ADVANCES IN THE APPLIED ARTS & SCIENCES Part 1

Eiffel and His Tower:

A Man for His Time, an Inspiration for Ours

By John Marhoefer

"Where there is no vision, the people perish."

"The best way to predict the future is to create it."

When Gustave Eiffel completed his great tower it was intended to be a temporary structure which could easily be torn down. That it survived to become a symbol of France is a testament to the technological, aesthetic, and economic value the tower proved to embody. Yet, it would never have been erected had not Eiffel, with a predisposition to innovation and a willingness to take the risk of leading, availed himself of opportunities that presented themselves. Because of his vision he realized a legacy which proved to be so innovative it defined an age and continues to inspire innovation and advancement today.

The idea of the tower was born in the 1870's when French government officials decided

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to hold an Exposition Universelle, or World's Fair, in 1889 to celebrate the 100th anniversary of the French revolution. Recently France had suffered military defeat in the Franco-Prussian war and subsequently, incipient civil war. But, Government officials were determined to celebrate the advancements of the industrial age. Or, as Georges Berger, general manager of the French Exposition of 1889 defined the goal for the Exposition:

> *We will show our sons what their fathers have accomplished in the space of a century through progress in knowledge, love of work and respect for liberty. We will give them a view from the summit of the steep slope that has been climbed since the dark ages. And if one day they should again descend to some valley of error and misery, they will remember what we did and they will remind their children of it and future generations will thereby be more determined than ever to climb still higher than we have. For the law of progress is immortal, just as progress itself is infinite.*

In keeping with this sentiment, the 1889 Exposition Committee announced on May 2, 1886 its invitation to French architects and engineers to "*study the possibility of erecting on the Champ de Mars an iron tower with a base 125 meters square and 300 meters (1000 feet) high*". Sixteen days were allotted to submit proposals to the Committee. This great tower would be located at the entrance of the exposition.

That a tower 1000 feet tall was an ambitious specification, was an understatement. The world's tallest structure, the Washington Monument, was only 555 feet high and had required 36 years to complete when it opened in 1884. The 1889 Exposition Committee had procrastinated so long, a scant two years remained in which to construct the tallest tower ever conceived and for which no guiding precedent existed. To anyone but the supremely confident Eiffel, the undertaking would have appeared foolhardy, questions of the basic wisdom of creating such an eccentric structure aside.

But, Eiffel had built a career on his expertise in metallurgy and an exceptional ability to plan and innovate. He had become Europe's master metal builder at a time when increasingly, the engineering profession was put on a more scientific basis and engineers were able to realize progressively more complex monumental and vital works. It was therefore fitting that Eiffel was advancing into an uncharted area of techniques in the Tower undertaking. Yet, the Tower project differed from previous works as Robert M. Vogel, curator of mechanical and civil engineering at the Smithsonian Institution in Washington, observed:

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> *"In almost every case, these other works had evolved, in a natural and progressive way, from a fundamental concept firmly based upon precedent. This was true of such notable structures of the time as the Brooklyn Bride and to a lesser extent, the Forth Bridge. For the design of this tower there was virtually no experience in structural history from which Eiffel could draw other than a series of high piers that his own firm had designed earlier for railway bridges."*

However, none of Eiffel's previous piers had reached even half as high as he now intended to go. Still, many recurring Eiffelian traits, *e.g. preference for wrought iron, careful attention to wind bracing and novel method of erection* would eventually be found in evolved form in the thousand foot tower. Eiffel regarded his work as a commitment to progress and innovation in the form of bold yet considered commitments.

Eiffel's desire to build the 1,000-foot tower had grown since he first became aware it was contemplated by the committee. He made plans on his own long prior to the request for submittal being issued (and without assurance that it ever would). He used his celebrity to 'lobby' committee members on his views of what should be built. For example, Eiffel's view that "*antiquity, the Middle Ages and the Renaissance have pushed the use of stone to the extreme and it hardly appears possible to go further than our predecessors have with the same materials, especially since masonry construction techniques have not progressed notably for some time,*" was in committee members minds as they reviewed proposals for the tower which considered the use of masonry.

Ultimately, Eiffel's tower design was commissioned and Eiffel undertook most of the financing of the project. Furthermore, he undertook construction at his own risk and was entirely responsible for any accidents. If the tower proved dangerous he would be charged with its demolition. The timid committee granted only a $300k subsidy along with a franchise to operate the tower, restaurants and other attractions on the tower during the exposition and for the following twenty years, after which ownership would revert to the City of Paris. It was up to Eiffel to provide the additional $1.3 million to construct the tower. Ultimately, Eiffel completed the work for 94% of his expected outlay of $1.6 million.

In order to complete the tower within the restrictive time frame and under budget, Eiffel employed a number of innovative and fore-running methods during construction. These included the placement of hydraulic jacks in each of the (16) base-frame legs to plumb the tower, as needed during construction. He also utilized several different

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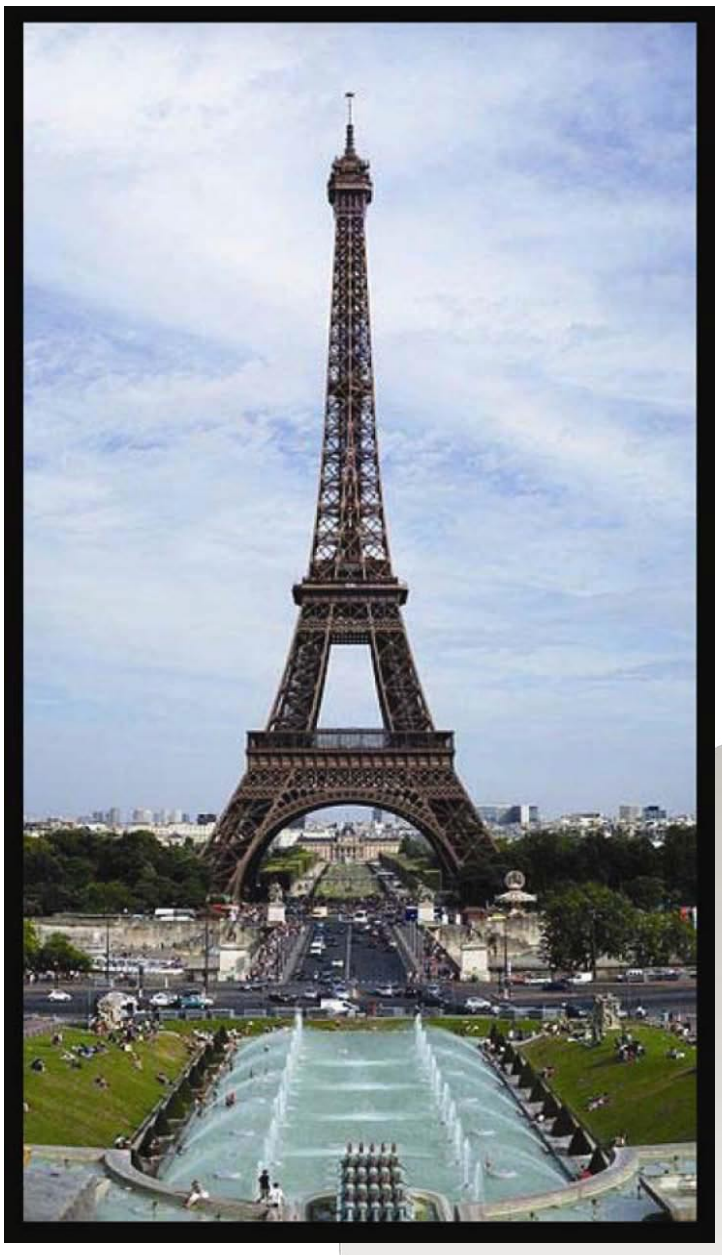
designs of tower construction cranes to maintain the flow of construction materials up to the working heights.

Eiffel understood from experience and research, the effects wind would play upon the tower. He recognized wind would be the primary load condition placed upon the tower and planned accordingly. To compensate, he deliberately designed the tower with enough open space for the wind to blow through it. Thus he was able to build a very tall, stiff tower with an extremely high margin of safety against wind loading conditions. It was this feature that effectively made the tower a tour-de-force of engineering design for the age.



Eiffel knew well that the structural stability of a material was as important as its ultimate yield strength. He selected wrought iron as the building material because it provided a means to render stable, strong and efficient (low weight) structural components and shapes.

By limiting the weight of metal pieces to no more than three tons, a relatively light maximum weight in view of the size of the structure, he would be able to construct the tower faster, safer, and more economically, even if this method did require more riveting. The construction of the Eiffel Tower was one of the first examples of large scale industrialized construction in which largely pre-fabricated pieces were shipped to site and subsequently assembled.

The result is a structure which is

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extraordinarily light. To illustrate, imagine a cylinder with a diameter equal to the base footprint of the tower and a height of 1000 feet. The air inside the cylinder would weigh nearly 10,000 tons compared to the tower's 8,000 tons of iron.

Since the then-state-of-the-art for elevators was too primitive to meet the elevator needs for access/egress of the tower, Eiffel pushed elevator constructors, including the famous Otis Elevator Company, to develop new methods for elevator transport. The tower required elevators able to ascend on a curve within each of the four semi-circular arches. Still, the idea of suspended elevator transport unnerved many. Through his confidence, testing and demonstrations he overcame resistance and installed the suspended elevator transport.

The tower was completed at the end of March 1889, only two years and two months after it was begun! It stood at its then, final height of 300.51 meters or 986 feet, dwarfing the Washington Monument completed only five years earlier, as the world's tallest structure. The Eiffel Tower would retain this title until the completion of the Chrysler Building in New York, in 1930.

When the Exposition closed on November 5th 1889 the future of the Eiffel tower was not certain. After Eiffel's twenty year lease expired there were thoughts of tearing it down. However, the tower proved useful for communications and scientific experiments of wind, weather, and radio waves, due to its height. Over time the perception of the tower changed. In addition to the technical achievements it represented, appreciation for its ascetic qualities grew. Today it is considered a striking example of structural art and has become a symbol of France as well as the world's best known landmark.

However, the tower is not just an interesting technological feat from the past. The technological breakthroughs which Eiffel utilized to construct the tower inspire innovation today. Recently, Tobias Schaedler, lead scientist at HRL Laboratories, announced their creation of the world's lightest solid. In the development of their ultra-lightweight, low-density metallic lattices, they were inspired by Eiffel's utilization of architectural structure to make the tower incredibly light and strong for its size. By applying principles of architecture into their design, they were able to make a structure with higher levels of stiffness, strength and conductivity than its parent materials.

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http://www.innovationnewsdaily.com/worlds-lightest-solid-takes-inspiration-from-eiffel-tower-2382/

The Tower's true achievement is relevance. It is an innovative technological masterpiece. It is a beautiful work of art. It is a symbol of Paris, of France, and a world treasure. It inspires new innovations and works of art. It is a tourist attraction. It is a center of communications. Ultimately, the Tower is an expression of the best humanity has to offer. And that is why we find it so captivating.

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