History

History At the end of the 19th Century , in the light of recovering French economy after the Franco-Prussian War, French republic announced the opening of a competition to design a 1000-foot tall tower for the 1889 Universal Exposition. The location of the tower was determined to be at Champ de Mars in Paris. Gustave Eiffel’s company engineer, Maurice and Emile alongside the architect Stephen Souvestre came out with a proposal to enter the competition. Their blueprint was selected unanimously out of all the proposal from all over the world. However many challenges were faced by Eiffel even before the construction began. From lack of financial fund to the unbelieving heart of the public to ascension of a tower doubling the then tallest structure in the world, Washington monument, Eiffel tower was built on the courage to overcome the people’s concept of ‘’height limitation’’ and Eiffel’s confidence and knowledge in structural construction. Materials One of the main reason of Eiffel tower being made of wrought iron because of the experience of Maurice and Emile in iron railroad bridges and Eiffel’s experience in his previous project including the iron framework of Statue of Liberty. This gave them a head start in this purely iron-made tower. According to the study commissioned by the Eiffel Tower Operating Co. , the chosen material is among the many factors that kept Eiffel standing until now. The elastic and ductile puddled iron has high strength to weight ratio and is able to withstand fatigue. With the fact that the weight of the air surrounding exceeds the weight of the tower itself, it can been seen that iron is a light yet durable material. However, due to the characteristic of metal, Eiffel tower expands and contract as temperature changes. Based on the CETIM’s model analysis, temperature changes and extreme wind conditions may cause the tower to double its weight and sway but it is not enough to cause any threatening destruction. Design The most concerned design criteria faced by Eiffel's would be the stability of the tower. Despite the criticism from the public, he was certain that his design and the way of the tower's construction was going to work out. After winning the bid for the Universal Exposition of building a 1000-foot tower, Eiffel and his engineers worked hard in improving the design. 1700 drawings were produced on the supporting framework of the tower and 3629 drawings detailed renderings were produced as the blueprint of the latticework tower. Although the deadline for the construction was tight but the time spent for the calculations for every pieces of the iron truss were done manually , one at a time, was prioritized. The production of blueprint was not an easy job as the standard of precision was set very high where rivet holes' position was specified to 0. 1mm and the angle to 1 second of arc. To increase wind resistance, the four curved piers of the tower supported by sand jacks were purposely made to tilt at an angle of 54 ° inwards. This design had enable the thrust of the whole tower to be exerted perpendicularly to the foundation. The legs of the tower were designed to bear the weight of 3 platforms, where the first platform was designed to be at 186 feet , following by the second platform at 377 feet and the third platform at 890 feet from the ground. Construction Before the construction began, a series of borings were carried out in preparation for the laying of the foundation. The result of the boring showed that the ground of Champ de Mars was composed of a layer of sand and gravel of different depth on top of a deep stratum of clay with capability of supporting weight in the range of 45 to 55 pounds. In the first month of 1887, foundation works finally took place on the ground of Champ de Mars. The base where the four piers of the tower would sit on was deeply excavated. A bed of quick setting cement 20 feet deep was poured into the excavation. Next, big blocks of limestone were placed on top of the cement. Finally, two great anchor bolts of 26 feet long and 4 inches in diameter were used to fix the cylindrical flanged iron shoe to the stone mass. Thus each pier of the tower was securely rested on the solid pile of cement and stone forming a strong foundation. For the 2 piers lying on less stable soil by the river Seine, it required a slightly more complicated tactic for foundation laying. This challenge was solved by installing compressed-air caissons of 46 feet long and 20 feet in diameter which gradually sink down to the desired depth as excavation took place below it. Later on, concrete was poured into the caissons to obtain the solid mass needed for the foundation of the tower. Every part of the tower was designed individually varying with the increased angle of columns and braces as the tower ascends. High design precision to the accuracy of one-tenth millimeter was required so that there will be minor errors of installation of rivets on site. Two-third of the 2. 5 million rivets were placed in the factory Levallois-Perret in advance. The subassemblies were transported using horse-drawn carts to the site. Pieces of girders were packed at a much smaller scale , not exceeding 3 tons each, for ease of handling. Bolts were first used but later replaced by rivets on site. Inserting the rivets hot enables it to contract when cooled ensuring the pieces of iron to be held tightly in place. On top of these, precision was highly emphasized where any unfit part of the18, 038 pieces of puddle iron was sent back to the factory for modification. Towards the end of 1887, as the pier legs had reached a height of 92 feet. In order that the four piers were supported before they reached a height of 180 feet where the first platform was intended to be, four enormous wooden trusses were built as a support system of scaffold. The prefabricated iron were lifted with the help of creeper cranes which were installed at each leg. This speeded up the construction work. In the year 1888, an installation of a 2nd huge scaffold was prepared for the construction of the first platform. The first platform was regarded as a ‘’thick metal belt’’ that not only connects the 4 piers but also provides a base for the rest of the tower to weigh on. Thus, a detailed alignment of the platform was crucial for the stability of the remaining tower. The method used was to level each of the four corner columns in each leg to a precise height and the exact angle where a horizontal platform can be placed up to an accuracy of 1 millimeter using 16 hydraulic jacks placed under the base of the 16 columns. These hydraulic jacks were later on replaced by pillars. Wind resistance The method of overcoming wind resistance was by reducing the surface area of the tower which in turn reduces the grip and thus pressure of wind blowing against the solid surface. The design of the iron truss gives the open lattice a great amount of allowance where wind can blow through. For safety purposes, Eiffel assumed a disastrous wind with even speed up to 134 miles an hour from the top to the bottom of the tower for his calculation. The result showed that wind forces such as this adding up with the weight of ten thousand visitors daily only barely sum up to 10% of the weight of the tower. In addition, a wind bracing X’s of laced trusses connected the 4 columns from the peak to the second platform to prevent the destruction caused by wind. Usefulness Due to the 20 year lease, Eiffel was almost torn down in the year 1909. The usefulness of Eiffel’s antenna for radio and telegraphic post purpose during World war I had saved the tower from demolition. Subsequently, International Time Service French radio and French television also benefited from the tallest structure in Paris. Even until today, the tower still serves its purpose of being a transmission tower for radio and television broadcasting. Weakness and Beauty The inability of iron beam to withstand large stress indicated the excessive iron trusses as redundant. The tower is said to be ‘’over- engineered’’. However the excess lattice iron beams projects a significant look of a plant cellular structure which gives it its beauty. Conclusion Contradicting to a French mathematics professor’s flat prediction of the collapse of Eiffel’s tower at 748 feet, the tower has been standing for 123 years and more to come at a height of 1063 feet. The success in the erection of the tallest structure in the world has not only changed the mindset of people on skyscraper but also proved to Eiffel and the future engineers that with sufficient knowledge structural stability design and wind resistance, a structure can stand tall for a good century or more.