Mila university centre
Civil engineering department 2024/2025
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Chapter 1:

General information about steel structures

1 . Historical overview:

In **1777**: First use of metal (iron) as a building material in England for the construction of an arch with a span of 30 m;

1780-1820: Construction of a large number of bridges (casting slit)

1850: Construction of a post-beam framework ... Prefabrication Idea

1855: THOMAS BESSEMER had invented a converter for the refining of slit and steel

1889: Construction of the Eiffel Tower with a span of 310 m for the Universal Exhibition.

1930: Idea of using welded joints in metal constructions

1931: Construction of the EMPIRE STATE BUILDING in New York, a 380 m high steel frame

1973: Construction of the WORLD TRADE CENTRE (two towers of 110 floors and 410 m high)

1974: Construction of a 109-storey, 422-metre-high building is built by SEARS TOWER in Chicago

1981: Construction of Humber Bridge, a 1410m suspension bridge with a central span in Great Britain

1998: The construction of Akashi Kaikyo Bridge in Japan, a 1990 suspension bridge with a central span

1999: Two tours in Malaysia (PERTONAS towers)

2 . Steel construction:

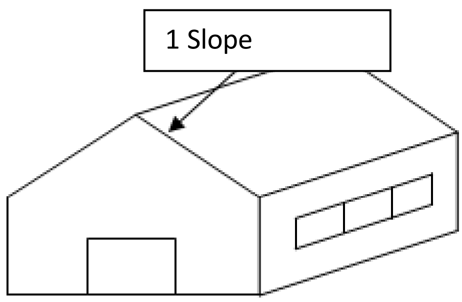
Steel has been widely used and in all areas, due to the advantages it offers to the structure, it is used in:

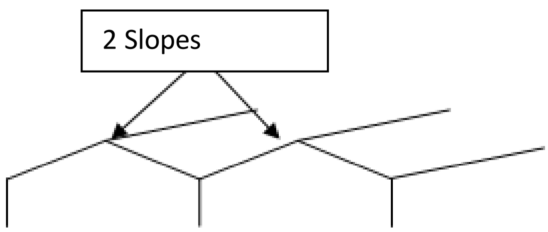
*Construction for residential use: -Single-family houses

*Towers for residential and even administrative use

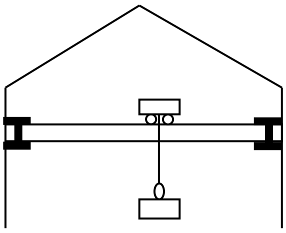
*School buildings

* Industrial sheds: large hall with a very large span ranging from 10m to 80m, they can be tiered or not, with a single slope, two slopes, or several.



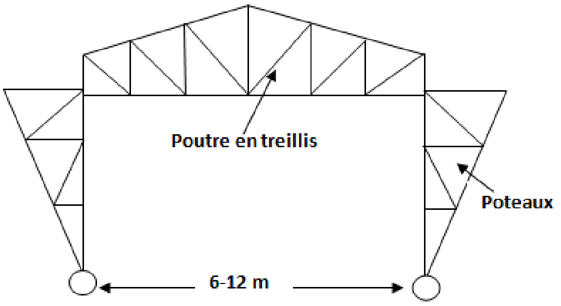


Equipped with overhead crane or not

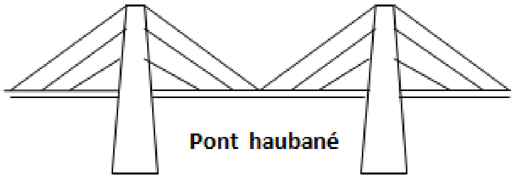


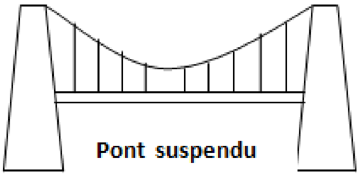
The industrial halls can be used as an assembly or repair room (factory, storage, and warehouse)

*Buildings with large lattice spans: such as sports halls, airport terminals, and construction shops



*Engineering structures: such as metal bridges, cable-stayed bridges, and suspension bridges.





*Masterpiece: like the Eiffel Tower

*Silos: for the storage of materials (cement, aggregates), or food (wheat)

*Tanks: gas, liquid

*Oil rigs: for offshore oil extraction

*Electricity pylons

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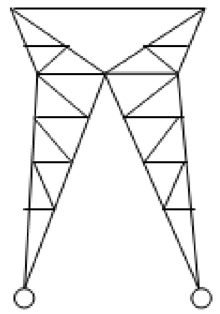
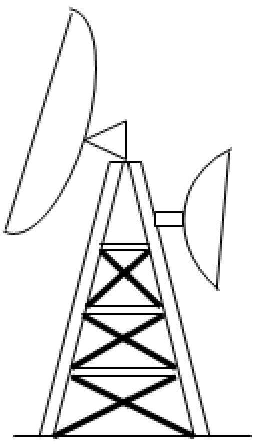
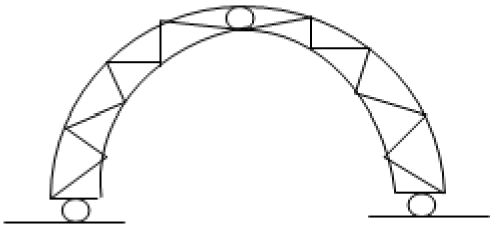


*Radio and television masts (transmitter)



*Cupolas: either arch or shell

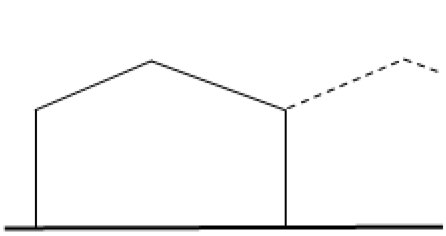


3/ Advantages and disadvantages of metal frames:

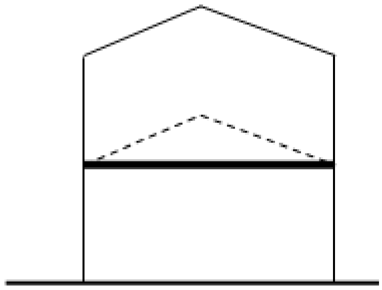
3.1- Advantages:

*Industrialization: possibility of pre-fabricating a building in the workshop with great precision and speed and then it will be assembled on site

*Transformation: can modify, adapt, elevate, or strengthen



Extension of an existant building



Existing elevated building

*Significant architectural possibility

*Retrieved elements from a hangar to reuse them again for a new structure

*Use of different grades of steel

*Easy movement of a metal building

*Elasto-plastic character: the metal frame can be overloaded, without going to ruin thanks to the plastic adaptation of the steel which offers this possibility

*Lightness: steel is a light material compared to concrete, e.g.: to an equal strength of the two materials; We have a section of concrete 5 times larger than the steel one.

3.2- Disadvantages:

*Lightness: this is a characteristic that plays a double role

*Susceptibility to instability phenomena due to the thinness of the elements (thin thicknesses)

*Poor resistance of steel to fire (fire) steel melts at about 1500 °C temperature, so it requires expensive protection which is:

-Special paint

-Plaster to slow down heat flow

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Concrete-coated metal profile ***Hollow metal profile filled with concrete***

*Corrosion: this is due to the rust of the steel elements, to protect against rust we must first clean the surfaces with rust:

-Simple cleaning with a wire brush

- By sanding

-By a stripper with acid

And then, one of the following solutions can be adopted:

-Use of paint (rustproof, bituminous)

-Metal coating: -Galvanizing steel

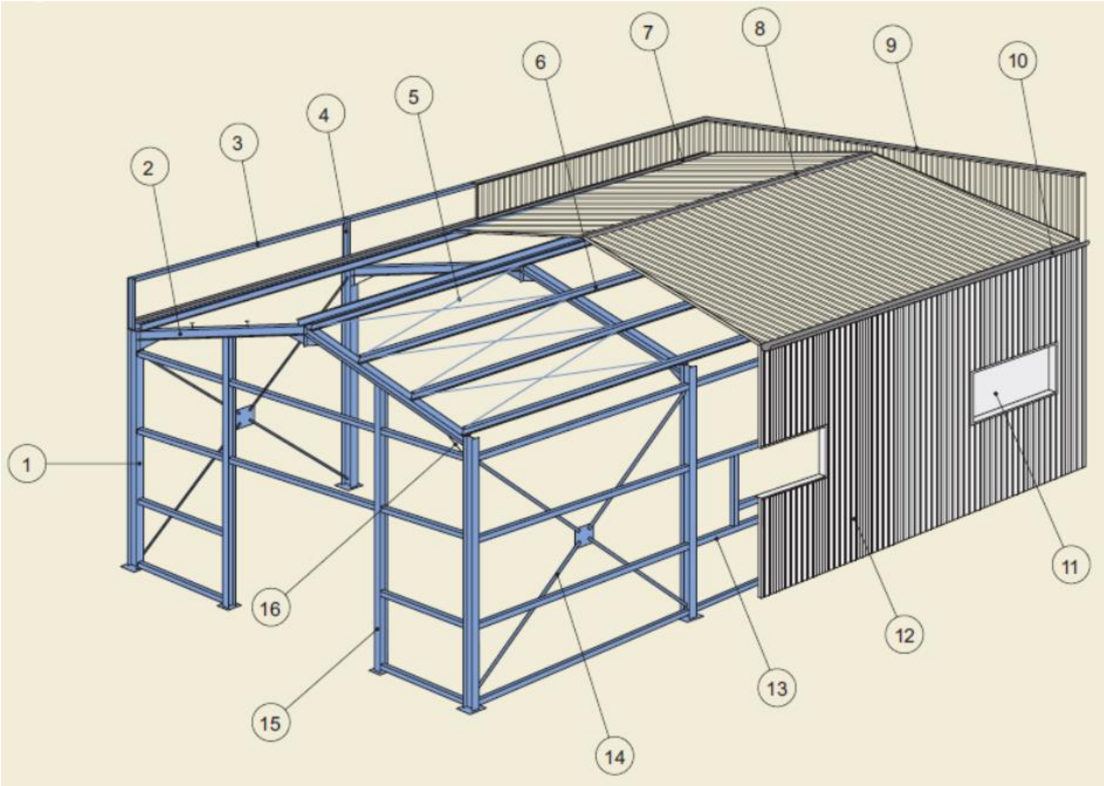
- Chromatization of steel

*Need for maintenance of metal structures

4 . Terminology of an industrial hangar:

The figure gives the main terms used for metal frames and cladding.

1	column (HEA or PEI)
2	Cross member (HEA or PEI)
3	Smooth
4	Bayonet
5	Slope diagonal
6	Failure (IPN or IPE)
7	Oak in folded sheet metal
8	Metal ridge
9	Metal Cover
10	Gutter 1/2 round
11	Glazed frame
12	Vertical wave metal cladding
13	Cladding Beam
14	St. Andrew's Cross
15	Gable post (HEA or IPE)
16	Hock



Part 2: MATERIALS, TESTS, AND STEEL 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, coke, and castine 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.

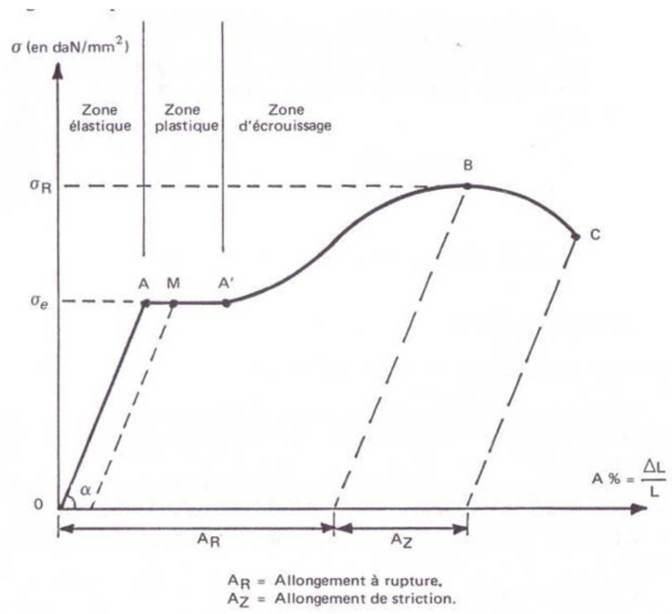
6.2 Destructive testing: (hardness, toughness, and tensileness)

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.

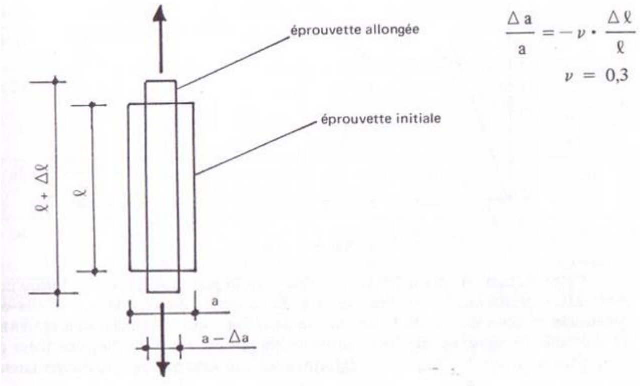
6.1.4 Tensile test: a specimen is used in uniaxial tension until fracture to determine its mechanical characteristics. We obtain an effort-strain diagram.



- 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), $E = tg\alpha = \sigma / A$
- The Poisson's coefficient υ
- ***G*** transverse modulus of elasticity,
- Ar% 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: $E=2.1*10^6$ DaN/cm²
- Poisson's ratio: ν=0.3
- Transverse Yield Coefficient: $G=8.1*10^5$ DaN/cm²
- Dilation: $\lambda=11*^{10-6}$
- Density: ρ=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
	t ≤ 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