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“The Iron Skeleton of the Statue of Liberty on Bedloe’s Island, New York Harbour.”

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THE recently completed statue on Bedloe’s island, near New York, comprises three distinct parts :—First, the masonry pedestal ; secondly, the wrought-iron skeleton ; thirdly, the copper skin. Some few details concerning the second part, which more specially concerns the art of the engineer, may be of interest.

The skeleton which supports the outer envelope or skin of the statue, has approximately the shape of an iron viaduct-pier. It is composed of four principals, which stand on a base 16 feet long and 12 feet 6 inches in breadth. The section of these principals is that of a large L, each side of which is 2 feet in length. The plates are $\frac{7}{16}$ inch thick. The summit of the angle is strengthened by four angle-irons 4 inches by 4 inches by $\frac{9}{16}$ inch, and the edges of the plates are also bordered by angle-irons $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{7}{16}$ inch. The bracing of the principals is riveted to the plates, and consists of horizontal bars and of diagonals. All these bars are of similar section, being formed of two angle-irons riveted together so as to present a **I** shape. The size of the angles varies from 4 inches by 4 inches by $\frac{9}{16}$ inch to $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{7}{16}$ inch.

The lower end of each principal is widened out by gusset-plates, so as to enlarge the bearing-surface of the plate, which rests on the supporting beams. In the three external angles thus formed, the holding-down bolts are lodged. These bolts, $4\frac{3}{4}$ inches in diameter, were at first intended to penetrate a solid mass of masonry to the depth of 26 feet 3 inches, which was largely sufficient to prevent any possibility of overturning. Architectural motives, however, have led, on erection, to the modification of this part of the design, and the monumental base provided for the statue is in reality a hollow mass. The walls of this pedestal are about 8 feet 6 inches thick at their thinnest part ; they are carefully built of granite with concrete backing, in which the fastening of the principals must needs take place.

The shaft or hollow space above mentioned, being 27 feet square, the bases of the principals fall within it. The latter have therefore been supported by steel-plate girders, the first set of which are six in number, arranged in two groups of three, each batch supporting two principals. Below these is a second set of six at right angles with the first, and crossing them exactly beneath the principals. The three holding-down bolts of each principal are thus connected to one of each of the two sets of girders. These rest on the top of the masonry at either end. They are 4 feet 3 inches in depth, made of a $\frac{5}{8}$ inch web and four angles 5 inches by 4 inches.

Since tensions may possibly arise in the principals from the action of the wind on the statue, the girders had to be securely tied down to the masonry. This was done by means of ties fixed near the end of the girders, and attached about 60 feet lower down to a similar set of plate girders. The ties are made of steel eye-bars of the form in common use in America. They are placed close to the inner faces of the shaft, in sixteen pairs, each consisting of two bars 5 inches wide and 1 inch thick. To each set corresponds a pair of lower girders, 41 feet long and 3 feet deep, making altogether sixteen girders firmly embedded in concrete at their ends. All pins and screw-ends are $4\frac{1}{2}$ inches in diameter. At their top ends the eye-bars, although connected to the girders by stout pins, are prolonged obliquely so as to join the principals at points about 12 feet above the base, thereby giving additional stability.

The skeleton frame is 93 feet in height, and thus reaches to about the chin of the statue. It is divided into eight panels of very nearly the same size. At top it is 7 feet 4 inches by 5 feet 11 inches. The two top panels, which together are 21 feet 4 inches in height, serve as abutment for a lateral girder which reaches into the uplifted arm of the statue, and as far as the torch which is borne by it. This girder or strut, although curved to requirement, is built up in lattice-work. The four booms are made of angle-irons, opposed at their corners thus $\begin{smallmatrix} \text{---} \backslash \\ \text{---} \end{smallmatrix}$, so as to attain the greatest possible stiffness in compression members. The diagonals are made of single angle-irons, fixed to the booms by means of gusset plates. They are single in every case and not crossed as usual.

Around the central pier is a complete skeleton frame designed to approach in every part as near as possible to the copper skin. This frame is simply built up of light angle-irons with diagonals and horizontals corresponding to those of the central part. On this frame are bolted flat bars, which accurately follow the contours of the skin, and to which the copper is fixed. The lower part of the pier is also surrounded by a platform on which the statue appears

to stand. Eight lattice girders go from the principals to the masonry; they support other similar girders upon which the copper skin for the base is spread out.

Scale $\frac{1}{16}$.

VERTICAL SECTION OF THE PEDESTAL.

The copper plates of the statue are 0·1 inch thick. They have riveted joints, the overlap being made so as to give a flush surface, and no rivet-heads are visible, these are countersunk on the outside. The skin is fixed to the skeleton by means of cop-

per bands 2 inches wide by $\frac{1}{8}$ inch thick, which are bent round the iron bars. They are thus allowed freely to move by expansion. To prevent clattering, and also because chemical action caused by electrical currents was feared, the iron bars have been first thickly painted with shellac and then enveloped in asbestos fibre. Should electrical currents really set up, this precaution may eventually be found to be of but little use.

The danger arising from atmospheric electricity is certainly not to be neglected, and the effects of lightning, more especially upon the foundations, might be very serious. To guard against this, lightning-conductors have been disposed inside the statue. They consist of five copper rods, each $\frac{3}{4}$ inch in diameter, leading into wells sunk at the base of the building. The rods dip into the water several feet. They are carried up through the interior of the metallic structure by lengths of 30 feet, made continuous by screwing into sockets of the same metal. The last piece is joined to the skin of the statue by soldering over a length of about 12 feet.

The calculation of the sections in the ironwork was made by the ordinary process.

Scale $\frac{1}{160}$.

ELEVATION OF THE SKELETON.

The weight to be carried by the skeleton has been estimated at about 120 tons for the ironwork, and 80 tons of copper skin. The pressure of the wind upon the projected surface of the statue has been calculated, but it is clear that such an estimate is more or less empirical. The wind-pressure has been assumed equal to 55 lbs. per square foot on the projected vertical surface. The bending-moments and transverse-strains have been determined on this assumption, the structure being considered as a vertical girder built in at its base. The torsional effects which will arise from the non-symmetrical form of the statue seem, however, to have been neglected, although it appears that they may very notably increase the calculated strains. The figures obtained show that in no part the strains on the metal exceed 5 tons per square inch. They range, however, in the same elements between 5 tons in compression to 3 tons in compression, which may appear rather heavy, taking into account the very sudden efforts which the wind may occasion, and also the greater effect caused by the rhythmic repetition of these efforts, when oscillation may ensue.

The use of the statue as a lighthouse was decided upon after some hesitation. Nothing had been originally provided for this purpose, and during erection the torch was prepared by cutting openings in the skin, thirty-six in number and 16 inches in diameter. These are glazed with plate glass. Within the torch, opposite these windows, are placed eight electric lights of 6,000 candle-power each, which shine in every direction, and can be seen from the open sea beyond the intervening island. The motive power for the lights consists of dynamos placed in a small building adjoining the pedestal, on one of the old bastions which surround the pedestal.