THE NEW YORK AND BROOKLYN BRIDGE.

The practical completion of the grandest piece of bridge engineering the world has yet seen necessarily attracts attention, not only in the immediate vicinity of the work, but throughout the civilized world; not only from curious sight seers, but from those who labor for the advancement of their fellows and rejoice in the success of a stupendous undertaking. In many respects this bridge has been an innovation, not only because of its vast proportions, but because of the materials entering into its construction. From time to time during the past thirteen years we have described and illustrated the main parts of the bridge at the time of their being finished, yet we do not think it amiss at the present time to summarize as briefly as possible the dominant features of this triumph of the science of engineering.

On the 16th of April, 1867, the Legislature of New York passed an act incorporating the New York Bridge Company, for the purpose of building a bridge over the East River between the cities of New York and Brooklyn. On the 23d of the following May, John A. Roebling was appointed chief engineer, and toward the close of the same year made his report, discussing at some length the three routes and the practicability of building suspended bridges of long span. The charter fixed the Brooklyn terminus at the junction of Main and Fulton Streets, but allowed the New York terminus to be at or below Chatham Square, but not south of the junction of Chatham and Nassau Streets. Considering the value of the property to be condemned, the grades, the difference in the cost, and the fact that City Hall Park would remain the center of travel for many years, it was thought best to build on the Park line. During the summer of 1869, a detailed survey of the route was made, and the Brooklyn tower located. It was while engaged in this work that Mr. Roebling met with a most serious accident. His right foot was crushed by the shock of a ferry boat against the fender rack of spring piles on which he was standing. Lockjaw set in, and after sixteen days of extreme suffering terminated in his death. In August of the same year his son Washington A. Roebling was appointed chief engineer.

The plan of the bridge was approved by the Secretary of War, and under date of June 21, 1869, the Chief of Engineers wrote to the company stating that under no conditions must the center of the span be less than 135 feet above mean high water; no portion of the tower foundations above the river bed must project beyond the pier lines; and no guys must ever be attached to the main span which will be below the bottom chords of the bridge.

An act was passed June 5, 1874, changing the name to that of the New York and Brooklyn Bridge, and making it a public work to be constructed by the two cities, Brooklyn paying two-thirds of the cost and New York one-third.

Taken as a whole the bridge consists of the approaches, one at each terminus; station buildings at the extreme ends; an anchorage, at the end of each approach, to which the four cables are fastened; two towers, over which the cables pass. To the cables are secured ropes on which hang six systems of longitudinal trusses, connected transversely by floor beams, dividing the width of the bridge into two roadways, two carways, and one promenade.

Work was commenced on the foundation of the Brooklyn tower on January 3, 1870. Borings, made previously, showed gneiss rock at a depth of 96 feet below high water, above which were layers of hardpan and trap bowlders embedded in clay and sand. This was considered compact enough to form a satisfactory foundation without going more than 45 or 50 feet below the surface of the water. Timber immersed in salt water is, practically, imperishable, and if placed below the bottom of the river will be out of reach of sea worms. It was therefore decided, in order to secure a bed of uniform character, to build a solid timber foundation having strength sufficient to act as a beam, and weight to insure even settling. The magnitude and importance of this feature in the great work becomes apparent when it is known that it would be called upon to sustain a dead weight of some eighty thousand tons.

The caisson was an immense box having a roof and sides but no bottom, so that when it was placed over the site and sunk, the water would not rise in the interior beyond the edges, thus forming an air chamber in which the men were free to work. The caisson was 102 feet wide, 168 feet long, the height of the air chamber being 9½ feet. A section through the sides formed a V, the inner slope of which had an angle of 45 degrees, and the outside of all the walls had a batter of 1 in 10. The walls sloped down to an edge, or shoe, formed by a semicircular casting, protected by boiler plate extending 3 feet up the sides. The timbers forming the V were held together by drift and screw bolts, and secured to the roof by angle irons and common timbers. The roof, upon which the tower was to rest, consisted of fifteen courses of Georgia pine timbers 12 inches square, alternate courses being laid in the same direction, and the pieces bolted both horizontally and vertically. To make the caisson air tight the seams were thoroughly calked, and in addition a vast sheet of tin was inserted between the fourth and fifth courses and down the four sides. There were shafts cut through the roof of the caisson for the passage of the laborers and to take out the excavated material and admit supplies. There were two water shafts made of boiler plate three-eighths of an inch thick, and having a rectangular section 7 feet by 6½ feet. These shafts were open both above and below, and the lower end extended below the edge of the shoe for 21 inches. Through these shafts descended dredges which grappled and raised any substance placed beneath the opening. There were two air shafts, 3½ feet in diameter, having an air-lock at each upper end, for the use of the men. The supply shafts were cylindrical, 21 inches in diameter and furnished with two doors, one above and one below. To admit material the lower door was closed, and the tube filled with the desired objects, after which the upper door was closed. The valve to the equalizing pipe was then opened, and as soon as the air pressure in the tube was equal to that in the chamber the lower door was opened, when the material fell into the chamber. All the doors to the air locks, as well as those to the shafts, fitted closely and swung into the chamber having the greater air pressure. Five massive frames, or walls, divided the air chamber of the caisson into six compartments. When this great box had been finished, it was launched and towed to its future resting place.

During the building of the caisson the site of the foundation had been cleared, and a rectangular space a little larger than the caisson, and having a depth of water sufficient to float it, had been prepared. On May 1, 1870, the caisson was towed down, and on the following day was warped into position. The tower proper was now commenced on the top of this caisson, but it was not until three courses of masonry had been laid that the caisson was weighted sufficiently to rest firmly on the bottom and resist the action of the tides. Six air compressors had been placed on the surface for the purpose of supplying air to the air chamber of the caisson. The pressure in this chamber was kept equal to the hydrostatic head, differences in the materials passed through making slight deviations from this rule necessary. The work of excavating was carried on from the chamber, all obstructions being removed from under the shoes and frames. At the same time the masonry was being laid on top with the aid of boom derricks and engines. When bowlders were encountered too large for easy handling, they were pulled out of the way by hydraulic jacks, then drilled and blasted. The blast produced no ill effects on the men, although some trouble was anticipated owing to the dense atmosphere.

Gradually but surely the caisson sank toward its final resting place, while the tower grew above it. At the end of five months 20,000 yards of earth had been removed. As the caisson proceeded downward the disproportion between the load above and the buoyancy became more and more, and to support this overweight additional shores were introduced, which rested upon a block and wedges and supported a cap placed against the roof. When the caisson had reached within three feet of its journey's end, 72 brick piers were built having bases averaging 20 square feet. These had strength enough to uphold the whole mass if the air pressure should from any cause be removed. When the caisson had reached a depth of 44½ feet below mean high tide, the operation of filling the entire air chamber with concrete was begun. The concrete consisted of one part of Rosendale cement, two of sand, and three of small sized gravel. The total quantity required, including the brick piers, was about 4,000 yards.

The danger from fire in an atmosphere of compressed air is very great, and the difficulty of quickly subduing it makes every known precaution necessary. At a pressure of 25 pounds to the square inch, the flame of a candle will return after having been blown out. On December 2, a fire was discovered in the caisson after it had been going some hours and attained considerable headway. Streams of water, steam, and carbonic acid were successively tried, but availed nothing. After struggling unsuccessfully for some time the caisson was flooded, and left so for two and a half days.

When the air was again admitted and the water expelled, about 200 borings were made in the roof to ascertain the extent of the fire. Vertically it was confined to the third, fourth, and fifth courses of timber, but laterally it extended to points 50 feet apart. Holes were made in the roof, the charcoal scraped from every burned stick, and the holes filled with cement. In order to prevent any settling at this point, a pier of square blocks of trap rock was built directly under the space burned. Cleaning and filling the burned section occupied 18 carpenters, working day and night, two months, besides common labor.

The Brooklyn caisson, completed, contained 250 tons of iron and 111,000 cubic feet of timber.

The New York tower is located in a direct line from the Brooklyn one, perpendicular to the stream, and at a distance of 1,595½ feet. Borings on the site did not encounter rock before reaching a depth of from 77 to 92 feet below high water, and as extensive beds of quicksand rested on the rock, it was necessary to go to it for a firm foundation. As this caisson would ultimately be subjected to a much greater pressure than the one upon the other side, the dimensions were made 102 by 172 feet. The roof was 22 feet thick, surmounted by a coffer dam reaching to high water mark, thus increasing the buoyancy, and lessening the pressure on the frames during sinking. The air chamber was 9½ feet high, and divided into six compartments. The interior of the chamber was lined with boiler iron, riveted together and calked. This lining made the chamber airtight and guarded against fire. Two sets of double air locks were built into the roof of the caisson, each being 6½ feet in diameter by 8 feet in height. There were four supply shafts, two of which were 24 inches in diameter and two 21 inches. The caisson was sunk to a depth of 78 feet in a manner very similar to that pursued on the other side, but owing to the nature of the material passed through, sand pumps were introduced, which utilized the air pressure in the chamber to force the sand out through tubes. The air chamber was filled as in the other case, except that the brick piers were deemed superfluous owing to the greater strength. The New York caisson contained 180 tons of bolts, 200 tons of iron work, and 118,000 cubic feet of timber.

The tower is not a solid mass of masonry, but consists of three buttressed shafts, joined together up to the roadway by four connecting walls. In the Brooklyn tower the course next the caisson is 17 feet thick; the thickness diminishes by offsets until at high water it is but 10½ feet. This forms two well holes, which are filled with concrete below water line, but left open up to the roadway. Spaces were also left from 2 feet above the arches to within 4½ feet of the top of the tower.

In one of the wide shafts is a small vertical opening 2 feet 5 inches by 3 feet, connecting with one of these small spaces. By means of a trap and iron ladder access can always be had to the roof. Above the roadway the tower consists of three columns having an oblong section, and united at the top by arches having a span of 39¾ inches. The points of the arches are 114½ feet above the roadway. The arches are pointed and are formed by the intersection of two arcs of circles having a radius of 48⅛ feet.

In order to guard against any possible change of form, heavy irons were inserted in the masonry and rods placed across the span. The masonry of the towers below water is largely limestone, except the facing of the two upper courses, which is granite. The backing above high water to the roadway is mostly granite, and all the remainder of the work is granite. To raise the stones from the yard at the foot of the tower to the work, engines driving drums were used. About the drums was wound a rope which passed over a pulley on the top of the completed course of the tower. A lewis having been put in the stone to be raised, it was attached to the rope and hoisted to the top. Here a car running on rails projecting over the edge was run under, and the stone lowered on it. Having reached the tower, the derricks carried it to its destination. Upon the upper portion of the work balance derricks were used instead of the boom derricks.

The vertical dimensions of the towers are as follows:

Height of roadway above mean high tide, 119¼ feet; height of springing of arches above high tide, 198 feet; height of springing of arches above roadway, 79¼ feet; height of ridge of roof stone, 271½ feet. The height of the ridge of roof stone of the Brooklyn tower above bottom of foundation is 316 feet. In the New York tower the height of ridge of roof is 349½ feet. A balustrade around the towers will increase the height to 276 feet above tide.

The following are some of the horizontal measurements: At the top of the caisson the Brooklyn tower is 151 by 49 feet, and the New York tower is 157 by 77 feet; at high water the Brooklyn tower is 57 by 141 feet, and the other 59 by 141 feet. At these points the towers have a solid section. At the base of the three shafts, or roadway, the Brooklyn tower is 45 by 131 feet; at the springing of the arches, 42½ by 128½ feet; at the base of the upper cornice it is 40 by 126 feet. The openings in the towers are 33¾ feet wide. Above high water the New York tower differs from the other by an increase of 3 feet in thickness in the direction of the axis of the bridge. The total weight of the Brooklyn tower, masonry and timber, is 93,079 tons. The greatest pressure at any point in the tower masonry will be at the base of the central shaft above roadway; this will be about 26 tons to the square foot, or 361 pounds per square inch.

At a distance of 930 feet from each tower is an anchorage designed merely to resist the pull of the cables which pass over the towers. These rest on timber foundations, the spaces between the sticks being filled with concrete. The masonry of the Brooklyn anchorage is 4 feet above tide, while the other is at high tide level. The Brooklyn foundation is 119⅓ by 132 feet; New York foundation, 119⅓ by 138 feet. The masonry is similar. The work is solid with the exception of two openings, or tunnels, in the river side, which are arched by semicircular arches of 23 feet span, springing at from 62 to 66 feet above tide. The anchorages are about 90 feet high above tide level. They are built of limestone and granite. The Brooklyn anchorage contains 27,113 cubic yards of masonry; the New York, 28,803 cubic yards.

In the end of each anchorage furthest from the towers are four anchor-plates (one for each end of each cable), which are held down by the dead weight of masonry piled upon them, and to which the cables are attached. The anchor-plates in the Brooklyn anchorage are placed 8 feet above tide, and those in New York 6 feet. These plates are cast-iron, 2½ feet thick at the center, and measure 16½ by 17½ feet on the surface. In form they much resemble an enormous wheel, having a massive hub and 16 spokes but no rim. Each plate weighs about 23 tons. The cables enter the corner of the anchorage diagonally opposite the plates, and after traversing a short distance horizontally, make a curve of about 90 degrees to the plates. The wires composing the cable do not come much beyond the corner of the tower, the connection between them and the plates being made by anchor bars. These bars start in double sets from each plate, one curving over the other, and are vertical for a distance of about 25 feet, when they curve about 90 degrees on a circle having a radius of 49½ feet. They then extend to within 25 feet of the front of the masonry, where they meet the cable wires. The bars have an average length of 12½ feet; the first three sets have a section of 7 by 3 inches, the next three 8 by 3, the next three 9 by 3 inches; the tenth set is double in number, and each 1½ by 9 inches section.

Piercing the center of the anchor-plates are two parallel sets of apertures, each set containing 9 holes. A bar is passed through each hole, and a bolt, or key, run through the eyes, or holes, which are in the end of each bar. These bolts bear firmly against the under side of the anchor-plate, and serve to distribute the strain to every part of the plate. The next series of bars are attached to these by a bolt 5 feet in length and 5 inches in diameter. In this manner the succeeding bars are united, forming a chain having very long links connected to each other by bolts passing through the eyes. These bolts vary in size from 5 to 7 inches in diameter, according to the strain to be placed upon them. At each knuckle of the chains a large piece of granite was placed with a heavy cast-iron plate inserted as a bearing for the heads of the links. The bars in the last link are increased in number to 38, and are arranged in four courses, one above the other. The wires of the cable are divided into 19 strands, and each strand is fastened around a grooved eye-piece so as to form a loop.

The total dead weight in the anchorage is about 1,000,000 pounds, and the weight on the anchor plates is about two and one-half times the force exerted by the cables against it.

It now becomes necessary to get a rope from one anchorage to the other passing over the two towers. To do this a reel containing the first ropes was placed in a frame erected on a scow, moored in front of the Brooklyn tower. The end of the rope was then hoisted over the tower and drawn down on the other side into the yard. Here it was fastened to a rope leading to an engine on the anchorage. Carefully it was hauled over, men being on the intervening buildings to protect them from injury. The scow with the reel was then towed across the river to the New York tower, where the other end was carried over the tower and down into the yard to the engine which had been used to hoist stone. Men were now stationed on the tower to watch the craft in the river, and when an open space with no boats near was obtained, word was given the engineer, who started up. Gradually but surely the rope was drawn over the tower; leaving the water, it rapidly rose until the desired deflection of 80 feet was reached.

A second rope was taken over in the same manner. After having been fastened to the top of the tower, the ends of the two ropes were hauled over the buildings to the New York anchorage. The ends of these ropes were spliced together around the driving and guiding wheels placed on the New York anchorage, thus forming an endless rope moving to and fro. In this way the first path across the East River was placed in position. This traveler was made of galvanized steel wire, three-quarters of an inch in diameter. Shortly after another traveler was erected alongside of this one, the ropes being carried over by the one already up. The first rope was taken over August 4, 1876, and eleven days after Mr. E. F. Farrington, master mechanic of the bridge, passed over the span, seated in a boatswain's chair. After this there were suspended a "carrier" rope 1¾ inches in diameter, and designed to bear the weight of the heavier ropes while being carried over; three cradle ropes 2¼ inches in diameter for supporting the cradles; two foot bridge cables; one auxiliary rope; two storm ropes attached to the foot bridge, and to each of the towers below the roadway, in order to prevent the wind from lifting the foot bridge; two ropes for hand rails for the bridge.

The cradles, ten in number, were nearly 48 feet long, placed perpendicular to the axis of the bridge, and arranged so that the strands of the main cables would be within easy reach of the men. The foot bridge was made of oak slats 3 by 1½ inches, laid two inches apart, and fastened to longitudinal strips which were secured to the ropes.

All the work we have heretofore described was erected for the purpose of holding in position 6,800,000 pounds of steel cable wire. These wires are made of hardened, tempered, and galvanized steel, size No. 8, full, Birmingham gauge. A length of fourteen feet weighs exactly one pound. Each wire has a breaking strength of not less than 3,400 pounds, which is equal to 160,000 pounds per square inch of solid section. As the cables were to be suspended in a salt atmosphere, galvanizing was deemed the only sure safeguard against corrosion, and this was done at a temperature that did not affect the temper of the wire. Every known prevention was taken to have the wires conform to the standard as set forth in the specifications, and every lot was critically examined by inspectors appointed by the bridge, and pieces cut from the delivered rolls were being constantly tested by engineers. The cable making machinery was located on the Brooklyn anchorage. Each traveler ran around a driving wheel 11 feet in diameter on an upright wrought-iron shaft, and by three guiding wheels. On the New York anchorage the traveler ran around two 4 foot wheels placed on a sliding frame, so that the slack in the rope could be taken up. These wheels were made of oak.

Placed in the wire shed on the Brooklyn anchorage were 32 drums having a diameter of 8 feet, face of 16 inches, and a depth of rim of 6 inches. These were to act as reels for the cable wire, and their working capacity was about 50,000 lineal feet. The first operation in actual cable making was that of adjusting four wires to be used as guides in obtaining the exact deflection of the balance. This was done by selecting four wires of uniform size and weight, and by adjusting them by referring to a tangent line for the land spans whose position had been calculated, and to a level line tangent to the lowest point of the curve for the center span. Allowances were made for the temperature prevailing at the time. A wire was fastened to the shoes in the anchorage, and then passed around a sheave which was attached to one rope of the traveler by iron arms from its axle.

The sheave carrying the bight then started on its journey to the other side, the speed of the traveler averaging 5½ feet per second, and as the wire ran out at twice the rate, 11 feet of wire were placed per second. On reaching the New York side the bight was passed around the shoe, when the sheave returned empty. The adjusting of the wire was commenced at the Brooklyn side. A tackle was attached to the wire as it passed over the Brooklyn tower, and it was hauled until the men stationed in the cradles previously mentioned signaled that it was up to the proper elevation, when it was held in that position on the tower. A tackle was then fastened to that part passing over the New York tower, and the river span was raised until pronounced all right. A similar operation was repeated between the tower and anchorage on the New York side, and the slack was taken around the shoe. The whole programme was again gone through with with the other wire, but in a contrary direction.

A strand consisted of 278 wires, and the first or lower one was finished and attached to the bars July 14, 1877. To keep the strands apart and prevent chafing, they were seized throughout their length at every 2⅛ feet and wrapped by about 5 turns of No. 14 annealed wire. Experience on the first strands showed that no difficulty would be experienced in obtaining a larger wire, and therefore it was increased to No. 7 instead of No. 8. This gave 11 feet to the pound instead of 14. After 12 strands had been finished, the central 7 (which formed the core of the cable) were brought together and bound at intervals. The last wire in the cables was run over October 5, 1878, and the 19 strands of the four cables were in place.

At a distance of 21½ feet from the anchor bars heavy clamps were put on the cables to draw them to a cylindrical form. This was made necessary, as the anchor bars spread so as to cover a space 5 feet square. The final work of wrapping the cables was now begun. The wrapping wire was No. 10, charcoal iron wire, drawn hard and galvanized. The wrapping wire was put on with a machine, and was very tightly drawn. The binding wires on the core were cut and clamps screwed on the cable in advance of the wrapping. As the work progressed, the whole was saturated with linseed oil.

As the bundles of cable wire came in comparatively short lengths, joining was frequently necessary. The coupling was made of Bessemer steel wire 0·281 of an inch in diameter and 1⅛ inch long. This was drilled, and a right and left screw cut in each end respectively. Reverse threads being cut upon the ends of the wire, the coupling was screwed up. After having been galvanized, the joint was equal in strength to the wire. The cables are 15¾ inches in diameter, and each one contains 3,515 miles of wire, wrapped by 243 miles of wire.

Passing over the towers alongside of the cables are a number of stays of steel wire rope. These stays are attached to the trusses carrying the floor system, and reach to a distance of about 400 feet from the towers, and at intervals of 15 feet. They are designed to sustain a portion of the load and to prevent vertical vibrations.

As the cables pass over the towers they rest in saddles, the object of which is to furnish a bearing with easy vertical curves. In plan they are rectangular, 13 feet long by 4$\frac{1}{12}$ feet wide, and have an extreme height of 4¼ feet, and a thickness of 4 inches. One cable passes over the center of each through a groove 19½ wide and 17¼ inches deep at the center. There are two smaller grooves on each side of the large one, in which four of the long stays are situated. Wherever there is a possibility of chafing the wire, the ends and edges are rounded.

To reduce the weight and secure uniformity in thickness, 17 openings were made beneath the grooves. Longitudinal edges are extended 1 inch below the under surface of the saddle to make bearings for iron rollers to be described shortly. The inner faces of these edges are true, and the under surface is planed so as to bear a straight edge in any direction.

The saddle-plates rest in seats prepared in the masonry and form absolutely true beds, on which the rollers travel. They are 16⅛ feet long and 14¾ inches high, the outside ones 8 feet wide at the center and 6¼ feet at the ends; the inner ones being 6½ feet wide at the center. The central portion is 4½ inches thick, and the sides 3¼ inches. The central channel is planed perfectly true, and the edges that form bearings for the rollers are also planed true.

Each saddle weighs about 25,000 pounds, and each saddle-plate about 11,000 pounds.

Between the saddle and saddle-plate are steel rollers, along which the saddle is free to move. By this means the cables are free to move backward and forward, and not only to accommodate themselves to any unequal loading that might occur during construction, but also to adapt themselves to changes caused by alterations of temperature and load after completion. All liability to wear while moving was thus obviated.

The floor system of the bridge consists of six longitudinal trusses, connected by floor-beams, the whole suspended from the cables by suspender ropes. Between the towers and on each side of them, with the exception of a short distance from each anchorage, the floors are below the cables. The suspender ropes are made of twisted steel galvanized wire, and are from 1⅝ to 1¾ inches in diameter. They are capable of sustaining about five times the load they will ever be called upon to bear, or about 50 tons. They are attached to the cables by wrought iron straps, ⅝ of an inch thick and 5 inches wide. The straps were placed on the cables when they were wound. The backs were heated in forges until they could be opened so as to admit the cable, when the two ends were drawn together, a thin plate of iron having been previously inserted between the cable and hot iron to prevent burning. The under side of the strap terminates in two lugs, ⅞ of an inch thick, through which passes an iron screw-bolt 1¾ inches in diameter, holding the wrought-iron closed socket on the upper end of the suspender rope. On the lower end of the rope is fastened a cast-iron socket having a hole in each end through which pass two stirrup-rods to hold the floor beam. These rods have long screw threads by which the beam can be raised or lowered.

As the floor system of the bridge is in a continuous line with the surfaces of the anchorages, and the cables leave the anchorages a few feet below, the floors rest on the cables until the latter rise above the grade. The beams are laid on posts varying in height to suit the distances, and braced by plate brackets. The lower end of the post is bolted to the upper half of a strap encircling the cable. The total number of suspender ropes is 1,520, and the number of posts, 280.

The floor-beams were made in half lengths, and when riveted at the center made a continuous beam the width of the bridge, 86 feet from end to end. They are 32 inches deep, 9⅜ inches wide, and weigh 4 tons. Each one has two top and two bottom chords braced together, so as to form a triangular lattice girder. The chords are of steel channel bars. They are suspended 7½ feet between centers and an I beam placed between each pair, resting on truss chords, so that the planking will be supported at every 3¾ feet. The floor-beams were hoisted to the floor of the arches in the towers and then attached by ropes to their respective suspender ropes, when they were swung off, raised to the proper height, and the stirrup bolts inserted. Those immediately adjacent to the towers were placed first, and a track laid as fast as the work progressed, upon which the more remote ones were run out. The number of double floor-beams is 450.

The six longitudinal trusses which divide the bridge into five passage ways have the following heights, measured from the top of the floor-beams: The two outside ones, 7⅛ feet, the four intervening ones, 15 feet 7½ inches between the floor and bottom of the top braces. Across the central opening is a system of light beams supporting the foot way; this foot way is 12 feet above the floor-beams. The outside divisions are 18¾ feet wide in the clear, covered with plank flooring, and designed for vehicles. The next two are 12⅝ feet wide, and will be used by passenger cars. The central opening—the foot path—is 15 feet 7 inches wide, and the elevation of the walk permits an unobstructed view of the surrounding country. As the foot passenger approaches the tower he ascends five or six steps, and to avoid the central shaft passes through the arches on a flooring laid on the beams over the car tracks. The cars and vehicle ways go through the arches side by side.

To prevent horizontal vibrations and resist the force of the wind, there are wind braces placed beneath the floor-beams. These braces are large wire ropes, and are anchored at the four facing corners of the towers to eye-bolts set in the masonry. From the corners to which they are attached they passed diagonally across the floor-beams to the opposite side of the bridge, where they are secured. The longest ones reach about one-third way across. Similar braces are placed on the land spans. As a further precaution, and particularly to secure stability in the center of the span, where the braces are of little effect, the outside cables are drawn in a short distance toward the center.

To allow for expansion and contraction of the long trusses, expansion joints are inserted between the towers and anchorage and in the main span.

The total weight of the suspended superstructure, including cables, trusses, suspenders, braces, timber flooring, steel rails, etc., is 14,680 tons; and the transitory load is estimated at 3,100 tons, making the total weight of the bridge 17,780 tons.

We have now finished the bridge from anchorage to anchorage, and shall devote the remainder of our space to considering the approaches, stations, cars, moving cars, and financial statements.

The approach on the Brooklyn side is 900 feet long on the center line, and commences at street grade at Sands Street, rising 2·85 feet per 100 to the rear of the anchorage, where it is 60 feet above ground. It is crossed by several streets, and has one curve at about 200 feet from Sands Street. It is 100 feet wide throughout. All the streets are crossed by box or plate girders. The New York approach is 1,546 feet long, commencing at grade at Chatham Street, and rising 3·25 feet per 100 to the rear of the anchorage, where it is 68 feet above ground. It is 100 feet wide for about 500 feet of the distance, and 85 feet for the remainder. At Franklin Square is an opening measuring 210 feet on one side and 170 on the other, which is spanned by a truss bridge. The other streets are crossed by semicircular stone arches. The approaches are a series of arches resting on heavy piers with fronts entirely of granite. The cornice over the arches has a dentil course below, surmounted by a heavy projecting coping course. The cornice is surmounted by an ornamental granite parapet, 4 feet high. The arches in the approaches will be fitted up for warehouses, and in order to sustain great weight the floor beams will be of steel and wrought iron.

Both the station buildings are constructed of iron. The viaduct to accommodate passengers at the Brooklyn end is about 600 feet long. Beginning at Sands Street it is 56 feet wide (the two passage ways for vehicles are at either side of the building) for 205 feet, of which 185 feet is roofed and inclosed on the sides. This forms a building, the ground floor of which is used by foot passengers, with the exception of a waiting room, 60 by 18 feet, on the left as we enter. The next floor is at a height of about 20 feet above Sands Street, and contains three lines of rails in the central space and two capacious passenger platforms, one at each side, and raised 2¼ feet above the rails. These platforms extend to some distance beyond the end of the building. The sides of the building from the main floor to the eaves of the roof are of ornamental cast-iron work and glass. The lantern framing is over the center of nearly the whole length of the building, and is 14 feet wide by 3 feet high. The car passengers enter the waiting room below, pass up wide stairs to the platform, and enter cars on the right track. Incoming passengers get off on the other side.

The New York station is 260 feet long by 52⅛ feet wide; the height to peak of small roof at rear end is 52½ feet, at front end 61 feet. The general arrangement is very similar to that of the other station.

The twenty-four cars are like those now in use on the elevated roads of this city. They are 44 feet between couplings, 9½ feet wide from out to out, and will comfortably seat 48 passengers. In the middle of the car the seats are placed crosswise, leaving an aisle between; near the doorways they are placed along the sides.

The cars are moved by being attached to an endless rope operated by powerful engines situated beneath the Brooklyn approach. This steel wire rope, 1½ inches in diameter, passes over the bridge in the middle of the right railway track, and returns along the other. It is supported throughout its length on 490 pulleys, placed 22½ feet apart. Motion is communicated to the rope by winding it three times around a pair of grooved driving drums, placed facing each other. These drums are made of cast iron, 12 feet in diameter, and have faces 27½ inches and 26 inches across respectively.

The drums are revolved by means of a friction drum placed between them, and being 5 feet in diameter and 31½ inches across the face. This drum is mounted upon a shaft of hammered wrought iron 12 inches in diameter, and at each end of the shaft is a crank to which the engines are attached. By means of a clutch at each end of the shaft the engines can be worked alone or together. The engines have a variable cut-off, 48 inches stroke, 26 inches diameter of cylinders, and will work safely with 100 pounds of steam. The boiler house contains 4 boilers, and is placed in a separate building located to the right of the approach. From the driving drums the rope passes upward and over a grooved sheave 10 feet in diameter, and a loop is then passed around another sheave of the same size, mounted on a heavily loaded car moving on a steeply inclined plane, thus serving as a balance weight to draw the rope tightly. The returning part of the rope goes under a third sheave, then up over a summit sheave placed between the rails, and then out on the pulleys. The switching of the cars on this side is done by dummy engines.

Just before the New York station proper is reached, the rope is passed down over a summit sheave around return sheaves to the other track, up over another summit sheave and back to the Brooklyn side. Before leaving the New York side the rope passes over and then under two sheaves placed near together, thereby giving them motions in contrary directions. On the shafts of these sheaves are small grooved friction drums, which can be pressed by a lever against either sheave according to the direction of the revolution desired. Wound about these two drums is an auxiliary rope leading into the station. After the car has discharged its passengers, it is attached to this auxiliary rope, which takes it to the upper end of the station. The grade of the road is such that upon being released the car descends by gravity to its station at the other platform, where it meets the endless rope over the bridge.

The engineers are not prepared to make public the plan of the clutching device by which the cars will be attached to the rope. From end to end the bridge is lighted by arc electric lights, the dynamos and engines being under the Brooklyn approach.

On the 31st of last March the financial condition of the bridge was, briefly stated, as follows:

Cash received from New York	$4,871,900 00
" " " Brooklyn.	9,423,692 73
" " " rests interest, sale of material, etc.	391,463 93
Total.	$14,687,057 66
There is still due from the city of New York	216,666 66
And from Brooklyn	433,333 34
Total cost of Bridge	$15,337,057 66

Some of the principal items of cost up to March 1, were:

Engineering, salaries, etc.	$498,963 68
Office expenses	167,446 41
Timber and lumber.	469,031 23
Construction	3,126,969 46
Labor	2,416,151 38
Machinery and Tools	161,015 56
Land, damages, and buildings	3,780.988 94
Limestone	668,041 37
Cast steel cable wire	623.733 16
Granite	2,129,004 93

The names of the engineers who planned and so successfully executed this work are:

John A. Roebling.
William A. Roebling.

C. C. Martin.	W. H. Paine.
F. Collingwood.	G. W. McNulty.
S. R. Probasco.	W. Hildenbrand.

E. F. Farrington.

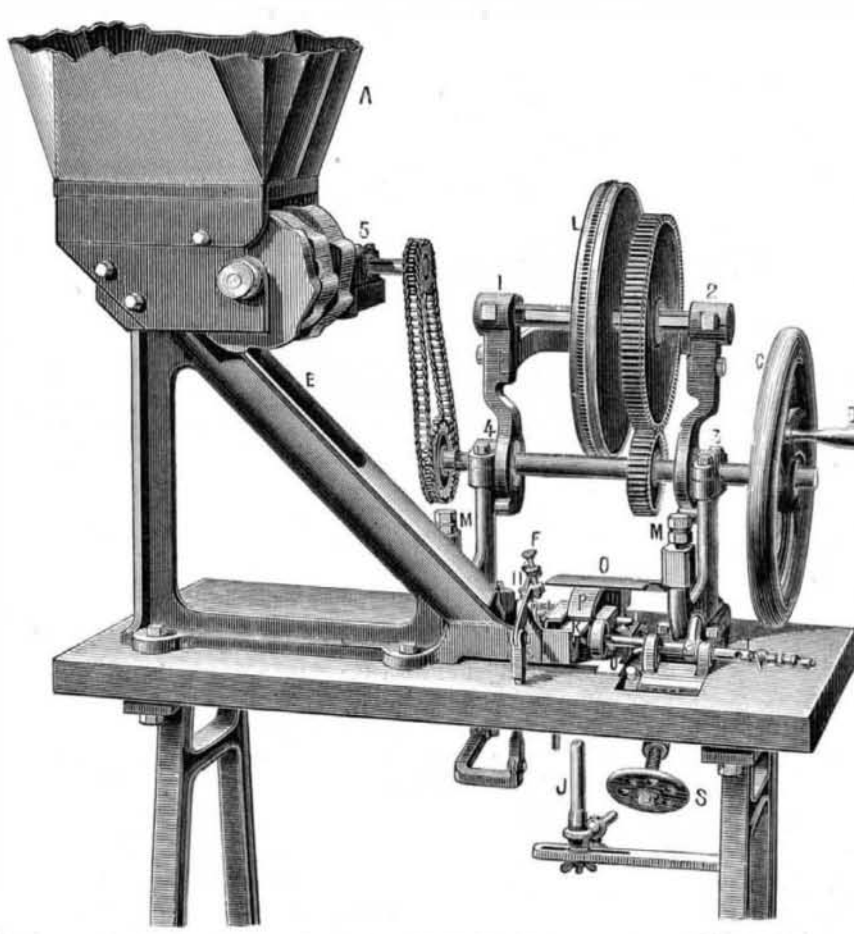

Fig. 1.—MACHINE FOR BRANDING CORKS AND STOPPERS.

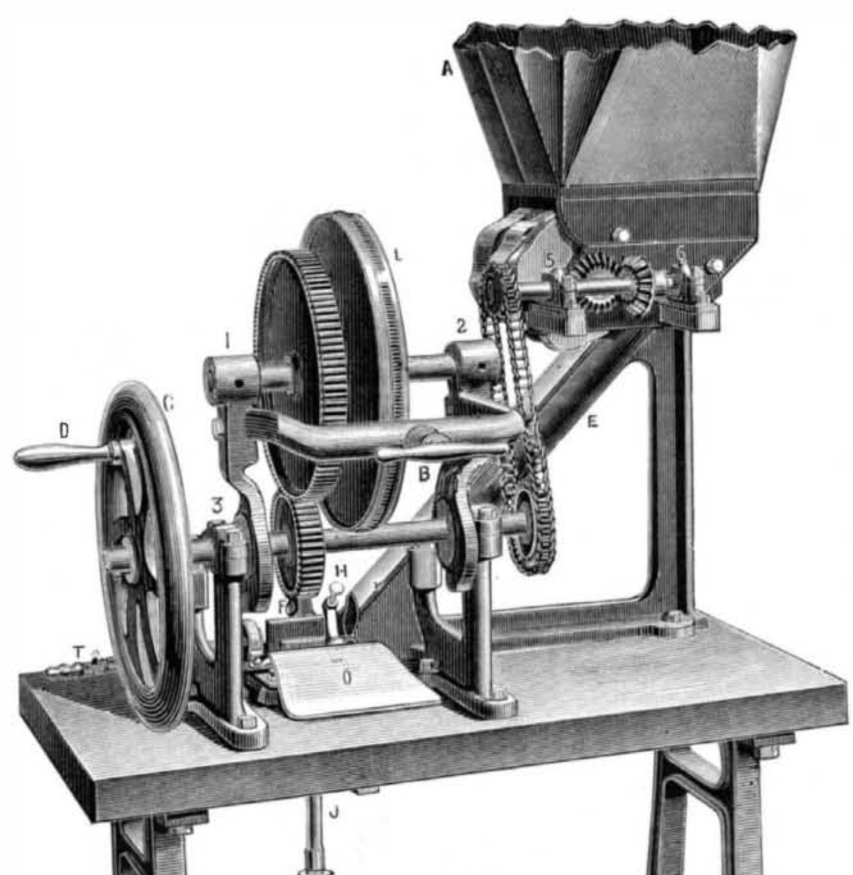

Fig. 2.—MACHINE FOR BRANDING CORKS AND STOPPERS.

MACHINE FOR BRANDING CORKS AND STOPPERS.

A number of machines for marking corks with hot irons have already been invented, but as a rule these machines have been designed to mark the cork only on its circumference. The machine which we describe below was invented by M. Chenet, and constructed by M. Leclère, of Paris, France. It differs from the machines which have been in use heretofore in that by one process it marks both the circumference and one of the ends of the cork. The machine Chenet is represented in elevation in the engravings given.

The corks are thrown loosely in the receiver, A, at the bottom of which is arranged an inclined duct, through which the corks are pushed one by one under the action of a wheel provided for the purpose, and constructed with two rows of bent teeth similar to those on a ratchet wheel. This wheel is connected with the crank, C, from which it receives its power by a sprocket wheel connected by an endless chain and by two miter wheels.

Each cork as it leaves the duct is guided by a screw and placed in a horizontal position by means of a suitable stop, against which it is brought in contact. At this instant the stop falls and the cork receives at its end the imprint of the brand, U, being held during this operation by the vise, F, which is attached to a lever that falls on the cork the same instant that the stop is withdrawn.

When this is accomplished the mark is pushed back by a spring, and the stop, as well as the lever, resume their original position. The cork thus branded on one end is now seized by the wheel with the serrated or grooved felly, L, which is represented in the drawings as raised and out of the way. The shaft, 1 2, which carries this wheel, being mounted upon the two levers, 1 4, 2 3, and united by the stirrup, B, may be given any position required by revolving it around the axis of the crank wheel, C. This arrangement is made with a view of rendering the wheel movable vertically when placed upon the cork, so that it may receive under the felly corks of a different size. The wheel, L, rests, as we have said, upon the cork already marked upon one end, and being put in motion by the crank wheel, moves the cork forward and rolls it to the point of discharge from the machine. Furthermore, the cork in being rolled along, passes over a key, which is not shown in the drawing, and which actuates on the one hand the screw, H, and on the other a marker. The cork then passes over a second brand, K, which acts upon the circumference of the cork; and finally it passes over a key which terminates in an inclined plane, after which the cork falls into a basket and the operation is completed. The same machine, with a few modifications in the details, could be used to mark corks upon both ends.

Rendering Cement Airproof.

A method of rendering cement impervious to air has been successfully practiced by Herr C. Pascher. This experimentalist claims to have found that the only way to render cement unalterable by atmospheric influences is by the application of a cold solution of 1 part of sulphate of iron in 3 parts of water. The articles to be protected should be left to soak in the solution for twenty-four hours, when they take a greenish black tint from the hydrated protoxide of iron. The absorbed solution is decomposed in the interior of the cement, which is increased in weight 10 per cent. All the pores of the mass are thus stopped by the hydrate; and as this compound is not attacked by air, the cement itself becomes impervious. Cement facings may be washed down with several coats of the solution. When dry, the cement may be covered with a wash of ocher, or by a solution of sulphate of alumina. If a greenish white face is desired, the surface may be first washed with a solution of chrome alum, and then with soapsuds. Either of these coats may be painted or colored in distemper. It has been observed that when oil colors are laid upon bare cement they easily peel or scale off; but this inconvenience may be avoided by washing the cement thoroughly with soapsuds, and when perfectly dry rubbing with a brush or linen cloth until the surface shines. Afterward the oil colors may be applied in the usual way.

A brass cannon, 6 feet long, has been found by an agriculturist, while plowing, at Coorum, near Soopa, in the Bhimthudy talooka. This cannon, it is said, was manufactured by Michael Burgerhays, and is dated 1640.