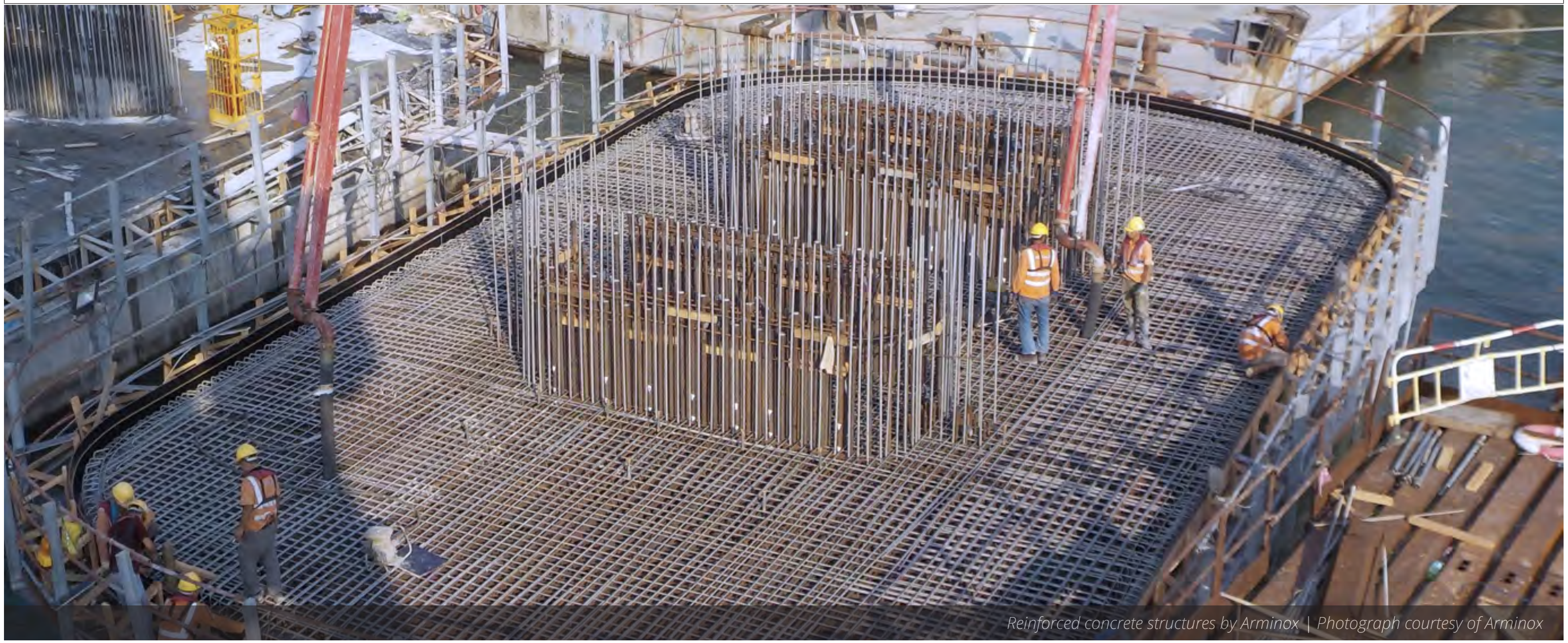
Projects with Roldan's STAINLESS STEEL REBAR

New Bridge in Sitra (Bahrain)

Reinforced concrete structures by Arminox | Photograph courtesy of Arminox

Shenzhen Western Corridor Bridge (Hong Kong)

Hong Kong – Macao Bridge



Reinforced concrete structures by Arminox | Photograph courtesy of Arminox

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STRUCTURAL APPLICATIONS

Causes of failure in concrete reinforced structures

Stainless steel rebar is a product similar to carbon steel reinforcing bar in size and shape, but with the special characteristic that its chemical composition is of a stainless steel type, which ensures a better performance against corrosion and provides mechanical properties, depending on the type of stainless steel used, similar or superior to those of carbon steel.

This product is used to reinforce concretes in particular areas where there is a high risk that the reinforcement will suffer corrosion problems .These problems can cause the structure to collapse.

There are two fundamental causes why a concrete structure reinforced with carbon steel can end up failing due to corrosion problems: the first one is **CARBONATION OF CONCRETE** and the second is **CHLORIDE ATTACK**.

While the first can occur in any dry environment, the latter is closely related to environments where chloride ions may exist. Although they are more likely associated with coastal environments , there are other environments such as those with use of de-icing salts in winter, which can be equally or even more aggressive.

Bridge built with carbon steel in 1960

Bridge built with stainless steel bar in 1930

Rebarino X

STRUCTURAL APPLICATIONS

Causes of failure in concrete reinforced structures

1

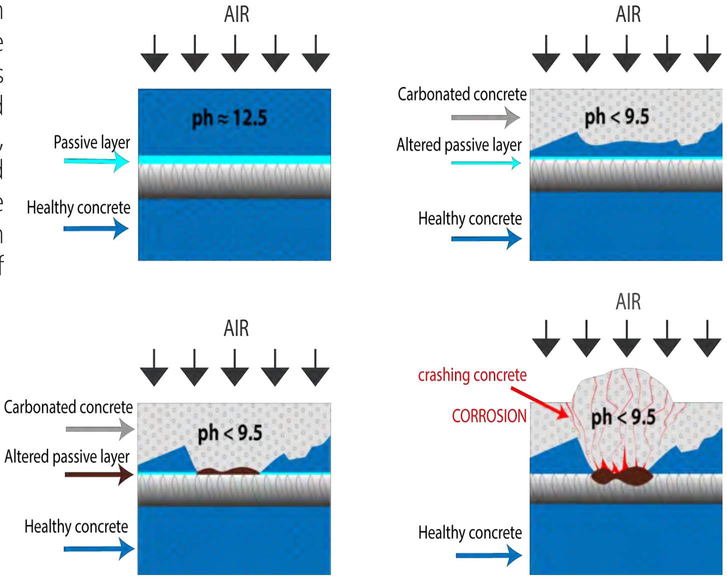
CONCRETE CARBONATION

In an initial state the carbon steel reinforcing bar remains unchanged, embedded and protected by the alkalinity of the concrete with a Ph around 12.5. However, as the concrete begins to react with the atmosphere, carbonation of concrete begins, in the presence of atmospheric CO2. Its Ph decreases until it reaches a point, below 9.5, in which the passive layer of carbon steel is broken and oxidation begins.

It should be noted that stainless steels in general, including the more economical ferritic types, are not susceptible to this type of corrosion by carbonation of the concrete, since its passive layer, formed by chromium oxide, remains unaltered and self-regenerates, in the presence of oxygen, from the chromium content of its composition.

It is very important to remember that the iron oxides that form on the surface of carbon steel tend to increase in volume as they oxidise.

As the bar is still embedded in the concrete, tensions begin to build up between the oxide that wants to expand and the concrete that contains it. These tensions eventually lead to the generation of cracks and fissures through which efforts are propagated and can cause even the concrete to come off leaving the armature fully exposed. (This phenomenon is usually called “Spalling of concrete“).



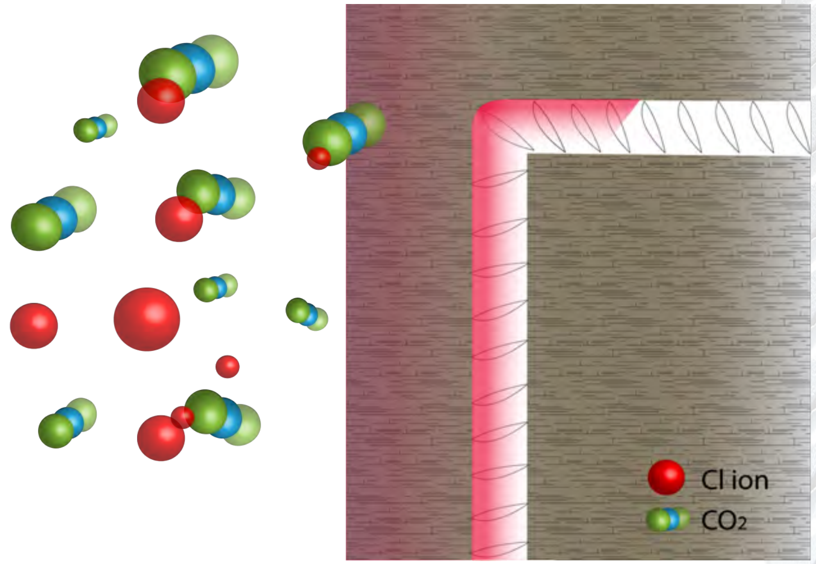
CARBONATION

2

In the case of the **CHLORIDE ATTACK**, it must be considered that this chloride ion is very aggressive, and has a lot of affinity for the metals. In the particular case of reinforced concrete structures, in the presence of chlorides, what causes corrosion is the arrival of the chloride ion in contact with the surface of the carbon steel.

The concrete cover on the reinforcement is the barrier that must protect it, because once the chloride ions arrive into contact with the carbon steel bar, it begins to produce a regular and continuous oxidation that results in cracks and tensions that even produce the rupture of that concrete cover.

CHLORIDE ATTACK



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COST EFFECTIVENESS

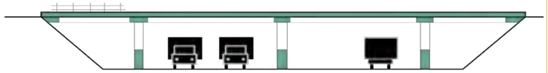
Stainless steel reinforcement

When the use of stainless reinforcement for an infrastructure is considered, it is normally limited to the critical areas of the project, which are susceptible to corrosion due to their location. In this way, a long life of the infrastructure is sought with assumed low increase of its cost.

In a bridge on the mainland, these zones are the expansion joints of the concrete planks and their union with the pillars. In bridges or tunnels where chlorides are used in the form of salts to combat ice, the stainless Steel reinforcement can be used in the most superficial part of the board (preventing the de-icing salt poured on the asphalt corrodes the reinforcement), and in the lower part of the pillars, where the splashes of salt water will strike the pillar.

Bridge cross section

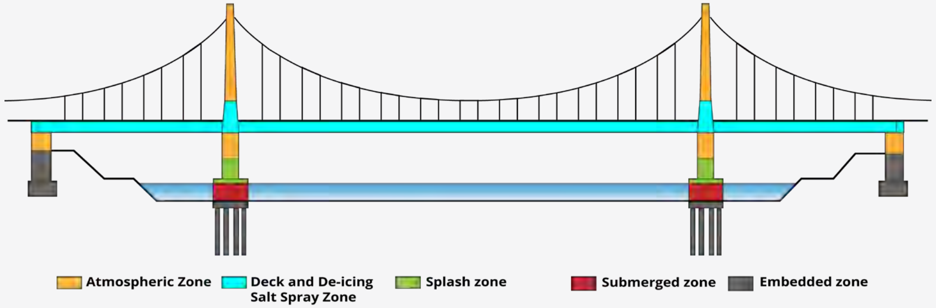
Bridge longitudinal section



All this can be seen in the following diagram, where the green areas indicate the preferred zones of use of the stainless steel.

In all cases where the structure's long life is required and it may be reduced by corrosion-related problems, the use of stainless steel must be considered.

Rebarino



Atmospheric Zone:
In this area, the infrastructure is only exposed to the atmosphere, and the risk of corrosion of concrete reinforcement differs depending on the location of the bridge. For bridges located in inner geographic areas the atmosphere is generally of low aggressiveness, so these bridges are not prone to corrosion, but bridges located near or over sea water have a greater possibility of corrosion of reinforcement, in that atmospheric zone.
Therefore a duplex type stainless steel rebar (ACX 903-EN 1.4482), or even the ferritic type (ACX 702-EN 1.4003) can be considered for bridges, in an atmospheric zone near the sea.

Deck and De-icing Salt Spray Zone:

Stainless steel duplex rebars (ACX 915-EN 1.4362 or ACX 917-EN 1.4462), are a suitable option for its use in bridge deck and surrounding areas where de-icing salts are used.

Splash zone:
Splash zone is a severe corrosive environment and it needs excellent protection against corrosion in the presence of chlorides. The duplex types rebars (ACX 915-EN 1.4362 or ACX 917-EN 1.4462) are suitable for this purpose

Submerged area :
Although the submerged area in salt water is less corrosive than the splash zone, due to the lower oxygen content, design engineers may consider the use of a ferritic stainless steel (ACX 702-EN 1.4003))

Embedded zone :
The area embedded in the ground often has a low corrosion potential risk, based on soil content and composition. Here, a ferritic type (ACX 702-EN 1.4003) can provide a suitable solution.

Case 1: AGGRESSIVE ENVIRONMENT

When the environment where the structure is to be placed is very aggressive, which normally occurs in locations with high temperatures and high concentration of chlorides, the risk of corrosion of the reinforcement is high.

The following images show a bridge, on the sea, in Bahrain for which the pillars have been reinforced by means of reinforcements of stainless steel rebars.

Sitra Bridge, Bahreim

COST EFFECTIVENESS

Stainless steel reinforcement

Case 2: DE-ICING SALTS

In an environment with frequent frosts, where the way to combat them is the use of de-icing salts, it is recommended to use stainless steel reinforcement.

When pouring salts melt and liquefy the ice, it becomes in a liquid state that can be filtered through the concrete structure and lead to corrosion problems.

On this Montana express-way, in the state of Nevada, near the border with Canada, in winter, temperatures are extreme, so that you should fight against icing to keep the highway in service. It is done using salts, and to avoid potential corrosion problems, it has been decided to place stainless steel reinforcement in the first layer just below the asphalt, so that if a filtration occurs, this is not critical.

Reinforced concrete structures by Arminox
Photograph courtesy of Arminox

Montana Highway, USA

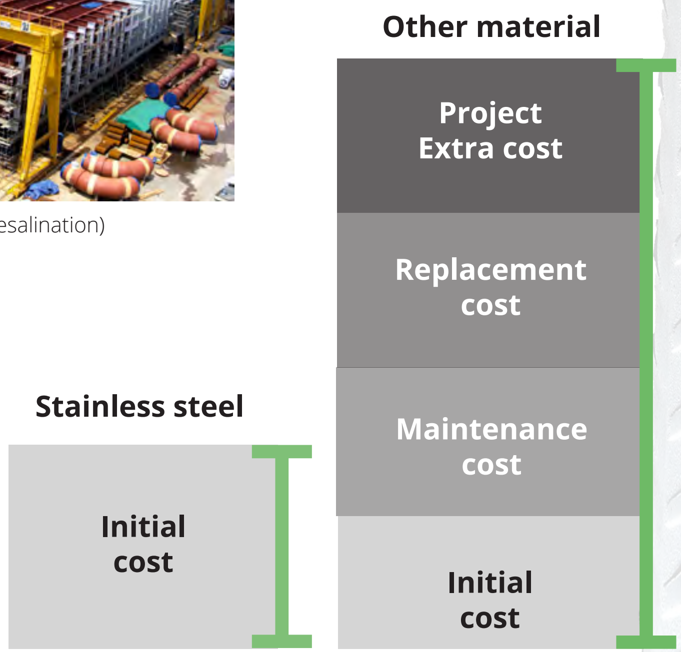
Case 3: DESALINATION PLANTS

The presence of a high content of chloride ions requires the use of many stainless steel parts in their facilities. In the specific case of stainless steel reinforcement, this would be located in the foundations..

Case 4: WATER TREATMENT PLANTS

Different chemical reagents containing chlorides can lead to corrosion of the reinforcements. For example, the use of ferric chloride may react with carbon steel reinforcing bars, resulting in fatal corrosion.

Saudi Arabia MED (Multi Effect Desalination) evaporator facilities



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COST EFFECTIVENESS

Stainless steel reinforcement

Case 5: LONG USEFUL LIFE

There are numerous examples of use of rebar in rehabilitation that have already been damaged by corrosion and should still have a long service life ahead.

The use of stainless rebars in the seams of rehabilitation usually does not assume a great quantity of material nor a significant increase of its cost, and is sometimes the only solution that guarantees a long durability with a proper structural resistance.

La Sagrada Familia, Barcelona, Spain (Internet photograph)

Case 6: DIFFICULT AND COSTLY INSPECTIONS AND REPAIRS

There are structures whose inspections and repairs can be very expensive, for which the best and most economical way of guaranteeing their resistance and preventing possible corrosion problems is the use of stainless steel rebar.

For bridges over the sea, possible repairs to be made on a pillar would need the creation of a sealed area to work, the use of divers and special equipment, etc.

SZ Bridge, Abu Dhabi (photographs courtesy of Arminox for the magazine Acero Inoxidable)

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STAINLESS STEEL

FAMILIES

MARTENSITIC	FERRITIC	DUPLEX	AUSTENITIC
12-18% Cr 0.2-1.2% C	Super ferritic Ferritic 'Utility' ferritic	Super duplex Duplex Lean duplex	CrNi(Mo) MnNCrNi Refractory

MAGNETIC | AMAGNETIC

Fe + Cr

Cr — Ni

According to the chemical composition and its alloy elements, stainless steel can be divided into 4 groups, that is: **martensitic** stainless steels, **ferritic** stainless steels, **duplex** stainless steels and **austenitic** stainless steels.

Austenitic is the main group. Those alloys are non-magnetic and own high ductility properties.

Duplex grades combine great corrosion resistance with high mechanical properties, making them the preferred option for stainless rebar.

Ferritic grades are less alloyed and therefore their price is more competitive. They are used as rebar when the environment is not very aggressive as their corrosion resistance is not as good as austenitic or duplex but fairly better than carbon steel.

Martensitic are high strength steels that are not commonly used as rebar.

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STAINLESS STEEL

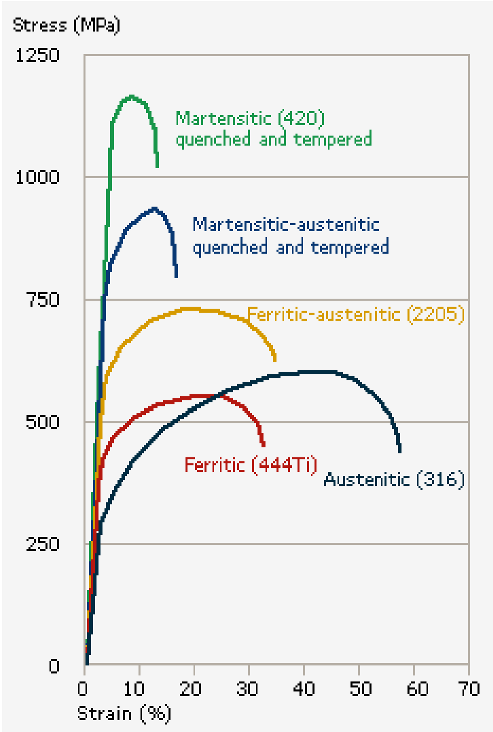
MECHANICAL PROPERTIES

1 Strain-stress curves

International standards such as BS 6744 entails an $R_{p0,2\%}$ ≥500 Mpa, that Roldan guarantees in every rebar.

As example, Roldan stainless steel rebars fulfil at least the minimum following values:

MECHANICAL PROPERTIES			
$R_{p0,2}$ min MPa	R_m min MPa	A_5 min %	A_{gt} min %
500	540	14	5
CARES certification Higher values on request			



2 PREN =Cr+3.3Mo+16N

Aggressive environments with high chloride content are generally a critical corrosion factor for most metals, aggravated by higher temperatures.

The choice of the correct stainless steel that guarantees its resistance is very important and it will depend on the particular conditions of service, such as existing rates of exposure to chlorides, temperature, pH, required durability, etc.

One of the most frequent ways of assessing the pitting corrosion resistance of different types of stainless steel is the **PREN (Pitting Resistance Equivalent Number)**. The higher PREN value the greater its resistance to pitting and localized corrosion in the presence of chlorides and other reducing liquids.

Typical values of PREN are given in the table below for various types of standard stainless steels, calculated according to the PREN formula and its corresponding chemical compositions

Corrosion resistance class (CRC)	Pitting resistance equivalent number (PREN)	Suitable grade according to UNE EN 10088-1
CRC.1	10<PREN≤20	1.4003
CRC.2	20<PREN≤25	1.4482
CRC.3	25<PREN≤30	1.4362
CRC.4	PREN>30	1.4462
PREN =Cr+3.3Mo+16N In the case of duplex steels, the last sum is calculated as 30% N.		

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STAINLESS STEEL

THE RIGHT CHOICE

Exposure class attending to EHE-08 & EUROCODE

CLASS (environment)	SUBCLASS	DESIGNATION EHE-08	DESIGNATION EUROCODE	TYPE OF PROCESS		RECOMMENDED STAINLESS STEEL EN	RECOMMENDED STAINLESS STEEL ACX
Non-aggressive		I	X_0	None	Inside areas with low humidity	not necessary	
NORMAL	High humidity	IIa	X_{C1}/X_{C2}	• Corrosion due to carbonation • Origin different from chlorides	• Inside areas with humidity >65% • Outside areas with frequent/ moderate rain	1.4003 1.4482	702 903
	Medium humidity	IIb	X_{C3}/X_{C4}				
MARINE	Aerial	IIIa	X_{S1}	Corrosion due to chlorides	Structure near the coast	1.4362 1.4462	915 917
	Submerged	IIIb	X_{S2}		Submerged structures		
	Tidal and splash zones	IIIc	X_{S3}		Elements in marine structures		
					• Indoor swimming pools • Water treatment	1.4462	917
with CHLORIDES DIFFERENT FROM SEA ONES		IV	X_{D1}/X_{D3}	Areas exposed to icing and de-icing attack		1.4482 1.4301/1.4307*	903 217
FROST	NO DE-ICING SALTS	H	X_{F1}/X_{F3}	De-icing salts attack		1.4362 1.4462 1.4401/1.4404*	915 917 339
	DE-ICING SALTS	F	X_{D1}/X_{D3}				
The following situations can occur independently or in combination with the previous ones							
CHEMICALLY AGGRESSIVE	LOW	Q_a	X_{A1}	Chemical attack		1.4003 1.4482	702 903
	MEDIUM	Q_b	X_{A2}			1.4362	915
	HIGH	Q_c	X_{A3}			1.4462	917

** Recommended grades for low temperatures below -50ºC, on request*

STAINLESS STEEL vs ALTERNATIVE MATERIALS

We have previously seen that the protection of carbon steel reinforcing bars is based on the protective layer of concrete that covers them and it is therefore important the selection of a high quality concrete, with a layer of sufficient depth over the reinforcement, which can protect it as long as possible.

The various materials alternative to stainless steel as reinforcement, also protect with their own corrosion resistances, both against carbonation and in contact with chlorides or other aggressive elements that can reach into contact.

Epoxy

1 EPOXY. It consists of applying an epoxy coating to the carbon steel rebar. Its initial cost is more economical than that of stainless steel, but on the contrary, being a surface coating, as soon as it breaks at some point, it stops performing its function and it becomes even more detrimental when a localized, more aggressive and fast corrosion occurs. Therefore, you should take special care when bending the coated bars.
The formation of possible bubbles during the pouring of the concrete during its installation can derive in pores where oxidation can start, and it is not resistant to high temperatures (welding or fire).

Galvanized

2 GALVANIZED. Surface coating, presents the same problems as epoxy in case of fracture at some point, so it cannot be easily folded, and it is necessary to properly supervise its handling in place to avoid fissures. An important limitation is that in pieces with a lot of machining this surface treatment must be done after the bending, and it is complicated to guarantee the same thickness of the coating in the whole piece. In addition there are pieces that by dimension cannot be easily treated.

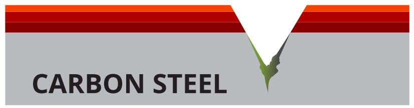
At the end of the life of the infrastructure, the zinc surface layer of the galvanized must be treated before being recycled as scrap, which is an additional cost to be considered.

3 REINFORCED FIBRE POLYMERS: This product has several problems for bending operations, where the plastic can break.

The high temperature resistance of plastics is much lower than that of metals so it does not offer guarantees against accidents with fire nor allows uses at high temperatures.

Durability

Surface layer: Chromium oxide
0.002 - 0.003 μm



1st Surface layer
2nd First layer
3rd Pre-treatment
20 - 200 μm

Finally, in the case of plastic materials, in case of a replacement or repair, the removed materials should be treated as contaminant waste.

4 CATHODIC PROTECTION: It consists in making the metal reinforcement to behave like a cathode so that there are no differences in galvanic potential that cause corrosion problems. This is achieved by using sacrificial anodes, with materials of lower galvanic potential and providing a continuous current to the reinforcement structure.
It has the advantage that it can be monitored but the installation or the design are more complex and the sacrificial anodes have a duration around the 25 years against the 100 that guarantees the suitable stainless steel type.

SOME CONCLUSIONS

1 Highly resistant to corrosion by chloride ions present in sea water and de-icing salts (While carbon steel tolerates maximum concentrations of chlorides (CCTL) of the order of 0.4% in weight of cement, stainless steel is resistant in concentrations up to more than 10 times higher, depending on the type used, pH and temperature).

2 It does not require high alkalinity of the concrete because of its self protection.

3 Use of stainless steel rebar enables reduction of the concrete cover depth.

4 It simplifies the selection of type of concrete used and eliminates the use of sealants for concrete, as protection of the reinforcement by diffusion of CO_2 ,and chloride ions.

5 Increases service life and prevents repair and maintenance works of infrastructures.

6 It has a competitive cost when used in areas of high risk of corrosion.

7 Stainless steel is completely recyclable, at no cost, at the end of the useful life of the infrastructure. On the contrary, its value as scrap is high, depending on the cost of its raw materials at that particular time.

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Stainless steel rebar
Created by Cedinox, Stainless Steel Development Association in Spain. www.cedinox.es