The WASHINGTON BRIDGE
HARLEM RIVER
·NEW YORK CITY·

W. R. HUTTON.

VOL. 1.

LEO VON ROSENBERG
35 BROADWAY
·NEW YORK·

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THE

WASHINGTON BRIDGE.

Compliments
of
Leo von Rosenberg
(Lipinsky)

No 35, Bway. N.Y.
March 22nd 1891.

Prof Fr. Steiner

CENTRAL PIER,

WASHINGTON BRIDGE.

THE

WASHINGTON BRIDGE

OVER THE HARLEM RIVER, AT 181ST STREET, NEW YORK CITY.

A DESCRIPTION OF ITS CONSTRUCTION

BY

WILLIAM R. HUTTON,

CHIEF ENGINEER,

Member of the American Society of Civil Engineers, and Société des Ingénieurs Civils of France.

ILLUSTRATED

WITH TWENTY-SIX ALBERTYPES, AND THIRTY-SEVEN DOUBLE AND SINGLE PAGE LITHOGRAPHS.

LEO VON ROSENBERG,

35, BROADWAY, NEW YORK.

PRESS OF
E. O. JENKINS' SON.
NEW YORK.

ALBERTYPES
BY
ALBERTYPE COMPANY.
NEW YORK.

LITHOGRAPHS
BY
BRETT LITHOGRAPHING CO.
NEW YORK.

THE

WASHINGTON BRIDGE.

(KNOWN DURING CONSTRUCTION AS HARLEM RIVER BRIDGE, AND MANHATTAN BRIDGE.)

Commenced, July, 1886. Completed, February, 1889.

COMMISSIONERS:

JACOB LORILLARD, VERNON H. BROWN,
DAVID JAMES KING.

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CHIEF ENGINEER:

WM. R. HUTTON.

CONSULTING ENGINEERS:

WM. J. McALPINE,
THEODORE COOPER.

RESIDENT ENGINEERS:

ALFRED NOBLE,
From August 1, 1886, to June 30, 1887.

JOHN BOGART,
From August 1, 1887, to March 31, 1889.

CONSULTING ARCHITECT:

EDWARD H. KENDALL.

CONTRACTORS:

THE PASSAIC ROLLING MILL CO. AND MYLES TIERNEY.

SUB-CONTRACTORS:

Anderson & Barr, for Caisson Foundation.
Jackson Architectural Iron Works, for Iron Cornice and Balustrade.
Barber Asphalt Paving Co., for Roadway.
John Peirce, for Granite.

PREFACE.

The publication of this work has been delayed many months, owing to circumstances beyond control. It was at first intended to present this matter as a paper for the Transactions of the American Society of Civil Engineers, but the magnitude of the work, the numerous inquiries that have been received, and the interest manifested, have led up to its publication in the present form.

The plates have been prepared from the working drawings, and from others made expressly for this work, together with numerous photographic views, taken during progress and since completion. They give full particulars and details, and render longer descriptions unnecessary.

By the original act of the Legislature, dated June 11, 1885, *the Bridge was to be completed by the Special Commission in three years from that date. The construction, commenced in July,* 1886, *was practically finished in the fall of* 1888, *although the final payments were not made until March,* 1889. *But the supplemental act of March* 5, 1888, *directed that land on both sides of the Bridge should be acquired by the Commission, and laid out as a public park. Owing to difficulties in obtaining the land, this improvement is not yet entirely completed. The Commissioners, therefore, having been appointed in July,* 1885, *are now in the sixth year of their unremunerated service. Their work speaks for itself. To their Secretary and representative, Mr. Niven, belongs a large share in whatever credit attaches to the work.*

Since the completion of the Bridge two of those most conspicuous in its construction have ceased from their labors—Mr. William Jarvis McAlpine, at first Chief Engineer, and later Consulting Engineer to the Commission, and Mr. Frank A. Leers, Engineer to the Contractors, by whom the metal structure was practically built. Mr. McAlpine, one of the fathers of the profession in this country and well known on both sides of the Atlantic, died on the 16*th of February,* 1890. *Mr. Leers, at a much earlier age, in a more modest sphere, thorough in his work, quiet and amiable in his ways, died on the* 19*th of May,* 1890.

My thanks are due to the publisher for the care and labor he has given to insure the sufficiency of the drawings, their accuracy, and their accurate reproduction.

W. R. H.

New York, Dec. 6, 1890.

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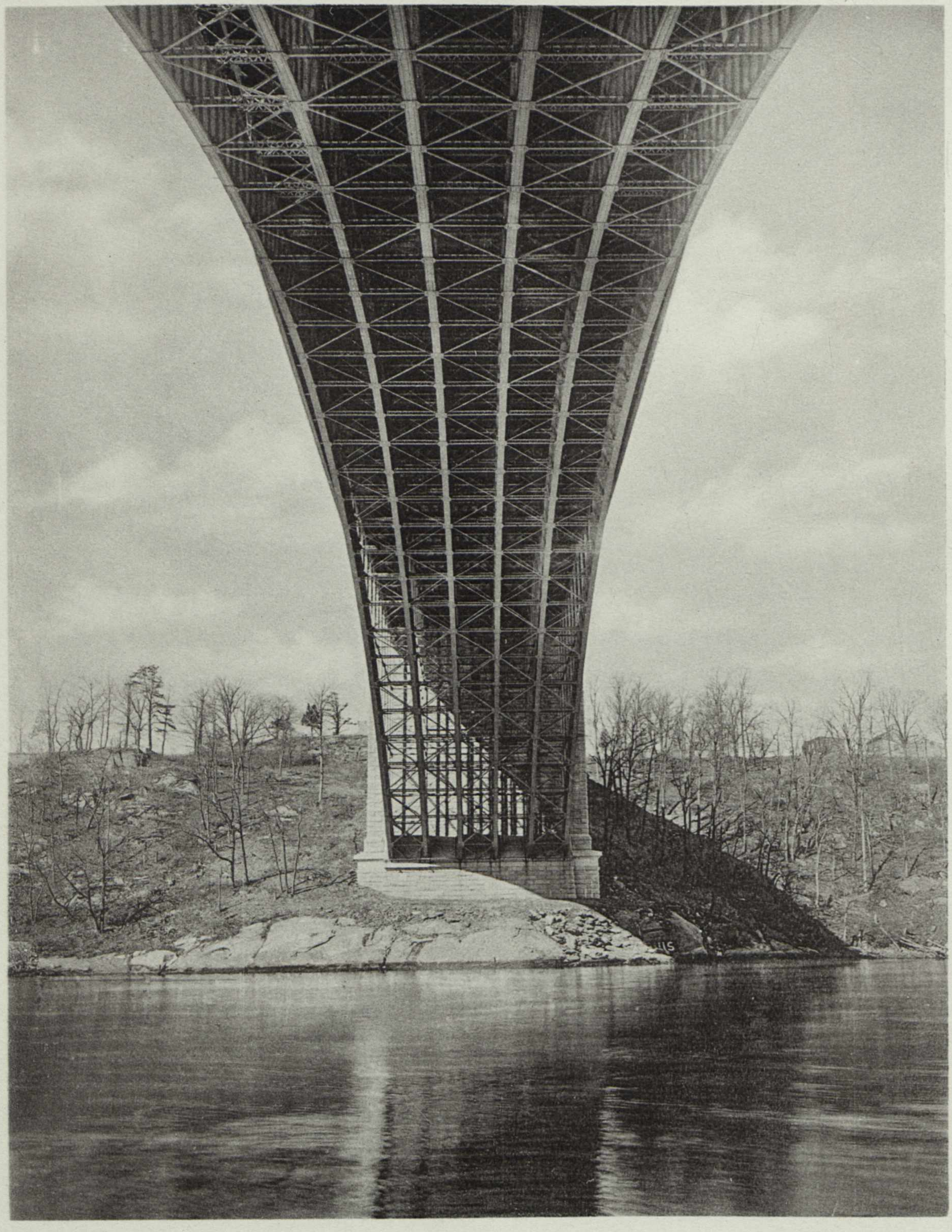


VIEW OF INTRADOS, FROM PIER II TO PIER I.

THE WASHINGTON BRIDGE.

MANHATTAN ISLAND, lying between the East River and the Hudson or North River, is separated from Westchester County on the north by the Harlem River and Spuyten-Duyvil Creek. The city of New York, originally built upon the southern extremity of the island, in its successive growths has absorbed the towns of Harlem, Yorkville, Manhattanville, Carmansville, and others upon the island, and by its latest extension it annexes a portion of Westchester County, outside of its island limits.

In the year 1868 examinations were commenced by the Board of Commissioners of Central Park for the purpose of determining where streets should be located in the upper portion of the city, and devising modes of communication between the counties of New York and Westchester, over the Harlem River.

In a report made to the Department by Mr. Andrew H. Green, for many years the executive officer of that Board, he suggests that "from High Bridge to Sherman's Creek suspension bridges might be built at as great an altitude as the High Bridge of the Croton Aqueduct, and from Sherman's Creek to the North River, tunnels could be constructed under the river and creek, or bridges over them wherever a crossing from shore to shore might be required."

In conformity with his suggestions an Act of the Legislature, passed in 1869, authorized the survey of a part of Westchester County, and the location of bridges and tunnels across Harlem River.

Upon this Mr. Green remarks that "an evidently expressed intention of the Act being to provide a bridge at or near the site of High Bridge, which would connect the high ground in New York and Westchester Counties, and the report of General Greene being unfavorable to the use of the High Bridge of the Croton Aqueduct for such purpose, special attention has been given to the subject, and surveys have been made which demonstrate that at a distance of some two thousand feet north of the High Bridge a very favorable location may be found for connecting travel between New York City and Westchester County, by a suspension bridge about two thousand feet long, having its roadway one hundred and fifty-three feet above high-water level, and extending from the Tenth Avenue to the high ground on the opposite shore, west of the Croton Aqueduct. If so built, it would be twenty-three feet higher than the present High Bridge of the Croton Aqueduct, and would form a very suitable and convenient connection between the elevated lands on both sides of the river. The site affords very favorable ground for foundations for piers and towers and anchorage for cables. The material difference in cost between it and a bridge over and resting on the Croton Aqueduct High Bridge would be the cost of towers and anchorages; its situation would be such that no interference with any roads crossing it could take place, and it might conveniently be so placed as to be directly opposite one of the main cross streets in the upper part of the city of New York, and thus afford direct connection with all lines of travel through the upper part of the city."

Ample authority to locate and build bridges across the Harlem River was conferred upon the Park Department by the Act of May 19, 1870.

On February 23, 1876, commissioners were appointed by the Supreme Court to take the land for approaches to the bridge. Their report was confirmed, and a strip of land one hundred feet wide, extending from Tenth Avenue to Aqueduct Avenue, was acquired by the city upon which to build the bridge. Seventeen hundred and thirty-one pieces of land were assessed for benefits and advantages by reason of the improvement.

In 1878 a memorial was presented to the Department of Public Parks, setting forth the delays that had taken place, and urging the construction of the bridge; and in February, 1881, Mr. Wm. J. McAlpine, Chief Engineer of the Department of Public Parks, reported to the Park Commission four alternative plans for a bridge at this site.

1. A suspension bridge of eight hundred feet clear span between towers, with half spans at each end. Estimated cost, $1,500,000.

PART OF NEW YORK CITY.

PLATE III

2. A suspension bridge of the same span, the approaches to be carried on arches of masonry. Cost, $2,100,000.

3. An iron cantilever over the river, with approaches on braced iron girders, and piers or towers of the same construction. Cost, $800,000.

4. A structure of masonry of six arches, the spans varying from 160 to 210 feet. Cost, $4,000,000.

The designs are shown on Plate IV. In each of these plans the roadway was to be thirty-five feet wide, with two sidewalks of seven feet six inches each, making the entire width of the bridge fifty feet.

The last-mentioned design was recommended as more monumental and durable, but no action appears to have been taken in the matter.

In 1883 the Park Commissioners employed Mr. A. P. Boller, Messrs. Buck & McNulty, and Wilson Brothers to study and report plans for this bridge.

Mr. Boller proposed a cantilever, one hundred feet wide, with approaches on iron piers and girders, estimated to cost $1,000,000.

Messrs. Wilsons' plans were:

1. A cantilever on masonry piers. Cost, $1,193,247.

2. A cantilever on iron piers, with masonry foundations. Cost, $1,062,954.

Messrs. Buck & McNulty submitted a plan for a metal arch of 543 feet span over the water-way with masonry approaches; width between parapets, ninety feet,—a very handsome structure. Cost, $3,064,624. It is said that this design was preferred by the Commission, but that the circumstances did not justify so large an expenditure.

Various other resolutions were passed and other proceedings taken from time to time by the Department of Public Parks, but practically nothing was accomplished for a period of nearly fifteen years, during which time the Department of Public Parks held full power to build this bridge. Finally, a movement was made by Mr. Green to confer the power to build the bridge on another authority, which was done by Chap. 487 of the Laws of 1885.

Thus, the scheme originally conceived by Mr. Green was pursued by him through its various delays and hindrances until, in 1885, the design and construction of the bridge was placed in the hands of the present Commissioners, who have erected the structure here described.

By the Act of the 11th of June, 1885, the Mayor, the Comptroller, and the President of the Board of Aldermen of the city of New York were authorized to appoint three commissioners, who were to serve without compensation, to construct the bridge for which provision was made in the Act. Under this authority, on the 21st of July of that year, Mr. Vernon H. Brown, Mr. Jacob Lorillard, and Mr. David James King were appointed Commissioners. The Commission met and organized on the 27th of July, electing Mr. Lorillard chairman.

On the 29th of September Mr. Malcolm W. Niven was appointed Secretary and Mr. William J. McAlpine Chief Engineer to the Commission, and on the 16th of October an advertisement was ordered for competitive plans, specifications, and preliminary estimates. On the 3d of December seventeen designs which had been received were examined, of which one was withdrawn, four were laid over for further consideration, and the rest were returned.

Later in December, Messrs. Clarke & Macdonald, of the Union Bridge Company, presented designs, estimates, and a tender for the construction of a bridge of three arches, each of two hundred and eighty feet span, to be executed in *béton Coignet*, with a facing of granite. The Commission was pleased with the design and disposed to accept the proposal, which was considered favorable; but upon further consideration, it was concluded that the material was unauthorized by law—being neither stone, steel, nor iron. (Their design is shown on Plate IV.)

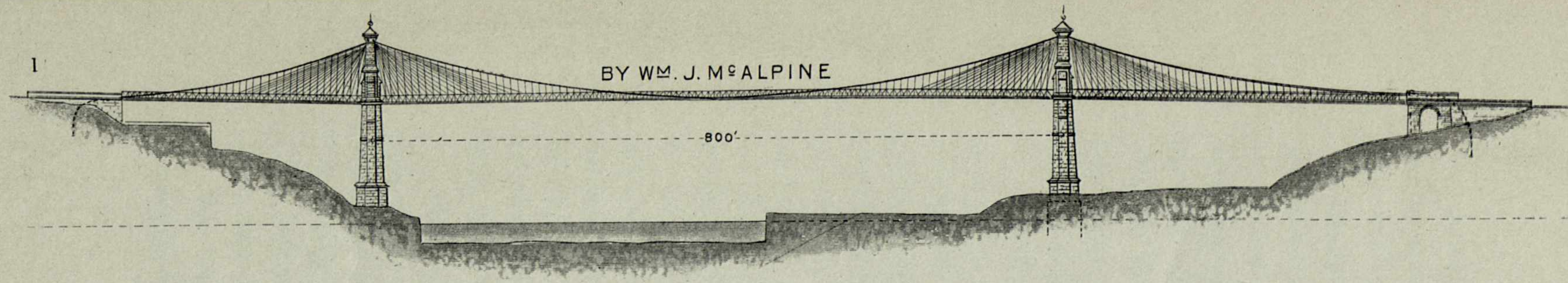
A board of experts to aid the Bridge Commission was then appointed, composed of Mr. P. P. Dickinson and Mr. Theodore Cooper, civil engineers, and Mr. Edward H. Kendall, architect, together with Mr. McAlpine, Chief Engineer. By their advice the first premium was awarded to Mr. C. C. Schneider and the second to Mr. W. Hildenbrand. No third premium was awarded.

Mr. McAlpine, Chief Engineer, had requested Col. Julius W. Adams to prepare a plan for a bridge of masonry. This design (shown on Plate

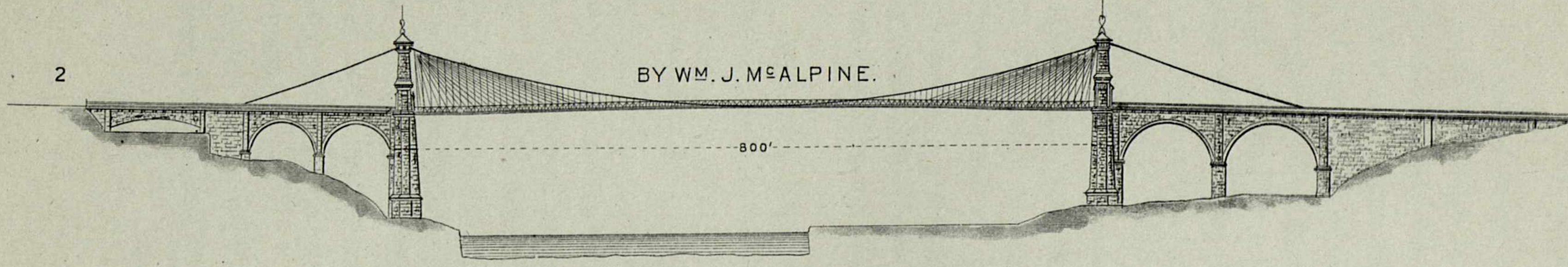
EARLY DESIGNS FOR HARLEM RIVER BRIDGE,
(NOW WASHINGTON BRIDGE.)

PLATE IV.

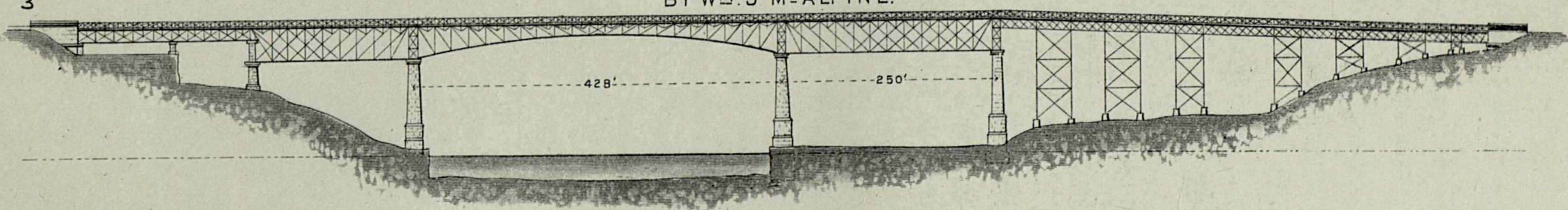
1 BY WM. J. McALPINE



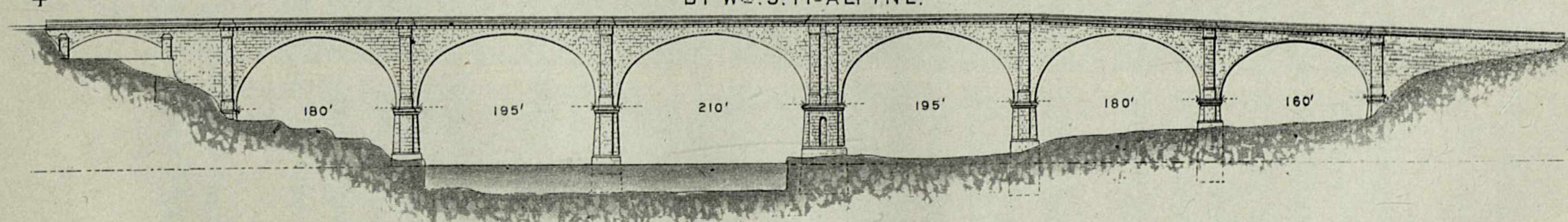
2 BY WM. J. McALPINE.



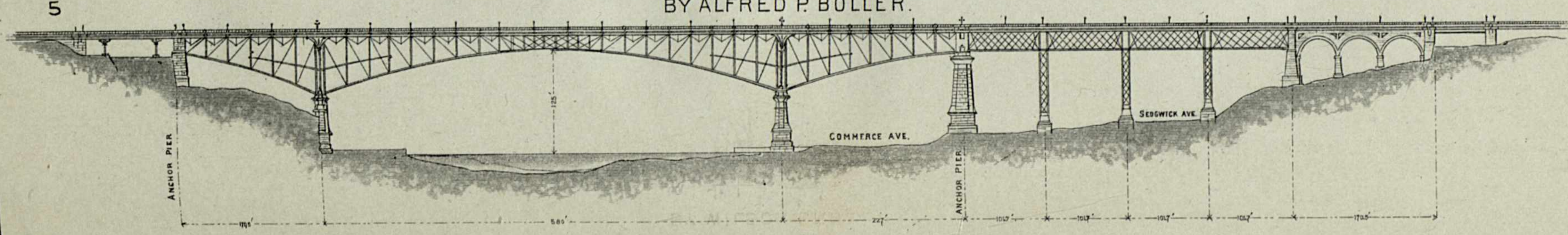
3 BY WM. J McALPINE.



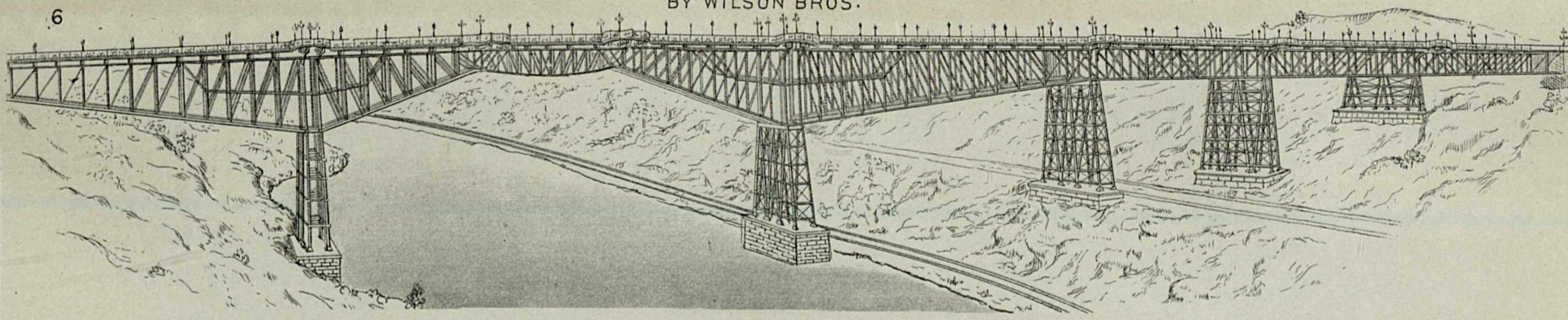
4 BY WM. J. McALPINE.



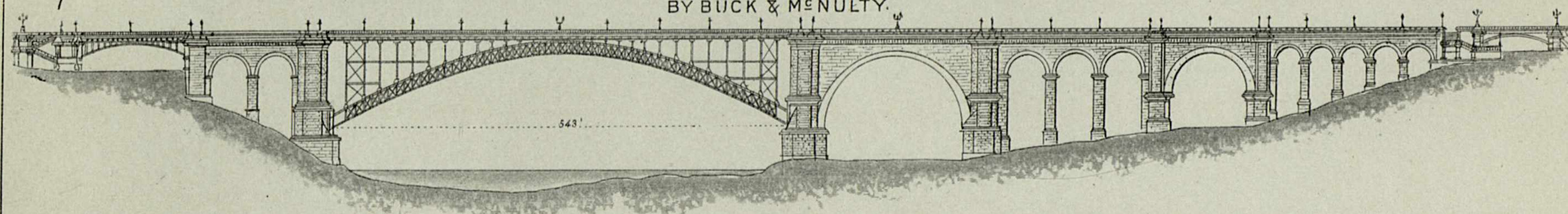
5 BY ALFRED P. BOLLER.



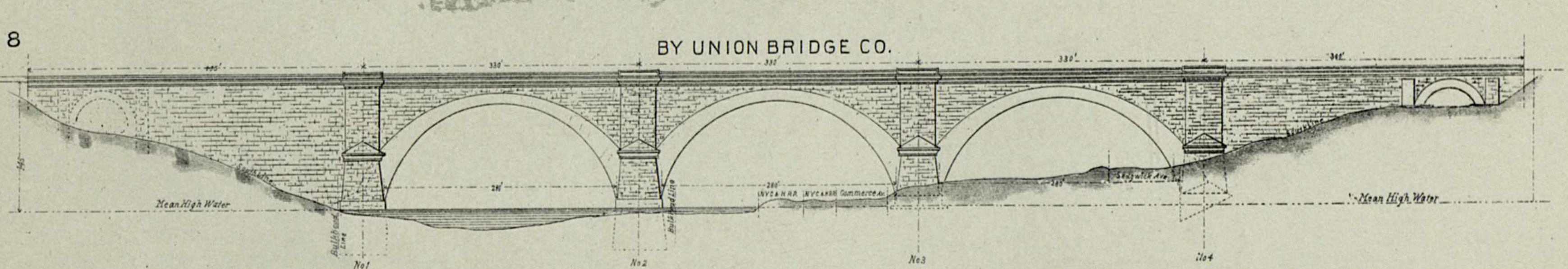
6 BY WILSON BROS.



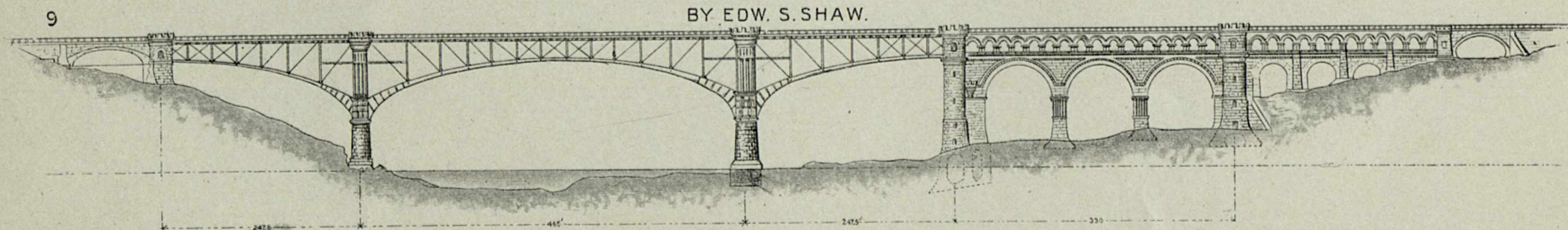
7 BY BUCK & McNULTY.



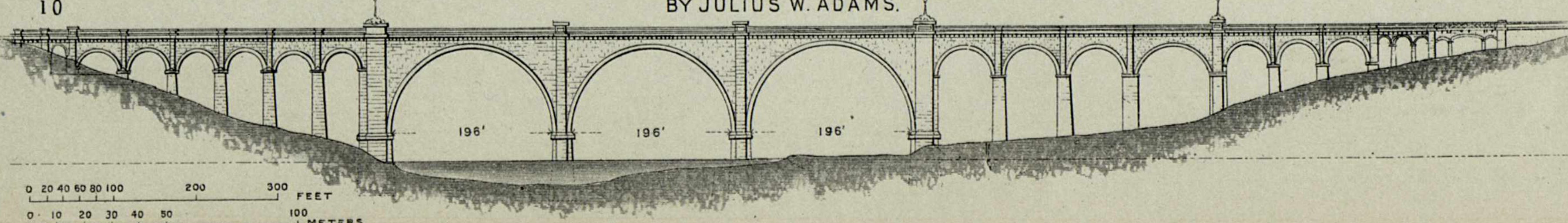
8 BY UNION BRIDGE CO.



9 BY EDW. S. SHAW.



10 BY JULIUS W. ADAMS.

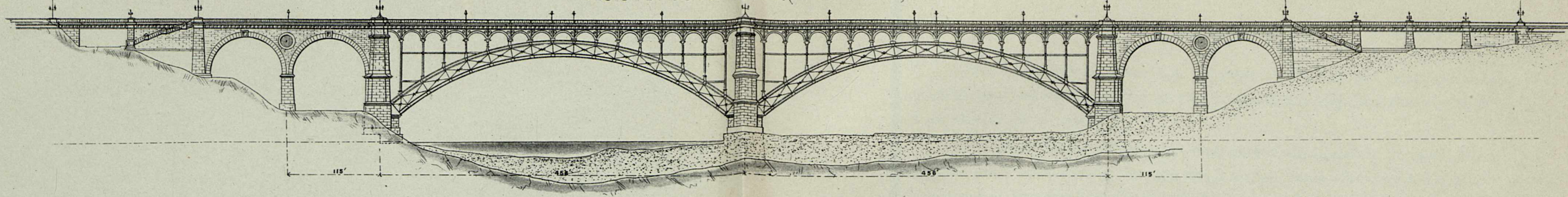


0 20 40 60 80 100 200 300 FEET

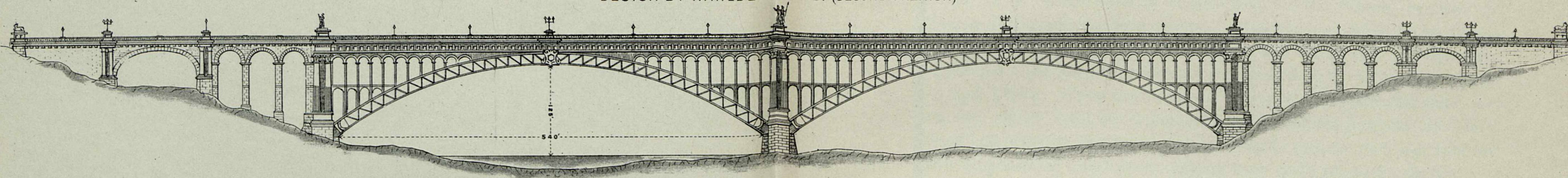
0 10 20 30 40 50 100 METERS

PLATE V.

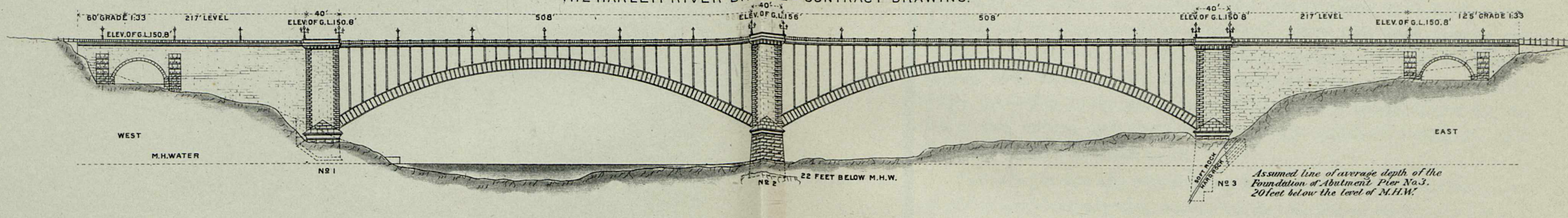
DESIGN BY C.C.SCHNEIDER. (FIRST PREMIUM)



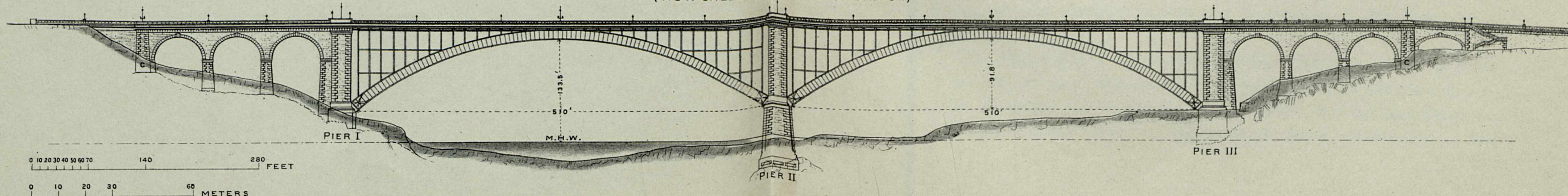
DESIGN BY W. HILDENBRAND. (SECOND PREMIUM)



THE HARLEM RIVER BRIDGE—CONTRACT DRAWING.



THE HARLEM RIVER BRIDGE AS BUILT,
(NOW CALLED WASHINGTON BRIDGE.)



IV.) was considered to have the greatest merit, but no premium was awarded to it, as the condition of the competition required that the main spans should be of metal.

The Union Bridge Company presented a modification of their *béton Coignet* plan, substituting for the *béton* arches, steel ribs with solid webs. This was not approved by the Commission, and they again submitted general plans, differing from those of Messrs. Schneider and Hildenbrand chiefly in the substitution of a plate web for the bracing between the flanges of the arch in those designs. After some modification by the engineers of the Commission, Mr. McAlpine and Mr. Çooper (the latter now appointed Consulting Engineer), these plans were finally adopted (Plates V. and XIII.). Upon them tenders were invited by advertisement, and on the 22d of April, the Commissioners opened ten proposals for earthwork and masonry, varying in amount from $1,093,400 to $1,697,700, and five proposals for metal work; ranging from $687,500 to $1,180,000.

It was desirable that the entire work should be let in one contract, and, after much effort to secure satisfactory arrangements between contractors of reputation for masonry, and others whose specialty was iron and steel, all these proposals were rejected. New bids were received, and finally, on the 14th of July, 1886, a contract was executed with the Passaic Rolling Mill Company and Myles Tierney to construct and complete the bridge according to the preliminary plans, and the specifications, for the sum of two million and fifty-five thousand ($2,055,000) dollars, of which $845,000 was for the metal work.

The designs for the metal spans had been carefully made from very complete specifications, and, except in the decorative parts—the cornice and balustrade—but few and slight changes were made in the details after the contract was executed. These were chiefly in the pedestals, in the sections of the flanges, and in the anchorage of the floor to the masonry.

The plans adopted for the masonry and approaches were not entirely satisfactory, but over thirteen months had elapsed of the three years allowed by law for the completion of the bridge, and the Commission was not willing longer to delay the beginning of actual construction. Work upon the foundations and substructure was therefore commenced at once, leaving desired modifications of the plans to be made during the progress of the work.

GENERAL DESCRIPTION.

The object of the structure is to carry one of the streets of New York (181st Street) over the deep valley of the Harlem, connecting Tenth Avenue on the west or New York side, with Aqueduct Avenue on the eastern side, the distance being 2,375 feet. Its clear height, 133.5 feet above the water, is ample for the needs of navigation.

It is composed of two steel arches, each of 510 feet span, three piers, two abutments, and approaches formed chiefly of embankments supported by retaining walls. These carry a roadway that is nowhere less than 80 feet in width between the parapets, of which 50 feet is a carriage-way, with two sidewalks each 15 feet in width. The latter are protected by heavy balustrades of iron and bronze, and an iron cornice and frieze covers the ends of the main floor-beams.

Tenth Avenue being 27 feet higher than Aqueduct Avenue, the grade descends eastwardly both on the east and the west approaches, at the rate of three and a half per cent. The abutments are level, 151 feet above mean high water. Over the steel arches the profile is a curve 1.34 feet higher at the centre pier than at the ends.

The main piers are 40 feet thick at the springing line of the steel arches and 98 feet long. To the top of the skew-backs they are solid, made of concrete, with a facing of dressed granite.

The weight and thrust of the six steel ribs forming each arch are borne by the skew-backs—large blocks of granite set normal to the thrust of the arch-ribs, and backed by granite blocks and concrete. Above the skew-backs the piers are cellular in construction, and nearly 100 feet in height.

The abutments, 235 feet in length, are formed of three semi-circular arches of masonry, each of 60 feet span, carried by small piers 13 feet thick at the springing line of the arches.

The main piers and abutments are crowned with a deep bracketed cornice, with parapet. The approaches have a much lighter cornice, and a lower parapet, and a portion at the eastern end is protected only by a heavy rail of bronze.

As has been said before, the land to be occupied by the bridge was acquired in 1876. Immediately upon the signing of the contract on the 14th of July, 1886, other necessary lands were leased and prepared for the reception and storage of material. Quarries were opened and arrangements made for the rapid prosecution of the work. By the 20th of July the excavations for foundations of pier III. were commenced ; and those of pier I. and the west abutment were begun early in August, 1886.

On the western bank of the river the bluff rises abruptly from the water, and there was no level space for the storage of materials. They were there delivered from time to time in small quantities as required, and when opportunity offered were placed around or upon partly-completed work, or stored upon the eastern bank. A wharf was built and arranged with the necessary derricks and tracks, and a single-track inclined plane was constructed, parallel with and close to the south face of the wall, from the wharf to the west end of the abutment. It was worked by a hoisting engine at the top of the incline. Materials were carried by it to the proper point alongside the work, and hoisted by derricks from the truck directly into place.

On the east bank of the river a wharf was built at the edge of the proposed channel, supported on piles and floored with plank as far back as the top of the rip-rap slope beneath it. Thence to the hard ground at the railway it was filled with earth. Channels were dredged from High Bridge, 1,500 feet below, to both the wharves, to a depth of twelve feet.

At first, material landed on the east wharf was hauled by wagons to its place over steep, soft roads. In the spring of 1887 a wide trestle-platform was constructed from the front of the wharf to Sedgwick Avenue, about 40 feet above the water. It was furnished with tracks, and over it much of the material for pier III. and the east abutment was carried. As the arches of the abutments were closed, tracks were erected over them from the pier to the end of the masonry. As soon as the iron flooring over the steel arches was laid, these tracks were extended to pier II.; and thereafter nearly all the material for the east abutment was hoisted from the water at pier II., and carried on these tracks to its position, where it was set with derricks.

The twenty-eight derricks used for the masonry were all of the type shown (Plate LXI.), having generally guys of wire rope, wire-rope falls, and iron blocks and sheaves; and all were operated by sixteen steam hoisting engines.

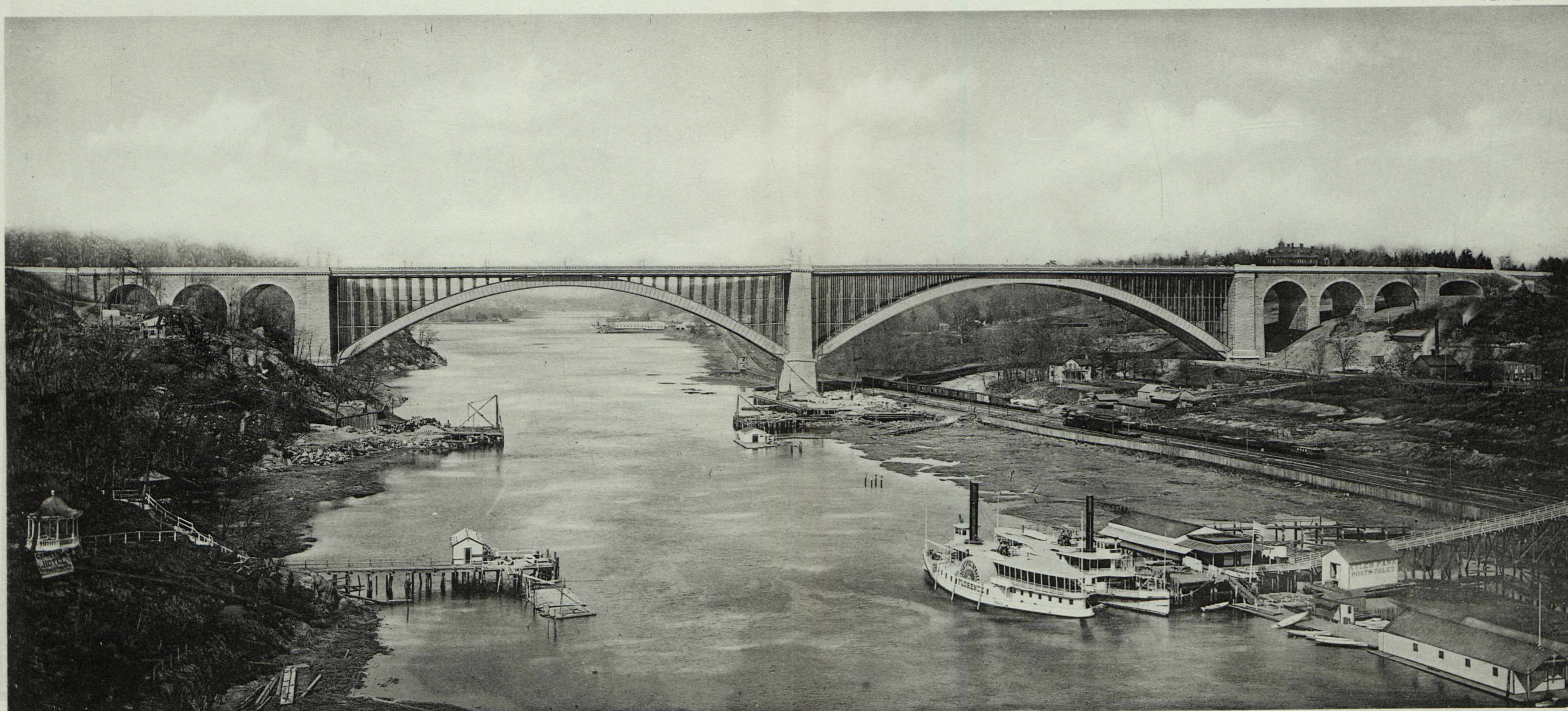
The derrick upon pier II., by which the largest quantity of material was hoisted, was worked from the stone-yard below. As the pier was built the derrick was supported from posts placed in the corners of the square cells or chambers in it, and raised from time to time as the work progressed. Upon the completion of the pier, the derrick was placed on top and the hoisting rope passed down the chamber, and out through an opening left in the walls, and so to the hoisting engine 150 feet below.

The wire rope for guys was seven-eighths of an inch in diameter. The hoisting ropes were three-quarters of an inch, the system having been arranged for a maximum lift of about six tons. The skew-back stones and the keystones of the arches weighed from eight and a half to nine and a half tons, and the guys were strengthened and the hoisting ropes doubled especially for hoisting them.

For the iron work a large derrick was erected upon the ground near the tracks of the New York Central Railroad, for the purpose of raising material from the cars to the working platform before mentioned, which extended from the front of the wharf to Sedgwick Avenue. Upon this platform the material was carried on trucks to within reach of the travellers. These travellers were frames arranged to move on rollers on the extrados of the arch ribs as the work progressed, and to be secured at the end of the ribs in place. They were provided with short boom-derricks for setting the parts. The hoisting ropes for the erection of metal work were of Manila rope, four and a half inches in circumference.

Upon the river span the material was hoisted directly from barges or floats.

PLATE VI.



THE WASHINGTON BRIDGE.

(GENERAL VIEW FROM THE SOUTH.)

Although all portions of the work were systematically pushed forward with a view to have them ready for their connections at the proper time, the principal effort was directed to the completion of the piers to the top of the granite skew-backs, so that the erection of the steel arches might be commenced as soon as the material was prepared.

While work was therefore actually begun under the plans of May, 1886, important changes in those plans were authorized, and changes, once commenced, did not cease until the completion of the bridge. Appreciating more fully as it progressed, the largeness of the work in their hands, the Commission decided that a higher class of constructive work and a more ornamented structure would amply justify the increased expenditure to the people of this great city, and all the changes were in the way of greater durability and beauty. The result has proved the correctness of their judgment.

MASONRY.

MATERIALS.

The granite used was from the quarries of Biddeford, Mt. Waldo, and Vinal Haven, all on the coast of Maine. As the latter has somewhat more color than that from Mt. Waldo, the effort was made to use them in different portions of the work, but this was soon found to be impracticable without delays. It is also undesirable for "rock-faced" or "quarry-faced" work.

The cornices, parapet, etc., were made from a finer quality of granite of uniform color, from the Mt. Waldo quarries.

The light gray gneiss ashlar for the long faces of the piers and facing the approaches, was from the Mine Hill quarries near Roxbury, Conn.

Rubble masonry was of gneiss from the vicinity, partly from a quarry on 7th Avenue, but largely from the excavations made for the foundations and for grading the adjacent ground.

The stone for concrete was chiefly supplied from limestone quarries on the Hudson River, which furnish large quantities to New York. It was crushed at the quarry by machinery, screened, and delivered by water at the site of the bridge.

The cement chiefly used on the work was Rosendale from the New

York and Rosendale Works. It was of excellent quality; tests for tensile strength of pure cement in twenty-four hours, ranging from 80 lbs. to the square inch to over 130 lbs., the average of over 2,000 tests being 96 lbs. tensile strain to the square inch. Small quantities of other cements were used, but the Rosendales are so well known and so cheap, that it was not thought well to try practical experiments with others. Nearly 40,000 barrels were used.

Portland cement, of which 24,000 barrels were used, was chiefly of the Hemmoor brand. It was finely ground and of excellent quality. Its strength under different conditions, is shown by the table of tests of cement. It was used chiefly where pressure might not be evenly distributed, whether from foundations of unequal hardness, or from pressure being applied at points, as under the skew-back courses, and generally in setting the face-stone.

The concrete was composed of one part by measure of cement to two parts of sand and five of broken stone, no fragment of the latter being more than two and a half inches in any dimension. The concrete-mixer was a cast-iron box, 8 feet long, and 2 x 2 feet in transverse section, placed at a slight inclination and revolved on its longitudinal axis by a special steam-engine, while the dry material was admitted from a hopper into its upper end. Water was supplied by a pipe, and after several revolutions the concrete was discharged from the open lower extremity. Owing to frequent irregularities in the flow of the material, it was difficult to regulate the quantity of water; otherwise the mixing by this machine was fairly good, and was thoroughly completed by the successive handlings, before the concrete was in place in the work. The economy of mixing by machine over hand-mixing is very great. The capacity of this mixer was 150 cubic yards per day, requiring the services of twelve men. It was operated by a special steam-engine, at the rate of forty revolutions per minute. The concrete was carried from the mixer in iron buckets containing about a cubic yard. The buckets were lifted from the car by a derrick, lowered into the pit, dumped, and the concrete was spread and rammed,—care being taken that the concrete was level with the granite facing before another granite course was set.

Early in the spring quarries were opened at Roxbury, Conn., in the expectation that all the arch stones, except the voussoirs of the faces, would be furnished from them. But it became apparent by midsummer that a sufficient quantity of material could not be obtained from them without delaying the work. Material for two arches could be supplied. A sub-contract was made for stone for one arch from a gneiss quarry near Sufferns, on the Erie Railroad. Granite from Maine was ordered for three others, and for the seventh, over Undercliff Avenue, red granite from Leetes Island, Conn., was adopted, the same as that used in the pedestal of the Statue of Liberty.

The contract for Sufferns stone was abandoned when half the material had been delivered and cut. Happily it was of good quality, and harmonized in color with the Maine granite, with which it was alternated in the arch.

SUBSTRUCTURE.

At the site of pier I., on the west side of the river, the solid rock was exposed, at or very near the surface of the ground, and no other preparation was required than to remove the surface-earth and shape the rock to receive the masonry. Some small holes under the face were filled with concrete, but generally the face-stones were fitted to the rock. All the piers to seat of metal arches are built of concrete, with a facing of granite in courses two feet high, not less than two feet wide, with headers five and six feet long, bonding the granite facing firmly to the concrete heart. The face-stones were set in mortar of Portland cement—the concrete is generally made with Rosendale cement—and the backs of the granite courses were plastered with cement-mortar before the concrete was placed against them, in order to secure a better union. The excavations for pier I. were commenced in August, and the masonry was begun on the 1st of October, 1886. It was ready for the pedestals in May, 1887, but they were not set until September.

At pier II., the solid gneiss rock, which is at or near the surface on the New York side, and again at the top of the hill on the eastern side, lies at a considerable depth between the bluffs of the river valley except at one point, where it rises to within seventeen feet of mean high tide in the river. This point, on the eastern side of the channel and close to the tracks of the New York Central Railroad, was, of necessity, selected as the site of pier II. The surface of the rock, however, was very uneven, sloping in every direction from the high point, and it was covered with boulders and heavy gravel to within eight feet of low water, the remainder being mud.

As the question of time was of the first importance, a foundation upon a timber caisson, to be sunk by means of compressed air, was adopted as least exposed to the delays and contingencies which might arise from bad winter weather and from accidents. Plans submitted by Anderson & Barr were approved on the 3d of September, 1886, and work upon it was immediately begun.

The caisson, which was built in place, is 104.8 feet long, 54.4 feet wide at base, and 13.3 high, with one foot batter in its height on all the sides. It is made of Florida pine timbers, twelve inches square, except the shoe or cutting edge, which is of oak. The walls of the chamber, three feet thick, are formed of superimposed horizontal timbers on the outside and inside, with an intermediate series of vertical timbers. Alternate verticals are cut off at the top of the working chamber ; the intermediate timbers rise nearly to the top of the caisson. By this arrangement, half the transverse and longitudinal timbers of which the roof is composed, extend to the extreme ends and sides of the caisson, and hold in place the verticals, which thus serve as stiffeners to the sides and ends. The roof or deck of the caisson is composed of four courses of 12 x 12 inch timbers laid transversely, and two intermediate courses laid diagonally. The latter are stopped some ten feet from the end of the caisson, and the course is completed with short timbers placed longitudinally, to secure the end verticals and tie them to the remainder of the structure. Each course was well fastened with drift-bolts to the course below, the whole forming a solid mass of timber about six feet thick. The sides of the chamber and the first courses of the roof were poured, as the timbers were placed, with hot coal-tar ; the remainder was grouted with cement. The inside of the working chamber was first lined with rough boards, then with a layer of asphalted paper, which was covered with tongued and grooved boards, 1¼ inches thick, the joints of which were put together with white lead.

The caisson was made with two longitudinal division walls, each two

VIEW FROM SOUTHWEST.

feet thick, extending from the roof to within two feet of the bottom. They were built of horizontal courses of 12 x 12 inch timbers, with openings 2 x 2 feet, for communication between the chambers formed by them; these were firmly secured by straps and bolts to the end walls. The side walls were braced and tied at nine points, with timber braces 12 x 12 inches, and iron tie-rods. There were two air-locks, as shown on the plans (Plate XXXIII.), one on top of the shaft, four feet in diameter, for general service; the other, five feet in diameter, was placed inside the caisson, as shown, and used for the extraction of material, which was loaded into buckets, placed in the air-lock, and hoisted out. There was also a shaft eighteen inches in diameter, through which the concrete for filling the chamber was introduced, and a number of blow-out pipes, four inches in diameter. The caisson was built in an enclosure formed by a temporary cofferdam. During its construction it settled two or three feet into the mud, and moved slightly out of position. It was secured to the bank with chains, and readily brought into place by means of turn-buckles on the chains.

The material to be excavated was first, mud to a depth of from eight to eleven feet, then heavy gravel with large boulders, and, finally, a very irregular rock, partly gneiss, partly marble, with veins and pockets of very hard quartz. A small portion of the mud was blown out by compressed air through the four-inch air-pipes, but the method did not work well, and it was soon abandoned. The rock on the northeast corner of the caisson rose to seventeen feet below mean high water, while at the southwest corner it was more than forty feet below.

The rock was drilled with a "Rand" drill, operated by air that was supplied to the drill at a pressure of eighty to one hundred pounds per square inch. Its exhaust was against a back pressure of about eighteen to twenty-two pounds, giving an effective pressure of sixty-two to eighty pounds per square inch. At first, dynamite ("forcite") was used as an explosive, but its gases were found to affect the workmen unfavorably, and it was replaced by "rack-a-rock," which proved entirely inoffensive, and was used until completion. The holes were usually four to six feet deep and three to four feet apart, 2¼ inches in diameter, charged with one, two, or sometimes three cartridges, 1½ inches in diameter, and nine inches long, the charge varying from one to two pounds. One to four holes were fired at one time by the electric battery. No serious damage was done to the walls of the caisson by shattered rock. About 1,500 cubic yards of rock were thus taken out.

The caisson was lighted with electric light by a dynamo capable of running seventy-five incandescent lamps of sixteen candle-power.

During the sinking, the caisson took a slight twist, and at one time the southwest corner was more than a foot lower than the others, causing some cracks in the masonry, then about six feet high upon it. Provision had been made in the dimensions of the base of the pier for small movements of the caisson, and from the time the masonry was brought to normal dimensions, no perceptible movement took place.

For the sinking of the caisson three compressors of different patterns were used, viz.: one single 12 x 18 inch Delamater, one duplex 10 x 16 inch Delamater, and one duplex 9 x 10 inch Clayton compressor. They were operated by two horizontal boilers of sixty and eighty horse-power, respectively.

Sinking was commenced on the 15th of November, 1886, and on the 17th of April, 1887, the caisson reached its final depth 40.6 feet below mean high water. There were some few points where the cutting edge did not rest upon the rock. These were excavated and filled with concrete. It was then sealed and filled two feet deep with concrete formed of Portland cement, with two parts of sand and four of broken stone. The remainder of the concrete filling was made with Rosendale cement. The masonry had been carried to a height of 27.5 feet, the level of mean high water, during the sinking of the caisson. It was continued without intermission, and was completed to the top of the skew-backs, 52.2 feet above high water, by the 17th of July, the cornice and skew-backs being set and ready for the iron.

521,000 feet B.M. of timber were used in the caisson.

Pier III. was located on the east side of Sedgwick Avenue, an important thoroughfare, and at or in the foot of the steep bluff. The hard rock was, in places, as indicated by the borings, at a depth of seventy-five feet below the surface. The excavations were in a partially decomposed gneiss of unequal hardness. The strata were very much inclined, and had a great tendency to slide. All the sides of the pit were therefore systematically supported by sheathing with four-inch plank, behind longitudinal stringers, these latter being shored with 12 x 12 inch timbers, extending entirely across the pit in both directions.

At a depth of forty-three feet the rock, when tested with twenty-four and twenty-six tons to the square foot, showed no signs of yielding. The excavations were then suspended, and a bed of concrete six feet in thickness, made with Portland cement, was laid over the entire bottom of the foundation pit, and upon it the masonry was commenced. This, as in the other piers, was made with a facing of heavy granite blocks and an interior of concrete. The masonry of this pier was commenced on the 16th of October, 1886, and it was ready for the iron work early in June following.

The ends of all the piers are vertical. The long faces of main piers below the springing line batter three-quarters of an inch to the foot, or one in sixteen.

The foundations of all the small piers were commenced in the winter and spring of 1887. On the west side of the river they were founded upon the hard gneiss at different depths—sometimes ten or twelve feet below the surface of the ground. The excavations were levelled up with concrete, and the pier was built up to natural surface with rubble masonry faced with gneiss dressed to horizontal beds. Above the surface the piers, which are solid throughout, are faced on the ends with granite; on the long faces with Roxbury gneiss with granite quoins and impost courses. The ends are vertical; the long faces batter one in twenty-four.

On the east side of the river the arch piers are founded upon the partially decomposed gneiss, which becomes harder as we ascend the hill, so that the pier (C) which separates the bridge proper from the approach is built upon the hardest rock. The east abutment of the Undercliff Avenue arch and the approach walls throughout are built upon the solid rock.

The work on the main piers did not stop with the setting of the skewbacks, but was continued without intermission until their completion to the height of the cornice courses.

SUPERSTRUCTURE.

Above the skew-backs, piers I. and III. are cellular in construction, with walls six and seven feet thick at the base and uniformly four feet thick at the top,—their height above this level being nearly one hundred feet.

Pier II. above the skew-backs was built of concrete with two vertical cells, each ten feet by ten feet, to a height of one hundred and thirty-two feet above tide-level, where larger chambers were formed and walls were arranged for the anchorages of the pier beams, which take the wind pressures from the metallic arches.

All the main piers are faced with granite ashlar, backed with rubble masonry or concrete, with granite quoins two feet by three by six. The interior walls are also of rubble, except pier II. as described above, and the lower portion of the walls of pier III., which were built and backed with concrete. The upper portions were made with rubble masonry. In one cell of each pier is a series of iron ladders reaching from the skew-backs to the roadway of the bridge.

The arches of the abutments are semi-circular, of sixty feet clear span, and a length between faces of eighty feet eight inches. The voussoirs of the faces are of granite (Plates XXXV. and XXXVIII.), all three feet in depth, except the keystones, and, alternately, four and six feet long. The interior voussoirs are of granite or gneiss, two feet two inches deep at the crown, and three feet six inches at the joint inclined thirty degrees. Below this they are of variable depth and are bonded into the rubble masonry of the spandrils. These are built solid to twelve and fourteen feet above the impost.

The masonry arches were commenced in September, 1887, and were carried forward as rapidly as the stone was received from the quarries, but they were not all closed until March, 1888. About one-third of the whole was set in December, 1887. Some seven hundred cubic yards of arch masonry were hoisted seventy-five to one hundred feet and set in nine days with a single derrick and steam hoister. Portland cement was used in setting the arch stones, as it is injured much less than the native cements by the low temperature prevailing during this period. Very few of the arch stones, however, were set when the thermometer was below freezing. For the spandril masonry salt was dissolved in the water used in making mortar, and on some three or four days during the season, when the thermometer was near zero, Fahrenheit, no masonry at all was laid.

Over the arches four longitudinal walls of rubble masonry, generally four feet thick, extend through the abutments and the adjoining piers, and with the side walls, divide the interior into five longitudinal chambers, which are covered by brick arches supporting the roadway. These arches, commenced in April, 1888, were not completed until July. They were built upon centres which, when a section was completed, were slightly lowered and pushed forward for building the next section, sliding upon wooden plates at the springing line. As they were built, they were backed and levelled up with concrete or rubble masonry. The roadway surface is coated with half an inch of coal-tar distillate and Trinidad bitumen in equal proportions, and upon this is laid the bituminous concrete substructure for the asphalt wearing-surface. The cellular structure of the abutments is continued over the Undercliff Avenue arch.

At the eastern end the hard rock rose nearly to the roadway surface. It was required, however, to open a new street along the south side of the east approach, the grade of which would be many feet below the roadway of the bridge. It was, therefore, necessary to excavate the rock to the grade of the street proposed, and to support the roadway of the bridge with a masonry wall.

The stairway, as shown on the plans, ten feet in width, was made to give access to the bridge from the street below. It is built of Roxbury gneiss with granite quoins, a string and parapet of finely-dressed (8-cut) granite, and platforms and steps of North River blue-stone—a material which does not, like granite, become slippery by long service.

The cornice, of Maine granite finely axed, was delivered finished at the bridge and ready to be set. The parapets, four feet high upon abutments and three feet six inches on the approaches, were of a finer granite—8-cut on all interior faces. They were delivered and set in the spring and summer of 1888.

On a portion of the east approach the sidewalk is protected by a rail in granite posts. The rails are of wrought-iron pipe, four and three inches in diameter, covered with bronze one-eighth of an inch thick drawn over the iron.

In the original plans there were two sixty-foot arches, which could have been built at any time during the progress of the work. The contractor, after building one, could have removed his centering and used it for the other. But with seven arches and the entire roadway of the abutments dependent upon them, it became necessary to provide and erect centering for all of them at the same time, that every delay might be prevented. The centres used were strong and unyielding. They contained an excess of material, and the height might have been considerably reduced. As a matter of fact, the contractor, wishing to build the spandril backing to a completed arch did, in several instances, set the arch stones of the adjacent arch to a height of ten or twelve feet above the impost before the centering for the arch was placed.

The centering for the oval arch over Undercliff Avenue was of a cheap and satisfactory form.

The voussoirs or arch stones were set by derricks, generally placed on the crown of the arch centres.

Great care was taken to set each stone accurately to its place, blocking up where necessary on the lagging of the centres. The centres were not struck ; they were simply allowed to stand until, by the action of the weather, they were found to be free. No perceptible settlements took place.

The stones were cut to plane beds to lay half-inch joints. They were laid in a good mortar of Portland cement. The courses near the crown, the beds of which were too steep to take a bed of mortar, were filled with thin mortar worked in with a steel blade.

1,500,000 feet B.M., spruce and hemlock, were used in trestles for landing materials, and in centres for masonry arches.

The roadway is of Trinidad asphalt on a bituminous base. Upon the fine concrete, hereafter described, on the metal part, and upon the coated concrete covering of the brick arches upon the masonry, the roadbed is made up to within three and a half inches of the top, with broken stone in layers four to six inches deep, each layer well rolled by a steam roller of about two hundred and fifty pounds to the linear inch; and over the broken stone hot coal-tar distillate is poured. Upon this is placed a binder course made of very fine broken stone and coal-tar distillate, mixed by machinery, spread two inches thick and well rolled; the asphalt wearing-surface, one and a half inches in thickness, is laid upon the binder course. The roadway is crowned nine inches in its width of fifty feet. The drainage of the roadway over the metal structure is to the abutments. The slope is very slight from the centre pier to the centre of the arches; being in hot summer weather not over four inches in two hundred and fifty-five feet, half of which is formed in the gutter and the remainder by the grade of the roadway. In cooler weather, when the fall in temperature has lowered the crown of the arch, the slope is greater. From the centre to the abutments it is from eight to twelve inches. Considering the smooth surface of the roadway and gutters, this slope was believed to be sufficient. On the abutments, which are level, the gutters are given a slope of three inches toward the basin heads of the drain-pipes, which are spaced from seventy to one hundred and forty feet.

The drain-pipes, eight and twelve inches in diameter, descend vertically, secured to the interior wall surfaces, and discharge into transverse underground drains which are connected with a twelve-inch and fifteen-inch *terra cotta* pipe, extending the entire length of the bridge on each side of the river.

The roadway, commenced in August, 1888, was not completed until November.

The sidewalks, about 75,000 square feet in area, are composed of large flags of blue-stone six and nine feet long, not less than five feet wide, and from three to five inches thick, planed on the top surface and axed on the heads, which rest upon the granite curb. They were laid in August, September, and October, 1888.

A channel is left in the concrete under the flags of the masonry portion, in which the gas-pipes are laid. They would be more accessible if placed under the longitudinal arches of the roadway, but a leak would fill the chambers with gas and might be the cause of an explosion, with possible loss of life. Pipes for electric conductors are laid alongside the gas-pipes.

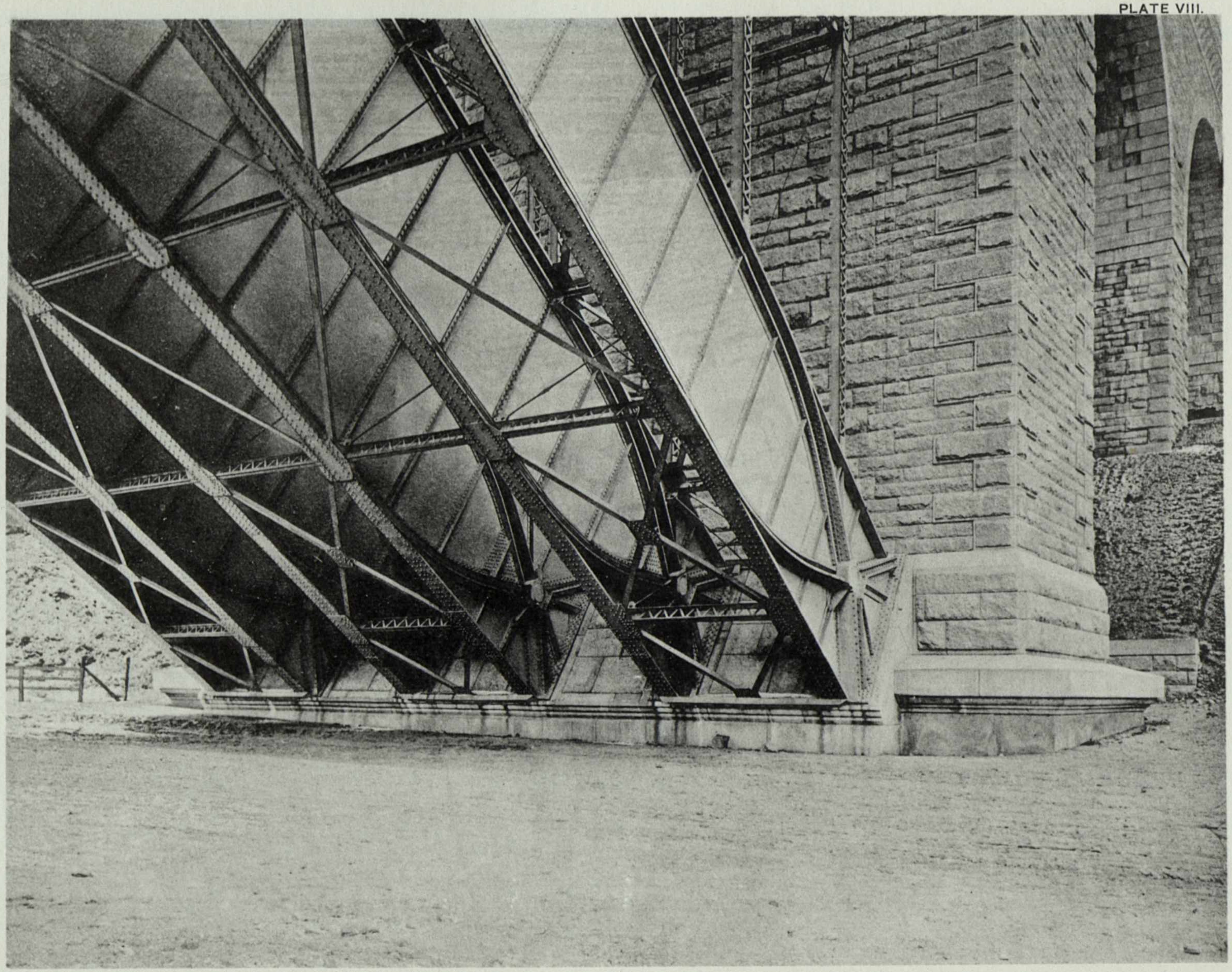
METAL WORK.

Each of the steel arches is composed of six ribs with free ends resting upon pins. The span between pin-centres is five hundred and eight feet eight and a half inches, the rise to neutral axis at crown eighty-nine feet ten inches. Clear span between piers, five hundred and ten feet; rise from apparent springing line to soffit, ninety-one and a quarter feet. The ribs are of a nearly uniform depth of thirteen feet (with slight variations caused by varying thickness of flange-plates), and are composed each of a web-plate of mild steel three-eighths of an inch in thickness (except for the end-panels, which are three-quarters of an inch thick), with double flanges at top and bottom, and stiffeners of angle iron at intervals of about five feet. The outer flange-plates are twenty inches wide, and vary in thickness from two and one-eighth inches to three and one-sixteenth inches. The inner flange-plates—two in each flange—are twelve inches wide by three-quarters of an inch thick. The six angle irons in each double flange are six by six by five-eighths inches.

Each rib is formed of thirty-four segments of such length that the horizontal projection of the extrados of each segment is fourteen feet eleven and a half inches—the distance between centres of the posts which stand upon the joints and carry the roadway.

The ends of the segments are planed and stiffened with angles, through which they are riveted together. The joints of the flanges are covered with splice-plates.

Each rib rests at its ends upon pins of forged steel, thirty-four inches long and eighteen inches in diameter. The pins lie in steel bearings, which are carried by pedestals made of plates and angles upon a base of two superimposed three-quarter inch steel plates, thirteen feet by four feet four inches, resting upon and bolted to the granite skew-backs. To secure uniformity of bearing and close contact, wool felt filled with asphalt is interposed between the pedestal and the granite. The ribs are connected by lateral bracing on both top and bottom flanges, and by sway-bracing on the segment joints—all of steel latticed beams and angles.



BEARING OF STEEL ARCH UPON PIER III.

The transverse floor-beams, spaced about fifteen feet, are built of plates and angles two feet six inches deep under the carriage-way, while the portions under the sidewalks rise to a height of about four feet. They are supported from the extrados of the ribs by posts, formed each of two ten and a half inch iron channels latticed on the sides. The posts are rigidly attached to the flanges of the ribs, to the horizontal longitudinal struts, and to the floor-beams, and are connected and braced transversely in two sets of three each by horizontal struts and diagonal ties, all pin-connected.

The transverse floor-beams carry longitudinal stringers—rolled "I" beams—fifteen inches deep under the carriage-way and ten and a half inches under the sidewalk; all spaced three feet between centres.

The flooring is formed of buckle-plates, which rest upon the longitudinal stringers and are riveted to them. They are made generally of plates three feet wide and fifteen feet long, swedged cold into shape, and forming in one piece five flat domes. These are crowned two inches. The metal is three-eighths of an inch thick. The transverse joints have cover-plates. The plates being thus connected to the stringers and to each other, the entire flooring forms one rigid surface, and no other wind-bracing is needed. But the wind-pressure must be transmitted to the masonry piers. To provide for this, and at the same time to permit the metallic flooring to expand and contract freely under changes of temperature, the end-stringers and the buckle-plates at each end of each span are riveted to a vertical transverse beam, on the lower flange of which an offset is built three and a half inches high, with planed vertical faces looking outward and about twelve and a half feet apart. This rests in a corresponding recess in a short, strongly-built beam firmly secured in the masonry. A pier beam of iron plates corresponding to that against which the stringers abut and, like it, rising nearly to the surface of the finished roadway, is anchored to the masonry of the pier, and attached to the movable beam by means of a trough of plate iron ten inches deep, and at mean temperature, eight inches wide. This gutter opens or closes as the metallic structure contracts or expands. The floor being fixed to the arch at the middle of the span, slides at both ends upon the masonry, and lateral movement is prevented by the short, wide projection or offset on its under side, confined in a corresponding recess fastened to the masonry, as above described.

The false-works for the iron spans are shown by Plate LVI. Those for the land span were erected in the spring and summer of 1886, the bents being generally supported upon timber, flat upon the ground. They were built of 10 x 10 inch hemlock posts, with 3 x 10 inch stringers, and braces of spruce timber put together with ⅞-inch bolts. About 1,500,000 feet B.M. of timber were used.

The false-works were carried over Sedgwick Avenue and the railroad tracks by using the iron floor-beams made for the bridge.

Some trouble was experienced when the arch was partially erected, partly from the deformation of the centering, partly from its settlement. It was re-enforced with struts transmitting the weights directly to fixed points.

The false-works for the river span were built upon piles driven into the mud of the river. No settlement or displacement of any kind occurred.

The method of manufacture of the steel was not prescribed. It was required to stand certain physical tests, as described in the Specifications, p. 73. A few of the tests are given in the accompanying tables, showing the form of inspector's return and some of the results of the tests.

The iron was manufactured by the Passaic Rolling Mill Company, and made up in its shops.

A small quantity of steel angles, procured from the Atkins Iron Works at Pottsville, were made by the Clapp-Griffiths process.

The steel plates and angles for the arch ribs were made in Pittsburg, by the Spang Steel Works, and by the Union Mills (Carnegie, Phipps & Co.), of open hearth steel. The plates were rolled in the universal mill, rendering unnecessary the planing of the edges, except on bearing edges. All steel was inspected at the mill.

The steel was shipped in plates and bars to the Passaic Rolling Mill Company's Works at Paterson, N. J., and there made up into parts, shipped thence to the site of the work, erected, bolted together, and when free from the centres, riveted up.

The parts for the East span were brought to the site by rail. For the transportation of the segments—thirteen feet deep and more than fifteen feet long—a slot was cut in the deck of a platform car between the trucks, the segment lowered through it, and supported from the deck of the car by inclined struts under the upper flange.

The method adopted in the shop for planing the joints of the segments to the proper angle was as follows:

The planer being fixed in position, a stake was placed in the field outside the shop on the line of action of the machine prolonged, at the point where the lines of the joints of the segment would intersect. The joint at one end of the segment being finished, the other end was placed under the tool, and the segment was turned until the finished end sighted exactly to the stake planted in the field several hundred feet from the machine. As the curve is a parabola and the segments are of unequal lengths, this distance varied for each of the seventeen segments in the half arch.

As the segments composing the ribs were lifted from the trucks by the travellers, they were set in place upon blocking on the false-works, bolted to the segment below, and the lateral and sway-bracing connected. The segments were set to a curve three inches higher at the crown than the intended rise, to allow for the compression of the material when the centres should be removed.

When all but the last segments in each rib were in place, the blocking was removed and replaced by screws, the bottom and top lengths of the segments to be set were accurately measured, the segments were finished in the shop to exact dimensions, placed, and the supports at once released.

Most of the field-riveting was done by machinery, with an Allen riveter, operated by compressed air.

The erection of the land span (or No. 2) was commenced September 1st; it was swung clear of its support on the 17th to 21st of December.

Upon the closing of the land span the travellers were removed to the river span, and the erection of the upper works upon the former was carried on with smaller hoisters.

Commencing at the crown, the posts were erected and braced simultaneously in both directions, the transverse floor-beams and the longitudinal stringers set, and finally the buckle-plates were placed and riveted up.

Span No. 1 was swung on the 30th and 31st of March, 1888.

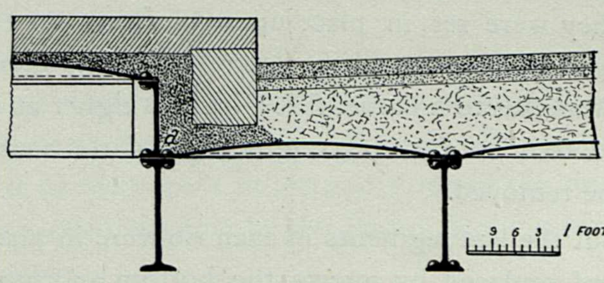
The erection of the two spans occupied an average of about two hundred men from September 1, 1887, to May 11, 1888, at which time the structural portion of the iron work was complete.

After erection all cracks and open joints were filled with a cement of lead and iron filings, and drain-holes were cut in all pockets where water could lodge.

All apparent iron and steel surfaces were painted an uniform gray color, darker than the granite masonry, but in harmony with it.

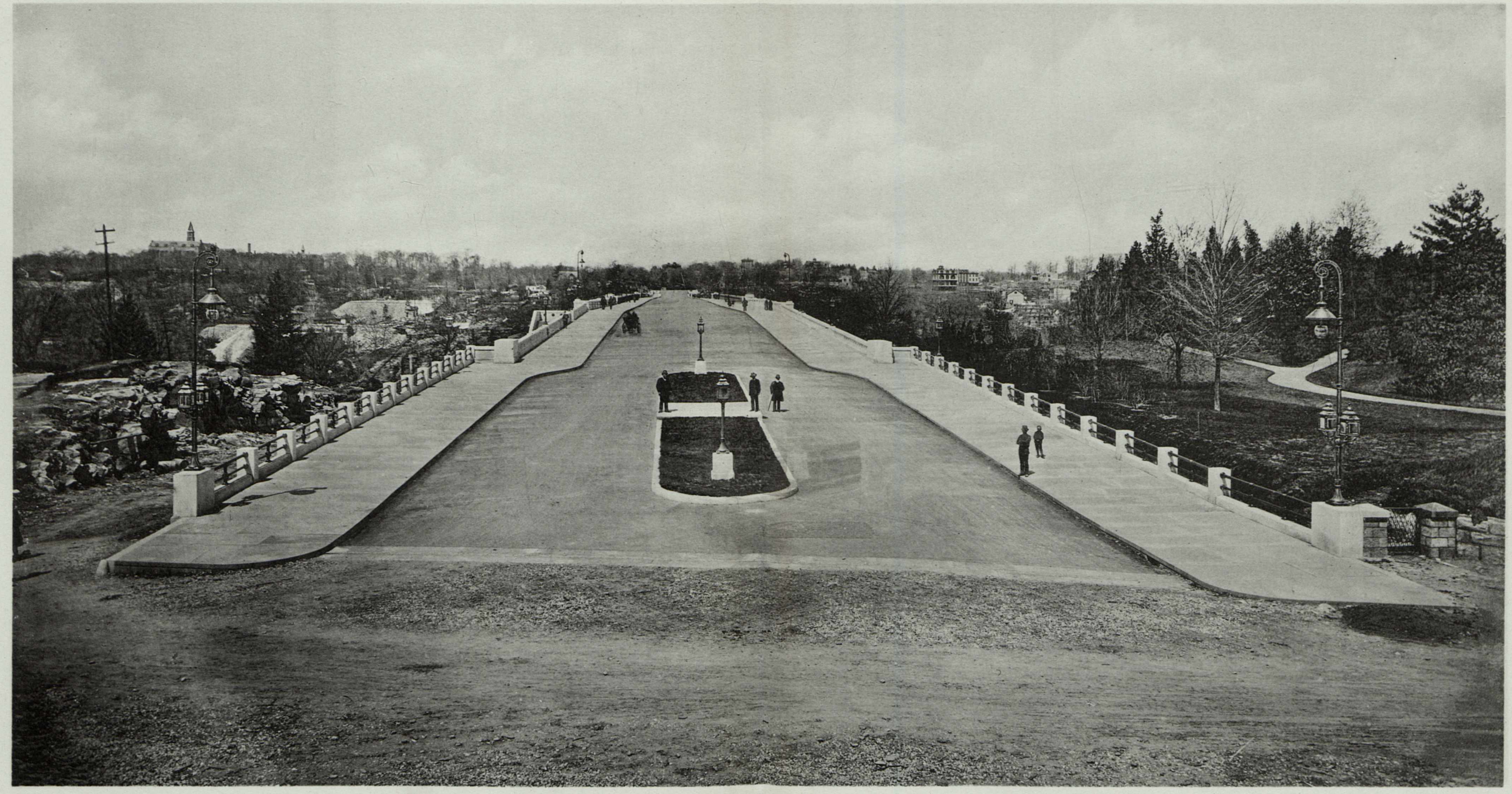
The painting, commenced in September, was completed early in December,—the average force employed being about 50 men.

When the buckle-plates were laid, they were painted with asphaltum varnish (Trinidad bitumen dissolved in light petroleum). This was covered with a fine bituminous concrete made with coal-tar distillate, mixed with



small broken stone and sand, afterward poured with hot distillate, and pressed with hot irons. Experience seems to have shown that the distillates of coal-tar retain their properties, when we can exclude the air, which promotes the evaporation of the oils remaining in them. They are more sensitive than the bitumen to the effects of heat and cold. Their impermeability, however, may be doubted.

The buckle-plates under the sidewalks are raised above those of the roadway. The space behind the curb was filled with the fine concrete mentioned, poured with distillate, and smoothed and pressed with heated irons; nevertheless, after the completion of the bridge, the rain water entering through the joints of the flagging, found its way to and through the joint at (*a*). The same thing may be observed on the very handsome



THE WASHINGTON BRIDGE.

(VIEW OF ROADWAY LOOKING WEST.)

Girard Avenue bridge in Philadelphia, which was first covered entirely with a coat of vulcanite, composed of distillate, Trinidad asphaltum, and fine sand. There is a continuous leak under the gutter of that bridge.

Over the metal arches the gas-pipes and pipes for electric wires lie on top of the floor-beams directly under the balustrade. They are boxed in or covered with non-conducting material.

The connection of the roadway on the metallic structure with the masonry by means of an expansion trough has already been described. It was expected that there would be cracks in the asphalt surface over this expanding gutter, but these were considered much less objectionable than the ordinary iron expansion plates. As a matter of fact, cracks did occur, though in no case so wide as the corresponding contraction of the iron. They were filled with soft asphalt, but reappeared when a cold wave followed a warmer temperature than that which had caused the crack. In the warm summer weather the edges came together, and the pressure continuing, they were tilted up, forming a low ridge across the roadway. The only objection to the crack has been that it was irregular and would extend outside the gutter, giving water access to the masonry. This may be remedied by simple means. Since the completion of the bridge, the expansion joints have been renewed and a metal plate or a smooth surface placed underneath the wearing part, in order to permit the expansion of the iron to be taken up by the stretch in a greater length of asphalt wearing-surface. It has not been a success; two cracks forming instead of one, and they not near the joint.

The cornice of the metal structure is of cast-iron built upon a wrought-iron plate five-sixteenths of an inch in thickness. It is bolted to the ends of the floor-beams and supported by intermediate brackets five feet apart.

The water-table and the large members of the cornice are supported by cast-iron brackets placed every five feet and bolted to the wrought-iron plate.

Provision is made for the total expansion and contraction by cutting away the return of the granite cornice and extending the iron cornice into it. The joint is close upon the face; on top it is covered with a copper plate.

To allow for the slight vertical movement of the end post under changes of temperature, the end sections of the cornice are attached by bolts in oval holes, the other end being supported on the masonry of the piers. The base and the rail of the end panel of the parapet slide freely in the half posts of bronze fastened to the masonry parapet. All contacts with the masonry are made by bronze parts to prevent discoloration by iron rust.

The lowest member of the cornice was made a closed section to prevent the collection of water and dirt, and is, therefore, cored.

Both the consoles and the dentils of the cornice were cast in single pieces. They were then placed in the sand, thus forming part of the mould, and the remaining metal poured around them to complete the member. All the parts of the cornice were cast in sections about five feet long, faced off on an emery wheel, and bolted end to end.

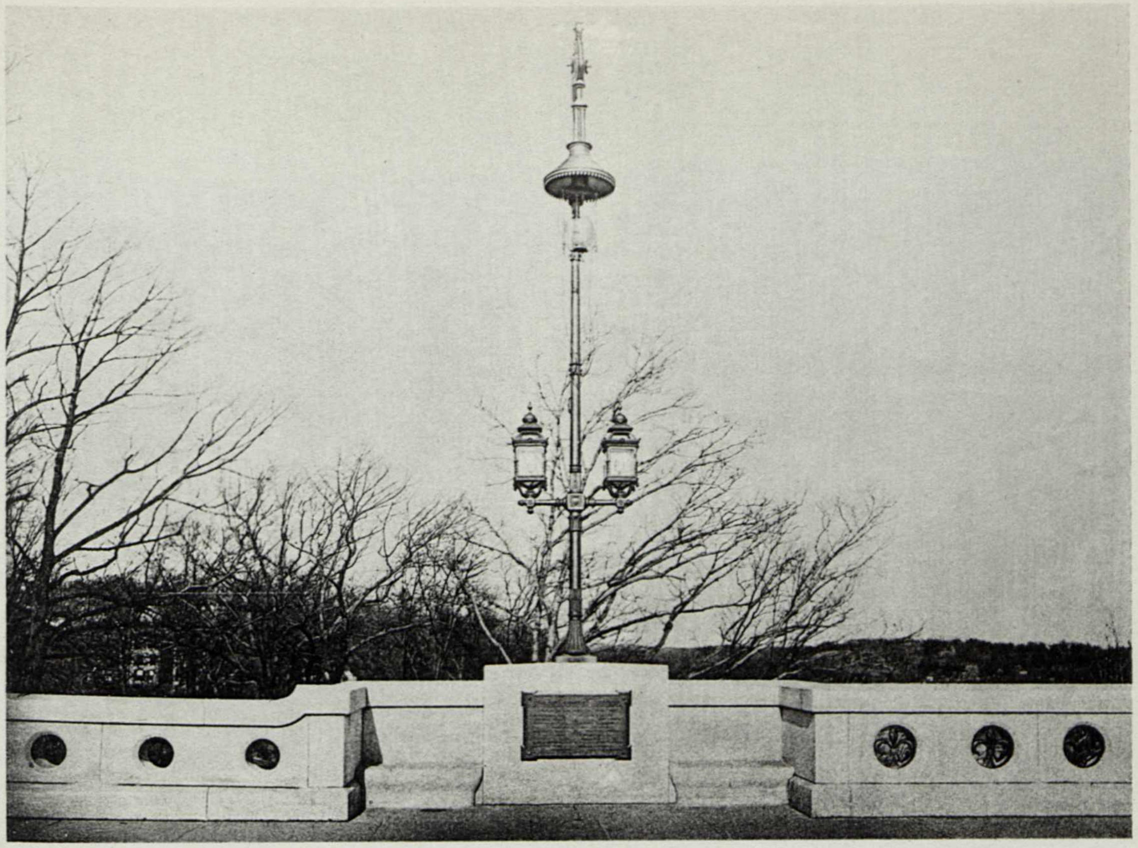
The posts of the cast-iron parapet rest upon and are bolted to the transverse floor-beams, obtaining thus a firm support. The ornamental panels, dome-cap, and base are attached to the post by countersunk screws.

The base, the rail, and the ornamental filling were each cast in one piece for each panel fifteen feet in length.

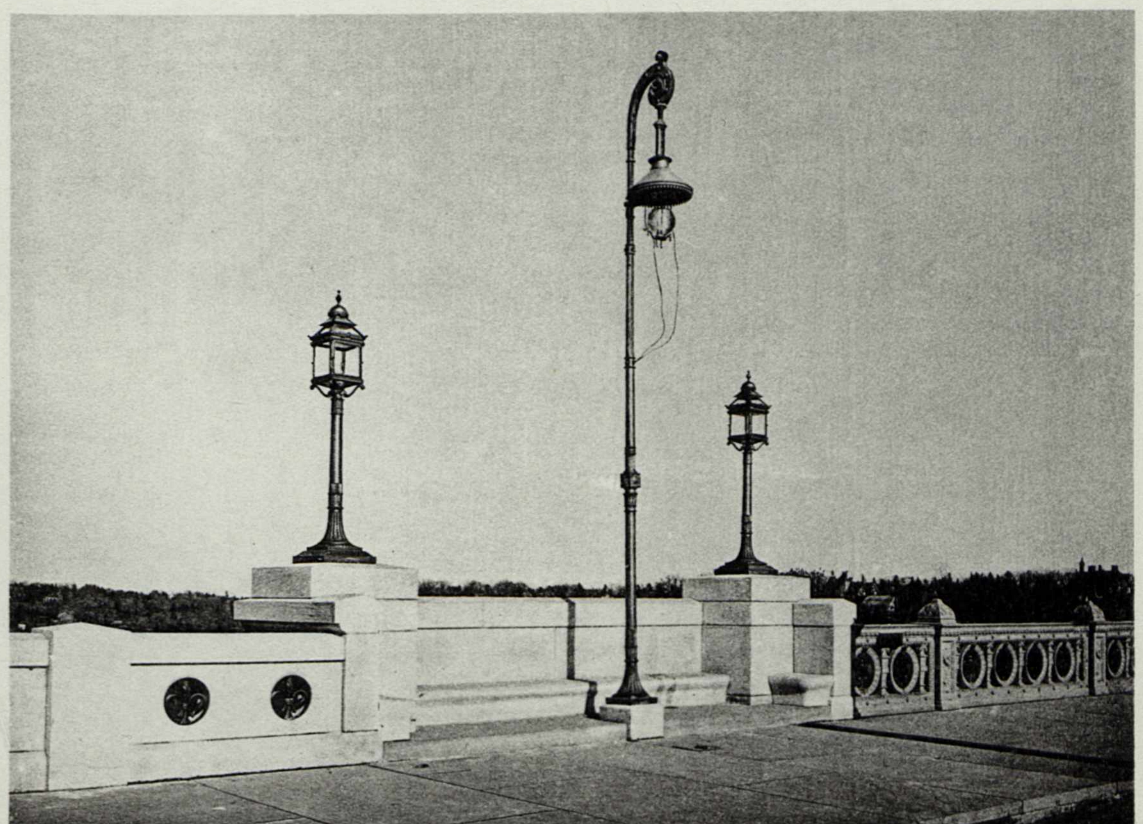
A panel of the parapet consists of three pieces—a top rail, an ornamental centre, and a bottom rail. The ornamental centre, like the other members, was cast in one length from post to post. It measured thirteen feet nine inches in length, and thirty-six inches in depth, weighed one thousand three hundred and fifteen pounds, and to cast a panel required one hundred and one separate cores.

The bronze ornaments in the panels are fastened with bronze tap-screws with a cylindrical head, conical on the underside, in countersunk holes. The screw was driven home, the head was sawed off and filed down, leaving no trace of the fastening.

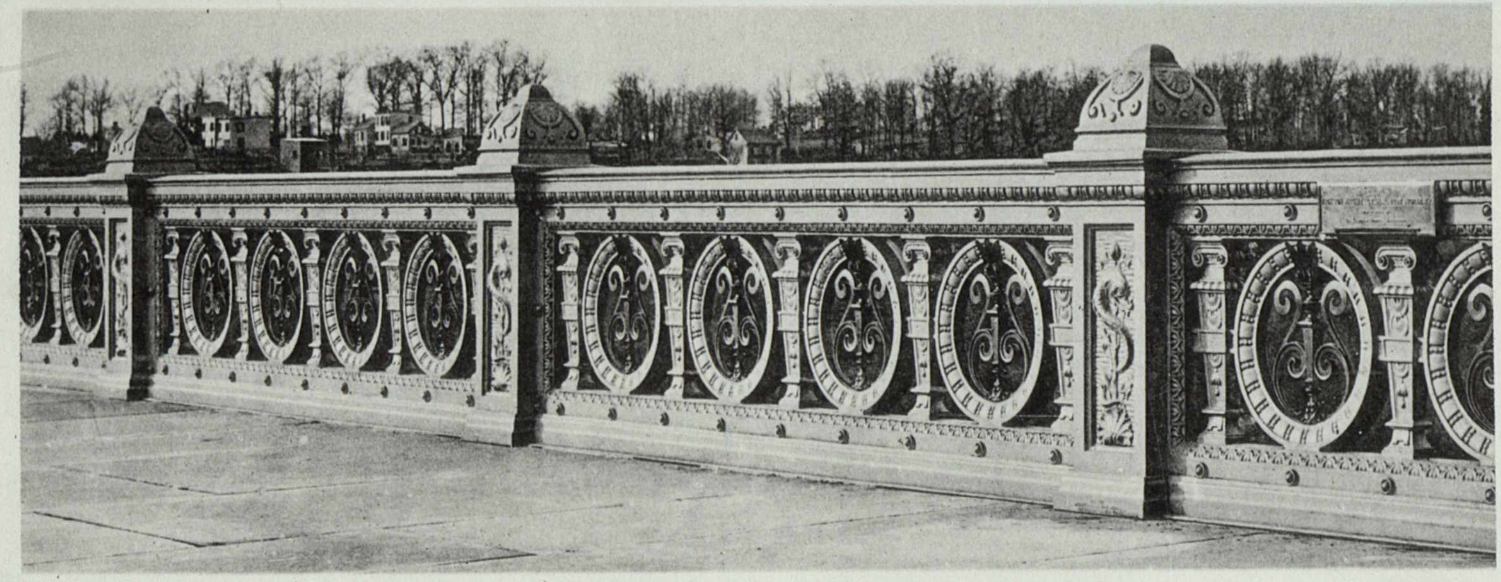
The gas and electric lamp-posts are entirely of bronze—fifty-seven for gas and fourteen for electric arc-lamps; eight of the latter also carry gas-lamps. Most of them stand upon the posts of the parapet, which, on the masonry, are drilled from top to bottom, and the gas-pipe or electric conductor passed through the granite block. The lamp-posts are secured by first dowelling to the granite an angle frame of cast-bronze, over which the



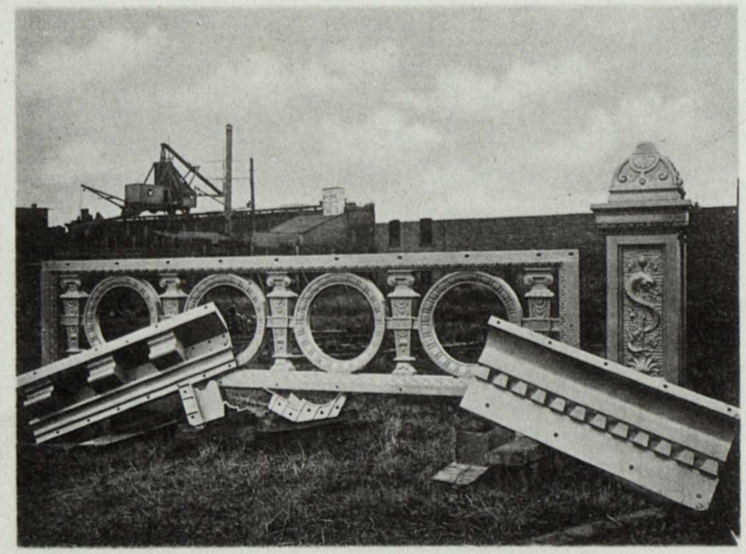
LAMPS, PIERS "C"

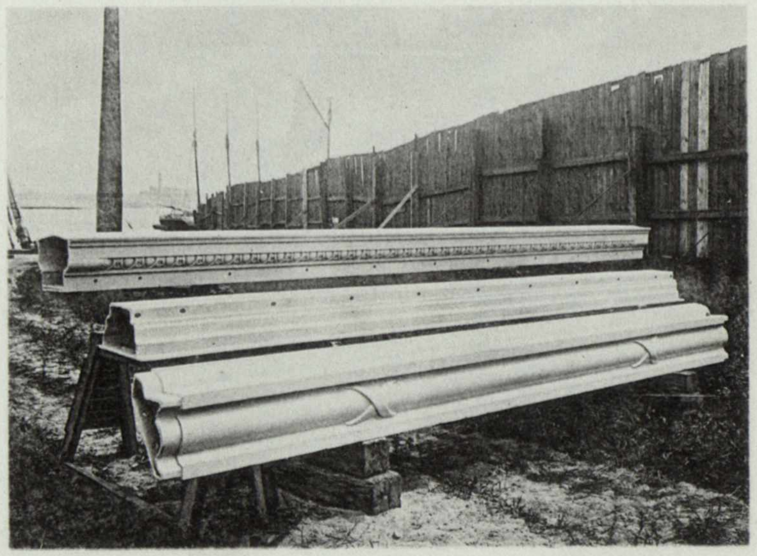


LAMPS, PIERS I. (II & III)



BALUSTRADE OVER METAL SPANS.





DETAILS OF BALUSTRADE AND CORNICE.

base of the post is placed, and to which it is secured with countersunk bronze screws. The electric lamps are overhung, carried by wire cords over small sheaves in the top of the post, and counterpoised by a weight inside the post. They may be drawn down to the sidewalk for cleaning, and are connected with the carbons by a flexible conductor issuing from the post at about half its height.

The work was substantially completed in December, 1888. The bronze lamps were finished after that date, electric conductors run, gas-pipes tested, etc., etc., and in March, 1889, the bridge was accepted from the contractors, and the final payments made to them. The entire cost up to that date was as follows:

Paid to Contractors, ...	$2,648,784.55
Engineering and Superintendence, . .	162,400.00
Expenses of Commissioners' Office, .	40,500.00

The force employed varied at different periods of the work. The average was about five hundred men, rather more than half being engaged upon the masonry. In addition to this, the granite and gneiss were cut at the quarries, the concrete stone was prepared at the quarry, and the iron and steel were made up at the contractor's shops.

The Act of 1888 required the Commission to purchase and lay out as a public park land one hundred and fifty feet in width on each side of the bridge. Owing to the difficulty of procuring the land, this portion of the work is still incomplete, although it is in progress.

PERSONNEL.

The Hon. William J. McAlpine was appointed Chief Engineer soon after the organization of the Commission in 1885, and retained that office until after the contracts were signed and work commenced. He was then, at his own request, relieved from duty as Chief Engineer and made Consulting Engineer, which position he held until the substantial completion of the work. He was succeeded by the author, who had been employed as Consulting Engineer some months previously, and remained as Chief Engineer until the completion of the work.

Early in 1886 Mr. Theodore Cooper was appointed on a special commission to assist the Bridge Commission in the selection of a plan, and was retained continuously as Consulting Engineer, revising plans and specifications, and later, more especially in charge of the inspection of the material, the construction, and erection of the steel arches.

Mr. Edward H. Kendall was Consulting Architect.

Upon the commencement of actual work in August, 1886, Mr. William F. Shunk was made Resident Engineer, which place he resigned in the latter part of September of the same year. Mr. Alfred Noble succeeded him on the 1st of October, and during his service all the foundations were completed, including the caisson work of pier II. The main piers were, generally, completed to the top of the skew-backs and ready for the steel arches; the small piers, from which the sixty-foot granite arches spring, were carried up to the impost courses, and the quarrying, cutting, and delivering of the arch stones commenced. At the end of June, 1886, greatly to my regret and that of the Commission, he resigned to take charge of the foundations and erection of the Cairo bridge over the Ohio, and since that time he has been engaged upon the deep foundations in the Mississippi (one hundred and four feet below low water) of the Memphis bridge.

Mr. John Bogart, well known as Secretary of the American Society of Civil Engineers and State Engineer and Surveyor of New York, followed him until the completion of the work, and he is still charged with making the park adjacent to the bridge.

The erection of the steel arches was superintended personally by Mr. Watts Cooke, the President of the Passaic Rolling Mill Company, who took up his residence near the site of the bridge during their erection. The working drawings of the metal work were designed by Mr. Frank A. Leers, Engineer of that Company, in consultation with Mr. Cooper, and in conformity with the specification and with the general plan adopted by the Commission. From them the plates of the metal structure in this volume were chiefly taken.

The original computations were also made by Mr. Leers and revised by Mr. Cooper. They were not, however, available to the author, and, as weights had since been modified to some extent, new computations were made for the stresses at every second joint. The results are given in the accompanying tables.

Mr. Tierney also, contractor for masonry, etc., was in personal charge of his portion of the work, giving it the closest attention from the beginning until final completion of the bridge.

The iron cornice and balustrade were designed by Messrs. De Lemos & Cordis, architects, for the Jackson Architectural Iron Works, by whom it was submitted in competition.

COMMISSIONERS:

Jacob Lorillard, from July, 1885.
Vernon H. Brown, from July, 1885.
David James King, from July, 1885.

SECRETARY:

Malcolm W. Niven, from September, 1885.

ENGINEERING DEPARTMENT:

William J. McAlpine, Chief Engineer, from September, 1885, to August, 1886; Consulting Engineer, from August 1, 1886.
Theodore Cooper, Consulting Engineer, from January, 1886.
William R. Hutton, Consulting Engineer, from April, 1886, to August 1, 1886; Chief Engineer, from August 1, 1886.
Edward H. Kendall, Consulting Architect.
William F. Shunk, Resident Engineer, from August 1 to Sept. 20, 1886.
Alfred Noble, Resident Engineer, from October 1, 1886, to June 30, 1887.
John Bogart, Resident Engineer, from August 1, 1887.
John McClellan, Principal Assistant Engineer.
Bernard Hufnagel, Assistant Engineer and Draughtsman.
George Devin, Ass't Engineer and Inspector of Erection of Metal Work.
Edward Raqué, Assistant Engineer.
George Leighton " "

JOHN GARTLAND, Assistant Engineer.
GEORGE H. CUSHING, " " and Inspector.
WILLIAM N. JACKSON, " "
J. H. GERCKEN, Assistant Engineer on Cost of Work.
GEO. J. BISCHOF, Assistant Engineer and Computer.
G. W. G. FERRIS, JR., Inspector of Steel Material.
F. W. SKINNER, Inspector of Steel Material.
C. S. COLBY, Inspector of Iron of Shop-work, and of Erection.
MICHAEL J. FENTON, Chief Inspector of Masonry.
L. L. C. BARTLETT, Inspector of Granite and Granite-cutting.
ADOLPH A. CAILLE, " " " "
O. W. VANDERBOSH, " " " "
ARTHUR CURRAN, Inspector of Masonry.
JOSEPH F. QUINN, " "
JOHN THORNTON, " "
GERALD MCMURRAY, " "
JAMES GIBLIN, " "
JOHN YOUNG, " "
S. P. HUGER, Inspector of Asphalt.
WILLIAM HUGHES, Inspector of Painting.
JACOB D. PATTERSON, Clerk; CHARLES F. STROHM, Book-keeper.

CONTRACTORS:

THE PASSAIC ROLLING MILL COMPANY, and MYLES TIERNEY.

WATTS COOKE, President Passaic Rolling Mill Co.
FRANK A. LEERS, Engineer Passaic Rolling Mill Co.
ST. JOHN CLARKE, Assistant Engineer, Passaic Rolling Mill Co.
JAMES YEARDLEY, Superintendent of Erection.

HERBERT STEWARD, General Assistant to MYLES TIERNEY.
CHARLES MCDERMOTT, in charge of all masonry on west side.
SOLON ANDREWS, in charge of receiving and distributing of material, east side.
BRYAN KELLY, excavation and concrete.
CHARLES SILLERY, Foreman of Masons.
ALEXANDER WHAN, " "
JOHN MCGOVERN, " "
ALBERT MCDERMOTT, " "

Mr. CHARLES B. BRUSH was employed by Mr. TIERNEY as Consulting Engineer.

SUB-CONTRACTORS:

For Foundation of Pier II., ANDERSON & BARR.
For granite, JOHN PIERCE, agent for the Bodwell and the Mt. Waldo granite companies.
For iron cornice and balustrade, bronze lamps, etc., etc., The Jackson Architectural Iron Works, GEORGE A. JUST, Engineer.
For asphalt roadway, The Barber Asphalt Paving Company, F. V. GREENE, Vice-President.

COMPARISON OF LARGE METAL ARCHES.

Elevations to the same scale are given on Plate LXIII. of all the existing metal arch bridges which exceed 500 feet span. The second and third are single track railway bridges, crescent shaped, with hinged ends and great depth at the centre. The first is a city street bridge, carrying two roadways at different levels. Unlike the preceding, it is deeper at the spring than at the crown, although supported by a hinged bearing at the extremity of the lower flange.

The St. Louis bridge carries a double track railway and a street for common travel at different levels. The curved chords are parallel throughout and the ends are fixed.

The Washington Bridge carries only a city street; the ribs are of uniform depth; the ends are articulated as in all the others except the St. Louis bridge. It alone has a solid plate web. All the others are braced between the upper and lower members.

The first three are constructed of iron. The original plans of the first provided for the use of 446 tons of steel in a total of 3,342 tons of metal. The use of steel was rejected by the examining commission. It was replaced with iron, adding 160 tons to the total weight of structure.

The St. Louis bridge is constructed of cast steel of very great strength, both tensile and compressive.

COMPARISON OF SOME METAL ARCHES OF LARGE SPAN.

	Name.	Location.	Character.	No. of Spans.	Length of Max. Span. Feet.	Rise to Intrados. Feet.	Depth at Crown. Feet.	No. of ribs to one Span.	Distance between ribs at Crown. Feet.	Distance between ribs at Springing. Feet.	Width between Parapets. Feet.	Weight of Structure per foot of span.	Weight of moving load per foot of span.	Ratio of dead to moving load.	Maximum strain upon metal. Lbs. per square inch.
1	Luiz I......	Douro R., Oporto, Portugal,	Two city streets at different levels, pin ends, braced web,	1	566	146.37	26.25	2	19.7	52.5	26.25	12963 lbs.	5186 lbs.	2.50	8674 lbs.
2	Garabit.....	Truyère R., Southern France,	Single track Railway, pin ends, braced web,	1	542	170.	32.08	2	20.4	65.6	16.4	2926 "	1034 "	2.83	7963 "
3	Pia Maria..	Douro R., Oporto, Portugal,	Single track Railway, pin ends, braced web,	1	525	132.4	32.87	2	13.	49.2	15.	2204 "	1647 "	1.34	7025 "
4	St. Louis...	Mississippi R., St. Louis, U. S.,	Double track Railway and city street, fixed ends, braced web,	3	520	47.	13.5	4	16.5	16.5	45.	8000 "	6000 "	1.25	*30000 " 20000 "
5	Washington..	Harlem R., New York, U. S.	City street, pin ends, plate web,	2	510	91.67	13.0	6	14.	14.	80.	13086 "	8000 "	1.656	14489 "

* 30,000 lbs. per square inch in compression.
20,000 " " " " " tension.

THE WASHINGTON BRIDGE.

(FROM THE NORTHEAST.)

TABLES OF STRESSES IN THE METAL OF THE ARCH RIBS.

R′ Stress, pounds per square inch due to bending moment.
R″ " " " " " tangential pressures.
R‴ " " " " " variation of temperature.

RESULTANT STRESSES, POUNDS PER SQ. INCH OF SECTION = R′ + R″ + R‴.
R_e " " on extrados or outer flange.
R_i " " on intrados or inner flange.

— indicates compression.
\+ " tension.
Extreme variation of temperature ± 75° Fahrenheit.

FORMULÆ FOR COMPUTATION.

NOTATION.

a = Half Span.
l = Half length of arc.
x, y = Co-ordinates of neutral axis.
s = Distance from origin to any section, measured on neutral axis.
Ω = Area of section of arch rib.
I = Moment of Inertia of same. v_1 v_2 dist. from neutral axis to upper or lower edge of rib.
α = Angle of tangent to neutral axis with horizontal.
F = Sum of the vertical forces, acting at any point.
r = rate of dilatation of metal per degree of temperature, Fahrenheit.
Q = Horizontal thrust.
M = Bending moment due to vertical forces (computed as for a straight beam).
Qy = " " " horizontal thrust.
μ = Resultant bending moment = M — Qy.
D = Coefficient for horizontal thrust—same for all loads.
N = Tangential pressure, *i. e.*, sum of projections of all exterior forces upon the tangent at the point x, y of neutral axis.
P = Shear, *i. e.*, sum of projection of all exterior forces upon the plane of the section.
E = Modulus of elasticity of the material (assumed 28,000,000).

$$D = \int_o^l \frac{y^2}{I} ds + \int_o^l \frac{ds}{\Omega}$$

$$\text{Horizontal thrust, } Q = \frac{\int_o^l \frac{My}{I} ds}{D}$$

Or by summation, s being the length corresponding to each section.

$$D = \Sigma_o^l \frac{y^2 s}{I} + \Sigma_o^l \frac{s}{\Omega}$$

$$Q = \frac{\Sigma_o^l \frac{My}{I} s}{D}$$

$N = F \sin \alpha + Q \cos \alpha$;

$P = F \cos \alpha - Q \sin \alpha$;

$R' = \frac{\mu v}{I}$, ($+\mu$ gives $-R'_e + R_i$).

$R'' = \frac{N}{\Omega}$

For temperature, $Q = \frac{E a r t^\circ}{D}$

$\mu = Qy$.

$N = Q \cos \alpha$.

$R''' = \frac{\mu v}{I} + \frac{N}{\Omega}$

I.—STRESSES IN ARCH RIB CAUSED BY DEAD LOAD.

Q = 1,422,600 lbs.

No. of Joint.	Bending.		Tangential.		Resultant.	
	R'_e	R'_i	R''_e	R''_i	R_e	R_i
1	— 546	+ 546	—8346	—8346	—8892	—7800
3	—1060	+1060	—7404	—7404	—8464	—6344
5	—1209	+1209	—6675	—6675	—7884	—5466
7	—1182	+1182	—6375	—6375	—7557	—5193
9	— 966	+ 966	—6183	—6183	—7149	—5217
11	— 745	+ 745	—6214	—6214	—6959	—5469
13	— 549	+ 549	—6444	—6444	—6993	—5895
15	— 357	+ 357	—6737	—6737	—7094	—6380
17	— 251	+ 251	—6856	—6856	—7107	—6605

II.—STRESSES CAUSED BY TOTAL MOVING LOAD—(100 LBS. PER SQUARE FOOT OF FLOOR).

Q = 502,460 lbs.

No. of Joint.	Bending.		Tangential.		Resultant.	
	R'_e	R'_i	R''_e	R''_i	R_e	R_i
1	— 40.5	+ 40.5	—2904	—2904	—2944	—2864
3	—106	+106	—2606	—2606	—2712	—2500
5	—195	+195	—2315	—2315	—2510	—2120
7	—200	+200	—2256	—2256	—2456	—2056
9	—239	+239	—2149	—2149	—2388	—1910
11	—276	+276	—2196	—2196	—2472	—1920
13	—314	+314	—2280	—2280	—2594	—1966
15	—346	+346	—2381	—2381	—2727	—2035
17	—359	+359	—2421	—2421	—2780	—2062

III.—STRESSES DUE TO MOVING LOAD ON ONE-HALF THE SPAN.

Q = 251,230 lbs.

	No. of Joint.	Bending.		Tangential.		Resultant.	
		R′ₑ	R′ᵢ	R″ₑ	R″ᵢ	Rₑ	Rᵢ
Loaded Side.	1	—1200	+1200	—1579	—1579	—2779	— 379
	3	—2921	+2921	—1354	—1354	—4275	+1567
	5	—3728	+3728	—1176	—1176	—4904	+2552
	7	—4548	+4548	—1093	—1093	—5641	+3455
	9	—4692	+4692	—1016	—1016	—5708	+3676
	11	—4454	+4454	—1035	—1035	—5489	+3419
	13	—3744	+3744	—1121	—1121	—4865	+2623
	15	—2361	+2361	—1204	— 204	—3565	+1157
	17	— 185	+ 185	—1211	—1211	—1396	—1026
Unloaded Side.	15	+2003	—2003	—1213	—1213	+ 790	—3216
	13	+3419	—3419	—1166	—1166	+2253	—4585
	11	+4179	—4179	—1115	—1115	+3064	—5294
	9	+4448	—4448	—1070	—1070	+3378	—5518
	7	+4389	—4339	—1087	—1087	+3252	—5426
	5	+3767	—3767	—1091	—1091	+2676	—4858
	3	+2805	—2805	—1148	—1148	+1657	—3953
	1	+1154	—1154	—1230	—1230	— 76	—2384

IV.—STRESSES DUE TO VARIATION OF TEMPERATURE = + 75° F.

Q = 25,240 lbs.

No. of Joint.	Bending.		Tangential.		Resultant.	
	R′ₑ	R′ᵢ	R″ₑ	R″ᵢ	Rₑ	Rᵢ
1	— 192	+ 192	—102	—102	— 294	+ 90
3	— 632	+ 632	— 97	— 97	— 729	+ 535
5	— 926	+ 926	— 94.5	— 94.5	—1020.5	+ 831.5
7	—1195	+1195	— 96.5	— 96.5	—1291.5	+1098.5
9	—1407	+1407	— 99	— 99.0	—1506	+1308
11	—1649	+1649	—104	—104	—1753	+1545
13	—1873	+1873	—111	—111	—1984	+1762
15	—2065	+2065	—119.8	—119	—2184	+1946
17	—2142	+2142	—121	—121	—2263	+2021

V.—STRESSES DUE TO DEAD LOAD, TOTAL MOVING LOAD, AND MAXIMUM VARIATION OF TEMPERATURE.

No. of Joint.	From Dead Load.		From entire Moving Load.		From Var. Temp. —75° F.		TOTAL.	
	Extrados.	Intrados.	Extrados.	Intrados.	Extrados.	Intrados.	Extrados.	Intrados.
1	—8892	—7800	—2944	—2864	— 294	+ 90	—12130	—10574
3	—8464	—6344	—2712	—2500	— 729	+ 535	—11903	— 8309
5	—7884	—5466	—2510	—2120	—1020	+ 831	—11414	— 6755
7	—7557	—5193	—2456	—2056	—1291	+1098	—11304	— 6151
9	—7149	—5217	—2388	—1910	—1506	+1308	—11043	— 5819
11	—6959	—5469	—2472	—1920	—1753	+1545	—11164	— 5844
13	—6993	—5895	—2594	—1966	—1984	+1762	—11571	— 6099
15	—7094	—6380	—2727	—2035	—2184	+1946	—12005	— 6475
17	—7107	—6605	—2780	—2062	—2263	+2021	—12150	— 6646

VI.—STRESSES DUE TO DEAD LOAD, MOVING LOAD ON HALF SPAN, AND MAXIMUM VARIATION OF TEMPERATURE.

No. of Joint.	Dead Load.		Moving Load on Half Span.		Temp. —75° F.		Resultant.		Resultant if Temp. = + 75° F.
	Extrados.	Intrados.	Extrados.	Intrados.	Extrados.	Intrados.	Extrados.	Intrados.	Intrados.
A									
1	—8892	—7800	—2779	— 379	— 294	+ 90	—11965	— 8089	— 8473
3	—8464	—6344	—4275	+1567	— 729	+ 535	—13468	— 4242	— 5506
5	—7884	—5466	– 4904	+2552	—1020	+ 831	—13808	— 2083	— 3934
7	—7557	—5193	—5641	+3455	—1291	+1098	**—14489**	— 640	— 3029
9	—7149	—5217	—5708	+3676	—1506	+1308	—14363	— 233	— 3047
11	—6959	—5469	—5489	+3419	—1753	+1545	—14201	— 505	— 3803
13	—6993	—5895	—4865	+2623	—1984	+1762	—13842	— 1510	— 5256
15	—7094	—6380	—3565	+1157	—2184	+1946	—12843	— 3277	— 7407
17	—7107	—6605	—1396	—1026	—2263	+2021	—10766	— 5610	— 9894
15′	—7094	—6380	+ 790	—3216	—2184	+1946	— 8488	— 7650	—11780
13′	—6993	—5895	+2253	—4585	—1984	+1762	— 6724	— 8718	—12464
11′	—6959	—5469	+3064	—5294	—1753	+1545	— 5648	— 9218	**—12516**
9′	—7149	—5217	+3378	—5518	—1506	+1308	— 5277	— 9427	—12241
7′	—7557	—5193	+3252	—5426	—1291	+1098	— 5596	— 9521	—11910
5′	—7884	—5466	+2676	—4858	—1020	+ 831	— 6228	— 9493	—11344
3′	—8464	—6344	+1657	—3953	— 729	+ 535	— 7536	— 9762	—11026
1′	—8892	—7800	+ 76	—2384	— 294	+ 90	— 9110	—10094	—10478
B									

Computed variation of rise under maximum variation of temperature, . . 2''.496

Observations were made of the variations of rise under different variations of temperature, and of the change of angle at the pin due to the same cause. The mean of the observations indicated a variation of rise per degree of temperature of . . . . 0''.053

Angle at pin, per degree 0.00001923

Computed deformation of the arch due to half the span being loaded.

At 9th joint, loaded side—Horizontal + 1''.30. Unloaded side, + 1''.25.
Vertical − 2''.31. + 1''.70.

Pressure on timber of caisson, foundation of Pier II., 111.6 pounds to the sq. inch.

The method of M. Henri de Dion for computing the resistance and deformation of a beam, either straight or curved, consists in the substitution of measurements by planimetre for the arithmetical computations, sometimes very long, that are otherwise required.

The formulæ for deflections due to bending moments are the following:

$$\Delta x = \Sigma \frac{\mu}{\mathrm{EI}} sy.$$

$$\Delta y = \Sigma \frac{\mu}{\mathrm{EI}} sx.$$

These require that the section with reference to which Δx or Δy is calculated, should have an invariable position. When the load is symmetrical the section at the key fulfils this condition.

On a line A B, the neutral axis developed, we lay off as ordinates the quantities $\frac{\mu}{\mathrm{EI}}$ at each point, and draw the curve through their extremities. The surface comprised between the line A B and the curve of $\frac{\mu}{\mathrm{EI}}$, measured with the planimetre, gives the total angular movement, counting as positive the surface above the line, and negative that which is below.

From this surface, and on a plane perpendicular to it, we lay off the values of y (or x) corresponding to each section and we obtain volumes having the surface for base and for heights the ordinates y (or x) — positive when they correspond to positive angular movements and to positive ordinates. The sum of the volumes for one curve gives the total horizontal (or vertical) displacement.

For the displacement of any other point whose ordinates are x', y', $x' - x$, and $y' - y$ must be substituted for x and y, and the curve of $\frac{\mu}{\mathrm{EI}}$ is used only so far as the point $x\ y$.

If the load is not symmetrical about the key the section at that point does not remain vertical. In that case the arch is supposed to be fixed at one end and the displacement of the different points ascertained as before. But the free end of the arch may come above or below its proper place, and a graphic projection is needed to bring it to its true position.

As this method of volumes is not suited to planimetric measurement, MM. Molinos and Seyrig suggest a further simplification—the graphical multiplication of $\frac{\mu}{\mathrm{EI}}$ by x or y, as shown by the construction at Section 11 of Fig. 1, Plate LXII. The value of $x' - x = (2a - x)$ is plotted at any convenient angle with the vertical, and upon it a length equal to unity is taken. From this point to the corresponding $\frac{\mu}{\mathrm{EI}}$ a line is drawn; a parallel to this line from the end of the oblique ordinate $(2a - x)$ intersects the vertical at a distance $\frac{\mu}{\mathrm{EI}}(2a - x)$ from the base. The operation being repeated for each point, the surfaces so formed, measured with the planimetre, give the volumes that would have been obtained by direct computation.

De Dion's method is not convenient for computing deflections of intermediate points under unsymmetrical loads, as it requires a separate construction for each point. It is better in such cases to recur to direct computation. The method indicated in Fig. 2, gives approximate results. The quantity $\frac{\mu s}{\mathrm{EI}}$ for each section (which may be measured from the curve given), is laid off from the tangent of the preceding section and extended to the vertical through the free end of the arch rib B. The curve terminates at B′, the position the free end of the arch would take under the conditions assumed, and the real deflections are measured from the line A B′. That this is only approximate is due to the necessary distortion of the figure. Deflections here referred to are those due to the bending moments. To them must be added for tangential compression:

$$\Delta x = \Sigma_{x'}^{o} \frac{Qs}{\mathrm{E}\Omega}$$

$$\Delta y = \Sigma_{y'}^{o} \frac{Fs}{\mathrm{E}\Omega}$$

CONDENSED STATEMENT OF QUANTITIES AND COST OF THE PRINCIPAL CLASSES OF WORK, ETC., IN THE COMPLETED BRIDGE.

	Quantity.	*Cost.*
Dressed granite in piers, . . .	8,358 cubic yards,	$203,101.22
Granite cornice and parapet, .	2,300 "	201,244.50
Voussoirs of arches — dressed granite and gneiss, ...	15,491 "	248,392.74
Ashlar facing — granite and gneiss, ...	16,545 "	174,761.50
Concrete, ...	29,348 "	161,052.00
Earth excavation, including deep foundations and foundations less than 22 feet under mean high water, ...	31,219 "	80,048.40
Rock excavation, ...	26,504 "	29,211.12
Embankment, ...	12,815 "	7,538.00
Cast-iron drain pipes, ...	61,180 pounds,	82,618.95
Flagging, ...	151,078 square feet,	49,576.95
Curb, ...	6,166 linear feet,	6,557.50
Gas-pipes and pipes for electric wires, ...	8,033 "	4,940.60
Gas lamps with bronze posts, .	73	16,062.30
Electric lamps on bronze posts,	14	11,228.00
Foundation for pier II., more than 22 feet below mean high water, ...	4,052 cubic yards,	182,353.50
Steps and platform, ...	1,663 linear feet,	4,910.75
Asphalt roadway, including 3,656 cubic yards of bituminous concrete base, ...	13,742 square yards,	62,782.30
Portland cement (cost in excess of the cost of Rosendale cement,—the latter estimated at $1 per barrel), ...	23,995 barrels,	32,355.25
Rosendale and other American cements (price included in price of masonry), ...	39,487 "	
Steel in arch ribs and bracing, .	7,549,606 pounds, }	777,359.00
Iron in posts, bracings, and floor,	5,927,816 " }	
Cast and wrought iron in cornice and balustrade, . . .	1,233,874 "	132,260.00

For specific prices, see schedule, page 76.

NOTE.—The data available when the original plans were prepared indicated a rock foundation for pier II. at 22 feet below mean high water. An additional price was inserted in the contract to provide for the greater depth made known by subsequent borings. The cost to the city of the foundation of pier II. below the level of mean high water was, for 7,726 cubic yards of masonry and timber sunk to 40.6 feet below high water, $30.64 per cubic yard.

WAGES PAID.

Foreman (General), ...	$7.00 to $8.00 per day.
Foremen, ...	4.00 "
Masons, ...	3.50 "
Stonecutters, ...	3.50 "
Drillers, ...	2.00 "
Laborers, ...	1.75 "
Blacksmith, ...	2.50 "
" helper, ...	2.00 "
Engine drivers, ...	2.50 "
Carpenters, ...	3.00 "
Foreman of painters, ...	2.50 "
Painters, ...	1.75 "
Carts, ...	3.00 "
Wagons, ...	6.00 "

CONTRACT AND SPECIFICATIONS

FOR THE CONSTRUCTION

OF THE

HARLEM RIVER BRIDGE.

CHAPTER 487. LAWS OF 1885 AND 1888.

CHAPTER 487.

AN ACT to provide for the Construction of a Bridge over the Harlem River in the City of New York.

Passed June 11, 1885; three-fifths being present.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. The Mayor, the Comptroller and the President of the Board of Aldermen of the City of New York, are hereby authorized to appoint three competent persons Commissioners, to construct a suitable bridge for the passage of persons, animals, vehicles and traffic across the Harlem River in said City, at a point measured along the easterly water line of said river, distant about fifteen hundred feet north of High Bridge, and where the land on both sides of said river for the approaches to a bridge has already been acquired by said City. Said Commissioners, when appointed, shall immediately proceed to construct said bridge.

SEC. 2. Said Commissioners shall hold office till such bridge is completed, which shall be within three years from the passage of this Act. Said Commissioners shall not receive any salary or other compensation, but may provide all necessary materials and employ such persons as they may deem necessary for the work of constructing said bridge, and fix their compensation. In case a vacancy shall occur in the office of such commission by death, resignation or otherwise, the officers mentioned in the first section shall appoint a person to fill such vacancy.

SEC. 3. Said bridge shall be constructed of stone, steel or iron, or of one or more of these materials; shall in its width for passage be not less than eighty feet; and the grade thereof shall be at an elevation not less than one hundred and forty-five feet above mean high-water mark of said river. Said bridge shall always be free for the passage of persons, animals, vehicles and traffic, and when completed shall be kept and maintained in good order and repair by the Department of Public Works of said City.

SEC. 4. The Board of Estimate and Apportionment of the City of New York, shall, on the requisition of said Commissioners, specify the amount needed in any calendar year for the work of constructing said bridge, raise such amount by taxation on the real and personal property liable to taxation in said City. The Comptroller of said City shall pay from such moneys upon vouchers certified by said Commissioners, in form to be approved by said Comptroller, the cost of the materials, labor and services required in the constructing of said bridge, and the necessary expenses connected therewith. The said Board of Estimate and Apportionment is hereby authorized to use any unexpended balance for any year prior to the year 1885, toward the payment of the cost of constructing said bridge, and also to provide the necessary moneys for the construction of said bridge, or any part thereof, by the issue of bonds of said City whenever said bonds can be issued without violating the provisions of the Constitution of this State; and whenever such cannot be so issued, then the moneys necessary for such construction shall be provided by taxation, as provided in the next preceding section.

SEC. 5. This Act shall take effect immediately.

STATE OF NEW YORK. G. O. 350. NO. 963. INT. 759.

IN ASSEMBLY.

MARCH 5, 1888.

AN ACT to provide for acquiring and improving lands adjoining the bridge in course of construction over the Harlem River, under chapter four hundred and eighty-seven, laws of eighteen hundred and eighty-five.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. The commissioners appointed under the provisions of said chapter four hundred and eighty-seven of the laws of eighteen hundred and eighty-five, shall have power to acquire, in the name of the mayor, aldermen and commonalty of the city of New York, by agreement with the owners thereof, all or any portion of the lands, not exceeding one hundred and fifty feet in width, adjacent to the northerly and southerly lines of the lands heretofore taken for said bridge, between Boscobel and Undercliff avenues and Tenth avenue and adjacent to said southerly line between Aqueduct avenue and Undercliff avenue; payment for lands so purchased and for the improvement thereof, and the other works hereinafter provided for, shall be made in the same manner in which payments are directed to be made by said chapter four hundred and eighty-seven, laws of eighteen hundred and eighty-five.

§ 2. Said commissioners shall have power to fence, lay out, grade and otherwise improve the lands so acquired, and any other lands belonging to the city, lying within one hundred and fifty feet of the lands taken for said bridge, and when so fenced and improved, the said lands shall be kept and maintained as public parks, except as provided in the next section of this act.

§ 3. Upon and over the lands to be acquired on the south of the lands already taken for said bridge, between Aqueduct avenue and Undercliff avenue, said commissioners shall have power to lay out, sewer, pave, grade, flag and otherwise improve a public highway or street to connect Aqueduct avenue and Undercliff avenue, and shall make suitable and proper means of access from said street to the said bridge.

§ 4. The said commissioners shall have power to change the lines and grades of said Undercliff avenue and of Boscobel avenue to conform to the easternmost arch of said bridge within a distance of five hundred feet of said bridge, and to acquire in manner aforesaid the lands necessary therefor, and to grade, pave and otherwise improve the said avenues for public use as highways.

§ 5. When said commissioners shall have fully completed the bridge provided for in said chapter four hundred and eighty-seven, laws of eighteen hundred and eighty-five, and the parks and highways provided for in this act, they shall file a map thereof in the department of public parks of the city of New York; and thereafter said bridge from Tenth avenue to Aqueduct avenue, and the parks and highways shall be kept and maintained as public parks and highways by said department of public parks, and for no other purpose.

§ 6. This act shall take effect immediately.

This Agreement, made this 14th day of July, one thousand eight hundred and eighty-six, by and between JACOB LORILLARD, VERNON H. BROWN and DAVID JAMES KING, as Commissioners appointed and acting under an act of the Legislature of the State of New York, entitled "An Act to Provide for the Construction of a Bridge over the Harlem River in the City of New York," being Chapter 487 of the Laws of 1885, and hereinafter called the "Commissioners," parties of the first part, and THE PASSAIC ROLLING MILL COMPANY, a corporation created and existing under the laws of the State of New Jersey, and MILES TIERNEY, of Jersey City, in the State of New Jersey, hereby binding themselves jointly and severally and hereinafter called the "Contractors," parties of the second part, WITNESSETH, as follows:

FIRST.—The Contractors, in consideration of the sum of two millions and fifty-five thousand dollars, to be paid in the manner hereinafter provided, shall and will furnish and provide all necessary materials and labor for the construction and completion of, and shall and will construct, finish and complete, ready for use and operation, the entire bridge to be erected over the Harlem River at One Hundred and Eighty-first street in the City of New York, pursuant to the provisions of the act of the Legislature of the State of New York, entitled "An Act to Provide for the Construction of a Bridge over the Harlem River in the City of New York," being Chapter 487 of the Laws of 1885. The said Contractors shall furnish all of said materials and perform all of said labor, and fully construct, finish and complete said bridge in strict conformity to the preliminary plans and specifications hereto annexed, marked Schedule "A," and the strain sheet submitted by the Contractors, and annexed hereto, marked Schedule "B," and in strict conformity to the working drawings to be made or approved by the engineer of the Commissioners, as hereinafter provided, and fully complete and deliver the said bridge in all its parts ready for use and operation in a thorough, workmanlike and substantial manner, on or before the eleventh day of June, 1888, to the full satisfaction of the Commissioners.

SECOND.—It is mutually understood and agreed that the Commissioners may at any time vary, alter, modify or amend the said preliminary plans and specifications, and in case by reason of any such change the quantity of any kind or class of work shall be increased beyond the amount thereof required by the said preliminary plans and specifications, then and in each such case the Contractors shall receive payment for such increased quantity at the rates set forth in the schedule hereto annexed, marked "C," in addition to the said sum of $2,055,000. And in case, by reason of any such change, the quantity of any kind or class of work shall be diminished from the amount thereof required by the said plans or specifications, then and in every such case, the said sum of $2,055,000 shall be diminished, according to the rates set forth in said last mentioned schedule. In case there shall be by reason of any such change an increase or decrease in quantity of any kind or class of work not specified in said Schedule " C," then there shall be added to or deducted from said sum of $2,055,000, as the case may be, such sum as shall be certified by the engineer as the cost of such increase or decrease in quantity. In every case the increase or decrease in quantity of any kind or class of work shall be conclusively fixed by the final estimate of the engineer to be certified to the Commissioners.

THIRD.—The Commissioners agree to pay to the Contractors the consideration hereinbefore expressed in the following manner: On or before the fifth day of each month the engineer shall estimate the proportion which the work done and material furnished during the preceding months shall bear to the whole amount of work to be done and material to be furnished under this contract, and shall thereupon certify to the Commissioners that the work embraced within said estimate has been done in accordance with the specifications, and shall also certify the amount due to the Contractors for such preceding month. The Commissioners shall thereupon audit the said statement and certificate, and upon being satisfied of its correctness, and that the Contractors have in all respects complied with this contract, then said Commissioners shall, on or before the 12th day of the month, pass and forward to the Comptroller of the City of New York, for payment, a proper voucher, in form to be approved by said Comptroller, in favor of the said Contractors, for ninety per cent. of the amount which shall be shown by said certificate to be due to the Contractors. The above mentioned estimates and certificates of the engineer shall be deemed approximate and provisional only, and any error in any of said estimates or certificates may be corrected by the engineer in any subsequent estimate or certificate. In case any statement or certificate herein provided for shall, in the opinion of the Commissioners, be incorrect, or require alteration or explanation, then the same may be returned to the engineer for such alteration, correction or explanation, and the time for auditing the same shall be extended until one week after a corrected or altered statement and certificate shall be received by the Commissioners.

FOURTH.—Detailed working drawings of the metal work shall be furnished by the Contractors, embodying any changes or modifications of the preliminary plans and specifications hereto annexed which the Commissioners shall require. Such detailed drawings, when approved by the engineer of the Commissioners, and any further drawings of masonry work made by the engineer, shall constitute a part of this agreement, and the work shall be made to conform to the same. It is further agreed by the Contractors that any change or alteration of the said plans or specifications shall not affect the price herein specified to be paid for said work, nor shall any claim for " extras," or increased or other compensation, be made by the Contractors for or by reason or on account of any such change or modification, or any difference thereby occasioned in the nature, cost or expensiveness of the work, except only as in the second article hereof expressly provided.

FIFTH.—And it is further understood and agreed that all work provided to be done under this agreement shall be of the best character, and shall be made complete and satisfactory before acceptance, and all material shall be fully inspected and tested by the engineer or his deputies before going into said bridge; but such inspection and tests shall not release the Contractors from liability to make good any defects in such materials then or afterwards discovered; and it is expressly understood and agreed that such inspection and tests shall be made at such times and in such manner as not to delay the progress of the work.

SIXTH.—And it is further understood and agreed that the engineer shall at all times have easy and ample access to said bridge and all parts of the work, and to the materials in the possession of the Contractors, and shall have assistance as he may require from the Contractors in testing, examining, inspecting and supervising the work provided to be done by this agreement, and said Commissioners shall have the right to place such inspectors on said bridge and in the workshops, &c., as they may see fit, who shall be afforded by the Contractors every facility for performing their duties.

SEVENTH.—And it is further understood and agreed that, except as in this contract otherwise provided, no omission in this contract or in the specifications for said bridge, nor any failure or omission on the part of the Commissioners, or any of their officers or agents, nor any failure to inspect or examine, nor any exercise of the power or the right to inspect, examine or test, nor acceptance of any work or material express or implied, nor any allowance of the same in said bridge, shall be held to absolve said Contractors from the responsibility and liability of completing and delivering said bridge as a whole and of every part thereof, to the full satisfaction of the Commissioners and in accordance with the requirements of this agreement.

EIGHTH.—It is further understood and agreed that the Contractors shall have the right to sublet any part of the work to be performed under this contract, but only with the written consent of the Commissioners, but such subletting shall not release the Contractors from any obligations imposed by law or the terms of this contract.

NINTH.—And it is further understood and agreed that the Contractors shall promptly pay the men, laborers and sub-contractors employed on said bridge, and also for the materials used therein, and in case any moneys due therefor in any month shall remain unpaid at the time of the making by the engineer of the estimate of the work done and materials furnished during the succeeding month, the Commissioners may pay the amount so due to said men, laborers or sub-contractors, or for such materials, and deduct the same from the amount of the voucher to be given to the Contractors upon said estimate, or from any moneys due or to grow due to them under this agreement, and the receipts taken therefor shall be full discharges and acquittances in settlement with said Contractors.

TENTH.—It is further understood and agreed that if the work to be done under this agreement shall be abandoned by the Contractors, or if this contract shall be assigned, whether by the act of the Contractors or by the operation of law, or if the same, or any part of the work, shall be sublet without the written consent of the Commissioners, or if at any time the engineer shall be of the opinion, and shall so certify in writing to the Commissioners that the said work or any part thereof is unnecessarily or unreasonably delayed by the Contractors, or that they are wilfully violating any of the provisions of this agreement, or of the specifications for said work, or fulfilling the said contract in bad faith, then the Commissioners, after giving ten days' notice in writing to the Contractors, may notify the Contractors to discontinue the work, or such part thereof as may be designated, and said Commissioners shall thereupon have power to make a contract or contracts with any person or persons for the completion of said work, or such designated part thereof, or to employ such and so many persons, and obtain by purchase or hire such animals, carts, wagons, implements or tools as said engineer may determine to be necessary to complete the same, and to use such material as may be found at the work, and may procure other material for the completion of said work, and charge to the Contractors the cost and expense of such labor, materials, animals, carts, wagons, implements and tools, and such cost and expense shall be deducted from any moneys due or to grow due to the Contractors under this agreement, and in case such moneys shall not be sufficient to pay for the same, the Contractors shall be liable for and shall pay the deficiency.

ELEVENTH.—The work under this agreement is to be prosecuted at and from as many different points, at such times and in such part or parts of the work, and with such force as the said Commissioners by their engineer, may from time to time determine, at each of which points an inspector may be placed to supervise the same.

TWELFTH.—The Contractors shall and will clean off all surplus materials, sand, dirt and rubbish from said work and the right of way, and from the land mentioned in the Twenty-first Article hereof, within thirty days after the work shall have been completed; and the work will not be accepted as completed until the same shall have been removed to the satisfaction of the engineer. And upon the full completion of the work embraced in this agreement, the Contractors will be required to file in the office of the said Commissioners a certificate, signed by the engineer, to the effect, that the stipulations relative to the removal of all surplus materials, sand, dirt and rubbish from the line of the work and the right of way and land above named have been faithfully complied with, and the final payment to the Contractors shall not be made until after such certificate shall have been filed.

THIRTEENTH.—All loss or damage arising out of the nature of the work to be done under this agreement, or from any unforeseen or unusual obstructions or difficulties which may be encountered in the prosecution of the same, or from the action of the elements, is to be sustained by the Contractors aforesaid; and in case any work shall be done in such manner as to require any consent, permit or license from municipal or other authorities, or from any other person or persons, corporation or corporations, the Contractors shall procure the same at their own cost and expense.

FOURTEENTH.—The Contractors hereby covenant to and with the Commissioners that they have full right and authority to use any and all patented improvements and appliances which may be used in the construction of said bridge, and expressly agree to indemnify the Commissioners and the City of New York, and save them and it harmless from any and all liabilities, damages, costs, charges and expenses which they or it may incur or suffer by reason of the use in the said bridge of any such patented articles, improvements or appliances, including all expenses or charges incurred by them or it in defending suits relating to the same.

FIFTEENTH.—No work shall be done in laying or setting masonry, curb, or flagging when the weather is below freezing point, except on the written consent of the engineer.

SIXTEENTH.—And the said Contractors further agree that the work shall be performed in the best manner, and the stone and iron and all other materials of which the work is composed shall be of such kind and quantity as shall be satisfactory to the engineer, and that a sufficient number of persons shall be at all times employed to execute the work with due dispatch, the whole to be done to the satisfaction of said Commissioners ; and any materials furnished or work done not satisfactory to the Commissioners, or their engineer, shall be immediately removed and satisfactorily replaced by the Contractors ; or if they shall neglect or refuse to remove the same when notified so to do by the said Commissioners, then the said Commissioners may remove, or cause the same to be removed, and satisfactorily replaced by contract or otherwise, and charge the expense thereof to the Contractors ; and the expense so charged shall be deducted and paid by the Commissioners out of such moneys as are or may become due under this agreement. And in case the same shall be insufficient for the purpose, the Contractors shall be liable for, and shall pay, the deficiency.

SEVENTEENTH.—And the said Contractors further agree that during the performance of the said work they will place proper guards upon and around the same for the prevention of accidents, and at night will put up and keep suitable and sufficient lights, and will take such other means as shall be required by the engineer for the prevention of accident to persons or property, and that they will indemnify and save harmless the Commissioners and the City of New York against and from all suits and actions of every name and description brought against them or it, and all costs and damages, charges and expenses to which they or it may be put by reason or on account of any injury or damages to person or property caused by the Contractors, their servants or agents, in the construction of the said work, or by or in consequence of any negligence in guarding the same, or of any improper materials used in its construction, or by or on account of any act or omission of the said Contractors or their agents ; and the said Contractors hereby further agree that so much of the moneys due to them under and by virtue of this agreement as shall or may be considered necessary by the Commissioners, shall, or may be retained by the said Commissioners until all such suits or claims for injuries or damages as aforesaid, shall have been settled, and evidence to that effect furnished to the satisfaction of the said Commissioners.

EIGHTEENTH.—It is further agreed that the return of the engineer shall be the account by which the amount of materials furnished and work done shall be computed; and that the certificate of the inspectors appointed to inspect said work, that the same has been faithfully performed in accordance with the requirements of this contract, approved, by the said engineer and filed with the said Commissioners, shall be a condition precedent to the right of the said Contractors to payment for work done by them under this agreement, or any part thereof.

NINETEENTH.—It is further expressly understood and agreed by and between the parties hereto that the action of the engineer by which the said Contractors are to be bound and concluded, according to the terms of this contract, shall be that evidenced by his final certificate; all prior certificates upon which ninety per cent. payments may be made, being merely estimates; and said final certificate may be made without notice to the Contractors thereof, or of the measurements upon which the same is based.

TWENTIETH.—And it is hereby expressly agreed and understood by and between the parties hereto that the said Commissioners, their successors and assigns, shall not, nor shall any department or officer of the City of New York be precluded or estopped by any return or certificate made or given by any engineer, surveyor, inspector, or other officer, agent or appointee of said Harlem River Bridge Commissioners, under or in pursuance of anything in this agreement contained, from at any time showing the true and correct amount and character of the work which shall have been furnished by the said Contractors, or any other person or persons under this agreement.

TWENTY-FIRST.—The Commissioners hereby covenant and agree to furnish to the Contractors the free and uninterrupted use of the land shown on plan hereto attached, and marked Schedule " E," for the purpose of depositing any working material.

TWENTY-SECOND.—The Contractors hereby further agree that they will give their personal attention constantly to the faithful prosecution of the said work, and will keep the same under their own control; that they will not assign, by power of attorney or otherwise, any of the moneys payable under this agreement, unless by and with the consent of the said Commissioners in writing; that no right under this contract, nor to any moneys to become due hereunder, shall be asserted against the Mayor, Aldermen and Commonalty of the City of New York, or against the said Commissioners by reason of any so-called assignment in law or equity of this contract, or any part thereof, and that no person other than the parties signing this agreement as the parties of the second part has now any claim hereunder. If at any time any overseer or workman who shall be employed by the Contractors shall be declared by the engineer to be unfaithful, disobedient or incompetent, the Contractors, on receiving written notices, shall forthwith dismiss such person, and will not again employ him on any part of the work, except with the consent of said engineer.

TWENTY-THIRD.—And it is further agreed by and between the parties hereto, that if at any time before, or within thirty days after, the whole work herein agreed to be performed has been completed, or accepted by the Commissioners, any person or persons claiming to have performed any labor or furnished any materials towards the performance or completion of this contract, shall file with the said Commissioners, or with the head of the Finance Department of the City of New York, any claim, under the act entitled "An Act to secure the payment of laborers, mechanics, merchants, traders, and persons furnishing materials towards the performing any public work in the cities of the State of New York"; then and in every such case, the said Commissioners shall retain, anything herein contained to the contrary thereof notwithstanding, from the moneys under their control, and due or to grow due under this agreement, so much of such moneys as shall be sufficient to pay off, satisfy and discharge the amount in such notice alleged or claimed to be due to the person or persons filing such notice, together with the reasonable costs and expenses of any action or actions brought to enforce such claim or the lien created by the filing of such notice. The moneys so retained shall be retained by the said Commissioners until the lien created by the said act and the filing of the said notice shall be discharged pursuant to the provisions of the said act. And the said Contractors hereby further agree that they will furnish said Commissioners with satisfactory evidence that all persons who have done work or furnished materials under this agreement, and who may have given written notice to the said Commissioners, at any time within ten days after the completion of the work aforesaid, that any balance for such work or materials is still due and unpaid, have been fully paid or satisfactorily secured such balance.

TWENTY-FOURTH.—Upon the completion of the whole work, the engineer shall examine the same, and in case he shall find that all the matters and things herein provided to be done by the Contractors have been done to his satisfaction, he shall make a certificate of that fact and file the same with the Commissioners, and shall also certify to the Commissioners the amount remaining due to the Contractors upon this contract. Said certificate shall be final and conclusive upon the Contractors unless the same shall be returned by the Commissioners to the engineer for correction, and upon the same being corrected accordingly, such corrected certificate shall be final and conclusive upon the Contractors. Upon the completion of the whole work in accordance with the requirements of this contract, and to the satisfaction of the Commissioners, and upon acceptance thereof by the Commissioners, and upon the filing of the certificate last above mentioned, and the performance by the Contractors of all acts and things by this contract required to be done by them, and upon the Commissioners being satisfied of the correctness of said certificate, the Commissioners shall pass and forward to the Comptroller of the City of New York, for payment a proper voucher, or proper vouchers, in form to be approved by said Comptroller, in favor of the said Contractors, for the amount shown by said certificate to be due to the said Contractors.

TWENTY-FIFTH.—Whenever in this contract or in the specifications for said bridge, it is provided that anything is to be, or to be done, or as, or when or where "required" or "specified," it shall be taken to mean and intend "required" or "specified" (as the case may be) by the engineer in charge of the work. Whenever the word "engineer" is used in this contract or in said specifications, it refers to and designates the engineer who may, by the said Commissioners be appointed regularly, or for the time being to have charge of the construction of the work herein specified.

TWENTY-SIXTH.—Nothing herein contained shall subject the parties of the first part, or either of them, to any personal or individual liability.

IN WITNESS WHEREOF, the parties of the first part and the said Myles Tierney have hereunto set their hands and seals, and the said Passaic Rolling Mill Company hath hereunto caused its corporate seal to be affixed, and these presents to be subscribed by its President, the day and year first above written.

JACOB LORILLARD, *Commissioner.* [SEAL.]
DAVID JAMES KING, *Commissioner.* [SEAL.]
VERNON H. BROWN, *Commissioner.* [SEAL.]
MYLES TIERNEY. [SEAL.]
PASSAIC ROLLING MILL CO. [SEAL.]

STATE OF NEW YORK,
City and County of New York, } ss.:

On this 14th day of July, in the year 1886, before me personally appeared Watts Cooke, the President of the Passaic Rolling Mill Company, with whom I am personally acquainted, who, being by me duly sworn, said: That he resided at Paterson, in the State of New Jersey; that he was President of the Passaic Rolling Mill Company; that he knew the corporate seal of said Company, and that the seal affixed to the foregoing instrument was such corporate seal; that it was affixed by order of the Board of Directors of said Company, and that he signed his name thereto by the like order as President of said Company.

EDMUND L. BAYLIES,
Notary Public (80),
New York County.

STATE OF NEW YORK,
City and County of New York, } ss.:

On this 14th day of July, in the year 1886, before me personally came Myles Tierney, to me personally known, and known to me to be one of the individuals described in and who executed the foregoing instrument, and acknowledged to me that he executed the same.

EDMUND L. BAYLIES,
Notary Public (80),
New York County.

HARLEM RIVER BRIDGE.

SPECIFICATIONS FOR ITS CONSTRUCTION.

General Description.

The bridge will consist of two arches of steel, each of 508 feet span in the clear; three piers each 40 feet thick at springing line of arches; with two abutments of masonry; the east abutment being about 342 feet long, the west abutment about 277 feet. Through each abutment will be a masonry arched passage of 60 feet clear span.

The contract will include such excavation, embankment, grading, paving, etc., etc., as may be required for complete connections between the masonry abutments and Tenth Avenue on the west side, and Aqueduct Avenue on the east side. These connections to be graded, paved, curbed and drained.

The total length of the bridge and its approaches will be about 2,373 feet. The clear width of the bridge 80 feet, 50 feet of which will be carriage way, and the remainder sidewalks of equal width.

The piers from the rock foundation to a level one foot below ground line or low water, shall be formed of dressed stone facing with an interior of concrete. The facing to be of granite in heavy courses. From this level to the springing line of arches, the general construction will be the same, but the facing will be of granite of *approved color and texture* with rusticated joints.

Above the springing line the piers will be faced with coursed ashlar of gneiss, rock faced, with quoins of dressed granite. Courses may change their height occasionally on the long faces of the piers.

Abutments will be faced with random coursed work of gneiss, or other approved stone, rock faced.

All backing and cross walls of rubble. Ring stones (   ) of arched openings will be of cut granite, the rest of the arch of dressed gneiss, cornices, balustrades, etc., of granite.

The roadway between Tenth Avenue and the west abutments and Aqueduct Street and the east abutment will be 80 feet wide, as on the bridge. Excavations for the roadway will be made 2½ to 3 feet below grade surface earth or rock.

Slopes of the roadway excavations and embankments, which would extend outside the city's land 100 feet in width, must be supported by dry retaining walls of rock from the excavations. Slopes of embankments will be protected by slope walls one foot thick.

The work will conform to the drawings exhibited, and to such others in explanation of details, or to conform to such new conditions as may arise, as may be furnished from time to time.

The contract will include preparation of the site, excavation, embankment, masonry, iron and steel work, and the entire construction and completion of the work according to the plans and specifications, together with the removal of all rubbish and surplus material.

Excavations will include all material removed for foundations, for grading the ground adjacent to the bridge, etc. Rock in places which require blasting, and boulders of more than 10 cubic feet, shall be classified as "rock"; all other material as "earth." But all excavation for the middle pier (No. II.) is to be classified as dredging; the price for which is applicable only to the net lines of the coffer-dam required, and to the depth shown on the exhibited plans as depth of foundation of pier No. II. Excavations will be made to such slopes as may be directed by the engineer, and be neatly finished.

Embankments will be formed of selected earth carted in layers of one foot in thickness, each layer to be kept as nearly horizontal as may be, wetted and rolled with a heavy grooved roller. Such rock as it may be necessary to use will be placed in the outer slopes, or, if any is permitted under the roadway, it shall not be larger than sixteen inches in any dimension. It shall be placed compactly, and all spaces and interstices filled with small stones, gravel, and earth. The upper three feet will be made with fine gravel and clay, wetted and rolled to be water tight.

FOUNDATIONS.

The piers will be founded upon the solid rock, and such means as the engineer shall direct shall be used to lay the rock bare and visible. The western abutment will also rest upon the rock, which, on the west side of the valley, will be found at or near the surface. On a portion of the eastern side the rock lies at a considerable depth, and the foundations of the abutment at such points will be on earth at such depth as the engineer may direct.

All rock which, in the opinion of the engineer, is too soft or too much decayed to give a suitable support, shall be removed to such depth as may be necessary.

The surface of the rock shall be levelled off or cut down to such planes as the engineer may direct, and all hollows and fissures will be filled with mortar or concrete, as directed.

If, in the opinion of the engineer, the solidity of the foundation will be injured by blasting, the rock must be removed by other means.

Where the facing stones of the piers rest upon the rock, proper beds will be prepared for them by dressing the rock.

The face stone in foundation of abutment walls will also be fitted to the rock in such manner as the engineer may direct. For rubble or concrete backing, it will be sufficient that the rock is approximately level.

Granite will be sound, strong, and durable,—to be approved by the engineer. All above the surface will be of uniform and approved color and texture, in courses two and three feet high; the highest courses in bottom of wall. Each stone shall have at least as much bed as rise.

It will be cut to fair, plane parallel beds, to lay half-inch joints with clean, sharp arrises—joints to be full for twelve inches back from the face.

Below the surface of ground and water—*i. e.*, from one foot below the graded surface of the ground, or extreme low water—the face shall be pitched off to the lines of the beds and joints, to the true batter.

From surface to springing-line, the lower bed and the vertical joints shall be cut straight and true to the rock face of the stone; the upper bed shall have a horizontal draft, four inches wide, sunk two inches from the general face of the stone, conforming to the batter of the wall, and a flat draft, corresponding to the same on each angle of the pier.

The quoins will be rock-faced; arranged to show, alternately, three and six feet on the front and side of pier, with a flat draft two inches wide around each face of each stone and two inches back from its general rock face.

All cornices and parapet to be cut to true surfaces with true, clean arrises,—to conform to drawings.

On coping of parapet, and all faces of same next the roadway, to be six-cut work,—outside wall to be plain axed.

Rails or coping and posts of parapet to be secured with such dowels or clamps as may be directed.

Face voussoirs of sixty feet arches (average depth, three feet) will be cut to close, plane beds and joints extending through the stone; to be fine cut (axed) on the soffit, rock-faced on the heads, with three-inch draft on each radial joint and on each exposed arris. Interior arch-stones may be of granite or gneiss, with fine cut beds and joints; face on soffit to be axed; the joints to be at right angles to the beds.

Bridge seats to conform to drawings of large, selected, dimension blocks of granite, closely dressed upon all sides; six-cut work on top where arches rest. To be well bedded and bonded and secured with clamps and holding-down bolts.

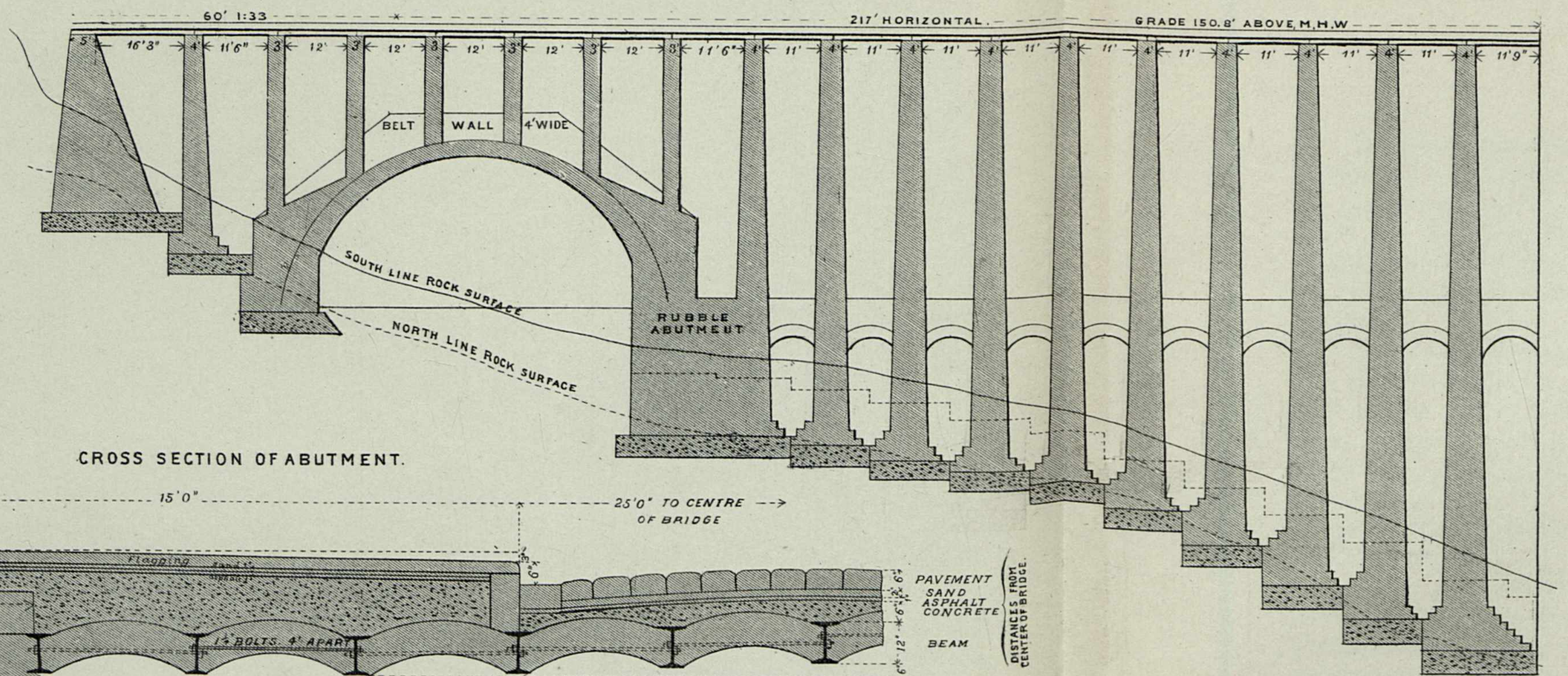
Coursed ashlar will be of the best quality; sound, durable New York or Westchester gneiss, or equally acceptable stone, in twelve to eighteen inch courses, dressed to plane parallel beds, with vertical joints six inches back from the face, to lay one-half-inch joints pitched to line, with not more than three inches of rock on the face; beds to average two and one-half feet wide if required.

Broken-range ashlar, same as above; but courses may vary by checking, or by the occasional use of levellers—no leveller to be less than four inches high. Joints may be three-quarter inch thick, but stones which range together must be of the same height, and beds must be truly horizontal.

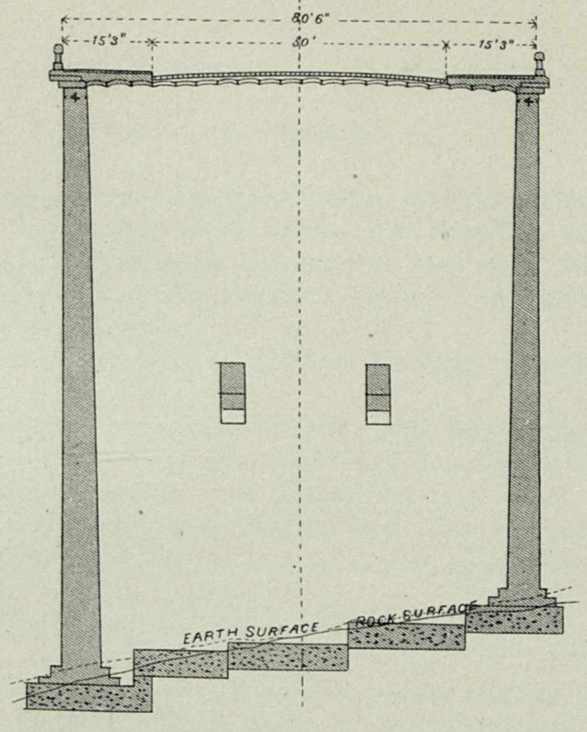
Random-coursed work for facing abutments will be of the same or other approved stone, with *horizontal* beds; end-joints need not be vertical, but as nearly so as the stone will break. No sharp, thin points allowed. All stones to have good beds, whether natural or made so with the hammer or other tool, to lay three-quarter inch joints.

CONTRACT DRAWINGS.

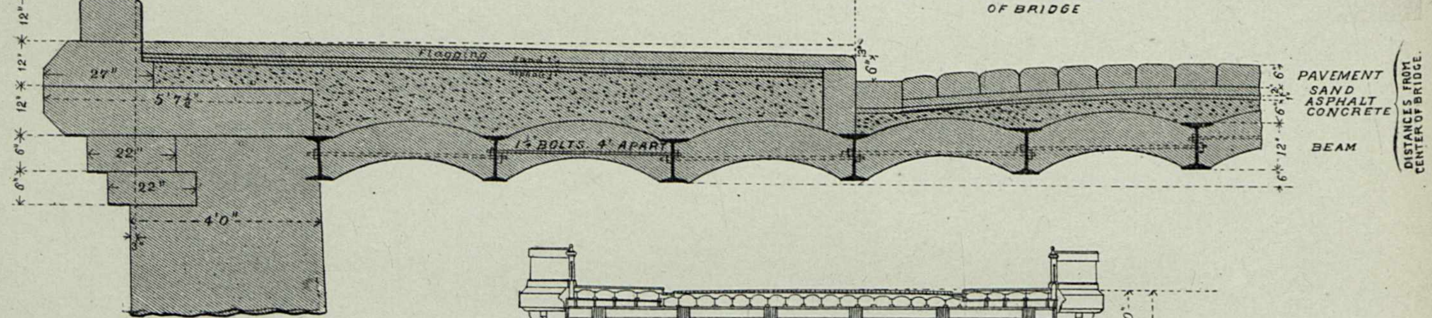
LONGITUDINAL SECTION OF ABUTMENT.



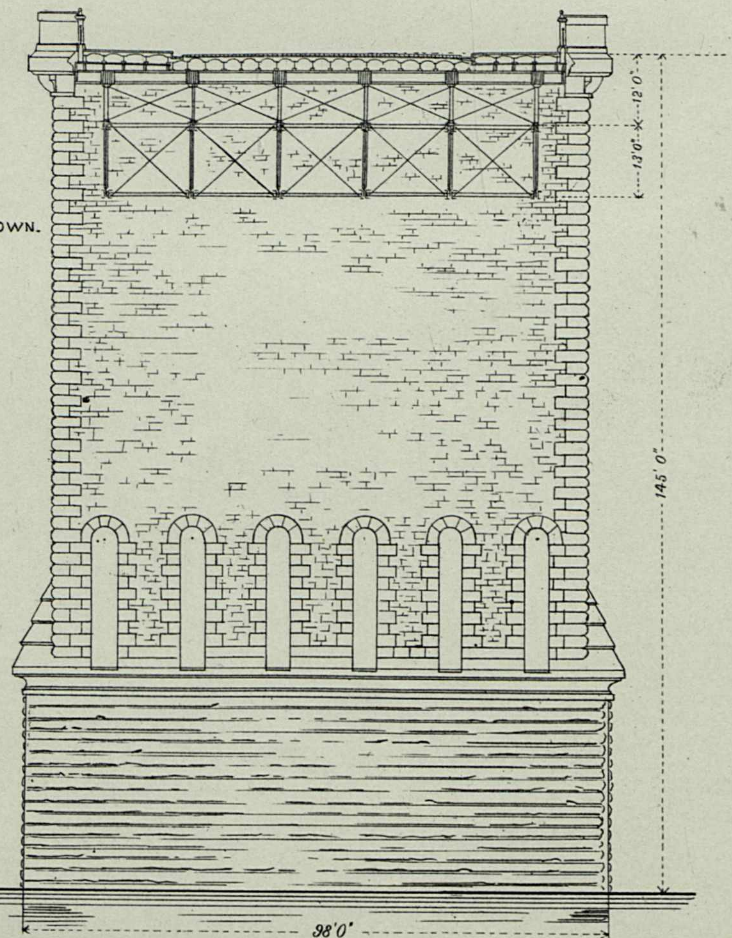
CROSS SECTION.



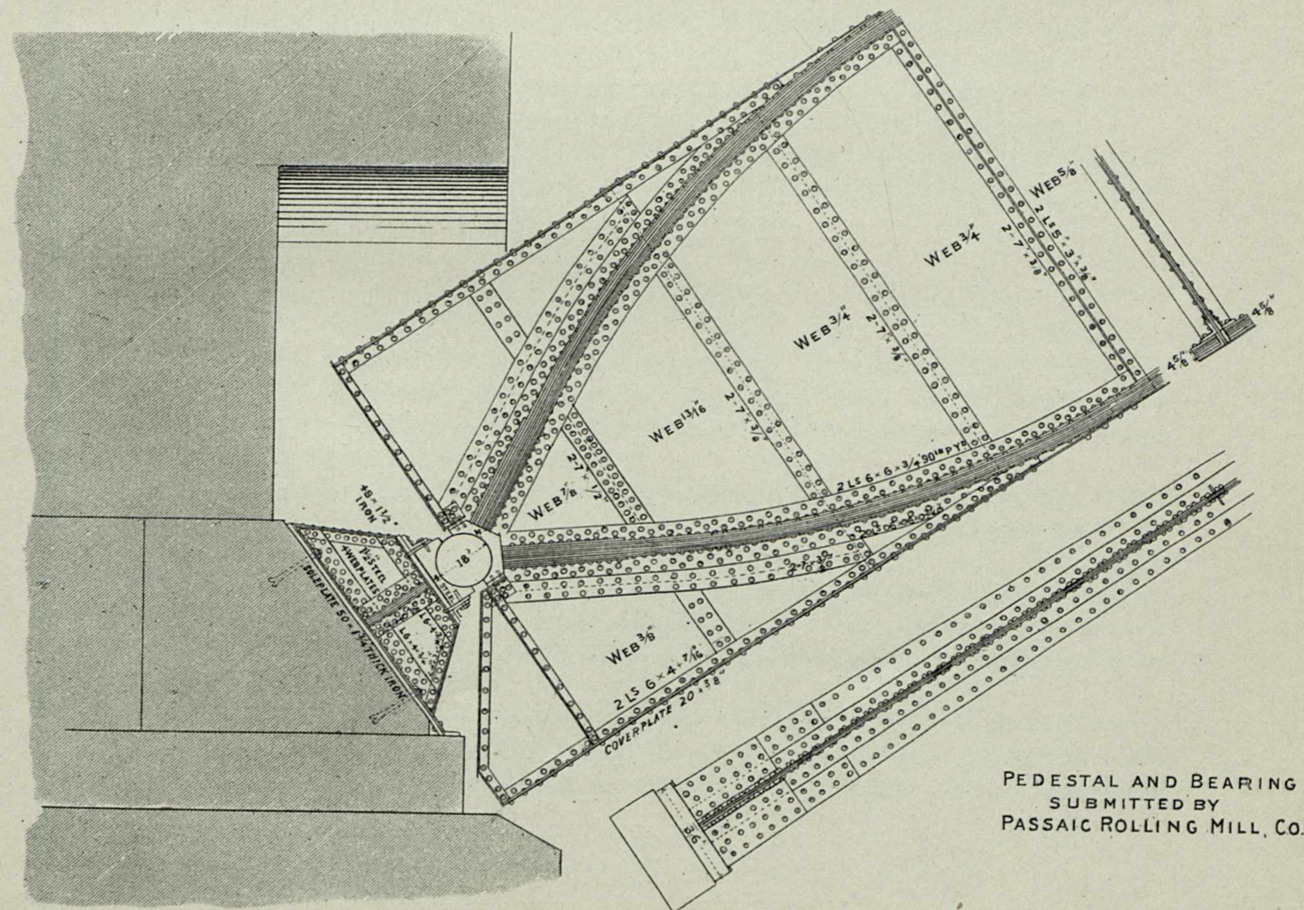
CROSS SECTION OF ABUTMENT.



LONGITUDINAL SECTION OF PIERS
SHOWING ALSO SECTION OF METAL ARCH AT CROWN.



FOR GENERAL ELEVATION
SEE PLATE V.
(3RD DESIGN)



PEDESTAL AND BEARING
SUBMITTED BY
PASSAIC ROLLING MILL, CO.

Rough rubble will be of hard, sound, clean, well-shaped—stone-hammered, if need be—to good, fair beds, so that they will lie solid; all to be well bonded.

Dry retaining-walls, of such thickness as the engineer may direct, will be laid up of the best stone taken from excavation, laid to a fair face, and bonded as well as the character of the stone will permit.

Slope walls of same stone will be laid by hand on the slopes of banks to line, well fitted.

Cement will be equal to the best Rosendale brands; to be fresh and ground so fine that ninety-five per cent. will pass through a sieve of 2,500 meshes to the square inch; to be subject to continual inspection and test and the approval of the engineer. Portland cement of approved quality shall be used when required by the engineer, and will be paid for at cost, less the cost of the same quantity of Rosendale cement.

Sand will be sharp, silicious, clean, and not too fine; screened when required by the engineer.

Mortar will generally be composed of one part of cement and two parts (by measure) of sand, thoroughly mixed (without excess of water) on a bed of plank protected from the sun and rain, and used before it has begun to set. It cannot be used as grout, or on the second set.

Concrete will be composed of one part (by measure) of cement, two parts of sand, and five parts of sound, hard, durable stone, broken to pass through a ring two and one-half inches in diameter; the stone to be clean and free from dust. The whole to be thoroughly mixed (without excess of water) by machinery where practicable, put in place, and compacted by ramming before it has begun to set.

Two parts of the broken stone may be replaced with approved gravel of proper size and character. When required, it shall be made of Portland cement, with two parts of sand and five parts of broken stone, as above.

LAYING MASONRY.

All stone shall be laid upon its natural bed. For granite facing of piers, no stretcher shall have less length than two and a half times its rise; every fourth stone shall be a header, with three feet breadth of bed and four to five feet long; joints shall be broken at least a foot.

For coursed and broken-range ashlar, the bond will be eight inches; one header in every ten feet of course, to be at least four feet long, be well bonded to the rough rubble backing.

All stone to be well and solidly laid to the proper lines in full beds of mortar and settled in place with a wooden maul; the stones to be clean and moistened at the time of setting. Joints of face stone will be filled with the trowel or other tool.

Rubble stone, also, will be laid perfectly solid in full beds of mortar and all joints well filled with the same. All spaces shall be filled with mortar and spalls and selected pieces of stone driven in until the whole is full. Every stone shall have at least one good, flat bed. It will be laid upon its best bed and a proper bed prepared upon it for the stone above.

The cross walls of rubble masonry and the rear of all walls backed with rubble will be neatly laid to line, with full, clean joints.

The walls must be solid; free from holes or voids.

Face work will be pointed and jointed as the work progresses with the same mortar with which the work is laid, pressed in and burnished with a proper tool; the whole to be left fair and clean when the work is finished.

Suitable machinery must be used for handling large stones, and every stone, the bond of which is broken, must be taken up and reset.

All stone for the same class of face work shall be as nearly as practicable of the same quality and color, that the appearance of the finished work may be uniform.

The cross and transverse walls will carry longitudinal beams of iron or steel, properly connected by tie rods. Upon these will be built arches of rubble or concrete, of such dimensions as may be prescribed. All metal to be well bedded in concrete or masonry and protected from the elements.

The face of the masonry shall be left clean and free from stains and spots. All masonry broken or injured shall be replaced by the contractor at his own cost. If by direction of the engineer the face should not be pointed as the work progresses, as hereinbefore provided, then, after completion, all joints shall be raked out to the proper depth and pointed with dark mortar made with finely ground Portland cement driven in with a caulking tool.

On the abutments the sidewalks shall be of blue-stone flags, not less than three inches thick, planed on the top surface and front edge. The joints are to be caulked.

The flags shall extend the full width of sidewalk, in not more than three lengths, breaking joints; to be from five to seven feet wide, and have an inclination of three inches toward the roadway. They shall be laid in cement mortar. The curb and gutter stone shall be of blue-stone, with its exposed surfaces axed, to be laid in cement mortar. At distances of about 150 feet in length of the bridge there shall be drain openings on each side, nine inches in diameter, from which drain pipes of cast iron shall extend, so as to deliver the water clear of the bridge. The openings shall be covered with suitable iron gratings. All of the above are to be furnished and placed by the contractor for masonry.

Upon the buckle plates or jack arches will be laid concrete to the depth of two inches, in which the stone shall be broken to not exceed three-quarters of an inch in diameter, and above this, additional concrete as before described, crowning to six inches at the centre, and over the latter a layer of one inch of Trinidad asphalt and sand, and so laid as to render it water tight.

Upon the asphalt covering shall be laid two inches of clean, coarse, sharp sand; upon which shall rest the granite paving, which shall consist of blocks of six inches deep, eight to twelve inches long, set three to four inches wide, separated by joints of one-half inch, which shall be filled with hot coal-tar and asphalt, into which double-screened, clean gravel shall be rammed. The paving stone shall be so selected and laid as to place those of nearly the same size contiguous.

There shall be gas lamps, of an approved pattern and of a value of at least $60 each, at about fifty feet apart on each side of the bridge; also clusters on the two outer corners of each pier, of a value of not less than $300 each, with the necessary pipes leading thereto, which shall be thoroughly tested by hydraulic pressure before acceptance.

There shall be fine cut stone seats in each refuge bay over the three piers of a value of not less than $500 for each bay.

Passage-ways in the walls shall be made where directed. The general plans of the masonry, as shown on sheets Nos. 2, 3, 4, and 5, are not intended for working plans, but solely to enable the bidders to determine the quantities, and, in connection with the specifications, the general character of the work. Modifications must be made in these plans to adapt the bridge seats to the plan of the arches, and to comply with the specifications in regard to the foundations.

From the ends of the abutments to Aqueduct Street on the east, and Tenth Avenue on the west, the roadway will be of granite blocks, sand, asphalt, and concrete, as on the bridge proper. The concrete will be nine inches deep, crowning six inches, and rest upon a bed of fine gravel of twelve inches depth, wet and rolled with a twenty-ton roller. The crowning of the roadway will be made on the earth embankment or excavation.

The sidewalks shall each be fifteen feet wide, of blue-stone flags and concrete, as on the bridge proper. The concrete shall be of the same depth as under the roadway. The curbs will be of blue-stone, six feet long, eight inches wide, and twenty inches deep; fine dressed on all exposed surfaces and end joints, and rough dressed elsewhere. The gutters, also of blue-stone, twelve inches wide, ten inches deep, and six feet long; dressed on top, side, and end joints; their surface will be placed one inch below the level of the pavement, and the latter bevelled off to meet it.

The drains will be of vitrified clay pipe, twelve to eighteen inches diameter under each gutter, at about five feet below ground, with manholes three feet square, provided with the usual cast-iron covers, gratings, and ladders, and silt basins below. On the embankments at the ends of the abutments will be placed granite posts six feet apart, each eight feet long, set four feet above and four feet below the surface, the upper half to be fine dressed, six inches square at top, and eight inches square at the surface of the ground. There will be two chains of half-inch galvanized iron attached to bolts passing through the post and leaded to it.

Vitrified pipe of twelve inches diameter, placed at five feet below grade, under each gutter, with manholes, silt basins, cast-iron covers, gratings, and ladders.

At the west end of the abutment the pipe from the south side will be extended across and connect with that on the north side, and then will descend vertically by a well on the rear of the abutment to its bottom, and pass through it to the interior, where it will connect with the drain pipe within the abutment.

The drain pipe within the abutment will follow the rear face of the north abutment wall, and be carried through or under all of the cross walls to the rear of pier No. I., and thence either through or around the north end of the pier, and thence to the river. This pipe will be twelve inches diameter, and placed at such depth as will drain all of the space under the abutments.

In each of the spaces between the cross walls will be dug in the rock a trench descending from the south to the north side and discharging into the main twelve-inch drain pipe.

The vertical cast-iron pipes from the roadway of the bridge will descend to and discharge in these cross drains.

The spaces within the abutment (east and west) will be levelled off to smooth surfaces, as may be directed.

Such of the materials excavated (rock, sand, etc.) as the engineer shall consider suitable for any portion of the work, may be used by the contractor without charge therefor.

All excavation, except the above, shall be deposited at such places within one-half mile haul, as the engineer shall indicate.

HARLEM RIVER BRIDGE.

SPECIFICATIONS FOR THE STEEL AND IRON WORK.

General Description.

The work comprised under these specifications will consist of two main arch spans, with their bracing, supporting columns, floor-beams, stringers, and buckle plates; also the floor-beams over the piers and abutments; also the hand-railing and cornice work over the main spans.

Main Spans.

The main spans will be arches, having a clear opening of 508 feet, with a rise of 90 feet, and a depth of arch rib of 13 feet, as per the general plan (sheet No. 2.)* Each span will have six arch ribs, spaced fourteen feet, centre to centre. Each rib will be formed of a plate web, properly stiffened, and of flanges of plates and angles. All parts of the ribs shall be of mild steel. The ribs must be united together by a system of wind-bracing on the line of each flange, and by a system of sway-bracing between all the ribs at every panel point.

The lateral and sway systems may be either of iron or steel.

The vertical columns supporting the cross floor-beams shall be formed of shaped-iron, latticed. These columns must be stiffened, transversely of the bridge, by a proper system of sway-bracing, and shall be rigidly connected to the arch ribs and the cross floor-beams.

The arch ribs may, at the option of the designer, be pivoted or fixed at the ends. For pivoted ends, the bearing pressure upon the pivot shall not exceed 5,000 pounds per square inch of effective bearing surface. The bearing surfaces must be of steel. For fixed ends, the anchorage must have a resistance equal at least to three times the overturning forces.

The floor shall be formed of cross floor-beams at intervals of about fifteen feet, and longitudinal floor-beams resting upon and securely fastened to the cross floor-beams with a floor surface formed of buckle plates.

The cross floor-beams will be rivetted girders, formed of angles and plates of iron or mild steel. The longitudinal beams will be rolled beams of steel or iron, and will be spaced at the proper distances apart to receive the buckle plates. The buckle plates will be of steel or iron, about three feet square, at least three-eighths inch thick, and crowning two inches at the centre. They must be firmly and closely

* See third Design, Plate V.

rivetted to the longitudinal beams and to each other. The floor-beams on the abutments and piers will be rolled beams of steel or iron.

All parts must be readily accessible for inspection, cleaning, and painting. No close sections will be accepted.

Loads.

The floor and its supports shall be proportioned to carry a dead load of 225 pounds per square foot of bridge floor, inclusive of its own weight, and either of the following live loads: (*a*) A distributed live load of 100 pounds per square foot of bridge floor; or (*b*), a twenty-ton road-roller of the ordinary dimensions placed in any position on the roadway. The floor-beams on the abutments and piers shall be proportioned for the above load and, in addition, the weight of the jack arches. The arches of the main spans shall be proportioned to carry their own weight, assumed at 15,000 pounds per lineal foot of arch, an assumed weight of floor and paving equal to 18,000 pounds per lineal foot of bridge, a live load assumed at 8,000 pounds per lineal foot of bridge, and a wind-pressure of 1,200 per lineal foot of bridge, distributed in proportion to the exposed surfaces.

A range of temperature of 75 degrees Fahrenheit, above and below the mean, shall be considered in proportioning all parts of the structure.

The modulus of elasticity for iron and steel to be assumed at 26,000,000 pounds.

Allowed Unit Strains.

The maximum strains produced by any combination of the above loads shall not exceed the following:

Tension or compression in the flanges of the arch ribs, per square inch of gross section,	15,000 pounds.
Tension in same, per net section,	18,000 "
Tension in flanges of cross floor-beams, per square inch of net section for iron,	10,000 "
Same for mild steel,	12,000 "
Tension of compression, extreme fibre of longitudinal beams, for iron,	12,000 "
Same for steel,	15,000 "
Tension, lateral and sway rods, iron,	15,000 "
Tension, lateral and sway rods, steel,	20,000 "

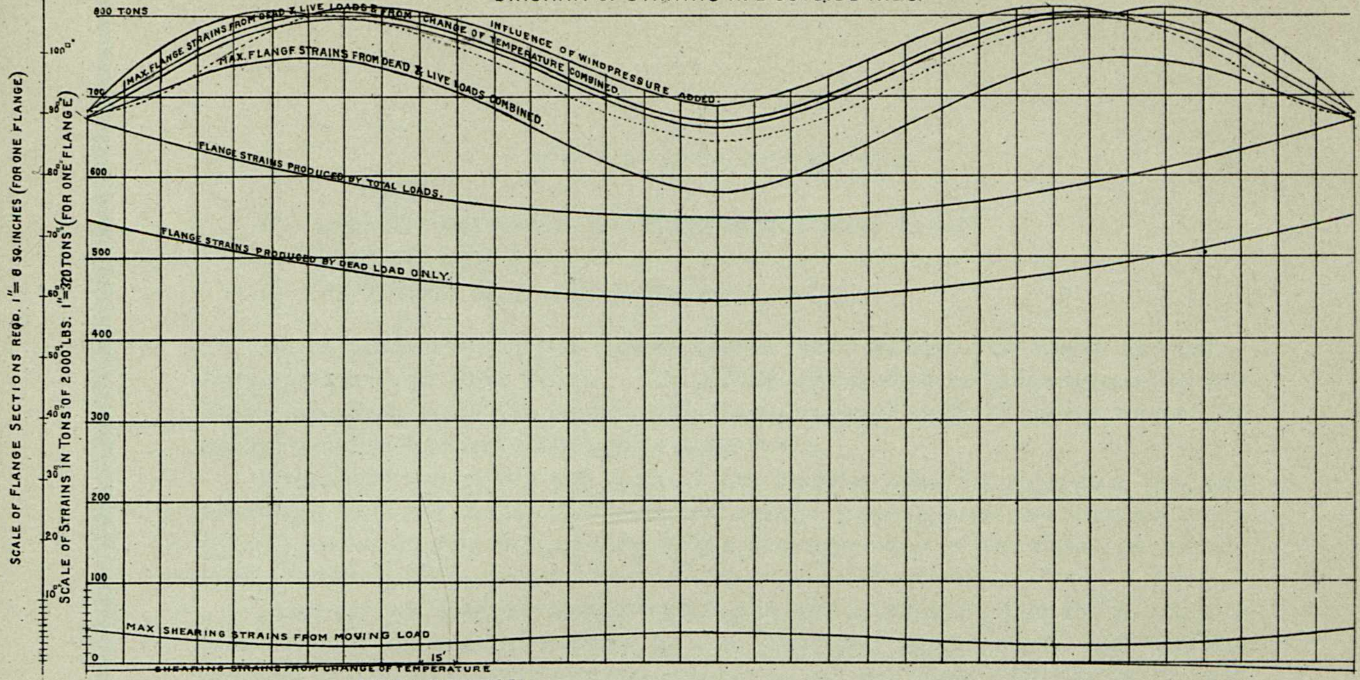
Compression of flanges of cross floor-beams to have same gross section as the tension of flanges.

The vertical columns shall be proportioned by the following formula:

$$P = \frac{10,000}{1 + \frac{L^2}{30,000\,R}}$$

HARLEM RIVER BRIDGE.

DIAGRAM OF STRAINS IN 2 OUTSIDE RIBS.



SCALE 1 INCH = 80 FT.

Span, 510 ft. c. c. Rise, 90 ft. c. to c.

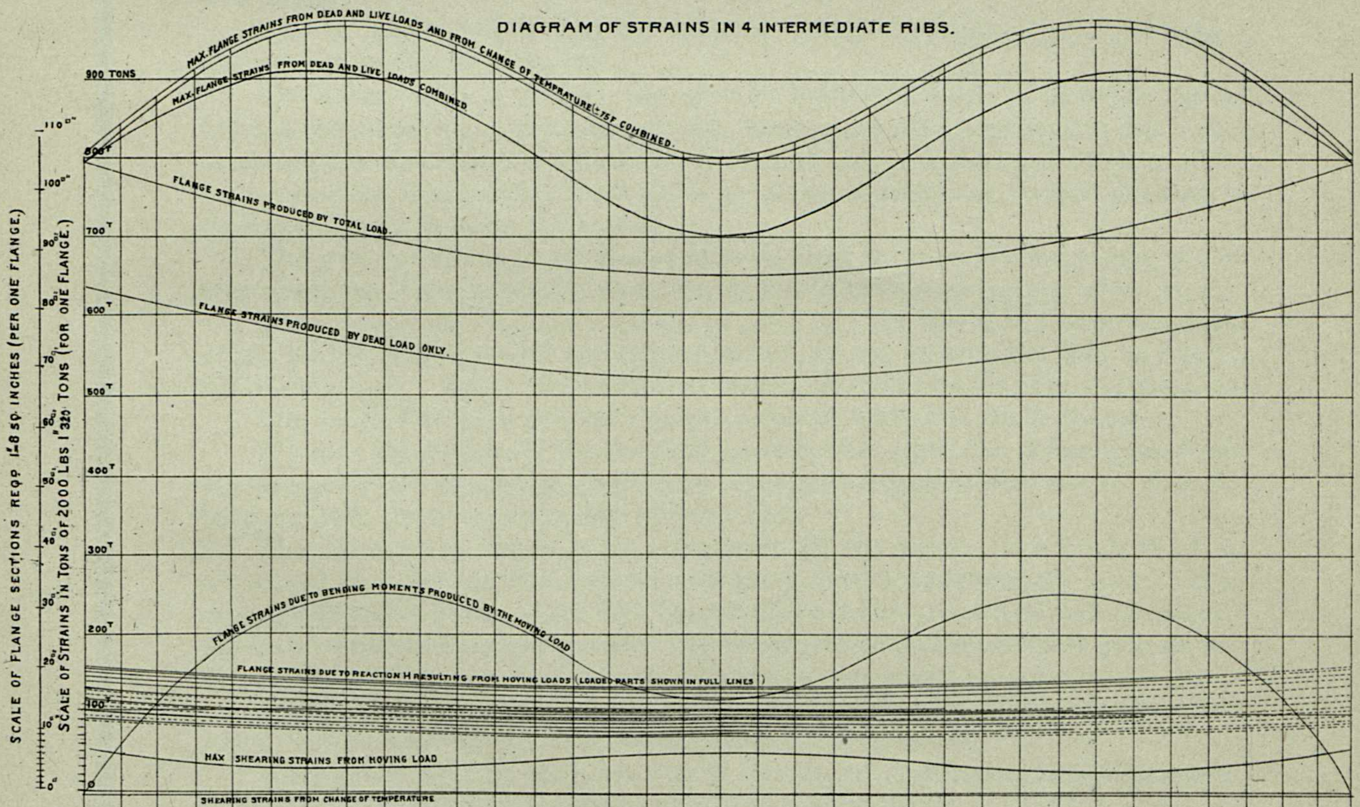
LOADS ON OUTSIDE RIBS.

Iron and steel, 1-6 of 15000 lbs. = 2500 lbs. per ft. × 510′ =	637½	tons.	
Floor, 11′ × 510′ = 5610 sq. ft. a 225 lbs. - - -	= 631	"	
Total dead load, - - -	1269½	"	
Moving Load, = 5610 sq. ft. a 100 lbs. - - - -	280½	"	
Total, - - - - - -	1550	"	(of 2000 lbs.)

Wind Pressure on Ribs assumed ⅙ of 1200 lbs. p. lin. ft. = 600 lbs. per lin. ft. or 0. 3t. × 510′ 153 tons.

Modulus of Elasticity, 26,000,000 lbs. p. sq. in.
Expansion for 1° F, - 0.00000,633 } for Steel.
Change of Temperature, ±75° F.

DIAGRAM OF STRAINS IN 4 INTERMEDIATE RIBS.



SCALE 1 INCH = 80 FT.

Span, 510 ft. c. c. Rise, 90 ft. c. c.

LOADS ON INTERMEDIATE RIBS.

Iron and steel, 1-6 of 15000 lbs. = 2500 lbs. per lin. ft. × 510′ =	637½	tons.
Floor, 14½′ × 510′ = 7395 sq. ft. a 225 lbs. - - - -	= 832	"
Total dead load, - - - -	1469½	"
Moving Load, = 7395 sq. ft. a 100 lbs. - - - -	370	"
Total, - - - - - -	1839½	"

Modulus of Elasticity, - 26,000,000 lbs. p. sq. in.
Expansion for 1° F, - 0.00000,633 } for Steel.
Change of Temperature, ±75° F.

Horizontal Reaction resulting from this change Ht. = 25513 lbs.

P = allowed compression, per square inch of cross section.
L = length in inches.
R = least radius of gyration in inches.

No compression member, however, shall have an unstayed length exceeding forty-five times its least width. The lateral struts shall be proportioned by the above formula to resist the resultant due to an assumed strain of 10,000 pounds per square inch upon all rods attached to these struts.

The rivets connecting the parts of any member must be so spaced that the shearing strain per square inch shall not exceed 7,500 pounds for iron, nor 9,000 pounds for steel; nor the pressure on the bearing surface of the rivets, per square inch, exceed 12,000 pounds for iron or 15,000 pounds for steel.

Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely by the upper and lower flanges, and that the shearing or web strains are resisted entirely by the web plate. No part of the web plate shall be estimated as flange area. The web plates shall not be subjected to a shearing strain per square inch greater than 4,000 pounds for iron or 5,000 pounds for steel. No web plate shall, however, be less than three-eighths inch thick.

Similarly, the web of the arch ribs shall be considered as resisting shearing strains only.

All web plates must be properly stiffened, and must be spliced at all joints by a plate or two angles on each side.

The flange plates of the arch ribs must be limited in width, so as not to extend beyond the outer line of rivets connecting them to the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness, or shall decrease in thickness outwardly from the angles.

The pitch of rivets in all classes of work shall never exceed six inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet.

The distance between the edge of any piece and the centre of a rivet hole must never be less than one and one-quarter inches, except for bars less than two and a half inches wide. Where practicable, it shall be at least two diameters of the rivet.

The rivets used shall generally be three-quarter inch or more in diameter.

All rivet holes must be so accurately spaced, that, when the several parts forming one piece are assembled together, a rivet one-sixteenth inch less in diameter than the hole can be entered, hot, into any hole.

The rivets when driven must completely fill the holes. The heads must be round and of a uniform size for the same sized rivets throughout the work. They must be full and neatly made and be concentric to the rivet hole and thoroughly pinch the connected pieces together. Wherever possible, all rivets must be machine-driven, both during the shop manufacture and the erection.

The several pieces forming one built member must fit closely together, and, when rivetted, shall be free from twists, bends, or open joints.

All joints in rivetted work, whether in tension or compression, must be properly spliced. All abutting ends shall be planed to careful fits.

All the details and connections of the several parts of the structure shall be of such strength that rupture would occur in the body of the members, rather than in any of their details or connections.

No steel or iron of a less thickness than three-eighths inch shall be used in any part of the structure.

No tension rod shall have a less sectional area than one and a quarter square inches.

The sheared edges of all the steel shall be planed off to a depth of one-quarter inch.

All punched holes shall be clean cuts, without torn or ragged edges.

All punched holes in steel must be reamed to a diameter one-eighth inch larger, so as to remove all the sheared surface of the metal.

All bed plates must be of such dimensions, that the greatest pressure upon the masonry shall not exceed 800 pounds per square inch. The bed plates must be firmly anchored to the masonry of the piers and abutments.

The workmanship of all parts of the work shall be first-class in every particular, not only as regards the effective working of all parts of the structure as to maximum strength, but to secure in all respects neatness of appearance and finish to all detailed parts.

Wherever the floor girders of the main arches are supported on the masonry, suitable bearings of cast or wrought iron shall be secured to the masonry to carry the same.

Provision must be made at the junction of the pavements on the abutments, piers, and main spans to allow for the movements from expansion.

The contractor shall furnish promptly all bolts and anchors, which must be inserted in the piers and abutments during the construction of the same. He will also furnish all necessary drawings, showing the proper location of each bolt and anchor, for the use of the masonry contractor.

The cornice and parapet over the arches shall be made of cast iron, as shown on sheet No. 6, and shall not weigh less than 190 pounds per lineal foot.

These castings must be clean and sharp on the edges, and perfectly straight and out of wind. They must be free from blow-holes and surface defects, and shall be equal to the best class of architectural iron-work.

Quality of Material.

Iron.—All wrought iron must be tough, fibrous, and uniform in character. It shall have a limit of elasticity of not less than 26,000 pounds per square inch.

Finished bars must be thoroughly welded during the rolling, and be free from injurious seams, blisters, buckles, cinder-spots, or imperfect edges.

For all tension members, the bars shall stand the following tests:

Full-sized pieces of flat, round, or square iron, not over four and a half inches in sectional area, shall have an ultimate strength of 48,000 pounds per square inch, and stretch twelve and a half per cent. in their whole length.

Bars of a larger sectional area than four and a half square inches, when tested in the usual way, will be allowed a reduction of 1,000 pounds per square inch for each additional square inch of section, down to a minimum of 46,000 pounds per square inch.

When tested in specimens of uniform sectional area of at least one-half square inch for a distance of ten inches, taken from the tension members, which have been rolled to a section not more than four and a half square inches, the iron shall show an ultimate strength of 50,000 pounds per square inch, and stretch eighteen per cent. in a distance of eight inches.

Specimens taken from bars of a larger cross section than four and a half inches will be allowed a reduction of 500 pounds for each additional square inch of section down to a minimum of 48,000 pounds.

The same sized specimens taken from angle and other shaped iron shall have an ultimate strength of 48,000 pounds per square inch, and elongate fifteen per cent. in eight inches.

The same sized specimens taken from plates less than twenty-four inches in width shall have an ultimate strength of 48,000 pounds, and elongate fifteen per cent. in eight inches (*a*).

The same sized specimens taken from plates exceeding twenty-four inches in width shall have an ultimate strength of 46,000 pounds, and elongate ten per cent.

All iron for tension members must be capable of being bent cold, for about ninety degrees, to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend 180 degrees to this curve without cracking. When nicked on one side and bent by a blow from a sledge, the fracture must be nearly all fibrous, showing few crystalline specks.

Specimens from angle, plate (*a*), and shaped iron must stand bending cold through ninety degrees, and to a curve whose diameter is not over three times its thickness, without cracking. When nicked and bent, its fractures must be mostly fibrous.

Iron rivets shall be made from the best double-refined iron.

STEEL.—The steel shall be uniform in character for each specified kind. The finished bars, plates, and shapes must be free from cracks on the faces or corners and have clean, smooth surfaces.

All steel for the arch ribs, girders, and tension rods shall have an ultimate strength of 62,000 to 70,000 pounds per square inch, with an elastic limit not less than 32,000 pounds per square inch, and a minimum elongation of eighteen per cent. when measured on an original length of eight inches.

All steel for rivets shall have an ultimate strength per square inch of 56,000 to 64,000 pounds, with a minimum elongation of twenty-five per cent.

Tests shall be made by samples cut from the finished material after rolling; the samples to be at least twelve inches long, and to have a uniform sectional area not less than one-half square inch. All the samples must show uniform fine-grained fractures of a blue, steel-gray color, entirely free from fiery lustre or a blackish cast.

Samples cut from finished material for the arch ribs, girders, or tension members, tested before or after heating to a low, cherry red, and cooled in water at eighty-two degrees Fahrenheit, must stand bending to a curve whose inner radius is one and a half times the thickness of the sample without cracking. Samples of rivet steel, before and after being heated to a light yellow heat and quenched in cold water, must stand closing solidly together without sign of fracture. To check the uniformity of the material, the manufacturers of the ingots shall cause to be made from each cast sample bars of three-quarter inch round, with a definite and uniform reduction equivalent to reducing a four-inch ingot to the sample size. They shall mark the same in a manner to identify the final product.

The usual chemical tests shall be furnished in connection with these samples.

No work must be put upon any steel at or near the blue temperature, or between that of boiling water and the ignition of hard-wood sawdust.

Any steel straightened or worked cold by use of the hammer or gag press must be afterward wholly annealed.

The contractor must furnish the use of a testing machine, capable of testing the above samples, at all mills where the iron or steel may be manufactured, free of cost.

All facilities for inspection of the material and workmanship shall be furnished by the contractor. He shall furnish the above samples, prepared, of both the steel and iron, without charge.

Painting.

All the steel and iron work, except the buckle plates, shall receive a thorough coating of pure linseed oil as soon as practicable after its manufacture, and an additional coat of paint before erection.

The paint shall be made of strictly pure linseed oil and finely ground red lead.

The paint must be well worked into all joints and open spaces.

Before painting, all the iron and steel work shall be thoroughly cleansed from rust or loose scale.

In rivetted work, all surfaces coming in contact shall each be painted before being rivetted together.

The buckle plates shall be treated by immersion, hot, into a bath of the usual preparation of coal-tar and asphaltum, now customary for cast-iron water pipe.

After erection, all exposed surfaces of the steel and iron work shall receive two full coats of white lead and linseed oil paint of six selected tints and shades.

Erection.

The contractor shall so conduct his operations during erection as not to obstruct the river passage or any public street without due authority, nor to interfere unnecessarily with the work of the other contractors.

He shall assume all risks of accidents to men and material prior to the final acceptance of the completed structure by the Commission.

At the completion of his work he must remove all false works, piling, and other obstructions or unsightly material produced by his operations.

GENERAL CLAUSES.

All working drawings required by the Commission must be furnished free of cost.

No work shall be commenced or materials ordered until the working drawings are approved in writing by the engineer of the Commission.

The iron hand-railing, cornice, and ornamental iron work will be in accordance with the general plans.

The Commission reserve the selection of the hand-railing and ornamental work, providing its actual cost in place to the contractor, plus ten per cent. profit, does not exceed the price of eighteen dollars per running foot for the iron hand-railing, and a fixed price of thirty-six dollars per lineal foot of span for the cornice and ornamental iron work, exclusive of hand-railing, but inclusive of all brackets and attachments.

SCHEDULE C.

PRICES TO GOVERN INCREASE OR DIMINUTION OF WORK.

Granite in piers more than one foot below low water, per cubic yard	$25.00
Granite in piers, thence to the arch spring line, per cubic yard	28.00
Granite in piers, caps of rusticated work, per cubic yard	36.00
Granite in piers, cornice courses below spring line, per cubic yard	40.00
Granite in piers, bridge seats for metal arch ribs, per cubic yard	44.00
Granite in piers, quoins above spring line, per cubic yard	33.00
Granite in piers, cornice and parapet on piers, per cubic yard	53.00
Granite in cornice and parapet on abutments, per cubic yard	50.00
Granite face voussoirs of sixty-feet arches, per cubic yard	37.00
Granite or gneiss, interior sixty-foot arches, per cubic yard	33.00
Granite seats at piers, for each refuge bay, each	500.00
Granite in stone posts for railing on embankments, per post	16.00
Gneiss in piers, facing on end and side of piers, per cubic yard	15.00
Gneiss facing of abutments, per cubic yard	11.00
Gneiss rubble, rear of the above and cross walls, per cubic yard	5.50
Blue-stone coping of buttress in abutments, per cubic yard	40.00
Pointing the whole face of the masonry, a gross sum of	2,600.00
Concrete, interior of piers, per cubic yard	5.50
Concrete under paving of approaches, per cubic yard	5.00
Concrete under foundation of piers and abutment, per cubic yard	5.50
Concrete in jack arches on the abutments and over buckle plates, per cubic yard	5.00
Excavation of earth ; dredging for pier No. II., per cubic yard	4.00
Excavation of earth for foundation of piers and abutments:	
For piers, per cubic yard	3.00
For abutments, per cubic yard	60
Excavation of earth for grading roadway beyond abutments, per cubic yard	50
Excavation of rock for foundation of piers and abutments, per cubic yard	2.00
Excavation of rock for grading roadway beyond abutments, per cubic yard	1.00
Embankments for grading roadway beyond abutments, including wetting and rolling, per cubic yard	40
Dry and slope wall on earth slopes, per cubic yard	2.00
Selected gravel under roadway and pavements, including wetting and rolling, per cubic yard	1.30
Vitrified drain pipes, including laying trenches and filling, viz.:	
For pipes six-inch diameter, per lineal foot	1.50
For pipes eight-inch diameter, per lineal foot	1.50
For pipes twelve-inch diameter, per lineal foot	2.75
For pipes eighteen-inch diameter, per lineal foot	2.75
Cast-iron vertical drain pipes from roadway down to piers, at each two taper pipes nine to six inches, and remainder six inches diameter, viz.:	
Lineal foot of tapers	1.25
Lineal foot of six-inch pipe	80

Cast-iron gratings at each, per grating	$5.00
Galvanized iron for clamps, dowels, and bolts, viz.:	
In buttress coping, in jack arches, in parapets, and in railing-posts, including lead, per pound	10
Galvanized chain for railing on embankments, per pound	10
Blue-stone flags (for whole length), including the caulking of the joints, per square foot	50
Curb-stone (for whole length), per lineal foot	1.00
Gutter-stone (for whole length), per lineal foot	80
Asphalt, covering about seventy-nine feet in width (for whole length), per square yard	1.30
Granite pavement, including asphalt and fine gravel in joints, and the sand beneath, per square yard	3.00
Gas pipes of wrought iron, three inches diameter, two lines (for whole length), per lineal foot	60
Gas lamps, fifty feet apart, on bridge and approaches, each	60.00
Gas lamps, clusters of twelve, each cluster	300.00
Foundations of pier III. below line shown on Plan 1, per cubic yard of masonry	25.00
For foundations of pier II., if compressed air is used, per cubic yard of displacement, timber, and masonry, below said line	45.00
For foundations of pier II., if any process other than compressed air is used, cost as certified to by the engineer, with ten per cent. added	...
For any decrease in foundations above said line, per yard to be deducted	10.00

ADDITIONAL PRICES UNDER SECOND SECTION OF CONTRACT.

Granite skewbacks and cornice, per cubic yard	$51.85
Granite cornice on piers and abutments, per cubic yard	80.00
Granite cornice on approaches, per cubic yard	90.00
Granite cornice on stairway, per cubic yard	145.00
Granite facing of piers and abutments, replacing gneiss, per cubic yard	19.00
Brick-work, per cubic yard	13.00
Portland cement, per barrel	$2.35 to 2.50
Blue-stone steps, per lineal foot	2.85
Blue-stone platforms, per square foot	$2.80 to 3.15
Gas-lamp posts, with lamps (bronze), standard	264.00
Gas-lamp posts, with lamps (bronze), on piers	314.00
Electric lamp-posts	790.00
Bronze rail on approach, per panel, ten feet long	110.00
Bronze ornaments in granite parapet, each	26.50
Asphalt roadway, binder and wearing surface, per square yard	3.15
Bituminous concrete, per cubic yard	5.00
Iron cornice and parapet, $138,066.41; of which, $71,400 included in original contract price for iron and steel work	138,066.41

SPECIFICATIONS FOR PAVING HARLEM RIVER BRIDGE.

FIRST. The wearing surface of said pavement will be three and a half inches thick when compressed, composed of a bituminous binder one and a half inches in thickness and a Trinidad asphalt surface two inches in thickness, laid upon a foundation of bituminous concrete or distillate base of the thickness hereinafter specified.

SECOND. The foundation will be composed of clean broken stone that will pass through a two-and-a-half-inch ring, spread in layers not exceeding six inches in thickness and well rammed and rolled with a steam roller until each layer is thoroughly compacted, after which each layer shall be sprinkled with hot composition expressly distilled for the purpose, using not less than about ten gallons to the cubic yard of stone, so as thoroughly to permeate all crevices or spaces, thereby making the layer one solid mass.

(*a*) Over the buckle plates the first layer of stone shall not exceed three inches in thickness, and shall be composed of broken stone to be not more than three-quarter inch in diameter; successive layers of stone will then be laid, rolled, and sprinkled with hot composition as above described, until the surface is exactly parallel to and three and a half inches from the surface of the finished pavement.

(*b*) Over the arches the foundation of the pavement will begin at the concrete surface, and will be laid in the manner just described, until its surface is exactly parallel to and three and a half inches from the surface of the finished pavement.

(*c*) Over the approaches, exclusive of the arches, the foundation of the pavement will begin on the filled surface, eight and a half inches below the finished surface of the pavement, and will be laid in the manner just described, until its surface is exactly parallel to and three and a half inches from the finished surface of the pavement.

THIRD. The foundation being thoroughly prepared in the manner specified, the second or binder course will be laid, composed of clean broken stone thoroughly screened, not exceeding one inch in the largest dimensions. The stone will be heated by passing through revolving heaters and thoroughly mixed by suitable machinery with No. 4 coal-tar distillate in the proportion of one gallon of distillate to one cubic foot of stone. The binder will be hauled to the work, spread upon the base course at least two inches thick, and immediately rammed and rolled with hand and steam rollers while in a hot and plastic condition, until it is compressed to a thickness of one and a half inches, and has a surface parallel to and two inches from the finished surface of the pavement.

FOURTH. The asphalt surface will be composed of: first, refined Trinidad asphaltum; second, heavy petroleum; third, sand containing not more than five per cent. hydro-silicate of alumina; fourth, fine powder of carbonate of lime. The asphaltum must be refined and brought to a uniform standard of purity and gravity. The petroleum oil must be freed from all impurities and brought to a specific gravity of eighteen to twenty-two degrees Beaume, and stand a fire test of two hundred and fifty degrees Fahrenheit. They will be mixed in the following proportion by weight:

Refined asphaltum, ...	100 pounds.
Petroleum, ...	14 to 17 pounds.

The asphalt cement, made in the manner above described, will be mixed with other materials in the following proportions by weight:

Asphalt cement, from	15	to	18
Sand, from	70	to	65
Pulverized carbonate of lime, from	15	to	17
	100		100

In order to make the pavement homogeneous, the proportion of the asphalt cement must be varied according to the quality and character of the sand. The carbonate of lime may be reduced, or omitted entirely, when suitable sand can be obtained. The sand and asphalt cement will be heated separately to about three hundred degrees Fahrenheit. The pulverized carbonate of lime while cold will be mixed with the hot sand in the required proportions, and then mixed with the asphaltic cement at the required temperature and in the proper proportion in a suitable apparatus, so as to effect a thoroughly homogeneous mixture. The pavement mixture, prepared in the manner indicated, will be laid upon the binder as follows: It will be brought to the ground in carts at a temperature of about two hundred and fifty degrees Fahrenheit, and carefully spread by means of hot iron rakes in such manner as to give a uniform and regular surface and to such depth, that, after having received its ultimate compression, it will have a thickness of two inches. This thickness will be tested by gauges approved by the Chief Engineer of the Harlem River Bridge Commission. The surface will then be compressed by rollers, after which a small amount of hydraulic cement will be swept over it, and it will then be thoroughly compacted by steam roller to weigh not less than two hundred and fifty pounds per lineal inch, the rolling being continued so long as it makes an impression upon the surface.

All materials used, as well as the plant and method of manufacture, will be submitted to the inspection and approval of the Chief Engineer of the Harlem River Bridge Commission.

FIFTH. In order to make the gutters impervious to water, a width of twelve inches next to the curb will be coated with hot, pure asphalt, smoothed with smoothing irons.

The Chief Engineer of the Harlem River Bridge may, at his option, require the gutters for a width not exceeding eighteen inches to be laid with a distillate composition composed of paving cement made of twenty-five per cent. of refined asphalt and seventy-five per cent. of coal-tar distillate mixed with other materials, as follows:

Clean, sharp sand will be mixed with pulverized stone of such dimension as to pass through a quarter-inch screen in the proportion of two to one; to twenty-one cubic feet of the above mixture will be added one peck of dry hydraulic cement, one quart of flour of sulphur, and two quarts of air-slacked lime; to this mixture will be added three hundred and twenty pounds of paving cement to compose the wearing surface.

These materials will be mixed and laid in the same manner as above described for the asphalt surface.

And the said Chief Engineer shall have the further option of requiring the gutters, for a width not exceeding eighteen inches, to be laid in Portland cement concrete with a facing of Portland cement mortar, in the following manner:

The gutter will be laid with a total thickness of three and a half inches, of which two inches shall be in concrete and one and a half inches in mortar; a wooden form with a thickness of three and a half inches will be laid upon the base with its edge at the distance of eighteen inches from the curb; said edge having such shape, either curved or notched, as may be prescribed by said Chief Engineer for the purpose of giving corresponding shape to the edge of the gutter. The concrete will be composed of one part best Portland cement (equal to Dykerhoff's or White's), two parts of clean, sharp sand, and three parts of clean broken stone, not more than one inch in their largest dimensions. These materials will be mixed with the least possible amount of water, and will be thoroughly compacted in place by ramming. The exposed surface of the gutter will be coated one and one-half inches thick with a cement mortar composed of one part best Portland cement, as above, and three parts of clean, sharp sand or of granulated stone, the fragments being of such size as to pass through a quarter-inch screen, and free from all dust. These materials will be mixed with the least possible amount of water, and will then be spread in place and thoroughly compacted by tamping with a straight edge, special care being taken to get an absolutely accurate grade, so as to facilitate the flow of water. The work will be carried on uniformly and the whole gutter completed while in a soft and plastic state, so that it will become a homogeneous solid when set. While still plastic, the curb and gutter will be sawed or cut at intervals of six or eight feet, as may be ordered, to allow for expansion and contraction and give it the appearance of cut stone. This gutter of Portland cement concrete will be laid in advance of the laying of the asphalt surface, and shall be allowed to set for not less than five days before the asphalt shall be laid against it.

In case the gutters shall be laid with either distillate or composition or Portland cement concrete, they shall be measured and paid for at the rate of two dollars and eighty-five ($2.85) cents per square yard; being the same price as for the above described pavement, consisting of asphalt surface and binder with a total thickness of three and a half inches.

SIXTH. The hot composition, referred to in the above specifications, shall be the residuum of the distillation of coal tar after extracting the lighter oils, and shall be of the consistency usually known to manufacturers as No. 4. It shall be of uniform standard of purity, free from all extraneous matter, and shall be subject to the inspection and approval of the Chief Engineer of the Harlem River Bridge Commission.

SEVENTH. One or more inspectors will be appointed by the Harlem River Bridge Commission, whose duty it shall be to point out any neglect or disregard of these specifications. The work shall be done in strict accordance with these specifications, and, upon all technical questions concerning the execution of the work in accordance with the specifications and the measurement thereof, the decision of the Chief Engineer of the Harlem River Bridge Commission shall be final.

EIGHTH. The Barber Asphalt Paving Company guarantees the wearing quality of the pavement to be laid under this contract for the period of five years from the completion of the laying thereof; and shall, during said period, at its own cost and without any expense or charge to the city of New York or any department thereof, repair and make good any injury to said pavement caused by the proper use of the same as a public highway, and shall keep and maintain the same in good order and repair for the entire period of five years aforesaid. Good and sufficient bond for said maintenance and repair shall be given to the Commissioners of the Harlem River Bridge and their successors in office and to the city of New York by the said The Barber Asphalt Paving Company.

(Approved.)

WILLIAM R. HUTTON,

Chief Engineer, Harlem River Bridge Commission.

DIAMOND DRILL BORINGS TAKEN

For the Piers of the proposed Bridge over the Harlem River, made under the direction of WM. J. McALPINE, Chief Engineer, by CHAS. B. BRUSH, Civil Engineer, January to August, 1886.

PIER III.

No. 1. Elevation 38.60.

Sand, Bowlders, etc.	30 feet.	
Sand and Clay	18 "	
Sand and Mica	24 "	Shist.
Soft Rock	2 "	Shist.
In Hard Rock	1 foot.	
	75 feet.	

Bottom at Elevation — 36.4.

No. 2. Elevation 41.7.

Soil and Gravel	11.66 feet.
Soft Rock (Shist)	15.50 "
In Hard Rock (Gneiss)	12.67 "
	39.83 feet.

No. 3. Elevation 68.70.

Soil and Clay	8 feet.
Coarse Gravel	23 "
Soft Rock (Shist)	20 "
In Hard Rock (Gneiss)	16.9 "
	67.9 feet.

No. 4. Elevation 42.7.

Soil, Clay, Bowlders	19.4 feet.	
Soft Rock, compact	6.6 "	32.6 feet Shist.
" " very soft	3 "	
" " compact	8 "	
" " very soft	3 "	
" " compact	3 "	
" " very soft	3 "	
In Soft compact rock	6 "	
	52 feet.	

Bottom at Elevation — 9.3.

No. 5. Elevation 40.60.

Soil, Sand, Gravel, and Bowlders	18.6 ft.	
Soft Rock, very soft	13 4 "	49.4 feet of Shist.
" " medium	10 "	
" " compact	26 "	
In Hard Rock (Gneiss)	17 "	
	85 feet.	

Bottom at Elevation — 44.4.

No. 6. Elevation 39.

Sand, Soil, etc.	4 feet.
Bowlders and Hard Gravel	17 "
Fine Mica Sand	3 "
Soft Rock (Shist), very soft	4 "
" " " medium	12 "
" " " compact	30 "
In Hard Rock (Gneiss)	5 "
	75 feet.

Bottom at Elevation — 36.

No. 7. Elevation, 68 80.

Sand, Gravel, and Bowlders	30 feet.
Soft Rock, medium (Shist)	6 "
" " compact "	5 "
In Hard Rock (Gneiss)	9 "
	50 feet.

No. 8. Elevation, 41 50.

Soil, Sand, Gravel, and Bowlders	20 feet.
Soft Rock, very soft (Shist)	15 "
" " (Shist)	8 "
Hard Rock (Gneiss)	10 "
Soft Rock (Shist)	18 "
In Hard Rock	3 "
	74 feet.

Bottom at Elevation — 32.5.

No. 9. Elevation, 40.30.

Soil, Sand, Gravel, and Bowlders	20 feet.	
Soft Rock, very soft	6 "	60 feet of Shist.
" " medium	16 "	
" " very soft	12 "	
" " compact	26 "	
In Hard Rock (Gneiss)	5 "	
	85 feet.	

Bottom at Elevation — 44.7.

EAST OF PIER III.

A, Elevation, 82.00.

Soil and Bowlders	16 feet.
Hard Rock or Bowlders	8 "
Medium Soft Rock	5.5 "
In Hard Rock	0.5 "

B, Elevation, 82.00.

Soil, Clay, and Bowlders	17 feet.

Bowlders or Rock on bottom.

C, Elevation, 110.40.

Soil, Sand, and Bowlders	13 feet.
Compact Soft Rock	6 "

D, Elevation, 120.3.

Soil and Bowlders	6 feet.
Medium Soft Rock	2 "

PIER II.

No. 10.

Depth of Water	4 feet.
Silt	9 "
Sand and Gravel	8 "
Very fine Sand	5 "
Hard White Sand	6 "
Marble	12 "
	— 12 feet.

No. 11.

Depth of Water	3.5 feet.
Silt	6.5 "
Sand	8.5 "
Coarse Sand and Gravel	6 "
Coarse Round Gravel	6 "
Yellow Clay	1 "
Very fine Sand	4 "
Sand and Gravel	4 "
Marble	1.5 "
Sand Seam	1 "
Shist	2.5 "
Marble, mixed with Gneiss	5 "
	—49.5 feet.

No. 12.

Water	4 feet.
Silt	11 "
Fine Sand and Bowlders	12 "
Coarse Gravel and Bowlders	18 "
Fine light Sand	3.8 "
Bottom Rock.	
	—48.8 feet.

No. 13.

Water	4 feet.
Silt	12 "
Fine Sand and Bowlders	10 "
Bowlders, Sand, and Gravel	8 "
Very fine Sand	4 "
Sand and Gravel	5 "
Bottom Rock.	
	—43 feet.

No. 14.

Water	4 feet.
Silt	10 "
Bowlders and fine Sand	6 "
Bowlders, Sand, and Gravel	21.8 "
Bottom Rock.	
	—41.8 feet.

No. 15.

Water	4.3 feet.
Silt	10 "
Bowlders, Sand, and Gravel	16 "
White Sand	6 8 "
Soft Marble	3.3 "
Marble with Gneiss	6 "
Micacious Gneiss	14.4 "
	—60.8 feet.

No. 16.

Water	4.4 feet.
Silt	12 "
Fine Sand	14.6 "
Bowlders, Sand, and Gravel	6 "
Fine Sand	5.4 "
Quartz, very hard	7.6 "
	—50.0 feet.

No. 17.

Water	4 feet.
Silt	10 "
Sand	7 "
Bowlders, Sand, and Gravel	7.6 "
Hard Gneiss	1.8 "
Very Soft Rock	10 "
Marble	1 "
" with Hard Gneiss	6.8 "
	—48.2 feet.

No. 18.

Water	4.3 feet.
Silt	11 "
Fine Sand	4.7 "
Bowlders	5 "
Sand and Gravel	15 3 "
Soft Rock and Marble	3.7 "
Very hard Quartz	4.3 "
	—48.3 feet.

No. 19.

Water	1 foot.
Silt	8.2 feet.
Sand and Bowlders	14.5 "
Soft Rock	1.1 "
Marble	1 "
Marble and Gneiss	26.1 "
	—51.9 feet.

No. 20.

Water	2 feet.
Silt	8 4 "
Bowlders, Sand, and Gravel	11.5 "
Marble and Gneiss	26.1 "
	—48.0 feet.

No. 21.

Water	4.3 feet.
Silt	11 "
Coarse Sand and Bowlders	13 "
Sand and Gravel	12.5 "
Marble Rock	7.8 "
	—48.6 feet.

No. 22.

Water	2.3 feet.
Silt	9.7 "
Bowlders, Sand, and Gravel	23.3 "
Hard Marble	14.3 "
	—49.6 feet.

No. 23.

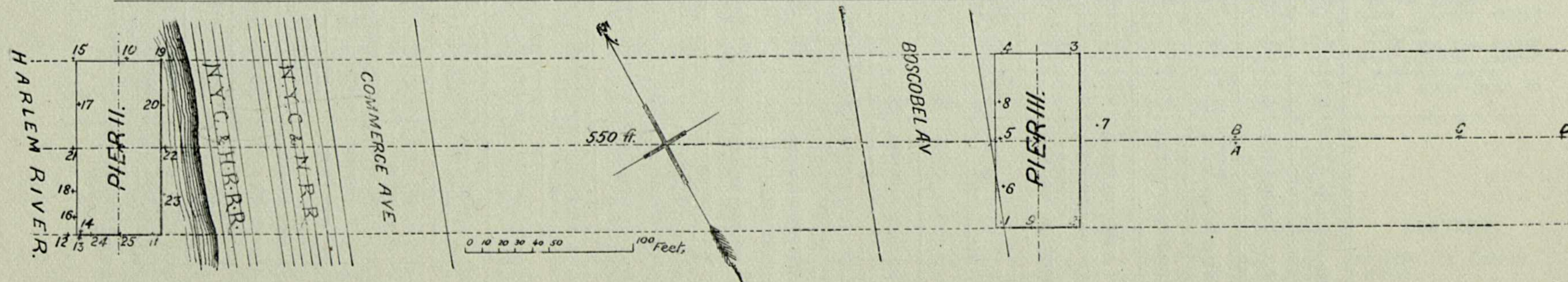
Water	3 feet.
Silt	8 "
Fine Sand and Bowlders	14 "
Gravel	10 "
Marble and Sand	2.4 "
Marble with Mica	13 "
Hard Blue Stone	0.6 "
Marble	2 "
	—53.0 feet.

No. 24.

Water	4.4 feet.
Silt	11.6 "
Sand	10 "
Bowlders, Sand, and Gravel	15.4 "
Hard Quartz	6.6 "
	—48.0 feet.

No. 25.

Water	3.6 feet.
Silt	8.4 "
Sand and Bowlders	11 "
Bowlders, Sand, and Gravel	15.6 "
Hard Quartz	14.4 "
	—53.0 feet.



Note.—Base assumed is 0.80 ft. higher than base of the Park Department. Base assumed is 0.50 ft. higher than base of the Board of Public Works.
" " " 4.046 ft. " " " " Aqueduct Commissioners. " " " 6.172 ft. " " " " Dock Department.
The difference between mean high and low water, as established here by the Dock Department, is 5.83 feet.

RECORD OF SINKING CAISSON FOR PIER II.—Readings taken at 9 A.M.

DATE.	Elevations of Cutting Edge.					Elevations of Sand.					Average Penetration of Caisson.	Sunk in 24 hours.	Surface in Contact.	Weights.				Elevation of surface of Water.	Depth Immersed.	Calculated Air Pressure.	Reaction due to Air Pressure.	Net Weight.	Average weight per square foot of surface exposed to friction.	REMARKS.
	N. E.	N. W.	S. E	S. W.	Average.	N. E.	N. W.	S. E.	S. W.	Average.				Caisson.	Masonry.	Sand.	Total.							
														Tons.	*Tons.*	*Tons.*	*Tons.*			*Lbs.*	*Tons.*	*Tons.*	*Lbs.*	
Nov. 17	5.77	7.36	5.58	6.59	6.33	.....	.....	.....	.....	.....	...	.....	.....	.....	.....	.....	1,077	.....	.....	.....	.....	.....	.....	
" 18	5.76	7.34	5.56	6.58	6.31	....	.....	.....	.....	....	.....	−0.02	.....	1,077	.....	....	1,077	.....	.....	.....	.....	.....	.....	Datum Plane—Zero, or Mean High Water.
" 19	5.78	7.54	5.61	6.66	6.40	....	.....	.....	.....	.....	.....	0.09	.....	1,077	.. ..	.....	1,077	.....	.....	.....	.....	.....	... .	Mean difference between High and Low Water, 5.83 feet.
" 20	5.79	7.48	5.59	6.61	6.37	4.35	3.03	4.35	3.03	3.69	2.68	−0.03	839	1,077	.....	.....	1,077	3.03	3.35	1.47	603	474	1,128	
" 21																								
" 22	5.79	7.63	5.67	6.85	6.48	.....	.....	.....	.....	.....	.....	0.11	.....	1,077	.....	.....	1,077	.....	.....	.....	.....	.....	.....	Mean distance around caisson, 313 feet.
" 23	5.83	7.59	5.74	6.84	6.50	4.81	2.96	4.52	3.65	3.99	2.51	0.02	786	1,077	.....	.....	1,077	2.96	3.54	1.56	640	437	1,112	
" 24	5.79	7.61	5.75	6.86	6.50	3.91	2.61	2.95	3.25	3.18	3.32	0.00	1,039	1,077	.....	.....	1,077	2.61	3.89	1.71	701	376	722	Area at bottom, 104.80 x 54.40.
" 25	5.78	7.65	5.76	7.09	6.55	3.81	2.80	3.87	3.43	3.48	3.07	0.05	961	1,077	.....	.....	1,077	2.80	3.75	1.65	677	400	832	
" 26	5.77	8.00	5.78	7.27	6.71	3.76	3.03	3.92	3.70	3.60	3.11	0.16	973	1,077	.....	.....	1,077	3.03	3.68	1.62	665	412	846	
" 27	5.82	8.26	6.60	7.56	7.06	5.72	1.74	6.01	4.13	4.40	2.66	0.35	833	1,077	.....	.....	1,077	1.74	5.32	2.34	960	117	280	
" 28	5.89	8.52	6.77	7.69	7.22	5.18	2.32	5.77	3.56	4.21	3.01	0.16	942	1,077	.....	.....	1,077	2.32	4.90	2.16	886	191	404	
" 29	5.92	8.80	6.99	8.22	7.48	4.80	3.12	5.49	4.24	4.41	3.07	0.26	961	1,077	.. ..	.....	1,077	3.12	4.36	1.92	788	289	600	
" 30	5.97	9.22	7.15	8.54	7.72	4.71	2.92	5.36	4.41	4.35	3.37	0.24	1,055	1,077	.....	.....	1,077	2.92	4.80	2.11	866	211	400	
Dec. 1	6.02	9.04	7.09	8.46	7.65	7.02	2.09	7.21	3.98	5.08	2.57	−0.07	804	1,077	.....	.....	1,077	2.09	5.56	2.45	1,005	72	179	
" 2	6.59	9.02	7.51	8.53	7.91	6.94	3.22	6.86	3.81	5.21	2.70	0.26	845	1,077	.....	....	1,077	3.22	4.69	2.06	845	232	548	
" 3	6.67	9.01	7.60	8.54	7.96	7.52	2.76	7.54	3.36	5.30	2.66	0.05	833	1,077	.....	.....	1,077	2.76	5.20	2.29	940	137	328	
" 4	6.63	9.04	7.58	8.54	7.95	6.81	2.71	7.58	3.35	5.11	2.84	−0.01	889	1,077	.....	.....	1,077	2.71	5.24	2.31	948	129	290	
" 5	6.70	8.92	7.57	8.47	7.92	7.24	3.57	7.59	4.69	5.77	2.15	−0.03	673	1,077	.....	.....	1,077	3.57	4.35	1.91	784	293	870	
" 6	6.61	8.45	7.67	8.33	7.77	6.79	3.72	7.13	3.74	5.35	2.42	−0.15	757	1,077	.....	.....	1,077	0.93	6.84	3.01	1,235	−158	−416	
" 7	6.67	8.16	7.62	8.28	7.68	6.71	3.50	6.89	3.60	5.18	2.50	−0.09	783	1,077	.....	.....	1,077	0.53	7.15	3.15	1,293	−216	−550	
" 8	6.76	8.76	7.70	8.41	7.91	6.67	3.19	6.84	2.80	4.88	3.03	0.23	948	1,077	45	.....	1,122	2.80	5.11	2.25	923	199	418	From Dec. 8, 1886, to Jan. 21, 1887, inclusive, 45 to 273 tons granite was placed at different points on caisson to increase weight. This is included in column of Weights of Masonry.
" 9	6.85	9.16	7.66	8.47	8.04	6.59	2.55	6.60	2.79	4.63	3.41	0.13	1,067	1,077	97	.....	1,174	2.55	5.49	2.42	993	181	338	
" 10	6.95	9.21	7.66	8.50	8.08	6.29	2.64	6.40	2.92	4.56	3.12	0.04	977	1,077	97	.....	1,174	2.92	5.16	2.27	931	243	496	
" 11	7.59	9.76	7 72	8.49	8.39	6.37	3.32	6.34	3.37	4.85	3.54	0.31	1,108	1,077	97	.....	1,174	2.63	5.76	2.53	1,038	136	244	
" 12	8.00	9.65	7.66	8.40	8.43	6.80	3.73	7.23	3.86	5.41	3.02	0.04	945	1,077	97	.....	1,174	3.63	4.80	2.11	866	308	650	
" 13	8.00	9.65	7.66	8.40	8.43	5.58	2.59	6.12	2.96	4.31	4.12	0.00	1,290	1,077	97	.....	1,174	2.59	5.72	2.52	1,034	140	216	
" 14	8.32	9.59	8.09	7.99	8.50	6.08	2.23	6.97	3.61	4 18	4.32	0.07	1,352	1,077	191	.....	1,268	2.23	6.27	2.76	1,132	136	200	
" 15	8.32	9.59	8.09	7.99	8.50	5.84	2.02	6.75	3.18	4.44	4.06	0.00	1,271	1,077	285	.....	1,362	2.02	6.38	2.81	1,153	209	328	
" 16	8.35	9.41	9.89	8.09	8.94	6.47	2.17	7.69	3.89	5.06	3 88	0.44	1,214	1,077	379	.....	1,456	2.17	6.77	2.98	1,223	233	382	
" 17	8.70	9.18	10.08	8.08	9.01	5.67	1.99	7.31	3.29	4.57	4.44	0.07	1,390	1,077	473	.....	1,550	1.99	7.02	3.09	1,268	282	404	
" 18	8 78	9.07	10.00	8.32	9.04	6.87	2.16	7.96	3.62	5.15	3.89	0.03	1,218	1,077	567	.. ..	1,644	2.16	6.88	3.03	1,243	401	658	
" 19	8.76	9.06	10.06	9.09	9.24	5.64	2.26	6.74	4 16	4.70	4.54	0.20	1,421	1,077	661	.....	1.738	2.26	6.98	3.07	1,260	478	672	
" 20	8.79	9.06	10.06	9.21	9.28	6.91	2.50	7.82	3.84	5.27	4.01	0.04	1,255	1,077	755	.....	1,832	1.23	8.05	3.54	1,453	379	602	
" 21	9.67	9.16	10.07	9.26	9.54	6.91	3.03	7.79	4.24	5.49	4.05	0.26	1,268	1,077	849	.....	1,926	0.63	8.91	3.92	1,609	317	500	
" 22	9.79	9.45	10.05	9.28	9.64	7.24	2.79	7.42	4.34	5.45	4.19	0.10	1,311	1,077	988	. ...	2,065	0.68	8.96	3.94	1,617	448	682	
" 23	9.79	9.62	10.09	9.39	9.72	7.32	2.72	6.88	4.10	5.26	4.46	0.08	1,396	1,077	1,093	....	2,170	+0.37	10.09	4.44	1,822	348	498	All elevations are minus except in those instances where plus sign is shown.
" 24	9.79	10.53	10.03	10.43	10.20	6.75	2.87	6.32	3.66	4.90	5.30	0.48	1,659	1,077	1,138	.....	2,215	1.43	8.77	3.86	1,584	631	760	
" 25	10.32	10.87	10.46	10.66	10.58	6.59	2.58	6.76	3.46	4.85	5.73	0.38	1,793	1,077	1,182	.. ..	2,259	2.58	8.00	3.52	1,444	815	908	
" 26	10.40	10.94	10.49	10.89	10.68	6.39	3.06	5.99	4.82	5.07	5.61	0.10	1,756	1,077	1,227	.....	2,304	3.06	7.62	3.35	1,375	929	1,058	
" 27	10.39	11.00	10.50	10.81	10.68	5.58	2.95	5.77	4.82	4.78	5.90	0.00	1,847	1,077	1,271	.....	2,348	2.95	7.73	3.40	1,395	953	1,030	
" 28	10.40	11.01	10.48	10.80	10.68	5.43	3.17	5.82	4.74	4.79	5.89	0.00	1,840	1,077	1.526	.....	2,603	3.17	7.51	3.30	1,354	1,249	1,356	
" 29	11.32	11.71	11.24	11.54	11.45	4.40	2.63	5.11	4.55	4.18	7.27	0.77	2,276	1,077	1,672	....	2,749	2.63	8.82	3.88	1,592	1,157	1.016	
" 30	11.64	11.83	11.64	11.89	11.75	3.45	2.99	3.01	4.46	3.48	8.27	0.30	2,589	1.077	1,870	.....	2,947	2.99	8.76	3.85	1,580	1,367	1,056	
" 31	11.65	11.85	11.66	11.84	11.75	2.71	3.24	2.22	4.37	3.13	8.62	0.00	2,698	1,077	1,956	.....	3,033	2.22	9.53	4.19	1,719	1,314	974	
Jan. 1	12 37	12.75	12.40	12.67	12.55	3.61	4.39	2.78	3.64	3.60	8.95	0.80	2,801	1,077	2,052	....	3,129	2.78	9.77	4.30	1,765	1,364	973	
" 2	12.45	12.80	12.42	12.76	12.61	2.80	2.80	2.20	2.60	2.60	10.01	0.06	3,133	1,077	2,149	.....	3,226	2.20	10.41	4.58	1,880	1,346	858	
" 3	12.68	12.87	12.50	12.76	12.73	2.37	1.49	1.75	1 16	1.69	11.04	0.12	3,456	1,077	2,245	.....	3,322	1.49	11.24	4.95	2,031	1,291	746	
" 4	13.37	13.60	13.36	13.52	13.46	2.85	3.21	2.60	2.40	2.76	10.70	0.73	3,345	1,077	2,342	4	3,423	0.83	12.63	5.56	2,282	1,141	682	
" 5	13.71	14.11	13.59	13.88	13.82	3.04	3.28	2.44	1.64	2.60	11.22	0.36	3,512	1,077	2,438	12	3,527	0.83	12.99	5.72	2,348	1,179	670	
" 6	14.06	14.47	14.11	14 36	14.25	3.11	3.55	3.19	2.13	3.00	11.25	0.43	3,521	1,077	2,459	27	3,563	2.13	12.12	5.33	2,187	1,376	780	
" 7	14.16	14.49	14.19	14.36	14.28	3.27	3.35	2.85	2.42	3.00	11.28	0.03	3,531	1,077	2,534	28	3.639	1 83	12.45	5.48	2,249	1,390	786	
" 8	15.01	15.15	15.03	15.14	15.09	2.65	3.75	+2.19	2.35	1.64	13.45	0.81	4,210	1,077	2,619	47	3,743	+2.19	17.28	7.60	3.119	624	296	
" 9	15 79	16.00	15.86	15.96	15.90	0.20	0.70	+3.10	0.55	0.80	15.10	0.81	4,726	1,077	2,693	67	3,837	+3.10	19.00	8.36	3,431	456	192	
" 10	15.77	15.99	15.87	15.98	15.90	1.50	2.45	+0.75	2.40	1.40	14.50	0.00	4,535	1,077	2,768	67	3,912	+0.75	16.65	7.33	3,008	904	398	
" 11	16.58	16.82	16.83	17.02	16.81	1.95	4.35	+2.45	3.95	1.57	15.24	0.91	4,770	1,077	2,843	89	4,009	+2.45	19.26	8.47	3,476	533	221	
" 12	16.59	16.83	16.83	17.03	16.82	1.90	3.95	+2.45	3.60	1.75	15.07	0.01	4,717	1,077	2,918	89	4,084	+2.45	19.27	8.48	3,480	604	256	
" 13	16.59	16.86	16.83	17.05	16.83	1.70	3.50	+2.45	3.15	1.48	15.35	0.01	4.805	1,077	2.847	90	4,014	+2.45	19.28	8.48	3,480	534	222	
" 14	17.50	17.86	17.66	17.88	17.73	1.65	4.40	+1.60	3.30	1.94	15.79	0.90	4,942	1,077	2,921	112	4,110	+1.60	19.33	8.51	3,492	618	250	Note.—As the material piled around the Pier
" 15	17.53	17.83	17.68	17.87	17.73	0.61	3.44	+1.07	2.94	1.48	16.25	0.00	5,086	1,077	2,987	112	4,176	+1.07	18.80	8.27	3,394	782	307	

"	16	18.34	18.64	18.53	18.71	18.56	2.12	4.96	+1.16	3.62	2.39	16.17	0.83	5,061	1,077	3,171	142	4,390	+1.16	19.72	8.68	3,562	828	327	shortly after sinking
"	17	18.33	18.63	18.55	18.71	18.56	0.11	4.38	+2.72	3.88	1.41	17.15	0.00	5,368	1,077	3,340	142	4,559	+2.72	21.28	9.36	3,842	717	267	commenced retained the
"	18	18.40	18.63	18.59	18.77	18.60	0.98	2.27	+2.64	1.14	+0.05	18.65	0.04	5,837	1,077	3,524	143	4,744	+2.64	21.24	9.35	3,838	906	310	water immediately about
"	19	19.36	19.62	19.45	19.68	19.53	0.66	4.18	+1.29	3.36	1.73	17.80	0.92	5,571	1,077	3,737	176	4,990	+1.29	20.82	9.16	3,760	1,230	441	the caisson, and was
"	20	19.42	19.64	19.51	19.71	19.60	0.89	4.03	+1.08	1.59	1.36	18.24	0.07	5,709	1,077	3,836	179	5,092	+1.08	20.68	9.10	3,735	1,357	475	generally above water in
"	21	20.32	20.52	20.40	20.64	20.47	1.59	4.82	+0.41	2.17	2.08	18.39	0.87	5,756	1,077	3,936	223	5,236	+0.41	20.88	9.19	3,772	1,464	508	river, the Elevations of
"	22	20.48	20.65	20.54	20.74	20.60	3.15	5.05	+1.25	0.45	1.85	18.75	0.13	5,869	1,077	3,977	230	5,284	+1.25	21.85	9.61	3,944	1,340	456	Surface of Water are all,
"	23	21.19	21.43	21.17	21.34	21.28	3.90	6.80	+4.00	+1.00	1.43	19.85	0.68	6,213	1,077	4,076	264	5,417	+4.00	25.28	11 12	4,564	853	274	with a few exceptions,
"	24	21.26	21.45	21.20	21.41	21.33	1.77	3.82	+1.41	0.54	1.18	20.15	0.05	6,307	1,077	4,176	267	5,520	+1.41	22.74	10.01	4,108	1,412	447	referred to the height
"	25	21.28	21.46	21.26	21.41	21.35	1.86	3.46	+1.55	0.42	1.05	20.30	0.02	6,354	1,077	4,275	268	5,620	+1.55	22.90	10.08	4,137	1,483	465	of this embankment in
"	26	22.14	22.34	22.12	22.30	22.30	1.03	2.79	+0.86	0.29	0.81	21.49	0.95	6,726	1,077	4,374	329	5,780	+0.86	23.16	10.19	4,182	1,598	475	contact with caisson.
"	27	22.16	22.32	22.33	22.44	22.31	3.35	0.65	+0.45	+0.15	0.85	21.46	0.01	6,717	1,077	4,513	330	5,920	+0.45	22.76	10.01	4,108	1,812	539	
"	28	22.41	22.45	22.69	22.70	22.50	3.40	0.51	+0.57	0.16	0.88	21.82	0 25	6,830	1,077	4,652	346	6,075	+0.57	23.13	10.18	4,178	1,897	555	
"	29	23.31	23.46	23.40	23.53	23.43	4.00	+0.45	+0.35	1.15	1.09	22.34	0.87	6,992	1,077	4,791	401	6,269	+0.45	23.88	10.51	4,314	1,955	559	
"	30	23.33	23.47	23.42	23.55	23.44	2.44	0.27	+0.88	0.24	0.52	22.92	0.01	7,171	1,077	4,930	402	6,409	+0.88	24.32	10.70	4,392	2,017	562	
"	31	23.38	23.49	23.44	23.56	23.47	3.58	+1.87	+0.92	+1.37	+0.15	23.62	0.03	7,393	1,077	5,069	404	6,550	+1.87	25.34	11.15	4,576	1,974	534	
Feb.	1	24.19	24.52	24.18	24.39	24.32	3.96	+1.39	+0.34	+0.99	0.31	24.01	0.85	7,516	1,077	5,128	461	6,666	+1.39	25.71	11.31	4,642	2,024	538	
"	2	24.47	24.61	24.45	24.49	24.51	1.75	+0.80	+0.40	+2 83	+0.51	25.02	0.19	7,831	1,077	5,187	474	6,738	+0.80	25.31	11.14	4,572	2,166	553	
"	3	24.50	24.61	24.56	24.48	24.54	+0.48	+0.84	+2.81	+0.39	+1.13	25.67	0.03	8,033	1,077	5,246	476	6,799	+2.81	27.35	12 03	4,938	1,861	463	
"	4	24.92	25.19	24.78	24.99	24.97	+1.84	+0.24	+2.49	0.11	+1.12	26.09	0.43	8,166	1,077	5,305	505	6,887	+2.49	27.46	12.08	4,958	1,929	472	
"	5	25.56	25.68	25.68	25.65	25.65	+1.66	0.29	+1.96	0.74	+0.65	26.30	0.68	8,232	1,077	5,365	550	6,992	+1.96	27.61	12.15	4.987	2,005	487	
"	6	25.60	25.68	25.67	25.64	25.65	+1.49	0.16	+1.59	0.07	+0.33	25.96	0.00	8,125	1,077	5,424	550	7,051	+1.59	27.24	11.99	4,921	2,130	524	
"	7	25.82	25.83	25.75	25.63	25.75	+1.43	0.77	+2.03	0.27	+0.61	26.36	0.10	8,251	1,077	5,483	557	7,117	+2.03	27.78	12.22	5.016	2,101	509	
"	8	26.69	26.75	26.88	26.78	26.78	+0.27	0.98	+0.97	0.63	0.09	26.69	1.03	8,354	1,077	5,542	631	7,250	+0.97	27.75	12.21	5,012	2,238	543	
"	9	26.69	26.75	26.88	26.78	26.78	0.00	+0.55	+0.95	+0.60	+0.53	26.23	0.00	8,210	1,077	5,601	631	7,309	+0.95	27.73	12.20	5,008	2,301	560	
"	10	26.81	26.78	26.88	26.76	26.81	0.12	1.32	+0.93	0.82	0.33	26.48	0.03	8,289	1,077	5,660	633	7,370	+0.93	27.74	12.21	5,012	2,358	568	
"	11	27.80	27.84	27.83	27.83	27.85	0.86	1.41	0.11	0.41	0.70	27.15	1.04	8,499	1,077	5,719	720	7,516	0.11	27.74	12.21	5,012	2,504	589	
"	12	27.84	28.03	28.00	28.07	27.99	0.74	0.64	0.54	0.64	0.64	27.35	0.14	8,561	1,077	5,778	732	7,587	0.54	27.45	12.08	4,958	2,629	614	
"	13	27.98	28.06	28.01	28.07	28.03	0.97	1.55	1.00	0.72	1.06	26.97	0 04	8,442	1,077	5,837	735	7,649	0.72	27.31	12.02	4,933	2,716	643	
"	14	28.16	28.18	28.31	28.23	28.22	0.67	0.87	1.32	+0.78	0.58	27.70	0.19	8,670	1,077	5,896	751	7,724	+0.78	29.00	12.76	5,237	2,487	572	
"	15	29.06	29.32	29.30	29.35	29.26	1.33	2.18	1.53	0.88	1.48	27.78	1.04	8 695	1,077	5,956	838	7,871	0.88	28.38	12.49	5,126	2,744	631	
"	16	29.11	29.36	29.35	29 39	29.30	0.91	+0.09	1.21	0.91	0.74	28.39	0.04	8,886	1,077	6,015	841	7,933	+0.09	29.39	12.93	5,307	2,626	591	
"	17	29.23	29.42	29.39	29.42	29.37	1.94	0.69	2.24	0.89	1.44	27.93	0.07	8,742	1,077	6,074	847	7,998	0.69	28.68	12.62	5,180	2,818	644	
"	18	29.63	29.60	29.71	29.53	29.62	1.45	0.60	0.60	1.05	0.93	28.69	0.25	8,980	1,077	6,152	968	8,097	0.60	29.02	12.77	5,241	2,856	636	
"	19	30.63	30.90	30.94	30.98	30.86	2.08	2.98	1.93	2.48	2.37	28.49	1.24	8,917	1,077	6,231	974	8,282	1.03	29.83	13.13	5,389	2,893	648	
"	20	30.68	30.92	30.89	31.03	30.91	1.92	1.50	1.51	0.97	1.48	29 43	0.05	9,212	1,077	6,309	991	8.377	0.97	29.94	13.17	5,405	2,972	645	Indicated Air Pressure,
"	21	30.73	30.92	30.97	31.03	30.92	2.32	2.20	1.67	2.20	2.20	28.72	0.01	8,[illegible]18	1,077	6,388	992	8,457	0.15	30.77	13.54	5,557	2,900	650	13 lbs.
"	22	30.95	31.01	31.05	31.04	31.01	0.66	0.86	0.16	1.16	0.71	30.30	0.09	9,484	1,077	6,466	1,000	8,543	0.16	30.85	13.57	5,570	2,983	628	
"	23	31.38	31.70	31.57	31.73	31.60	2.45	1.75	+0.70	1.75	1.31	30.29	0.59	9.481	1,077	6,544	1,051	8,672	+0.70	32.30	14.21	5,832	2,840	599	
"	24	32.10	32.39	32.17	32.36	32.26	2.15	3.05	0.60	1.35	1.79	30.47	0.66	9,537	1,077	6,623	1,109	8,809	0.60	31.66	13.93	5,717	3,092	648	
"	25	32.15	32.44	32.21	32.37	32.29	2.75	2.65	0.35	1.40	1.79	30.50	0.03	9,547	1,077	6,701	1,112	8,890	0.35	31.94	14.05	5,767	3,123	654	
"	26	32.20	32.45	32.37	32.43	32.36	2.50	1.50	0.55	1.20	1.44	30.92	0.07	9,678	1,077	6,779	1,118	8,974	0.55	31.81	14.00	5,746	3,228	667	
"	27	32.39	32.53	32.33	32.36	32.40	0.45	2.50	1.45	1.13	1.38	31.02	0.04	9,709	1,077	6,858	1,122	9.057	0.45	31.95	14.06	5,771	3,286	676	
"	28	32.66	32.66	32.59	32.48	32.60	2.57	0.12	0.62	1.14	1.11	31.51	0.20	9,863	1,077	6,936	1,139	9,152	0.12	32.48	14.29	5,865	3,287	666	
Mar.	1	33.60	33.87	33.65	33.80	33.73	2.39	0.94	1.49	1.84	1.67	32.06	1.13	10,034	1,077	7,015	1,238	9.330	0.94	32.79	14.43	5,923	3,407	679	
"	2	33.64	33.89	33.69	33.83	33.76	2.55	1.45	1.50	1.95	1.86	31.90	0.03	9,985	1,077	7,093	1,241	9,411	1.45	32.31	14.21	5,832	3,579	716	
"	3	33.65	33.89	33.71	33.82	33.77	1.39	0.89	1.39	1.39	1.22	32.55	0.01	10,188	1,077	7,171	1,242	9,490	0.89	32.88	14.47	5,939	3,551	697	
"	4	33.76	33.92	33.92	33.88	33.87	0.94	0.69	1.49	1.19	1.08	32.79	0.10	10,263	1,077	7,250	1,251	9,578	0.69	33.18	14.60	5,993	3,585	698	
"	5	33 93	33.96	34.08	33.99	33.99	0.35	0.95	0.95	2.00	1.06	32.93	0.12	10,307	1,077	7,323	1,262	9,667	0.35	33.64	14.80	6,075	3,592	697	
"	6	34.12	34.29	34.41	34.49	34.33	0.87	0.77	1.37	1.12	1.03	33.30	0.34	10,423	1,077	7,406	1,294	9,777	+0.63	34.96	15.38	6,313	3,464	664	
"	7	35.10	35.34	35.41	35.53	35.35	0.50	2.31	0.75	3.61	1.79	33.56	1.02	10,504	1,077	7,483	1,384	9,946	0.36	34.99	15.40	6,321	3,625	690	
"	8	35.16	35.39	35.44	35.55	35.39	0.40	2.00	+0.55	0.70	0.64	34.75	0.04	10,877	1,077	7,563	1,388	10,028	+0.55	35.94	15.81	6,489	3,539	657	
"	9	35.30	35.47	35.54	35.62	35.48	0.69	1.84	+0.61	1.45	0.84	34.64	0.09	10,842	1,077	7,642	1,396	10,115	+0.61	36.09	15.88	6,518	3,597	663	
"	10	35.47	35.57	35.60	35.62	35.55	0.64	2.14	+0.61	0.54	0.63	34.72	0.07	10,867	1,077	7,720	1,402	10,199	+0.61	36.16	15.91	6,530	3,669	675	
"	11	35.57	35.60	35.62	35.59	35.60	0.83	1.88	0.28	0.63	0.91	34.69	0.05	10,858	1,077	7,798	1,406	10,281	0.28	35.32	15.54	6,378	3,903	718	
"	12	35.88	36.16	35.90	36.05	36.00	1.13	2.97	0.22	2.03	1.34	34.66	0.40	10.849	1,077	7,877	1,419	10,373	0.22	35.78	15.74	6,461	3,912	721	
"	13	36.69	36.93	36.96	37.06	36.91	1.84	3.52	1.47	4.69	2.88	34.03	0.91	10,651	1,077	7,955	1,524	10,556	1.47	35.44	15.59	6,399	4,157	780	
"	14	36.71	36.94	36.96	37.04	36.91	1.76	1.96	1.36	1.51	1.65	35.21	0.06	11,021	1,077	8,034	1,525	10,636	0.46	36.45	16.04	6,584	4,052	734	
"	15	36.78	36.95	36.97	37.03	36.94	0 87	0.87	0.47	0.72	0.73	36.21	0.03	11,334	1,077	8,112	1,527	10,716	0.47	36.47	16.05	6,588	4,128	728	
"	16	36.90	36.91	37.00	37.06	36.97	1.92	0.87	1.17	0.57	1.13	35.84	0.03	11,218	1,077	8,190	1,530	10,797	0.57	36.40	16.02	6,575	4,222	752	
"	17	37.10	37.06	37.02	37.03	37.05	1.09	1.29	0.29	0.54	0.80	36.25	0.08	11,346	1,077	8,269	1,537	10,883	0.29	36.76	16.17	6,637	4,246	748	
"	18	37.33	37.38	37.05	37.06	37.21	1.09	0.34	0.49	+0.26	0.42	36.79	0.16	11,515	1,077	8,347	1,552	10,976	+0.26	37.47	16.49	6,768	4,208	730	
"	19	37.45	37.73	37.43	37.63	37.56	1.34	0.99	0.64	0.19	0.79	36.77	0.35	11,509	1,077	8,425	1,584	11,086	0.19	37.37	16.44	6,748	4,338	753	
"	20	38.37	38.56	38.47	38.66	38.51	2.84	1.97	1.89	1.52	2.05	36.46	0.95	11,412	1,077	8,504	1,670	11,251	0.59	37.92	16.68	6,846	4,405	771	
"	21	38.38	38.57	38.49	38.67	38.53	2.21	2.21	1.36	1.86	1.91	36.62	0.02	11,462	1,077	8,582	1,672	11,331	0.44	38.09	16.76	6,879	4,152	776	
"	22	38.40	38.58	38.52	38.69	38.55	2.60	2.30	1.70	2.00	2.15	36.40	0.02	11,393	1,077	8,661	1,674	11,412	+1.29	39.84	17.53	7,195	4,217	740	
"	23	38.50	38.63	38.56	38.68	38.59	2.84	2.19	1.89	1.99	2.23	36.36	0.04	11,351	1.077	8,739	1,678	11,494	1.89	36.70	16.15	6,629	4,865	857	
"	24	38.66	38.69	38.57	38.68	38.65	2.07	2.22	0.82	1.92	1.51	37.14	0.06	11,625	1,077	8,817	1,684	11,578	0.82	37 83	16.65	6,834	4,744	816	
"	25	38.77	38.77	38.60	38.69	38.71	1.91	1.81	0.71	1.46	1.47	37.24	0.06	11.656	1,077	8,896	1,690	11,663	0.71	38.00	16.72	6,862	4,801	823	
"	26	39.06	39.12	38.62	38.75	38.89	1.86	1.81	0.36	1.61	1.41	37.48	0.18	11,731	1.077	8.974	1,707	11,758	0.36	38.53	16.95	6,957	4,801	818	
"	27	39.20	39.31	38.64	38.76	38.98	2.31	1.31	0.96	1.16	1.44	37.54	0.09	11.750	1,077	9,052	1,716	11,845	0.96	38.02	16.73	6,866	4,979	847	Indicated Air Pressure,
"	28	39.24	39.40	38.68	38.84	39.04	2.72	1.52	1.67	1.47	1.85	37.19	0.06	11,640	1,077	9,131	1,721	11,929	1.52	37.52	16.51	6,777	5,152	885	18 lbs.
"	29	39.27	39.52	39.03	39.26	39.27	2.62	1.72	0.84	1.52	1.68	37.59	0.23	11,656	1,077	9,209	1,744	12,030	0.84	38.43	16.91	6,941	5,089	873	
"	30	40.20	40.30	40.18	40.27	40.24	1.96	1.16	1.66	1.01	1.45	38.79	0.97	12,141	1,077	9.288	1,830	12,195	1.01	39.23	17.26	7,084	5.111	841	
"	31	40.47	40.59	40.55	40.67	40.57	0.61	1.91	1.61	1.66	1.45	39.12	0.33	12,245	1,077	9,366	1,890	12,333	0.61	39.96	17.58	7,216	5,117	835	
April	1	40.47	40.58	40.56	40.66	40.57	0.58	2.08	1.53	1.83	1.50	39.06	0.00	12,226	1,077	9,366	1,890	13.333	0.58	39.99	17.60	7,224	5,109	836	Indicated Air Pressure,
"	2	40.46	40.61	40.56	40 67	40.57	+0.25	1.85	0.05	+0.15	0.38	40.20	0.00	12,5[illegible]3	1,077	9,366	1,928	12,361	+0.25	40.82	17.90	7,372	4,989	792	19 lbs.
"	4	40.49	40.78	40.57	40.67	40.63	+0.01	0.94	0.09	+0.41	0.15	40.48	0.06	12,670	1,077	9,366	1,928	12,361	+0.41	41.04	18.06	7,413	4,948	781	

TESTS OF MATERIALS.

TESTS OF CEMENT.

NAME.	NO. OF TESTS.	PARTS OF SAND TO ONE OF CEMENT.	AGE WHEN TESTED.	MEAN TENSILE STRENGTH.	REMARKS
ROSENDALE :					
N. Y. and Rosendale.......	2,345	Neat,	1 Day	98.5	
" "	612	"	7 Days	127.5	
" "	50	"	14 "	144	
" "	258	"	15 "	122.5	
" "	640	"	23 "	207	
" "	11	"	3 Months	463	
" "	10	Sand 1—C. 1	7 Days	78	
" "	23	" 1—C. 1	23 "	171	
" "	22	" 1—C. 1	3 Months	353	
" "	10	" 1—C. 1	6 "	286	
" "	10	" 1—C. 1	1 Year	326	
" "	40	" 2—C. 1	7 Days	35	
" "	39	" 2—C. 1	28 "	74	
" "	72	" 2—C. 1	3 Months	155	
" "	60	" 2—C. 1	6 "	142	
" "	40	" 2—C. 1	1 Year	133.5	
" "	10	Mortar,	30 Days	52	Mortar from Works.
" "	10	"	60 "	77.4	"
" "	10	"	3 Months	131.4	"
" "	10	"	6 "	157 4	"
" "	10	"	1 Year	187.8	"
Norton's (Rosendale)	62	Neat,	1 Day	69.5	
" "	80	"	1 "	106	
" "	80	"	7 Days	126	
" "	50	"	15 "	165	
" "	50	"	28 "	182	
" "	5	"	28 "	171	
MISCELLANEOUS :					
Akron....................	6	Neat,	1 Day	56	
"	14	"	1 "	98	
"	15	"	7 Days	114	
"	12	"	1 Month	229	
"	12	Sand 1—C. 1	3 Months	285	
Howe's Cave..............	10	Sand 1—C. 1	7 Days	131	
"	10	" 1—C. 1	28 "	244	
"	10	" 1—C. 1	3 Months	285	
"	10	" 2—C. 1	7 Days	72	
"	10	" 2—C. 1	28 "	98	
"	10	" 2—C. 1	3 Months	170	
"	10	" 2—C. 1	6 "	221	
"	10	" 2—C. 1	1 Year	252	

TESTS OF CEMENT.—*Continued.*

NAME.	NO. OF TESTS.	PARTS OF SAND TO ONE OF CEMENT.	AGE WHEN TESTED.	MEAN TENSILE STRENGTH.	REMARKS.
PORTLAND:					
Hemmoor	75	Neat,	1 Day	188	
"	1,073	"	7 Days	636.1	
"	50	"	14 "	687.6	
"	100	"	28 "	683.64	
"	13	Sand 1—C. 1	28 "	699	
"	12	" 1—C. 1	3 Months	728	
"	10	" 2—C. 1	7 Days	189	Mortar from Works.
"	10	" 2—C. 1	28 "	257	"
"	10	" 2—C. 1	3 Months	323	"
"	10	" 2—C. 1	6 "	389	"
"	10	" 2—C. 1	1 Year	300	
"	30	" 2—C. 1	7 Days	169	
"	50	" 2—C. 1	28 "	248	
"	40	" 2—C. 1	3 Months	294	
"	50	" 2—C. 1	6 "	374	
"	20	" 2—C. 1	1 Year	314	
Alsen	22	Neat,	1 Day	209	
"	443	"	7 Days	690	
"	6	"	28 "	653	
"	12	"	3 Months	631	
"	25	Sand 1—C. 1	28 Days	482	
"	13	" 1—C. 1	3 Months	435	
"	21	" 2—C. 1	1 Month	315	
"	22	" 2—C. 1	3 Months	282	
"	25	" 2—C. 1	3 "	299	Mortar from Works.
"	10	" 2—C. 1	6 "	382.6	
"	10	" 2—C. 1	1 Year	486.4	
Imperial	5	Neat,	1 Day	98	
"	5	"	2 Days	244	
"	5	"	3 "	325	
"	3	"	7 "	507	
"	5	"	28 "	712	
Hanover	5	Neat,	1 Day	216	
"	83	"	7 Days	463	
White's	15	Neat,	1 Day	192	
"	10	"	7 Days	442	
"	10	"	1 Month	662	
London & Imperial	10	Neat,	7 Days	629	
" "	10	"	28 "	674	
" "	10	"	3 Months	876	
" "	10	Sand 2—C. 1	7 Days	192	
" "	10	" 2—C. 1	28 "	254	
" "	10	" 2—C. 1	3 Months	275	
" "	10	" 2—C. 1	6 "	299	

TESTS OF STONE.

Gray gneiss from Roxbury, Conn. Test pieces were cubes 2¼ inches by 2¼ inches by 2¼ inches.

No. 1,	tested on natural bed,	yielded under	11,051	lbs. per sq. inch.	
" 2,	" " " "	" "	15,130	" " "	
" 3,	" " edge,	" "	13,838	" " "	

TESTS OF CONCRETE.

Concrete taken from interior wall of pier III., composed of one part of Rosendale cement, two parts of clean sand, and five parts of broken stone,—all by measure, mixed by machine. Age in the work, three months. Blocks were detached by drilling holes obliquely from above and below, and then roughly squared with a tool. Three rough cubes were tested, the bearing faces being rendered smooth and parallel by coating with Portland cement.

No. 1,	crushed under	340.0	lbs. per sq. inch.
" 2,	" "	406.4	" " "
" 3,	" "	479.0	" " "

HARLEM RIVER BRIDGE.

REPORT OF TESTS OF OPEN-HEARTH STEEL PLATES MANUFACTURED BY SPANG STEEL AND IRON COMPANY, PITTSBURGH.

Date.	Heat No.	No. of Spec.	Chemical Analysis. C.	Mn.	P.	S.	Si.	Test piece cut from	Nominal Size.	Cross Dimensions. Original.	Fractured.	Area. Orig.	Frac.	% of Red'n	Elastic Limit. Act'al	Lbs. per sq. in.	Maximum Load. Act'al	Lbs. per sq. in.	Extensions. In 8 in.	% in 8 in.	Modulus of Elasticity.	Fracture.	Bending Tests. Natural.	Quenched.	Remarks.	Accepted or Rejected.
1887									*In.*																	
Jan. 4	2919		17	42	.087			Sketch pl. ⅝ in. th'k	18 long	.616 × .635	.454 × .422	.3912	.1961	49.87	16000	40900	27300	69780	1.56	19.5		½ cup, silky.	Flat down.	Flat down.		Accepted.
" 4	142		18½	42	.092			"	"	.616 × .645	.420 × .380	.3973	.1596	59.83	15300	38510	24500	61670	1.96	24.5		"	"	"		"
" 4	202		18	44	.089			Pedestal pl. 1 in. th'k	"	1.018 × .655	.922 × .610	.6668	.5624	15.66	24400	36590	46750	71000	1.26	15.75		90 % gran.	175° & b'ke	"	2d test ordered.	
" 4	204		19	44	.098			"	"	1.028 × .605	.791 × .467	.6219	.3694	40.56	23300	37430	42400	68110	1.64	20.50		Silky cup.	Flat down.	"		Accepted.
" 4	208		18	45	.094			"	"	1.014 × .627	.920 × .577	.6358	.5308	16.52	24000	37750	42400	66680	0.90	11.25		70 % gran.	"	"	2d test ordered.	
" 4	210		18	42	.096			"	"	1.018 × .615	.858 × .518	.6261	.4444	29.02	23500	37530	44000	70270	1.44	18.00		100 % gran.	180° & b'ke	"		Rejected.
" 4	216		18	43	.085			"	"	1.022 × .615	.550 × .927	.6285	.5099	18.87	23500	37390	41700	66350	1.00	12.50		"	Flat down.	"	2d test ordered.	
" 4	208		..	..	..			"	"	1.015 × .637	.936 × .595	.6466	.5569	13.87	23500	36350	42500	65730	0.80	10.00		"			2d test of above.	"
" 4	216		..	..	..			"	"	1.030 × .617	.934 × .571	.6355	.5333	16.08	24000	37770	42300	66560	1.08	13.50		"			"	"
" 6	200		17	42	.098			"	"	.998 × .647	.774 × .540	.6457	.4180	35.26	22500	34850	41200	63810	1.76	22.00		Silky.	Flat down.	Flat down.	*	Accepted.
" 6	208		..	..	..			"	"	1.005 × .634	.792 × .543	.6372	.4301	32.50	23000	36100	42000	65910	1.38	17.25		"	"	"		"
" 6	216		..	..	..			"	"	1.005 × .635	.795 × .520	.6382	.4134	35.22	23000	36040	42300	66280	1.50	18.75		"	"	"		"
" 6	194		19	45	.097			"	"	1.003 × .650	.800 × .600	.6520	.4800	26.38	24000	36810	42500	65180	1.00	12.50		90 % gran.	"	"	2d test ordered.	
" 6	212		18	42	.099			"	"	1.005 × .636	.830 × .563	.6392	.4673	26.88	23300	36450	42400	66330	1.30	16.25		Silky.	"	"	b'ke nr. shoulder.	Accepted.
" 6	214		18	42	.096			"	"	1.000 × .600	.786 × .505	.6000	.3969	33.85	22000	36660	40400	67340	1.48	18.50		½ cup, silky.	"	"		"
" 6	218		17	44	.087			"	"	1.005 × .627	Lost	.6301	Lost	Lost	23500	37300	41600	66020	0.78	9.75		100 % gran.	"	"	2d test ordered.	
" 6	218		..	..	..			"	"	1.012 × .646	.759 × .507	.6538	.3848	41.14	21750	33270	39500	60420	1.84	23.00		Silky.			2d test of above.	Accepted.
" 7	218		..	..	..			Pedestal pl. ½ in. th'k	"	1.283 × .507	.980 × .340	.6505	.3332	48.78	24500	37660	40600	62410	1.80	22.50		½ cup, silky.	"	"		"
" 12	232		19	46	.090			20 × ⅝ in. U. M.	"	.650 × .633	.405 × .425	.4415	.1938	52.90	15500	37670	28300	68770	1.88	23.50		¾ cup, silky.	"	"		"
" 12	234		..	..	..			"	"	.646 × .631	.450 × .412	.4076	.1852	54.56	15800	38770	28200	69180	1.86	23.25		Full cup, silky.	"	"		"
" 12	236		19	44	.092			"	"	.645 × .630	.460 × .446	.4064	.2052	49.51	16000	39370	28000	68900	1.84	23.00		¾ cup, "	"	"		"
" 15	266		19	45	.090			Pedestal pl. ⅜ in. th'k	"	1.307 × .380	1.091 × .286	.4967	.3120	37.19	23000	46300	36000	72480	1.64	20.50		@ 45° "	"	"		"
" 15	208		..	..	..			"	"	1.298 × .372	1.022 × .255	.4829	.2606	46.04	22000	45560	34600	71650	1.66	20.75		½ cup, "	"	"		"
" 15	224		..	..	..			"	"	1.292 × .370	1.032 × .254	.4780	.2621	45.17	21400	44770	35000	73220	1.52	19.00		@ 45° "	"	"		"
" 15	238		19	46	.099			"	"	1.295 × .394	1.036 × .366	.5102	.3792	25.68	24400	47820	37000	72520	1.44	18.00		½ cup, "	"	"		"
" 15	240		17	46	.097			"	"	1.300 × .391	1.111 × .282	.5083	.3133	38.37	23000	45250	37100	72990	1.54	19.25		"	"	"	Specimen broke	"
" 15	242		19	44	.098			"	"	1.300 × .385	1.064 × .280	.5005	.2979	40.48	22700	45360	35800	71530	1.40	17.50		@ 45°, silky.	"	"	in grips.	"
" 15	244		18	42	.086			"	"	1.307 × .386	1.055 × .265	.5045	.2790	44.70	23000	45590	36600	72540	1.48	18.50		"	"	"		"
" 15	260		18	42	.090			"	"	1.300 × .362	1.046 × .230	.4706	.2406	48.88	22200	47180	33550	71300	1.94	24.25		¾ cup, silky.	"	"		"
" 15	262		18	44	.095			"	"	1.300 × .366	1.034 × .252	.4758	.2606	45.23	22600	47500	34150	71720	1.56	19.50		"	"	"		"
" 17	244		18	42	.086			20 × ⅝ in. U. M.	"	.645 × .635	.410 × .415	.4096	.1702	58.45	16450	40160	26850	65550	1.94	24.25		"	"	"		"
" 17	248		19	44	.096			"	"	.645 × .630	.417 × .418	.4064	.1743	57.11	16500	40610	26000	63980	1.78	22.25		"	"	"		"
" 17	250		18	42	.092			"	"	.645 × .613	.480 × .465	.3954	.2232	43.55	16400	41480	26300	66520	1.70	21.25		½ "	"	"		"
" 17	252		19	42	.094			"	"	.635 × .611	.425 × .414	.3880	.1760	54.64	15800	40720	25500	65730	1.82	22.75		"	"	"		"
" 17	256		19	44	.099			"	"	.635 × .610	.420 × .428	.3874	.1798	53.59	15000	38720	25400	65560	1.88	23.50		¾ "	"	"		"
" 17	258		18	42	.092			"	"	.632 × .614	.400 × .415	.3880	.1660	57.20	16500	42530	25200	64950	1.80	22.50		"	"	"		"
" 19	254		17	44	.098			"	"	.635 × .752	.544 × .455	.4775	.2475	48.17	18000	37700	31700	66390	1.86	23.25		"	"	"		"
" 19	256		..	..	..			20 × ¾ in. U. M.	"	.634 × .754	.497 × .582	.4780	.2893	39.48	17800	37240	32000	66940	1.82	22.75		"	"	"		"
" 19	258		..	..	..			"	"	.628 × .754	.553 × .464	.4735	.2566	45.81	18200	38440	31500	66520	1.72	21.50		"	"	"		
" 22	186		19	42	.088			Sketch pl. ¾ in. th'k	"	.638 × .749	Lost.	.4779	Lost	Lost	18800	39340	31300	65500	Not taken.			100 % granular.	"	"	†	
" 22	226		17	42	.087			"	"	.643 × .746	"	.4797	"	"	19000	39600	32000	66700	"				"	"		
" 22	280		18	44	.088			"	"	.640 × .747	.534 × .460	.4781	.2456	48.63	19000	39740	33000	69020	1.68	21.00		½ cup, silky.	"	"		Accepted.
" 22	282		18	42	.090			"	"	.640 × .747	.563 × .503	.4781	.2832	40.77	19800	41430	33000	69240	1.60	20.00		"	"	"		"
" 22	284		17	44	.096			"	"	.640 × .749	.524 × .468	.4794	.2452	48.86	19100	39840	32600	68000	1.56	19.50		@ 45°, silky.	"	"		"
" 26	186		..	..	..			"	"	.748 × .648	.520 × .460	.4847	.2392	50.65	20600	42500	33300	68700	1.47	18.37		½ cup, "	"	"	2d test of above.	"
" 26	226		17	42	.087			"	"	.749 × .647	.480 × .538	.4846	.2582	46.72	20500	42300	33900	69960	1.68	21.00		"	"	"	"	"
" 26	268		17	42	.080			"	"	.743 × .652	.429 × .581	.4844	.2063	57.41	17200	35510	30300	62550	2.32	29.00		Cup, silky.	"	"		"
" 26	286		17	42	.080			"	"	.744 × .650	.450 × .513	.4836	.2309	52.26	17100	35360	30200	62450	2.12	26.50		¾ cup, silky.	"	"		"

* All the previous tests of these heats were sheared out; these last were cut on planer.

† Both specimens broke in shoulder; second test ordered.

TESTED ON 5,000 LB. OLSEN MACHINE AT SPANG STEEL & IRON COMPANY.

GEORGE W. G. FERRIS, JR., *Inspector*.

HARLEM RIVER BRIDGE.

REPORT OF TESTS OF STEEL MANUFACTURED BY UNION IRON MILLS, PITTSBURGH.

Date.	Heat No.	No. of Spec.	Chemical Analysis.					Test piece cut from	Nominal size.	Cross Dimensions.		Area.			Elastic Limit.		Maximum Load.		Extensions.		Modulus of Elasticity.	Fracture.	Bending Tests.		Remarks.	Accepted or Rejected.
			C.	Mn.	P.	S.	Si.			Original.	Fractured.	Orig.	Frac.	% of R on	Actu'l	Lbs. per sq. in.	Actu'l	Lbs. per sq. in.	In 8 in.	% in 8 in.			Natural.	Quenched.		
1887								*In.* *Lbs.*																		
May 4	8652							6 × 6 angle 24.2		.625 × .605	.445 × .425	.3781	.1819	49.99	14250	37690	24300	64270	2.10	27.00		Partial cup	Bent double	Bent double	Silky and floury	Accepted
" 4	8628							6 × 6 " 24.2		.605 × .605	.412 × .400	.3660	.1648	54.97	14000	38250	22000	60100	2.22	27.75		"	"	"	"	Rejected
" 5	8688							6 × 6 " 24.2		.800 × .590	.585 × .401	.4720	.2346	50.30	18600	39410	30700	65040	2.10	26.25		"	"	"	"	Accepted
" 5	8718							6 × 6 " 24.2		.795 × .580	.600 × 410	.4611	.2460	46.65	17800	38600	29700	64410	2.08	26.00		"	"	"	"	"
" 5	8616							6 × 6 " 24.2		.796 × .593	.565 × .380	.4720	.2147	54.51	17600	37290	29150	61760	2.26	28.25		"	"	"	"	"
" 5	8548							6 × 6 " 24.2		.866 × .575	.610 × .275	.4980	.1677	54.06	18800	37750	30300	60840	2.30	28.75		"	"	"	"	"
" 10	8658							6 × 6 " 24.2		.880 × .608	.625 × .399	.5350	.2494	53.38	20500	38320	34500	64490	2.16	27.00		"	"	"	"	"
" 10	8662							6 × 6 " 24.2		.735 × .605	.510 × .380	.4446	.1938	56.41	17300	38910	29400	66130	2.04	25.50		"	"	"	"	"
" 10	8634							6 × 6 " 24.2		.740 × .598	.500 × .385	.4425	.1925	56.50	16800	37970	27500	62150	2.10	26.25		@ 45 %	"	"	"	"
" 10	8527							6 × 6 " 24.2		.740 × .592	.530 × .390	.4381	.2067	52.82	17900	40860	28700	65510	2.20	27.50		"	"	"	"	"
" 10	8646							6 × 6 " 24.2		.710 × .610	.520 × .420	.4331	.2184	49.57	17000	39250	27900	64420	2.00	25.00		Partial cup	"	"	"	"
" 10	8574							6 × 6 " 24.2		.875 × .610	.630 × .411	.5337	.2589	51.49	21100	39530	33850	63420	2.12	26.50		"	"	"	"	"
" 10	8766							6 × 6 " 24.2		.870 × .610	.590 × .384	.5306	.2265	57.31	21500	40520	34700	65400	2.00	25.00		"	"	"	"	"
" 11	8736							6 × 6 " 24.2		.918 × .620	.640 × .396	.5691	.2534	55.48	23200	40770	36000	63260	2.30	28.75		"	"	"	"	"
" 11	8790							6 × 6 " 24.2		.930 × .594	.630 × .355	.5524	.2237	59.50	21300	38560	33500	60640	2.40	30.00		"	"	"	"	"
" 11	8724							6 × 6 " 24.2		.917 × .611	.660 × .405	.5602	.2672	52.28	22100	39450	36000	64260	2.20	27.50		@ 45 %	"	"	"	"
" 11	8742							6 × 6 " 24.2		.800 × .616	.646 × .470	.4928	.3036	38.40	19400	39360	32700	66360	1.96	24.50		"	"	"	"	"
" 11	8754							6 × 6 " 24.2		.804 × .600	.570 × .415	.4824	.2366	50.96	18800	38970	31000	64260	2.36	29.50		Partial cup	"	"	"	"
" 11	7878							6 × 6 " 24.2		.806 × .606	.565 × .394	.4884	.2226	54.42	19100	39110	30800	63060	2.20	27.50		Full cup	"	"	"	"
" 11	7882							6 × 6 " 24.2		.808 × .600	.600 × .415	.4848	.2490	48.64	19600	40430	32100	66220	2.26	28.25		¾ cup	"	"	"	"
" 11	8556							6 × 6 " 24.2		.770 × .603	.562 × .408	.4643	.2293	50.60	19400	41780	30600	65900	2.12	26.50		Partial cup	"	"	"	"
" 11	7886							6 × 6 " 24.2		.840 × .602	.565 × .390	.4840	.2204	54.46	20000	41330	31400	64880	2.10	26.25		"	"	"	"	"
" 11	8610							6 × 6 " 24.2		.810 × .596	.562 × .375	.4828	.2108	56.34	19200	39770	32100	66500	2.08	26.00		Full cup	"	"	"	"
" 11	8706							6 × 6 " 24.2		.800 × .606	.605 × .425	.4848	.2571	46.97	19600	41430	32300	66640	2.00	25.00		@ 45 %	"	"	"	"
" 11	9088							6 × 6 " 24.2		.800 × .595	.584 × .420	.4760	.2453	48.47	19700	41390	31800	66810	2.00	25.00		Partial cup	"	"	"	"
" 11	8604							6 × 6 " 24.2		.810 × .590	.580 × .395	.4779	.2291	52 06	19600	41020	31200	65300	2.32	29.00		Full cup	"	"	"	"
" 13	8664							6 × 6 " 24.2		.880 × .615	.600 × .385	.5412	.2310	53.32	21100	38990	32500	60050	2.40	30.00		Partial cup	"	"	"	"
" 13	8682							6 × 6 " 24.2		.895 × .605	.658 × .390	.5414	.2566	52.60	21200	39160	35800	66120	2.16	27.00		"	"	"	"	"
" 13	9172							6 × 6 " 24.2		.720 × .590	.530 × .412	.4248	.2184	48.60	17200	40490	27300	64260	2.12	26.50		¾ cup	"	"	"	"
" 13	8864							6 × 6 " 24.2		.900 × .606	.660 × .408	.5454	.2693	50.62	21400	39240	35900	65820	2.16	27.00		Full cup	"	"	"	"
" 13	8784							6 × 6 " 24.2		.730 × .595	.554 × .430	.4343	.2382	45.15	17300	39830	38600	65860	2.10	26.25		Partial cup	"	"	"	"
" 13	8706							6 × 6 " 24.2		.905 × .610	.656 × .416	.5520	.2779	50.56	21600	39130	36000	65220	2.08	26.00		@ 45 %	"	"	"	"
" 13	8774							6 × 6 " 24.2		.730 × .595	.530 × .415	.4343	.2200	48 35	17000	39140	29500	67920	1.96	24.50		Partial cup	"	"	"	"
" 13	8727							6 × 6 " 24.2		.810 × .615	.560 × .400	.4981	.2240	55.02	19700	39550	32400	65050	2.16	27.00		½ cup	"	"	"	"
" 13	9076							6 × 6 " 24.2		.820 × .610	.601 × .412	.5002	.2476	50.50	9900	39780	34200	68360	2.20	27.50		Full cup	"	"	"	"
" 13	9523							6 × 6 " 24.2		.818 × .612	.605 × .413	.5006	.2499	50.08	20400	40750	35600	71120	2.10	26.25		¾ cup	"	"	"	"
" 13	9256							6 × 6 " 24.2		.825 × .595	.610 × .422	.4908	.2574	47.55	20100	40950	33900	69060	2.06	25.75		@ 45 %	"	"	"	"
" 13	9264							6 × 6 " 24.2		.792 × .594	.580 × .400	.4704	.2320	50.70	20000	42520	33500	71220	2 20	27.50		Partial cup	"	"	"	"
" 14	9140							6 × 6 " 24.2		.840 × .608	.652 × .434	.5107	.2830	44.59	19900	38970	33500	65600	2.12	26.50		"	"	"	"	"
" 14	9076							6 × 6 " 24.2		.850 × .604	.630 × .415	.5134	.2615	49 06	20000	38960	33700	65640	2 10	26.25		"	"	"	"	"
" 14	9252							6 × 6 " 24.2		.765 × .620	.520 × .390	.4743	.2028	57.24	18000	39950	30300	63880	2.16	27.00		"	"	"	"	"
" 14	9280							6 × 6 " 24.2		.750 × .605	.545 × .412	.4542	.2245	50.57	18500	40730	30250	66600	2.00	25.00		"	"	"	"	"
" 14	9232							6 × 6 " 24.2		.820 × .600	.590 × .406	.4920	.2395	51.32	19750	40140	32300	65650	2.00	25.00		"	"	"	"	"
" 14	9090							6 × 6 " 24.2		.816 × .594	.590 × .400	.4847	.2360	51.31	19200	39610	31900	65820	2.06	25.75		Irregular	"	"	"	"
" 14	9284							6 × 6 " 24.2		.745 × .603	.540 × .410	.4492	.2214	50.71	18200	40520	30800	68570	1.96	24.50		Partial cup	"	"	"	"
" 14	9064							6 × 6 " 24.2		.765 × .605	.586 × .431	.4628	.2526	45.42	19000	41060	31100	67200	1.92	24.00		@ 45 %	"	"	"	"
" 14	8927							6 × 6 " 24.2		.802 × .603	.541 × .356	.4836	.1926	60.17	19350	40020	31000	64100	2.16	27.00		Nearly f. c.	"	"	"	"
" 14	8989							6 × 6 " 24.2		.820 × .600	.590 × .410	.4920	.2419	50.83	19200	39030	31700	64440	2.22	27.75		Partial cup	"	"	"	"

TESTED ON OLSEN MACHINE AT UNION IRON MILLS.

GEO. W. G. FERRIS, JR., *Inspector*.

HARLEM RIVER BRIDGE.

REPORT OF TESTS OF STEEL MANUFACTURED BY THE SPANG STEEL AND IRON CO., LIMITED, PITTSBURGH.

Date.	Heat No.	No. of Spec.	Chemical Analysis.					Test piece cut from	Nominal size.	Cross Dimensions.		Area.			Elastic Limit.		Maximum Load.		Extensions.		Modulus of Elasticity.	Fracture	Bending Tests.		Remarks.	Accepted or Rejected.
			C.	Mn.	P.	S.	Si.			Original.	Fractured.	Orig.	Frac.	% of Red'n	Actu'l	Lbs. per sq. in.	Actu'l	Lbs. per sq. in.	In 8 in.	% in 8 in.			Natural.	Quenched.		
1887								*In.*																		
May 3	551.		.18	.42	.094			20 × 13/16 Plate		.803 × .561	.576 × .411	.4505	.2367	47.46	16950	37620	29450	65380	1.66	20.75		@ 45 %	Bent double	Bent double	Silky and floury	Accepted
"	565.		.19	.44	.098			"		.803 × .566	.574 × .400	.4545	.2296	49.48	17350	38130	29150	64140	1.70	21.25		Partial cup	"	"	"	"
"	567		.19	.42	.079			"		.805 × .560	.560 × .400	.4508	.2240	50.30	16800	37270	29100	64560	1.80	22.50		@ 45 %	"	"	"	"
May 4	569.		.19	.42	.084			"		.881 × .800	.665 × .575	.7048	.3824	45.75	28500	40470	44100	62580	1.88	23.50		"	"	"	"	"
"	571.		.19	.42	.090			"		.850 × .811	.700 × .675	.6894	.4725	31.61	30400	44100	46300	67160	1.60	20.00		"	"	"	"	"
"	573.		.18	.42	.088			20 × ¾ Plate		.865 × .739	.655 × .555	.6392	.3685	43.10	26750	41850	41600	65080	1.75	21.87		Partial cup	"	"	"	"
"	577.		.18	.42	.096			"		.876 × .745	.630 × .515	.6526	.3245	50.28	26550	40690	42800	65580	1.70	21.25		"	"	"	"	"
May 6	545.		.19	.44	.095			"		.752 × .730	.525 × .516	.5490	.2709	50.66	22650	41260	35050	63840	1.85	23.12		"	"	"	"	"
"	575.		.19	.43	.093			"		.751 × .730	.508 × .484	.5482	.2458	55.16	22600	41230	35200	64220	1.70	21.25		"	"	"	"	"
"	579.		.19	.44	.098			20 × 13/16 Plate		.859 × .815	.712 × .700	.7000	.4984	28.80	28300	40420	46700	66700	1.50	18.75		@ 45 %	"	"	"	"
"	592.		.18	.42	.086			20 × ¾ "		.863 × .747	.681 × .555	6447	.3780	41.36	22650	35180	40800	63300	1.66	20.75		"	"	"	"	"
May 9	592.		.18	42	.086			20 × 13/16 "		.868 × .798	.615 × .530	.6927	.3260	52.94	27650	39920	44500	64240	1.76	22.00		Partial cup	"	"	"	"
"	594.		.19	.46	.088			"		.894 × .806	.720 × .680	.7206	.4896	32.06	27100	37600	45450	63070	1.48	18.50		@ 45 % R. s	"	"	W. sps. in centre	"
"	596.		.17	.42	.098			"		.875 × .805	.635 × .560	.7044	.3556	49.52	27000	38330	44950	63810	1.75	21.87		Partial cup	"	"	Silky and floury	"
May 12	598.		.18	.44	.099			20 × ¾ Plate		.780 × .744	.560 × .500	.5803	.2800	51.75	22600	38950	37550	64710	2.00	25.00		"	"	"	"	"
"	600.		.18	.44	.096			"		.774 × .747	.645 × .580	.5782	.3741	35.30	23100	39950	37800	65380	1.60	20.00		"	"	"	"	"
"	602.		.19	.46	.095			"		.757 × .757	.548 × .525	.5730	.2877	49.97	23350	40750	39800	69460	1.60	20.00		Full cup	"	"	"	"
"	604.		.19	.42	.093			"		.890 × .742	.650 × .535	.6604	.3477	47.35	24950	37780	44250	67000	2.00	25.00		Partial cup	"	"	"	"
May 14	465.		.18	.42	.099			⅜ Sketch plate		1.020 × .365	.775 × .250	.3723	.1938	47 95	15800	42440	24050	64600	1.86	23.25		@ 45 %	"	"	"	"
"	561.		.19	.42	.091			"		1.020 × .359	.745 × .213	.3662	.1587	56.67	15300	41780	23300	63710	1.80	22.50		"	"	"	"	"
"	523.		.19	.44	.099			"		.973 × .365	.730 × .240	.3552	.1752	50.68	14800	41670	24800	69820	1.52	19.00		"	"	"	"	"
"	527.		.19	.44	.099			"		.973 × .362	.740 × .237	.3522	.1754	50.20	14900	42300	24200	68720	1.72	21.50		Partial cup	"	"	"	"
"	529.		.18	.44	.099			"		1.043 × .368	.748 × .228	.3838	.1705	55.58	14900	38820	24100	63800	1.82	22.75		@ 45 %	"	"	"	"
"	555.		.19	.46	.090			"		.973 × .376	.730 × .238	.3658	.1737	52.52	16500	45110	26000	71080	1.68	21.00		"	"	"	"	"
"	557.		.19	.48	.088			"		1.027 × .367	.740 × .240	.3769	.1776	52.88	14500	38480	23450	62220	1.90	23.75		"	"	"	"	"
"	559.		.19	.46	.097			"		1.029 × .369	.775 × .235	.3797	.1821	52.04	16300	42930	25250	66500	1.80	22.50		"	"	"	"	"
"	563.		.19	.42	.084			"		1.030 × .363	.800 × .230	.3739	.1840	50.80	16800	44930	26600	71140	1.66	20.75		½ cup	"	"	"	"
"	601.		.18	.43	.087			"		1.015 × .362	.743 × .231	.3674	.1716	53.30	15950	43420	23050	62740	1.96	24.50		@ 45 %	"	"	"	"
"	603.		.19	.44	.098			"		1.017 × .374	.748 × .232	.3804	.1735	54.40	15900	41800	25700	67560	1.75	21.87		Partial cup	"	"	"	"
"	605.		.18	.44	.098			12 × ¾ Plate		.756 × .640	.545 × .460	.4839	.2507	48.20	20600	42570	32700	67580	1.88	23.50		"	"	"	"	"
"	606.		.19	.46	.097			"		.753 × .641	.549 × .485	.4827	.2663	44.85	20250	41950.	33600	69600	1.78	22.25		"	"	"	"	"
May 17	259.		.19	.45	.088			⅜ Sketch plate		1.263 × .366	.958 × .255	.4623	.2443	47.15	19800	42830	30800	66620	1.84	23.00		@ 45 %	"	"	"	"
"	334.		.18	.42	.088			⅜ "		1.259 × .371	.942 × .230	.4070	.2167	53.60	19750	42300	30750	65850	1.80	22.50		"	"	"	"	"
"	363.		.19	.45	.091			⅜ "		1.260 × .365	943 × .218	.4599	.2056	55.30	19650	42730	30300	65880	1.66	20.75		Full cup	"	"	"	"
"	491.		.18	.42	.096			⅜ "		1.006 × .361	.740 × .225	.3632	.1665	54.16	15400	42400	24100	66350	1.70	21.25		Partial cup	"	"	"	"
"	517.		.18	.42	.097			⅜ "		1.248 × .372	.932 × .225	.4642	.2097	54.83	19500	42010	30900	66570	2.00	25.00		"	"	"	"	"
May 19	800.		.15	.56	.099			12 × ¾ Plate		.730 × .717	.500 × .464	.5234	.2320	55.67	21200	40500	33400	63820	1.86	22.50		"	"	"	"	"
"	814.		.13	.56	.102			"		.730 × .710	.455 × .450	.5183	.2047	60.50	20650	39840	32500	62700	2 10	26.25		"	"	"	"	"
"	815.		.14	.56	.102			"		.730 × .708	.446 × .444	.5169	.1980	61.70	20600	39860	32300	62490	2 20	27.50		"	"	"	"	"
"	818.		.14	.56	.102			"		.730 × .710	.473 × .460	.5183	.2176	58.02	21150	40800	32350	62410	2.40	30.00		"	"	"	"	"
May 21	802.		.14	.66	.102			"		.726 × .678	.495 × .459	.4922	.2272	53.84	22000	44700	31400	63800	1.68	21.00		"	"	"	"	"
"	805.		.14	.68	102			"		.727 × .668	.475 × .450	.4856	.2138	55.97	21000	43250	31500	64870	1.80	22.50		"	"	"	"	"
"	826.		.12	.60	.098			"		.740 × .721	.532 × .528	.5335	.2809	47.35	22000	41240	34800	65230	1.70	21.25		"	"	"	"	"
"	831.		.13	.60	.098			"		.730 × .678	.485 × .464	.4950	.2250	54.55	22600	45660	31300	63240	1.86	23.25		"	"	"	"	"
"	836.		.13	.60	.098			"		.745 × .716	.485 × .480	.5334	.2328	56.36	20850	39090	33000	61870	1.80	22.50		¾ cup	"	"	"	"
"	841.		.15	.64	.103			"		.753 × .710	.475 × .463	.5346	.2060	58.87	20800	38900	33500	62660	2.18	27.25		"	"	"	"	"
"	861.		.12	.56	.103			"		.743 × .720	.545 × .540	.5350	.2946	44.94	21200	39650	34000	63550	2.05	25.62		"	"	"	"	"
"	864.		.13	.64	.103			"		.743 × .722	.560 × .557	.5364	.3119	41.85	22000	41020	34600	64500	1.90	23.75		Partial cup	"	"	"	"

TESTED ON OLSEN MACHINE AT ETNA.

GEO. W. G. FERRIS, JR., *Inspector*.

HARLEM RIVER BRIDGE.

REPORT OF TESTS OF STEEL MANUFACTURED BY THE SPANG STEEL AND IRON CO., LIMITED, PITTSBURGH.

Date.	Heat No.	No. of Spec.	Chemical Analysis. C.	Mn.	P.	S.	Si.	Test piece cut from	Nominal size.	Cross Dimensions. Original.	Fractured.	Area. Orig.	Frac.	% of Red'n	Elastic Limit. Actu'l	Lbs. per sq. in.	Maximum Load. Actu'l	Lbs. per sq. in.	Extensions. In 8 in.	% in 8 in.	Modulus of Elasticity.	Fracture	Bending Tests. Natural.	Quenched.	Remarks.	Accepted or Rejected.
1887								*In.*																		
July 9	470.		.14	.70	.105			20 × ¾ Plate		.735 × .784	.530 × .472	.5763	.2502	56.58	22550	39130	37700	65420	2.18	27.25		Partial cup	Bent double	Bent double	Silky and floury	Accepted
"	476.		.14	.74	.105			"		.736 × .784	.510 × .450	.5771	.2295	60.23	23350	40460	37250	64550	2.04	25.50		"	"	"	"	"
"	501.		.14	.65	.101			"		.740 × .798	.528 × .461	.5905	.2434	58.78	24000	40650	38600	65370	1.96	24.50		"	"	"	"	"
"	690.		.19	.46	.10			"		.745 × .730	.545 × .524	.5439	.2856	47.49	21450	39440	37650	69220	1.70	21.25		"	"	"	"	"
"	721.		.19	.44	.093			⅜ Sketch plate		1.196 × .353	.929 × .235	.4222	.2183	48.29	19000	45000	29900	70820	1.70	21.25		Irregular	"	"	"	"
July 12	723.		.19	.43	.10			"		1.227 × .381	.907 × .240	.4675	.2177	53.43	20000	42780	31400	67170	1.78	22.25		Partial cup	"	"	"	"
"	725.		.19	.42	.098			"		1.185 × .370	.915 × .235	.4385	.2150	50.97	18000	41050	29300	66820	1.92	24.00		Full cup	"	"	"	"
"	729.		.19	.42	.090			"		1.234 × .373	.902 × .235	.4603	.2120	53.94	19000	41280	28850	62680	1.90	23.75		@ 45 %	"	"	"	"
"	522.		.14	.66	.101			20 × ¾ Plate		.739 × .715	.490 × .489	.5284	.2396	54.65	20300	38420	34500	65290	2.05	25.75		Irregular	"	"	"	"
"	529.		.15	.60	.101			"		.735 × .721	.455 × .446	.5299	.2029	61.71	20150	38030	33000	62280	2.00	25.00		Full cup	"	"	"	"
"	537.		.14	.68	.098			"		.738 × .720	.500 × .480	.5314	.2400	54.83	21300	40080	35000	65860	1.88	23.50		"	"	"	"	"
"	545.		.15	.70	.098			"		.735 × .719	.450 × .448	.5284	.2016	61.85	19650	37190	32600	61700	2.24	28.00		¾ cup	"	"	"	"
July 14	731.		.19	.42	.095			⅜ Sketch plate		1.190 × .377	.946 × .250	.4486	.2365	47.28	19700	43920	30650	68320	1.54	19.25		Partial cup	"	"	"	"
"	735.		19	.44	.098			"		1.205 × .386	.889 × .258	.4651	.2294	50.67	18800	40430	30100	64720	1.90	23.75		@ 45 %	"	"	"	"
"	556.		.15	.76	.098			20 × ¾ Plate		.737 × .725	.480 × .465	.5343	.2232	58.22	20300	38000	34800	65130	1.90	23.75		½ cup	"	"	"	"
"	562.		.14	.80	.103			"		.738 × .700	.455 × .448	.5166	.2038	60.55	20500	39680	34400	66590	2.00	25.00		Full cup	"	"	"	"
"	570.		.15	.80	.103			"		.736 × .696	.460 × .451	.5123	.2075	59.49	20300	39630	34000	66370	2.18	27 25		"	"	"	"	"
"	576.		.15	.60	.099			"		.742 × .701	.468 × .457	.5202	.2139	58.88	21000	40370	35000	67280	2.06	25.75		¾ cup	"	"	"	"
July 18	584.		.15	.64	.099			"		.740 × .739	.475 × .455	.5469	.2161	60.53	21000	38400	35700	65280	1.90	23.75		"	"	"	"	"
"	592.		.15	.68	.105			"		.740 × .737	.470 × .467	.5454	.2195	59.75	21500	39420	35500	65090	2.08	26.00		"	"	"	"	"
"	600.		.15	.70	.105			"		.742 × .738	.495 × .480	.5476	.2376	56.61	20800	37980	36000	65740	2.10	26.25		"	"	"	"	"
"	607.		.15	.80	.105			"		.740 × .739	.475 × .450	.5469	.2138	60.90	20400	37300	34850	63730	2.00	25.00		½ cup	"	"	"	"
"	733.		.19	.42	.100			⅜ Sketch plate		1.226 × .363	.937 × .248	.4450	.2324	47.80	19200	43150	30500	68540	1.84	23.00		@ 45 %	"	"	"	"
July 29	752.		.19	.42	.092			"		1.249 × .368	.928 × .232	.4596	.2153	53.15	19200	41780	29900	65060	1.84	23.00		Full cup	"	"	"	"
"	614.		.14	.78	.095			20 × ¾ Plate		.738 × .723	.468 × .455	.5336	.2129	60.10	19650	36830	34700	65030	2.14	26.75		¾ cup	"	"	"	"
"	620.		.15	.82	.095			"		.734 × .708	.469 × .459	.5197	.2153	58.57	20200	38870	33500	64460	2.00	25.00		Partial cup	"	"	"	"
"	628.		.15	.80	.095			"		.740 × .727	.482 × .470	.5380	.2265	57.90	20500	38110	35300	65620	2.12	26.50		Full cup	"	"	"	"
"	634.		.14	.80	.098			"		.734 × .726	.496 × .484	.5329	.2401	54.94	20800	39030	34750	65210	1.92	24.00		"	"	"	"	"
Aug. 4	756.		.19	.42	.097			"		.754 × .760	.545 × .525	.5731	.2861	50 10	23800	41530	38300	66830	1.40	17.50		Irregular	"	"	* "	
"	758.		.19	.46	.099			"		.748 × .758	.524 × .550	.5670	.2882	49.18	23100	40740	38100	67200	1.52	19.00		¾ cup	"	"	"	Accepted
"	760.		.19	.44	.096			"		1.245 × .503	.935 × .323	.6262	.3020	51.79	25600	40880	41800	66760	1.80	22.50		Partial cup	"	"	"	"
"	762.		.18	.44	.086			"		.745 × .752	.650 × .595	.5602	.3867	30.97	23800	42480	38800	69260	1.36	17.00		Irregular	"	"	* "	
"	800.		.19	.48	.084			20 × ⅝ Plate		.624 × .983	.475 × .750	.6134	.3562	41.93	25000	40760	41000	66840	2.00	25.00		@ 45 %	"	"	"	"
Aug. 8	756.		.19	.42	.097			20 × ¾ Plate		.747 × .755	.560 × .585	.5640	.3276	41.92	23400	41490	37900	67200	1.72	21.50		Partial cup	"	"	"	"
"	762.		.18	.44	.086			"		.751 × .756	.557 × .592	.5678	.3297	41.93	24500	43150	38300	67450	1.56	19.50		@ 45 %	"	"	* "	"
Aug. 10	804.		.19	.46	.096			"		.748 × .810	.592 × .675	.6059	.3996	34.05	24000	39620	40350	66600	1.70	21 25		Irregular	"	"	"	"
"	806.		.19	.48	.093			"		.742 × .808	.620 × .685	.6052	.4247	29.83	23850	39410	39700	65600	1.48	18.50		"	"	"	"	"
"	808.		.19	.44	.093			"		.747 × .829	.580 × .652	.6193	.3782	38.93	24300	39240	40700	65720	1.52	19.00		"	"	"	"	"
"	812.		.19	.42	.090			"		.750 × .826	.580 × .685	.6195	.3973	35.87	24200	39060	40400	65220	1.57	19.62		"	"	"	"	"
"	814.		.19	.46	.098			"		.748 × .805	.575 × .640	.6022	.3680	38.72	25000	41520	39650	65850	1.64	20.50		"	"	"	"	"
"	816.		.19	.48	.096			"		.751 × .823	.536 × .620	.6181	.3323	46.24	24350	39400	40000	64720	1.90	23.75		"	"	"	"	"
Aug. 13	818.		.18	.45	.095			20 × ⅞ Plate		.873 × .802	.567 × .596	.7001	.3379	51.73	28000	40000	47700	68130	2.00	25.00		Partial cup	"	"	"	"
"	822.		.19	.48	.099			20 × 13/16 Plate		.820 × .770	.570 × .555	.6314	.3164	49.89	25200	39910	42000	66520	1.92	24.00		"	"	"	"	"
"	824.		.19	.46	.097			"		.816 × .659	.560 × .465	.5377	.2604	51.57	22700	42220	36700	68250	1.88	23.50		Irregular	"	"	"	"
"	828.		.19	.42	.098			20 × ⅞ Plate		.864 × .778	.624 × .587	.6722	.3663	45.51	25900	38530	44250	65830	1.74	21.75		"	"	"	"	"
Aug. 17	752.		19	.42	.097			⅜ Sketch plate		1.246 × .370	.940 × .240	.4610	.2256	51.06	18700	40570	29600	64210	2.00	25.00		¾ cup	"	"	"	"
"	754.		.18	.44	.099			"		1.245 × .363	.938 × .220	.4519	.2064	54.33	18800	41600	29500	65280	1.92	24.00		Full cup	"	"	"	"
"	756.		.19	.47	.098			"		1.240 × .378	.942 × .230	.4687	.2167	53.76	19250	41070	31700	67640	1.86	23.75		"	"	"	"	"

TESTED ON OLSEN MACHINE AT ETNA.

* Second test ordered.

GEO. W. G. FERRIS, JR., *Inspector*.

HARLEM RIVER BRIDGE.

REPORT OF TESTS MADE ON 3/4 INCH ROUND STEEL, MANUFACTURED BY CARNEGIE, PHIPPS & CO., LIMITED, PITTSBURGH.

Date.	Heat No.	No. of Spec.	Chemical Analysis. C.	Mn.	P.	S.	Si.	Test piece cut from	Nominal Size.	Cross Dimensions. Original.	Fractured.	Area. Orig.	Frac.	% of Red'n	Elastic Limit. Act'al	Lbs. per sq. in.	Maximum Load. Act'al	Lbs. per sq. in.	Extensions. In 8 in.	% in 8 in.	Modulus of Elasticity.	Fracture.	Bending Tests. Natural.	Quenched.	Remarks.	Accepted or Rejected.
1887								*In.*																		
May 5	8909.							3/4 Round		.762	.495	.4560	.1924	57.81	18500	40570	28900	63370	2.44	30.50		Partial cup.	Bent double	Bent double	Silky and floury.	Accepted.
"	8913.							"		.765	.510	.4596	.2043	55.55	18000	39170	29300	63750	2.32	29.00		"	"	"	"	"
"	8927.							"		.765	.467	.4596	.1713	62.73	18000	39170	29100	63320	2.46	30.75		Full cup.	"	"	"	"
"	8933.							"		.760	.518	.4536	.2107	53.55	18300	40350	29400	64820	2.40	30.00		Partial cup.	"	"	"	"
"	8989.							"		.766	.475	.4608	.1772	61.55	18200	39500	28600	62060	2.52	31.50		Full cup.	"	"	"	"
May 10	8995.							"		.754	.473	.4465	.1757	60.65	17500	39190	28200	63160	2.40	30.00		"	"	"	"	"
"	9056.							"		.744	.519	.4347	.2116	51.32	18200	41870	29200	67170	2.30	28.75		Partial cup.	"	"	"	"
"	9060.							"		.753	.478	.4453	.1795	59.69	18000	40430	28650	64340	2.28	28.50		"	"	"	"	"
"	9064.							"		.754	.525	.4465	.2165	51.51	17900	40090	29500	66070	2.16	27.00		"	"	"	"	"
"	9068.							"		.750	.536	.4418	.2256	48.94	18300	41420	29800	67450	2.16	27.00		"	"	"	"	"
"	9072.							"		.748	.505	.4394	.2002	54.44	18300	41650	28600	65090	2.14	26.75		"	"	"	"	"
"	9076.							"		.755	.520	.4477	.2124	52.55	18600	41550	30100	67240	2.26	28.25		"	"	"	"	"
"	9080.							"		.750	.528	.4418	.2190	50.43	17900	40520	30700	69490	2.20	27.50		"	"	"	"	"
"	9084.							"		.756	.468	.4489	.1720	61.68	17600	39210	28900	64390	2.20	27.50		"	"	"	"	"
"	9088.							"		.757	.528	.4501	.2190	51.34	18000	39990	28800	63980	2.14	26.75		"	"	"	"	"
"	9092.							"		.750	.530	.4418	.2206	50.07	17500	39610	29700	67220	2.18	27.25		"	"	"	"	"
"	9096.							"		.752	.483	.4441	.1832	58.75	17400	39180	28000	63050	2.30	28.75		Full cup.	"	"	"	"
"	9100.							"		.755	.454	.4477	.1617	63.86	17900	39980	28400	63440	2.42	30.25		"	"	"	"	"
"	9104.							"		.756	.460	.4489	.1662	62.97	17800	39660	28400	63270	2.50	31.25		Partial cup.	"	"	"	"
"	9108.							"		.753	.496	.4453	.1932	56.61	17500	39300	29500	66240	2.16	27.00		"	"	"	"	"
"	9112.							"		.756	.498	.4489	.1948	56.60	17800	39650	28600	63710	2.46	30.75		"	"	"	"	"
"	9116.							"		.756	.495	.4489	.1924	57.14	17300	38540	28700	63930	2.44	30.50		"	"	"	"	"
"	9120.							"		.755	.456	.4479	.1633	63 52	17600	39310	28300	63210	2.36	29.50		"	"	"	"	"
"	9124.							"		.753	.530	.4453	.2206	50.46	18000	40420	28600	64220	2.12	26.50		"	"	"	"	"
"	9128.							"		.754	.496	.4465	.1932	56.73	17800	39870	28300	63380	2.16	27.00		"	"	"	"	"
"	9132.							"		.757	.465	.4501	.1698	62.27	17300	38440	27000	59990	2.34	29.25		Full cup.	"	"	"	Rejected.
"	9136.							"		.760	.522	.4536	.2140	52.82	17800	39250	30000	66140	2.40	30.00		Partial cup.	"	"	"	Accepted.
"	9140.							"		.757	.475	.4501	.1772	60.63	18300	40660	28100	62440	2.66	33.25		"	"	"	"	"
"	9144.							"		.756	.498	.4489	.1948	56.60	18000	40100	30700	68390	2.20	27.50		"	"	"	"	"
"	9148.							"		.757	.513	.4501	.2067	54.08	17200	38210	28600	63540	2.36	29.50		"	"	"	"	"
"	9152.							"		.760	.509	.4536	.2035	55 13	17000	37480	30600	67460	2.20	27.50		"	"	"	"	"
"	9160.							"		.755	.513	.4477	.2067	53.83	17600	39310	29200	65220	2.30	28.75		"	"	"	"	"
"	9164.							"		.762	.492	.4560	.1901	58.31	17800	39040	29600	64910	2.10	26.25		Full cup.	"	"	"	"
"	9138.							"		757	.503	.4501	.1987	55.85	17800	39550	29200	64870	2.32	29.00		Partial cup.	"	"	"	"
"	9172.							"		.757	.490	.4501	.1886	58.10	18000	39990	28600	63540	2.50	31.25		"	"	"	"	"
"	9176.							"		.756	.488	.4489	.1870	58.34	17100	38100	28800	64160	2.42	30.25		"	"	"	"	"
"	9180.							"		.757	.480	.4501	.1810	59.78	17600	39100	28000	62200	2.40	30.00		"	"	"	"	"
"	9184.							"		.757	.510	.4501	.2043	54.61	17100	37990	29100	64650	2.30	28.75		"	"	"	"	"
"	9188.							"		.754	.480	.4465	.1810	59.46	17800	39870	28300	63380	2.38	29.75		Full cup.	"	"	"	"
"	9192.							"		.757	.491	.4501	.1893	57.94	18100	40220	28800	63990	2.16	27.00		"	"	"	"	"
"	9196.							"		.760	.500	.4536	.1963	56.72	18100	39900	29400	64820	2.40	30.00		Partial cup.	"	"	"	"
"	9202.							"		.754	.513	.4465	.2067	53.70	18400	41210	29500	66070	2.36	29.50		"	"	"	"	"
"	9208.							"		.754	.501	.4465	.1971	55.86	18200	40770	29200	65400	2.26	28.25		"	"	"	"	"
"	9214.							"		.757	.452	.4501	.1605	64.34	17600	39100	28200	62650	2.44	30.50		Full cup.	"	"	"	"
"	9220.							"		.764	.523	.4584	.2148	53.15	17400	37960	29700	64790	2.24	28.00		Partial cup.	"	"	"	"
"	9226.							"		.757	.520	.4501	.2124	52.81	18100	40220	28400	63100	2.12	26.50		"	"	"	"	"
"	9232.							"		.762	.443	.4560	.1541	66.21	17900	39260	28600	62790	2.52	31.50		"	"	"	"	"
"	9236.							"		.754	.456	.4465	.1633	63.43	18200	40760	27300	61140	2.60	32.25		"	"	"	"	Rejected.

TESTED ON OLSEN MACHINE AT UNION IRON MILLS.

GEORGE W. G. FERRIS, JR., *Inspector.*

HARLEM RIVER BRIDGE.

REPORT OF TESTS OF ⅞ INCH RIVET STEEL MANUFACTURED BY THE PENNSYLVANIA STEEL COMPANY, ROLLED BY THE PASSAIC ROLLING MILL COMPANY.

DATE.	Heat No.	No. of Spec.	Chemical Analysis.					Test Piece cut from	Nominal Size.	Cross Dimensions.		Area.			Elastic Limit.		Maximum Load.		Extensions.		Modulus of Elasticity.	Fracture.	Bending Tests.		Remarks.	Accepted or Rejected.
			C.	Mn.	P.	S.	Si.			Original.	Fract'red	Orig.	Frac.	P. Ct. of Red'n	Actu'l	Lbs. per sq. in.	Actu'l	Lbs. per sq. in.	In 8 in.	P. Ct. in 8 in.			Natural.	Quenched.		
								In.	In.	In.	In.								In.							
Jan. 13		1						⅞ round	⅞	.855 dia.	.521 dia.	.574	.213	62.89	21540	37520	35660	62120	2.43	30.37		Silky cup.......	bent 180° flat	bent 180° flat		Accepted.
" 13		2						" "	"	.854 "	.547 "	.573	.235	58.98	20700	36120	35900	62650	2.4	30.0		" "	"	"		"
" 13		3						" "	"	.857 "	.53 "	.577	.221	61.69	22200	38470	36390	63060	2.5	31.25		" "	"	"		"
" 13		4						" "	"	.854 "	.553 "	.573	.240	58.11	19980	34860	36000	62820	2.41	30.12		" "	"	"		"
" 13		5						" "	"	.853 "	.524 "	.571	.216	62.17	20400	35720	36120	63250	2.25	28.12		" ¾ cup......	"	"		"
" 13		6						" "	"	.856 "	.551 "	.575	.238	58.60	21190	36850	35990	62590	2.4	30.0		" perfect cup.	"	"		"
Mar. 13		1						" "	"	.854 "	.542 "	.573	.231	59.68	20240	35320	36200	63170	2.42	30.25		" "	2 "	2 "		"
" 13		2						" "	"	.849 "	.514 "	.566	.207	63.42	20200	35680	36180	63920	2.3	28.75		" "	2 "	2 "		"
" 13		3						" "	"	.852 "	.529 "	.570	.220	61.40	19890	34890	36200	63500	2.36	29.5		" "	2 "	2 "		"
" 30		1						" "	"	.855 "	.532 "	.574	.222	61.32	199[illegible]	34700	35690	62170	2.5	31.25		" "	"	"		"
" 30		2						" "	"	.856 "	.541 "	.575	.230	60.0	20000	34780	35600	61910	2.43	30.37		" "	"	"		"
" 30		3						" "	"	.854 "	.527 "	.573	.218	61.95	19200	33500	35420	61810	1.97	24.62		" "	"	"		"
" 30		4						" "	"	.857 "	.527 "	.577	.218	62.21	19800	34310	34900	60480	2.37	29.62		" "	"	"		"
" 30		5						" "	"	.849 "	.541 "	.566	.230	59.36	20000	35350	36200	63950	2.29	28.62		" cup........	"	"		"
" 30		6						" "	"	.848 "	.592 "	.565	.275	51.32	20200	35750	36000	63710	2.27	28.37		" "	"	"		"
May 8		1						" "	"	.851 "	.542 "	.567	.231	59.25	20290	35780	34900	61550	2.4	30.0		" "	"	"		"
" 8		2						" "	"	.846 "	.546 "	.562	.234	58.36	21270	37840	35230	62680	2.42	30.25		" ¾ cup.	"	"		"
" 8		3						" "	"	.854 "	.522 "	.573	.214	62.65	21100	36820	35640	62190	2.29	28.62		" "	"	"		"
" 8		4						" "	"	.849 "	.537 "	.566	.226	60.0	21200	37450	35600	62890	2.31	28.87		" "	"	"		"
" 19		1						" "	"	.855 "	.528 "	.574	.219	62.36	19990	34820	36100	62890	2.37	29.62		" "	"	"		"
" 19		2						" "	"	.857 "	.541 "	.577	.230	60.13	20200	35000	36190	62720	2.27	28.37		" "	"	"		"
" 19		3						" "	"	.856 "	.543 "	.575	.232	59.65	21220	36900	36170	62900	2.42	30.25		" "	"	"		"
" 19		4						" "	"	.851 "	.547 "	.573	.235	59.0	20890	36450	35990	62800	2.39	29.87		" "	"	"		"
June 6		1						" "	"	.839 "	.599 "	.553	.282	49.0	17100	30920	35690	64530	2.25	28.12		" 45°	2 "	2 "		"
" 6		2						" "	"	.838 "	.582 "	.552	.266	51.81	17200	31150	35280	63910	2.32	29.0		" "	2 "	2 "		"
" 26		1						" "	"	.847 "	562 "	.563	.248	55.95	19600	34810	35420	62910	2.03	25.37		" "	"	"		"
" 26		2						" "	"	.850 "	.549 "	.567	.237	58.2	20420	36010	35100	61900	2.25	28.12		" "	"	"		"
" 26		3						" "	"	.852 "	.537 "	.570	.226	60.0	19900	34910	34900	61220	2.19	27.37		" "	"	"		"
" 26		4						" "	"	.857 "	.539 "	.577	.228	60.48	19860	34410	35120	60860	2.24	28.0		" "	"	"		"
" 26		5						" "	"	.854 "	.550 "	.573	.238	58.46	18900	32980	35200	61430	2.14	26.75		" "	"	"		"
" 26		6						" "	"	.856 "	.541 "	.575	230	60.0	19110	33230	35420	61600	2.27	28.37		" "	"	"		"
Aug. 18		1						" "	"	.861 "	.511 "	.582	.205	64.77	21300	36590	35240	60550	2.5	31.25		" cup.......				"
" 18		2						" "	"	.853 "	.510 "	.571	.204	64.27	21400	37470	35050	61380	2.5	31.25		" "				"
" 18		3						" "	"	.854 "	.505 "	.573	.200	65.09	21700	37870	34900	60900	2.46	30.75		" "				"
" 18		4						" "	"	.847 "	.514 "	.563	.207	63.23	20400	36230	35090	62320	2.37	29.62		" 45°				"
Oct. 8		1						" "	"	.847 "	.525 "	.563	.216	61.63	20200	35870	34370	61040	2.43	30.37		" "				"
" 8		2						" "	"	.853 "	.538 "	.571	.227	60.21	20900	36600	34830	60990	2.37	29.62		" cup.........				"
" 8		3						" "	"	.857 "	.539 "	.577	.228	60.48	20480	35490	35270	61120	2.57	32.12		" "				"
" 8		4						" "	"	.842 "	.545 "	.557	.233	58.16	20600	36980	34460	61860	2.4	30.0		" 45°				"
" 13		1						" "	"	.855 "	.534 "	.574	.224	60.97	20000	34840	35080	61110	2.37	29.62		" ½ cup.....				"
" 13		2						" "	"	.856 "	534 "	.575	.224	61.04	20400	35490	35080	61000	2.37	29.62		" "				"
" 29		1						" "	"	.856 "	.614 "	.575	.296	48.52	20800	36170	34500	60000	2.12	2.65		" 45°.........				"
" 29		2						" "	"	.854 "	.515 "	.573	.208	63.70	20100	35090	34200	59680	2.32	29.0		" ¾ cup......				"
" 29		3						" "	"	.853 "	.525 "	.571	.216	62.17	21300	37300	33830	59240	2.35	29.37		" 45°.........				"
" 29		4						" "	"	.855 "	.530 "	.574	.221	61.50	21400	37280	34500	60100	2.27	28.37		" "				"

TESTED ON RIEHLE MACHINE AT PASSAIC ROLLING MILL.

CHARLES B. COLBY, *Inspector*.