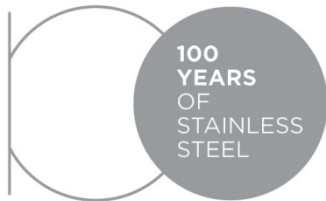


Supporting presentation for  
lecturers of Architecture/Civil  
Engineering

## **Chapter 04**

**What are the stainless steels?**

# Videos



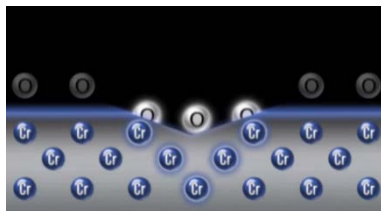
100 Years of Stainless Steel

<http://www.stainlesssteelcentenary.info/Home/Video>



Alloyed for Lasting Value

[http://www.worldstainless.org/files/issf/mov\\_video\\_files/Alloyed%20for%20lasting%20value/Alloyed%20for%20lasting%20value%20English.mov](http://www.worldstainless.org/files/issf/mov_video_files/Alloyed%20for%20lasting%20value/Alloyed%20for%20lasting%20value%20English.mov) or  
<http://youtu.be/l4Z1UVWm3DE>

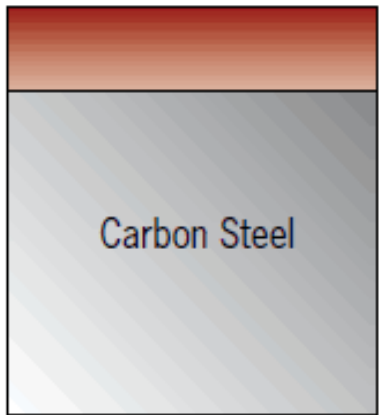


Self-repairing for Lasting Value

[http://www.worldstainless.org/files/issf/mov\\_video\\_files/Selfrepairing%20for%20lasting%20value/Selfrepairing%20for%20lasting%20value%20English.mov](http://www.worldstainless.org/files/issf/mov_video_files/Selfrepairing%20for%20lasting%20value/Selfrepairing%20for%20lasting%20value%20English.mov) or  
<http://youtu.be/ngnT6dYo-M0>

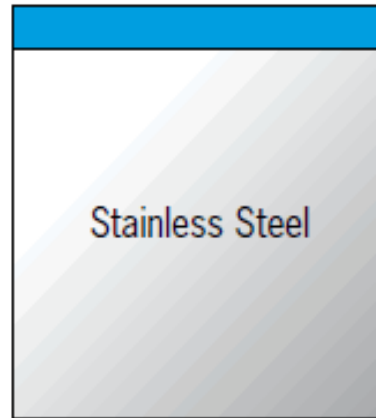
# Stainless steels are Iron-base alloys containing at least 10.5% chromium

Surface Oxide (rust)  
> 20 $\mu$ m thick



< 11% Chromium

Surface Passive film  
~ 2nm thick

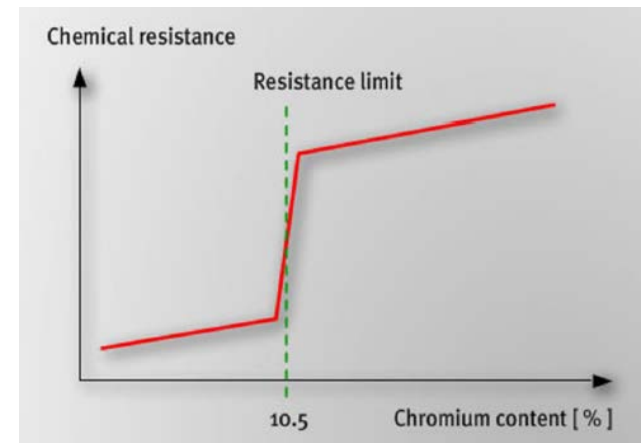


>11% Chromium

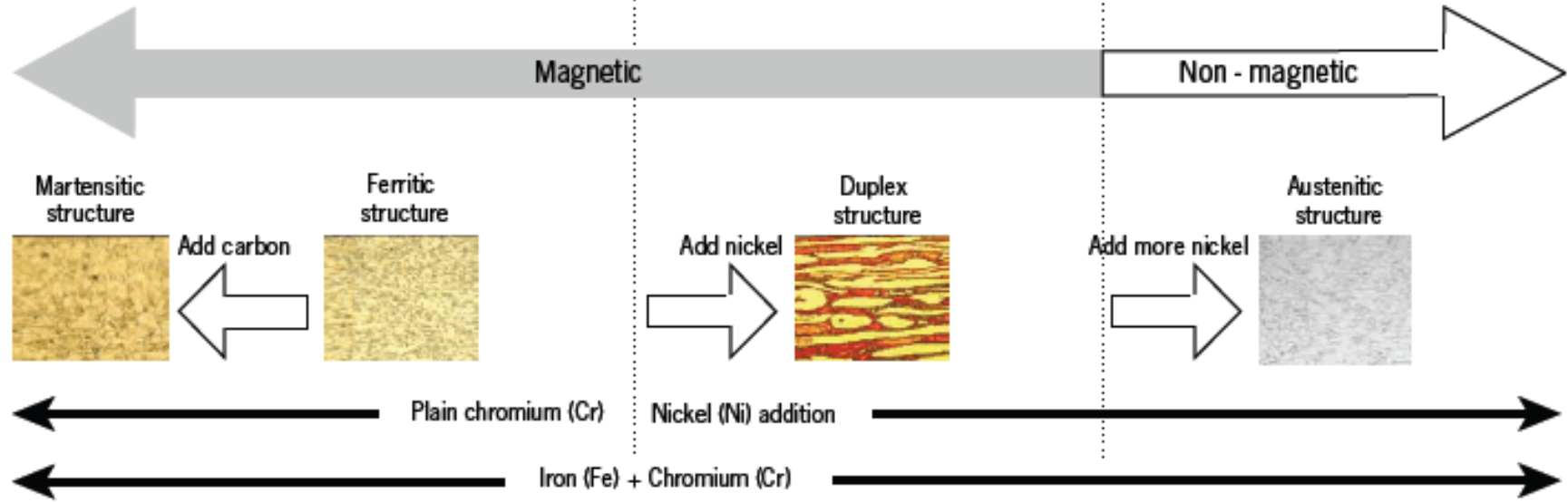
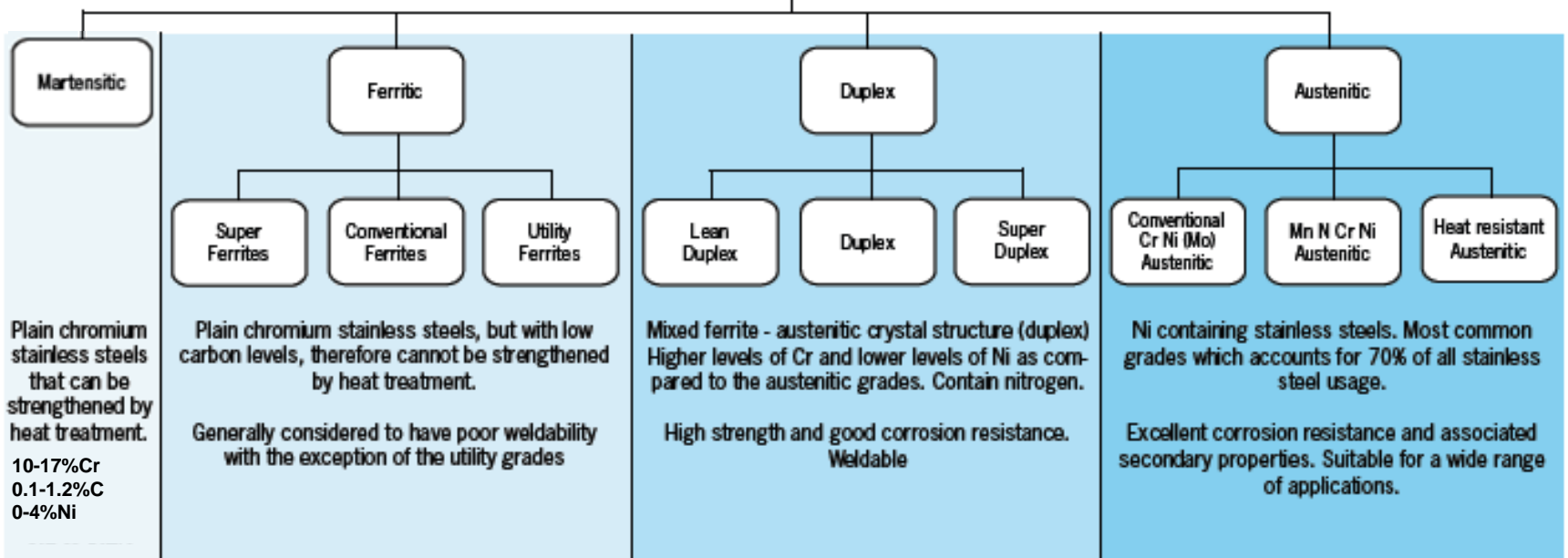
**→ corrosion resistance**

**The passive film forms  
in a few minutes**

Increasing Cr content increases the effectiveness of the passive film... but there are other important factors that influence the corrosion resistance (see Chapter 3)



Stainless steels



# Cr-Ni Grades (Austenitics)<sup>4</sup>

## Sub-groups:

▪ Cr-Ni	Typically EN 1.4301/AISI 304	Cr: 18	Ni: 9	Fe: Balance
▪ Cr-Ni-Mo	Typically EN 1.4401/AISI 316	Cr: 18	Ni 10 Mo: 2.5	Fe: Balance

## Common Properties:

- Very good corrosion resistance, increases with alloy content
- ... but can be susceptible to SCC in hot chloride environment (e.g. swimming pools)
- High ductility and impact resistance at all (including very low) temperatures
- Strength can be increased by cold working (but not by heat treatment)
- Very good fire resistance
- Very good cold and hot forming properties (ductility, elongation)
- Easy to weld (TIG, MIG)

The best known  
and still the most  
used today

# Cr-Mn Grades (Austenitics with Manganese)<sup>5</sup>

## Typical grade:

- Cr-Mn-Ni-N Typically EN 1.4372/AISI 201 Cr: 17 Mn: 7 Ni: 4 N:0.15 Fe: Balance

## Common Properties:

- Lesser corrosion resistance
- ... but far more susceptible to SCC and to pitting, particularly at low Ni and Cr levels
- Higher strength
- Poor cold forming properties due to high work-hardening
- Poor machinability
- More difficult to weld
- Cost less than Cr-Ni Austenitics ... but more than Cr ferritics

Used mostly in  
India and China

# Cr Grades (Ferritics)<sup>6</sup>

## Sub-groups:

▪ Cr	Typically EN 1.4016/AISI 430	Cr: 17	Fe: Balance
▪ Cr-Mo	Typically EN1.4521/AISI 444	Cr: 18 Mo: 2 Ti+Ni: 0.4	Fe: Balance

## Common Properties:

- Inensitive to Stress Corrosion Cracking
- Good ductility (lower than austenitic grades, though)
- Not suitable for use at very low temperatures
- Strength can be somewhat increased by cold working (but not by heat treatment)
- Very good cold forming properties: (less springback, lower tool wear but lower elongation requires a different deep drawing process compared to austenitics)
- Stabilized grades (i.e. with Nb and/or Ti) are easy to weld (TIG, MIG)

Offer an optimum performance/cost for many applications and are increasingly used

# Cr Grades (Martensitics)<sup>7</sup>

## Sub-groups:

▪ C-Cr	Typically EN1.4021/AISI 420	Cr: 13	C:0.2	Fe: Balance
▪ C-Cr-Ni	Typically EN1.4057/AISI431	Cr: 16	Ni: 2 C: 0.2	Fe: Balance
▪ Precipitation Hardening	Typically EN1.4542/AISI630	Cr: 17	Ni: 4 Cu:4	Fe: Balance

## Common Properties:

- Fair to good corrosion resistance, increases with alloy content
- High strength obtained by heat treatment (not by cold work). Limited elongation.
- Not suitable for use at very low temperatures
- Not suitable for forming, often processed by machining
- Can be welded (TIG, MIG), but require usually post-weld heat treatment

Are used as  
engineering steels  
with corrosion  
resistance

Colour code:   ▪ Corrosion resistance   ▪ Mechanical properties   ▪ Fabrication



# Duplex (Austenitic-Ferritic)<sup>8</sup>

## Sub-groups:

▪ Cr-Ni	Typically EN1.4362	Cr: 23	Ni: 4	Fe: Balance	
▪ Cr-Ni-Mo	Typically EN1.4462	Cr: 22	Ni: 5	Mo: 3	Fe: Balance

## Common Properties:

- Excellent corrosion resistance, increases with alloy content
- Inensitive to Stress Corrosion Cracking
- High strength, good ductility
- Strength can be increased by cold working (but not by heat treatment)
- Good cold and hot forming properties (ductility, elongation)
- Weldable (TIG, MIG)

Offer the best  
combination of  
corrosion resistance  
and mechanical  
properties

# Physical properties<sup>9, 10</sup>

Materials	Modulus of Elasticity Gpa	Thermal Expansion Coefficient $10^{-6} \text{K}^{-1}$	Thermal Conductivity $\text{W m}^{-1} \text{K}^{-1}$	Ferro-Magnetism	Density $\text{Kg/dm}^3$
Cr-Ni Austenitics	210	18	15	No	7,8
Cr-Mn Austenitics	210	17	15	No	7,8
Cr Ferritics	220	11	23	Yes	7,7
Cr-Ni (Mo)-N Duplex	210	14	15	Intermediate	7,8
Cr-C Martensitics	215	11	30	Yes	7,7
Carbon Steel	210	12	18	Yes	7,8
Copper	135	17	380	No	8,3
Aluminum	70	22	230	No	3,9
Glass	65	9	1,7	No	2,5
Concrete	48	10	1	No	2,5

# Standards on Stainless Steels

## Main World Standards:

ISO



EN



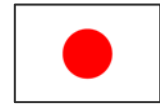
ASTM/AISI



UNS



JIS



### Notes:

Most countries refer to the above standards, which are widely accepted.  
A lot of the grades are very similar in all of the above standards.

List of the American Standards: ref 11

List of European Standards: ref 12

Correspondance tables are available: refs 13 - 15

# Main grades in Architecture Building and Construction: EN 10088-4 (for sheet/plate/strip)<sup>16, 17</sup>

Grade	ASTM UNS	C Wt%	Cr Wt%	Ni Wt%	Mo Wt%	Other Wt%	Typical use <sup>3,4</sup>
4003	S40977	0,02	11,5	0,5	-	-	heated and unheated interiors
4016	430	0,04	16,5	-	-	-	decorative interior cladding
4509	S43932	0,02	18	-	-	Nb Ti	inland roofing and rainwater goods - often Tin-coated for patina
4510	439	0,02	17	-	-	Ti	
4521	444	0,02	17,8	-	2,1	Ti	domestic plumbing market
4301	304	0,04	18,1	8,1	-	-	building interiors and exteriors in normal industrial atmospheres away from the coast
4307	304L	0,02	18,1	8,1	-	-	
4306	304L	0,02	18,2	10,1	-	-	
4401	316	0,04	17,2	10,1	2,1	-	permanently wet applications, locations in a coastal atmosphere, polluted industrial atmospheres or near roads where de-icing salts can be an issue
4404	316L	0,02	17,2	10,1	2,1	-	
4571	316Ti	0,04	16,8	10,9	2,1	Ti	
4529	N08926	0,01	20,5	24,8	6,5	N, Cu	road tunnels and indoor swimming pools
4547		0,01	20,0	18,0	6,1	N, Cu	
	S31254						

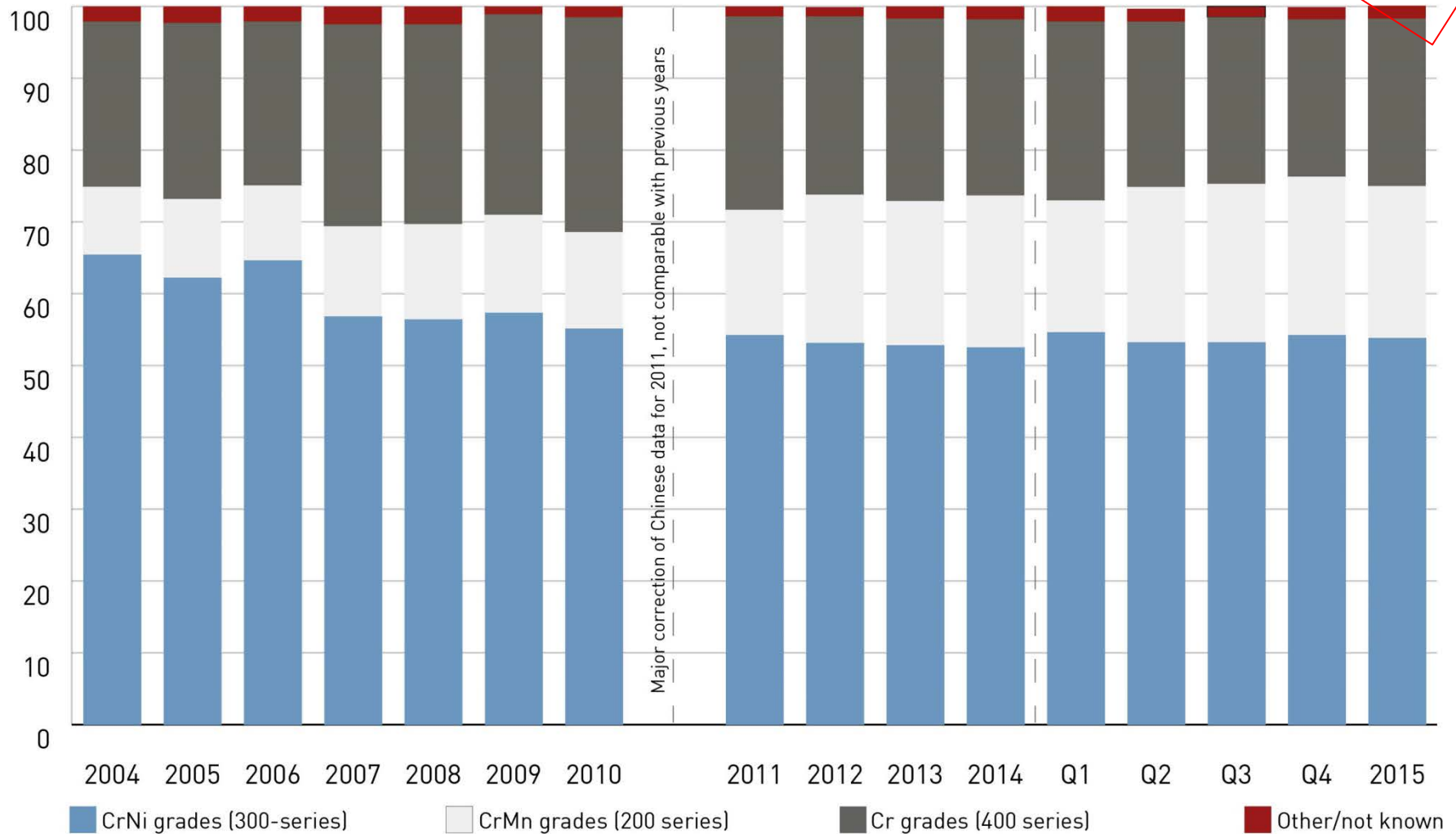
# Main grades in Architecture Building and Construction: EN 10088-5(for bars/wires/sections)<sup>18</sup>

Grade	ASTM UNS	C Wt%	Cr Wt%	Ni Wt%	Mo Wt%	Other Wt%	Typical use <sup>6</sup>
4003	S40977	0,02	11,5	0,5	-	-	
4016	430	0,04	16,5	-	-	-	Slate hooks
4542	630	0,04	16,0	4,0		Cu,Nb	Tie bars
4301	304	0,04	18,11	8,1	-	-	Rebar A2 fasteners
4307	304L	0,02	8,118	8,1	-	-	
4311	304N	0,02	,1	8,6	-	N	
4567	304Cu	0,02	17,1	8,6	-	Cu	
4401	316	0,05	16,6	10,1	2,1	-	Building interiors and exteriors in normal industrial atmospheres away from the coast, Rebar
4404	316L	0,02	16,6	10,1	2,1	-	
4429	« 316LN »	0,02	16,6	11,1	2,6	N	
4529	« 926 »	0,01	20,5	24,8	6,5	N, Cu	Road tunnels and indoor swimming pools
4547	S31254	0,01	20,0	18,0	6,1	N, Cu	
4362	S32304	0,02	22,5	3,6	0,3	N, Cu	Rebar and mechanical components
4462	S32205	0,02	21,5	4,6	2,8	N	Rebar and mechanical components



# Breakdown of the world production by family<sup>19</sup>

UPDATED  
2016 !



High Ni prices favour the replacement of popular CrNi grades by Cr-Mn or Cr Grades  
Duplex grades marginal today, are expected to grow in the future

UPDATED !

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UPDATED !

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Thank you!