

Alexandre Gustave Eiffel

December 1993 is the 70th anniversary of the death of Alexandre Gustave Eiffel, a renowned civil engineer and architect, best known for the wrought-iron-lattice tower in Paris that bears his name. Nicknamed the “magician of iron,” Eiffel successfully completed radical new designs by carefully studying properties of the new building materials available to him, as well as by obtaining advanced knowledge of the behavior of the metal truss and arch forms under loading, such as from wind forces. Eiffel’s controversial successes brought about a revolution in civil engineering and architectural design.

Eiffel was born December 15, 1832, in Dijon, France. At the age of 23 he graduated with honors from the Ecole Centrale des Arts et Manufactures, and he immediately began to specialize in metal construction, with a particular interest in bridges.

In 1858, only three years after his graduation, Eiffel directed the construction of an iron railroad bridge across the Garonne River at Bordeaux. One of his notable innovations for this bridge was the use of compressed air to drive the piles and foundation caissons. After completing several other bridges, Eiffel worked for the Paris Exposition of 1867, designing the arched and lofty Gallery of Machines. In the same year, he set up his own firm for the construction of viaducts, bridges, and harbor works.

After the U.S. Civil War, the French historian Edouard de Laboulaye proposed the creation of a great statue—the Statue of Liberty—to commemorate the friendship between the United States and France. The French people contributed funds, and work began in 1875 under the direction of the prominent sculptor Frederic-Auguste Bartholdi. Eiffel himself designed the gigantic iron support framework, working with Eugene-Emmanuel Viollet-le-Duc. In 1885 Eiffel also designed the movable cupola for the observatory at Nice, which stood at a record 84 m.

In 1877 Eiffel built a spectacular bridge over the Douro River in Portugal, using a 162 m trussed parabolic steel arch which was constructed from the piles without scaffolding. From 1880 to 1884 Eiffel made use of the same bridge design and a slightly larger arch (166 m) over the Truyere in southern France. At 120 m above the river, this bridge—the Viaduct

at Garabit—held the record as highest in the world for many years.

Between 1887 and 1889, Eiffel completed his most famous work, the Eiffel Tower on the Champ de Mars in Paris. The French government had held a competition for designs for a suitable monument to commemorate the 100th anniversary of the French Revolution. Out of more than 100 plans submitted, the Centennial Committee chose Eiffel’s vision of a 300 m tower constructed of an open lattice of wrought iron, to be dedicated at another Paris exposition, the Centennial Exposition of 1889. The Tower was twice as high as the dome of St. Peter’s in Rome or the Great Pyramid of Giza—and nothing like it had ever been built.

Though steel was newly available as a mass-produced construction material, Eiffel chose to use primarily wrought iron for constructing his great Tower. Kirby et al. wrote that although steel was being used in other large construction projects in Scotland, Eiffel preferred to use iron, though it would require more metal (*Engineering in History*, McGraw-Hill, 1956). Albert France-Lanord, director of the Centre de Recherches de L’Histoire de la Siderurgie, states that this decision was probably made for economic reasons because at the time steel was even more expensive in France than wrought iron.

Though the project aroused great skepticism and vocal opposition on engineering as well as aesthetic grounds, Eiffel succeeded in raising his tower in record time, with a small labor force and a cost of only about a million dollars. The cost of construction was recouped from admission receipts during the first year alone.

The tower required 6,400 metric tons (640,000 kg) of metal. Eiffel created a detailed set of plans, indicating all 12,000 pieces of the Tower. Each part was prefabricated and numbered for assembly. The actual construction used 2.5 million rivets, most of them in place before the structure was erected on the site.

The four semicircular arches in the Tower’s base required elevators to ascend on a curve, and special glass-cage cars were designed for the purpose. The entire construction proceeded smoothly and efficiently, completed (except for installation of the special elevators) in less than 27 months. The June 15, 1989

issue of *Scientific American* noted that the construction was “without error, without accident, and without delay.”

Eiffel’s cross-braced, open-air design offered minimum wind resistance; even under a loading of hurricane force winds, the top of the Tower has an estimated movement of only 22 cm. The Eiffel Tower’s record height was not surpassed until 1931 with the completion of the Empire State Building in New York City, which topped the height of the Tower by 82 m.

Another notable but somewhat similar construction was completed for the 1889 Paris Exposition—the huge metal and glass Gallery of Machines, designed by engineer Victor Contamin and architect C-L-F. Dutert. The open Gallery was supported by great three-hinged arches spanning 114 m and extending 420 m. At 48,727 m², the Gallery still holds the world’s record for the largest glass-enclosed area. Unfortunately, the Gallery was so enormous that after the Exposition, the French could find no regular use for the facility and it was demolished in 1910.

On a less successful note, Alexandre Gustave Eiffel became involved in France’s failed Panama Canal venture, which caused his reputation to suffer. This project was headed by Ferdinand Marie de Lesseps, who had directed the construction of the Suez Canal. Excavation began in 1882, with the aim of making a sea-level passage that would require no locks to allow ships to pass through. By 1886, however, it became apparent that this was beyond the scope of their engineering abilities, so de Lesseps modified the design to allow for a series of massive locks to raise and lower ships across the passage. Eiffel was chosen to build these enormous locks, but the many financial scandals surrounding the entire project—corruption, waste, and mismanagement—ultimately bankrupted the venture.

Eiffel turned his interests to aerodynamics for the rest of his life. Outside of Paris, he built the first aerodynamics laboratory, which included a wind tunnel, and he continued to perform aerodynamic tests from his great Tower in Paris. He dropped objects of various shapes and sizes down a wire slipway and measured their velocities on the ground. In his later years he wrote ground-breaking treatises on the science of aerodynamics.

The “magician of iron” died in Paris on December 27, 1923, after a life filled with spectacular achievements.

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