THE BROOKLYN BRIDGE  
Harper's Monthly, 1883

PEOPLE who seventeen years ago divided an amphibious existence between New York and Brooklyn will long remember their arctic voyages in the East River during the severe winter of 1866-7. There were days in that season when passengers from New York to Albany arrived earlier than those who set out the same morning from their breakfast tables in Brooklyn for their desks in New York. The newspapers were filled for weeks with reports of the ice gorges, and with vehement demand for and discussion of the bridge, which all agreed must be built at once from New York to Brooklyn.

Public feeling was soon highly gratified by the announcement that leading citizens of Brooklyn were moving in the matter, and that a bill for chartering the New York Bridge Company had been introduced into the Legislature then in session at Albany. The popular excitement gave but a timely lift to a movement already ripe, and to a charter already placed before members of the Legislature and government of the State, months in advance of the session, while the waters of the East River were sparkling in the warm sunshine as if ice gorges were never to be known. As early as 1865 Mr. William C. Kingsley, of Brooklyn, of whom the public has since heard much in connection with this enterprise, had employed an eminent engineer to draw a plan and make estimates for a suspension bridge very nearly in the location ultimately fixed for the present work.

The charter originally and provisionally fixed the capital at $5,000,000 (with power of increase), and gave the cities of New York and Brooklyn authority to subscribe to the capital stock of the company such amount as their Common Councils respectively should determine. This latter was in effect a sort of "caution money," or a guarantee of the sound interest which those who were to govern the work ought to take in it, for it was wisely judged that neither private capital nor municipal management could be relied on to carry such a work successfully to completion. Public credit must be joined with private enterprise, in the hands of men who had too much at stake in the work to permit it to be perverted to political purposes.

But by the time the foundations of the towers—the chief difficulty to be overcome—had been successfully completed, popular jealousy of a company enjoying the control of so much public expenditure began to make itself felt in various ways, and to serve as the instrument of various personal and political rivalries and enmities. At the same time, the work was so well advanced, and its plans and methods so firmly fixed by what had already been done, that its friends now felt prepared to resign the great enterprise entirely to the two cities (acting through a commission or board of trustees, appointed half by the Mayor and Comptroller of each city, and including those officials), and prepared a bill to that effect, which was approved by the Legislature and accepted by the city governments. Under the charter thus amended, the bridge is public property, 662/3 per cent. to be paid for and owned by the city of Brooklyn and 331/3 per cent. by the city of New York, the actual payments by the private stockholders having been reimbursed and their title extinguished. The engineers, etc., as well as the principal working members of the directory, retained their places as from the first, so that the work is, after all, a unit from beginning to end.

On the organization of the company, in May, 1867, one month after the passage of the incorporating act, John A. Roebling was appointed engineer (May 23,1867), and he made his report of surveys, plans, and estimates on the 1st of the following September. In March, 1869, a board of consulting engineers was convened at the request of Mr. Roebling to examine his plans, and also to report upon the feasibility of the work. In the following May a commission of three United States engineers was appointed by the War Department to report upon the general feasibility of the project, and particularly as to whether or not the bridge would be an obstruction to navigation. The plans of Mr. Roebling were fully endorsed by both boards of engineers, the government commission recommending however, an increase of five feet in height. The work of preparing the site of the foundation of the Brooklyn tower was commenced January 3,1870, but Mr. Roebling did not live to see the first stone laid in the magnificent structure that was to crown his illustrious career. In the summer of 1869, while engaged in fixing the location of the Brooklyn tower, a ferry-boat entering the slip thrust the timbers on which be stood in such a manner as to catch and crush his foot. The injury resulted in lock-jaw, from which be died sixteen days after.

A fit successor was found in his son, Washington A. Roebling, who had not only been the accomplished associate of his father in some of his principal works, but had aided him most efficiently in the preparation of the designs and plans of the bridge. We say a fit successor was found, for at this time, when the grandest monument of engineering skill the world has ever seen is practically completed, certainly no other testimony is needed as to the great engineering ability and preeminent fitness of the younger Roebling to direct such a great undertaking. During the fire in the Brooklyn caisson in December, 1871, Mr. Roebling became himself a victim to the "caisson disease," but even from his sick-room his oversight of the work has not flagged.

Before the actual work of construction had commenced, however, it became apparent that in order to more perfectly adapt the structure to its intended uses, and to make ample provision for the rapidly increasing volume of inter-urban commerce consequent upon the development and growth of the cities, considerable modification must be made in the original design. The changes were, of course, in the direction of not only a larger and more capacious structure, but also of increased solidity and strength throughout. Such changes involved a very considerable addition to the cost. Mr. John A. Roebling originally estimated the cost of the bridge at $7,000,000, exclusive of the land required, which has cost about $3,800,000, and the time of building at about five years. The actual cost of the bridge, when completed, will be about $15,500,000, which, as compared with the original estimate of $10,800,000, shows an increase in cost of nearly $5,000,000. The items of additional cost are as follows: First, the United States government required an increase of five feet in height, making the clearance under the centre of the bridge 135 feet. At the same time it was decided to widen the bridge from 80 to 85 feet. These changes involved an increase of 8 per cent. in the cost of the entire bridge, including superstructure, towers, foundations, and anchorages. Second, the amount set apart for building the foundations of the towers in the original estimate was found to be entirely inadequate. For the New York tower a pile foundation was originally intended, whereas it was found necessary to go down 78 feet to the bedrock, and the cost of labor in compressed air at such unprecedented depths proved to be four and a half times as much as was anticipated, as was also that of excavating the hard conglomerate under the Brooklyn tower. Third, steel was substituted for iron as the material to be used in the construction of both the [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) and the suspended superstructure, thereby vastly increasing the strength of all the parts. The items thus far enumerated foot up nearly two millions, which covers the excess in cost on the bridge proper. In his original plan and estimate, Mr. John A. Roebling contemplated approaches constructed of light iron girders, or trestle-work, supported by pillars of brick or stone, but it was concluded to build entirely of granite and brick—a change that has resulted in one of the finest masonry viaducts in the world. This involved an increased expenditure of about one and a half millions. The archways have been constructed with a view to their utilization as warehouses, and $400,000 has been set apart by the trustees for the placing of fronts and floors in them. As Mr. Roebling in his original report says, the cost of these [IMPROVEMENTS[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) should not be charged in that of the bridge, and it was accordingly omitted by him. Then there are the station buildings and the elevated railway structures that are now building on the approaches, making a connection of the system of rapid transit of New York with that of Brooklyn when it shall have been built. Of course this was not originally contemplated, and it has swelled the cost of the bridge by nearly half a million. Finally, there is a comprehensive item which could not have been anticipated, but which would be underestimated at half a million, namely, the preliminary expenditures, general superintendence, interest and discount on city bonds, and expenses legal, medical, funereal, and prandial. These additions to the cost, however, would never have swelled to so large an amount if it had not been for the needless and costly delays caused by the failure of the city of New York to promptly provide its proportion of the necessary funds. That this has caused an enormous increase in the cost of the bridge is well known, but it would be difficult to name an amount. The land expenses will be largely redeemed by the rentals the cities will receive from the warehouses under the approaches.

The principal ferry to Brooklyn takes a diagonal course up stream to a point determined by the abrupt falling off of the heights near Fulton Street. The bridge takes its Brooklyn departure in obedience to the same topographical consideration. [ITS COURSE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) is a straight line drawn from near the junction of Fulton and Main streets, Brooklyn, to the terminus fixed upon in New York, on Chatham Street, opposite the City Hall. This line and terminus were fixed upon as the result of Mr. Roebling's exhaustive examination and discussion of the question in his first report, of September 1, 1867, and no reason has been found to modify or to question the wisdom of his conclusions.

This line strikes the river at its eastern or Brooklyn shore close alongside of the north slip of Fulton Ferry. [ITS COURSE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) across the river is not exactly at right angles to the shore, but makes a little down stream, striking the New York side at the foot of Roosevelt Street—four blocks further up stream, however, than the still more oblique ferry route. Here, then, are four points defined in a straight line: the two ends, and the two points at the water line, 1595½ feet apart, to be connected by the bridge proper with a single span. Three points in the air line of the bridge are also determined: the central altitude of 135 feet above mean high water required by the United States government, and the two terminal elevations, in New York and Brooklyn respectively, of 38.27 and 61.32 feet above high-water mark. The rise from these two to the central altitude gives the line of the bridge a gentle upward curve from either end to the centre, where it will be fifteen feet higher than at the towers, and forty-six feet higher than at the anchorages.

The adoption of a suspended span of 1595½ feet, at a height of 135 feet, also determined (in combination with other mathematical and mechanical considerations) the height of the towers (2762/3 feet) from which the span must be suspended, and two other points in the air line of the bridge, at which the ends of the suspension [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) are secured—in other words, the anchorages—for the [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) are not to pull on the tops of the tall towers, but to rest on them with nearly a simple vertical pressure, being not even fastened; and thus, so far from tending to pull the towers over, the suspended weight tends only to hold them in position. The cables are therefore anchored inland, at a distance of 930 feet back from the towers on each side.

The anchorages are solid cubical structures of stone masonry, measuring 119 by 132 feet at the base, and rising some 90 feet above high-water mark. Their weight is about 60,000 tons each, which is utilized to resist the pull of the [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html). The mode of anchoring the [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) will be described in its proper place. Suffice it for the present to conceive them thus anchored by their extremities on each side the river 930 feet back from the towers, and at the water-line on each side lifted up with a long, lofty, and graceful sweep over the top of a tower 276 feet high, and drooping between the two towers in a majestic curve which one can liken to nothing else for grandeur but the inverted arch of the rainbow.

Rising from the towers at an elevation of 118 feet above high-water mark in gentle but graceful curve to the centre of the river span, where it meets the [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) at an elevation of 135 feet above high-water mark, is the bridge floor, an immense steel framework bewildering in its complexity. The framework consists essentially of two systems of girders at right angles to each other. The principal crossbeams or girders supporting the floor proper are light trusses thirty-three inches deep, placed seven feet six inches apart, and to these are attached the four steel rope suspenders from the cables. Halfway between these principal floor beams are lighter ones, to give additional support to the planking. To unite these cross-beams together, and to give the proper amount of stiffness and strength to the floor, there are six parallel trusses extending along the entire length of the bridge. The floor beams are further united together by small longitudinal trusses extending from one to the other, which, together with a complete system of diagonal braces or stays, form a longitudinal truss of eighty-six feet in breadth. It will be seen, thus, that this combination has immense strength, weight, and stiffness, laterally, vertically, and in every direction. To relieve the cables in a great measure of this enormous burden, and at the same time effectually prevent any vertical oscillations in the bridge floor, there is a multitude of suspensory stays of steel [WIRE ROPES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) diverging from the tops of the towers to points about fifteen feet apart along the bottom of four of the vertical trusses. These stays extend out for a distance of 400 feet from the towers, and are of themselves capable of sustaining unaided that portion of the great frame and its load in position. At the towers the framework is firmly anchored down, and again confined against the lifting or pushing force of the wind by a system of under-stays lying in the plane of the floor, so that no conceivable cause can ever disturb its rigid fixity of position and form. At and near the centre of the span, however, where these stays do not act so efficiently against any tendency to distortion, and to still further unite and stiffen the whole system, the two outside cables are drawn inward toward each other at the bottom of their curves. By this means each of them presents its weight in the form of an arch against, an oblique pressure from below and the opposite side, and resists more or less in the same way any force from the like directions. The two inner cables at the same time are drawn apart at the bottom of their curves, thus approaching each its outside neighbor, and pairing with it, so as to combine their opposing arches against lateral forces from either direction. The weight of the whole suspended structure (central span), cables and all, is 6740 tons, and the maximum weight with which the bridge can be crowded by freely moving passengers, vehicles, and cars is estimated at 1380 tons, making a total weight borne by the cables and stays of 8120 tons, in the proportion of 6920 tons by the cables and 1190 tons by the stays. The stress (or lengthwise pull) in the cables due to the load becomes about 11,700 tons, and their ultimate strength is 49,200 tons.

The great frame, as above described, presents on its upper side five parallel avenues of an average breadth of sixteen feet, separated by the six vertical lines of trussing, which project upward like so many steel fences. The outside avenues, devoted to vehicles, are each nearly nineteen feet wide. The central avenue has a width of fifteen and a half feet, and is elevated twelve feet above all the others, for a footway, thus giving to the pedestrians crossing the bridge an unobstructed view of the river. The vertical trussing forms outside parapets eight feet high above the common bridge floor, for the security of vehicles, etc., while the inner lines of the same will form inner parapets to the cars and footways, supplemented by wire netting which will break the force of the wind. The intermediate avenues, one on each side of the footway, will be occupied by cars, constantly and rapidly moving back and forth from terminus to terminus by means of a stationary engine and endless [WIRE ROPE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html).

The great steel cables, fifteen and three-quarter inches in diameter, are not, however, limited to supporting the main span, but are prolonged over the tops of the towers, and descend thence to the anchorages on the shores, at distances, as before stated, of 930 feet. The portions of the cables suspended from the towers to the anchorages support the shore spans of the bridge, which are constructed precisely like the central span already described. The anchorages are therefore the next feature of the work to be noticed. They are structures at once exceedingly simple and satisfactory to the mind. There is little more to imagine than a great four-square mass of masonry, with a pair of broad arched passages through it, partly to exclude superfluous cost, and partly to afford convenient avenues for locomotion. The dimensions of this mass are 90 by 119 by 132 feet, and its weight, which is its chief importance, the inconceivable amount of 120 million pounds. At the bottom of the structure, and near its rear side from the bridge, are imbedded four massive anchor plates of cast iron, one for each of the cables. These plates measure 16½ by 17½ feet on the face, and are 21 feet thick at the centre. The weight of each plate is over 46,000 pounds. And yet it is far from being a solid mass, which would waste perhaps half its material in perfectly ineffective positions. On the contrary, it is formed like a star, with many rays stretching from a massive centre, and tapering to their extremities, where greatly reduced strength and narrowed bearings are quite sufficient for the simple purpose of uniting the resistance of the superincumbent masonry upon the point of pull at the centre. This point is made by two rows of nine parallel oblong apertures through the two and a half feet of solid iron, and through these apertures pass eighteen forged bars of iron, with an eye at each end. Through each of the nine eyes matched in position as one, below the under side of the anchor plate, passes a round iron bolt or key, which is drawn up against the plate, fitting in a semi-cylindrical groove, and thus the first link in the anchor chain is constructed and made fast. The link bars average twelve and a half feet long; and in the first three links, where the pull from the cables is least felt, they are seven inches wide and three inches thick, being swelled at the ends sufficiently to preserve their full strength with eye-holes five to six inches in diameter. The bars of the fourth, fifth, and sixth links are increased in size to eight by three inches, and after these the size is nine by three, with the exception of the last link, in which the number of bars is doubled, and the thickness halved. The pins or bolts connecting link to link are turned shafts of wrought iron five feet long and five to seven inches in diameter.

The four great anchor plates being set in position at the bottom of the masonry, each with the first double ninefold link of its anchor chain made fast through its centre, and standing erect above it, the masonry is next built over the anchor plates, and close around the chain bars, to the height of the latter, and extended over the whole area of the structure to the same height. Then the second link or set of chain bars is set, the eyes of the new nine fitting between those of the former nine, and the heavy bolt passing through all the eighteen eyes at once, and uniting each of the two ninefold links with a joint like that of a hinge. Each new link after the first two is now made to incline forward to the bridge a little more than its predecessor, forming a regular curve, so adjusted as to bring the chain out near the opposite (upper) corner of the structure to that from which it started. Here the cables enter the face of the anchor wall for about twenty-five feet, and meet the ends of the chains. The bars of the last link number thirty-eight, arranged in four tiers. There are nineteen strands in each cable, and the end of each strand is here separately bent and fastened in a loop around an eye-piece of cast iron, called a "shoe," having a groove in its periphery to fit the strand. The ends of the strands are thus "eyed" like the link bars, and fraternize with the last set of the latter, fitting between them eye to eye, and keyed together with them by the eyebolt. The ends of the great cables are now anchored fast with what seems to the imagination an enormous superfluity of weight and strength. It seems as if the cables would be torn apart ten times over by a force that was sufficient to pluck out their monstrous spread of iron roots from the foundations of that solid cemented mass of rock. Undoubtedly this is true; but the intention of the engineer is not merely to equal the strength of the cables with that of their anchorage, but also to give the anchorage a solidity to be absolutely unaffected in the slightest degree by the incessant pull of loads and tug of storms for a hundred years, so that no loosening or vibration can ever be initiated.

To make assurance fourfold sure, the metal for this, as for every part of the work, has been tested by means of specimen pieces under the enormous power of the hydraulic press to its breaking point, a wide margin being always required above the highest possible strain that it is estimated can ever come upon it.

All this is plain work. The anchorages are far within-land. But the great suspension towers to be connected by the central span of the bridge must be pushed out to the extreme wharf line in deep water, for even then the breadth of water to be bridged at one spring is such as no engineer ever attempted before—nearly 1600 feet—and not only the difficulty but the cost of the work is increased in an enormous ratio by every foot of added length in a single span. We have therefore before us here one of the most interesting problems and one of the most brilliant triumphs of engineering: to build great works of masonry up from beneath the bed and through the rushing tides of a deep arm of the ocean, with all the precision and cemented solidity of the dryland anchorages we have just been viewing. This part of the work, therefore, was first in order: this achieved left nothing problematical, whether as to availability or cost, in the remainder of the work.

Probably to the end of time thoughtful spectators unversed in the mysteries of engineering will pause, as they now do, before these gigantic towers, more wonderful than the Pyramids, with the everlasting sea beating their mighty bases, and will perplex themselves in vain to imagine by what means the granite masonry could have been laid so solid and true beneath not forty feet depth of rushing tides alone, but eighty feet below their surface, on the rock which those tides had not touched for untold ages.

To explain this mystery in one word, the submarine portion of the tower was really built above-water, in the open air, and thence sunk toward its bed as soon as built. But this is to put a new mystery in place of the first, for how could such a mass of masonry be set firmly to a hair's breadth in its bed against the mighty current, or how could its bed be excavated to this enormous depth to receive it?

The principle of the diving-bell, supplemented by the air force-pump, or compressor, is the solution of the difficulty. Only the diving-bell must be a peculiar one, made to carry on its back the giant tower as it dives to the bottom, as it delves into the bowels of the earth, and as it reposes at length and forever on the rock. It is technically called a *caisson* (having been first used in France), from its resemblance to an inverted chest. Imagine your diving-bell, or caisson, made of an oblong form, corresponding to the shape and size of its burden, with a margin of eleven feet excess on all sides. You must, of course, also have it built with sufficient durability of material and strength of mass both to carry down the masonry entire, without flinching, and to rest under it forever without yielding or decay. It will be best to have the sides of our oblong diving-bell flare a little, and on the inner side to taper them to a sort of edge (well shod with heavy iron), so as to make room for the laborers within to excavate conveniently to the very extremity of the dimensions of their diving-bell. To obtain sufficient strength and rigidity in the structure for its tremendous back-load, let its entire top, 102 feet by 172, be built to a thickness of 22 feet of dense Southern pitch-pine in timbers twelve inches square, laid in solid courses crossing each other, fastened with powerful through-bolts, and all the joints and seams filled with pitch. (The bolts and angle-irons of this caisson at New York aggregated 250 tons.) Let the sides be eight feet thick at their junction with the top, built in the same manner, but tapered on the inside, as already suggested, down to an iron-shod edge only eight inches thick, and let the iron bolts and angle-irons, of course, be so strong and numerous that nothing can loosen timber from timber save by tearing each stick into splinters. Further, let the back or platform that is to carry down the great tower in its descent to the bed-rock be supported at intervals by six cross partitions of solid timber four feet thick, with a door in each for communication between the compartments thus formed. These partitions, like the four sides, will ultimately rest on the bedrock, and bear their part of the monstrous and everlasting load. Finally, let the whole cavernous interior be lined with [BOILER[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) iron, seamed air-tight, for its perfection as a diving-bell, and for protection against the danger of fire, which experience in building the first or Brooklyn tower of this bridge has shown to be imminent at all times while working by gaslight and with blasting explosives in compressed air.

Of course there must be means of ingress and egress for men and materials. There must be a well-hole through the top, and an iron well leading to it from the open air above-water for the men to go in and out. It must be lined with iron, continuous and air-tight with the lining of the interior, and must have an air-tight [IRON DOOR[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html), or rather two successive doors with an air-tight chamber between them large enough for a gang of men to enter, that the outer door may be closed on them while the inner door is opened to admit, them to the artificial submarine cavern. This chamber is called an air lock, and its principle is like that of a canal lock, or still more exactly that of a pump. In going out, the men enter the air lock while, its outer door is closed tight, and after the inner door through which they entered is closed behind them the outer door may be opened for their egress. Thus the loss of compressed air by the entrance and exit of a gang of men is simply what the air lock will contain and no more.  
  
This would be too tedious a process, however, for the removal of the excavated earth. For this purpose water locks are used. The iron wells for the removal of material descend through the caisson into open pits in the ground below the level at which the water is held down by the compressed air. The water of course rises in the pits and wells to that level, and thus the compressed air is "locked" out of them, while the earth and stones dumped into the pits by the miners in the caisson tumble to the bottom of the wells, where they can be got at by simply reaching under water. In each of these wells operates a Morris and Cummings dredging-machine (either of the grapnel or "clam-shell" pattern, as each was required), like those constantly seen at work at one point or another in this and most other harbors where slips and [CHANNELS[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) have to be made or deepened, or cleared of deposits, the difference being that these are of the second class in size and power, adapted to the capacity of the caisson and workmen for supplying them with materials. While the harbor machines of forty horse-power remove 2000 cubic yards of mud per day, the caisson machines of twenty-five horse-power can raise 1500 yards; and without working their full capacity, clear the pits of earth as fast as it is practicable to mine it in the caisson. The iron "clam-shell" scoop of the machine descends by its chain to the bottom of the well with its jaws open, plunging into the mud, where the jaws are drawn together by the action of the machinery through another chain. This action operates like the pull of a ship's cable on the anchor, dragging its fluke downward into the bottom. In like manner the flukes of the dredging scoop are forced down into the mud as they are drawn together, and grasp a giant handful, exactly imitating, to use Mr. Roebling's expression, the action of the human hand in picking up handfuls. The force of this grasp is illustrated by the fact that large rocks are picked up as well as earth and small stones, even when only a corner of the rock is seized between the valves of the scoop. All the rock blasted out in Hell Gate by the vast submarine excavations was picked up from the bottom and raised in this way.

While the caisson with its entrances and appurtenances approaches completion in the shipyard, arrangements must next be made for placing it in position on the bottom of the stream. First a slip or dock must be built to fix it in the exact position of the intended tower. The "water lot" marked for occupation is levelled as well as possible by dredging, and a row of piles is driven as deep as possible along the landward line, a length of 172 feet. At right angles with this a row of piles is driven out 102 feet into the river from each end, making three sides of an oblong inclosure or stockade. Into this inclosure the caisson is towed. The exact lines of the [PIER FOUNDATION[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) are mathematically fixed by the engineers, and the caisson is placed in the proper position to a hair by blocking and wedging on all three sides. It now rises and falls with the tide, however, and is therefore not yet capable of being exactly and finally placed. The next business, accordingly, is to commence the foundations of the pier on the massive platform or raft of solid timber 22 feet thick and 102 by 172 feet square, which we have figuratively called the back of the submarine monster which is to carry the whole burden down to its final bed. The huge squared blocks of granite are now laid at leisure in hydraulic cement in uniform courses, and soon their weight overcomes the buoyancy of the caisson, and settles it to the bottom, with its top still visible above-water. The compressed air is now let into the diving-bell interior, forcing the water out beneath the iron-shod edges of the sides where they rest on the bottom. This done, the workmen can go down into the very wet cellar, and complete the levelling of the earth under the supporting edges of the structure. Now, while the caisson barely touches bottom by its weight, but does not rest too heavily, the engineers can, with their mathematical instruments and wedges, finally adjust the mass in exact position, and by easing away the bottom under it wherever required, with much patience, they at length get it level, and uniformly supported by blocking placed under its cross partitions. A few more blocks of granite laid on will make it immovable. All is now ready for the dredges to begin lifting out the mud and stones which the men of pick, shovel, and wheelbarrow pour into the water locks or wells beneath the dredging shafts.

Many formidable difficulties have thus been surmounted, and the curious observer now sees how everything so far can be done by the puny hand of man when guided by his mighty mind. But with our thoughts fixed on the mountain-like mass of rock descending full built, we are staggered still by the difficulty of letting it down eighty feet into the submarine earth, with its position as plumb and level and unchangeable at every moment of descent as that of the cornerstone at rest in its bed under any great building on land. If it should sway from its position ever so little, the mathematical accuracy and beauty of the whole after-work would be marred, and what power on earth could move it back a hair's-breadth toward its place? If a side or a corner should be hindered or hastened in its descent a little more than the rest, the mass would be wrenched and disjointed by its own irresistible weight, and the disintegrating force thus initiated within the structure could never be eradicated or counteracted. But the mode of achieving this miracle of descent—not only moving mountains, but moving them to a hair, through the earth, as the piston descends in the cylinder of a steam-engine—is so commonplace and simple that it seems almost childish. No machinery of vast and imperceptibly slow leverage or screw-power, and of admirably scientific adjustment, is here called to our aid. Nothing but pine blocking under the six cross partitions of timber on which, as on so many legs or feet, the monstrous burden-carrier stands. As fast as the earth is dug away to make room for the descending-tower, the blocking is knocked away to let it down. Impossible? Let us see. Suppose a blocking at every two or four feet beneath the supporting partitions, can not we knock out alternate blockings all round? True; but how shall we knock out the rest, and what would become of the structure deprived of support now at this point and now at that, and pitching downward this way and that with rock-rending force? Not so fast. By knocking out the alternate blockings we have just doubled the weight and compression on their fellows. By such increased compression of [ITS SUPPORTS[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) the tower has settled in some measure, of course, and in the most uniform measure possible. Now we just drive in again the blockings we have removed, as tightly as possible, after levelling, away the earth under them. But it is evident that we can not drive them as tight as they were before under the actual weight of the tower. Besides, the new ground they now rest on is susceptible of fresh compression. Therefore, if we next knock out the blockings before undisturbed, the tower will settle down on the replaced blockings as far as its weight can compress them and the new ground under them. The fact proves to be that one complete process of this kind lets the tower down about one inch by the compression alternately of the two sets of blockings and the subjacent earth.

But what if our blockings should be driven tighter or prove harder, themselves or their foundations, at some points than at others: will not this produce an unequal settling, and strain the integrity of the masonry? No; for both the weight and strength of the mass are so predominant as to make nothing of such minor resistances, and the only result is that the presumptuous block is crushed. This mode of equalizing the pressure by its own irresistible weight was frequently observed. Again, if it be asked how we are to restrain so uncontrollable a mass from veering in one direction or another from its true position as it descends, the answer to this difficulty also is given by that same uncontrollable weight. Since it can not be influenced in position a hair's breadth by all the power that man could bring to bear upon it, it will be equally insensible to all the fortuitous forces that would bias the direction of a more limited mass in descending, such as bowlders temporarily encountered by the under edges of the caisson at particular points, or the pressure of the tides. The mass and its movement are too majestic to suffer any influence whatever from such casual obstructions. Only if an obstruction were permanently left in the way at one point, while the caisson was lowered at other points, could such causes act against the plumb descent of the structure.

The last operation, after laying bare the bed-rock, and testing its soundness and solidity at all points, is to fill up the caisson with a solid hydraulic concrete, which will harden into rock and unite itself immovably with the rock on which it rests, becoming to the caisson what a tenon is in a mortise. This concrete is rammed as tightly as possible under the roof of the caisson; but if it be impossible to drive it as tight as if the weight of the tower actually rested on it, this is not amiss. For the [CONTINUED[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) and increasing weight on the wooden supports will certainly compress them further in time, and will eventually, in all probability, bring the weight of the tower firmly, if not altogether, upon the incompressible concrete with which the caisson is filled.

With regard to the danger of decay in wood, which presents itself to most minds in this connection, experience has long since shown that, when buried beyond reach of air and changes of temperature, wood is perfectly incorruptible, and will endure, so far as we can judge, as long as stone. Oxygen, chemically free as it is in air, is the agent of decomposition, and in its absence all substances are alike incorruptible. The seaworms make no trouble at the depth below the bottom where we have left our timber platform. It may safely be trusted to support the bridge between New York and Brooklyn as long as there shall be need of it.

The caisson for the Brooklyn tower was towed into its berth on the 2d of May, 1870. Ten of the fifteen feet thickness of timber in its roof were built on after this, *in situ*. On the 15th of June the first granite blocks were laid on the timber. They are of from four to seven tons weight. The masonry, faced throughout with granite, is partly built of the less expensive blue limestone from Kingston, New York. The compressed air was let in, the water driven out, and excavation commenced on the 10th of July. The bed being a tenacious conglomerate of clay, sand, and bowlders, extending to a great depth, it was not necessary on this side to sink the pier to the bedrock, and at forty-five and a half feet beneath the bottom of the river the caisson was filled up with concrete and left in its final position. The latter operation was completed on the 11th of March, 1871. Two months had been lost by the accident of a fire in the caisson, requiring the interior to be flooded with water to extinguish it. This accident cost $15,000, and its recurrence in the New York caisson was guarded against by a lining of [BOILER[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) iron throughout, at an expense of $20,000.

The New York foundation was a work of much greater magnitude and difficulty. From the sandy nature of the ground it became necessary to sink the pier to the bed-rock, seventy-eight feet below high-water mark. The process was not different in method, but was much more trying to the workmen, from the greater pressure of air required in the caisson to keep out the water. The caisson was placed in its berth in October, 1871, and rested on the rock in May, 1872, after less than one year's work in sinking it to its bed.

The Construction of the towers above the water line was, of course, a simple though enormous piece of mason-work. The Brooklyn tower was completed in May, 1875, and the New York tower in July, 1876. Everything was now ready for the work of [CABLE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html)-making, into which, having already anticipated the construction of the great floor or bridge proper, we must enter somewhat minutely, to give the reader a clear idea of its curious and interesting processes.

Let us first imagine the cable as constructed—simply a bunch of wires, not twisted, but laid parallel, and bound together by a continuous wrapping of wire. The wires are of size No. 7, or a little over one-eighth inch in thickness; they number over 5000 in each cable, and make a bundle 15¾ inches thick. To lay and bind this prodigious bunch of wires straight and parallel would be impossible except by subdividing the mass into skeins or strands, which are first laid and bound separately, and afterward united. Each cable contains nineteen strands of 278 wires each. They are formed precisely like skeins of yarn or thread. Each skein is a continuous wire almost exactly one million feet, or nearly 200 miles, in length, passing from anchorage to anchorage, back and forth, 278 times. The turns of the wire at each extremity of the skein pass around a solid block of iron shaped externally like a horseshoe, with a groove in its periphery, in which the bend or bight of the skein lies as a skein of yarn is held on one's thumbs for winding. Each shoe or eye-piece is fixed (after the strand is finished) between the ends of two anchor bars, a seven-inch iron bolt passing through the three, and so connecting the strand with the great anchor chain at either end. After a skein is fully laid in position (passing, of course, over the tops of the towers) it is compressed to a cylindrical form at every point by large clamp tongs, and tightly bound with wire at intervals of about fifteen inches throughout its length. The men who do this work go out for the purpose on the strand in a "buggy," so called, which is a board seat slung by ropes from the axis of a grooved wheel fitting and travelling on the strand as bound together. When the strands are thus completed and duly regulated, the final work of wrapping the cable is accomplished in a similar manner, as hereafter described.

But to follow the process of construction, we return to the day when the towers and anchorages stood complete, but disconnected, with the intermediate spaces occupied only by the trackless air, and the question was how to initiate a connection between them all. To this end a three-quarter-inch [WIRE ROPE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html), long enough to reach from anchorage to anchorage over the tops of the towers, was coiled on board a scow by the Brooklyn shore. First, its end was hoisted up the water face of the Brooklyn tower, and passed over the top, let down the land face, and then carried back to the top of the anchorage, and made fast. Next—waiting until an opportunity when the river was clear of vessels at that point, and stationing boats as to warn coming vessels to halt—the scow was towed across to the New York tower, paying out the wire rope into the water as it went. The end remaining on board was then hoisted up the water face of the New York tower, passed over, and lowered again on the landward side. Then it was made fast to a drum connected with a powerful steam-engine, which wound up the rope from the bed of the river and over the tower, until it swung clear from side to side in mid-air, and the first connection between the shores was made. It remained only to carry the New York end back to the anchorage, hoist it up, and secure it in position there.

A second span of three-quarter-inch rope was carried over in substantially the same manner, and the ends of the two were then joined at the anchorages around grooved driving-wheels or pulleys, making an [ENDLESS BELT[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) or "traveller" revolving by steam-power throughout the whole distance from anchorage to anchorage.

To accomplish the succeeding operations would require men to work hanging on this slender cord all the way from tower to tower. Mr. E. F. Farrington, the master-mechanic who superintended this part of the work on the bridge, and who had previously been engaged on the suspension bridges at Cincinnati and Niagara Falls, now took the resolution to make the first passage of the line, and to give his men as good an example of courage and confidence as they would ever have occasion to copy.

On Friday afternoon, August 25, 1876, the running gear for the endless traveller rope was in readiness. A boatswain's chair, consisting of a bit of board for a seat, slung by the four corners, with as many short ropes uniting in a ring overhead, was secured to the traveller rope at the Brooklyn anchorage, and Mr. Farrington took his seat on the slung bit of board for a private trip over the line of the future bridge in sight of his men. Having made his preparations so quietly, and being so quiet a man, his surprise was great, on looking down from his high starting point, to see the house-tops beneath him black with spectators, the streets far below paved, as it were, with upturned faces, the ferryboats conveying like stacks of humanity, and the New York shore crowded in a similar manner. As he gave the signal to start the wheels and swung out, with the rushing rope hissing and undulating like a flying serpent through the air, the boom of cannon far below announced to the modest and unsuspecting aeronaut that his intended private trip for the encouragement of his men was a public triumph. Away went the whirring rope, invisible or like a spider's thread to the eyes below, bending and swaying with the human weight that rode its cantering waves, to all appearance self-impelled, like some strange creature of serpentine flight, sweeping first downward toward the house-tops till the deepest curve his weight could give the slender rope was passed, and thence soaring sharply upward to the top of the first tower in his course. Here he gave a signal to slow the rope nearly to a stop, while the men on the tower, with excited cheering, lifted the rope and its slung rider over the parapet, supported both across to the other side, and launched them off the [DIZZY[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) height again. Again the cannon roared, and the myriads of spectators swung their hats and cheered with wild excitement, while all the steam-whistles on land and water shrieked their uttermost discordance. The trip occupied twenty-two minutes, and at the end the explorer was glad to hide from the pursuing crowds that would fain have caught him as a trophy and carried him through the streets in triumph.

It was after this an easy matter to carry across the other carrier ropes; the ropes from which the "cradles," or hanging platforms, for regulating the wires, were suspended; those which supported the foot-bridge for the workmen, over which sight-seers were sometimes allowed to pass; and the "storm [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html)," which, stretching upward from the towers below the roadway, steadied the [TEMPORARY STRUCTURE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) against the wind.

Meanwhile all was ready in the large sheds that covered the Brooklyn anchorage for the regular and long-to-be-protracted machine-work of [CABLE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html)-making. Thirty-two drums, eight feet in diameter, were rigged in the position of carriage-wheels just clear of the floor, eight drums behind the destined position of each of the four [CABLES[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html). Hundreds of coils of wire, already delivered in the yard below, had been dipped in linseed-oil and dried again and again. A screw thread had been cut on every end of wire by a convenient machine constantly at work for this purpose (opposite ends being cut with right and left screws respectively), and the little steel coupling tubes, with inside screw-threads to match, had united fifty-two coils, or nearly ten continuous miles of wire, upon each of the thirty-two drums.

Now the shoe, or eye-piece, around which the skein of wire to form a strand of the [CABLE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) is to be turned at each extremity, is secured in a temporary position on the anchorage, and the work of winding the skein is begun. A wire is fastened to the shoe, and passed around a sheave or grooved pulley fixed and suspended to the traveller rope by iron arms reaching up from its axle. The traveller rope is set in motion, and bears forth the sheave, carrying the bight or turn of wire before it, thus taking across two spans, or a complete circuit, of the wire at once. On reaching the New York side (which takes about eight minutes) the bight of wire is passed around the shoe, completing once the circuit of the skein. The sheave, released, returns empty to the Brooklyn side.

Next the circuit of wire that has been carried across must be "regulated," that is, adjusted to the exact length and height required by its place in the strand. On the top of the Brooklyn tower, first, a clamp is fastened on the first span of wire—*i.e.*, that directly reaching from the end fastened at the Brooklyn anchorage—a small tackle-block is hooked on, and two men haul up the slack between the tower and anchorage until the regulator men in the cradle signal that the position is accurately adjusted at their respective points. A similar regulation is made on the New York tower to adjust the curve of the wire between the towers, and the same process is likewise repeated on the New York anchorage, until the fall of the wire off that point is also accurately located. The return span is then adjusted in the same manner, in reverse order, beginning at the New York tower. On the Brooklyn side, when the last span of this circuit of wire is adjusted in position, it is passed around the shoe, held fast, and the bight is again placed on a sheave, and the traveller starts again to carry over a second circuit of the skein. Thus the skein is wound round and round its eyepieces at either anchorage with unbroken continuity, with uniform tension, and with exact parallelism between all its threads, until the full number of 139 circuits has been made, and 278 wires are ready to be bound together in a round and solid cord three inches thick. On either side the eyepiece, of course, the cord is parted, and for a few inches is bound in two separate strands of 139 wires each, but it is shortly brought into one, leaving a loop at each end of the strand, inclosing the eye-piece or shoe, which, as before stated, is pinned between and together with two of the eighteen anchor bars in which the great anchor chains unite with each cable. Strands for each of the four great cables are made and placed simultaneously. A circuit of wire is laid and regulated in about thirty minutes, including ordinary delays. Two travellers are running, so that four circuits, or eight full lengths, of wire might be laid per hour. If weather never interfered, the 21,000 wires of which the four cables are composed could have been laid in less than a year. In point of fact, however, as it was useless to make the strands faster than the engineers could locate and adjust them in the cables—which is the grand difficulty of the work—it was doing well to lay forty wires on an average each working day.

On the commencement of impracticable weather in winter, such as incrusts the wires with snow and ice, it becomes impossible to regulate the wires properly. Then the work is necessarily suspended for the time being.

But the chief delay, as before remarked, arose from the difficulty of regulating the strands from two causes—sun and wind. Obviously the unity and strength of the cable depend on getting each strand into its exact and peculiar place. As the locations of the individual strands vary in height, the strands must vary in length. Each must hang in its own peculiar length and curve to a mathematical nicety; for if left but half an inch too long or too short for its true position, it will be too slack or too taut for its fellows, and it will be impossible to bind them solidly in one mass, and make them pull equally together. In the abstract this is a matter of exact mathematical science. But in practical engineering the actualization of the calculations is interfered with by variable forces which can not be resisted, evaded, or calculated. The chief of these in cable-making is temperature, which fluctuates so irregularly and unceasingly that the length of the strand is rarely the same for an hour together; and what is far more baffling to the engineer, the different spans are unequally acted on by the sun. One curve is in shadow while another is in full sunshine; one is exposed vertically to the sun, while another is struck by its rays at an extremely dull angle. In short, when the sun shines the several curves of each strand are all "at sixes and sevens," too unstable in position to be adjusted. The same is true of them in another sense when they are kept swaying and undulating by the wind. Hence the engineers can do nothing with them except at hours when two conditions concur—freedom from the influences of wind and direct sunshine. The hours from daylight to sunrise (when calm), and occasionally a few hours of calm and cloudy weather, are the only times available to the engineer for adjusting the length of his strands. This is done by changing the position of the "shoe." The figures of the engineer show that the deflection of the cables from the tops of the towers is 127.64 feet at 50 degrees F., while at 90 degrees it is 128.64 feet—a variation of nearly one-third of an inch for every degree of temperature, so that the engineer is likely to find his cables varying as much as half a foot in height In the course of a day. In short, the ponderous thing, though neither small nor agile, has a trick in common with the minute and lively insect which, when you put your finger on him, isn't there.

The running and regulating of the cable wires commenced June 11, 1877, and the last wire was run over October 15, 1878. The nineteen strands for each of the four cables having been thus made and located, the final operation is to unite and wrap them with wire. This is done by a little machine. An iron clamp is provided, the interior of which is of the size and cylindrical shape of the cable before wrapping. The temporary fastenings of wire around each strand are removed as fast as this work proceeds, and the clamp, screwed tightly, compresses the nineteen strands together, symmetrically arranged in a true cylinder, with the odd strand in the centre, and the other eighteen filling two circles around it. The [WRAPPING MACHINE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) follows up the clamp, and binds the cable with a close spiral wrapping of wire. This machine or implement consists of an iron cylinder cast in halves, to be bolted together about the cable, compressing it firmly. A reel or drum of wire encircles the cylinder. The wire winds off the drum through a hole in a steel disk on the rear end of the cylinder, whence it passes with a single turn around a small roller attached to the disk, and thence to the cable. The disk is turned by hand by a lever attached to it, and thus the wire, being held in severe tension by its turn around the roller, is tightly wound on the cable, and as it advances in its spiral or screw travel pushes forward the cylinder from which it is reeled.

The cables, thus completed, were ready for their load, the floor or bridge proper, already described. The suspender bands were next put on the cables; to these are attached the [WIRE ROPE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) suspenders, and these in turn hold the steel floor beams of the roadway. The suspender bands are made of wrought iron five inches wide and five-eighths of an inch thick. The bands are cut at one point, and the two ends turned outward, so that they may be opened (by heating), and placed over the cables. The two ends, or ears, which hang vertically down when the bands are in place, have holes through them for a screw-bolt one and three-quarter inches in diameter, which serves as the support of the suspenders, and also for tightening the bands and the cable. By the aid of these suspenders at short intervals all the way, it was easy to place, first, the crossbeams of the bridge floor, beginning with those nearest each anchorage and each face of the towers. The nearest suspenders hanging ready to receive the first iron beam had only to be drawn in and attached thereto by their clamps or stirrups, and the beam was swung out in position, ready to support planks for the workmen to stand on and launch the second beam, and so on. The cross beams being laid and braced together, forming the horizontal truss, the vertical truss-work is also put in, with the diagonal bracing below the floor, and the stays from the towers both above and below, and the bridge is at last ready for the planking.

The suspenders are for the most part at equal distances from each other But it will be noticed that at the centre two suspenders from each of the four cables hang close together, sometimes but a few inches, sometimes more than a foot, apart, These give the clew to that problem of engineering and puzzle to the public as to how the expansion and contraction, by heat and cold, of the floor or bridge proper, are to be provided for. The great span may be said to be in two pieces or half-lengths connected at the centre by an "[EXPANSION JOINT[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html)." Each half of a truss is attached to one of the two suspenders mentioned, and the two halves are connected by plates attached to one, and sliding in channels or ways in the other. No weight comes upon these guide-plates, as the two suspenders support the halves of the truss independently of each other. The planking is so arranged as to be always continuous, and the iron rails for the cars are at this point split in half lengthwise, so that one half plays upon the other, guide-rails on either side protecting the cars.

At 118 feet above high-water mark each of the towers of the bridge is divided into three masses by the two broad openings, 31½ feet wide, which here commence. The six lines of the great steel trusses or framework forming the bridge pass, unbroken in their continuity, through these openings of the piers, resting on the masonry underneath, and firmly anchored down to it by huge bolts and ties of [WIRE ROPE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html). An idea of the strength of these trusses may be obtained when it is considered that for over one hundred feet out from each side of the tower they are of themselves, without any support whatever from the cables or stays, sufficiently strong to carry all the load that may ever come upon them. The openings continue to the height of 120½ feet, where they are closed by pointed arches. Above these arches the reunited tower rises thirty feet higher, where it receives a set of iron bed-plates, on which rest the "saddles" in which the great suspension cables ride. These are iron castings in the form of a segment of a circle, with a groove to receive the cable on the upper and convex side. The under and plane side lies on a layer of small iron rollers held in place by flanges on the surface of the bed-plate. The object of these is to give sufficient play to the bearings on which the cables rest to prevent the cables themselves slipping and chafing in the saddles if affected by the force of storms or variations of load, or when lengthening and contracting under changes of temperature. From the saddles each way the cables sweep downward in a graceful curve, the landward ends entering the anchor walls, as already described, and supporting the shore ends of the bridge, while the main bow, or inverted arch, hanging between the towers, holds up the central truss of nearly 1600 feet span.

A great work of engineering is a battle with nature, in which, as in other wars, Death must take his toll. There have been employed upon the works at one time as many as six hundred men, a small army in themselves, and in the fourteen years since the master-mind, John A. Roebling himself, became the first sacrifice, more than twenty men have been fatally hurt. Several more have been victims to the it "caisson disease,"**\*** resulting from working in compressed air; but, despite the [DIZZY[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) height, no one has fallen from the main span into the water below. Besides the fire in the Brooklyn caisson, which cost no lives, and the fall of the derricks on the Brooklyn tower, which had more serious results, there has been one great accident only; but the imagination can scarcely picture anything more dreadful. On June 19, 1878, one of the great strands broke loose from the New York anchorage, carrying with it the "shoe" and its ponderous attachments. As the end swept from the anchorage it dashed off several of the men at work, and then, with a frightful leap, grazing the houses and peopled streets below, it landed for the instant in the bridge yard close under the Now York tower. The great weight mid-stream whizzed it over the tower with frightful and increasing rapidity, and the whole span plunged madly into the river, narrowly missing the ferry-boats that ply, crowded with human freight, below the line of the bridge. In these years the enterprise has lost also its president, Henry C. Murphy, and its first treasurer, J. H. Prentice, as well as its chief engineer. But, in strange and happy contrast, there has not been a single break in the engineering staff, Engineers Martin, Paine, Collingwood, McNulty, Probasco, and Hildenbrand having served [CONTINUOUSLY[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html), most of them from the very first. And now all the extraordinary engineering difficulties are overcome, and with them the vexatious delays from unfriendly opposition, political feuds, the stoppage of financial supplies, and the adoption of a new structural material. In a few years these will have been forgotten, and the forty million passengers who are expected to cross the bridge yearly will think only of the great boon that emancipates them from the delays of fog and ice, the possible collisions, and the old-time delays in waiting for the ferry-boats. Yet the ferries will still have plenty to do.

The summer of 1883 will be memorable for the opening of the great bridge, uniting New York and Brooklyn into a metropolis of nearly two million people—a population that will soon outgrow Paris, and have only London left to vie with. The bridge is practically a new street, belonging jointly to the two cities, and making with Third Avenue, the Bowery, and Chatham Street, New York, and Fulton Street continuing into Fulton Avenue on the Brooklyn side, a great thoroughfare fourteen miles long, already continuously built up, from the Harlem River to East New York. This is longer than the great street which stretches east to west across London, under its various names, from Bow to Uxbridge Road, spanning the valley where was once the Fleet brook by that other fine work of engineering, the Holborn Viaduct. The bridge roadway from its New York terminus opposite the City Hall to Sands Street, Brooklyn, is a little over a mile long (5989 feet), and it will take the pace of a smart walker to make the aerial journey, with its arched ascent, in twenty minutes. The cities will probably decide, confining the tolls to vehicular traffic, not to charge him the one cent first proposed for the privilege of taking this trip on "foot's horse." But for five cents he can jump at either end into fine cars, built on the pattern of the newest Manhattan elevated cars, which move apparently of their own volition, until one finds the secret in the endless [WIRE ROPE[http://cdncache-a.akamaihd.net/items/it/img/arrow-10x10.png](http://www.catskillarchive.com/rrextra/bbstory.Html)](http://www.catskillarchive.com/rrextra/bbstory.Html) underneath that is worked by stationary engines on the shore and makes continual circuit, across under one roadway and back under the other. These will take him across in a little less than five minutes, and it is not improbable that through trains will ultimately convey passengers from the northernmost end of New York over the Brooklyn Elevated that is to be, bringing them nearer to the health-giving beaches of Long Island by nearly half an hour's time.  
  
But the wise man will not cross the bridge in five minutes, nor in twenty. He will linger to get the good of the splendid sweep of view about him, which his aesthetic self will admit pays wonderful interest on his investment of nothing. The bridge itself will be a remarkable sight, as he looks from his central path of vantage down upon the broad outer roadways, each with its tide of weighted wagons and carriages of his wealthier but not wiser brethren, and nearer the centre the two iron paths upon which the trains move silently and swiftly. Under him is the busy river, the two great cities now made one, and beyond, completing the circuit, villa-dotted Staten Island; the marshes, rivers, and cities of New, Jersey stretching to Orange Mountain and the further heights; the Palisades walling the mighty Hudson; the fair Westchester country; the thoroughfare of the Sound opening out from Hell Gate; Long Island, "fish-shaped Paumanok," with its beaches; the Narrows, with their frowning forts; the Bay, where the colossal Liberty will rise; at last the ocean, with its bridging ships. And when he takes his walks about New York he can scarcely lose sight of what is now the great landmark which characterizes and dominates the city as St. Peter's from across the Campagna dominates Rome, and the Are de Triomphe the approach to Paris, and the Capitol on its height our own Washington—the double-towered bridge, whose massive masonry finds no parallel since the Pyramids. Those huger masses were the work of brutal force, piling stone upon stone. The wonder and the triumph of this work of our own day is in the weaving of the aerial span that carries such burden of usefulness, by human thought and skill, from the delicate threads of wire that a child could almost sever.

\* The "caisson disease" is the result of living under atmospheric pressure greatly above that to which the human system is normally adapted. The blood is driven in from the exterior and soft parts of the body to the central organs, especially the brain and spinal cord. On emerging into the open air, violent neuralgic pains and sometimes paralysis follow. Advanced consumption is, on the other band, stayed, and sometimes remedied, by compressed air. Dr. Andrew H. Smith, surgeon to the Bridge Company, reported one hundred and ten cases of the "caisson disease," of which three were presently, and probably more finally, fatal.