Supporting presentation for lecturers of Architecture/Civil Engineering

# Chapter 03

# Why stainless steels?

# Introduction

Main materials used in architecture, building and construction

# Relative use of the main building materials today

UPDATED 2018!

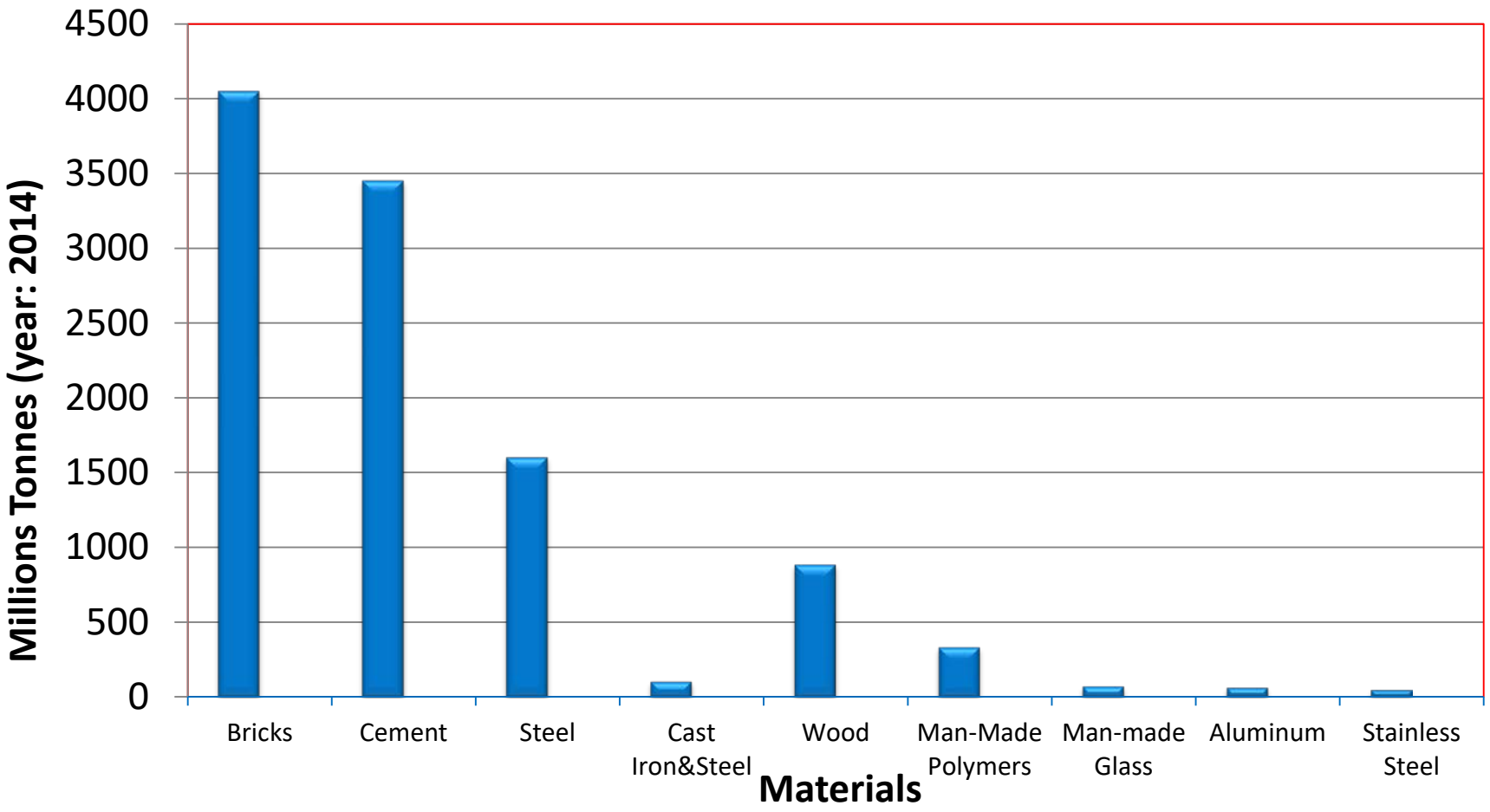
| Materials | World Production * | Average Density | Remarks |
|---|---|---|---|
| Rammed earth, *pisé* | na | | Was used for traditional houses in Africa mostly.<br>Some renewed interest for its environmental properties |
| Bricks [2] Traditional production is very polluting and unhealthy | 4050 | 2,0 | Year believed to be 2016<br>Of which 87% in Asia |
| Cement [3] | 3452 | 2,4** | (To obtain the figure for concrete multiply by 3-4)<br>**Concrete density - Note: 2015 figures |
| Steel [4a] | 1604 | 7,8 | (Crude Steel production 2016)<br>14% goes into infrastructures - half as rebar [10]<br>42% goes into buildings [12] |
| Cast Iron and Steel[4b] | 104 | 7,8 | 2016 Figures |
| Wood [5]<br>Deforestaion keeps gaining ground | 887 | 0,56 | Sawn wood+wood-based panels only (2016 figures)<br>Excluding pulpwood (about 656)<br>Excluding wood fuel (1860) &other wood products |
| Man-Made Polymers [6] | 335 | 1,1 | Some Natural Polymers: Cellulose, Rubber, Silk, Chitin<br>2016 figures |
| Man-made Glass [7] | 73 | 2,6 | Flat glass only (80% of total glass market)<br>Main other markets: Automotive, Solar energy Glass |
| Aluminum [8] | 63 | 2,7 | (Primary Aluminum Production in 2017)<br>24% goes into construction [10] |
| Stainless Steel [9] | 48 | 7,8 | 2017 figures 17% goes into construction [11] |

na: not available

* in Millions Metric Tons

UPDATED 2018!

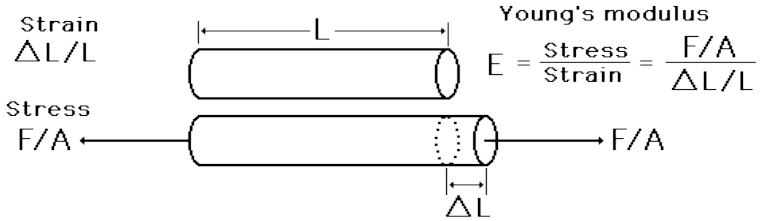
# Relative use of the main building materials today: Bar Chart



# Young's modulus E of various materials[12] (stiffness )

| Material | Young's Modulus E (GPa) |
|---|---|
| Steels | ~210 |
| Stainless steels | ~210 |
| Copper alloys | ~130 |
| Titanium Alloys | ~100 |
| Aluminum alloys | ~70 |
| Concrete | ~40 |
| Wood | ~10 |
| Plastics | ~4 |

Stainless steels are as stiff as steel



# Strength/weight ratio[13] of architectural metals

Stainless steels offer a strength/weight ratio comparable to steels and to Al alloys

| Material | Strength (YS)/Specific Weight | Yield, Stress, Mpa | Ultimate Tensile Strength, Mpa | Specific wt (Kg/dm³) | Min Elongation, % |
|---|---|---|---|---|---|
| Stainless 304 or 316, annealed | 26 | 205 | 515 | 7,8 | 35 |
| Stainless 304 or 316, work-hardened CP 350 | 45 | 350 | - | 7,8 | - |
| Stainless 304 or 316, work-hardened CP 500 | 62 | 480 | - | 7,8 | - |
| Duplex 2205 | 64 | 500 | 700/950 | 7,8 | 20 |
| Stainless 630, aged | 103 | 800 | 950/1150 | 7,8 | 10 |
| C-steel commercial sheet, Hot rolled | 30 | 234 | 317 | 7,8 | 35 |
| Structural Steel (plate and bar) | 32 | 250 | 400/550 | 7,8 | 23 |
| HSLA Steel | 49 | 380 | 460 | 7,8 | 25 |
| Engineering Steel 4140 Q&T | 96 | 750 | 930/1080 | 7,8 | 12 |
| Aluminum Alloy 3003- H14 | 37 | 145 | 150 | 2,7 | 40 |
| Aluminum Alloy 3105- H14 | 38 | 150 | 170 | 2,7 | 5 |
| Aluminum Alloy 5005- H16 | 44 | 170 | 180 | 2,7 | 5 |
| Aluminum Alloy 6061- T6 | 71 | 275 | 310 | 2,7 | 12 |
| Aluminum Alloy 6063- T5 | 37 | 145 | 185 | 2,7 | 12 |
| Copper | 23 | 195 | 250 | 8,3 | 30 |

# Simplified overview of different materials[14]

| | Properties | Stainless Steels | | | Copper | Aluminum | Carbon Steel | Plastics |
|---|---|---|---|---|---|---|---|---|
| | | EN 1.4521 AISI 444 | EN 1.4301 AISI 304 | EN 1.44O1 AISI 316 | | | | |
| Physical | Density | - | - | - | - - | + | - | + + |
| | Linear expansion | + + | 0 | 0 | 0 | - | + | - - |
| | Electrical Conductivity | - - | - | - | + + + | + + | 0 | - - - |
| | Ferromagnetism | YES | NO | NO | NO | NO | YES | NO |
| Mechanical | Stiffness (Young's modulus) | + + + | + + + | + + + | + | - | + + + | - - - |
| | Tensile | + | + + | + + | 0 | - | + / + + | - - |
| | Elongation | + | + + + | + + + | + + + | + + | 0 | - - / + + + |
| Other | Fabrication | + + | + + | + + | + | 0 | + + | - |
| | High temperatures | + + | + + | + + + | 0 | - | + | - - - |
| | Low temperatures | - | + + + | + + + | + | 0 | - | - |
| | Corrosion resistance | + + + | + + + | + + + + | + + | + | - - | + |

Symbols + Advantage - Weakness (relative to the other materials)

# Stainless steel remains a « young » material

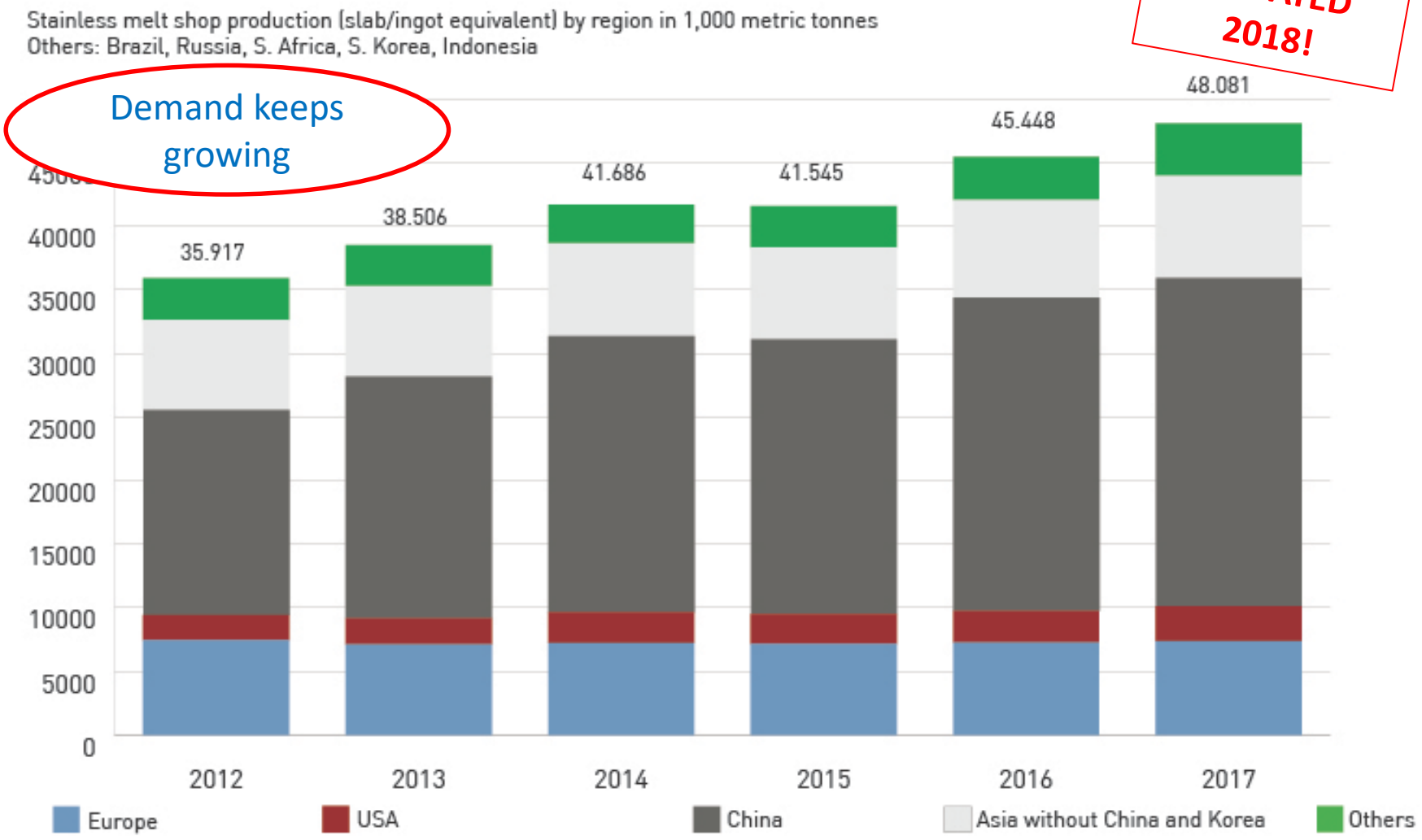
# New materials have appeared in the course of history
# Stainless steel is the most recent*

| Materials | Timeframe | |
|---|---|---|
| Rammed earth, *pisé* | | Has been used since the dawn of mankind! |
| Wood [15] | | Has been used since the dawn of mankind! |
| Brick [15] | 7500 BC<br>4500 BC | Fired bricks/ceramics |
| Steel [15] | 4000 BC<br>1858 | Blacksmiths' shops<br>Bessemer Process |
| Man-made Glass [15] | 3500 BC<br>100 BC<br>1950 | First glassmaking<br>Clear Glass<br>Pilkington (Float Glass) Process |
| Aluminum [15] | 1825<br>1886 | Oersted discovers Aluminum<br>The Hall –Heroult process |
| Reinforced Concrete [15] | 1850<br>1885 | But cement is much older<br>Rotary Kiln Process |
| Man-Made Polymers [15] | 1846<br>1907<br>1939 | Celluloïd<br>Bakelite<br>Nylon |
| Stainless Steel [2] | 1912-1913<br>1954<br>1955 | Early alloys<br>AOD Process<br>Hot Strip Rolling |

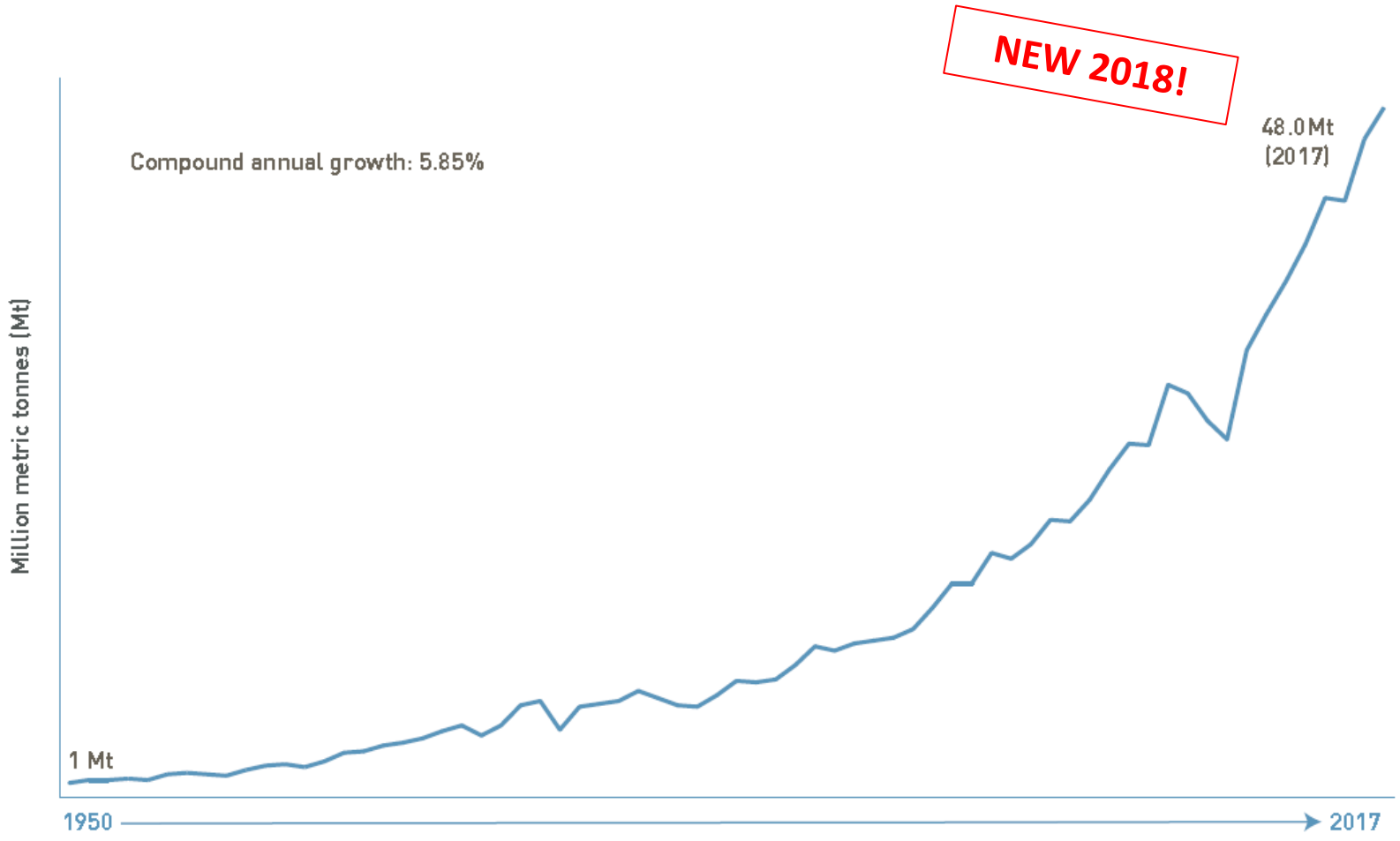
* There are newer materials, of course, but not used in significant quantities

# World Stainless Steel Production by area[22]

UPDATED 2018!



# Compound annual growth of world Stainless Steel meltshop production[22] (Millions of Metric tons)



# Why Stainless steel?

# Because of an outstanding set of properties

1. **Corrosion resistance** (see chapter 3 )
   - In all environments: tropical to polar, sea or desert, polluted or not…
   - Self-repairing, unlike coatings
2. **Lasting forever** with little or no maintenance
3. **Wide range of mechanical properties** allowed by several stainless families(Cr-Ni Austenitics – Cr-Mn Austenitics – Cr Ferritics – Duplex – Cr C Martensitics) and now built into the major building codes. Plus an excellent fire resistance (see Chapters 4 and 5)
4. **Aesthetics**: Large selection of surface finishes à colors available (see chapter 6). Plus resistance to damage in public areas
5. **Easy fabrication/joining** (see chapter 7)
6. **Excellent sustainability** (see chapter 9)
   - allows a long service life with no or little maintenance,
   - 100% recyclable (and more than 85% recycled) at the end of life into stainless steel without loss of properties
7. **Safe and Hygienic**: Inert, no contamination, easy to clean & disinfect
8. **Specific properties**: magnetic/non magnetic, ….

# What limits the use of stainless steels: the price

Stainless Steels are expensive: True? Or False?

Answer: Yes and No

**Yes:**

If the initial material cost is all what matters (usually because of limited funding…)

But then a bad choice may be very expensive:

- Stainless steel usually represents a small part of the project
- Untimely repairs and maintenance may add huge direct and indirect costs

**No:**

if

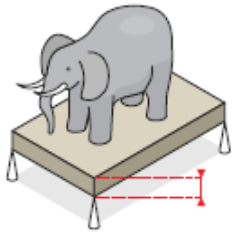
- the Life Cycle Cost (the « real » cost) is taken into account, i.e. if maintenance, service life and recycling issues are factored in*
- the design is optimized: thin sheets, profiled into complex shapes can result, in strong, stiff structures that use little material.

*The owner's best interest is always to make choices based on LCC analysis

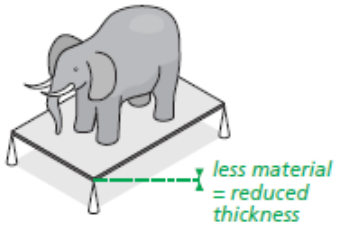
# Stainless (and other metals) use less material[16]

## DOING MORE WITH LESS

Due to their high strength, metals can bear high loads with less material or be used to reinforce other materials.



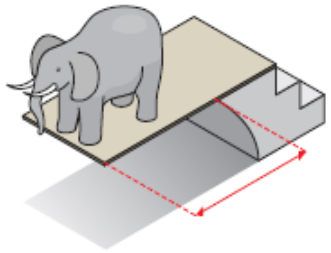
*non-metallic material*



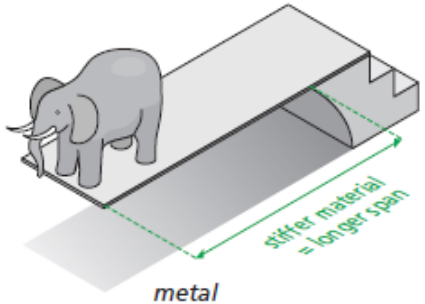

*metal*

## FREEDOM FOR DESIGNERS

Thanks to their high stiffness, metals can span greater distances, allowing more design freedom.



*non-metallic material*




*metal*

Thin gauge 0,4mm and 0,6mm thick stainless steel sheets are commonly used. Weight: 3,12Kg and 4,68Kg respectively per $m^2$ only!

# Why stainless steel is not expensive if the life cycle cost is taken into account

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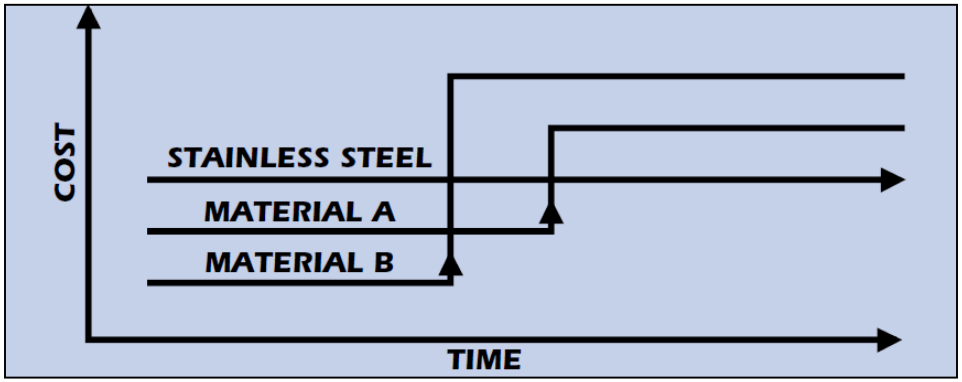
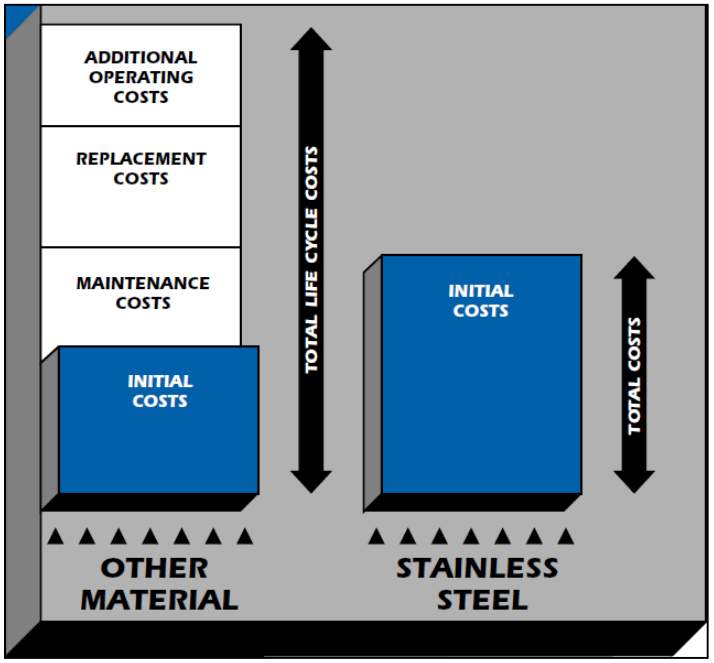
The cost of structures made of other materials substantially increases over time while the cost of stainless steel structures normally remains constant.




**The Cost of corrosion exceeds 276 Billions $ in the USA alone (2002 estimate)** [17]

# Life Cycle Cost Comparison of 2 old structures[18,19]

| Structures | Completed | Material | Height | Maintenance |
|---|---|---|---|---|
| Eiffel Tower – Paris *  | 1889  | Wrought iron | 324m | Every 7 years. Every painting campaign lasts for about a year and a half (15 months). 50 to 60 tons of paint, 25 painters, 1500 brushes, 5000 sanding disks and 1500 sets of work clothes. |
| Chrysler Building (Roof and Entrance) – New York  | 1930 (roof 1929)  | Austenitic Stainless Steel (grade: 302) | 319m | Twice in 1951, 1961, 1995. The 1961 cleaning solution is unknown. A mild detergent, degreaser and abrasive was used in 1995. |

* The Eiffel tower was built before stainless steel was invented…and it was supposed to be a temporary structure, but the public loved it !

**Example:**

Comparison of the maintenance of 2 very well known bridges[20, 21]

- Golden Gate Bridge in San Francisco
- Stonecutter's Bridge in Hong Kong

In the next 2 slides

# The Golden Gate bridge (1937), San Francisco

<- Maintenance

"a rugged group of **13 ironworkers** and **3 pusher ironworkers** along with and **28 painters**, **5 painter laborers**, and **a chief bridge painter** battle wind, sea air and fog, often suspended high above the Gate, to repair corroding steel. Ironworkers replace corroding steel and rivets with high-strength steel bolts, make small fabrications for use on the Bridge, and assist painters with their rigging. Ironworkers also remove plates and bars to provide access for painters to the interiors of the columns and chords that make up the Bridge. Painters prepare all Bridge surfaces and repaint all corroded areas." [20]

# Stonecutter's bridge (2009), Hong Kong

<- Maintenance

**Project details :** 1,596m-long dual 3-lane high-level cable-stayed bridge, with a clear span of 1,018m. Typhoon resistant.

**Material :** Stainless Steel EN1.4462 (Duplex) plate with 450MPa yield stress used for the towers above +175m to top (+295m) and for towers skin.

**Why stainless rather than C-steel:** designed for 120 years life in a hot and polluted seawater environment. Designed for no maintenance. [21]

# Main references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22. http://www.worldstainless.org/statistics/publications_and_papers

# Thank you

Test your knowledge of stainless steel here:

https://www.surveymonkey.com/r/3BVK2X6