The fatigue analysis of railroad bridges with deck in steel and composite structure, under the action of freight traffic, is the subject of the technical article of this issue of "Metálica". The bridge of the River "Sonho" in Brazil is used as a case study, being tested with different loading scenarios, which influences the estimated lifetime of the bridge.

The design article details the procedures for the necessary certification of power plant suppliers / service providers in the frame of nuclear power plants in France, in order to carry out the fabrication and assembly of the steel structure of 27 buildings for the protection of nuclear power generators (DUS building).

In the regular opinion articles we are introduced to the history of the construction of the Statue of Liberty, to the potentialities and possible problems of dissimilar steel welding, to the construction of the Trade House in Salvador, Brazil, and to the benefits of using high strength steels.

Also in this edition of "Metálica" Prof. Carla Gomes from IPO (National Institute for standardization) gives us a brief presentation of the current situation of standardization in the Portuguese construction sector, which includes the execution of steel structures.

The organization of the XII Conference on Steel and Composite Construction is already in progress. This year it will take place at the "Convento São Francisco" in Coimbra and will have as its special theme "Steel structures as an answer to climatic changes". Some of the confirmed invited speakers are already announced in this journal.

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Freedom Illuminating the World

"La forme au grand sculpteur c'est tout et ce n'est rien. Ce n'est rien sans l'esprit, c'est tout avec l'idée!"

Victor Hugo

The idea of representing freedom through a statue was firstly a collaboration of Edouard Laboulaye, a prestigious professor at the Parisian Collège de France. This jurist was an enthusiastic supporter of Republican ideals, understanding that the French's contribution to the independence process of the United States should be clearly visible and that he had counted on the iron opposition of Great Britain. This conviction of Laboulaye, corroborated by some of his closest friends, was turned into a challenge by the young sculptor Frederic Auguste Bartholdi during a dinner at Glény, outside Versailles, April 1865. This feat materialized in a statue which, conveying the ideal of freedom, would be a symbolic interpretation of the Roman goddess Liberty (libertas), since one of the burning themes was the recent abolition of slavery proclaimed by Abraham Lincoln. There is no doubt that the Statue of Liberty is intended to be a commemorative monument of the centenary of US independence. Unfortunately, by various events, at that time, only a small section of the statue, which corresponded to its highest part, was completed: the hand holding the torch.

Having decided to develop in France such a complex task of building a gigantic statue, the main problem beyond the technical issues was the economic viability of this venture. As an example of one of the solutions found to fund this project was the sale of some reproductions of the statue's first clay model, a little one meter high, which would later be retouched by Bartholdi, with the donation published in a gold book. Quickly these models move to two and three meters, perhaps even a copy of about 11.5 meters high (at a scale of 1/4 of the original) to Paris, in bronze, offered by the American community of the city light. This replica, inaugurated on May 13, 1885, would initially be in a position with its back to New York and only at the end of the year with its relocation on the Grenelle Bridge, where it currently stands, could be deployed so that it faced the West and symbolically promoted more privileged relations with the American continent.

The case of the Statue of Liberty, whose initial designation was Liberty illuminating the world, corresponds to a situation in which the work clearly surpasses the creator. The work was immortalized and its creator was gradually sent to the trunk of oblivion. For the time, the hypothesis of the realization of a statue with such colossal dimensions as the one Bartholdi set out to do was an unfeasible situation since it was the largest work ever built and in the Parisian context, corresponded to a construction that far surpassed the forty-four meters of the existing column in Place Vendôme, built by Napoleon Bonaparte in the early nineteenth century.

But if the idea in this case is always something that definitely marks and distinguishes its author, most likely, neither the original plan was exclusively conceived by Bartholdi, as what lasted for the future was the force of a gigantic work that surpassed copyrighted domain and claimed itself as a world renowned legendary artifact.
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It is almost certain that Bartholdi’s trip to Egypt in the company of four fellow painters in November 1866 and in contact with all that ostentatious statuary came to influence this sculptor, especially in what concerns his interests around the monumental scale. No wonder, therefore, that in 1869, in the context of a second trip to Egypt, he presented the project of building an image called Égypte éclairant l’Orient, corresponding to a lighthouse statue and which in many respects will be a credible antecedent of his subsequent celebratory proposal for friendship between France and the American continent. In the case of the Egyptian statue, located at the entrance of the Suez Canal, it would have as its excuse the recent opening of the waterway of enormous strategic and commercial value, which linked the Mediterranean Sea to the Red Sea, whose venture, led by Ferdinand de Lesseps, was inaugurated on November 17, 1869 after 10 years of intense and costly work. In fact, the nature of the remarkable engineering work was of sufficient value to assert itself as the monument itself, and no complementary construction was deemed necessary to exalt it. But the desire to mark Lesseps’ achievement led to the erection of a 12 metre tall bronze statue in 1899, honoring the man and marking the northern entrance to the Suez Canal in the Egyptian city of Porto Said. In fact, Bartholdi’s proposal for the statue in Egypt has been seen as a preliminary version of the one implemented in New York. But in reality, if we look at the dates, what was in the French sculptor’s prior judgment was an idea developed by Laboulaye to erect a monument that represents the fraternity between two peoples with genuine respect for the values of freedom. And in that strict sense, any more rigorous analysis will see in the proposal for Egypt a passage through a path that had a beginning directed to the American soil and was concretized precisely in that same country.

Egypt and its statues of enormous size were inevitably an enormous influence on the development of a type of sculpture that substantially increased the dimension of men and things, which forced us to rethink the problems of scale and relations. And if in the case of Egypt the materiality was preferably stone, a story that was certainly contiguous to the imaginary of the time was what related to the Colossus of Rhodes and which had tested the use of metal over its three dozen or so meters high. In this case, this bronze monument, by Greek Carés de Lindos (considered one of the seven wonders of the world), representing Helius, God of the Sun, had each of his feet resting on opposite banks of the city’s port access channel, forcing the passage between his legs and his raised right hand, he held an ostentatious lighthouse whose mission was to guide the sailors at night.

Faced with the outcome of the non-fulfillment of the Egyptian Bartholdian dream, the strategy was developed from an idea that gained new impetus given the proximity of the date of the celebration of the centenary of American independence. So instead of being Egypt illuminating the east, most likely, and fortunately for Bartholdi, the future is oriented to the west side of France, and the ephemeral of the approaching date is inevitably a window of opportunity to do something really big. In the transformation from pharaonic lighthouse woman to woman with lighthouse tiara, the name, the geography, most likely the speech, slightly changed, but overall the physical and aesthetic model remained. That is, the occasion set the course and turned a project outright rejected into a work adapted opportunistically to another context that came to give it viability. However, some details would be added that would give a better framework to the event: some discreet broken chain links and a fiery left-handed Law Board with the inscription of the Independence Day; July 4, 1776. If in the biblical context the Boards of the Law were written after the liberation of the people of Israel from the slavery of Egypt, which symbolically the Statue of Liberty carried marked the liberation of the Americans in the face of English influence, thus justifying the breaking of the fetters that so much suffering had caused people who would have little native language and whose society was beginning to build up in a continuous immigration of multiple European geographies. The tablets of divine law gave way to the tablets of law established by the will of men.

In terms of possible influence on Bartholdi, the sculptural ensemble, called Marine marchande, by François Jourfroy, dated 1868, which is located in the Lesdiguières pavilion in the ticket window area, is not

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1 Namely, Jean-Belley, Narcisse Bicherè, Jean-Aimé Gérôme and Edouard Imre.
2 Selet, Robert and Bermond, Daniel, Bartholdi, p. 237.
3 This monument was erected between 220 and 210 BC and was intended to celebrate the retreat of the Macedonian king Demetrius, who had unsuccessfully attempted the conquest of Rhodes. This statue, set on a prominent and facing the harbor, was to be knocked down in 226 BC in the context of an earthquake.
to be ignored. There, attached to the parietal surfaces that define the vaults that give access to the Place du Carrousel, on the Seine-facing façade, a female figure appears, in Roman costumes, holding a torch in her right hand and which may resemble the Statue of Liberty. But while Delacroix’s 1830 painting, entitled Liberty Guiding a People, was certainly a vision that fueled the most progressive spirits towards gaining the right to choose, Ange-Louis Janet’s painting with an allegory to the Republic may have given in 1848 the previous motto for exploring the idea of the female figure illuminating the path, whatever it may be.  

The Liberty, at a height of 46 meters, from the sole of the foot to the end of the torch, fully covered with the copper plate, had as one of its biggest challenges, to keep the statue stable, being able to withstand the weather and winds that could be felt on the spot. Earlier in the process, Bartholdi invited Viollet-le-Duc (who was reportedly his former professor) to develop the difficult structure needed to support his monumental statue. Unfortunately, unexpectedly, Viollet-le-Duc died on September 17, 1879, leading to the invitation of an iron construction expert – Gustave Eiffel – to continue the work begun by the prestigious architect who had already obtained a wide acclaim at the level of written production, his work around historical rehabilitation and revival architecture. The original proposal envisaged that the outer sheet metal would function as a supporting structure that would be reinforced inside by sand-filled masonry compartments. Solution that should be implemented at least up to the giant statue’s hips, giving stability to the exterior shape. The use of sand as filler would facilitate the expeditious process of unloading and would allow the creation of interior voids in case of an accident. The configuration of the riveted sheets, connected through steel bars, would be obtained by direct molding on wood molding, using a technique known as repoussé. In this last aspect, we can say that, later, this was the strategy adopted by Eiffel. However, the statue’s support solution would be particularly

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different from Viollet’s, with Eiffel subsequently playing a major role in the implemented solution.

If Viollet’s proposal exploited the self-supporting principle of the statue’s outer shell and complemented this circumstance with an equally rigid interior, the clearly much more modern Eiffel solution considered the self-supporting character of the outer skin, but introduced a much lighter and flexible structure in the interior. That is, Viollet’s solution used the self-supporting potential of the copper foil, but it needed inner weight to ensure stabilization of the outer shape, while Eiffel introduced an iron frame inside that somehow clutched the different plates that all joined together ensured themselves exemplary structural performance, capable of reliably responding to wind or possibly seismic actions. In practice, what Eiffel developed was a rigid interior mast that constituted the main structural element and then a secondary latticed, connecting structure with more flexible characteristics. Basically as main structure are made four slightly sloping pillars, virtually defining a trunk of a pyramid, to which are attached a sequence of sections in “X”, each pair drawing a cross of Saint Andrew. This structure, also with asymmetrical development in the area corresponding to the statue’s shoulder, presented a new structure, similar to the main one, with a slender and thin design, allowing sequentially the definition of the statue’s arm, forearm and right hand.

The final conformation of the statue was implemented piece by piece, through a process, with successive enlargements, which at first was initiated by a small statue (just over 1 meter). This would later be duplicated giving rise to a new statue. Then another statue was made, also intermediate, four times larger than the previous one (subdivided into 12 parts). That is, eight times larger than the original statue. In the end, after another fourfold increase, a solution would also be made with the implementation of sectioned parts of the statue, with dimensions identical to what it actually has. Knowing that the Statue of Liberty is about 34 meters from the feet to the top of the head, the intermediate versions were about 2.15 meters and 8.5 meters.

For the construction of the different sections of the real dimension of the statue a wooden structure was developed that was later covered with plaster to define continuous configurations and that helped to stabilize the wooden grids that previously defined the forms still very archaic. In turn these models - or life-size jigs - worked as molds for later, by hammer adjustment, the copper plates were accommodated to the intended form. For the full definition of the volume of the statue, three hundred and ten sheets of copper were needed, with the dimension of three by two meters with a thickness of about 2.4 millimeters. As the different parts of the statue were finished, the molds were methodically destroyed, making room for the development of new parts of the statue and logically facilitating a better continuation of the work in progress.

Recognized that Gustave Eiffel’s work in the field and construction of steel structures for countless bridges and viaducts was already outstanding, it seems understandable that Bartholdi used his good crafts to overcome the difficulty of making such a big and ambitious wish possible as was the realization of a monument like the one at stake. In the context of the work developed by Eiffel and Koechlin in terms of calculation and steel structures, the work for the Statue of Liberty, being a huge challenge, does not indicate any conducting wire when compared with the other constructions of the French engineer. 84

The Statue of Liberty project was to be developed in the aftermath of the Franco-Prussian War, where in 1870 Bartholdi served his country with dignity, believing to prevent his home region of Alsace from passing into German hands, and as such he served as field assistant the famous general Giuseppe Garibaldi. A struggle in vain and that in the following times would condition strongly the access to his hometown of Colmar. A conflict that would also be a pretext for another statue, the Belfort lion, signaling a heroic resistance of this city against the belligerent, majority force, which in the end of 1870 and in the beginning of the following year resisted the Prussian invasion during 103 long days. This other example, which was completed in 1880, with a height of 11 meters and a width of 22 meters, historically constitutes a colossal sandstone sculpture that perpetuated fame and gave consistency to the author competence of this prominent French sculptor.

and whose apparatus was certainly influenced by the visit and study of Egyptian art. What is most fascinating about this sculpture, besides its scale, is the way Bartholdi takes advantage of the site, making the place itself participate in the show. 

After a first visit to the United States to assess the receptivity of the idea of a monumental statue offered by the French people to the American people, and probably with some prospects of the ideal place for its implantation, Bartholdi is developing his work in a cyclical manner. It was logical that this could be ready as an apothecary event on July 4, 1876, when the 100th anniversary of the Declaration of Independence was celebrated. With the creation of a Commission for the Franco-American Union in 1874 by Bartholdi and Laboulaye, there was a more consistent structure in exploring possible sources of funding for the achievement of the Statue of Liberty. No wonder, therefore, that during the 1878 Paris Universal Exposition, the head of the Statue of Liberty was exposed, enabling visitors to purchase a ticket to climb inside and thereby help fund the venture. In addition and also related to the theme, a panoramic apparatus, about 11 meters high, was created in the Jardin des Tuileries which created on the surface of a semicircular canvas by Jules Chéret, representing a combination of the view of New York Bay with the monument that was intended to be built there. Once again, the objective was to disseminate the project, but above all to find sources of revenue that eventually in this case would not have been careless given the nearly seven thousand tickets in the two-month period.

Slowly the progress of the work was taking place under Bartholdi’s auspices and the close vigilance of the French Commission in charge of the work, chaired by Édouard de Laboulaye until his death on May 25, 1883. From that date the commission presided over by Ferdinand Léon, and precisely on July 4, 1884,

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6. Arm and Torch of Statue of Liberty, Bartholdi’s Atelier, 1878.

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96 Bobet, Robert and Bermond, Daniel, Bartholdi, p. 193.

on the day of the United States, the long-awaited statue would be made public. At a ceremony attended by several people on both sides of the Atlantic, with special thanks to Bartholdi for the project and Monduit-Béchet & Cie (Gaget-Gauthier's predecessor) for the execution, in a context where Lesseps announced that the costs of transport would be supported by the French government.

The assembly of the statue was made as the various parts were completed and able to take their place in the set. These diligent works were carried out between the buildings on Rue de Chazelles, near the "Pommerie et Cuivrerie d'Art", premises of the above-mentioned company responsible for the construction of the statue, over a long period of eight years (1876–1884), time that mediated the installation of the first rivet and the conclusion of the assembly work of the statue in Parisian soil[1]. All this work was methodically documented photographically by Pierre Petit and, especially by Albert Fernique who would become a specialized photographer of engineering and architectural works, making it possible that there are still testimonies of many works done at the time and especially that there are numerous images that witness the entire process of construction of the giant statue. Unmistakably, the still lengthy process of building the statue on Rue de Chazelles must have given rise to a heightened interest and was a source of immense curiosity for the Parisian population. There is no doubt that the visual impact in the context of the city is great and the visit of illustrious people is very frequent, either to the workshops or to the place where the statue was installed. One of the episodes of particular interest mentioned was when on a visit by Victor Hugo, accompanied by his grandson that, being welcomed by Bartholdi, the French banker Henri Cernushi is said to be in the presence of "two giants watching one another".[2]

The Parisian period of the construction of Liberty coincided with the implementation of Baron George Eugène Haussmann's ambitious plan, begun in 1853 under Emperor Napoleon III. This very important plan for the history of architecture made possible a new urban layout for the city of Paris, at the expense of a methodical and extensive demolition of its historical area.

Upon completion of the work, what would have been expected would be the dismantling of the statue in parts, its accommodation in packaging so that it could safely make its Atlantic crossing by boat. However, given the delayed work on the other side, the statue was able, to the delight of the Parisian population, to remain on display and accessible until January 1885, then closed and sequentially replaced for transport. Given the fact that the steel was not yet oxidized, one can only imagine the impact that it would have in the city of Paris with the still gleaming appearance of the copper plate with its intense red-orange glue.

Thus, after the dismantling of that steel colossus, and accommodating all sectors, seventy railway wagons were crowded, allowing the transport of the statue of Paris to the river port of Rouen, allowing in that place and using the Seine river navigability, the loading in the ship Isère, heading for New York. Starting on May 22, 1885, the ship left French soil, which was distinguished in public act by a solemn salute and carried in addition to the precious cargo, symbolically, a boarding document signed by numerous personalities, including the President of the French Republic, Jules Grévy and, of course, Frédéric Auguste Bartholdi. [3 3]