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3D aluminium structures

Federico M. Mazzolani

Department of Structural Engineering, University of Naples "Federico II", Naples, Italy

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ABSTRACT

The main aspects of theory, design, codification and application of 3D aluminium structures are examined, by emphasising the peculiar differences with steel, by referring to real cases. The main applications in the field of geodetic domes represent a challenging example of 3D aluminium structures. The theoretical and experimental results were used for setting-up Part 1.5 "Shell Structures" of Eurocode 9.

1. Why aluminium

Aluminium is a very new material. The use of aluminium alloys in structural engineering is a quite recent activity, because this family of materials is very young and its history is very short. In fact, aluminium and its alloys are available since the end of the 19th century only.

The possibility of isolating the aluminium element was foreseen by Sir Humphry Davy at the beginning of the 19th century (1807), but the first concrete result was obtained by Whoeler after 20 years of research (1827). The industrial production of aluminium started just in 1886 as soon as a Frenchman, Paul Luis Touissant Hérnoult and an American, Charles Martin Hall patented in the same time, but independently, the electrolytic process.

The end of the 19th century assisted to a first big challenging structural application: the Schwarz and Zeppelin dirigibles. Since the beginning of the 20th century, aluminium alloys were initially used for applications where there was virtually no substitutive material. The most significant case was the one of the aeronautical industry, where wood and tissues were gradually substituted by the new light metal, giving rise to the basis of the modern aircrafts.

Afterwards, the use of aluminium alloys rapidly spread into many fields both structural and non-structural (window frames, door furniture, claddings, industrial chemistry, and armaments).

Since many years after World War II, these materials are successfully used in transportation, such as the rail industry (subway coaches, sleeping cars, etc.), the automotive industry (containers for trucks, motorcars, moving cranes, etc.) and the shipping industry (civil and military hydrofoils, motorboats, sailboats, etc.).

A parallel trend for aluminium alloys consists on their use in the so-called civil engineering structures, where these materials can be considered as new and they have to also compete with steel, the most widely used metallic material in this field. The development in the field of "civil engineering" started after the World War II.

In the early fifties the first building structures made of aluminium alloy appeared in Europe under form of prefabricated systems. At that time, the development of these kind of applications was undermined by the inadequacy or quite complete absence of codification and recommendations, making the structural design difficult for consulting engineers and controlling bodies.

Nowadays, this limitation has been completely overcome at European level, starting from the first edition of the ECCS Recommendations issued in 1978 by the ECCS Committee T2 [1] and going on at the present time with the preparation of the Eurocode EC9 "Design of Aluminium Structures" by the Technical Committee CEN-TC 250/SC9 [2], which is now in its final configuration.

What probably is still acting in negative sense is the lack of information about the potential of these materials in structural applications, being their peculiar advantages very seldom considered by structural engineers, who are much more familiar with steel structures, despite the publication of "ad hoc" volumes on the design of aluminium alloy structures [3,4].

Aluminium is selected for structural applications, when it becomes competitive with respect to other structural materials. It happens in all cases, where the designer can exploit the aluminium prerequisites, which are: lightness, corrosion resistance and rational use of extruded shapes. Large span roofing systems represent a very competitive field, under form of space structures for plane and curved shapes [5,6].

On the following, a state-of-art summary of the main aspects concerning the structural applications of aluminium alloy, and

E-mail address: fmm@unina.it

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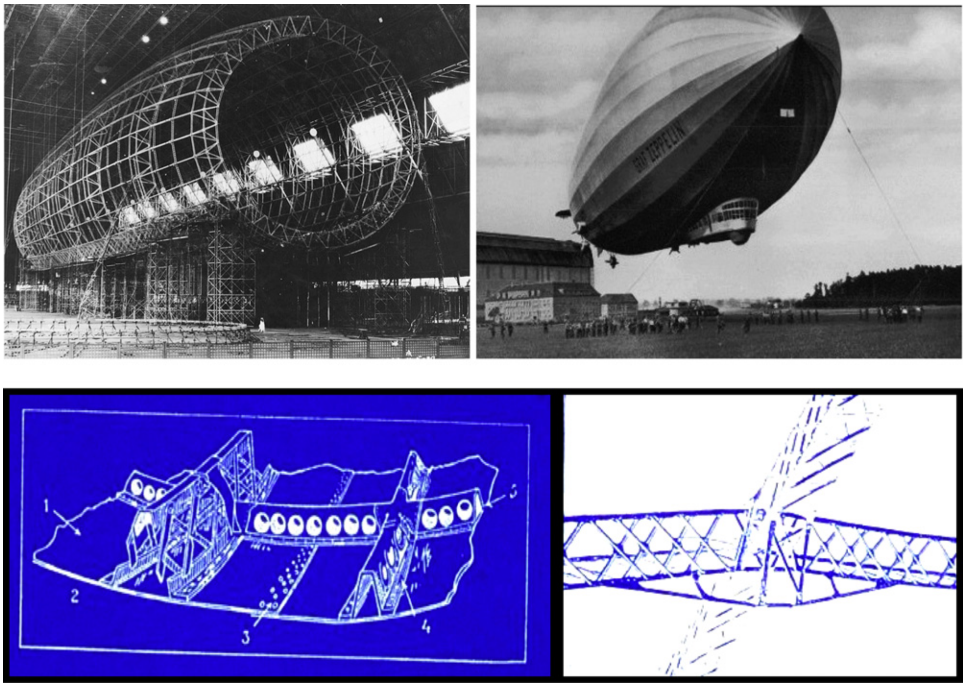

Fig. 1. Aluminium structure of a dirigible and its structural details.

some specific problems related to the calculation and design of these structures are presented.

2. Fields of 3D applications

The first important applications were done for building the skeleton of the dirigibles (Schwarz and Zeppelin), which represented the first 3D metal structure, as ancestor for the development of the modern aeronautic industry (see Fig. 1).

The structural details shown in Fig. 1, even if dated about one century ago, look very rational and modern, going from reticulated trusses to cold-formed omega sections.

After this challenging start, this new material was used in many structural applications in the field of transportations (on air, ground, and water): from aircrafts to ships, from trains to automotive, the aluminium alloys are present under form of 3D structures. In these fields, many applications of structural engineering are developed, where the 3D schemes of stiffened and unstiffened shells are used for storage vessels, silos, tanks, industrial domes. Fig. 2 shows the structure of a railway or metro car composed by curved plates, which are produced by extrusion with the stiffeners included.

Some applications of aluminium tanks and silos for storage corrosive material in the chemical and petrochemical industry, as well as for food, are illustrated in Fig. 3.

Roofing structures having a particular architectural values have been erected in the last decades [4]. Fig. 4 shows some of them erected in UK (the Conference Centre in Glasgow, the Incinerator and the Lords Cricket Ground in London, the roof of the Millennium Stadium in Welles).

The first important aluminium dome, called "Dome of Discovery" was built in UK in 1951 for the Festival of Britain. It was the largest in the World at that time, with a diameter of 100 m, made of three-directional reticulated arches and having a total weight of 24 kg/sqm (see Fig. 5(a)). It was followed by the Palasport in Paris in 1959 with a diameter of 61 m (see Fig. 5(b)).

Fig. 2. Structure of a railway or metro car.

Fig. 3. Aluminium silos.