

Chapter 02

Steel grades, properties and products.

1 . The steel material:

Steel is a material made mainly of iron and a little carbon, which are extracted from natural raw materials extracted from the ground (iron and coal mines). Carbon is only used in a small part of the composition (generally less than 1%).

Steel is generally obtained by a 2-phase operation:

1st phase: the introduction and combustion of iron and coke in a blast furnace makes it possible to obtain pig iron (material with more than 1.7% carbon)

2nd phase: liquid cast iron is converted into steel, at a temperature of about 1500°C, under oxygen insufflation. This operation is carried out in a converter and has the purpose of decarburizing the cast iron. The resulting steel has only a small percentage of carbon.

There are two processes for making steel:

*The "**BESMER**" process produces a steel of common quality.

*" **MARTIN**" process: it uses an electric furnace, the steel of better quality is obtained.

At the end of the steelmaking process, it is cast in, either:

□ **Ingot casting** : Steel is cast and solidified in cast iron molds, called ingot molds. Once the solidification is complete, the ingots are removed from the mould. After reheating to 1200°C, they are crushed in a large rolling mill to be slabbed, roughed into flat products (slabbing) for future long products (blooming).

□ **Continuous casting** : Liquid steel is cast in a copper mould, with a square, rectangular or round section (depending on the semi-finished product manufactured). The metal begins to form a solid skin in the violently water-cooled mould. The semi-finished products are heated in ovens before moving on to the next step (rolling). This process makes it possible to obtain semi-finished products directly without the blooming-slabbing step of ingot casting.

2 . Classification of steel: According to their carbon content:

Steel	C content (%)	Area of use
Mild steel	0,05 – 0,3	Framework, bolts
Semi-mild steel	0,3 – 0,6	Rails, forgings
Hard steel	0,6 – 0,75	Tools
Extra-hard steel	0,75 – 1,2	Tools (punches)
Wild Steel	1,2 – 1,7	Special parts

3. Steel products:

The steel products used in metal construction are:

3.1 Lime rolled products: A distinction is made between:

3.1.1 Long products:

- ☐ I-sections: IPE or IPN, they are used as flexed elements working in simple bending, such as main or even secondary beams
- ☐ H-profiles: HEA, HEB, or HEM: used for elements subject to compound loads such as columns.
- ☐ U-profiles: UAP, or UPN used as secondary elements, such as cladding beams
- ☐ L-angles: used in lattice structures, and connecting elements
- ☐ T-sections: TPB, or TPH: rarely used in metal structures except as secondary assembly elements.
- ☐ Flat bars: used for the production of P.R.S: Welded Reconstituted Profiles (reconstruction of an I or H section from 3 flats), and as assembly elements (column-beam assembly plates)
- ☐ Round or square bars: can be used as bars for lattice structures or stressed shear bars in tension or compression.

3.1.2 Flat products: used in industrial construction such as: silos, hulls

- ☐ Wide flats: are sheets of white-rolled steel (slab rolled with lime on all 4 sides in order to obtain a wide flat)
- ☐ Sheets: (lime rolled slab on 2 sides)

3.2 Cold-formed products:

Are products obtained by cold forming from (thin) sheets, are characterized by a low thickness, and elaborate shapes, there are:

Profiles: used as secondary elements

Smooth sheets: corrugated or ribbed, used as roofs, roofs, cladding, or formwork for composite floors

Embossed sheets: example: ribbed sheet metal with honeycomb relief, can be used as roofs, stairs.

Tubular profiles: there are 3 types, the circular, square, or rectangular tube, these are cold-drawn dishes then rolled according to the desired shape.

4. Residual stresses: Are of mechanical or thermal origin, thermal stresses occur in parts:

*Hot rolled

*Welded Assembled

*Cut with a blowtorch

Mechanical stresses are generally due to cold dressing of the elements in order to make them straight after having undergone deformations during storage or even during transport)

6. Steel inspection tests: there are two families of tests:

6.1 Metallographic testing (non-destructive testing):

- * Macrography: it is to examine a steel part with the naked eye
- * Micrography: this is to examine a steel part using a microscope
- * X-ray: this is to examine steel in the laboratory using X-rays, or on site by ultrasound.

The goal is to have qualitative information on the chemical composition of steels, as well as their crystalline structure.

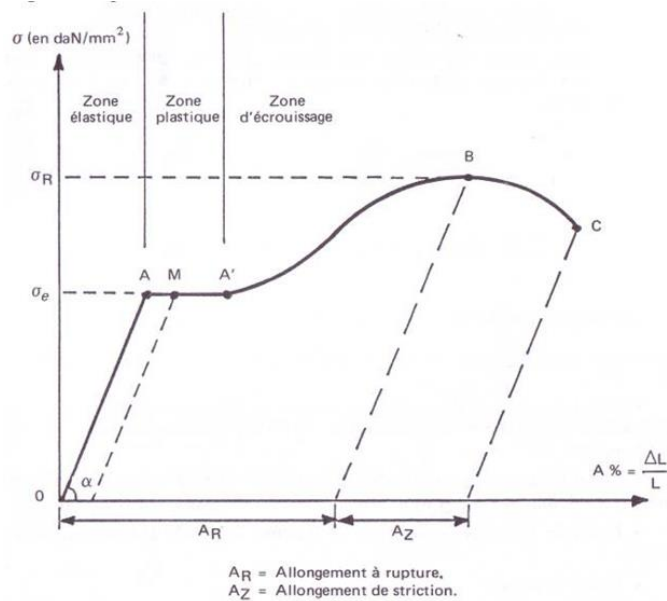
6.2 Destructive testing: (hardness, toughness, and tensileness)

6.1.1 Hardness test: he studies the penetration of a ball or a point and then defines the degree of hardness of the steel, in order to find an empirical relationship between the strength of the part f_u and H_b the diameter of the ball/point, and h the depth of the deformation.

6.1.2 Impact test: (impact bending): it measures the energy produced by a specimen during its failure. This energy makes it possible to characterize the ductility of the steel and its sensitivity to brittle fracture of the steel as a function of temperature, it serves as a reference to define the quality of the steel

6.1.3 Bend test: This is used to assess the ductility of the steel and its suitability for cold forming. It consists of forcing a metal sample, under specified conditions, to bend to a required angle (generally 180°). The edges are then inspected and especially the extended face. For good cold bending suitability, the extension face should in principle not have cracks, cracks or tears.

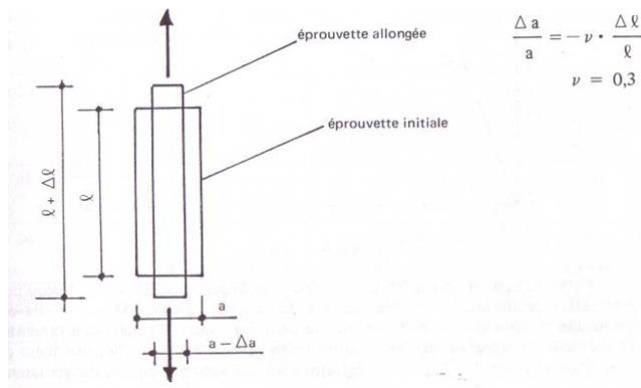
6.1.4 Tensile test: a specimen is used in uniaxial tension until fracture to determine its mechanical characteristics. We obtain an effort-strain diagram.



- OA: a rectilinear area for which there is a proportionality between the deformation and the applied force. It is a reversible elastic area
- AA': horizontal bearing, reflecting elongation under constant load. There is a flow of the material, this is the plastic area.
- A'B: the load increases again with elongation up to point B. if the specimen is unloaded in the plastic zone A'B, a residual elongation is observed; If it is reloaded, elastic behaviour is observed up to the previous load: the yield limit has been increased, the metal has been hardened.
- BC: the elongation continues, although the load is decreasing, until the point C where there is a failure. In this phase there is a shrinkage: the plastic deformation is localized in a small portion of the specimen and is therefore no longer homogeneous.

We measure:

- f_y yield strength, point A. Conventionally this yield strength is defined as the stress corresponding to a residual elongation of 0.2%.
- f_u ultimate tensile strength, point B
- E longitudinal modulus of elasticity of the steel (slope of OA), $E = \tan \alpha = \sigma / \epsilon$
- The Poisson's coefficient ν
- G transverse modulus of elasticity,
- $A_r\%$ elongation at fracture, corresponding to the deformation measured between the initial and final fracture states



The ductility bearing AA' represents a safety reserve, thanks to the phenomenon of plastic adaptation: if a part is stressed beyond the elastic limit, it has this bearing to discharge in the surrounding areas. The higher the carbon content, the shorter the ductility bearing becomes, the more the elongation at break decreases, thus decreasing safety, because the parts risk perishing by sudden failure, without any premonitory signs (large deformations). This is why only mild (low-carbon) steels are allowed in steel construction.

Mechanical characteristics of steel:

- Longitudinal modulus of elasticity: $E=2.1 \cdot 10^6$ DaN/cm²
- Poisson's ratio: $\nu=0.3$
- Transverse Yield Coefficient: $G=8.1 \cdot 10^5$ DaN/cm²
- Dilation: $\lambda=11 \cdot 10^{-6}$
- Density: $\rho=7850$ DaN/m³

For comparison, concrete has a density of 2400 DaN/m³

7. Characteristics of normalized steels:

Steels used in steel constructions are regulated by EN 10025.

This standard defines grades that correspond to their mechanical characteristics f_y and f_u

Exp: S 235: it is the steel with elastic limit $f_y = 235$ MPa

Steel grades	Thickness t (mm)				Elongation at Break ϵ_r (%)
	$t \leq 40$ mm		$40 < t < 100$		
	f_y (MPa)	f_u (MPa)	f_y (MPa)	f_u (MPa)	ϵ_r (%)
S235	235	360	215	340	26
S275	275	430	255	410	22

S355	355	510	335	490	22
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