The Eiffel Tower A Classic of Engineering

THE EIFFEL TOWER. By G. Eiffel. From the New Review, reprinted in the Report of the Smithsonian Institution for 1889. Washington, 1890.

The notion of a tower 1,000 feet in height is not new. It has haunted the imagination of Englishmen and Americans. As early as 1833, the celebrated English engineer Trevitick proposed to construct a cast-iron tower 1,000 feet high, of which the diameter should be 100 feet at the base and 4 feet at the summit. But his project was never put in execution, and was but imperfectly worked out even on paper.

At the time of the Exhibition in Philadelphia, in 1876, the great American engineers, Messrs. Clarke and Reeves, brought forward a new project. Their tower was to consist of an iron cylinder 9 meters in diameter as a nucleus, and supported by a series of metal buttresses disposed round it and starting from a base with a diameter of 45 meters. This was a distinct improvement on the English project, although it still left room for criticism; and yet the Americans, in spite of their enterprising spirit and the national enthusiasm excited by this conception, shrank from its execution.

Tower in Paris Proposed

In 1881, M. Sébillot proposed to light Paris by an electric lamp placed at a height of 1,000 feet. This idea, which has, in my opinion, no practical value, had no better fate than its predecessors. I need only mention the designs, some in masonry, some in metal work and masonry combined, others, lastly, in wood, like the proposed tower for the Brussels Exhibition, which were produced at the same time as my own. But all these remained in the domain of fancy, proposals easy to frame but hard to execute. I come to the project which has been realized.

In 1885, after the studies which my engineers and I had occasion to make with regard to the lofty metal piers which support railway viaducts like that of Garabit, we were led to believe that it was possible to construct these without any great difficulty of a much greater height than any hitherto made, which did not exceed 230 feet. We planned on these lines a great pier for a viaduct which should have a height of 395 feet and a base of 131 feet.

The result of these studies led me, with a view to the exhibition of 1889, to propose the erection of the tower, now completed, of which the first plan had been drawn out by two of my chief engineers, Messrs. Nouguier and Koechlin, and by M. Sauvestre, an architect.

The fundamental idea of these pylons or great archways is based on a method of construction peculiar to me, of which the principal consists in giving to the edges of the pyramid a curve of such a nature that this pyramid shall be capable of resisting the force of the wind, without necessitating the junction of the edges by diagonals, as is usually done.

On this principal the tower was designed in the form of a pyramid, with four curved supports, isolated from each other and joined only by the platforms of the different stories. Higher up only, and where the four supports are sufficiently close to each other, the ordinary diagonals are used.

Eiffel's Plans Accepted

In June, 1886, a commission nominated by M. Lockroy, then minister of commerce and industry, finally accepted the plans I had submitted to it, and on January 8, 1887, the agreement with the State and the City of Paris was signed, fixing the conditions under which the tower was to be constructed.

It is needless to state that considerable energy and perserverance were required to attain this result, for there was much resistance to overcome, and my project had many opponents.

Hence the material of which the tower was to be built was determined not only by the fact that it rendered construction possible, but also because it would supply a brilliant example of a modern industry in which France has been more especially distinguished since its introduction.

The base of the tower consists of four great piers, which bear the

names of the four cardinal points. The first matter which offered itself for consideration was the question of the solidity of the foundation of these four piers. A series of borings showed that the subsoil in the Champ de Mars was composed of a deep stratum of clay capable of supporting a weight of between 45 pounds and 55 pounds to the square inch, surmounted by a layer of sand and gravel of varying depth, admirably calculated to receive the foundations. The actual position of the tower was determined by considerations relative to the depth of this stratum, since it was impossible to rest the piers directly on the clay. The foundation of each pier is now separated from the clay by a sufficient thickness of gravel.

Method of Construction

Each of the main supports of the tower rests on blocks of masonry, and the masonry rests on beds of concrete which cover an area of 60 square meters. In the center of each pile of stone-work, are two great iron bars 25 feet 6 inches in length and 4 inches in diameter, which, by means of iron clamps, unite almost all parts of the masonry. This anchorage, which is not necessary to the stability of the tower—sufficiently assured by its own weight—gives nevertheless additional security, and has moreover been useful in the construction of the iron-work.

It will be seen from the foregoing description that the foundations are established under conditions of great security, and that in the choice of materials and in the dimensions ample margin has been allowed, so as to leave no room for doubt with regard to their solidity.

Nevertheless, to render perfectly certain that the feet of the tower should remain absolutely level in any event, we have made room, at the angles of the piers where they rest on the masonry, for hydraulic presses of 800 tons. By means of these presses each pier can be displaced and raised as much as is necessary by inserting steel wedges beneath it.

The raising into place of the iron-work which forms the upper part of the tower was accomplished by derricks and windlasses. As soon as the piers reached a height of 100 feet their inclination rendered scaffolding necessary to carry on the construction to a height of 169 feet, at which point are established the horizontal beams uniting the four piers and forming the skeleton of the first story. The solid construction of the first platform was a great step toward the success of the work.

The raising of the pillars between the first and second platforms was rapidly accomplished by the same method as that employed between the ground and the first story, *i. e.*, the pieces of iron were raised by four cranes attached to the beams of the lift placed in each pier.

The work went forward so rapidly that in July, 1888, the four pillars were united by the beams of the second story, at a height of 387 feet, and by the 14th of the month the second platform was fixed, on which fireworks were displayed at the Fête Nationale.

The erection of that part of the tower comprised between the second platform and the summit was carried out by means of the same cranes as had served for the lower part; but these no longer worked on an inclined plane, but were raised along an upright, formed by the central guide of the higher lifts.

The total weight of the iron-work in the tower is rather more than 7,000 tons, without counting that in the caissons, which form a portion of the foundations, or that in the machinery of the lifts.

The different parts of the tower are reached by staircases and lifts. There are easy stairs in the east and west piers, which give access to the first story, and it is calculated that by using one for ascent and one for descent they will allow more than two thousand persons to go up and come down in the hour. From the first platform to the second there are four winding staircases, one in each pier, and from the second platform to the summit there is a single winding staircase, which, however (unlike the others) is not intended for the use of visitors, but for officials only.

The Three Platforms

On the first platform is a covered gallery, with arcades, whence visitors can enjoy a view of Paris and its environs, as well as of the Exhibition, with four refreshment rooms in the center,—Anglo-American, Flemish, Russian, and French. On the second story is a second covered gallery; and in the center is the station where passengers change from the lifts which move on an inclined plane of the lower half of the tower, to the vertical lifts of the upper portion.

On the third story is a great saloon more than 50 feet square, shut in by glass on all sides, and whence, sheltered from wind and weather, the spectator can contemplate the magnificent panorama, 45 leagues in extent, which is displayed beneath him. Above this room are laboratories and observatories for scientific purposes, and in the center the winding stair leading to the light-house whence the electric light shines over the whole of Paris.

The lifts are on three different systems, and all are provided with breaks, and otherwise insured against the possibility of serious accident...

I will not weary my readers with the enumeration of all the experiments to be made on the tower, of which a programme has been already drawn up by our scientific men, and which include the study of the fall of bodies through the air, the resistance of the air to varying velocities, certain laws of elasticity, the study of the compression of gases of vapors under the pressure of an immense manometer of 400 atmospheres, a new realization on a great scale of Foucault's pendulum demonstrating the rotation of the earth, the deviation toward the East of a falling body, etc., etc.; lastly, a series of physiological experiments of the deepest interest. . . .

Scientific Uses of the Tower

Thus it will be an observatory and laboratory such as was never until now at the disposal of science; and from the first all our scientific men have encouraged me with their warmest sympathy. On my side, and in order to express in a striking manner that the monument which I have raised is dedicated to science, I decided to inscribe in letters of gold on the great frieze of the first platform, and in the place of honor, the names of the greatest men of science who have honored France, from 1789, down to our own day.

Besides all these uses, which I might have explained in greater detail, but which, even in this rapid summary, will serve to show that we have not erected an object of barren wonder, the tower possesses in my eyes a usefulness of a totally different order, which is the true source of the ardor which has inspired me in my work. . . .

My object was to show to the whole world that France is a great country, and that she is still capable of success where others have failed.