Keywords: Large Spans; History; Materials; Evolution.

1. Introduction – Throughout the whole history of man, all constructed buildings have been conditioned by technical limitations [1]. In the nineteenth century, with the inclusion of iron in the construction field, structural layouts subjected to traction could be used for the first time in history. Before then, any building was based on compressive forces, such as structural systems like the arch, the vault and the dome, which through an intuitive adaptation to the antifunicular scheme, large spans can be constructed by using compressive forces. Centuries of experimentation have allowed us to evolve from the Roman arches (very thick) with the ability to resist many antifuniculars, to the Gothic structures (very thin) designed for a very limited set of scheme loads.

The qualitative leap enabled by new materials was introduced with arch bridges such as in Coalbrookdale Bridge (England, 1775), which reinterprets a previous structural model with the advantages of the new material [2]. Today the arch continues to be used as an efficient system for large spans, as in the case of the Chaotianmen Bridge (China, 2009), that covers 552 meters (Table 1). But this dimensional range is very small compared to other constructive solutions that exceed this structural type. In fact, the arch from 1811 has been surpassed by another structural layout, the suspension bridges [3].

Suspension bridges have evolved through advances in materials and the ways in which these materials are produced [4]. In this regard, the first suspension bridges employing chains later used bars as linear links. The bar bridge built over the valley of Sarine in Fribourg (Switzerland, 1834) managed to cover 265 meters. But in the mid-nineteenth century, the new material, the cables, got in the lead in the dimensional aspect, and progressed rapidly throughout the nineteenth century in its internal configuration and its wire drawing process. The cables have become a vital resource for the conception of the largest bridges in the world.

Since suspension bridges got in the lead by covering a record distance of 306 meters with the bridge Wheeling (United States, 1849), there have been great strides until today, and now the Great Akashi Kaikyo Bridge (Japan, 1998) covers 1991 meters (Table 2). These dimensional ranges now are technically surmountable, as evidenced by the bridge project to the Strait of Messina (Italy), that is designed and calculated with spans of 3.3 kilometers.

In this scenario it is necessary to take into account the great impact of costs and especially the formwork. In this aspect, employing wires cable-stayed bridges (Table 3) offer an economical option. This typology doesn't reach the dimensional ranges of suspension bridges [5], but considerably reduces costs.
by not requiring formwork. One of the most common ways to build these bridges is using successive cantilever, usually a very advantageous system.

Over the last two centuries, the bridges have been the leading reference for technology [6], they are the testing ground where limits of what's workable are plotted. This has an impact on subsequent architecture that benefits from this experimental work [7].

2. Methods – This study is the result of a long process of collecting examples of bridges built along the eighteenth, nineteenth and twentieth centuries, establishing a direct link with the advances produced, both in materials and in construction techniques. Throughout the centuries, bridges have been a reflection of the technological landscape of the moment; in this experimental field the largest spans and the limits of what can be constructed are being obtained. So a series of diagrams were elaborated to compare the dimensional limits of each technique, allowing to see the influence of certain developments and historical events in the evolutionary process of the bridges. This study lets you see which solution is best at all times when having to cover a determined span and see which options are available.

3. Results and Discussion – As a result of the study, the diagrams with the maximum reachable spans for each of the techniques explained during the last two centuries are obtained. In addition, the dimensional limit for each construction technique is also highlighted (Table 4), describing the historical overview in which we find ourselves today.

4. Conclusions – Over the last two centuries, the field of architecture moves away gradually from the technical limitations. Bridges have been a field in which there has been a greater technical experimentation. History and technology are inseparable for understanding the evolution of architectural spatiality. The technological variety now offers a wide range of options, each with particular aspects, whether related to the dimensional ranges, construction or economic conditions. The construction is conceived from a technical point of view as the election of the most appropriate choice for an specific problem. Therefore, a good understanding of the technical landscape is necessary for understanding the framework in which architectural production is performed.

References

TECHNOLOGICAL AND CONCEPTUAL LEAPS ON BRIDGES: LEADING SECTOR OF TECHNOLOGICAL EXPERIMENTATION DURING THE LAST TWO CENTURIES

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Throughout the whole history of man, all constructed buildings have been conditioned by technical and material [2] limitations. In the nineteenth century, with the inclusion of iron in the construction field, structural layouts subjected to traction could be used for the first time in history. Before then, any building was based on compressive forces, such as structural systems like the arch, the vault and the dome, which through an intuitive adaptation to the antifunicular scheme, large spans can be constructed by using compressive forces. Centuries of experimentation have allowed us to evolve from the Roman arches (very thick) with the ability to resist many antifuniculars, to the Gothic structures [very thin] designed for a very limited set of loads only.

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1. Historical view of large span bridge

Discoveries of material science

- 1700 – Abraham Darby invented charcoal as source of coal in the iron foundry with reducing agent, using coke (first fuel). This combustible needed a larger tonnage fuel, developing a new method to obtain coal.
- 1783 – James Hargreaves invented the spinning jenny, allowing the mass production of textiles.
- 1811 – Bessemer method for steel production. The Impurities are removed from the molten metal by introducing air into the furnace, causing an oxidation reaction, reaching the necessary temperature for the obtention of a usable steel.
- 1949 – Giulio Natta developed a method to synthesize polypropylene.
- 1954 – Smith and Newall started developing a machine for producing stainless steel.

The first high steel wire was drawing mechanical process.

- 1867 – Siemens-Martin steel production. The Impurities are removed from the molten metal by introducing air into the furnace, causing an oxidation reaction, reaching the necessary temperature for the obtention of a usable steel.
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2. Bridges that defined the dimensional limits of technology

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3. Structural Systems and dimensions