DESIGN CRITERIA FOR ALUMINIUM ALLOY STRUCTURES

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DESIGN CRITERIA FOR ALUMINIUM STRUCTURES IN CIVIL ENGINEERING

- How can aluminium and its alloy satisfy the requirements of civil engineering structures?
- In which applications can they compete with other structural materials, like steel?

HISTORICAL BACKGROUND

Birth of aluminium :

- **1807 – isolation of AL element**
  (Sir Humphry Davy – U.K.)
- **1827 – first aluminium nugget**
  (Whoeler – Germany)
- **1854 – first electrolytic reduction**
  (Henry Sainte Claire – France)
- **1886 – industrial electrolytic process**
  (Paul Luis Touissant Héroult – France and Charles Martin Hall – USA)

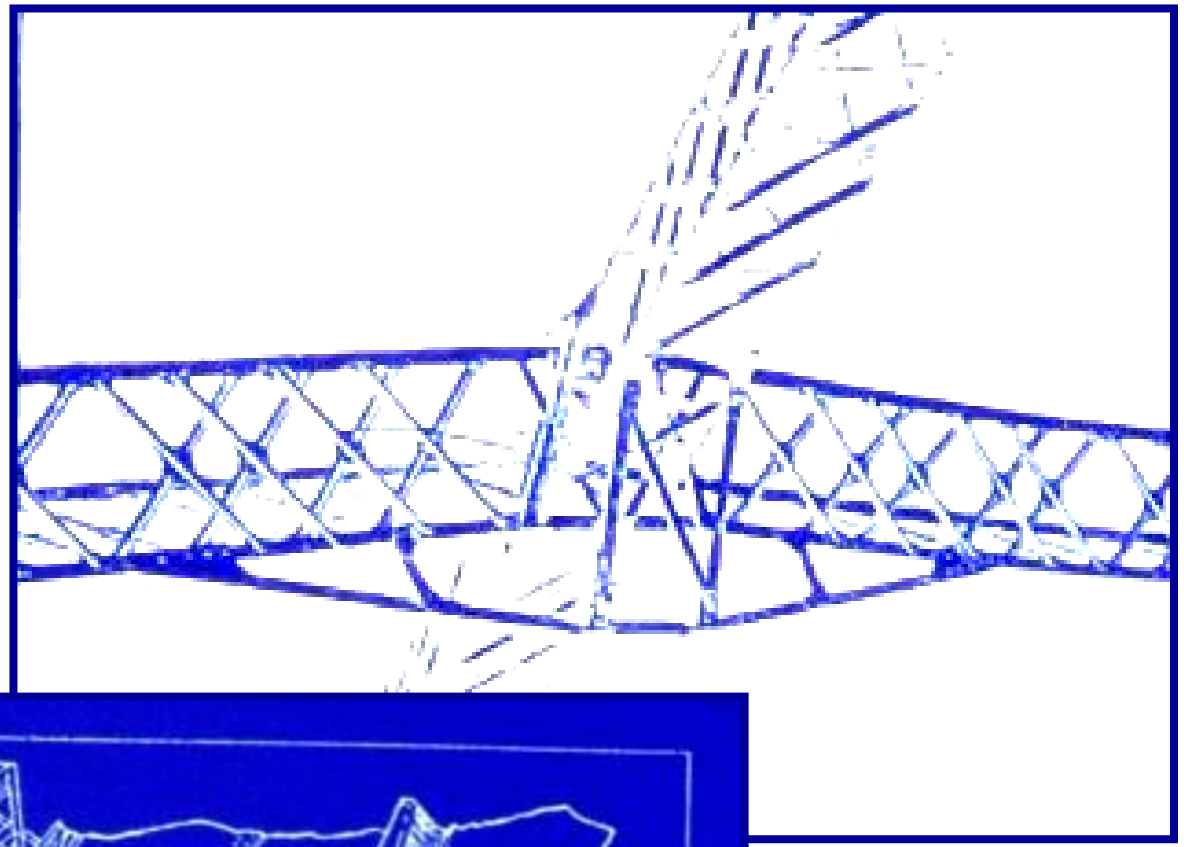
FIRST APPLICATIONS

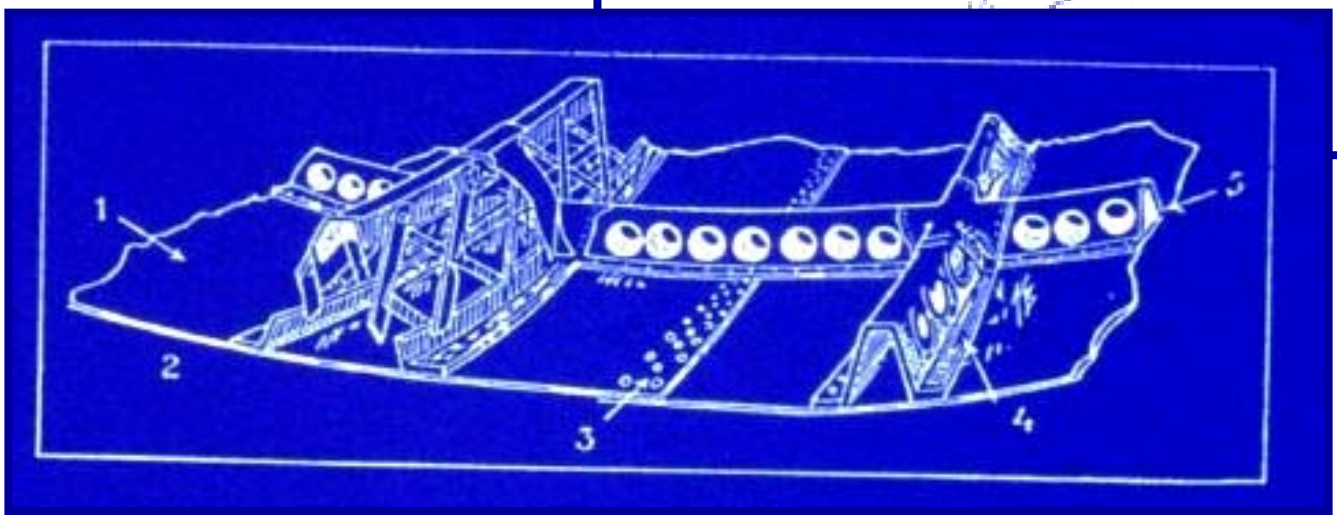
- **Eagles of the Napoleon III's insigna (1851-1870)**

- **Dirigible structures:**
  Schwartz (1897)
  Zeppeling (1900)

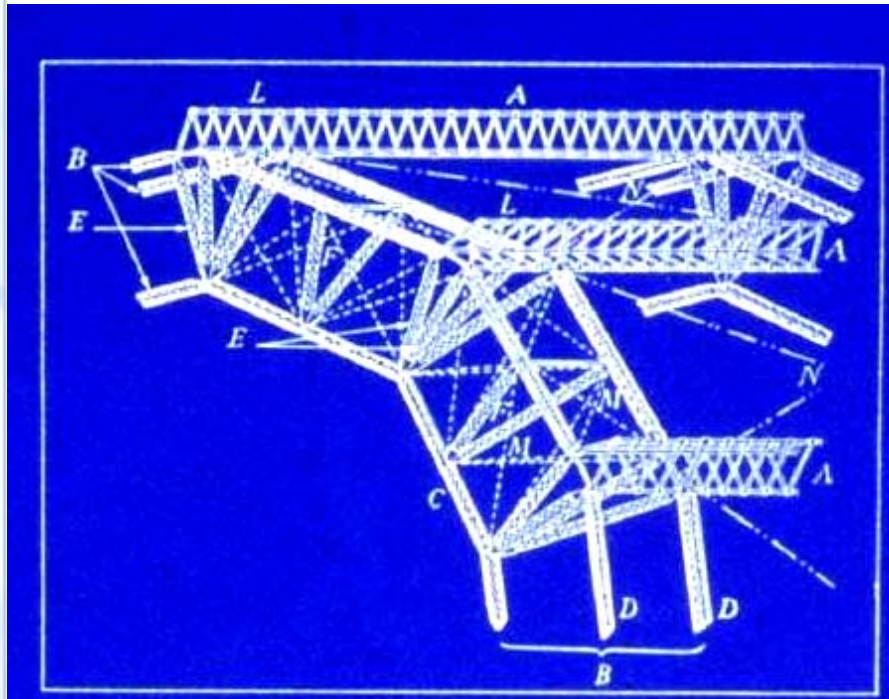
- **Armaments and equipment for the First World War (1915-1918)**

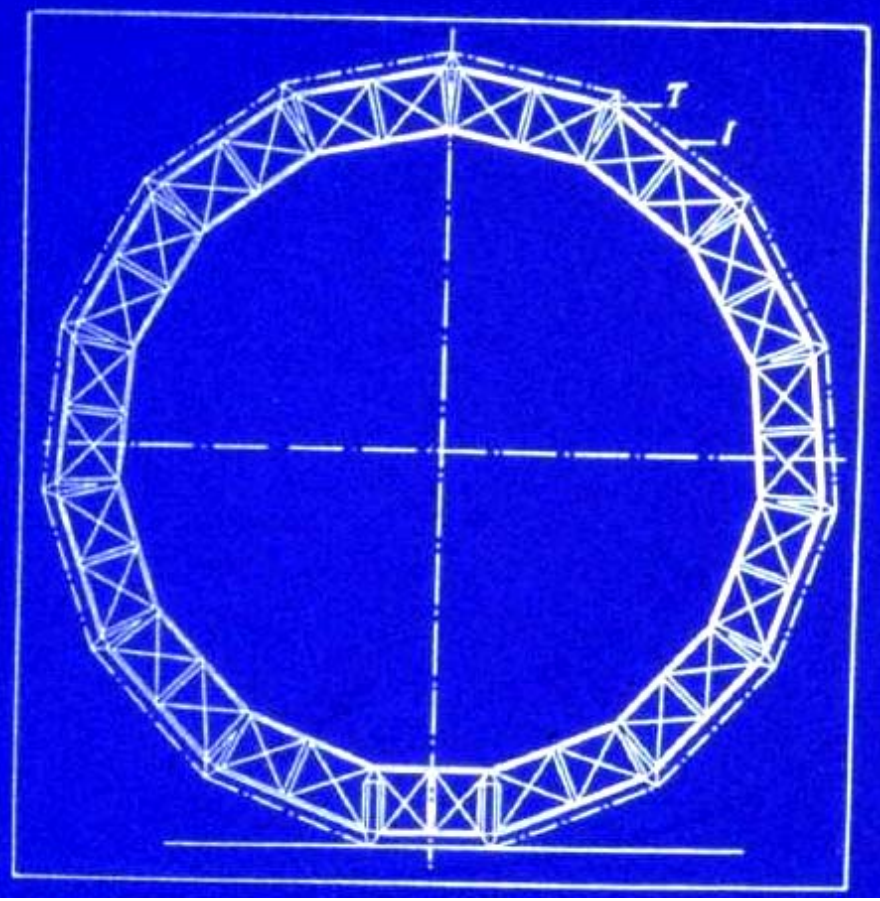
- Dirigible structures (details)





- **Dirigible structures (details)**





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Presence of aluminium in different surroundings

- **Navy structures**

- **Aircraft structures**

- **Railway structures**

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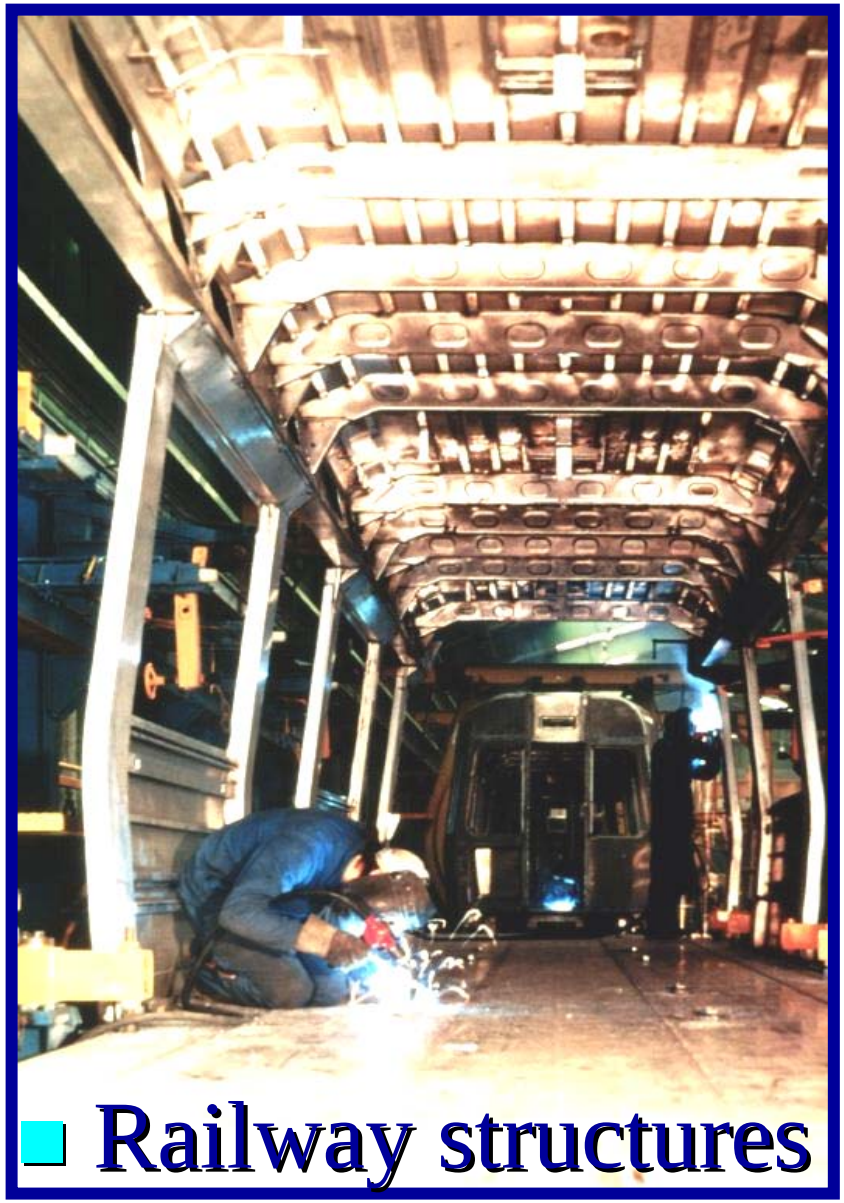
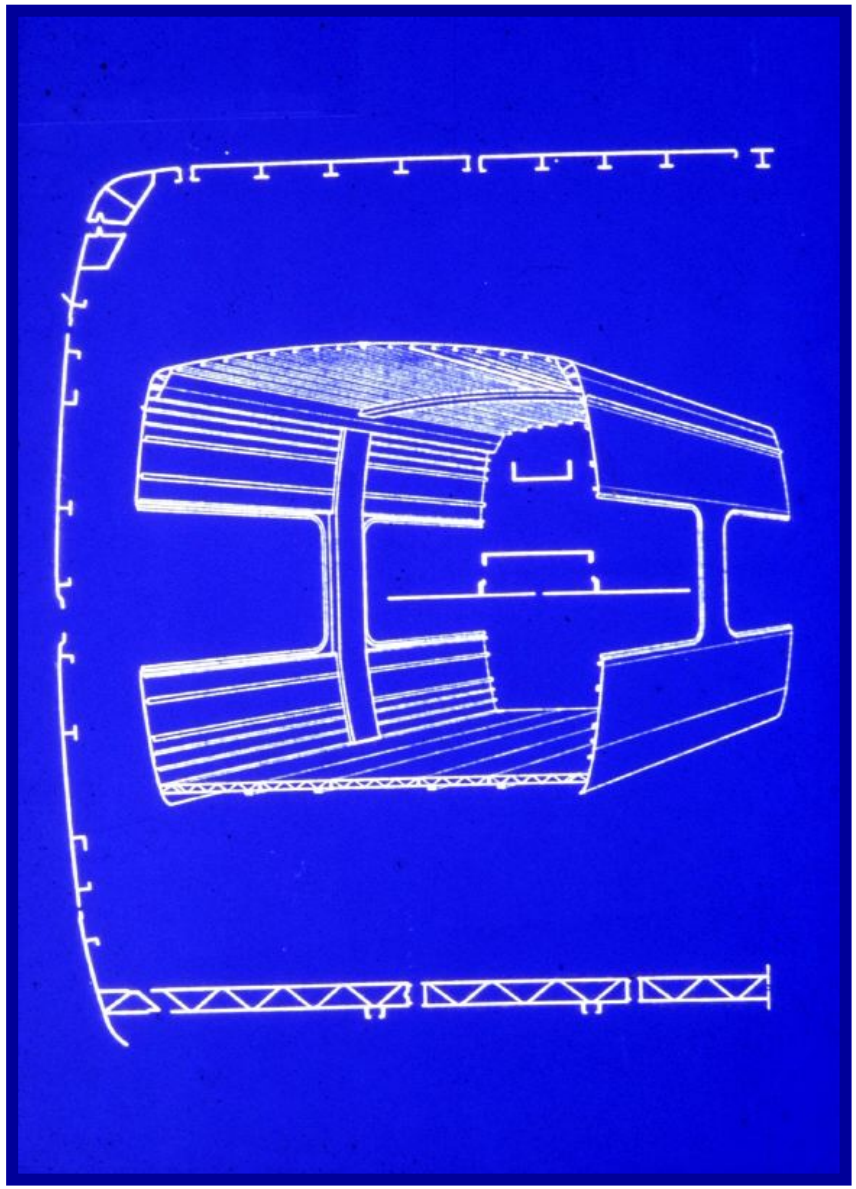
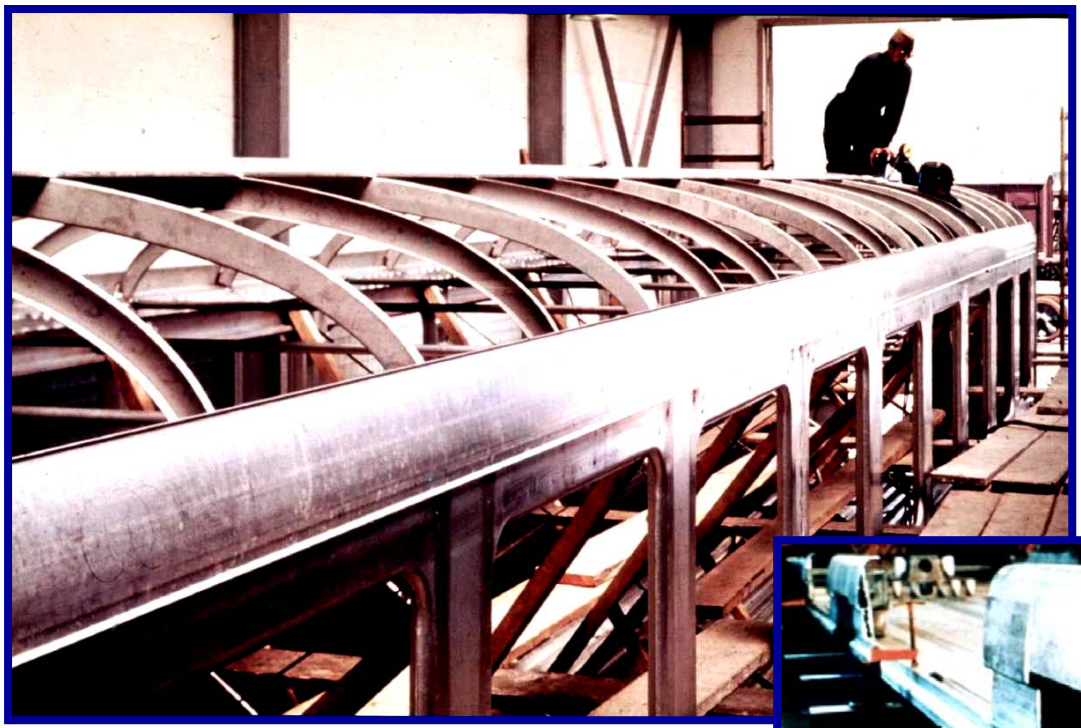
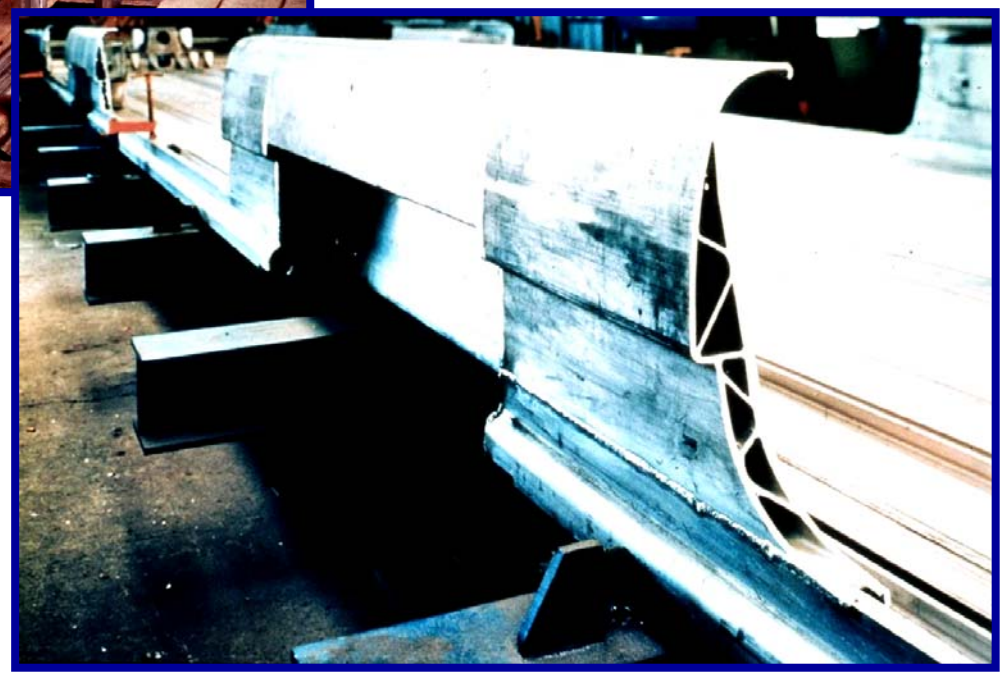


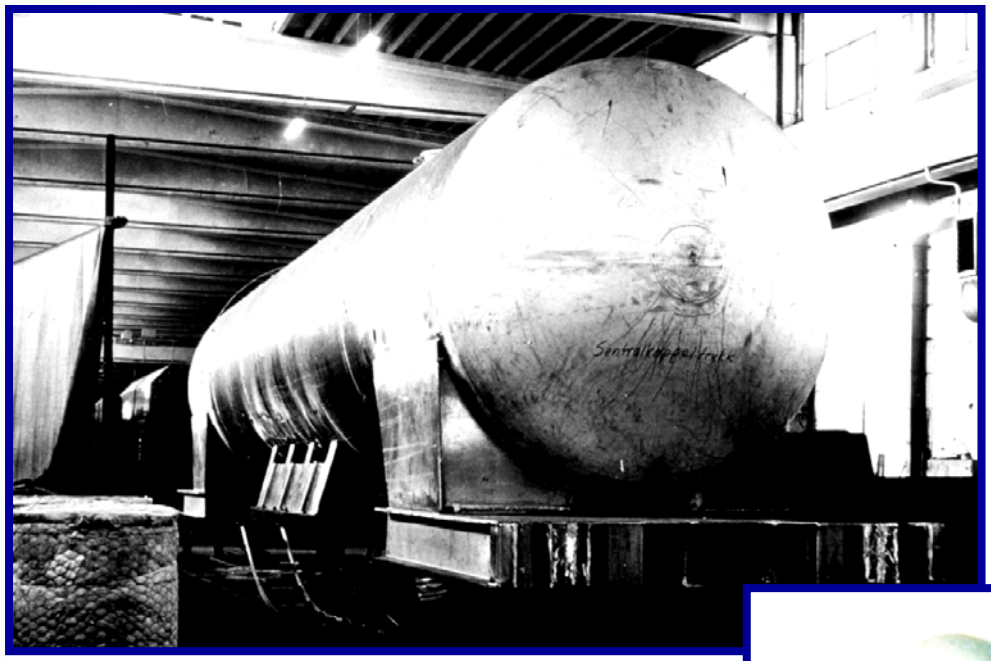


- Railway structures



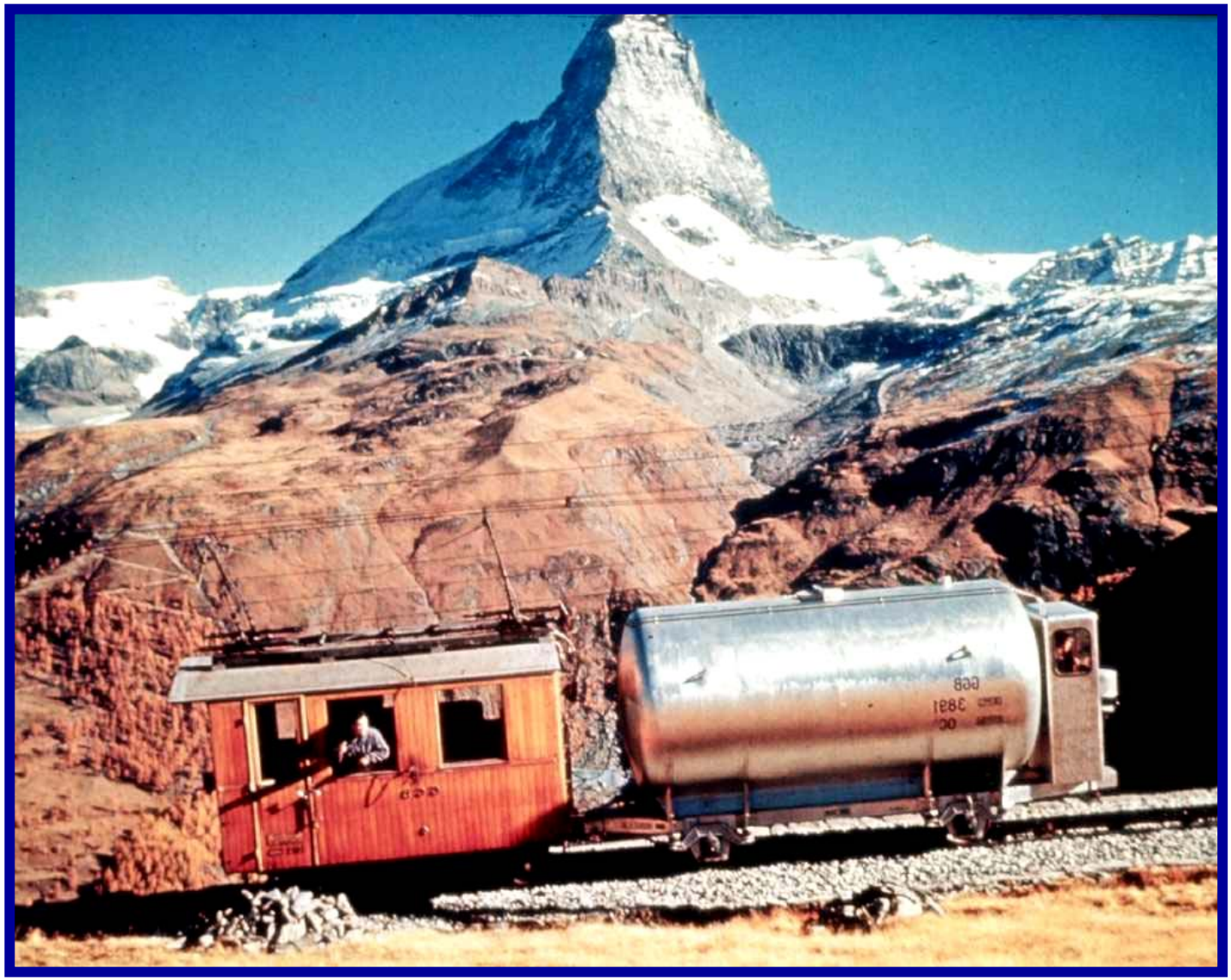
- **Railway structures**





- **Reservoirs for Railway**

Reservoirs for Railway



- **Cladding**

Aluminium sheets
installed more than a century ago for cladding
the dome of the San Gioacchino church in Rome

- **Windows**

The Empire State Building in New York was the first building using anodised aluminium for windows

- **Decoration**

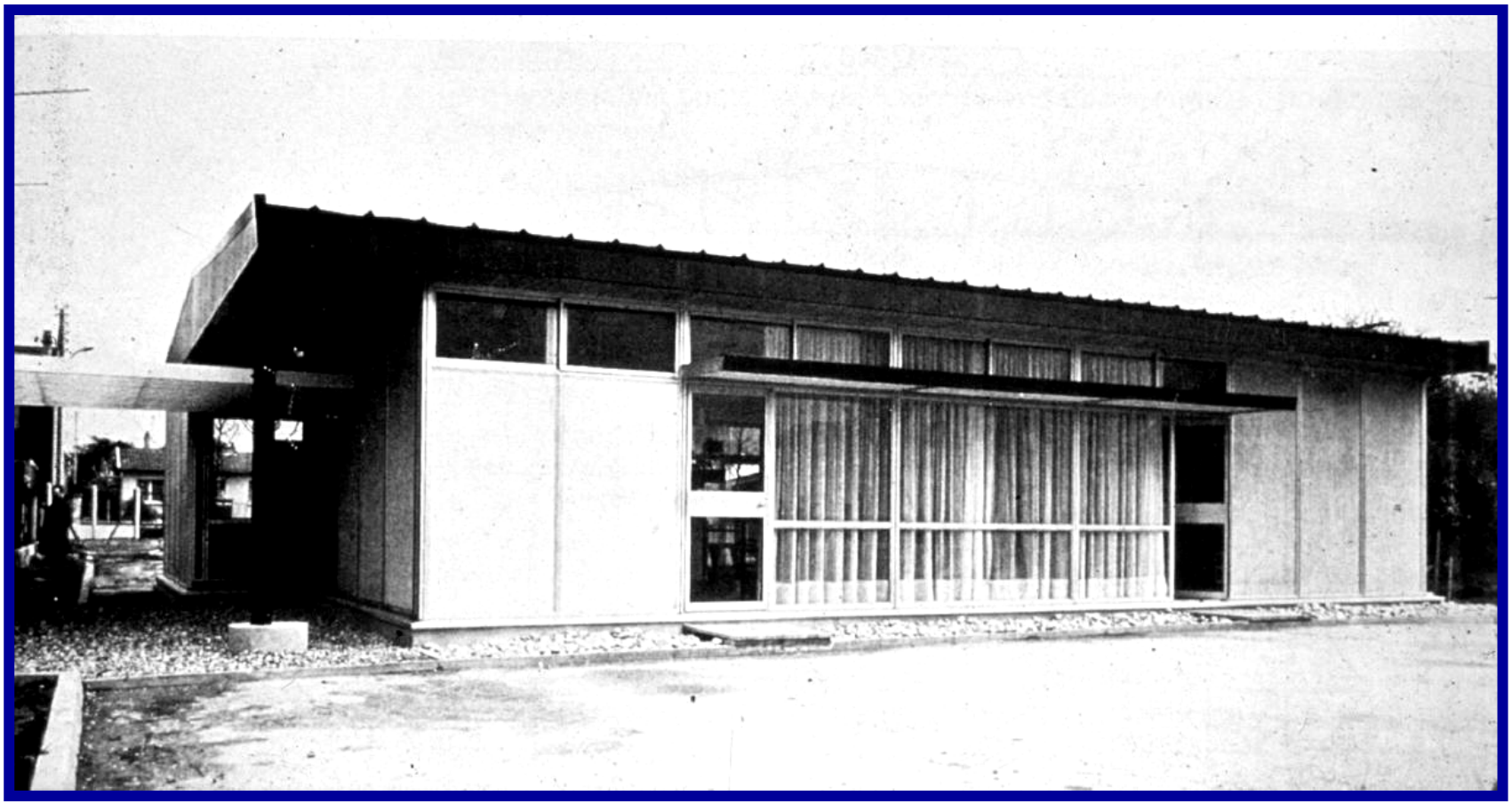
The statue of Eros in Piccadilly Circus London

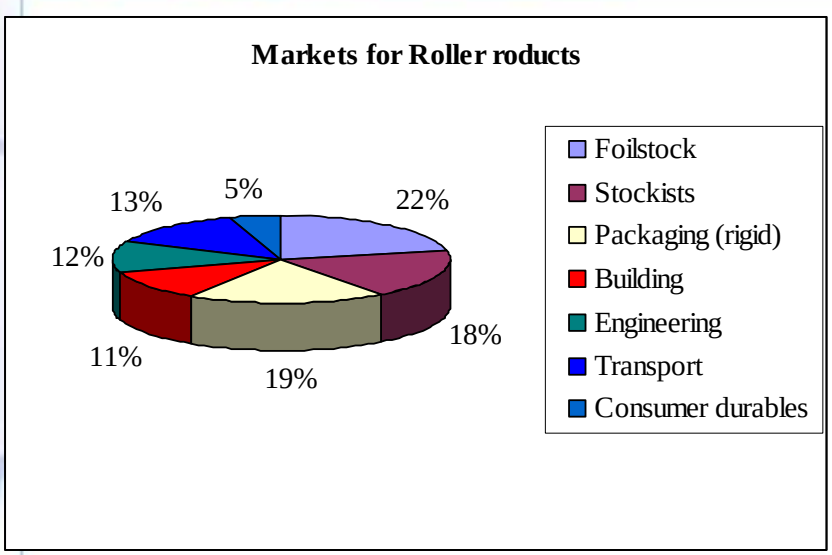
(only recently cleaned and renovated)

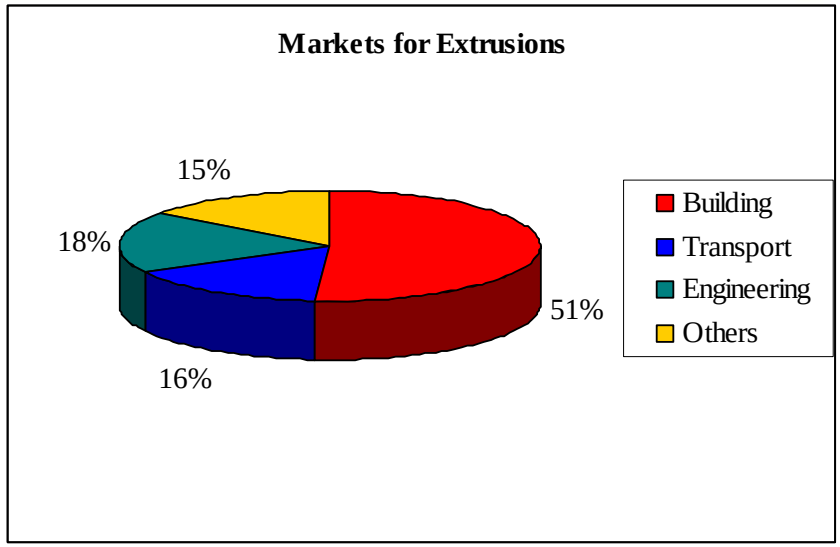
The Atomium was built for the Universal Exhibition of Brussels in 1958, nevertheless aged over the years.
The Atomium is a structure that is half way between sculpture and architecture, symbolising a crystal molecule of steel by the scale of its atoms, magnified 165 billion times.
The aluminium cladding - initially conceived to last six months – has served its purpose for almost 50 years and is ready for a new life.
Now the Atomium is undergoing renovation:
the original aluminium skin will serve for new purposes.
A thousand aluminium triangular panels are available for sale with a certificate of authenticity for collectors and Atomium fans.
The remaining 30 tonnes of aluminium will be recycled.

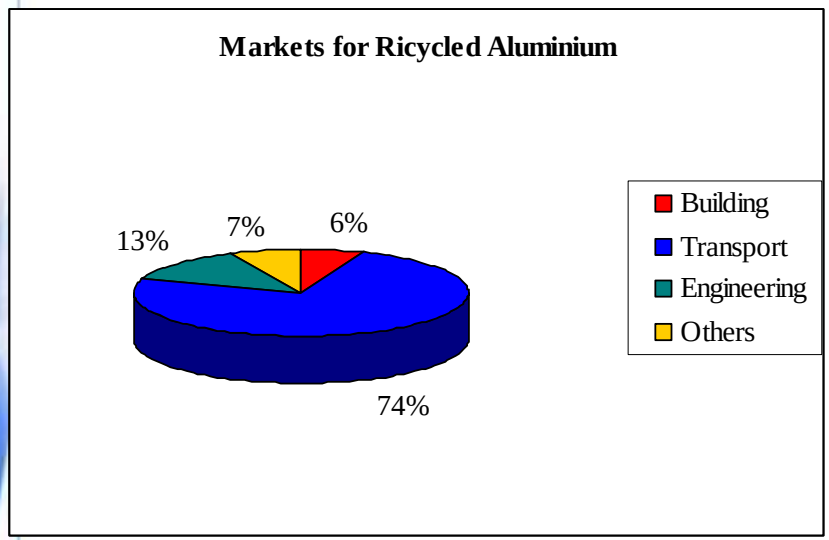
- **Symbolic works**

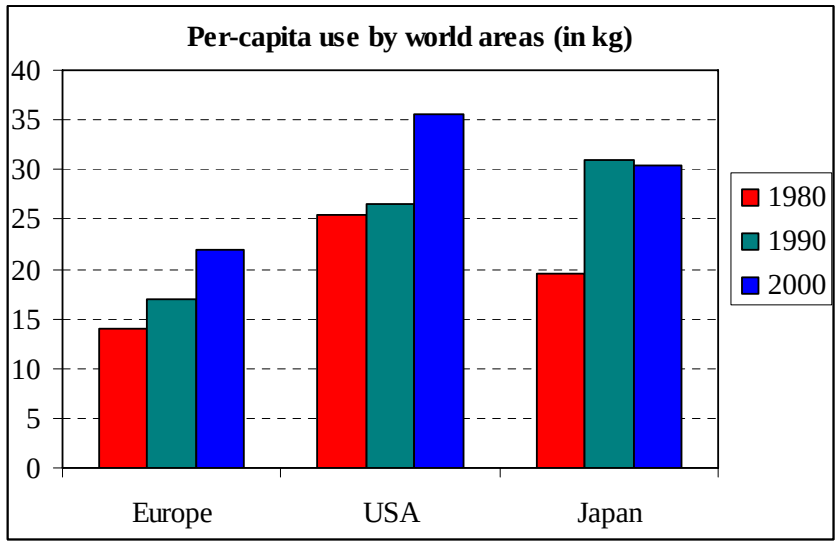
- **Housing structures**



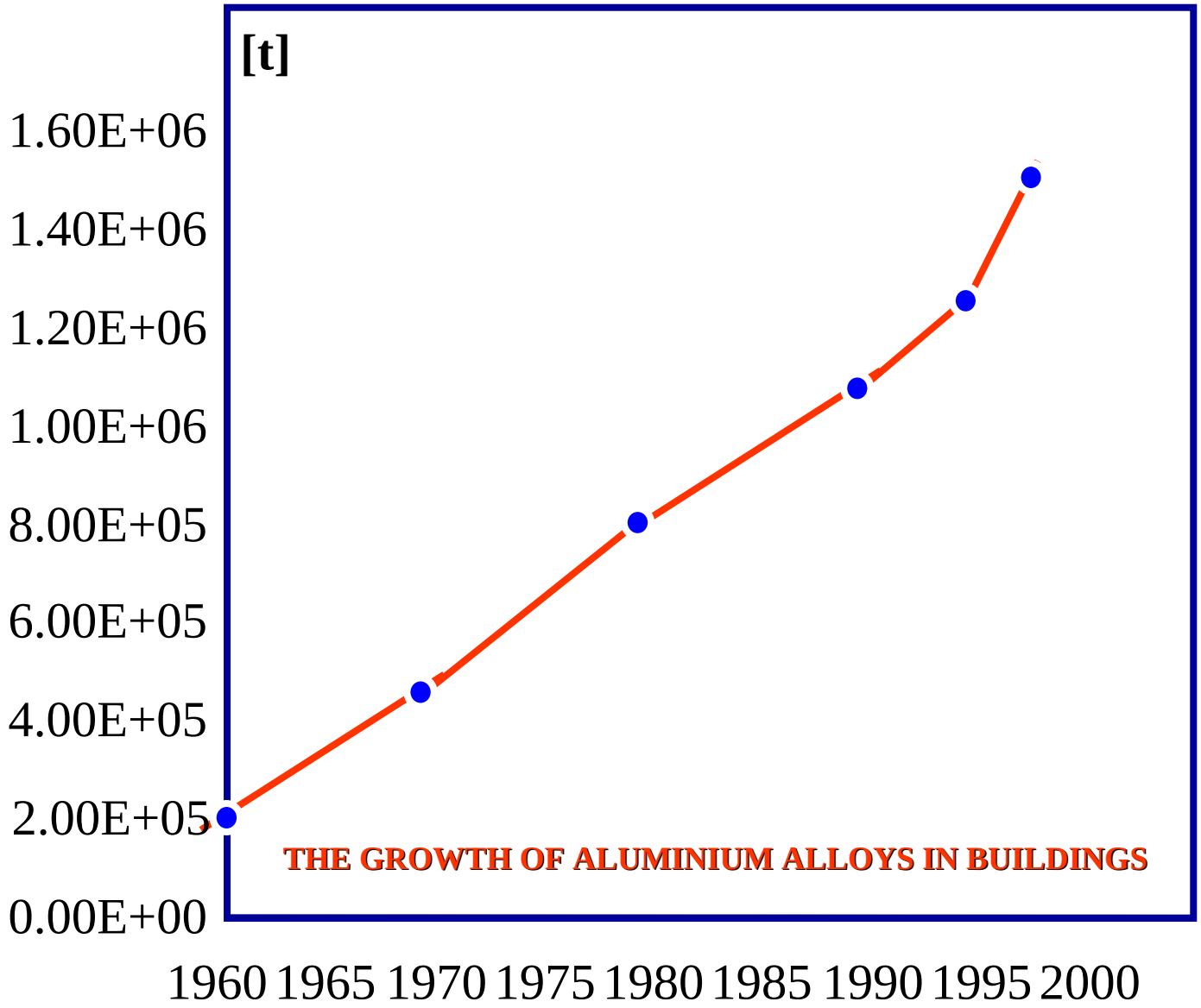








Different markets for aluminium products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1.60E+06
1.40E+06
1.20E+06
1.00E+06
8.00E+05
6.00E+05
4.00E+05
2.00E+05
0.00E+00
1960 1965 1970 1975 1980 1985 1990 1995 2000
THE GROWTH OF ALUMINIUM ALLOYS IN BUILDINGS

BASIC PREREQUISITES OF ALU-ALLOYS

- **Wide family of constructional materials,covering the range of mechanical properties of mild steels**
- **Corrosion resistance makes normally not necessary to provide protection coating**
- **Weigth reduction (respect to steel is 1 to 3) gives many advantages in transportation and erection**
- **Low elastic modulus increases the sensitivity to deformability and instability problems**
- **The material itself is not prone to brittle fracture**
- **Fabrication process by extrusion allows individually tailored shapes to be designed**
- **Either bolting,riveting and welding techniques are available as connection solution**

BASIC CONDITIONS FOR COMPETITION WITH STEEL

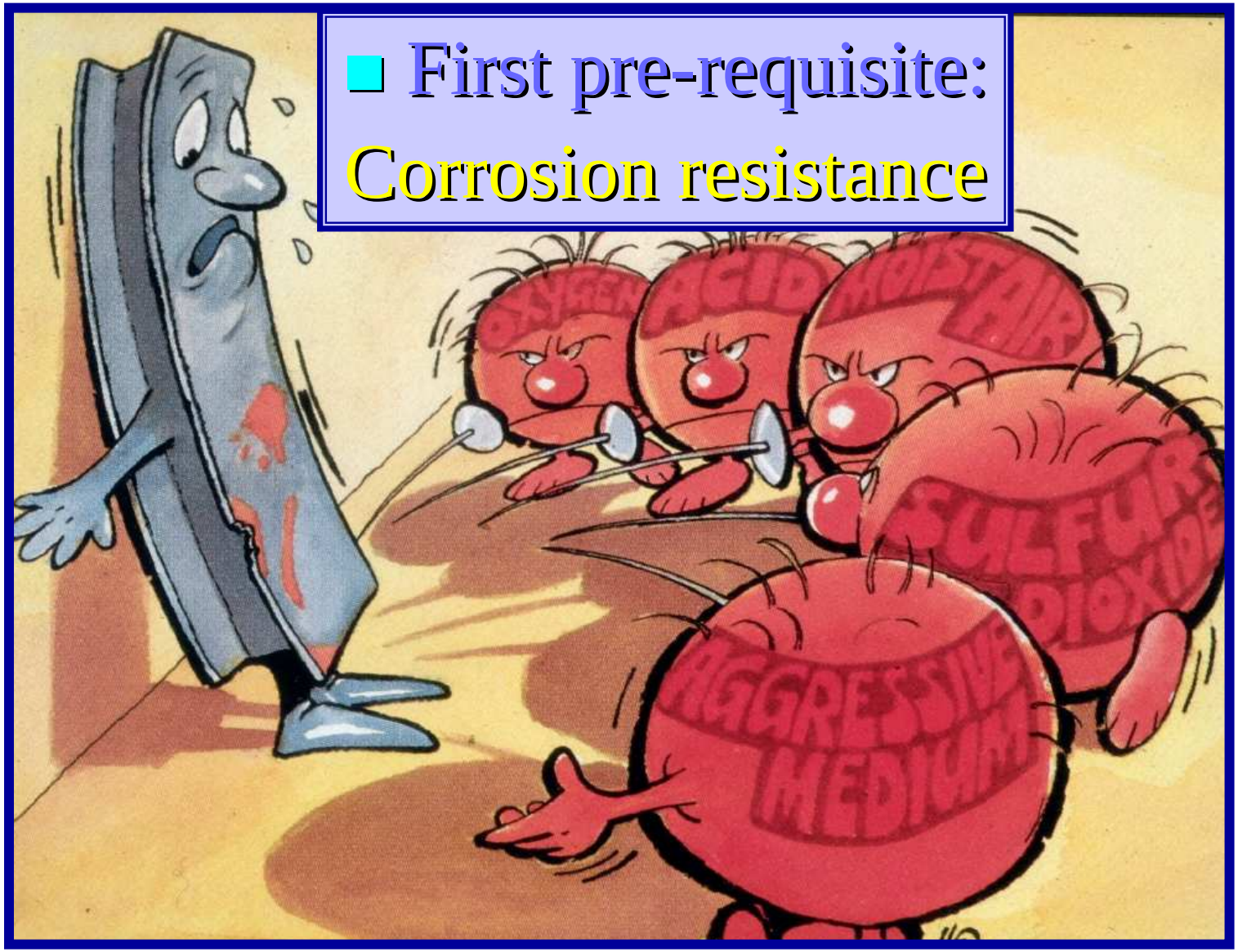
- First pre-requisite:
  Corrosion resistance (C)

- Second pre-requisite:
  Lightness (L)

- Third pre-requisite:
  Functionality of sections due to extrusion (F)

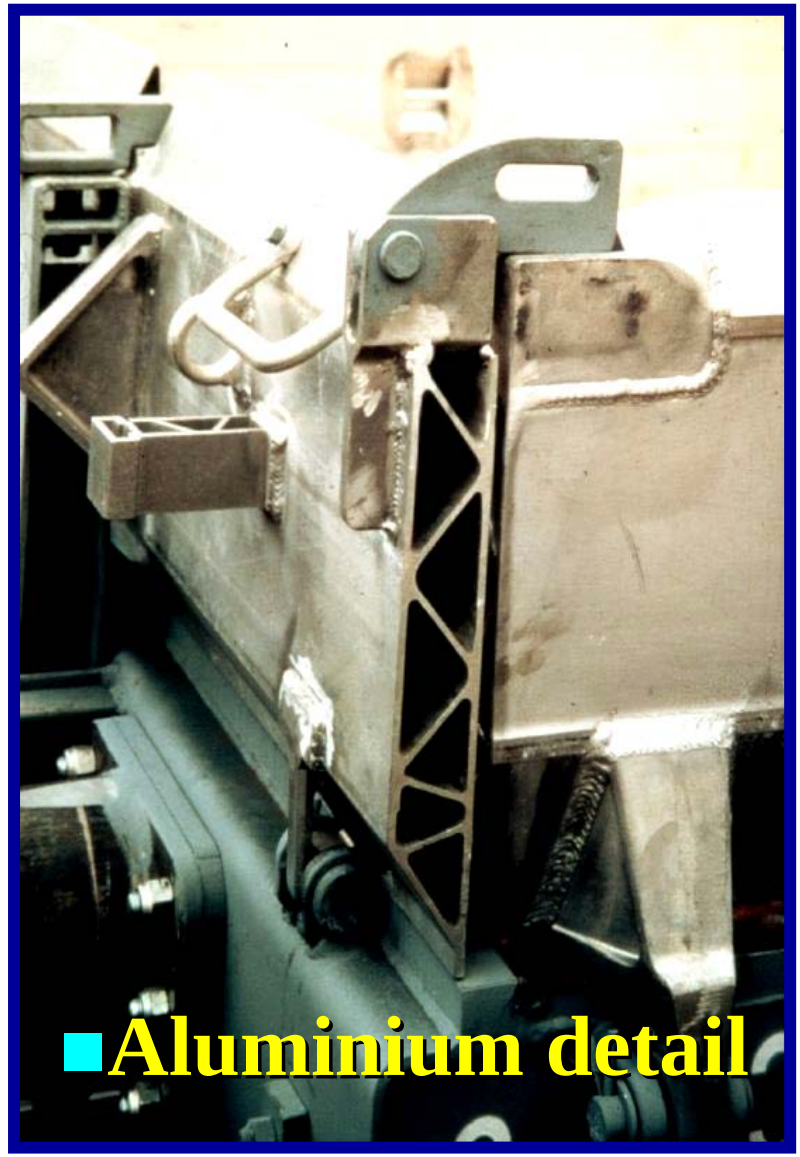
- First pre-requisite:

Corrosion resistance



Details of steel bolted connections

- Steel detail



- Aluminium detail

- Second pre-requisite:
  Ligthness

- Second pre-requisite:
  Ligthness

- Second pre-requisite:

Ligthness

- Second pre-requisite:
  Ligthness

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- steel hot rolled sections

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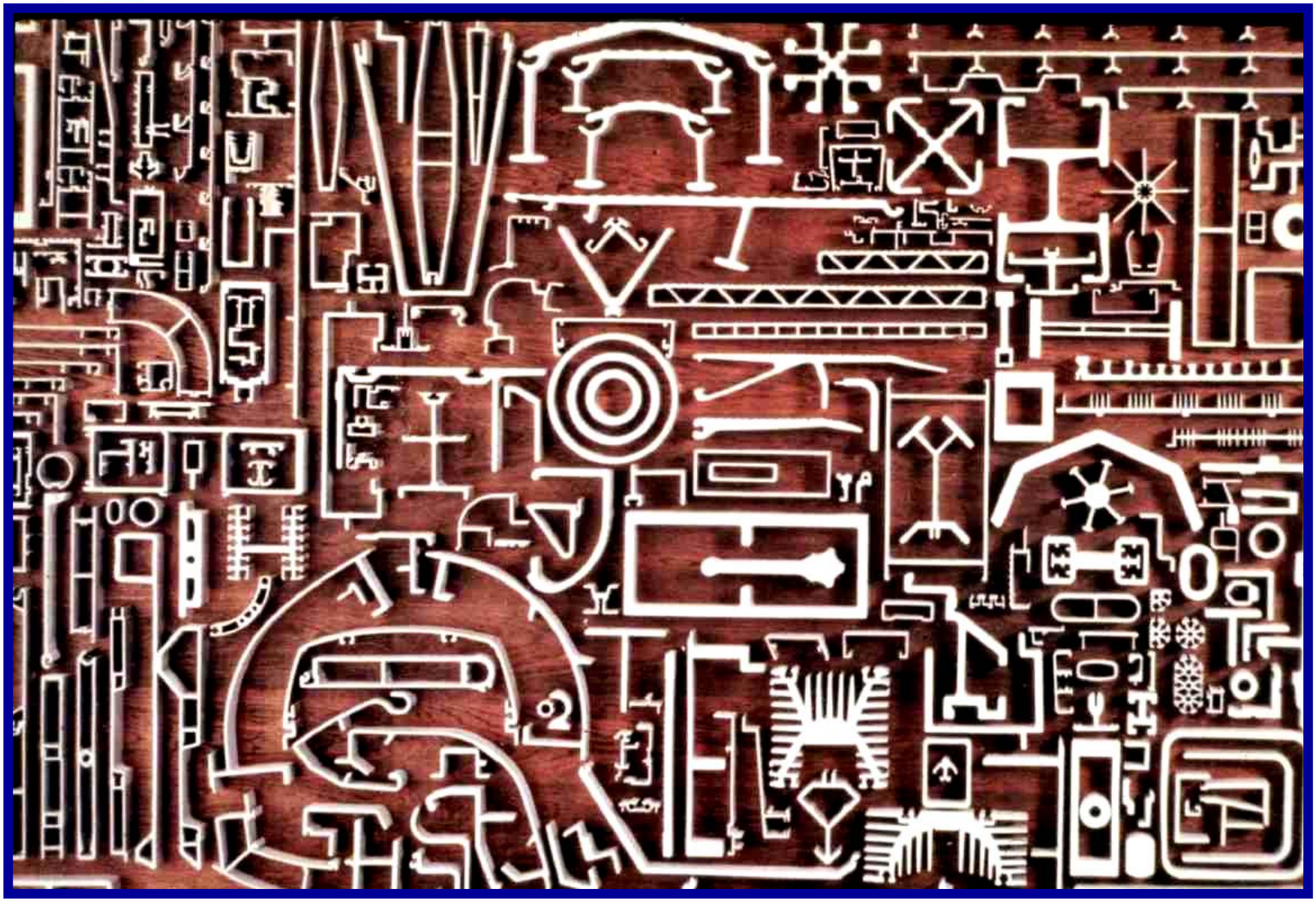
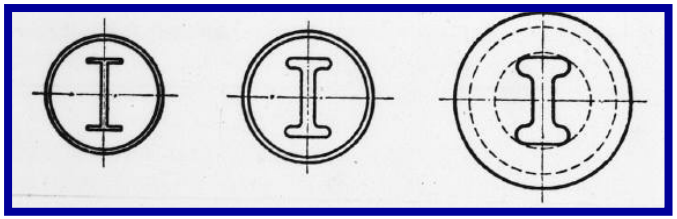
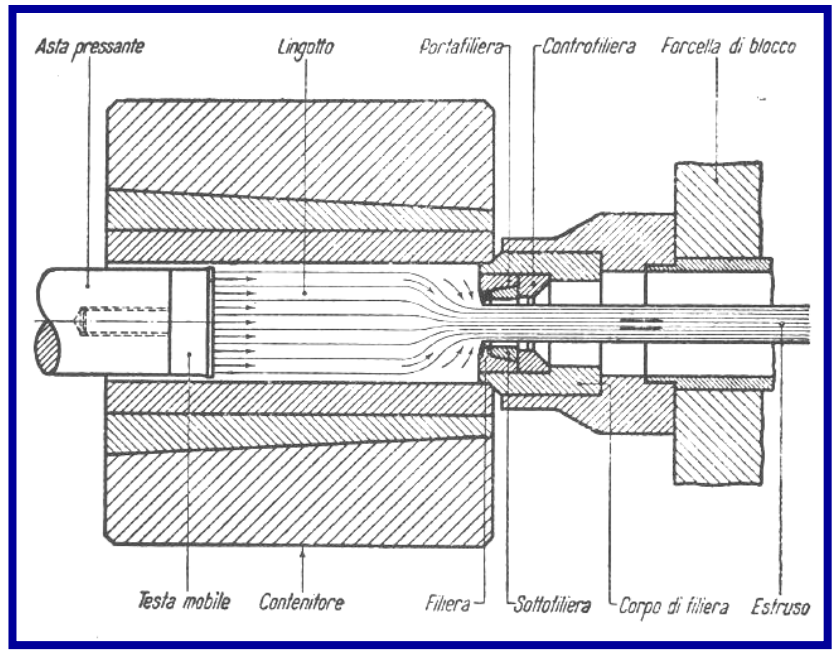
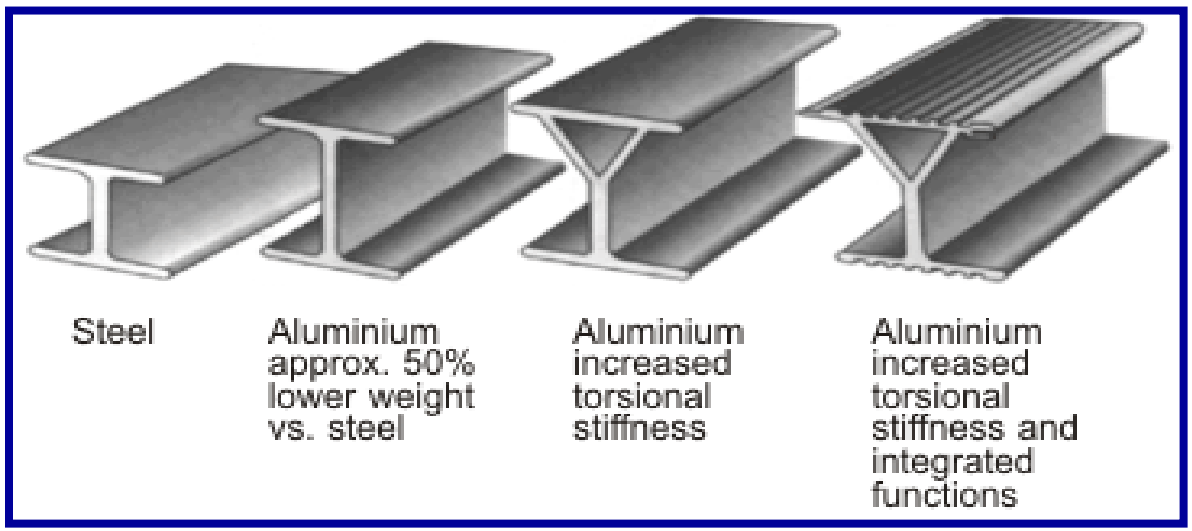


- **aluminium extruded sections**

- **extrusion process**







1.Billets in parking

2. Heating (480°C)

3. Cutting

4. Transfer to extrusion

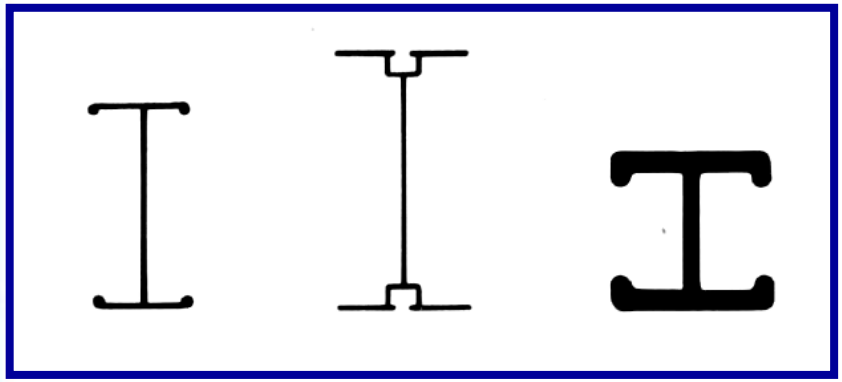
5. Extrusion

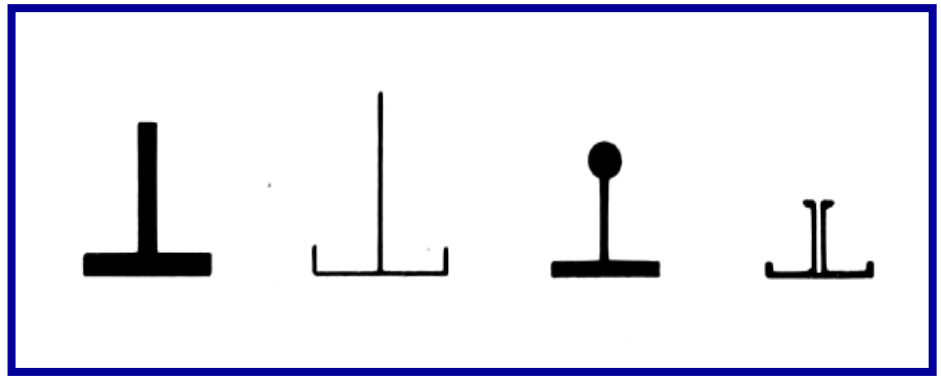
6. Termal treatment

Phases of the extrusion process

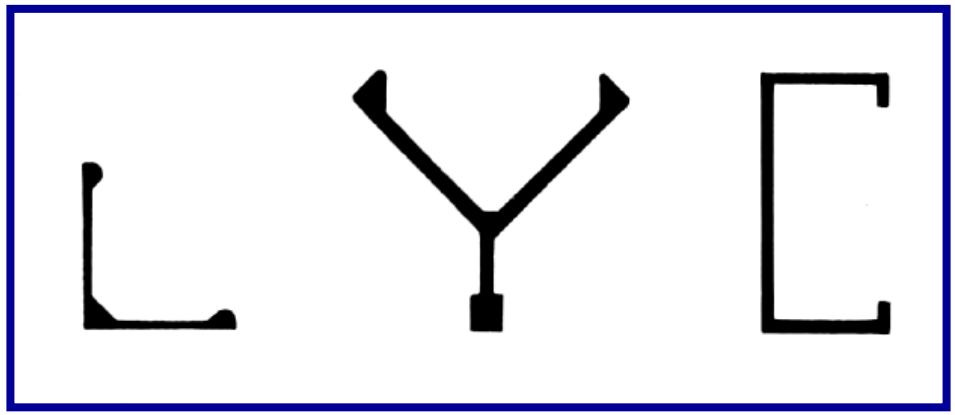
- Third pre-requisite:

Functionality of sections due to extrusion



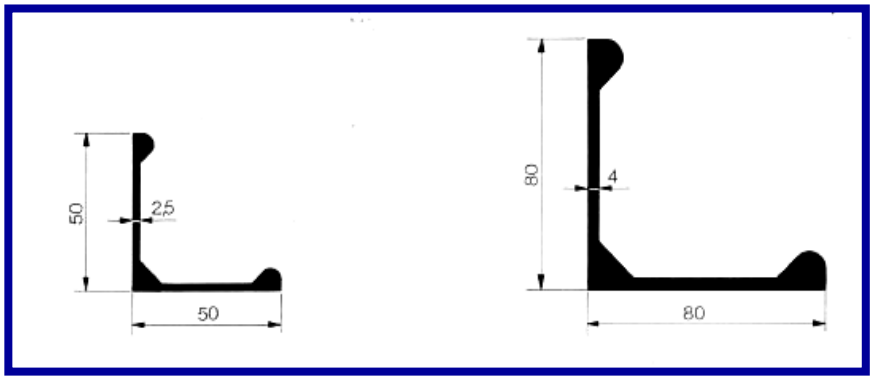


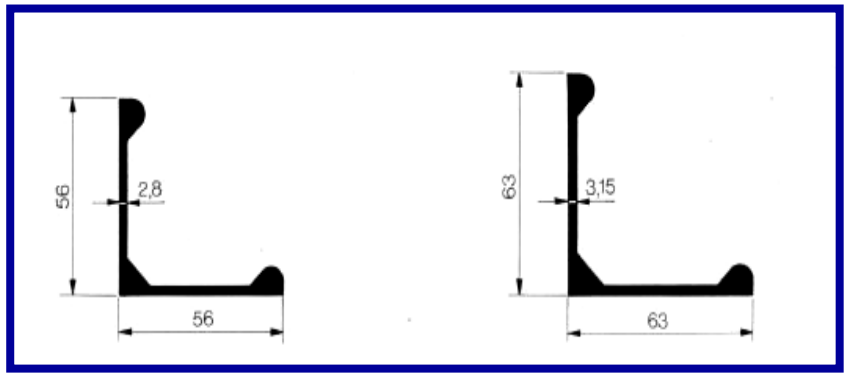
"The geometrical properties of cross-section are improved by designing a shape which simultaneously gives the minimum weight and the highest structural efficiency"



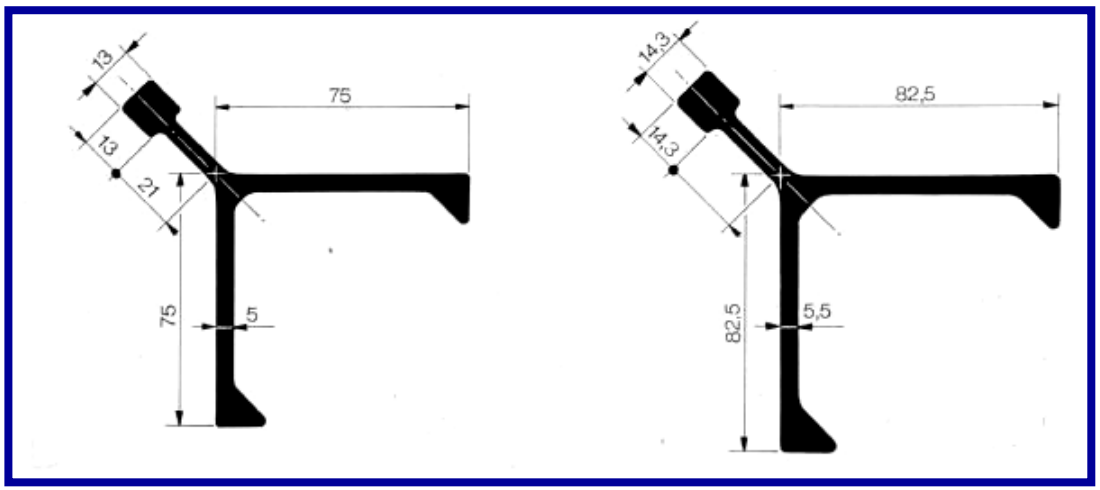
- Third pre-requisite:

Functionality of sections due to extrusion





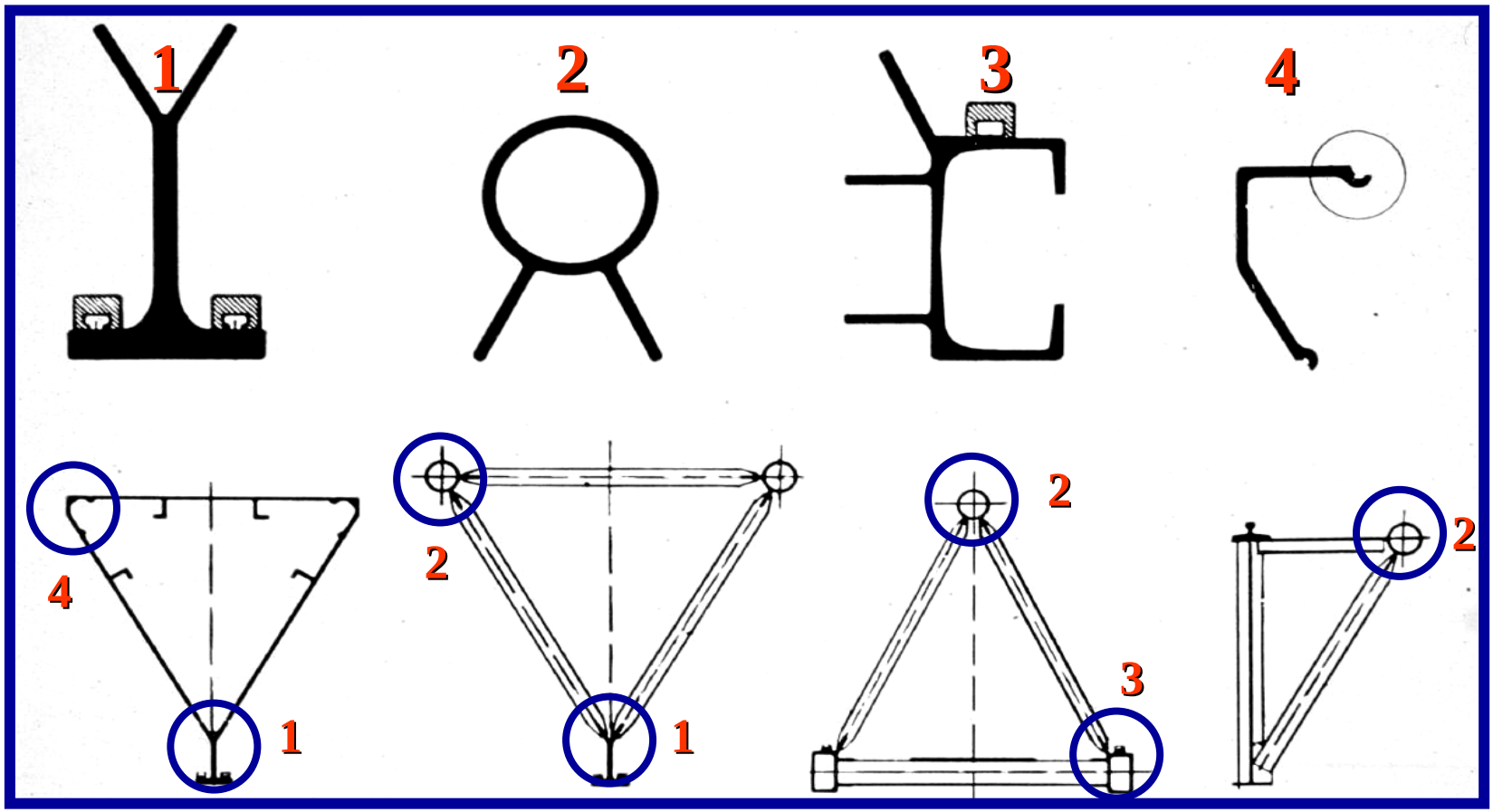
Sections for electrical towers



- Third pre-requisite:

Functionality of sections due to extrusion

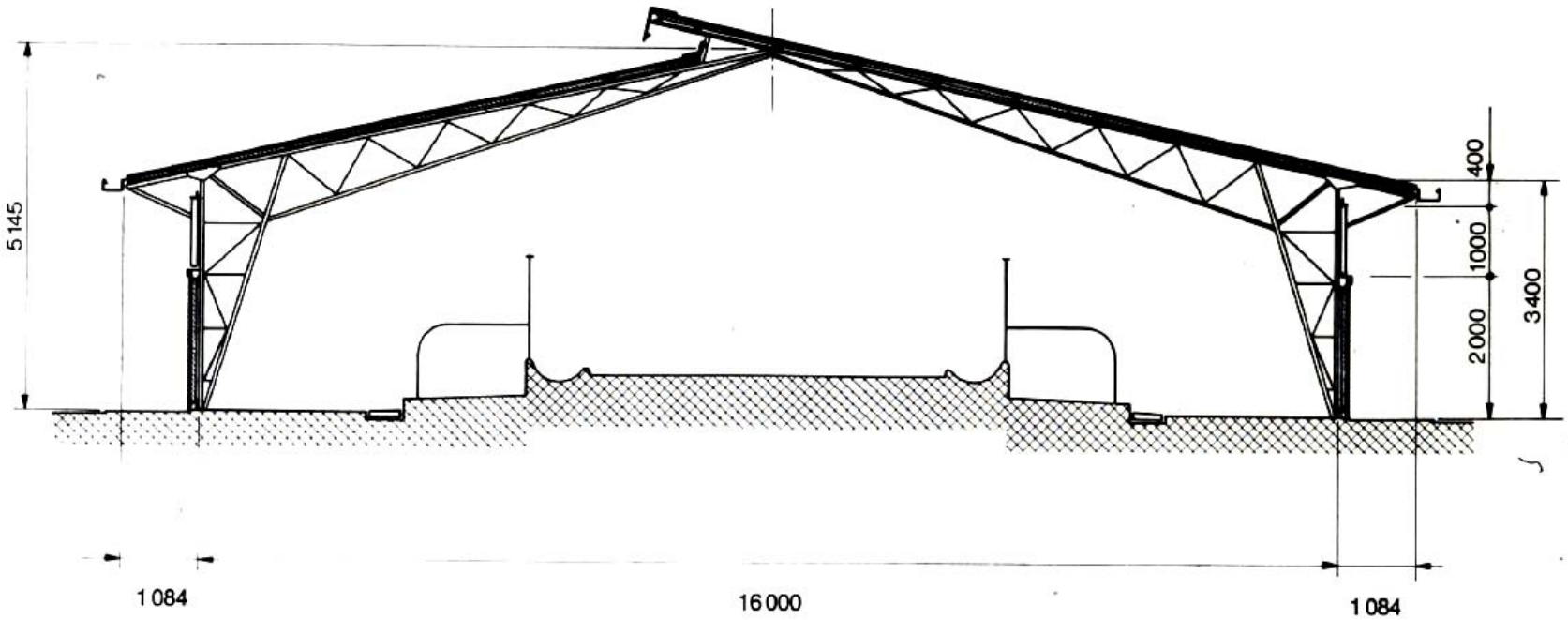
"The connecting systems among different component are simplified,thus improving joint details"



Sections for crane structures

- **Third pre-requisite:**

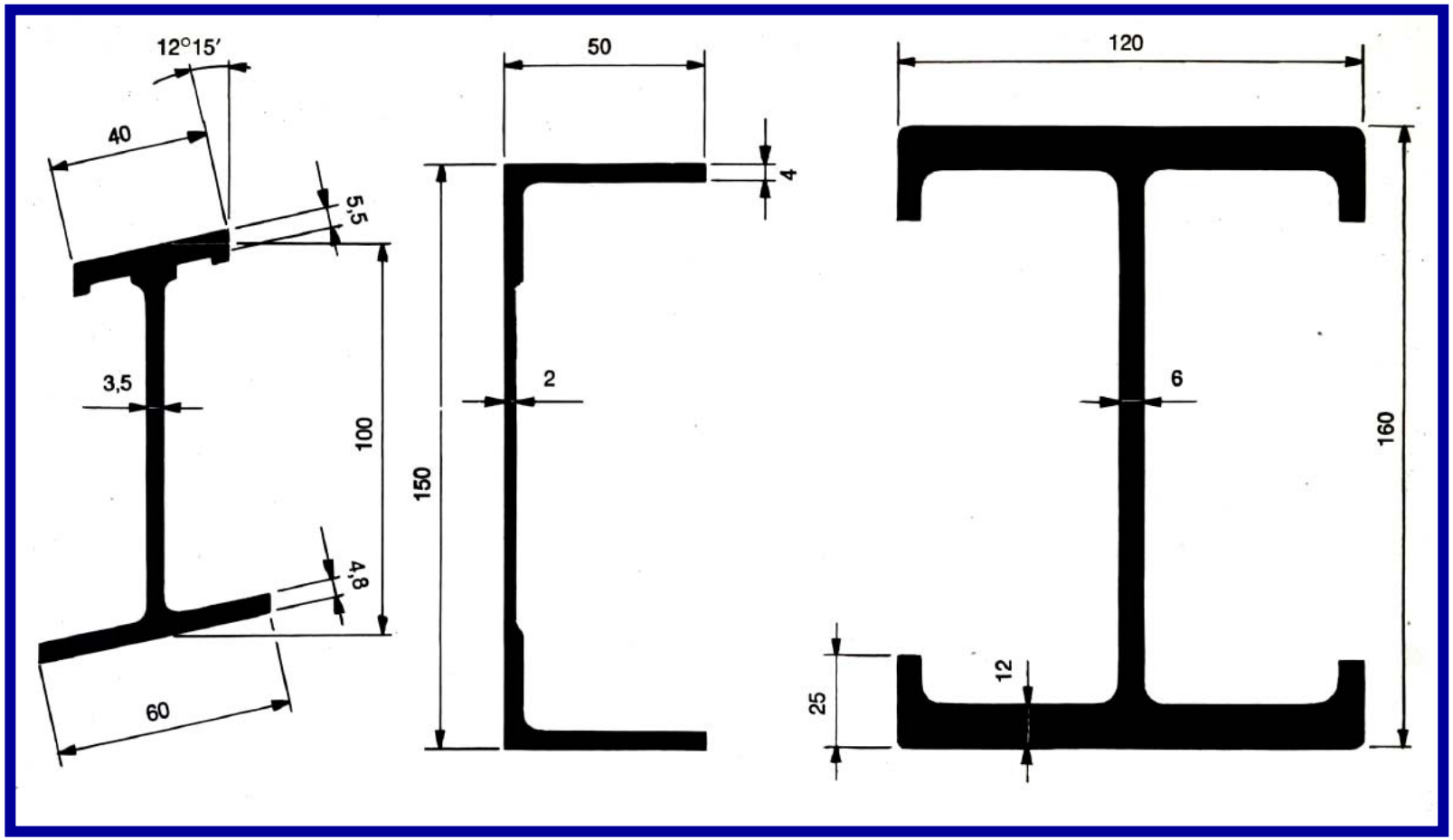
Functionality of sections due to extrusion



Building for agriculture

- **Third pre-requisite:**

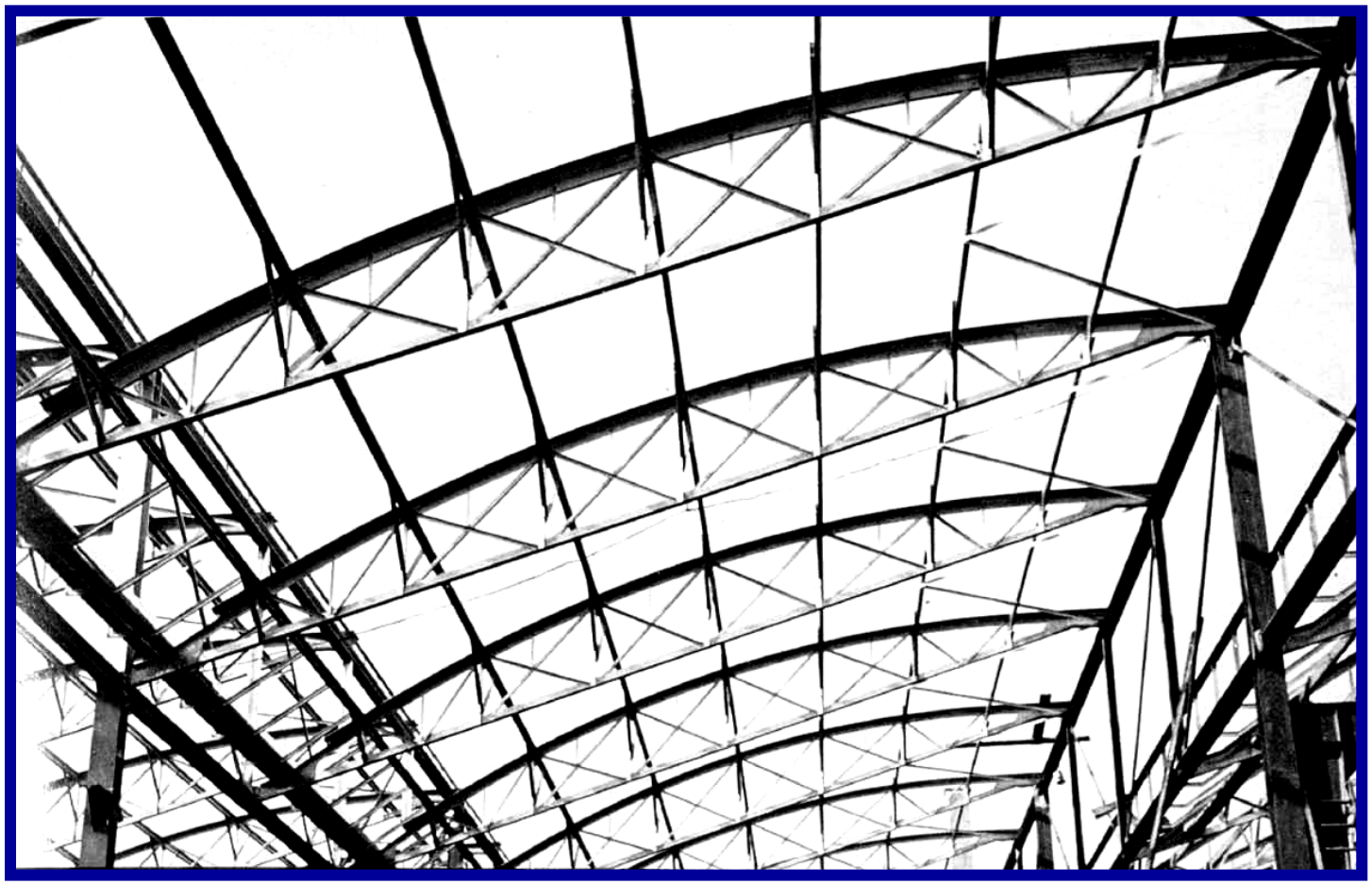
Functionality of sections due to extrusion



Sections used in the building for agriculture

- **Third pre-requisite:**

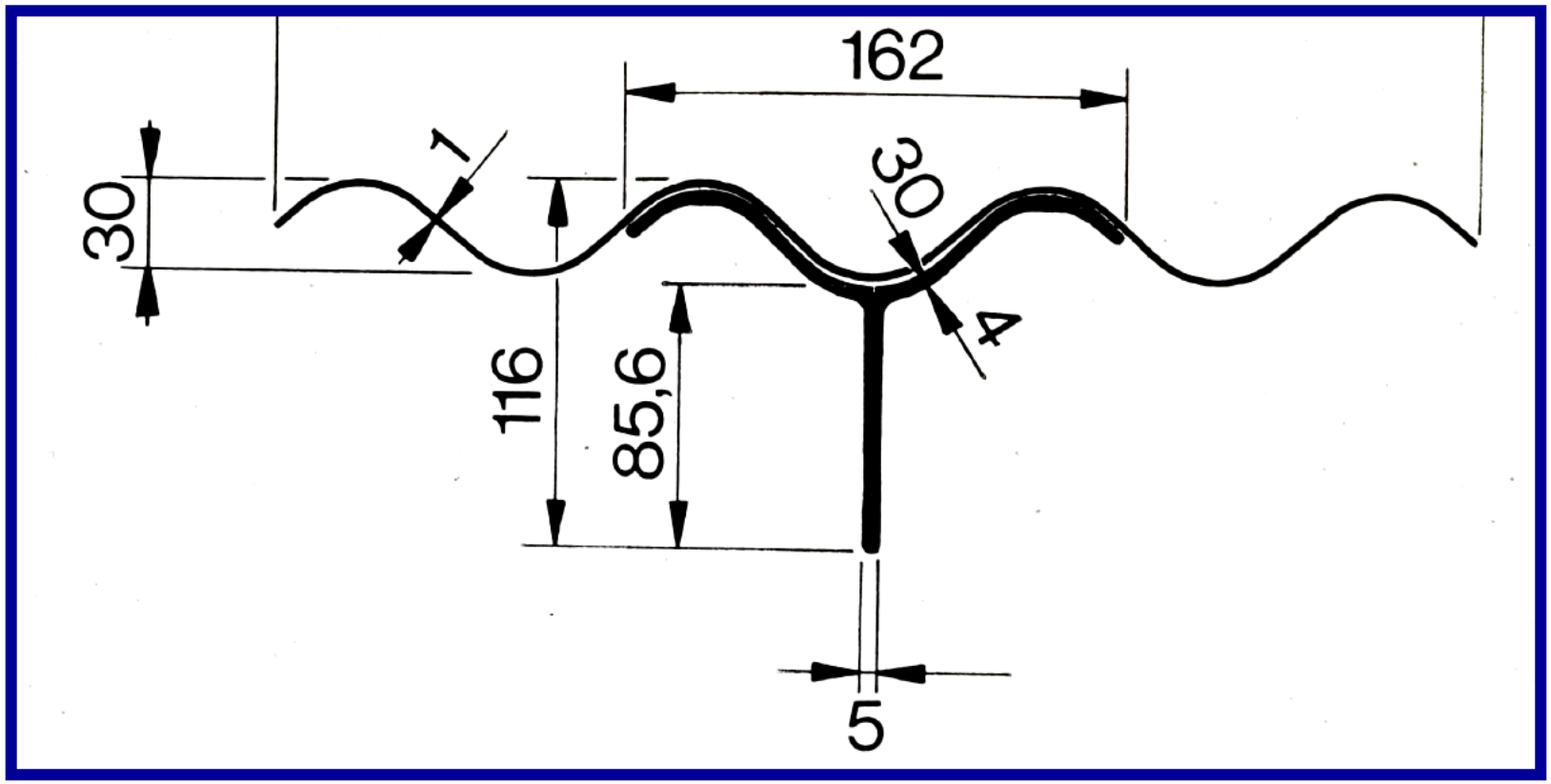
Functionality of sections due to extrusion



Industrial building

- **Third pre-requisite:**

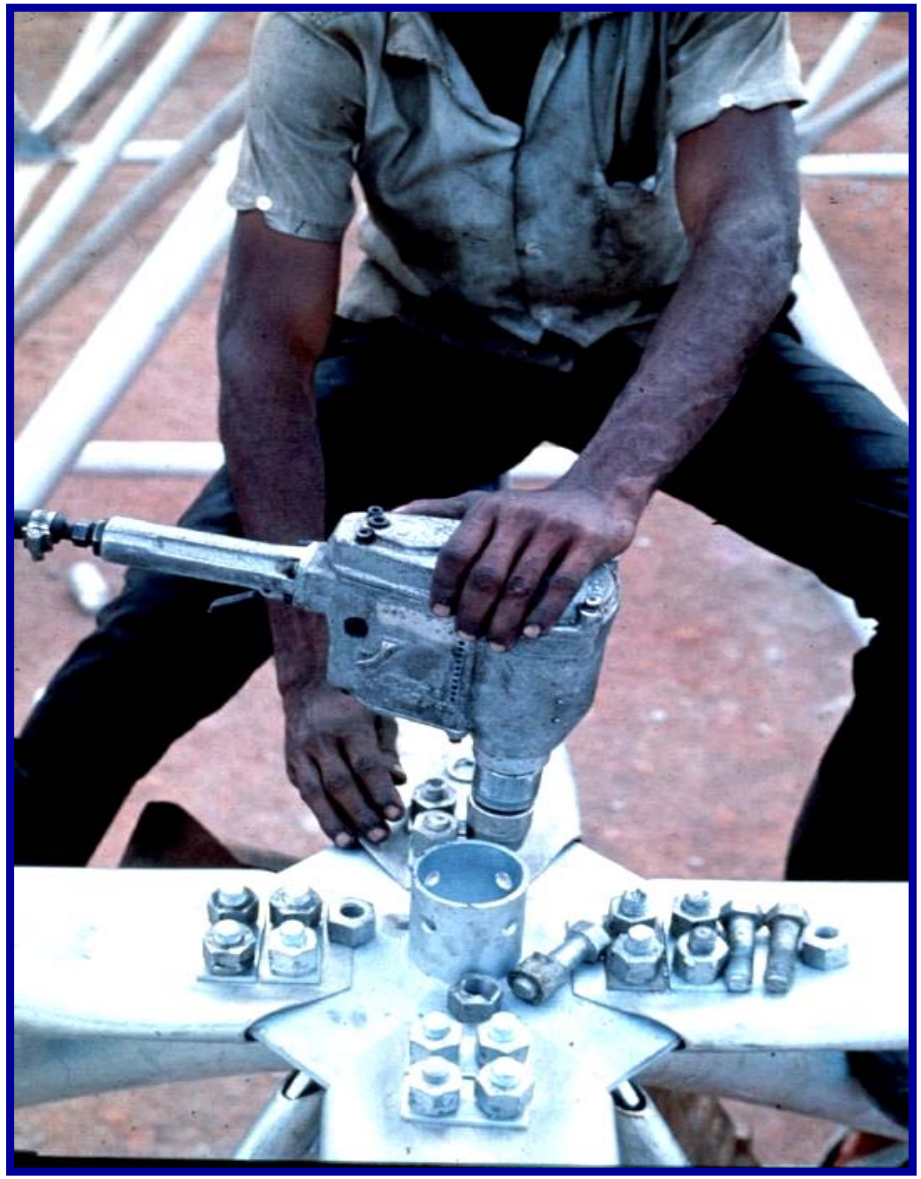
Functionality of sections due to extrusion



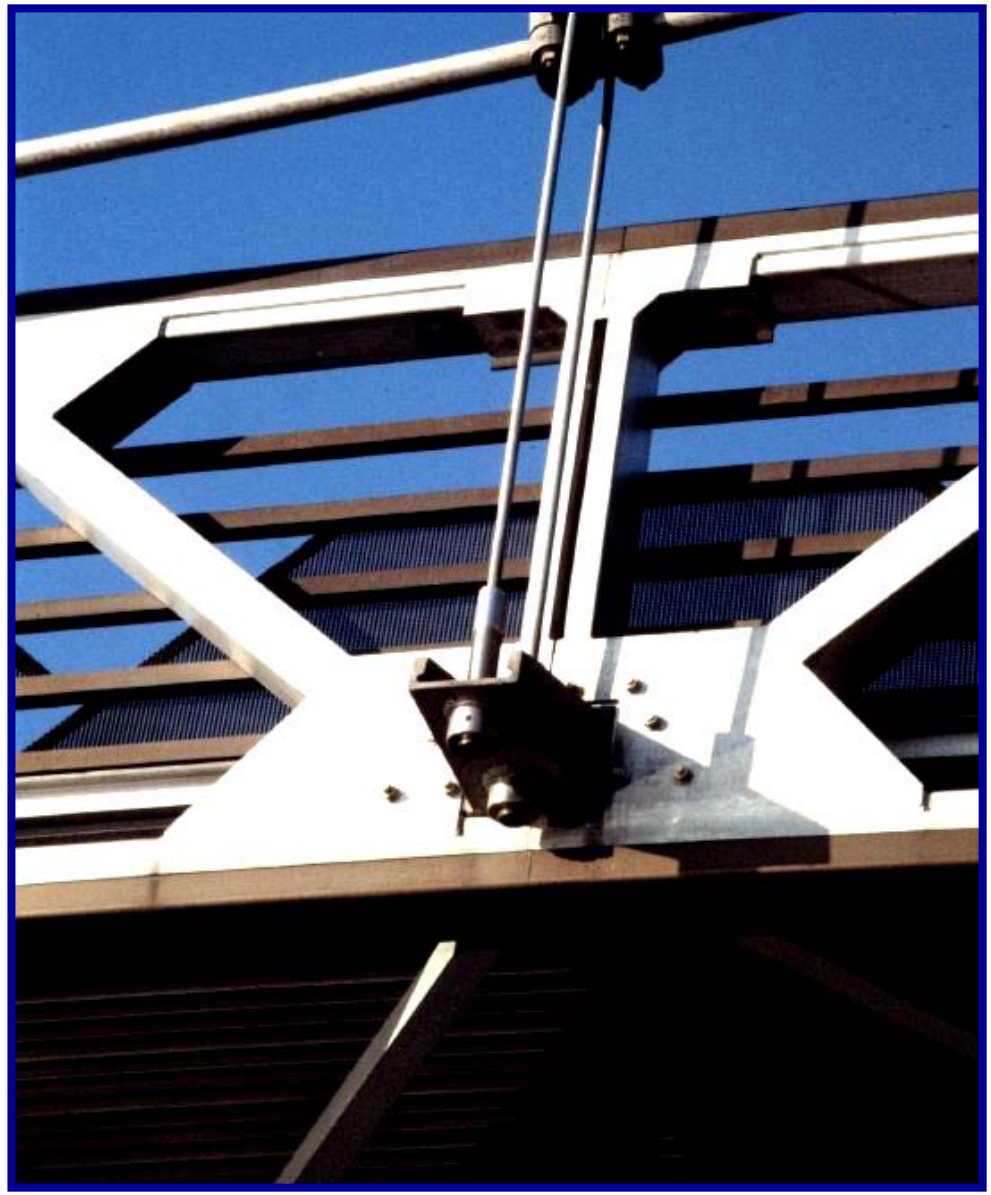
Section of the upper chord

Section for innovative floor structure

Bolted connections



Welded connections



FIELDS OF STRUCTURAL APPLICATIONS

C

- Storage vessels
- Lamp columns
- Profiled roof and wall cladding
- Support for railway overhead electrification
- Enclosure structures for sewage works
- Sound barriers
- Vehicle restraint systems
- Sewage plant bridges*
- Silos*
- Traffic signal gantries*
- Traffic signal poles*

C + L

- Lighting control towers
- Flag poles
- Aircraft access bridges
- Transmission towers
- Bridge inspection gantries
- Offshore structures (living quarters, bridges)*
- Tank flotation covers

L

- Crane booms
- Lorry mounted cranes
- Pit props
- Bridges*
- Mobile bridge inspection gantries
- Scaffolding systems
- Ladders
- Cherry pickers
- Telescopic platforms
- Masts for tents

C + F + L

- Grating planks
- Helidecks*

C + F

- Domes over sewage tanks*
- Marina landing stages
- Roof access staging
- Dam logs
- Curtain walling
- Overcladding support systems
- Pedestrian parapets
- Chicken house structures
- Wood drying kilns
- Space structures (domes, etc.)*
- Exhibition stands*
- Swimming pool roofs*
- Canopies
- Bus shelters
- Green houses/Glass houses*

F

- Prefabricated balconies*
- Conveyor belt structures
- Monorails
- Robot support structures
- Shuttering form work
- Tunnel shuttering

F + L

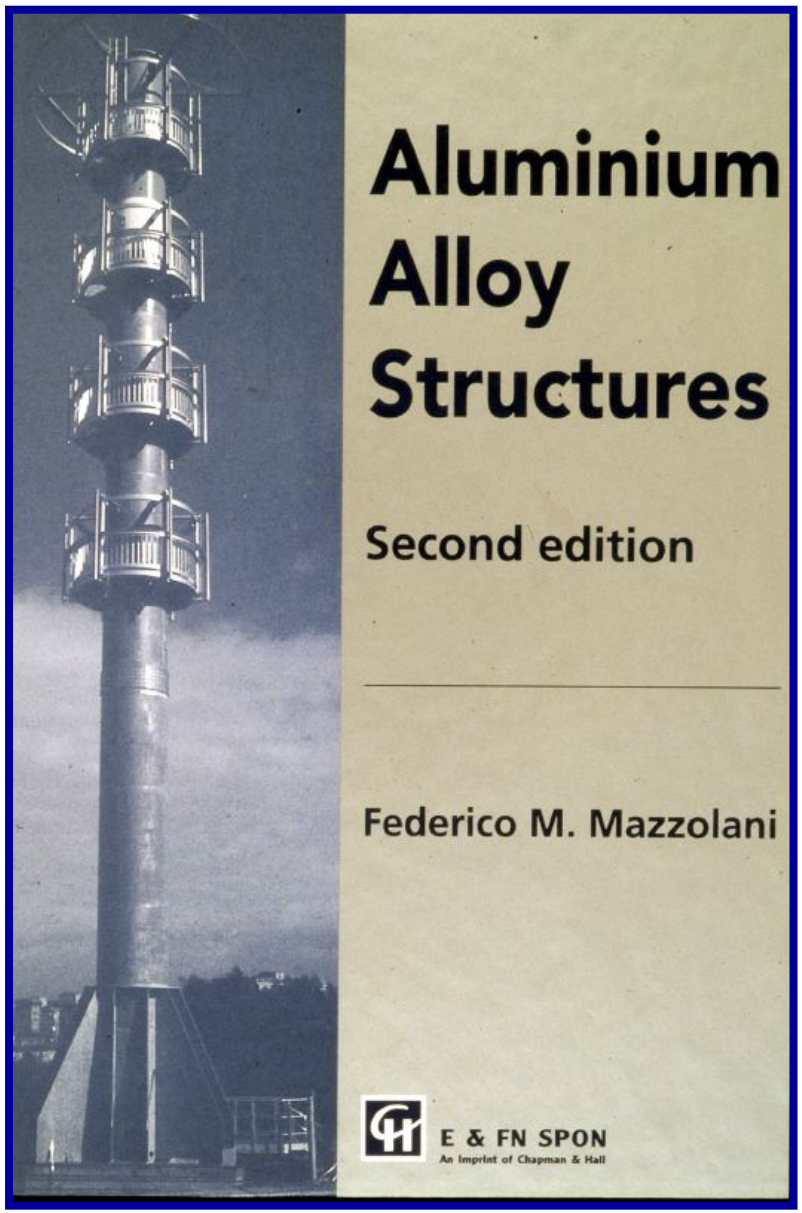
- Access ramps
- Support for shuttering
- Track ways (temporary)
- Elevators for building materials
- Scaffold planks
- Trench supports
- Grave digging supports
- Loading ramps
- Landing mats for aircraft
- Access gangways
- Shuttering support beams
- Military bridges*
- Radio masts
- Shuttering
- Telescopic conveyor belt structures
- Grandstand structures (temporary)
- Building maintenance gantries
- Fabric structure frames

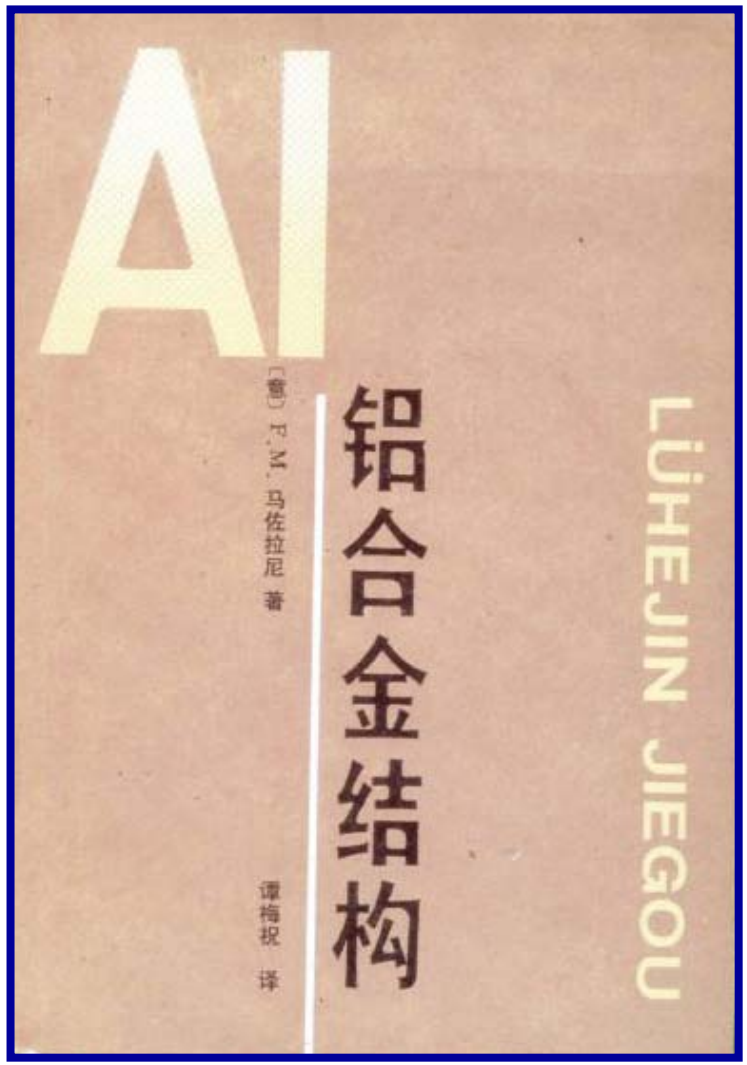
Table 1.1: The main structural applications of aluminium alloys in structural engineering

FIELDS OF APPLICATION IN CIVIL ENGINEERING

- Long span roof systems (**reticular schemes of plane and space structures**) , where live load is small compared to dead load
- Structures located in corrosive or humid environments (**swimming pool roofs,river bridges,hydraulic plants,off-shore superstructures**)
- Structures with moving parts,so that the lightness means economy during service (**moving bridges on rivers or channels,rotating crane bridges on circular pools in sewage plants**)
- Special purpose structures for which maintenance operations are particularly difficult (**masts,lighting towers,motorway sign portals**)
- Structures situated in inaccessible places far from the fabrication shop,so the transport economy and ease erection are extremelly important (**electrical transmission towers,stair cases,provisional bridges**)

Technical references



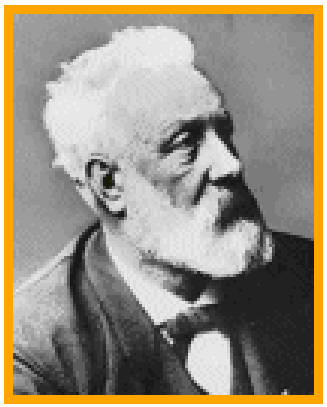


Competition between steel and aluminium

Reference from literature

Charles Dickens (1812-1870) wrote :

"Within the course of the last two years … a treasure has been divined, unearthed and brought to light ... *what do you think of a metal as white as silver, as unalterable as gold, as easily melted as copper, as tough as iron, which is malleable, ductile, and with the singular quality of being lighter that glass? Such a metal does exist and that in considerable quantities on the surface of the globe.* The advantages to be derived from a metal endowed with such qualities are easy to be understood. Its future place as a raw material in all sorts of industrial applications is undoubted, and we may expect soon to see it, in some shape or other, in the hands of the civilised world at large".



Reference from literature

Jules Verne (1844-1896),the father of modern science fiction, wrote "From Earth to the Moon":

"This valuable metal possesses the whiteness of silver, the indestructibility of gold, the tenacity of iron, the fusibility of copper, the lightness of glass. It is easily wrought, is very widely distributed, forming the base of most of the rocks, is three times lighter than iron, and seems to have been created for the express purpose of furnishing us with the material for our projectile".

THANK YOU
VERY MUCH FOR
YOUR KIND
ATTENTION