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)
Presence of aluminium in different surroundings
- Navy structures
Aircraft structures
Railway structures
Railway structures
Railway structures
Reservoirs for Railway
Reservoirs for Railway
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
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
- Weighth 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: **Lightness**
Second pre-requisite: **Lightness**
- Second pre-requisite: 
  Lighthness
Steel hot rolled sections
aluminium extruded sections
extrusion process
Phases of the extrusion process

1. Billets in parking
2. Heating (480°C)
3. Cutting
4. Transfer to extrusion
5. Extrusion
6. Termal treatment
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”
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
# Design Criteria for Aluminium Alloy Structures

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

<table>
<thead>
<tr>
<th>C</th>
<th>C + L</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C</strong></td>
<td><strong>Lighting control towers</strong></td>
<td><strong>Crane booms</strong></td>
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<tr>
<td></td>
<td><strong>Flag poles</strong></td>
<td><strong>Lorry mounted cranes</strong></td>
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<td></td>
<td><strong>Aircraft access bridges</strong></td>
<td><strong>Pit props</strong></td>
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<td></td>
<td><strong>Transmission towers</strong></td>
<td><strong>Bridges</strong></td>
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<td></td>
<td><strong>Bridge inspection gantries</strong></td>
<td><strong>Mobile bridge inspection gantries</strong></td>
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<td></td>
<td><strong>Offshore structures</strong> (living quarters, bridges)*</td>
<td><strong>Scaffolding systems</strong></td>
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<td></td>
<td><strong>Tank flotation covers</strong></td>
<td><strong>Ladders</strong></td>
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<tr>
<td><strong>C + F</strong></td>
<td><strong>Grating planks</strong></td>
<td><strong>Cherry pickers</strong></td>
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<tr>
<td></td>
<td><strong>Helidecks</strong>*</td>
<td><strong>Telescopic platforms</strong></td>
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<tr>
<td><strong>C + F + L</strong></td>
<td><strong>Prefabricated balconies</strong>*</td>
<td><strong>Masts for tents</strong></td>
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<tr>
<td></td>
<td><strong>Conveyor belt structures</strong></td>
<td><strong>Exhibition stands</strong>*</td>
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<td></td>
<td><strong>Monorails</strong></td>
<td><strong>Swimming pool roofs</strong>*</td>
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<td><strong>Robot support structures</strong></td>
<td><strong>Canopies</strong></td>
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<td></td>
<td><strong>Shuttering form work</strong></td>
<td><strong>Bus shelters</strong></td>
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<td></td>
<td><strong>Tunnel shuttering</strong></td>
<td><strong>Green houses/Glass houses</strong>*</td>
</tr>
</tbody>
</table>

## 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

- **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*

- **C + F + L**
  - Grating planks
  - Helidecks*

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

- **F + L**
  - Access ramps
  - Support for shuttering
  - Trackways (temporary)
  - Elevators for building materials
  - Scaffolding 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

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**EUROCODES**

 Brussels, 18-20 February 2008 – Dissemination of Information Workshop
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 of erection are extremely important (electrical transmission towers, stair cases, provisional bridges)
Technical references
Competition between steel and aluminium
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”.

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