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THE MEMPHIS BRIDGE

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THE MEMPHIS BRIDGE.

A REPORT

TO

GEORGE H. NETTLETON,

PRESIDENT OF THE KANSAS CITY AND MEMPHIS RAILWAY AND BRIDGE COMPANY,

BY

GEORGE S. MORISON,

CHIEF ENGINEER OF THE MEMPHIS BRIDGE.

NEW YORK:
JOHN WILEY & SONS,
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BY
GEORGE S. MORISON.

CHICAGO, March 1st, 1894.

GEORGE H. NETTLETON, ESQ.,
President Kansas City and Memphis Railway and Bridge Company.

DEAR SIR:—

I submit the following Final Report in relation to the bridge across the Mississippi River at Memphis, Tennessee.

Yours truly,

GEORGE S. MORISON,
Chief Engineer Memphis Bridge.

CONTENTS.

SUBJECTS.

		Page
I.	Preliminary Narrative	5
II.	General Description	7
III.	Substructure	8
IV.	Superstructure	16
V.	Viaduct	25
VI.	Approaches	26
VII.	Shore Protection	27
VIII.	Cost	28

APPENDICES.

A.	List of Engineers, Employees and Contractors	29
B.	Act of Congress, approved February 26, 1885	30
C.	Act of Congress, approved April 24, 1888	31
D.	Contract with War Department	32
E.	Report of February 15, 1887	33
F.	Report of August 2, 1888	37
G.	Argument for Amendment of Charter	39
H.	Ordinance of Taxing District, passed March 23, 1891	42
I.	Cost of Sinking Foundations	45
J.	Progress of Sinking Foundations	54
K.	Specifications for Masonry	63
L.	Specifications for Superstructure	65
M.	Supplementary Specifications, May 6, 1890	70
N.	Supplementary Specifications, January 1, 1891	71
O.	Tests of Full Sized Eye Bars	72
P.	Report of Testing Committee	74

LIST OF PLATES.

1. General Map.
2. Bridge and Immediate Vicinity.
3. Profile and Alignment.
4. General Elevation and Plan.
5. Profile showing Stratification on Bridge Line.
6. Water Record at Government Gauge, seven years.
7. Water Record, Government and Bridge Gauges, four years.
8. Record of Soundings, seven typical dates.
9. East Abutment.
10. Anchorage and Small Piers.
11. Pier I.
12. Caisson, Pier I.
13. Pier II.
14. Pier III.
15. Position of Mats at Piers II and III.
16. Caisson, Pier II.
17. Caisson, Pier III and Cutting Edge.
18. Stratification of Clay at Pier III.
19. Pier IV.
20. Caisson, Pier IV.
21. Pier V.
22. Weaving Barges.
23. Anchorage of Caisson III.
24. Launching Ways.
25. Clay Hoist and Sand Pump.
26. Special Hoist and Lock.
27. Concrete Mixing Plant.
28. Diagram of Sinking Progress.
29. Elevation, Anchorage Span.
30. Elevation and Section, Anchorage Span.
31. Elevation, Cantilever Arm.
32. Elevation, Central Span.
33. Elevation and Section, Central Span.
34. Elevation, Intermediate Span.
35. Elevation and Section, Intermediate Span.
36. Viaduct East of Anchorage.
37. Anchorage Connection.
38. Bearings, Piers I and III.
39. Expansion Bearing, Pier II.
40. Bearing, Pier IV.
41. Joints in Chords, Central Span.
42. U_0 Panel Point, Central Span.
43. Expansion Joints, Intermediate Span.
44. Adjustment at Ends, Intermediate Span.
45. Adjustments at Center, Intermediate Span.
46. Elevation, Deck Span.
47. Elevation and Section, Deck Span.
48. Details, Deck Span.
49. Floor.
50. Strain Sheet, Intermediate Span.
51. Strain Sheet, Cantilever Arm.
52. Strain Sheet, Anchorage Arm.
53. Strain Sheet, Central Span.
54. Strain Sheet Details, Central Span
55. Strain Sheet, Deck Span.
56. West Approach Viaduct.
57. West Approach Piers.
58. Details, West Approach Viaduct.
59. Viaduct Floor and Girders.
60. Highway Approach.

THE MEMPHIS BRIDGE.

I.

PRELIMINARY NARRATIVE.

The construction of a bridge at Memphis has been a matter of professional interest among American engineers for many years. In 1867 the bridge across the Missouri River at Kansas City, the first bridge across that river and the bridge whose construction led to the building of the railroad of whose system the Memphis Bridge now forms a part, was begun. At this time a bridge at Memphis was talked of as one of the works of the future. Like other works which were considered far in the future, the difficulties of the problem were overestimated: the depth of the river was overstated and other conditions were considered much more difficult than they really were. At that time, however, the construction of a bridge at Memphis would have been a matter of great expense, and the changes which finally rendered the building of this bridge a comparatively simple affair represent the advances which bridge engineering has made in twenty years.

The Kansas City Bridge was begun in 1867 and opened in 1869. The Memphis Bridge was begun in 1888 and was opened for traffic in 1892. The Act of Congress under which the Kansas City Bridge was built was approved July 25th, 1866; the Act of Congress under which the Memphis Bridge was built was approved April 24th, 1888. The two bridges were really about twenty-two years apart.

The first definite action looking to the construction of a bridge at Memphis was the passage by Congress of an Act approved February 26th, 1885, conferring on two corporations the right to construct and maintain a bridge across the Mississippi River from or near Memphis in the State of Tennessee to or near the town of Hopefield in the State of Arkansas.

The physical requirements of this charter were favorable, and the people who obtained it hoped that it would prove a profitable enterprise. As it is of interest to compare this charter with the one subsequently granted to your company it is printed in Appendix B.

Some months after the granting of this charter Mr. Simon Stevens of New York, who represented the parties holding the charter, called at my office in New York to consult me in regard to the construction of a bridge under its provisions, and at that time I made some crude estimates and prepared some crude plans. The plan which at that time seemed to me the best contemplated crossing the river with two long spans having a double pier on a single foundation in the middle of the river. This plan, however, was prepared without surveys, the data being obtained from some old maps. When actual surveys were made, the width of the river was found to be materially greater than these maps showed and the plan became impracticable. The matter was one which interested me greatly from the start, and I also thought that if a bridge was to be built there it should be in the interest of the Kansas City, Ft. Scott & Memphis System of railroads.

On the 15th of January, 1886, I called upon you in Kansas City and we had our first conversation in relation to this bridge. It is from this date that the connection of your system with the scheme really began. I left Kansas City that night and reached Memphis on the afternoon of the following day. The river was full of ice and it was difficult to go about; but I made a short trip on the transfer-boat Charles Merriam and climbed up the bluff on the Memphis side of the river. On this day I selected the location for a bridge, this location being fixed by the top of a rude staircase on the Memphis side and by a log cabin in the bottom-land on the Arkansas side. I never had occasion to alter this location and the bridge was built upon it.

Nothing definite was done for several months thereafter, but towards the end of the year you authorized me to make an examination of the site and a report on the cost of a bridge on this location. On the 23d of November, 1886, I again visited Memphis, taking with me Mr. E. Duryea, Jr., as my assistant, to make borings in the river. Mr. Duryea continued at Memphis till the spring of 1887 and during this time a careful set of borings were made. These borings gave results more favorable than I had expected, as they showed that a layer of hard clay was to be found entirely across the Mississippi River at depths within the limits to which foundations could be sunk by practical methods.

The results of these borings and examinations were embodied in a report dated February 15th, 1887, which I addressed to you and which I have thought best to attach to this report as Appendix E. This report contemplated crossing the river with three equal independent spans of about 660 feet each, which the charter of 1885 permitted, and which after a careful examination seemed to me the best arrangement. It also considered a 1300 feet span of cantilever construction.

The charter of 1885 was found to be unsatisfactory, in various particulars, to the interests which you represent, and in the winter of 1886–87 a bill was introduced in Congress granting another charter to a corporation in your interest. This bill did not pass.

During the following season another bill was introduced which became a law: this is the Act under which your bridge has been constructed; it was approved April 24th, 1888 and is given in Appendix C.

This Act fixed the minimum length of the channel span at 700 feet or 150 feet more than the length of clear spans specified in the previous Act. A more serious difference, however, was that it fixed the height above high water at 75 feet instead of 65. The Act also required that provision should be made for highway traffic. I was at that time in quarantine at San Francisco, but plans were prepared by my partner, Mr. E. L. Corthell, and submitted to the Secretary of War for approval.

The Act provided that the Secretary of War should order three engineer officers from the Engineer Bureau to examine by actual inspection the location where the bridge was to be built and report what should be the length of the main-channel span and of other spans. A board was appointed consisting of Col. W. E. Merrill, Major O. H. Ernst, and Captain D. C. Kingman. It met at Memphis in May, 1888. On the 25th day of that month I arrived at Memphis; Mr. Corthell was already there. We met the board and explained the situation while various gentlemen representing the steamboat interests were also present.

The full proceedings of this board and the action of the Secretary of War are given in Appendix WW 22 of the Report of the Chief of Engineers, U. S. Army, for 1888 (pp. 2514–2525). The board did not agree in their report, the two junior officers recommending a minimum channel span 1000 feet long, while the senior officer, whose professional standing made his opinion of unusual weight, considered 700 feet in the clear enough. The board was unanimous in locating the channel span next to the Tennessee shore and this location was accepted.

The findings of this board were overruled by the Secretary of War, who decided that if a clear width of 730 feet, at all stages of water, could be provided under the channel span it would be enough, and who intimated that if this length of span could be increased to 770 feet by placing the east pier 40 feet back from the low-water line, it would be unnecessary to provide any special fenders to keep tows from striking this pier.

As the requirements of the new charter and the conditions imposed by the Secretary of War made essential modifications in the plan of the bridge which affected the cost, you asked for another estimate. This estimate was made and is embodied in a report dated August 2d, 1888, which is attached to this report as Appendix F.

The last suggestion of the Secretary of War was adopted. On the 3d of August, 1888, I submitted personally to the Hon. William C. Endicott, Secretary of War, in Washington, the plans of a bridge meeting these conditions. These plans were approved in a contract between the War Department and the Bridge Company, which is printed in Appendix D.

The charter required that provision should be made "for the passage of railway trains, and wagons and vehicles of all kinds, (and) for the transit of animals." The Secretary of War insisted that the plans should show provisions of this character; and as he considered it possible that a provision for highway traffic on the same floor with the railroad traffic, the arrangement which has been in use for twenty years at Kansas City and at other places, might prove inadequate, a special clause was inserted in the contract under which the Bridge Company agreed to run ferry trains, similar to those formerly run between Omaha and Council Bluffs, whenever the accommodations afforded for highway traffic should prove inadequate.

As the financial arrangements for the construction of the bridge were not then completed, I advised you to put in the foundation of Pier IV during the low-water season of 1888, in advance of any final action as to the construction of the bridge, believing that the information to be obtained by sinking this pier might be of great assistance in preparing the plans for the other piers. The authority to put in this foundation was given.

On the 1st day of October I appointed Mr. Alfred Noble, who was then Resident Engineer of the Cairo Bridge, Resident Engineer of the Memphis Bridge; it being understood that he should divide his time between the two bridges until the Cairo Bridge was done.

Lines were retraced, the axis of the bridge was definitely marked, and on the 7th of November, 1888, actual construction was begun by framing timber for the caisson of Pier IV. Meanwhile the steamer JOHN BERTRAM, fitted with a complete pneumatic plant, and which had been used on the Rulo and Nebraska City bridges, had been bought and brought to Memphis.

The work continued during the fall and winter, though it was confined entirely to the foundation of Pier IV. The foundation of this pier was completed in February, 1889, and about the time of its completion the plans were worked up for the large caissons of the two river piers.

In January I was authorized to proceed with construction in the hope that the bridge could be finished in 1891.

To accomplish this it was necessary to put in the foundations of the two river piers (II and III) during the low-water season of 1889. If the season had been favorable this could have been done. But the season was too short, and the foundation of Pier II had to be abandoned before it was completed. No harm was done, but two seasons instead of one were required for the foundation work.

In June, 1889, a special building adapted to the requirements of an engineer's office was erected on the bluff at the foot of Virginia Avenue a little north of the bridge line. This office served a very useful purpose during the whole construction of the bridge, and its situation was such that it was a comfortable place to work in at all seasons of the year.

The original estimates contemplated building the piers of limestone. It was decided, however, to make the face stone of granite.

On the 3d of April, 1889, a contract was executed with Lewis M. Loss to build the masonry of the piers.

On the 24th of January, 1890, a contract was entered into with the Union Bridge Company for the manufacture of the superstructure.

On the 10th of May, 1890, a contract was entered into with the firm of Bair Brothers for the erection of the superstructure.

On the 6th of March, 1891, a contract was entered into with the Pennsylvania Steel Company for the manufacture of the viaduct on the west approach.

These four contracts were the only important contracts let during the entire work. All other work was either done by the company's own forces working under the direction of the Resident Engineer, or consisted of small work let to local contractors.

In the early part of 1890, during the long session of the Fifty-first Congress, an attempt was made to have the charter amended so as to permit the bridge to be built sixty-five feet above high water, the height permitted by the Act of February 26th, 1885, and a bill to accomplish this was introduced in the United States Senate by the Hon. Isham G. Harris. I had a careful set of measurements made of the heights of smoke-stacks and pilot-houses of nearly every important steamboat running on the lower Mississippi River and embodied the results of these measurements in a printed argument which, as it contains many valuable facts which may otherwise be lost, is printed in Appendix G of this report. The bill failed to pass and the bridge was built of the elevation required by the charter. The result is a heavy grade on the east approach which could otherwise have been avoided, a disturbance of street levels, and the constant hard working of locomotives within the city limits.

An ordinance of the Taxing District of Shelby County, passed March 23d, 1891, authorized the crossing of streets and alleys along the line of the east approach. A copy of this ordinance is printed in Appendix H.

The erection of the superstructure began in January, 1891, with the anchorage span. This erection continued without interruption, the last part of the superstructure erected being the central portion of the channel span. This was connected through on the 8th of April, 1892, sixteen days before the expiration of the time limited by the charter for the completion of the work and finally swung clear on the 23d of April, one day before the expiration of the charter time.

The small amount of work then remaining to be done to open the bridge for the passage of trains was rapidly completed, and on the 12th of May, 1892, the bridge was formally tested by the passage of a train of eighteen locomotives and was immediately thereafter opened to railroad traffic, since which time it has been a source of revenue to your company. The opening of the bridge was made the occasion of a great public celebration in Memphis on the 12th and 13th.

The deflections and other movements under the passage of the test trains were carefully observed by a committee of engineers especially selected as a testing committee, whose report will be found in Appendix P. The same appendix contains a list of the eighteen locomotives.

There still remained a considerable amount of work, the principal features being the sloping and paving of the east bluff, additional riprap protection around the river piers, and the construction of the highway approaches, so that the bridge could be opened to highway traffic as required by its charter.

Mr. Noble left Memphis on the 1st of June, 1892, and Mr. M. A. Waldo was given the title of Resident Engineer, though Mr. Noble continued to assist me in the supervision of the work.

The highway approaches and floor were completed so that the bridge was opened for highway traffic January 26th, 1893; but the amount of highway traffic has not proved enough to pay the expenses of collecting the tolls or in any way to interfere with railroad traffic.

On the 31st of December, 1892, all work, except the pavement of the east bank and some riprap protection, being completed, the care of the bridge was turned over to Mr. W. A. Nettleton, Superintendent of Terminals. On the 1st of May, 1893, this other work also being completed, everything was placed in his hands.

II.

GENERAL DESCRIPTION.

The Memphis Bridge and approaches, being the entire line of railroad owned by the Kansas City and Memphis Railway and Bridge Company, extend from the connection with the main line of the Kansas City, Ft. Scott & Memphis Railroad in Crittenden County, Arkansas, to a connection with the tracks of the St. Louis, Iron Mountain & Southern Railway on the west side of Kentucky Avenue in the city of Memphis, Tennessee, a total length of 15 903 feet, or 3.01 miles.

For convenience, a point arbitrarily selected on the east bluff was made the starting-point for all measurements and numbered Station 100.

The point of connection with the Kansas City, Ft. Scott & Memphis tracks is at Station 230 + 35 and the connection with the rails of the St. L., I. M. & S. Ry. at Station 71 + 32. At Station 187 + 46.4 the line crosses the main track of the St. L., I. M. & S. Ry. in Arkansas and connection is made with that railroad. At Station 209 + 61.5 the line crosses the main track of the Little Rock & Memphis R.R. and connection is made with that railroad. At Station 76 + 71 the line crosses Kansas Avenue in the city of Memphis and connection is made with the tracks of the Kansas City, Ft. Scott & Memphis Railroad, which are laid in that street.

The entire railroad is a single-track line, excepting between the east end of the bridge and Pennsylvania Avenue, where there are two tracks. East of Pennsylvania Avenue one of these tracks forms a connection for the St. L., I. M. & S. Ry.

Two long side tracks, which form the basis of a west side yard, have been put in immediately west of the crossing of the St. L., I. M. & S. Ry., and a station has been established here named Bridge Junction.

The total amount of track laid and belonging to the Kansas City & Memphis Railway and Bridge Co. is 20 990 feet, or 3.98 miles. The length of track belonging to the Bridge Company and used by the Kansas City, Ft. Scott & Memphis R. R. is 19 166 feet, or 3.63 miles. The length of track used by the St. L., I. M. & S. Ry. is 11 668 feet, or 2.21 miles.*

The East Approach ascends to the bridge with a grade of 1.31 per cent (69.17 feet per mile), this maximum grade being 1200 feet long, but a total ascent of 26 feet is made in 2500 feet.

The West Approach ascends to the bridge with a grade of 1.25 per cent (66 feet per mile), the total ascent being 77 feet, all of which is made in a uniform continuous grade varied only by vertical curves at the two ends.

The general location is given on Plates 1 and 2. The grades and alignment are shown on Plate 3.

The entire line thus briefly described may be divided into four parts:

1. The East Approach, including everything east of the East Abutment.

2. The Bridge proper, extending from the East Abutment to Pier V inclusive.

3. The Viaduct, extending from Pier V to Pier 54.

4. The West Approach, extending from the viaduct to the connection with the Kansas City, Ft. Scott & Memphis Railroad in Arkansas.

These several parts will be more fully described hereafter. The bridge crosses the Mississippi River in latitude 35° 8′ and longitude 90° 5′, 232 miles below the confluence of the Mississippi and Ohio rivers at Cairo, Illinois. It is the first bridge built across the real Mississippi.

The Mississippi is really formed of four great tributaries. The two eastern branches are the Ohio and Tennessee rivers which unite at Paducah, Ky., forming a single river only for 50 miles, from Paducah to Cairo. They are both rivers of stable régime, but subject to extreme floods.

The two western tributaries are the Mississippi and the Missouri, which come together near Alton, Ill., forming a single river for about 200 miles. They are rivers of very different character, the Mississippi being a quiet stream of comparatively stable character and the Missouri a silt-bearer of the first magnitude. The Missouri gives the character to the united river below the junction. It is a silt-bearer subject to floods, but not to as violent floods as those in the Ohio.

Of the four great tributaries, the Missouri must be rated as the greatest, and the Mississippi as the least. The Mississippi and the Missouri combined into one river form a stream of about the same size as the Ohio and Tennessee combined into the Ohio. Where the two great rivers unite at Cairo they are of about equal magnitude.

Though these two great rivers are of about equal magnitude, they are of very different character, and the Mississippi proper below Cairo feels the effect of both. Like the Missouri, it is a great silt-bearer. Like the Ohio, it is subject to extreme floods. As is always the case when magnitude is increased, the changes in channel and the local disturbances are much less rapid than on the Missouri, but they are of the same character, and on a much larger scale. The floods which are most active and dangerous come from the Ohio. The flood season in the Ohio is in the winter and early spring; the flood season of the Mississippi and Missouri is in the spring and early summer; the flood season of the two rivers covers about one half of the year, extending from about the first of January into July. The whole working season which can be safely depended upon in the Lower Mississippi covers only about five months of the year.

The flood stages are shown graphically on Plate 6. In studying this plate it must be remembered that every flood which occurs at Memphis is really a flood of the river itself, there being no great tributary below to cause backwater, and every flood being accompanied by a rapid current.

The strongest current ever actually observed was on March 20th, 1890, being at the rate of 11¾ feet per second, or eight miles per hour. The usual average current was perhaps three miles per hour, this, however, being largely conjectural. In extreme low water there were times when the current was less than a mile an hour; fortunately one of these times occurred during the placing of the caisson for Pier II.

Levels were connected with the benches established by the Mississippi River Commission, and all elevations referred to the datum plane of mean tide-water at Biloxi, as given by those benches.

The Government gauge at Memphis is at the foot of Jefferson Street 9600 feet, or 1.82 miles, above the bridge. Gauge-readings were kept dur-

* These lengths of track are the amount laid at the time I gave up control of the work. Some further additions have since been made by the Operating Department.

ing the entire progress of the work at the bridge. The readings of the two gauges have been platted together and are given on Plate 7. This plate is specially instructive as it shows the great difference in fall between those two gauges at different stages in the river, the fall varying from 2.46 feet at extreme high water to 0.2 foot at low water. The total range at the bridge line is, therefore, 2.26 feet less than at the Government gauge. These local variations are not uncommon on sinuous rivers like the Mississippi.

The highest water ever observed at Memphis was on March 25th, 1890, when it reached 218.36 at the Government gauge and 216.2 at the bridge site. The height of the top of the stringer on the bridge was fixed at 296.25, the track being made level from the East Abutment to Pier IV. The elevation of the lowest point of the superstructure is 291.0, this being the bottom of a lateral pin. The clearance between extreme high water of 1890 and the lowest point of iron-work is 74.8 feet. At the time the plans of the bridge were approved the highest water at the Government gauge was 218.01, occurring in 1887, this being 0.35 lower than the water of 1890; if the fall of the river was the same then as in 1890, the clearance would have been 75.15 feet. Low water, which is a very rare occurrence, is 181.76 feet at the Government gauge. No such water was observed during the construction of the bridge, but the estimated corresponding height at the bridge is 181.6 feet.

The rainfall in this portion of the Mississippi Valley is abundant and the climate of Memphis rather damp. While some snow falls nearly every winter, the amount of frost is not enough to have any essential influence on construction. During three of the four winters while the bridge was building no ice was seen in the river.

The river has remained without change for a long series of years at the site of the bridge, and, as always happens in such cases with silt-bearing rivers, it has become narrow and deep. The low-water width is about 2000 feet, though the west-shore line has been more or less variable.

Although the Memphis bridge is the first bridge across the Mississippi River proper and is built within the limits of the alluvial delta, its foundations do not rest in the alluvial sand. As already stated, the borings which were made by Mr. Duryea showed that a substantial clay extended completely across the river. About the time that these borings were made a number of artesian wells were bored in Memphis to supply the city with water. These showed that the whole country was underlaid with a clay about 150 feet thick, which is perfectly water-tight, and under which is an indefinite thickness of saturated sand and gravel. The clay is now known as the La Grange formation, and the underlying sand and gravel come to the surface about 50 miles east of Memphis, and probably at a greater distance west. The clay and the underlying sand and gravel are of pre-alluvial character. The clay is very substantial, and its continuity is shown by the fact that the water in artesian wells at first rose about seven feet above the water in the Mississippi River.

The general arrangement of the bridge proper is given on Plate 4. It extends from the east abutment to Pier V, a total length of 2682 feet, or of 2698 feet from the east face of the abutment to the centre of Pier V. The track is level from the abutment to Pier IV, and the deck-span west of Pier IV is built on a vertical curve which connects with the grade on the viaduct.

The general plan of the viaduct is also given on Plate 4. It is 2290 feet $7\frac{1}{2}$ inches long, and is built throughout on a 1.25 per cent grade (66 feet per mile).

The total length of the permanent structure from the east face of the abutment to the west end of the iron-work of the viaduct is 4988 feet 9 inches.

In this report I have thought it best to divide the bridge proper into two parts, the Substructure and the Superstructure, the Substructure embracing everything below the top of the masonry, the Superstructure embracing all of the metal work as well as the floor.

III.

SUBSTRUCTURE.

The Substructure includes nine piers, eight of which are of masonry construction and one is principally of concrete. These nine piers are as follows:

East Abutment,
Pier A,
Pier B,
Anchorage Pier,
Pier I,
Pier II,
Pier III,
Pier IV,
Pier V.

The East Abutment is shown on Plate 9. It has a concrete foundation and is designed at once to form the retaining-wall at the end of the embankment and to afford office accommodations for telegraph-operator, toll-collectors, and others. The weight of superstructure carried is slight. The foundation is of concrete, and the Abutment below the level of the track is built hollow, there being a passageway completely through from north to south and staircases leading from this passageway to both offices above. This particular arrangement was adopted because it was thought that at some future time it might be desirable to open the bridge to foot travel and lead pedestrians to either side without crossing the track; this, however, is not likely to be done so long as the bridge is open for highway traffic. The masonry of the Abutment below the level of the track is built of Bedford limestone. The two small buildings above the floor level are of brick, the facing being of St. Louis pressed brick; they are entirely of incombustible construction, excepting the roof. Some furniture from the engineer's office has been moved to the second story of the north building, and a set of blue prints of the plans of the bridge have been placed there.

Piers A and B are shown on Plate 10. They are small stone piers having concrete foundations. Each of them simply carries the weight of one panel point. The foundations are of concrete, the copings of granite, and the remainder of the work of Bedford limestone.

The Anchorage Pier is also shown on Plate 10. This pier likewise has a concrete foundation; the upper courses are of granite, and the greater part of the pier of limestone. The principal feature of this pier is the method in which it is made to serve as an anchorage. Imbedded in the concrete foundation is a platform of steel I beams which carries the entire weight of masonry above it; under this platform are placed steel washer-plates with conical sockets through which the anchor-rods pass, the weight being transferred to the anchor-rods on conical countersunk heads; the anchor-rods are built solid into the masonry, and run through steel plates on top; the top of each rod is turned down, and screws of two different diameters are cut on it; the nuts on the lower screws, $3\frac{1}{2}$ inches in diameter, screw up against the plates on top of the masonry, thus taking up any possible slack in advance of strain; the upper and smaller screws, $3\frac{1}{4}$ inches in diameter, carry two nuts, besides a check-nut on top, and these two nuts hold between them the cross-blocks which carry the pin on which the outside rods attach; under each truss there are 16 rods in the masonry, these rods connecting with eight blocks which carry the single pin on which four anchor-bars connect.

After the adjustment of the structure, folding wedges were placed between the steel plate and the blocks and tightened up so as to prevent any possible horizontal bending strain on the anchor-rods.

The other five piers all have deep foundations which were put in by the plenum pneumatic process. Two of them, Piers I and V, come on dry ground during high water. Pier IV comes at the edge of the west shore as it was ten years ago and as it is now being restored by the protection work. The other two piers, II and III, come in the main channel. Piers I, II, III, and IV are all of similar shape, with straight parallel sides and ends formed of two circular arcs meeting in points, except above high water, where the ends are semicircular. They are of the same general plan which the Chief Engineer had used on other similar structures of less magnitude. The plans of these piers, showing the masonry as actually built, are given on Plates 11, 13, 14, and 19.

The masonry was all built by contract by Mr. Lewis M. Loss. The exposed portions of all these piers are of granite from Lithonia, near Atlanta, Ga. The backing throughout and the face stones of the lower courses are of limestone from Bedford, Indiana. Piers I, II and III measure 12 feet thick and 47 feet long at their least dimension, which is under the belting course. Pier IV is 10 feet thick and 43 feet long at the same place. Pier II is hollow below elevation 212; Pier III is hollow below elevation 195.6. Pier IV has niches on the west side to carry the end of the deck-span. The specifications for the masonry are given in Appendix K.

No attempt was made to make the lower portion of the chambers in the masonry water-tight, but the water rises and falls in the hollow masonry. To prevent any internal air-pressure from this source, the two end spaces are connected with the central spaces near the top by four-inch horizontal pipes, and a pipe from six to four inches in diameter was built near the centre of the pier, extending vertically from the top of the chamber to the coping, and terminating in a cap flush with the top of the coping. In the cap a small hole is drilled.

The concrete used was composed of crushed limestone, sand, and cement. The sand was dredged from the bottom of the Mississippi River and of excellent quality. The cement used generally was the natural American cement manufactured at and near Louisville, Ky.; in special portions of the work German Portland cement was used. The concrete was generally mixed in a machine mixer made by the Cockburn Barrow and Machine Company of Jersey City, N. J.; its capacity was about 20 cubic yards per hour. The mixer, together with a derrick and hoisting-engine, was carried on a barge 90 feet long, 30 feet wide, and 5½ feet deep. A platform large enough to handle three batches of concrete was built on the barge about five feet above the deck and the mixer placed under this platform. The cement and sand were first thoroughly mixed together, spread over the crushed rock and shovelled while dry into the mixer where the water was added. The mixer discharged the concrete directly into dumping-buckets, and the derrick delivered the buckets where wanted.

The concrete above the working-chamber was generally made in the proportions of one barrel of cement to 7½ cubic feet of sand and 13¾ cubic feet of crushed rock. In the lower portion of the V-shaped walls, where some leakage-water was present, the proportion of crushed rock was reduced nearly one half. Louisville cement was used everywhere above a horizontal plane two feet above the roof of the working-chamber, except in contracted places around the air-locks and working-shafts; in these places Portland cement was used. The concrete used to fill the working-chamber was generally mixed in the same proportions as that used above, but the amount of crushed rock was reduced in all places difficult of access; the lower two feet of concrete was mixed entirely with Portland cement, and the six inches of filling under the shoulder of the cutting edge, the cross-walls, and the flat surface of the roof were a Portland cement mortar, three parts of sand to one of cement and without stone; all other parts of the filling were the usual Louisville cement concrete.

The five numbered piers are founded on hard clay (into which it was desirable to sink them several feet) and at depths which it was expected would vary from 60 to 100 feet below low water. The fact that they had to be sunk to and into a clay which was too hard to be excavated by any dredging process made it expedient to use the plenum pneumatic process, and this was decided on from the start.

As the work was of unusual magnitude, it was thought unwise to have it done by contract, and a force was organized to do the work under the direction of the resident engineer.

The full equipment provided for handling the work in the river consisted of the following:

Two steamboats with pneumatic plant complete.
One tugboat.
Two anchor-barges.
One derrick-boat.
One pile-driver boat, used also as a derrick-boat.
One boat with concrete-mixer.
One house-boat for workmen.
Two barges with weaving ways for mattresses.
Seven material barges.

The two steamboats were each built originally to serve as transfer-boats on the Missouri River. They were side-wheel boats of the type common on western rivers, each having four high-pressure boilers and two long-stroke poppet-valve engines, with independent wheels. The space in the middle of the boat usually occupied by the track for cars was roofed over, and in this space were placed two No. 4 Clayton air-compressors each having two steam and two air cylinders 14 inches in diameter and 15 inches stroke; one large Worthington pump with steam-cylinders 18¼ inches diameter, water-cylinders 10¼ inches diameter, with 10-inch stroke, and an incandescent electric-light plant. One of these steamers, the JOHN BERTRAM, had been used previously at the Rulo and Nebraska City bridges; the other, the JOHN F. LINCOLN, was fitted up for this work with machinery which had previously been used on the Sioux City Bridge. They both proved very efficient tools. The nine barges last mentioned were ordinary coal barges used on the Mississippi River, 25 feet by 130 feet and 7 feet deep; they were decked over to fit them for use. This plant was exclusive of the floating plant used by the masonry contractor.

The general organization of the pneumatic force employed on the pneumatic foundations was as follows:

PRESSURE FORCE.

1 principal foreman.
1 night foreman.
3 to 8 gang foremen, the number depending on the depth.
2 lock tenders.
12 clay hoist tenders.
60 to 120 pressure men.

MACHINERY FORCE.

1 master mechanic.
3 machinists.
4 steamboat engineers.
4 firemen.
4 coal-passers.

The first foundation put in was that of Pier IV, which was made in a considerable degree experimental, the observations during the placing of this foundation being used in working up the plans of the two deepest foundations. The principal information obtained in this way related to the character of the clay; and this, in connection with the borings made by Mr. Duryea and other borings made immediately before beginning work (the position of these borings is shown on Plate 5), were the authorities for the character of the bottom. This information proved correct in nearly all respects, but the slight details in which it was incomplete led to features in the plans which would not otherwise have been adopted.

The general plan of caisson used was similar to that of the various bridges which have been built under my direction across the Missouri and some other rivers, the general principle followed being timber walls filled with concrete. In the case of the two principal foundations (Piers II and III) these plans were necessarily materially modified on account of the great size and other conditions of the foundations.

It was thought that a good foundation for Pier II could not be found above elevation 83, but that a safe foundation for Pier III could be found at elevation 103, and the plans of the caissons were made on the basis of this difference of twenty feet. This was an error in judgment. The foundation of Pier III is actually a little deeper than that of Pier II. The caissons, which were designed to be 60 and 40 feet high for these two respective foundations, should have been made precisely alike, and each 50 feet high. The difference, however, does not affect the stability of the structure.

It has seemed to me best to describe the several piers in the order of their position rather than that of time. The time at which the foundations were put in is shown graphically and briefly on Plate 28.

PIER I.

The location of Pier I was fixed by the Secretary of War at a point where the west face of this pier should come in water nine feet deep at the highest stage, and while the irregularities of a shore which is constantly subject to slight changes prevented this being done accurately, it was practically accomplished.

The ground at the site of the pier was levelled off and the caisson was built in position on blocking. The plans of this caisson are given on Plate 12. It was 70 feet long, 30 feet wide, and the total height of the timber work was 52.84 feet. The framing of the timber of this caisson was begun December 11th, 1889. Piles were driven above the site of the pier as a protection from drift during high water. The cutting edge was placed December 21st and the erection of the timber work begun on the following day.

The first concrete was placed in the walls of the caisson on the 2d of January, and on the following day the blocking was removed from under the edge. Air pressure was applied January 9th and sinking prosecuted until the 19th. Rainy weather delayed and a rise in the river impeded the construction of the upper works, and it became necessary to suspend sinking from January 19th to February 14th. Sinking was then resumed and prosecuted continuously until completion.

The construction of the timber and concrete portion of this pier was finished March 9th, 1890, and masonry begun on the following day.

On April 18th, 1890, the caisson reached its full depth and was stopped in hard clay with the cutting edge at elevation 137.85. On the 22d of April the filling of the working chamber was completed.

This pier is located at the foot of the bluff and was sunk for practically the whole depth through the class of material of which the bluff is composed. This material, however, was by no means uniform. Its character is shown on Plate 5. As a general rule, none of the sandy strata were free from clay and few of the clay strata entirely free from sand. It was generally removed either in sacks or by the clay hoists (Plate 25). For twenty-four feet, from elevation 183 to elevation 159, the material was so largely of sand that it could be removed with a sand-pump, and progress was more rapid. The last twenty feet were almost entirely through clay. The clayey nature of the material for the greater part of the distance explains the time consumed in sinking this foundation.

Detailed statements showing the cost and progress of sinking of this foundation are given in Appendices I and J.

The total volume of the foundation is 30 by 70 by 52.84 feet, equal to 110 964 cubic feet, so that the cost of the foundation, not including sinking and protecting foundation, was $0.369 per cubic foot, and the cost, including everything, $0.637 per cubic foot.

The masonry of Pier I was finished June 23d, 1890, it being the first pier entirely completed.

The total cost of the entire pier was as follows:

	Material.	Labor.	Total.	
Protection pile work	$204.64	$545.01	$749.65	
Caisson	13 170.64	8 119 49	21 290.13	
Concrete above chamber	9 893 86	5 523.76	15 417 62	
Concrete in chamber	2 115 79	1 143 67	3 259.46	
Cost, not including sinking, protection, etc.	$25 384.93	$15 331.93	$40 716 86	$40 716 86
Sinking	$6 566 05	$21 300 91	$27 866.96	
Riprap protection	1 738.00	81.22	1 819.22	
Insurance	246.24		246.24	
Sinking, protection to foundation, etc.	$8 550.29	$21 382.13	$29 932.42	29 932.42
Total foundation				$70 649 28
Masonry (2695 cu. yds.)				70 386.66
TOTAL COST OF PIER				$141 035.94

PIER II.*

The plans of the caissons for Piers II and III were worked up together in January, 1889. Soundings had shown the bottom of the river to be at elevation 145 at the site of Pier II, and borings had found clean river sand to elevation 98 where clay was encountered.

The two prominent facts which had to be faced in the preparation of these plans were that the caissons must be placed in water from forty to fifty feet deep on a sandy bottom, which in its natural condition would be washed away from under the edge of the caisson as this settled on the bottom, and the foundations when finally placed would rest on clay, the compressibility of which was but imperfectly known.

The three requirements which were borne in mind in the preparation of these plans were:

1. To limit the weight of the pier as much as possible.
2. To limit the scour at least during the construction of the work.
3. To make the base of the foundation large enough to keep the pressure within safe limits on a compressible clay.

To keep down weights it was determined to build a very high quality of masonry, reducing the dimensions of the piers to a minimum

* The account of Piers II and III is slightly modified from a paper entitled "The River Piers of the Memphis Bridge," published in Volume CXIV of the Minutes of the Proceedings of the Institution of Civil Engineers, London. The apparent discrepancy in the cost of the piers in the two accounts is due to some changes in the distribution of cost of plant.

and building their lower portions hollow, which, in the mild climate of Memphis, was considered entirely unobjectionable.

The method adopted to limit the scour was to carpet the bottom of the river with a woven mat similar to those which are used by the Mississippi River Commission for the protection of eroding banks. This device, which is believed to have been entirely original, proved perfectly successful.

The general rule followed in determining the size of the foundations was based on making the caissons of such construction that the weight of material in the foundations below the bottom of the river should not be greater than that of the sand which they displaced; and that after deducting four hundred pounds per square foot for friction on the sides of the caissons the weight placed on top of these caissons should not produce a pressure on the bottom of the foundation exceeding two tons to the square foot.

The size required for the base of such foundations was 47 feet wide by 92 feet long, and it was thought best to build the caissons with vertical sides below the bottom of the river.

The caisson for Pier II is shown on Plate 16. It is 59.4 feet high, 47 feet wide and 92 feet long.

The caissons were built of Southern pine timber most of which came from the State of Mississippi. The cutting edge is of iron, of a form used by the Chief Engineer on other bridges. This shape is preferred, because it at once gives convenient access to the actual edge when obstacles are encountered, and provides a shoulder above the edge on which the caisson can come to a bearing when sinking through sand, the edge projecting below this shoulder preventing an influx of sand from without. The V shaped walls surrounding the working chamber, and the entire space between the timbers for a height of 17.3 feet above the bottom were filled solid with concrete which was put in after placing the caisson in position. Above this solid concrete filling, for a height of 26.7 feet, the interior portion only of the structure was filled with concrete, the outer parts being left empty. The upper 15.4 feet of the 59.4 feet were built of solid timber.

The vertical side walls are bound by 54 two inch rods the lower lengths of which pass through the timbers, the nuts being screwed up against the under side of the shoulder of the cutting edge and against washers on top: in the upper part of the work these rods are placed immediately inside of the timbers. There are also 24 two inch rods similarly placed in the cross-walls, these being connected with 1½″ rods extending through the concrete. Besides these, 112 1½″ rods are placed near the timber intersections, extending from the roof of the caisson to the top of the concrete. The inclined walls of the caisson are tied to the outside vertical walls with 96 1½″ rods passing across the V shaped space. The two sides of each cross wall are tied together by 36 one inch bolts, and the timbers of the roof are tied together by 390 one inch bolts. The successive courses of timber in the outside walls are fastened together with one inch round drift bolts 34 inches long, spaced five feet apart, and as these bolts alternate in successive courses the real distance between the bolts is only 30 inches. The timbers of the inclined walls of the working chamber are fastened with drift bolts 30 inches long three feet apart, and the cross walls are fastened with drift bolts in the same manner as the outside vertical walls. The timbers of the solid filling above the concrete are fastened with 34 inch drift bolts driven eight feet apart in every stick, thus making the actual distance between drift bolts four feet. The outside planking was secured by two 7″ × ½″ boat spikes to each square foot of plank, and all other planking was fastened with two 7″ × ⅜″ boat spikes to each square foot of plank. The corners are rounded and plated with ⅜″ iron.

Pier II contains 1560 M. B. M. of timber and 450 000 pounds of iron.

The great depth to which the foundation was to be sunk, as well as the fact that a considerable amount of clay was to be penetrated, made it important to provide special machinery both for passing the men up and down and for removing the clay. The caisson was provided with four 24-inch shafts for the removal of material, which same shafts were used to send in the concrete with which the working chamber was finally filled. Besides this there was one 36 inch shaft with a double air lock at the bottom, of a form used on the piers of other works built by the Chief Engineer, and also one six foot shaft with a special air lock at the bottom, and fitted with an elevator cage for the use of the men. Besides this the usual provisions of pipes for air and water supply and the removal of sand were made.

The device selected for the removal of the clay was what is known as a clay hoist. It was originally designed by the Chief Engineer for use on the Rulo Bridge and had been used at Sioux City and Riparia. This arrangement is shown in detail on Plate 25. The clay hoist consists of an air lock at the top of the shaft, back of which is placed a cylinder in which runs a piston; the speed of this piston is multiplied by two sets of sheaves so that the short stroke of the piston will lift a bucket from the bottom of the caisson to the air lock on top; the air lock is provided with two doors, one of which opening into the shaft below, is closed by a lever with a balance weight on the outside, and the other opening into the open air is worked by the attendant outside; the air is equalized through a large valve worked from the outside; the only power used is the air pressure of the caissons; the full working of the apparatus will appear from the plan. The bucket carried 6½ cubic feet, and when the work has been pushed 12 buckets have been passed out by a single hoist in an hour. Four hoists were provided, but no more than two were ever used at a time.

Plate 25 also shows the form of sand-pump used to remove sand by a water column; this sand-pump has the same principle of action as the Eads' Pump used on the St. Louis Bridge, but is very much simpler in construction.

The details of the special air lock and passenger hoist are given on Plate 26. It is simply a hoisting-engine placed on top of the working shaft, and so arranged that it could be taken off with a derrick and quickly replaced when it was necessary to add a section to the shaft. The engine was made with very large cylinders, so that it could be worked at low pressure and instead of being driven by steam was driven by air from the caisson. The upper shaft through which the elevator-cage runs is a cylinder six feet in diameter, the air lock itself is a cylinder six feet in diameter, and the shaft leading to the caisson a cylinder four feet in diameter; the three cylinders are tangent to each other, and the shells are connected by cast iron door frames carrying doors, while a fourth door opening outwards was placed at the bottom of the lower shaft; in working, the door between the two shafts was always kept closed, and the door at the bottom of the bottom shaft was always left open; it was possible, however, if an emergency had arisen, to use the lower section of the shaft as an air lock by itself; when the filling of the working chamber was completed the bottom door was permanently closed. The only power used to raise either men or material was the air of the caisson. While this arrangement may not be as economical of power as the direct use of steam, it has the great advantage of convenience, and the further advantage of improving the ventilation of the caisson.

The plans for this work were determined on in January, 1889. Bills of material were prepared and arrangements made for the immediate beginning of work with the hope that the two river foundations could be completed during the low-water season of the following fall, a hope which was destined to disappointment.

The first timber for the caissons was received on the 1st of April and framing was begun on the 18th of that month. The timber was received in a material yard on the east side of the river about 2000 feet below the bridge line. A Daniels planer was set up here and used to size the timber, the 12 inch timber being thus reduced to 11¾ inches; this reduction explains the slight irregularity in vertical dimensions. All other work except this sizing was done by hand with ordinary carpenters' tools.

The caisson was put together on launching-ways, the ways being built directly in front of the framing yard and at the edge of the water. These ways, which were very substantial, are shown on Plate 24. The foundation was of cypress piles which were generally driven about 25 feet into the ground. The piles were cut off and capped with 12″ × 12″ timbers running parallel with the river, and on these were placed the ways proper, which were drift-bolted to the caps, and given an inclination of one in four for a width of 48 feet, and one in 3.43 for the remaining distance. The launching-shoes, which were simply transverse timbers, were placed on these ways, the cutting edge was set up on these shoes, and the caisson built up to a height of 17.8 feet from the lower edge of the iron in this position.

The first pile for the ways was driven on the 24th of April, and the ways were sufficiently completed to place the first iron cutting edge upon them and begin building the first caisson on the 18th of May. The building of the caisson and the construction of the lower portion of the ways, including the submerged portion, went on simultaneously. The ways were entirely completed on the 27th of July, and two days later the caisson for Pier II was successfully launched. The caisson was fitted with a false bottom, which bottom, however, was simply intended to prevent the lower edge of the caisson settling too rapidly in the water and was not made tight; when the caisson was launched it drew about 12 feet. The caisson was then kept near the bank until the river should be in proper condition to put it in position.

Before the caisson could be placed in position the mats which were to protect the pier sites from scour had to be placed. Two barges, the general plan of which is given on Plate 22, were fitted with ways for weaving the mats, and two mooring barges were anchored above the pier site transversely with the stream. The weaving barges were then placed below the mooring barges and the material barges were brought up to the lower side of the weaving barges; the mat was then woven on the ways and the upper end of it fastened to the mooring barges and also to the anchors which held the mooring barges, each anchor carrying two lines, one leading to one of the mooring barges and the other under the mooring-barge to the mat. As the weaving proceeded the weaving barges were dropped down stream so that when the mat was entirely completed the weaving barges were at the lower end and the whole mat was floating on the water. The mat woven in this way was 240 feet wide and 400 feet long. It was then loaded with stone until it barely floated, and enough stone was thrown on the upper end to sink this end. The upper end of the mat was then submerged first and held near the surface by the line leading from the mooring barges. Two barges loaded with stone were then floated over the upper end of the mat and stone was thrown from them on the floating mat below; as the mat was sunk the barges were dropped down stream until the entire mat was settled on the bottom. When the sinking barges had passed over about half the length of the mat, the lines connecting the upper end of the mat with the mooring barges were cast off and the mat allowed to sink to the bottom. The whole time required to sink the mat was not over ten minutes. In the case of the first mat sunk, soon after the upper end had been released from the mooring barges, the anchors dragged, and the mat took a position about 120 feet farther down stream than was intended. Two mats were placed at the site of Pier II, the first mat being sunk on the 27th of August and the second on the 10th of September. The exact position of these two mats is shown on Plate 15. Each mat contained 1000 cords of brush and poles, 900 tons of riprap, and 10 000 pounds of wire.

The weaving and sinking of the first mat are shown on the illustration on the opposite page.

To facilitate handling the caisson in position two special barges were built which were anchored above the pier site; the lines by which the caissons were held in position were fastened to these barges, and a double-drum winding engine placed on one of them gave power to adjust the lines. The anchors used were of the pattern known as box anchors consisting of timber cribs, each a ten-feet cube inside the timbers, filled with stone. They were built on barges, thrown overboard at the place where they were wanted and left there, the anchors never being recovered. Each barge was held by six steel wire ropes 1½ inches in diameter, each leading to a separate anchor, so that 12 anchors and 12 wire cables were used for one caisson.

On the 23d of September, these anchorage arrangements having been completed, the caisson for Pier II was brought up into position and held at first by two wire ropes leading to the anchor barges. It was also anchored laterally by fastening two anchors on each side about 500 feet distant and leading a 4½-inch Manilla rope from each of these anchors to the caisson and thence through a snatch-block to one of the anchor-barges above.

Fortunately the current in the river was very light at this time and no special difficulties were experienced in placing the caisson. After it was once securely anchored the concrete filling of the spaces above the working chamber was begun and the building of the upper works was carried on at the same time. As this proceeded the draught of the caisson increased, and the number of anchor lines leading from the caisson to the barges was increased until the strength of the lines leading to the barges was about the same as that of the lines from the barges to the anchors. On the 7th of October, the caisson grounded on the bottom at elevation 151.6 in 36 feet of water.

The whole method of anchoring and handling the caisson in the river was devised and carried out by Mr. Noble, the Resident Engineer.

Air pressure was applied on the 10th, and 14 days, from the 11th to the 24th, were spent in cutting away and removing the two thicknesses of mat. Meanwhile the concrete filling of the caisson was finished on the 11th of October; and the entire caisson, including all upper works, was completed on the 24th of that month. The sinking proceeded regularly from this time, the sand being excavated by columns of water driven through sand pumps. On the 23d of October the laying of masonry was begun; about the middle of November the caisson reached the clay, and the removal of material by the clay hoists was started on the 17th. On the 30th of November all work on this pier was suspended for nine months, the water having risen to such a height that it was considered inexpedient to do anything more at that time. The shoulders under the cutting edge were blocked and the foundation abandoned till low-water season of the following year.

On the 2d of September, 1890, work was resumed. No work had been done on this foundation for nine months; for more than three months the entire work had been submerged, though a barge had been kept anchored to the pier and a light maintained on it. Early in the morning on the 10th of February the steamer PORT EADS, going down the river with a tow of barges, struck the submerged pier and sunk; the accident, which was evidently due to a mistake of position by the pilot, unfortunately resulted in the loss of five lives. The steamer LINCOLN

THE MEMPHIS BRIDGE

SINKING MATTRESS AT PIER II.

was brought to this pier while the BERTRAM remained at Pier III. The cutting edge reached its final elevation at 88.09 on the 16th of October. An experimental well was sunk to elevation 86.0 and a boring carried from the bottom of this well to elevation 76.3. The sealing of the working chamber was completed on the 24th.

The rate of progress of sinking this foundation will be readily seen from Plate 28. An examination of this plate will show that for 28 days in September and October the work was carried on in over 100 feet of water. Full detailed records of the cost and progress of this work are given in Appendices I and J.

The total cost of the entire pier was as follows:

	Material.	Labor.	Total.	Total.
Launching-ways	$1 799.81	$1 824.51	$3 624.32	
Caisson	44 165.87	24 233.12	68 398.99	
Concrete above chamber	10 177.26	3 847.05	14 024.31	
Concrete in chamber	3 799.21	1 310.46	5 109.67	
Cost, not including sinking, protection, etc.	$59 942.15	$31 215.14	$91 157.29	$91 157.29
Mattresses	$17 003.62	$9 520.87	$26 524 49	
Anchoring caisson	5 949.89	2 087.55	8 037.44	
Sinking caisson	14 631.71	51 031.46	65 663.17	
Lighting pier	260.70	2 398.71	2 659.41	
Riprap	5 514.05	839.93	6 353.98	
Insurance	552.51		552.51	
Sinking, protection to foundation, etc.	$43 912.48	$65 878.52	$109 791.00	$109 791.00
Total Foundation				$200 948 29
Masonry (4 197 cu. yds.)				108 669.14
TOTAL COST OF PIER				$309 617.43

The total volume of the foundation is 47 by 92 by 59.4 feet, equal to 256 846 cubic feet; so that the cost of the foundation, not including sinking, protection to foundation, etc., is $0.360 per cubic foot; and the cost, including everything, $0.783 per cubic foot.

The whole pier, including masonry, was finished on the 25th of April, 1891. This foundation had been sunk six feet less than had been expected, and the differences required to correct dimensions of masonry were obtained by a slight offset. This is shown on the plan of the masonry on Plate 13.

The foundation of this pier is sunk 13 feet into the clay, which is entirely solid and free from sand.

Special tests were made to determine the bearing strength of this clay. The method adopted was to cut out a large block of the clay and bring it out of the caisson; then, without giving time for the clay to dry out or slack, it was trimmed so as to make a two inch cube on top attached to a large mass of clay below; pressure was then applied to the top of the two inch cube.

Four samples were tested which were taken from the chamber of Pier II about one foot above the final position of the cutting edge. These gave the following results:

First sample. Broke under 423 lbs. pressure. As weight was applied it compressed gradually. When it was compressed $\frac{1}{32}$ inch it gave way suddenly at bottom, two thirds of top being uninjured. Bottom mashed as though much softer than top.

Second sample. Broke under 343 lbs. This sample compressed $\frac{1}{32}$ inch as above and then broke suddenly into several pieces.

Third sample. Broke under 303 lbs. Did not compress but broke suddenly along dry cracks.

Fourth sample. Broke under 343 lbs. No compression. Top slipped off very suddenly along joint in clay. Broke in two nearly equal pieces.

In behavior the clay resembled rock rather than an ordinary clay and was evidently safe for very much greater pressures than the foundations put upon it. It is also a material well adapted to resist scour.

It is important to compare the strength of the clay as thus tested with the actual weights put upon it. Each foundation being 47 feet by 92 feet, has an area of 4324 square feet. The four tests made of clay from Pier II show an average strength of 93 pounds per square inch, or 13 400 pounds per square foot, when entirely unsustained at the sides.

The greatest actual weight which the foundation of Pier II will ever be called upon to bear is as follows:

130 041 cu. ft. timber at 50 lbs.	6 502 050 lbs.	
Iron work	450 180 "	
3 379 cu. yds. concrete at 3 780 lbs.	12 772 620 "	
4 197 cu. yds. masonry at 4 200 lbs.	17 627 400 "	
Total weight of pier	37 352 250 "	
Superstructure	4 908 000 "	
Live load 791 ft. at 4000 lbs.	3 164 000 "	
Total weight on foundation	45 424 250 lbs.	= 10 505 lbs. per sq. ft.
Deduct for buoyancy 257 500 cu. ft. below elevation 182 at 62.5 lbs.	16 093 750 lbs.	
Immersed weight	29 330 500 lbs.	= 6 783 lbs. per sq. ft.
It is expected that at least 40 feet of this foundation will be perpetually buried in the sand, and to obtain the increased pressure on this area of foundation the weight of this sand in water should also be deducted, this weight being 172 960 cu. ft. at 58 lbs.	10 032 000 lbs.	
Fatigue weight on bottom of foundation	19 298 500 lbs	= 4 463 lbs. per sq. ft
From this may be deducted the skin friction on 40 vertical feet of caisson, which is assumed to be at least 400 lbs. per square foot on 11 120 sq. ft.	4 448 000 lbs.	
Actual probable fatigue measure	14 850 500 lbs.	= 3 434 lbs. per sq. ft.

It would, therefore, appear that with no allowance whatever for buoyancy the pressure on the foundation is within the strain borne by the unsupported cubes experimented on without material compression and with no deformation of shape; while the actual fatigue pressure, without allowance for skin friction, is less than one half what these cubes bore. Furthermore, it must be remembered that this foundation is 40 feet below the bottom of the river, and that the mats around the piers are expected to maintain the bottom where it now is.

During the progress of the work the river at the bridge line showed a gradual tendency to deepen. This is illustrated by the seven different lines of river bottom shown on Plate 8. It will be observed that the tendency to deepen has been much greater in the western half of the river than in the eastern, and it will also be noted that elevation 125, or about 40 ft. above the bottom of the foundation, is the probable limit of scour. Of course this scour may be very greatly increased by local disturbances, but it is hardly conceivable that even with great neglect the bottom of the river should ever be less than 20 feet above the bottom of the foundations. Should this deep scour occur, the value of the breadth of the foundations will be evident. The soundings show the effects of the mats around the pier sites.

The working of the mats was so satisfactory that it was thought best to reinforce them with an additional mat of the same dimensions as one of the original ones, and to make this mat the foundation of a heavy riprap protection. This foundation mat was put in in September, 1892, weaving having been begun on the 4th of that month, and the sinking of the mat completed on the 15th of September; 1228 cords of brush and 879 tons of riprap were used in it. The riprap was put in in February, 1893. It was of a comparatively heavy character and was brought from quarries on the Ohio River near Rose Claire. The total amount of riprap placed was 2504 gross tons. This additional work is included in the statement of cost given above.

PIER III.

The plans for Pier III were worked up in connection with those for Pier II. Soundings had shown the bottom of the river to be at elevation 160 at the site of Pier III, and borings had found clean river sand at elevation 108 where clay was reached.

The caisson for Pier III is shown on Plate 17. It is 39.6 feet high, 47 feet wide, and 92 feet long, and in construction was similar in all respects to the caisson for Pier II. The outer pockets were left empty for a height of 11.0 feet, and the upper 10.4 feet of the whole 39.6 feet were built of solid timber.

Pier III contains 1085 M B.M. of timber and 367 000 pounds of iron.

Precisely the same machinery was used here as at Pier II. The cutting edge of the caisson was placed on the 30th of July on the same launching ways from which the caisson for Pier II had been launched, and this caisson was itself launched on the 26th of October.

The situation of Pier III had been considered less exposed than that of Pier II, and one mat only was woven for this pier. The caisson was brought into position without serious trouble on the 28th of October and the concrete filling begun on the 5th of November. It was none too early; the river had already begun to rise, and it continued to rise till the 25th, when it attained a 23 feet stage. These three weeks formed perhaps the most critical time of the entire work. During this rise the current in this part of the river made an angle of about 10 degrees with the axis of the pier and tended to move the caisson towards the west; on the 19th of November the caisson was 20 feet out of place; finally, by the aid of two tugs and of five lines leading to Pier II, the caisson was brought back into position five feet east of where it belonged; four days later all the lines leading east and one of the northeastern lines parted, and the caisson was carried 50 feet west of its true position. Five coils of wire rope were ordered and brought down on a passenger train from St. Louis (350 miles) in one night. Additional anchors were put on until the caisson was held by 18 wire ropes leading up stream and five leading eastward. The arrangement of the anchorage at this time is shown on Plate 23. With these lines the caisson was brought into practically correct position and held there until it was finally landed on the 10th of December, at elevation 157, in 44 feet of water; on the following day the caisson and upper works were completed. It had been necessary to build up the sides of the caisson before putting in the solid timber and to carry it up four to six feet above the intended height by false sides. If the water had been five feet deeper it would have been impossible to land this caisson.

The caison had been saved and no loss experienced. Its safety may be ascribed to two things: first, the mat, which alone prevented the deepening of the bottom; and second, the strength of the anchorages. The credit for the former is due to the Chief Engineer, that of the latter to the Resident Engineer.

Air pressure was applied on the 16th of December, the first work done being to cut through the mat, which occupied six days. Sinking was conducted in the same manner as at Pier II, and the clay was reached at elevation 109.0 on the 7th of February, 1890; one week later work was suspended until the river should be at a more favorable stage. Before stopping work borings had been made below the edge of the caisson and a well sunk into the clay. The character of the clay was less substantial than had been expected, and it was evidently not prudent to stop at elevation 103 as originally intended.

During March and April the river attained a height exceeding anything before observed, the maximum height at the bridge site being 216.2 feet on the 25th of March.

By the middle of June the water had fallen enough for it to be safe to resume work, which was done on the 18th of that month. The progress of sinking through clay was slow, especially as three of the five clay hoists proved to be of inferior workmanship. On the 18th of August the cutting edge reached its final position at elevation 85.39, eighteen feet lower than had originally been intended. An experimental well was sunk to elevation 78.15 and a boring carried from the bottom of this well to elevation 72.15. On the 4th of September this foundation was completed.

Full detailed records of the cost and progress of sinking are given in Appendices I and J. The rate of progress of sinking is shown graphically on Plate 28. For twenty-five days in August and September, 1890, the work was carried on in over 100 feet of water; the actual maximum depth at which men worked was about 108 feet.

The detailed cost of the entire pier was as follows:

	Material.	Labor.	Total.	Total.
Launching ways	$1 890.30	$1 788.07	$3 678.37	
Caisson	32 780.14	18 006.78	50 786.92	
Concrete above chamber	7 170.56	2 449.91	9 620 47	
Concrete in chamber	6 373.14	2 174.86	8 548.00	
Cost, not including sinking, protection, etc.	$48 214.14	$24 419.62	$72 633.76	$72 633.76
Mattresses	$10 433.48	$6 698.43	$17 131.91	
Anchoring caisson	7 608.75	3 778.95	11 387.70	
Lighting pier	55 81	178.69	234 50	
Sinking caisson	16 842 81	59 773 08	76 615 89	
Riprap	5 446.72	826.86	6 273.58	
Insurance	394.81		394.81	
Sinking, protection to foundation, etc.	$40 782.38	$71 256.01	$112 038.39	112 038 39
Total Foundation				$184 672 15
Masonry (4870 cubic yards)				124 679 77
TOTAL COST OF PIER				$309 351.92

The total volume of the foundation is 47 feet by 92 feet by 39.6 feet, equal to 171 230 cubic feet; so that the cost of the foundation, not including sinking and placing, was $0.424 per cubic foot and the cost including everything $1.078 per cubic foot.

The entire pier, including the masonry, was completed on the 23d of January, 1891. The pier had been sunk 18 feet deeper than originally intended, this increase of height being made entirely in the masonry and the pier kept to its proper dimensions by a reduction of batter, which is shown on Plate 14.

Three samples of the same character as those taken from Pier II were taken from the clay on which Pier III rests and tested with the following results:

First sample	Broke under	503 pounds		
Second "	"	"	503	"
Third "	"	"	603	"

The first and second samples had small cracks in them and the third sample appeared sound.

The weights and pressures for Pier III are as follows:

90 458 cu. ft. timber @ 50 lbs	4 522 000		
Ironwork	366 970		
2379 cu. yds. concrete @ 3780 lbs	8 992 620		
4870 cu. yds. masonry @ 4200 lbs	20 454 000		
Total weight of pier		34 336 490	
Superstructure		4 908 000	
Live load		3 164 000	
Total weight on foundation		42 408 490	9 808 lbs. per sq. ft.
Deduct for buoyancy 212 700 cu. ft. below elevation 182 @ 62.5 lbs		13 293 750	
		29 114 740	6 733 " " " "
Deduct for sand displaced as above		10 032 000	
Fatigue weight		19 082 740	4 413 " " " "
Deduct skin friction as above		4 448 000	
Actual probable fatigue pressure		14 634 740	3 385 " " " "

The fatigue pressure, therefore, on this foundation is a little less than on Pier II. As already stated, it would have been wiser to make both caissons alike and both 50 feet high instead of 40 and 60 feet.

The foundation of Pier III is sunk 21 feet below the surface of the clay; but as the last nine feet of clay were of a sandy character, this foundation is, if anything, inferior to that of Pier II. The clay which it rests on, however, is entirely solid and free from sand.

In August, 1892 an additional mat was placed around this pier in the same manner as was done at Pier II: 1550 cords of brush and 879 tons of riprap were used in it. In March, 1893, 2504 tons of heavy riprap, brought from the Ohio River, was placed upon this mat.

PIER IV.

The foundation for Pier IV was the first one put in. It was made in a measure an experimental foundation, and the greater part of the work upon it was done before the construction of the entire bridge was authorized.

The caisson, including the upper works of concrete and timber, is 26 feet wide, 60 feet long, and 50.43 feet high. The details of this caisson are given on Plate 20. The caisson was built on launching ways on the west bank of the river, about 100 feet below the bridge line.

The framing of the timber for this caisson, which was really the beginning of the construction of the Memphis Bridge, began November 7th, 1888. The cutting edge was set up on the launching ways November 23d, and the caisson launched on the 15th of December and placed at the site of the pier two days later; it was launched with a false bottom which was then removed. The concrete filling was begun on the 22d of December and air pressure applied and sinking actually begun on the 27th. The timber and concrete work were completed January 5th, 1889.

As this foundation was put in before any arrangements had been made for building the masonry of the bridge, it was surmounted by a tight curb made of 12″ by 12″ timbers planked on the outside with one course of three inch plank. This curb was made 20 feet high, and when the foundation was completed the top of it was about 12 feet above low water. During the progress of the work the river rose 23 feet above low water, and a rough timber crib was built above the curb to protect the shafts and pipes from floating drift.

When air pressure was first put on the cutting edge of the caisson was at elevation 172.09. The material excavated was clean sand which was handled easily by the sand pumps, and progress was rapid until January 27th, when clay was reached at elevation 126.56. A clay hoist was then brought into use, and the sinking continued until February 5th, when the caisson was brought to its final position at elevation 122.94.

The clay was tested in the same manner as was afterwards done at Piers II and III, the average crushing strength of two-inch cubes being 440 pounds, or 110 pounds per square inch. To determine better the nature of the material, especially with reference to the river piers, a well was sunk thirteen feet below the bottom of the caisson, or to elevation 109. This well passed through six feet of hard sandy clay similar to that on which the caisson rests, and penetrated seven feet of hard tough clay nearly free from sand, which when tested showed a crushing strength in two-inch cubes of 408 pounds.

The sealing of the working chamber with concrete was begun on the 6th of February and finished four days later.

The clay on which this foundation rests, a strong hard clay, not entirely free from sand, is not as well fitted to resist scour as that found at the bottom of the well. This pier, however, is a shore pier and stands behind the line of shore protection hereafter described. It is, therefore, entirely secure.

Nothing further was done for six months; but in August 1889, construction of the bridge being fairly in progress, the curb was pumped out, the mud which had collected in it during high water was removed, and laying of masonry was begun. The first stone was laid on the 27th of August 1889, but the work was not prosecuted continuously and the pier was not finished until September 3d, 1890.

The rate of progress of sinking the foundation is shown graphically on Plate 28. Detailed tables showing the cost and progress of sinking of the foundation are given in Appendices I and J.

The total cost of the entire pier is given in the following table:

	Material.	Labor.	Total.	Total.
Launching ways	$927.42	$716.87	$1 644.29	
Caisson	14 856 94	6 210.02	21 066.96	
Concrete above chamber	6 744.71	2 070.94	8 815.65	
Concrete in chamber	845.21	445.85	1 291.06	
Cost, not including sinking, protection, etc.	$23 374.28	$9 443.68	$32 817.96	$32 817.96
Sinking	$3 053.72	$8 489.63	$11 543 35	
Pumping and removing coffer-dam	120.78	1 062.99	1 183.77	
Riprap	1 366.98	415.75	1 782.73	
Insurance	210.99		210 99	
Sinking, protection to foundation, etc.	$4 752.47	$9 968.37	$14 720.84	14 720 84
Total Foundation				$47 538.80
Masonry (2761 cu. yds.)				71 828.21
TOTAL COST OF PIER				$119 367.01

The total volume of the foundation is 26 feet by 60 feet by 50.43 feet, equal to 78 671 cubic feet; so that the cost of the foundation, not including sinking, etc., was $0.417 per cubic foot and the cost including everything $0.604 per cubic foot.

PIER V.

Pier V is located in the bottom land west of the shore line. The construction of this pier was not originally contemplated, it having been intended to extend the iron viaduct to Pier IV, but as the west shore was cut away during the high water of 1887 and 1888, it was thought best to replace the eastern portion of the viaduct by a deck span, which called for Pier V.

This pier differs from the other piers in not being a masonry structure. The lower portion is of timber and concrete, and the upper portion consists of two cylinders of soft steel $\frac{3}{8}$ inch thick, which extend well into the concrete mass below and are covered by copings of Bedford stone. This pier is illustrated on Plate 21.

The caisson is 22 feet wide by 40 feet long and the total timberwork is 80 feet high. The first timber was framed February 21st, 1890; the cutting edge was set up on blocking at the site of the pier April 25th, 1890; and the lower section of the caisson was completed so that the blocking was removed on the 7th of May and air pressure was applied the following day.

The timber work with its concrete filling was completed May 30th and the clay was reached at elevation 126 on the 7th of June. The caisson reached its final position with the cutting edge at elevation 124.93, about one foot below the top of the clay, on June 8th, 1890. The working chamber was at once sealed with concrete, the sealing being completed on the 12th of June.

The clay on which the caisson rests was tested in the same manner as that under the other piers, four two inch cubes showing an average strength of 180 pounds, or 45 pounds per square inch. The clay was of a somewhat sandy character but entirely satisfactory for a foundation at this location.

A well was sunk eight feet below the cutting edge and a hole was bored with an auger $8\frac{1}{2}$ feet further. At elevation 109 a hard tough clay, like that found under the bed of the river, was reached, but it was not considered expedient to go to the additional expense of sinking this foundation to that elevation.

The steel cylinders were put in position soon after the completion of the foundation, but the concrete filling and the coping were not hurried, and the pier was not finally finished till May 15th, 1891.

The detailed tables showing the cost and progress of sinking of this foundation are given in Appendices I and J.

The actual cost of the pier is as follows:

	Material.	Labor.	Total.	Total.
Caisson	$8 594.47	$5 523.07	$14 117.54	
Concrete above chamber	6 414.61	2 479 16	8 893.77	
Concrete in chamber	811.17	596.80	1 407.97	
Cost, excluding sinking, etc.	$15 820.25	$8 599.03	$24 419.28	$24 419.28
Sinking	$2 310.87	$6 239 52	$8 550.39	
Insurance	95.25		95.25	
Sinking, etc.	$2 406.12	$6 239.52	$8 645.64	8 645.64
Total Foundation				$33 064.92
Cylinders				7 323.77
TOTAL COST OF PIER				$40 388.69

The total volume of the foundation is 22 feet by 40 feet by 80 feet, equal to 70 400 cubic feet; so that the cost of the foundation, not including sinking, etc., was $0.347 per cubic foot, and the cost, including everything, $0.470 per cubic foot.

GENERAL.

The total cost of the Substructure of the Memphis Bridge was as follows:

East Abutment	$11 872.87
Pier A	485.32
Pier B	600.58
Anchorage Pier	36 267.79
Pier I	141 035.94
" II	309 617.43
" III	309 351.92
" IV	119 367.01
" V	40 388.69
Total	$968 987.55

The four large piers (I to IV) are really the only portion of the Substructure which are of special interest, and it is desirable to compare the quantities and cost of these piers. The total quantities in the several piers are as follows:

Piers.	Timber, Ft B.M.	Iron, Pounds.	Concrete, Cubic Yards.	Limestone Masonry, Cu. Yds.	Granite Masonry, Cu. Yds.
I	336 768	187 206	3 079	1 292	1 403
II	1 560 492	450 187	3 379	2 459	1 738
III	1 085 496	366 967	2 379	2 868	2 002
IV	266 472	145 147	2 065	1 157	1 604
Total	3 249 228	1 149 507	10 902	7 776	6 747

The total volume and cost of the several piers are given in the following table:

Material.	Pier I.	Pier II.	Pier III.	Pier IV.	Total.
Timber, cubic feet	28 064	130 041	90 458	22 206	270 769
Concrete, " "	83 139	91 237	64 223	55 751	294 350
Masonry, " "	72 767	113 312	131 492	74 561	392 132
Voids, " "	444	48 145	30 518	714	79 821
Total	184 414	382 735	316 691	153 232	1 037 072
Cost	$141 035.94	$309 617.43	$309 351.92	$119 367.01	$879 372.30
Cost per cubic foot	$0.765	$0.809	$0.977	$0.779	$0.848

This table does not take into account concrete below cutting edge or clay left in chamber above cutting edge of the several caissons.

This includes the entire cost of everything except the equipment. The original cost of the equipment was kept in a separate account called "Tools and Machinery," but the repairs were charged to the several foundations on which the equipment was being used at the time those repairs were made. The Tools and Machinery account was subsequently credited with the amounts received from the sale of the plant. The balance remaining charged to equipment was $30 865.54, of which $23 341.80 belongs to the Substructure of these piers, amounting to $0.0225 per cubic foot for all the piers. If this is included, the total cost per cubic foot of all the piers would be as follows:

	Pier I.	Pier II.	Pier III	Pier IV.	Total.
Total cubic feet	184 414	382 735	316 691	153 232	1 037 072
Cost	$145 186.62	$318 231.80	$316 479.81	$122 815 87	$902 714 10
Cost per cubic foot	$0.787	$0.832	$0.999	$0.801	$0.871

IV

SUPERSTRUCTURE.

The Superstructure may be divided into two parts: the Continuous Superstructure, which reaches from the East Abutment across the river to Pier IV, and the deck span, between Pier IV and Pier V. The Continuous Superstructure covers the whole length of the bridge which affects navigation and so came under the requirements of the general charter and the findings of the Secretary of War. The deck span is entirely west of what was the shore line at the time of my visit to Memphis, in January, 1886, and of the restored shore line as it will exist when the west rectification works have had their full effect.

CONTINUOUS SUPERSTRUCTURE.*

The plans which were submitted to and approved by the Secretary of War provided for a channel span 770 ft. long in the clear and two spans 600 ft. each in the clear, these three spans crossing the entire navigable river, the long span being next to the Tennessee shore. Adding to each span the estimated thickness of the piers at low water, the design called for one span of 790 ft. and two of 620 ft. each, measured between centres of piers.

The arrangement which would have been most satisfactory to the engineer would have been three equal spans of about 675 ft. each. If, however, one span of extra length was required, it would have been preferable to place it at the centre, making this central span a cantilever structure, the cantilevers projecting from the ends of two heavy side spans. The arrangement required by the War Department, however, placed the long span next to the east shore, so that if this span was built as a cantilever span it was necessary to provide an independent anchorage on the Memphis bluff. This course was adopted.

The length fixed for the channel span was 790 ft., or 170 ft. more than either of the other spans. By projecting a cantilever 170 ft* long from Pier I (on the Tennessee shore), the distance between the end of this cantilever and Pier IV (on the Arkansas shore) was divided by the two other piers into three equal spaces of 620 ft. each. By making the central span a fixed span with continuous chords and projecting a cantilever 170 ft. long from each end of this fixed span, there remained two spaces, each 450 ft. long, to complete the bridge, one of these being between two cantilevers and the other between a cantilever and Pier IV. With this arrangement the bridge would consist of a central span 620 ft. long, of three 170 ft. cantilevers precisely alike, of two 450 ft. spans also alike, besides the anchorage span east of Pier I.

In order to simplify construction it was desirable to make the panels of uniform length throughout, and this required that the panel lengths should be common divisors of the lengths of the cantilevers, of the suspended spans and of the central span. No such common divisors existed for 170 ft. and 450 ft.; but by shortening the length of the cantilevers to 169 ft. 4½ in. and increasing the length of the suspended span to 451 ft. 8

* This account of the Continuous Superstructure is reprinted, with some very slight changes, from the Transactions of the American Society of Civil Engineers, September, 1893.

in., 56 ft. 5¼ in. became a common divisor. The lengths were, therefore, slightly changed, and a panel 56 ft. 5¼ in. long was made the unit for the entire bridge, this panel being divided into two panels in the floor system. Each cantilever arm was divided into three panels, each suspended span into eight panels, and the central span into 11 panels.

As the bluff rose rapidly back of Pier I a long anchorage span was not required, and it was thought best to limit it to such length that there would be no reversal of strains; it was made four panels, or 225 ft. 10 in., long.

The anchorage span consists of four panels; the channel span of 14 panels, three in each cantilever and eight in the suspended span; the central span of 11 panels; and the west span of 11 panels, of which three are in the cantilever and eight in the suspended span. The total number of panels is, therefore, 40; and the total length of the continuous superstructure is as follows:

Anchorage arm	225 ft. 10 in.
Channel span	790 " 5 "
Central span	621 " 0½ "
West span	621 " 0½ "
Total	2 258 ft. 4 in.

The arrangement of these spans is given on Plate 4.

As each truss panel is divided into two floor panels, there are 80 panels in the floor system. Moreover, the floor system is extended eastward on a viaduct of three floor panels beyond the anchorage pier, and a deck span of 12 floor panels reaches from the shore side of Pier IV to Pier V which is located back of the shore line. The entire floor system of the bridge, therefore, consists of 95 panels and is 2681 ft. 9¼ in. long.

The lengths of the spans being fixed, the next thing to determine was the width. The principal limit in determining this was the length of the central span. In the matter of transverse stiffness the position of this span corresponds with the separate spans of a common bridge, whereas the longer span by its cantilever construction was held rigidly at the ends. The central span being 620 ft. long, it did not seem wise to make the width between trusses less than 30 ft. This corresponded with widths which have been adopted with good results in shorter spans. The channel spans of the Cairo bridge are 518.5 ft. long and the trusses placed 25 ft. between centres, the ratio between length and width being almost exactly the same as between 621 ft. and 30 ft. A width of 30 ft. was adopted.

The next feature to determine was the depth of the trusses, and in determining this other considerations than economy of metal work governed.

The difficulties of erection made it important to keep the dimensions within limits to which ordinary falsework could be adapted. The magnitude of the structure and its cantilever design made it important to use such proportions that vibrations would be reduced to a minimum. It was not thought best to make the depth at any part of the superstructure much more than two and one half times the breadth of base. The breadth of base could not be increased without increasing the length of the piers, which would have added to the already excessive cost of the foundations. By fixing the depth of both the central and the suspended spans at one eighth of the span and making all three of the cantilevers alike, the depth of the structure over each of the piers and for the whole length of the central span became 77 ft. 7$\frac{1}{16}$ in., and the depth of the suspended spans, 56 ft. 5¼ in. These dimensions were adopted.

It was at one time proposed to make the central span in eight panels of greater length than those used elsewhere, but as the plans matured this seemed unwise, and a uniform panel length was adopted throughout.

The form of trusses adopted was the double triangular or double Warren girder. It was intended to erect the channel span without falsework, building out from either end, and this form of truss was thought to have advantages in the manner in which it sustained the upper chord from which the work would be done.

The floor system is suspended from the intersection points of the two systems of web members, and the upper chord is supported from the same points by struts.

As the depth of the cantilevers over the piers corresponds to the depth of the central span, while their outer ends correspond to the depths of the suspended spans, the chords are not parallel. The same may be said of the anchorage arm. In order to keep the floor panels uniform, it was necessary to keep the points of intersection of the web members over the panel centres. This made the panel lengths of the upper chord irregular, but as these chords were formed of eye bars the irregularity was not material.

The cantilever construction made it possible to bring the weight of the spans on each side of each pier together in a single point and transfer this weight directly to the centre of the pier, instead of taking it nearer the edge of the pier, as is always done with separate spans. This allowed the use of somewhat lighter piers than would otherwise have been needed, and the increased cost of the superstructure design over three equal separate spans was in a measure balanced by the decreased cost of the substructure.

The only span which is continuous from pier to pier is the central span, and provision had to be made at one end of this span for expansion and contraction. All other expansion was taken up by sliding joints at the ends of the cantilevers. As there are two sliding joints in the channel span and only one in the west span, there was a double chance to take up expansion in the chords and floor system of the channel span. For this reason the west end of the central span was fixed and the east end placed on expansion rollers.

Principal Details.—The general dimensions and form of truss having been adopted, it next became necessary to fix the character of the principal details. The American form of construction with pin connections was adopted from the first. The chords of the central span, being subject to reversals of strains from the action of the cantilevers, were necessarily both made stiff, and the same stiff bottom chords were necessarily extended out as the bottom chords of the cantilevers. The top chords of the cantilevers being always in tension were made of eye bars. As the east suspended span (in the channel span) was to be erected without falsework, the two halves being built out as continuations of the cantilevers, it was necessary that the bottom chord of this truss should also be made stiff for the greater part of its length, while the top chord, being in compression in the finished structure, was of course stiff. It was determined to sacrifice some material and to make the bottom chord of the suspended span stiff throughout, and to make both suspended spans (or intermediate spans, as they were called on the drawings) with stiff chords throughout. The chords of the anchorage arm correspond to those of the cantilevers. The bottom chord is therefore stiff throughout the entire length of the superstructure, and the only portions of the top chord which are made of eye bars are in the anchorage and cantilever arms and in the end half panels of the central span, this special arrangement being adopted from the difficulties of packing a stiff chord into an eye bar chord at the extreme ends of the span.

The stiff chord provision undoubtedly adds to the lateral stiffness of the bridge and, to a certain extent, to its vertical stiffness. The sliding joints at the ends of the cantilevers are carefully fitted, and in spite of its cantilever construction the bridge is very free from vibration.

The lateral bracing is formed of diagonal rods attached to pin plates riveted to the chords and so placed that the axial lines intersect at the centre of each chord. The lateral bracing is adjustable, and is the only adjustable portion of the bridge. It would have been preferable to make it stiff, but the plan was adopted in conformity to the practice hitherto followed by the Chief Engineer of the bridge, he not being satisfied with the detail connections of any stiff system which he had worked out at the time these plans were prepared.

The transverse bracing is rigid throughout and is made in the form of lattice frames, so as to stiffen, not merely the centre of each post, but intermediate points above. The principle which led the engineer to adopt this form of bracing was his belief that the two trusses of a bridge should be made as nearly as possible a single truss. So far as the chords are concerned this cannot be done; but if the compression members of the web are united by stiff frames they become in a large degree a single compression member of the full width of the truss, this single compression member transferring its strain to two chords at the top and two chords at the bottom. This principle of transverse bracing was followed throughout the whole superstructure. In the end posts of the intermediate and central spans and the posts of the cantilevers which carry the weight of the intermediate spans the stiffening was carried further by extending portal plates down the sides of each separate post, thereby increasing the width of the posts and uniting the two sides with a stiff portal. In the case of the large vertical post over the piers, these portal frames were united with the floor beams below, so that the two posts form from top to bottom practically a single member.

The floor system consists of two stringers placed eight feet between centres, these stringers being riveted to the webs of the floor beams at each panel and half panel point. At the full panel points the floor beams are supported on short posts to which they are riveted, which posts rest directly on the pins. At the half panel points the floor beams are suspended from the web intersections above.

Although the width between trusses is sufficient for a double track bridge, the bridge, being designed but for a single track, has but two lines of stringers. (The management did not feel justified, at the time the bridge was built, in bearing the additional expense which a double track structure would have entailed.) It should, however, be mentioned that the Memphis Bridge, though designed for a single track only, is at least two and one half times as strong as some important single track bridges built less than fifteen years ago.

The charter from the General Government required that the bridge should be adapted to the passage of vehicles and animals. This provision is met by making a tight floor 20 feet wide; on each side of the floor are steel fences supported at the panel points, these fences being in fact lattice girders which carry the ends of the ties and so make practically four lines of stringers. The ties are planked longitudinally with 3-inch pine plank sized to 2¾ inches, and diagonally with 2-inch oak plank sized to 1¾ inches, this making 4½ inches of solid planking. Between the rails the oak plank is laid longitudinally. It is doubtful whether this expensive highway floor will be much used.

In many respects the design of the superstructure may be criticised as not strictly economical. This is admitted; but such criticisms are ill considered unless they include, not merely the metal in the superstructure, but all the material in the piers and masonry. The substructure of the bridge, which under the present design cost more than the superstructure, would have been rendered much more expensive by those changes which mere economy of superstructure design called for.

In the design attention was everywhere given to stiffness as well as to strain. This is a matter to which too little attention has been given and which has often been overlooked in competitive design. It is perfectly possible to design a structure in which no metal under any ordinary supposition will be overstrained, and yet without such overstrain vibrations can exist which would be utterly inadmissible. This may occur in trusses of extreme depth and also in structures with cantilever details in which loose fitting is permitted at expansion joints.

It was with a view to avoid vibrations as much as possible that stiff chords were adopted throughout, and that the principle was followed of uniting the compression members of opposite trusses as far as possible into single members. For the same reason, the sliding joints at the ends of the cantilevers were so carefully fitted that lost motion in these places practically does not exist.

While these ideas undoubtedly made the structure more expensive than a competitive design might have been, the engineer believes that the results fully justify his work; but in studying details these facts should be remembered.

Special Details.—With these conditions stated, attention is called to a few of the special details of the superstructure.

1. The stiff chords of the central span, including one full panel of the bottom chords of each adjoining cantilever, were made with four webs. This form of construction was adopted for two reasons. First, to reduce the thickness of the metal and so to reduce the lengths of the rivets in the splices. With the present arrangement the maximum length of rivets is 3⅝ inches between heads, and the larger part of the rivets are in double shear, the splices being balanced on the two sides of each web, this being the condition under which the rivets are least likely to get loose and least likely to cause trouble if they become loose. The second object was to reduce the bending strains on the pins; the connections with the web members are all made in the narrow spaces between the outside and the interior webs, so that the pins, by which the whole horizontal strains are transferred to the chords, are supported at four points, and the unsupported length is reduced to a minimum. The objection to high theoretical bending strains in pins is not so much the danger to the structure from the failure of the pins as the fact that by the distortion of the pins the strains may be distributed unequally among the several pieces attaching to them. With the arrangement adopted here, this danger is reduced to a minimum.

The four web chords are confined to 10 full (20 half) panels of the top chord of the central span, to 11 full panels of the bottom chord of the same span, two full panels of each cantilever arm and two full panels of the anchorage arm. Two web chords were used in the remaining bottom panels of the cantilever and anchorage arms and throughout the whole length of the suspended spans. In the bottom chords of the suspended spans the rivets became objectionably long.

The sections of the stiff chords were generally made in full panel lengths, 56 ft. 5½ in. long, the riveted joints being placed midway between the panel points and over the intermediate points; the only exceptions to this rule were in the upper chords of the intermediate spans and the lower chords of the cantilever arms and anchorage span. The details of the riveted joints are given on Plate 41.

2. The shortness of the anchorage arm insures the connection being always in tension and never in compression. The details of the anchorage are given on Plate 37. (Under each truss there are 16 rods in the masonry, these rods connecting with eight blocks which carry the single pin on which four anchor bars connect.) The anchor bars are simply flat bars of steel with pin holes at top and bottom. (After the adjustment of the structure, folding wedges were placed between the steel plate and the blocks and tightened up so as to prevent any possible horizontal bending strain on the anchor rods.) On the centre of the pier was placed a tetrapod of steel, the four corners of which were anchored to the masonry, and the apex of which fits into a guide at the centre of the end floor beam, the connection being such that no weight can be thrown upon it, but a full horizontal stiffening is obtained.

The general arrangement of the anchorage is such as to place all adjustable or movable parts in the open air above the masonry in plain sight, there being no unexposed portions and no ironwork buried in chambers, the only iron out of sight being the long rods and the I beam platforms, which being buried solid in Portland cement are protected from oxidation, while there is a large excess of material in the rods.

3. The superstructure and moving load throw on each of the two points of support on Piers I, II and III a weight of about 2000 tons, this weight, however, being thrown directly over the axis of the pier. To distribute this weight properly on the masonry requires an area of about 100 square feet and a sufficient height between the masonry and the chords of the superstructure to distribute it with some degree of uniformity. On Piers I and III the bearings are fixed. They are shown on Plate 38. In each instance the weight is transferred first to a 14 inch pin, passing through the centre of the chord. The three posts, one vertical and two inclined, rest on this pin, being made with semicircular pin bearings at the ends, no pin plates passing around the pins, this arrangement being adopted partly for convenience in erection and partly because the weight always carried here is so great that nothing approaching to tension can ever exist. This 14 inch pin rests on a steel casting cast with ribs placed directly under the bearings of the posts on the pin. The inclined posts are two-web posts and the vertical posts four-web posts, but they are so packed that the whole weight is transferred to six ribs in the castings. The steel casting rests on two iron castings which are packed with long bolts and locked together with a grooved steel plate between them. These two castings rest again on four castings which are locked together in the same manner at the centre. The whole was fastened together by turned bolts passing through drilled holes. The actual weight of each pedestal casting between the pin and the masonry is about 45 tons. The centre of the 14 inch pin is 9 ft. 10 in. above the masonry, which brings the top of the stringer of the bridge 13 ft. above the masonry.

4. On Pier II the bearing, which carries the same weight as those on Piers I and III, had to be made an expansion bearing to allow of the expansion of the central span, temperature alone here representing an expansion of about eight inches. It is shown on Plate 39. The piers are slender and the expansion great; it was, therefore, deemed necessary to provide a joint which would move with the least possible friction, and which should not be liable ever to become clogged or stopped by the collection of dirt. The joint must also be so arranged that the structure would be held laterally and the motion limited longitudinally. It was therefore determined to use rollers 15 in. in diameter, and to make these segmental rollers of a pattern resembling the European practice, the rollers being placed 6 in. between centres.

Each expansion bearing as constructed consists, first, of a steel casting precisely similar to those used at the fixed ends. This steel casting rests on a bolster composed of a horizontal top plate, then of eleven 12 in. I beams running transversely, of a second horizontal plate, of sixteen 12 in. I beams running longitudinally, and of a third and thicker horizontal plate, the lower surface of which is polished smooth. It had originally been intended to make this bolster of two steel castings with a planed steel plate between them, and this arrangement would have been preferred; but the delays in getting the castings and the uncertainty of securing the finished product in time made it necessary (after three castings had been made and rejected) to change the plan.

Under the bolsters came the rollers. The rollers are in two lengths, and are separated by two steel guide plates, one of which is built in between the polished bottom plates of the bolster and the other between the iron castings below. These serve as the transverse guides. There are thirty rollers in each joint, fifteen on each side of the central guides. The rolling surfaces of these rollers are polished, and each roller has two holes drilled completely through it, through which pass turned rods, so that the rollers on one side of the centre must always work with those on the other, while the distances between the rollers are kept constant by two side plates drilled to fit the rods, the rods being held in place by nuts outside the side plates. The upper side plates are made with hooked ends, which, striking against the ends of the lower side plates, limit the possible motion of the rollers and prevent any possible overturning.

Under the rollers is the bearing plate (commonly called the rail plate). This is of the pattern which the engineer has used universally for the last ten years. It is formed of T rails riveted on a plate below, the tops of the rails being about ¼ in. apart and the top surfaces planed and polished. This arrangement makes a stiff surface for the rollers to roll upon and provides adequate means for cleaning. The rail plates are in two parts, divided by the centre plate which guides the rollers.

The motion of the top bearing is further limited by a lock plate which is fitted over the lower guide plate, the upper jaws of which would strike the edges of the top bearing plate before a motion could occur which might cause the top plate to slide on the rollers.

Under the rail plates are the castings, which bear directly on the masonry and are like the lower sections of the fixed end castings.

The result of this arrangement is a very sensitive and very powerful expansion bearing. For convenience of observation it was fitted with vernier scales, and the record, which has been kept of the motion so far, indicates that this bearing works practically without friction.

5. A somewhat different form of support was used at the end of the intermediate span over Pier IV. This is shown on Plate 40. Here, also, the weight is distributed on the masonry by iron castings, and the weight is transferred to the iron castings through a pin on a steel casting; but the pin is placed below the level of the chord, the whole weight being transferred by a small upright support, which also holds the floor beam. While this works fairly well, it is not as satisfactory a detail as the other bearings. It was adopted with a view to keeping the construction of this particular panel point as nearly uniform as possible in the four places where it occurs, this supported upright taking the place of the suspended uprights at the other three points.

6. The expansion between the cantilevers and the suspended spans is taken up by sliding joints in the top and bottom chords, the long suspender swinging. No special addition was made to this suspender in consequence of this swinging motion, the extra strain which can possibly be produced in this way being less than that which is usually produced in horizontal eye bars by their own weight. The sliding joint in the bottom chord is placed in the last panel of the cantilever. The sliding joint in the top chord is placed in the first panel of the suspended span. As the end web members of cantilever and suspended spans are parallel compression members, both of these sliding joints come where no strain exists.

The sliding joint in the bottom chord is shown on Plate 43. It slides between polished steel surfaces with a play of only $\frac{1}{32}$ in. This joint is placed near a floor beam and the lateral system of the cantilever arm ends at this floor beam, which forms the lateral strut. The lateral system of the suspended span ends on the other side of the sliding joint, there being an independent strut to hold the two chords in position; this strut was put in after the erection of the superstructure, the pin holes being reamed in position. There is no observable lost motion at this joint. The top lateral strains are transferred at the ends of the suspended spans to the bottom chord by the portal bracing, and there is no lateral system in the top chord of the end panels of the suspended spans. The sliding joint in the top chord is made, therefore, simply an oblong pin hole between two sets of stiffened tension members. The same oblong pin hole was used in the bottom chord joint, but principally for necessities of erection.

7. The large expansion existing at the ends of the suspended spans made some special expansion arrangement necessary in the connection between the stringers and the floor beams. An ingenious arrangement to accomplish this end was designed by Mr. Ralph Modjeski, Assistant Engineer, and is shown on Plate 43. It dispenses entirely with a long sliding surface and supports the end of the stringer perfectly.

8. As the end of the anchorage arm consists only of tension members, it was difficult to make a satisfactory form of portal which would at once resist vibrations and have the substantial appearance which seemed important in the most conspicuous part of the bridge. The result was accomplished by making a stiff frame, entirely independent of the tension members, consisting of posts placed between the inclined eye bars of the end panels, these posts being connected by a stiff strut at the center, and the rectangular panel above divided by stiff diagonals. This stiff frame is attached to the pins of the truss, but the pin holes in the stiff posts are made one inch larger than the diameters of the pins, so that the tensile strains should not be disturbed.

Loads.—The views of the Chief Engineer have long been opposed to proportioning bridge superstructure for precise wheel-base loads, these precise loads being always those of a special locomotive, either actual or assumed, and subject to constant change. The superstructure of the Memphis Bridge is proportioned in accordance with the practice now followed by that engineer, the load per foot on a length of 20 ft. being taken as twice the load per foot on a length of 120 ft. and upwards, and the load per foot being increased by one per cent for each foot in length less than 120 ft. The excess variation in web members, being the difference between the strains produced by a moving load and by a fixed load of equal intensity, is taken on a basis one half greater than the uniform moving load. In the case of the Memphis Bridge the unit load was taken at 4000 pounds per foot of track, and the wheel-base load on 20 ft. was consequently 8000 pounds per foot of track, while the stringer load, the panels being a little more than 28 ft., was taken $[4000 \times (1 + 0.92) = 7680]$ at 7680 pounds per foot of track. These weights were used in calculating the live loads given on the strain sheets shown on Plates 50 to 54, inclusive.

In the central span the dead load was assumed in the strain sheet at 4000 pounds per lineal foot of truss, or 8000 pounds per lineal foot of bridge, being just double the assumed live load. In point of fact, the actual weight of this span is 8300 pounds per lineal foot, exclusive of end posts which stand directly over the piers. This excess of weight amounts to less than four per cent, and is no greater than the difference in weight between the kind of floor used on this bridge to accommodate highway traffic and the usual railroad floor.

In the intermediate or suspended span the dead load was assumed at 5400 pounds per lineal foot. In point of fact it is 5660 pounds, or a little less than five per cent in excess of the calculated weight, the actual difference being almost exactly the same as in the central span.

In the anchorage and cantilever arms no fixed rate of dead load was assumed, but the strain sheet was made by assuming the estimated weights of the different members as concentrated at the separate panel points, these concentrations, of course, being greatest nearest the piers. In every case the weight of a tension member was supposed to be carried at the upper end of that member, and the weight of a compression member to be carried at the lower end of that member, this, of course, only applying to the resultant portion of that weight which moved in the direction of the axis of the member. The panel point loads are given on the strain sheets.

The upper lateral system is proportioned to resist a horizontal pressure of 300 pounds per lineal foot of bridge. The bottom lateral system is proportioned to resist a horizontal pressure of 600 pounds per lineal foot. In both instances the whole horizontal pressure is treated as a moving load. This differs from the usual practice; but the allowance made for moving loads is inadequate rather than too great, as it is among the possibilities that when half of a span is exposed to a wind pressure in one direction, the other half may be exposed to a wind pressure in precisely the opposite direction.

No allowance is made in the strain sheets for the disturbances of the distribution of weight by wind pressure. A simple calculation showed this to be unnecessary. The lateral pressure on the top chord will exercise its greatest disturbing effects in the central span. Taking this pressure at 300 pounds per foot, multiplying it by the depth of the truss, and dividing it by the distance between truss centers, we have a resultant of 800 pounds as the possible increase of weight on one truss due to this cause, this being 20 per cent of the estimated dead load and 13 per cent of the total estimated load. If we take a wind pressure of 400 pounds per lineal foot applied on a train of maximum weight at an average elevation of 8 ft. above the rails, the effect of this wind pressure is to move the center of gravity of the moving load 0.75 ft. from the center of the track; as the center of the track is 15 ft. from the center of each truss, this increases the moving load carried by one truss five per cent and diminishes that carried by the other five per cent, thus actually increasing the weight thrown on one truss 100 pounds. Taking these two disturbances together, the total extreme weight which can be thrown on one truss amounts to 900 pounds per lineal foot, or 15 per cent above the assumed calculations.

No addition was made to the chord sections to provide for lateral strains. The assumed lateral force on the bottom chord is 600 pounds per lineal foot; the assumed total weight carried by each truss is 6000 pounds per lineal foot; the depth of the trusses is 2.6 times the distance between centers of trusses, so that the strain thrown into the chord by the lateral system is equal to 26 per cent of that thrown in by weight. In the top chord the effects of the lateral strain would be one half this amount, or 13 per cent.

As the effect of the disturbance in weight by wind pressure is to increase the tension in the leeward bottom chord 15 per cent, while the effects of the strain in the lateral system are to increase the tension in this chord by 26 per cent, the total effect is an increase of tension of 41 per cent in the leeward chord and a corresponding reduction of tension on the windward chord. In the top chord the effects are much less. With the unit strain allowed, these strains are well within safe practice.

Proportioning of Materials.—The entire superstructure of the Memphis Bridge is of steel, and it was all worked as steel, the rivet holes being drilled in all principal members and punched and reamed in the lighter members.

The tension members were proportioned on the basis of allowing the dead load to produce a strain of 20 000 pounds per square inch, and the live load a strain of 10 000 pounds per square inch. In the case of the central span, where the dead load was twice the live load, this corresponded to 15 000 pounds total strain per square inch, this being the greatest tensile strain.

The compression members were proportioned on a somewhat arbitrary basis. They were generally designed so as to make them of symmetrical section, and almost always so as to make them symmetrical about the line dividing the least transverse dimension. No distinction was made between live and dead loads in proportioning compression members. A maximum strain of 14 000 pounds per square inch was allowed on the chords and other large compression members where the length did not exceed 16 times the least transverse dimension, this strain being reduced 750 pounds for each additional unit of length. In long compression members the maximum length was limited to 30 times the least transverse dimension, and the strains limited to 6000 pounds per square inch, this amount being increased by 200 pounds for each unit by which the length is decreased.

THE MEMPHIS BRIDGE

EAST PORTAL, MAY 23, 1894.

The form of the structure is such that reversals of strains occur in the web members of both central and intermediate spans and in the chords of the central span. Wherever this occurs the member was proportioned to resist the sum of compression and tension on whichever basis (tension or compression) there would be the greatest strain per square inch; and, in addition, the net section was proportioned to resist the maximum tension and the gross section to resist the maximum compression.

The floor beams and girders of the floor system were calculated on the basis of the moment of inertia, the strain being limited to 10 000 pounds per square inch in extreme fibres. In the floor beams the rivet holes in cover plates and flanges were deducted. In the stringers, where there are no cover plates, and pains were taken to avoid rivet holes in the flanges, the gross section was used.

The rivets, all of which are of steel and in drilled or reamed holes, were proportioned on the basis of a bearing strain of 15 000 pounds per square inch and a shearing strain of 7500 pounds per square inch, and special pains were taken to get the double hear in as many rivets as possible. This was the requirement for shop rivets. In the case of field rivets the number was increased one half. In the splices of the chords of the central span, which is strained both in tension and compression, but in which the faced ends of the several sections were carefully fitted to close bearings, the number of rivets was based on the sum of the two strains; but the increase in the number of field rivets over what would have been required for shop rivets was made 25 instead of 50 per cent. The chords of this span are of uniform section throughout, and all the riveted joints are alike.

The pins were proportioned on the basis of a bearing strain of 18 000 pounds per square inch and a bending strain of 20 000 pounds per square inch in extreme fibre, the diameters of the pins being never made more than one inch less than the width of the largest eye bar attaching o them. Special pains were taken in packing the pins to divide the strains from the members on one side among those of the members on the other side, the general principle being to take the strain in each eye bar by itself, and consider that one half of it goes into the eye bar on either side leading in the other direction. With this system of packing the bending strain in extreme fibre is a matter of little importance.

The weight on the rollers of the expansion joint on Pier II is 40 000 pounds per lineal foot of roller, or 3333 pounds per lineal inch, the rollers being 15 inches in diameter.

DECK SPAN.

The deck span is a single triangular truss divided into six panels, the floor being sustained at the half panel points by vertical posts. The floor is kept uniform throughout, the east pair of stringers being riveted to the end floor beam of the Continuous Superstructure, this floor beam being directly over the centre of Pier IV. As the length of the floor panels is the same as in the Continuous Superstructure (27 ft. 2$\frac{3}{8}$ in.), the length of this span is 338 ft. 9 in. The only peculiarity about this span is the fact that the support is taken in niches on the west side of Pier IV; this made it necessary to shorten the end post and to deflect the bottom chord bars upwards. At the west end the full depth of the truss is maintained, and an expansion bearing on rollers similar to those used over Pier II is used.

The actual weight of the deck span, including the floor system and excluding end bearings, etc., is 3600 pounds per lineal foot, this being somewhat in excess of the weights estimated in the first calculation. The strain sheet given on Plate 55 is calculated on this basis. It will be observed that the actual sections are in some instances slightly less than the theoretical, but the maximum aggregate strains in tension never exceed 13 000 pounds per square inch, and those in compression never exceed 15 000 pounds per square inch.

MATERIAL.

As the sections of the superstructure were necessarily unusually heavy, and the strains from dead load were greatly in excess of those from moving load, it was thought best to use a slightly higher steel than is now generally used for lighter structures, and to work this steel without punching, all holes being drilled. A somewhat softer steel was used in the floor system, lateral connections, and other lighter parts.

The details of the requirements both for steel and manufacture are given in the Specifications dated January 4th, 1890, which accompany this report, marked Appendix L. The principal requirements which were to be obtained as the results of tests on samples cut from finished material were as follows:

	High-grade Steel.	Medium Steel.	Soft Steel.
Maximum Ultimate Strength, lbs. per sq. in.	78 500	72 500	63 000
Mimimum " " " " "	69 000	64 000	55 000
" Elastic Limit, lbs. per sq. in.	40 000	37 000	30 000
" Percentage of Elongation in 8 in.	18	22	28
" " " Reduction at fracture.	38	44	50

A piece of each sample bar was also required to be bent 180°, and to close up against itself without showing any crack or flaw on the outside of the bent portion.

The specifications as originally drawn provided for a preliminary test on a $\frac{3}{4}$ inch round bar, and allowed the steel to be made by either the open-hearth or Bessemer process. So much difficulty was experienced, however, in getting a satisfactory Bessemer steel, and the requirements for the preliminary test on the round bar were so much reduced as to amount to little, that all steel was required to be made by the open-hearth process. These requirements appear in the supplementary specifications dated May 6th, 1890, which is attached to this report and marked Appendix M.

After the first tests had been made on full-size eye bars it appeared expedient to adopt for this purpose a steel midway between the high grade and medium steel of the former specifications, and steel of the following requirements, denominated Eye-bar Steel, was prescribed thereafter:

	Eye bar Steel
Maximum Ultimate Strength, lbs. per sq. in.	75 000
Minimum " " " " "	66 000
" Elastic Limit, lbs. per sq. in.	38 000
" Percentage of Elongation in 8 ins.	20
" " " Reduction at fracture.	40

These requirements were provided for in a supplementary specification dated January 1st, 1891, which accompanies this report, and is marked Appendix N.

The results showed that this material was thoroughly satisfactory for most of the purposes for which it was wanted. It was specially so in the 10 in. eye bars which form the tension members of the anchorage and cantilever arms, and of the webs of the central span. The smaller eye bars which suspended the intermediate points did not give quite as satisfactory results. Tests were made of 56 full-size eye bars and the results are given in Appendix O attached to this report. An inspection of this list shows the excellent character of the 10 in. bars.

Owing to the difficulty of getting satisfactory small bars, the sizes of the suspenders which support the floor beams at the intermediate points were increased from 6 × 1$\frac{3}{16}$ in. to 7 × 1$\frac{5}{16}$ in., and from 6 × 1$\frac{1}{8}$ in. to 7 × 1$\frac{3}{16}$ in., and a softer steel was accepted than the specifications required. A corresponding change was made in the diagonal eye bars of the intermediate span last manufactured, the width of these bars being increased from 8 to 9 in., with no other change.

The results of these tests and observations on other work seem to indicate that in large bars a comparatively high steel gives the best results, and, if they are well annealed, is quite as soft as it is desirable to have. On the other hand, in small bars as low a steel as is consistent with sound ingots is probably the best material, but it must be remembered that in trying to get a very soft and ductile steel the chance of blow holes and other unsound features is increased. For one other reason the use of a higher steel for heavy eye bars seems wise, as where heavy bars are used it may generally (though not always) be assumed that the strain due to live load is small in proportion to that due to dead load.

In the west intermediate span, being the one which was built by A. & P. Roberts & Co., the riveted members were made of medium steel throughout, the work being punched and reamed. In the other intermediate span the requirements of the specifications were adhered to.

CONTRACTORS.

The contract for all the material for the superstructure was originally taken by the Union Bridge Company, and about five eighths of the whole was actually manufactured by them at their shop at Athens, Pa., the remaining three eighths being made at various other places. The largest contract placed elsewhere was with A. & P. Roberts & Co., who built one of the intermediate spans and the deck span west of Pier IV, except the eye bars, the Union Bridge Company relinquishing this portion of their contract and a new contract being made with A. & P. Roberts & Co.

The other shops generally did their work as sub-contractors for the Union Bridge Company, though in some cases special things were ordered direct.

The actual weights and percentages manufactured by the different shops were as follows:

	Pounds.	Per cent.
Union Bridge Company	10 432 020	63.9
A. & P. Roberts & Co.	3 113 250	19.07
Elmira Bridge Works	1 127 584	6.94
Lassig Bridge and Iron Works	806 617	4.94
Scaife Foundry and Machine Co.	423 963	2.59
Keystone Bridge Co.	310 585	1.90
Pittsburg Steel Casting Co.	61 935	0.37
New Jersey Steel and Iron Co.	40 712	0.25
Pittsburgh Bridge Co.	7 171	0.04
	16 323 837	100.00

The work manufactured by the Elmira Bridge Works consisted principally of web members of the central and intermediate spans.

The Lassig Bridge and Iron Works furnished the four vertical posts and portals at the ends of the central span besides some other web members.

The Scaife Foundry and Machine Company furnished the large castings on the piers.

The Keystone Bridge Company furnished the anchor rods within the masonry of the anchorage pier, a quantity of eye bars, and the bearing plates upon the rollers on Pier II.

The Pittsburgh Steel Casting Company furnished the steel castings over Piers II, III and IV.

The 15 in. expansion rollers, which were very finely finished, were made by the New Jersey Steel and Iron Company.

All the steel used in this bridge (except a small portion of that manufactured by A. & P. Roberts & Co.) was made by Carnegie, Phipps & Co., Limited (now the Carnegie Steel Company). It was all open-hearth steel and a large portion of it was made in basic furnaces.

The work was manufactured in the several shops named, according to working plans prepared by the engineer of the bridge, and shipped to the bridge site ready for erection.

ERECTION.

A contract was executed on the 10th day of May, 1890, with William Baird and Andrew Baird, comprising the firm of Baird Brothers, for the erection of the superstructure for a fixed sum, this sum being divided between the several spans. The contractors received the material as it arrived, took responsible care of it and erected it in position. The requirements which governed this erection are contained in the specifications which form Appendix L.

All of the bridge except the suspended span between the cantilevers of the channel span was erected on falsework. This suspended span was projected from the ends of the cantilevers, connected at the center and then swung free.

Bents were placed under the panel points of the trusses. Each bent had nine posts, the centre post and the third post from each side being plumb throughout, the other posts battered. All posts were of 12″ × 12″ timber, and the bents were built in three stories. The falsework was braced longitudinally by girths at each story, the girths at the ends being bolted to the stone piers. Each bent rested on 18 piles, these piles generally being cut off at elevation 205, or 11.2 ft. below high water. On the top were placed 20 lines of stringers, four at the center and eight on each side, to carry the traveler tracks.

This falsework terminated at the proper level to receive the bottom chord. Four lines of rails, two on each side, were laid to carry the traveler which was made long enough to reach over one and one half full panels, or three floor panels.

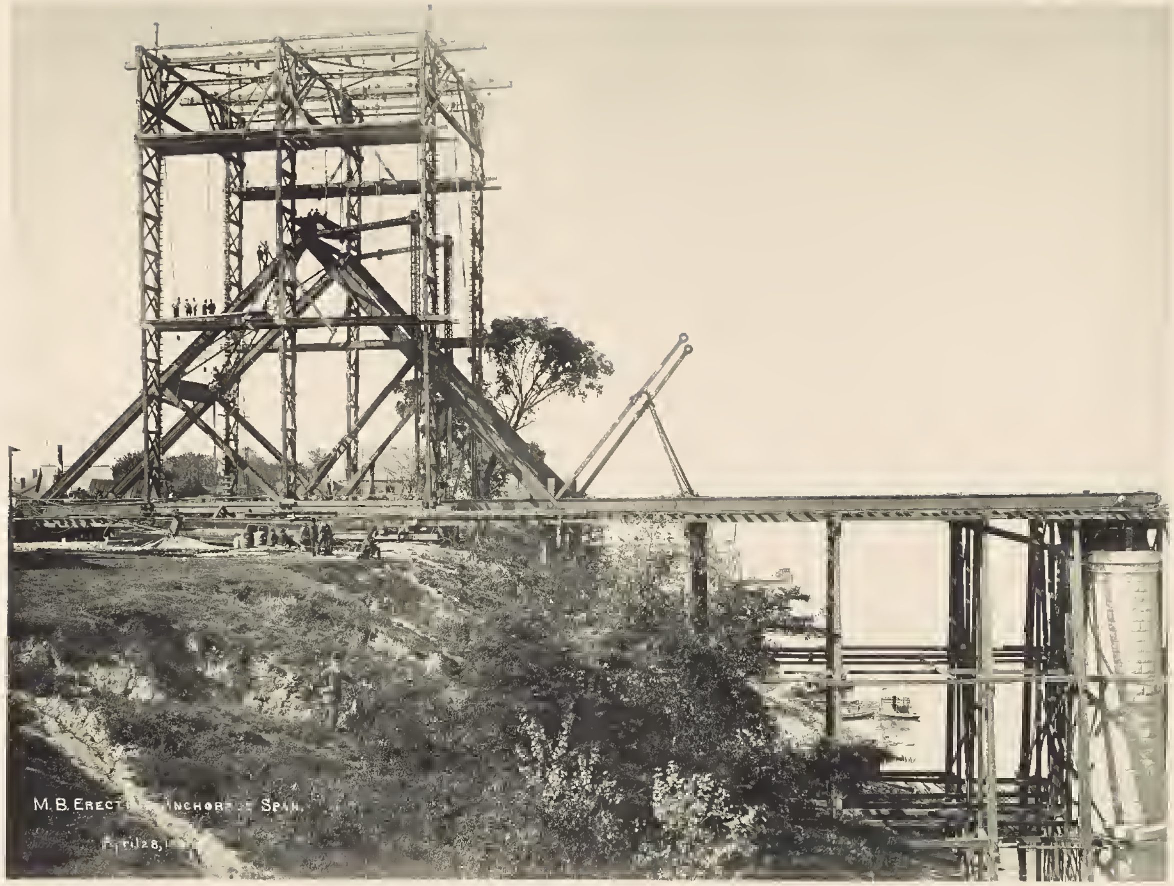
The material for the anchorage arm and the adjoining cantilever was received on cars at the top of the bluff east of Pier I. All other superstructure material was received in a yard under the bluffs, where it was stored and subsequently handled by barges.

Erection was begun on the east shore, and the traveler was set up on the ground back of Pier I; on the 31st of March, 1891, this traveler was completed and ready to begin work, the falsework at that time only extending as far as Pier I. The first piece of bottom chord section was placed on the 3d of April, and the anchorage arm was virtually completed on the 6th of May. Meanwhile the falsework had been extended westward to the end of the east cantilever arm, and the erection of this cantilever arm was practically completed on the 20th of June, though the falsework and traveler were maintained in this position, and some further work was done on the last panel as late as July 31st.

The driving of the falsework for the central span was begun in July. The work was begun west of Pier III, the piles for six bents being driven west of that pier. The two westward bents were placed close together, and on top of these were erected derricks by which the material was lifted from barges. The entire falsework between Piers II and III was completed by the end of August. This falsework was placed in the middle of the Mississippi River immediately after the flood season. It was very heavy and expensive, the piles generally being from 90 to 100 ft. long and driven about 20 ft. in hard sand below the bottom of the river.

When this falsework was completed the traveler which had been used on the east side was taken down and set up on the falsework. It was in itself a pretty large structure, standing 97 ft. above the track on which it ran and nearly 200 ft. above the surface of the water. This traveler when completed consisted of four bents, only three of which had been used on the east side.

Two derricks were set up at the west end of the falsework west of Pier III, and all the members of the central span were taken by barges from the material yard under the bluff on the east side of the river to the west end of the falsework, where they were raised by the derricks to the



THE MEMPHIS BRIDGE

TRAVELER AS USED ON EAST END, APRIL 28, 1891.

THE MEMPHIS BRIDGE

ERECTION OF EAST INTERMEDIATE SPAN, MARCH 2, 1892.

floor level, there placed on push cars, and carried out to the traveler by which they were put in position. Everything was handled by steam, the engines being placed near Pier III.

The erection began with the placing of the first piece of the bottom chord on September 13th, 1891, the castings and the expansion bearing on Pier II having been previously erected. The entire bottom chord was put together and riveted up, the riveting being generally done by air riveters carried on a special small traveler. These riveters were of two patterns, one designed by Mr. Charles Vogel under the direction of the Chief Engineer, and the other by the Allen Riveting Machine Company of New York.

On the 25th of September the erection of the web members began. The erection was begun one panel east of the centre and the traveler moved westward. On the 3d of October the end posts at the west end of the span were placed; the traveler was then moved eastward, and on the 11th of October the end posts at the east end were placed. The span was swung on the 15th of October, 1891. The erection from the placing of the first chord section to the swinging of the span occupied 32 days.

This span, the total weight of which is 5 122 252 pounds, is believed to be the heaviest and longest span that was ever erected on falsework. A single member, the section of top chord between panel points U1 U3, weighed 61 944 pounds.

On the completion of the erection of this span the falsework was driven for the cantilever which projects from the east end of it, and this cantilever was also raised with the traveler, it being completed on the 31st of October.

The traveler was then moved to the west end of the span; the false work was removed from under the east projecting cantilever and the eastern end of the span to the span between Piers III and IV. On the 24th of November the western cantilever was completed. On the 7th of December the entire falsework was finished so that the erection of the suspended span reaching to Pier IV could begin. The bottom chord of this span had to be riveted before it was swung, but the connections were all made by December 16th.

This completed the erection of the continuous superstructure except the suspended span over the channel. The traveler which had done its work was now taken down and the falsework removed.

The actual erection of the last suspended span, the only portion of the Memphis Bridge which was erected without falsework, was begun on the 9th of February. A traveler of simple character, which consisted of a platform resting on the top chords and carrying two derricks guyed to a stiff frame, was set up at the east end of the west cantilever of this span (this being the cantilever which projects from the east end of the central span). The material was taken out in a barge under these derricks and lifted into position.

The weight of this suspended span was so great that the Chief Engineer hesitated about employing the adjustable wedges which have been used on similar structures at the connection between the cantilever arm and a suspended span. Oblong holes, each carrying two pins, were placed at the sliding joints (see Plate 44), and by placing adjustable wedges between these pins the position of the end of the projecting span could have been raised or lowered, or the span could have been moved backward. The Engineer, however, decided to erect the west end without any adjustment and the east end with a hydraulic adjustment, and to make the connection between the bottom chords with eye bars, which, acting as a toggle joint, could take up variations of length. The Engineer now admits that this was an error in judgment. Wedges could have been used to better advantage than the fixed connections at the west end or the hydraulic connection at the east end. The hydraulic connection at the east end was used only in the bottom chord, a double wedge arrangement being used in the top; the double wedge is not as good as the single wedge.

After the cantilever arms had been built out, the opening between them, which had been carefully triangulated, was measured direct with a steel wire. Computations were made showing the changes in length of the members of the central span, the anchorage span and the cantilever arms resulting from the building out of the half spans of the intermediate span. The positions of the ends of the cantilever arms at the adjustment point under that condition were then calculated, as well as the form of the half span when built out. These calculations gave data for fixing the distance between the adjustment pins of the first half span (the west one) that was built. The distance between these pins, which determined the position of the free end of the half span when built out, was fixed by stationary castings (shown in Plate 44); these were made in two parts for convenience in handling. After the erection of the half span had been commenced no change could be made in its final position.

When calculating the final position of the half span it was assumed that the erecting outfit of traveler, engines, lines and scaffolds would remain on it until the span was swung. This was an error; the unusual weight of the span insured much difficulty in swinging, and it should have been assumed in the first place that all appliances not absolutely necessary in swinging the span would be removed as soon as the half spans were built out. They were removed, and the free end of the west half span, after their removal, was 5 inches above the elevation intended; this added materially to the subsequent difficulties.

The adjustment pins and castings for the west half span were placed February 9th and 12th. Erection was proceeded with and the half span erected to within one panel of the center of the span during the next twenty days. The traveler used for this purpose was then removed and the erection engine, lines, etc., run back to the end of the cantilever arm.

The distance fixed between the adjustment pins had been based on calculations of extensions or contractions due to the increased strain resulting from the building out of the half spans; these computed changes in length were applied as corrections to the measured distance across the opening between the cantilever arms. The corrections to the upper chord opening depended on computed changes in length of chord members for a distance of 1863 feet; the corrections to the lower chord opening depended upon computed changes in length for a distance of 1411 feet. A slight error in the assumption as to loading would produce an appreciable difference in the total extension or contraction in these distances; moreover, the members were in the main riveted members with heavy splice plates, tie plates and lattices, all of which increased the average cross-sections, so that with a correct strain sheet the calculated changes in length might be to a considerable extent inexact. It was therefore thought necessary to provide for a small adjustment for the east half span.

Wedges (shown in Plate 44) were made for the upper chord adjustment. They provided for a total variation in distance between pin centers of only 1 in. Some small variations from plan dimensions reduced this range to about $\frac{3}{4}$ in.

The removal of all appliances from the west half span not only caused the free end to rise above the elevation intended, but, by reducing the strains in all members, caused the free end of the upper chord to be about 1 in. west of the place expected. On the other hand, the time required for erecting the span was greater than had been expected, so that the connection at the center was made later in the season and at a higher temperature than had been assumed. These two changes in condition almost balanced each other.

It was expected that the wedges would be immovable after the half span had been built out its full length; they were to be used, however, for a final adjustment after the half span had been built out half its length. Before beginning the erection of the half span, the distance across the opening was again measured and the wedges placed at nearly mid-position, the measurement having checked previous measurements and computations within a small part of an inch. After the wedges had been placed and the erection of the half span commenced, the adjustment was not changed until the span had been released at the adjustment points at the west end.

When an attempt was made to move these wedges, the double wedge was found defective. One of the wedges would move first; the immediate result was a great increase of pressure on the other wedge applied at its small end; this fixed it in place, and as the screw was turned to continue the withdrawal, the movement of the first wedge continued until some means were used to prevent its movement.

For the lower chord adjustment at the east end of the span a hydraulic jack (Plate 44) was provided for each truss. Each jack had a plunger 14 in. in diameter, with a stroke of 3¾ in. One force-pump was provided for operating these jacks; it was of special design and very simple in construction. The ordinary leather cup-packing proved inadequate and was replaced by soft lead. The adjustment in the lower chord was simply the thrusting out of the hydraulic jacks to the proper distance to give the end of the half span, when built out, the same elevation as the end of the west half span already built. The stroke of the jacks was not enough for this, but this was provided for by placing crescent-shaped fillers in the elongated pin holes between one of the pins and the webs of the chord. When the half span was built half its length, the jacks were used to increase the distance between the adjustment pins ¼ in. With this adjustment the limit of the capacity of the pump was reached; and as the erection proceeded, this half span, like the west one, became unadjustable. When the half spans met at the center they were so nearly the same elevation that little difficulty was met in driving the center pins of the upper chords which closed the span and completed the connection between the upper chords and the web systems.

To supply the place of the end adjustments ordinarily provided for swinging the span, the Chief Engineer decided to depend mainly on expansion by temperature to extend the upper chord, and on a toggle joint to shorten the lower chord, so that the adjustment pins could be withdrawn. For one full truss panel of the lower chord there were substituted two lengths of eye bars connected to adjoining sections of bottom chord by temporary pins and to each other by short coupling bars. A short vertical rod 2 in. square, having a nut at the lower end and an eye at he upper end, passed between each pair of coupling bars and through a washer which took bearing on the lower edge of the coupling bars. The toggle joint was completed by lifting on the 2 in. square rods. The eye bars and couplings were placed to permit the insertion of the riveted lower chord sections after swinging the span, the top flange angles being removed and riveted back again after placing. The arrangement of the bars is shown on Plate 45. The eye bars were called the toggle bars, the joint at center was called the toggle joint, and the rods by which the toggle joint was pulled up were called the toggle rods.

As the ends of the half spans were too high, the opening in the lower chord between the ends of the riveted sections (one section at the center being left out), when the joints in the upper chord were just brought into bearing, was nearly 4 in. less than the length of the closing section. It was necessary to raise the toggle joint 3 ft. before the toggle bars became taut. By loading the adjoining cantilever arms the lower chords were compressed so that the toggle bars became taut when the toggle joint was lifted 1¼ ft.

The erection of the east half span ready for the closing sections was completed April 8th; the traveler and all superfluous material were removed; a derrick was erected on the end of each arm to handle the closing sections. The season was well advanced, and for several days the temperature had been too high to close the upper chord sections, if all preparation had been made; but cooler weather came opportunely, and at 9 a.m. of April 10th they were inserted with an opening of only $\frac{1}{16}$ in. more than required.

During the next three days the inclined rods (Plate 45) for lifting the toggles were placed; in addition, two pairs of heavy triple blocks rove with manilla line 2 in. in diameter were placed in each truss, connecting the upper and lower chords at the center of the span, each pair of blocks having a capacity of 25 tons. The derricks were taken down, and all was in readiness to swing the span; but the weather became cold when heat was wanted.

During the swinging of the span changes in strain causing changes in length must occur. The total shortening thus caused in the upper chords amounted to about 4⅝ in. The distance between the fixed points on Piers I and III was 1411 ft. 5½ in. The change in length for 1° Fahr. was 0.0095 ft. To produce a change in length of 4⅝ in. required a change of 41°. The top chord at the center of the intermediate span became closed at 56°. A temperature of 97° was necessary to release the adjustment pins in the upper chord. This natural temperature could not be had, and various means were tried to swing the span at a lower one, all tending to increase the length of the upper chord.

During the several days of cool weather which followed the connection of the top chords at the centre of the span, the cantilever arms between Piers I and II were loaded with timber, rails, locomotives, etc., to about 6000 pounds per lineal foot. The toggle rods were screwed up daily and the adjustment pins watched closely, but there was no sign of loosening. The resident engineer, Mr. Alfred Noble, adopted the expedient of heating the upper chord of the intermediate span with steam. A 1½ inch pipe was placed in each chord for the entire length of the span. Canvas was placed under the pipe on the lacing to retain the heated air in the chord; on the 19th of April steam from the locomotives was turned on the pipes, the toggle rods were screwed up, and as heavy a strain as they would stand was put on the lines, and blocks placed to assist in raising the toggle joint. As the temperature approached its maximum for the day it was found that Piers I and III were being pushed apart, the movement of Pier I being ¼ in. and of Pier III, 1¼ in.; the possibility of this motion had been considered, both in its effects on the masonry of the piers and in swinging the span. Masonry, like all other construction, is elastic; the piers could move much more than these amounts without injury. The motion of the piers, however, worked against the shortening of the top chord by compression, and this attempt to swing the span failed. It almost succeeded, however, as was shown by the fact that some of the upper chord web bearings could be moved on the pins.

During the next two days four rods, each 1¾ in. round, were placed on each truss, to connect the toggle joints with the center of the upper chord and aid in lifting the toggles; steam pipes were laid in the upper chords of the central span extending half way from Pier II to Pier III. Clamps (shown on Plate 44) were placed at the adjustment points in each of the upper chords at the west end of the intermediate span; each clamp consisted of four rods. 2½ in. diameter, with upset ends and nuts, bearing against pieces of rail and through oak blocks bearing against the edges of the tie plates of the chord sections.

On the morning of April 22d the operation of lifting the toggle joints began; there were 24 toggle rods, and the work of turning up the nuts required several hours of steady work; the joint was finally raised 3.75 feet above the line of the lower chord. At 4 p.m. the steam pipes were connected to the locomotives and a heavy strain put on the clamps; in an hour the adjustment pins at the west end of the upper chords became loose and were taken out; the adjustment wedges in the upper chord at the east end of the span were loosened; the upper chord being now released at both ends, all difficulties were over and the span was practically swung. Night had come and work was suspended until morning, when the hydraulic jacks in the lower chord at the east end of the span were slackened off and taken out, the wedges were removed, the castings in both chords at the west end of the span taken out and the pins put back in place. The toggle rods and lines were then slacked off, allowing the lower chord to assume its normal position, and the permanent sections of bottom chord were inserted.

During the erection and swinging of the intermediate span the adjoining cantilever arms had been subjected to strains exceeding those due to the loading assumed in proportioning the members, but not exceeding safe limits. Twelve days were spent in swinging this span.

The erection of the channel span completed the continuous superstructure of the Memphis Bridge. The floor system was put in, the riveting was continued, and the entire structure was ready for the passage of trains on the 12th of May, when the bridge was formally opened.

WEIGHTS.

The following table gives the weight of the superstructure classified by spans. In this table the vertical posts over Piers I, II, and III, and the supports on the piers, are divided between adjacent spans:

	Pounds.
East Approach	66 812
Anchorage Span	1 606 727
Cantilever Pier I	1 252 365
East Intermediate Span	2 329 759
Cantilever Pier II	1 284 674
Central Span	5 122 252
Cantilever Pier III	1 260 452
West Intermediate Span	2 327 845
Deck Span	1 072 951
	16 323 837

These are the actual shop weights, and the sum is the total amount of metal in the bridge.

The following table gives the weights as divided in estimating the strains. The portions directly over the piers, which are carried by the piers instead of by any portion of the trusses, are eliminated from the weights of the spans:

	Pounds.
Approach from Abutment to Anchorage Pier, including fence	66 812
Anchor rods and plates in Anchorage Pier	74 995
Anchorage bars, blocks, etc., below lower chord	57 936
Tetrapod and castings	6 777
Anchorage Span, exclusive of posts L_0 U_0 and castings on Pier I	1 305 084
Posts L_0 U_0, portal between same and castings on Pier I	323 869
East Cantilever Arm	1 090 431
East Intermediate Span	2 329 759
Cantilever Arm, Pier II	1 090 430
Posts L_0 U_0, portal for same, rollers, etc., and castings on Pier II	388 489
Central Span, exclusive of end posts, castings, etc	4 757 987
Posts L_0 U_0, portal for same, castings, etc., on Pier III	340 041
Cantilever Arm Pier III	1 090 431
West Intermediate Span, exclusive of castings	2 269 340
Castings on top of Pier IV	58 505
Deck Span Castings in niches of Pier IV	11 262
Deck Span, exclusive of end supports and posts L_0 U_0 W	1 019 664
Castings Pier V and posts L_0 U_0 W	42 025
Total	16 323 837

The weights per foot referred to in this paper are calculations on the basis of this table.

These several tables give the weight of the steel in the structure. The weight of the wooden floor is additional and was estimated to weigh 630 pounds per lineal foot, this including rails and connections.

COST.

The total cost of the Superstructure was as follows:

	Total.	Per Lineal Foot.	Per Ton.
Steel work	$739 582.77	$275.76	$90.61
Erection	211 746.86	78.96	25.94
Painting	8 692.60	3.24	1.07
Total	$ 959 972 23	$357.96	$117.62

The total cost of the floor was $20 018.81, or $7.46 per lineal foot.

V.

VIADUCT.

The West Approach Viaduct begins at Pier V and extends to Pier 54, a total length of 2268.5 feet. An iron girder 22.125 feet long reaches to the east bent of the timber trestle thus making the entire length of the ironwork 2290.625 feet.

Between stations 144 and 146 the line of the viaduct crosses the tracks of the Kansas City, Ft. Scott & Memphis Railroad and the St. Louis, Iron Mountain & Southern Railway, and to prevent interference with these tracks it was decided to put in two spans each 75 feet long in clear of masonry. The angle of the crossing is 49° 1′, and this length of span left abundant room for three tracks for each railroad. As a precaution against possible accidents from derailment on the lower tracks these two spans were placed on masonry piers.

The location of these three masonry piers was fixed by the position of the lower tracks, and this fixed the length of the viaduct spans. The general plan of viaduct selected was the usual one of a plate girder superstructure resting on iron towers, the spans between the towers being made twice the length of the spans over the towers. The spans over the towers measure 29.5 feet long between centers and the spans between the towers 59 feet, this length bringing the east masonry pier in proper position. The whole viaduct is shown on Plate 56.

The numbering of the piers of the main bridge was continued through the viaduct but designated by Arabic instead of Roman numerals, the three masonry piers being 44, 45, and 46, and the west pier of all 54. As each of the piers under the towers is built in the form of two small piers, there are in all 95 piers under the viaduct.

The viaduct piers are shown on Plate 57. Each pier rests on seven piles which were driven in pits excavated to elevation 205; these pits were filled with hexagonal blocks of concrete into which all piles except the center piles extend four feet. The piers are nine feet high above the concrete foundation, the lower four feet of which are built of brick in all cases and the upper five feet of which are in piers 6 to 11 made of concrete enclosed in a shell of $\frac{3}{8}$ inch steel plate five feet high, in piers 12 to 27 of concrete enclosed in a shell of $\frac{1}{2}$ inch iron plate $4\frac{1}{2}$ feet high and in the other piers of brick; there is little reason for preferring one form of construction to the other. These piers are covered with cast iron caps, and in each pier are two U-shaped anchor rods of iron $1\frac{1}{4}$ inches in diameter which extend from the concrete foundation to a height 10 inches above the caps. Long screws were cut on these rods so as to permit of adjustment in case of settlement which is always liable to occur with so large a number of small foundations. After the completion of the viaduct an embankment 50 feet wide was built around these piers, finishing at elevation 218, this being above high water and, therefore, preventing any flow of water between the piers. The hexagonal concrete block was made of Louisville cement concrete; Portland cement was used every where else in the small piers.

Piers 44, 45 and 46 are also shown on Plate 57. They have pile foundations, the piles being enclosed in a block eight feet high of Louisville cement concrete surmounted by eight feet of Portland cement concrete, above which they are built of limestone masonry. The limestone used in these piers is from southwestern Missouri; it is an inferior stone having bad crowfoot seams, but it was thought that in this position, where it was away from the river, it would prove durable. A recent examination shows that this confidence was misplaced; the stone already is weathering badly, and it would have been much wiser to have used Bedford stone, the cost of which would have been less.

The details of the ironwork are given on Plate 58. They require but little explanation. All the bracing of the towers was made stiff and without adjustment, but the diagonals were calculated as tension members.

The spans are not divided over the center of the posts but in such position that the aggregate weight of the long and short spans shall come over the axis of each post. Provision for expansion and contraction is made at the upper (eastern) end of each long girder. The viaduct is of iron, though soft steel is used in the wide web plates of the girders and in some other unimportant places.

A contract for this material was let to the Pennsylvania Steel Company, but the greater part of the work was manufactured at the shops of Cofrode & Saylor at Pottstown, Pa.

The longer spans of plate girders were made by A. & P. Roberts & Co. of Pencoyd, Pa. They are shown on Plate 59.

The floor system is of the form usually used by the Chief Engineer on permanent structures. It is also shown on Plate 59.

At the east end of the viaduct a plate girder span 60 feet long reaches from the first long span to a timber trestle which forms the highway approach. This span is shown on Plate 60.

The quantities of the various kinds of material in the viaduct are given in the following tables:

SUBSTRUCTURE.

Piles, in work	lineal feet	24 040
Concrete in foundations	cubic yards	1 837
" " cylinder Piers 6-27	" "	148
Steel in cylinder shells, Piers 6-11	pounds	34 058
Wrought iron in cylinder shells, Piers 12-27	pounds	48 663
Cast iron in caps	"	122 850
Wrought iron in U rods	"	31 739
Brick masonry	cubic yards	665
Stone masonry in Piers 44, 45 and 46	" "	668

SUPERSTRUCTURE.

Iron and soft steel in towers	pounds	1 482 273
Steel in girders, Pier V-6	"	47 175
Iron and soft steel in girders on towers	"	1 595 262
" " " " " " " Piers 44, 45 and 46	"	179 549
Cast iron pedestals and anchor bolts on Piers 44, 45 and 46	"	12 023
Total	"	3 316 282

The average amount of metal in the superstructure per lineal foot of viaduct from Pier V to the end of the ironwork is 1 448 pounds. If the special girders over the St. Louis, Iron Mountain & Southern and Kansas City, Fort Scott & Memphis Railways be omitted, and also the half spans on either side of these girders and the half spans next to Pier V, the average amount of metal per lineal foot becomes 1 509 pounds.

The first work done on the foundations of the viaducts was on the 28th of June, 1890. The small piers were all finished on the 19th of August, 1891. The larger piers (44, 45 and 46) were finished September 5, 1891. The earth embankment around these piers was finished December 21, 1891. The ironwork was erected by the company's own men. A traveler which ran on a track placed on the ground was set up at the west end of the viaduct and everything was handled with this traveler, an illustration of which taken from a photograph is given on the accompanying plate. The erection of this viaduct was completed on the 7th of May, 1892.

The total cost of the viaduct was as follows:

SUBSTRUCTURE.			
Excavating and Backfilling	$ 2 740.85		
Pile work	11 351.13		
Concrete in Foundations	12 799.09		
Iron work	7 849 90		
Brick Masonry	11 448.94		
Concrete in Cylinders	1 350.70		
Masonry Piers 44, 45 and 46	11 427 66		
Total FOUNDATIONS		$ 58 974 27	
SUPERSTRUCTURE.			
Iron and Steel	$112 155 55		
Erection	16 657 63		
Painting	3 424.81		
Floor	10 793.90		
Total SUPERSTRUCTURE		$143 031.89	
Total Cost of VIADUCT			$202 006 16

The average cost of each of the two small piers under one bent of the viaduct was $432.57 and that of the masonry piers 44, 45 and 46 was $6 392.57.

The cost of viaduct complete, including painting and floor, was $88.19 per lineal foot of gross length. The cost of the floor was $4.71 per lineal foot and that of painting $1.50, or $2.07 per ton.

Omitting again the special structures as before the cost per foot of viaduct, including floor and painting, becomes $84.18.

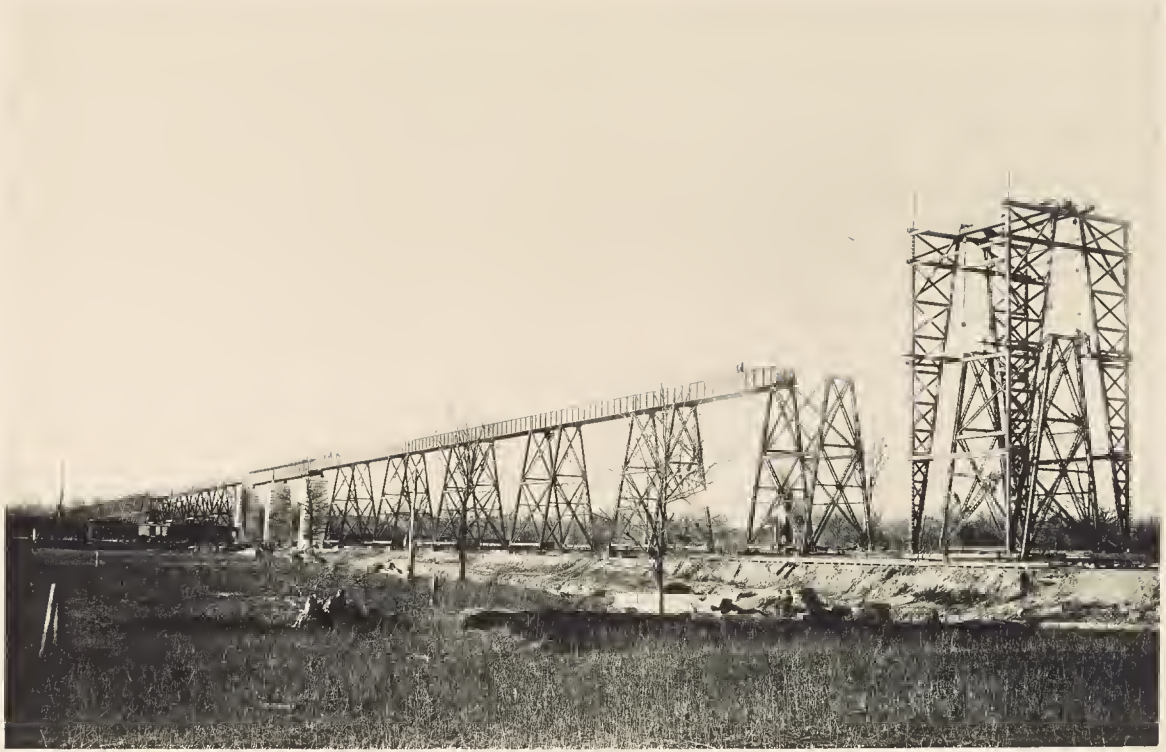
VI.

APPROACHES.

The East Approach calls for no special description. It is simply a line of railroad built within the limits of the city, the only structure on which is a double track plate girder bridge across Delaware Avenue. Delaware Avenue was depressed to pass under this bridge and an eight inch vitrified sewer pipe laid eastward from the lowest point in the depression, the street under the bridge being paved with brick; at some future date it will probably be expedient to turn this drainage towards the river; until this is done special care will be required to keep the drainage pipe clean.

From the west end of the viaduct to station 181 + 06 the West Approach is built in the form of a timber trestle. Of this 2507 feet are a framed structure on pile foundations and the remaining 605 feet a simple pile trestle. Special care was taken in the selection of the timber for this trestle. The piles are of oak and the timber is all of long leaf southern pine. The position, however, is one in which timber decays rapidly, and the whole trestle ought to be replaced by a solid earth embankment before the end of 1898. This will require 310 000 cubic yards, or, if the filling should begin with the year 1894, an average of 62 000 cubic yards per year, the estimated cost of which would be $20 000 a year, the haul being very long.

From the end of this trestle to the west end of the Approach the track is laid on a solid earth embankment, excepting that there is a pile trestle 300 feet long between stations 213 and 217. This trestle will probably have to be kept open.



THE MEMPHIS BRIDGE

WEST APPROACH VIADUCT, JANUARY 31, 1892.

The track is laid throughout with 80 pound steel rails of what is known as the Michigan Central pattern, or Pattern 8001 of the Illinois Steel Company by which they were rolled.

The Highway uses the same floor as the railroad from the East Abutment to Pier V. At the east end of the bridge the Highway Approach is a solid earth embankment, finished with a granite pavement laid on Portland cement concrete foundation and 30 feet wide between curbs; this paved approach is on the line of Virginia Avenue, and it descends with a 13 per cent. grade from the abutment, reaching the street grade near the east line of Delaware Avenue. At the west end the Highway Approach makes two rectangular turns. A 60 feet plate girder span, supported at the south end on the first viaduct span and at the north end on an iron bent, connects the bridge floor with a wooden trestle; this wooden trestle, which is parallel to the viaduct and 80 feet from it between centers, is a simple cheap structure 20 feet wide on top, descending towards the west with an eight per cent grade.

The quantities of the principal materials in the approaches are as follows:

EAST RAILROAD APPROACH.

Earthwork	cubic yards	15 076
Delaware Avenue Bridge, Concrete	" "	216
" " " Masonry	" "	408
" " " Iron in Superstructure	pounds	87 130
" " " Brick paving under	square yards	209

EAST HIGHWAY APPROACH.

Earthwork	cubic yards	1 140
Granite paving	square "	363

WEST RAILROAD APPROACH.

Earthwork	cubic yards	69 525
Piles in work	lineal feet	27 267
Timber in work	feet B M.	976 092
Iron, bolts, etc.	pounds	69 344

WEST HIGHWAY APPROACH.

Iron in girders and support for same	pounds	60 430
Timber in trestle	feet B M.	238 000
Piles " "	lineal feet	3 123
Iron " "	pounds	14 513
Earthwork	cubic yards	876

VII.

SHORE PROTECTION.

While comparatively little shore protection was done at Memphis, that little was very important. It was put in with reference to two things; to hold the bluff which forms the east shore both from abrasion by the river and from surface-wash, and to restore the west shore to something like its position in 1886.

The east shore protection consisted; first, of a mat, the upper edge of which was near the high water mark; and second, of grading the bank to a uniform slope from the east abutment to Pier I and paving this slope.

The mat was of the character used by the Mississippi River Commission in its shore protection work. It is 365 feet wide and 1320 feet long, extending from 240 feet below the axis of the bridge to 1080 feet above it. This mat was put in in September to December 1890. It consists of brush and poles and is heavily covered with riprap. The portion below low water is secure. The portion above low water may require repairs and will at all events require watching, or it will be destroyed by the negroes who would steal the poles for fuel.

There were used in this mat 6520 cords of brush and poles and 9304 tons of stone.

The sloping of the bluff was done with special reference to preventing surface water cutting in around the edge of the small piers and so undermining the foundations. This work was postponed till after the completion of the bridge. The ground was graded to a uniform slope of one vertical to four horizontal; and this inclined surface was not made a true plane, but sloped slightly from the center and each edge so as to form two parallel valleys 120 feet apart, the total width of the above slope being 180 feet. This slope was then paved with limestone blocks laid rather roughly and bedded in sand. This pavement will require some little repairs from year to year, and these should be made immediately whenever it shows sign of settlement. They should be made by removing the stones which have settled, filling the cavity underneath with well packed gravel, and replacing the original stones.

The protection of the west shore was of an entirely different character and consisted principally of a screen dike which was intended to form a deposit behind Pier IV; the general location of this screen dike is shown on Plate 2. It is 1155 feet long, of which 1080 feet are above the axis of the bridge and 75 feet below. It was constructed by first placing a mat 150 feet wide, 50 feet inside and 100 feet outside of the center line, on the bottom of the river; this mat extended below the lower end of the screen dike 155 feet and 370 feet above the upper end of the screen dike; for a length of 550 feet from the upper end, the mat was made 250 feet wide extending from the bank of the river outward. Two lines of piles, 14 feet apart and 15 feet between centres in each line, were driven through the mat, waling pieces were bolted to the piles, and the bents were braced. A second mat, 76 feet wide, was woven, the upper edge of which was attached to the top of the piles and the lower edge allowed to fall on the foundation mat; this was held in position by putting riprap on the lower edge. The upper end of the screen dike was connected with the shore line by a short dike built of brush and stone, the top being at the same elevation as the top of the screen dike itself. This structure forms a current deadener, and with each successive flood an additional deposit is made behind it, so that in due time the whole space should be filled to the level of the bottom land. When this has occurred the new shore line should be heavily riprapped.

Some trouble was experienced by the river cutting behind the upper end of the screen mat, and to meet this condition the short brush and stone dike was raised to the level of extreme high water and extended inland about 200 feet to a point where the natural surface of the ground is within a few inches of high-water level. This dike may require repairs from time to time. Two other dikes of a more or less temporary nature were put in to hasten the silting action back of the screen.

There were used in the screen mat and the auxiliary work 14 476 lineal feet of piles, 67 M. ft. B.M. of timber, 23 500 pounds of bolts and washers, 5040 cords of brush and poles, 19 900 pounds of wire and 6466 tons of rock.

VIII.

COST.

The cost of the Memphis Bridge is given in the following table:

East Abutment		$11 872.87	
Small Piers		1 085.90	
Anchorage Pier		36 267.79	
Pier I.			
Foundation	$70 649.28		
Masonry	70 386.66	141 035.94	
Pier II.			
Foundation	$200 948 29		
Masonry	108 669.14	309 617.43	
Pier III.			
Foundation	$184 672.15		
Masonry	124 679.77	309 351.92	
Pier IV.			
Foundation	$47 538.80		
Masonry	71 828.21	119 367.01	
Pier V.			
Foundation	$33 064 92		
Cylinders	7 323.77	40 388.69	
Total Substructure			$968 987 55
Steel work		$739 532 77	
Erection		211 746 86	
Painting		8 692 60	
Floor		20 018.81	
Total Superstructure			$979 991.04
East Shore		$57 167.02	
West Shore		36 516.42	
Total Protection			$93 683.44
East Approach.			
Grading	$8 457.78		
Masonry	7 157.26		
Bridge Superstructure	3 519.09		
Highway Approach	2 642.32	$21 776.45	
West Approach.			
Viaduct	$202 006.16		
Timber Trestle	33 551.76		
Grading	21 631.51		
Highway Approach	10 785.50	$267 974.93	
Total Approaches			$289 751.38
Permanent Track		$38 895.33	
Engineering		128 523.12	
Tools and Machinery		30 865 54	
Service Tracks		6 880.12	
Buildings		4 443.37	
Unused Material		344.56	
Total Sundries			$209 952.04
TOTAL COST			$2 542 365.45

This includes everything done under the direction of the Chief Engineer to January 1, 1894. The item of Tools and Machinery is the net balance remaining in that account after crediting it with all sales. The expenses of running and repairing the machinery were charged to the several pieces of work on which the tools were in use at the time such expenses were incurred. The charge for Engineering includes all the salaries and expenses of engineers and inspectors.

The table may be briefly condensed into the following:

Substructure	$968 987.55		
Superstructure	979 991.04		
Total Bridge proper		$1 948 978.59	
Approaches	$289 751.38		
Permanent Track	38 895.33		
Protection	93 683.44		
Tools, Service Tracks, etc	42 533.59	464 863.74	
Engineering		128 523.12	
TOTAL COST			$2 542 365.45

This statement is the cost of construction as expended under the direction of the Chief Engineer. It does not include land purchases nor the various other expenses in the way of interest during construction and the like with which the capital account was properly chargeable. These items, as reported by the Comptroller, are given in the following table:

Total Construction as above	$2 542 365.45	
Real Estate	218 369.94	
Additional sidings, signals, water station, taxes, insurance, etc., less rentals	7 425.47	
Interest during construction	206 409.86	
General Expense	23 573.33	
TOTAL COST, including EVERYTHING		$2 998 144.05

APPENDIX A.

LIST OF ENGINEERS, EMPLOYEES, AND CONTRACTORS.

ENGINEERS AND COMPANY'S EMPLOYEES.

Name and Occupation.	Time of Service.
George S. Morison, Chief Engineer,	

RESIDENT STAFF.

A. Noble, Resident Engineer, ...	Oct. 1, 1888, to May 31, 1892.
M. A. Waldo, Assistant Engineer, ...	Oct. 24, 1888, " Dec. 31, 1892.
J. M. Heiskell, " "	Oct. 22, 1888, " Oct. 31, 1891.
W. E. Angier, " "	Feb. 10, 1889, " May 14, 1892.
E. H. Mayne, " "	Nov. 8, 1889, " June 5, 1890.
D. A. Molitor, " "	Sept. 8, 1890, " May 31, 1892.
C. Vogel, Draughtsman, ...	Nov. 30, 1891, " May 30, 1892.
E. K. Barrett, Rodman, ...	Jan. 5, 1890, " Apr. 17, 1893.
Geo. Reynolds, Inspector of Masonry, . . .	Aug. 15, 1889, " Oct. 14, 1889.
Joshua Dixon, " " " . . .	Sept. 15, 1889, " Apr. 30, 1891.
Aug. T. Holmgren, Inspector of Cement, . . .	June 16, 1889, " Nov. 28, 1891.
D. A. Kelsey, Clerk, ...	Feb. 8, 1889, " Dec. 31, 1892.
Sanford Morison, Clerk, ...	Apr. 21, 1889, " June 5, 1892.
H. C. Churchill, "	Jan. 1, 1890, " Sept. 19, 1890.
R. F. Thayer, Time-keeper, ...	May 20, 1889, " June 3, 1892.
Julius Thompson, "	Nov. 11, 1888, " May 16, 1891.
L. S. Stewart, General Foreman, ...	Oct. 26, 1888, " Apr. 25, 1892.
D. Leonard, Foreman of Pressure Work, . . .	Nov. 17, 1888, " Oct. 24, 1890.
D. Brophy, Master Mechanic, ...	Nov. 17, 1888, " Oct. 25, 1890.
C. H. Wilson, Foreman of Mattress Work, . .	July 17, 1889, " Jan. 23, 1891.
J. E. Griffin, Foreman of Carpenters, . . .	Jan. 25, 1892, " Apr. 12, 1893.
Geo. W. Fenton, Master of Steamers Bertram and Lincoln, ...	Nov. 1, 1888, " July 7, 1890.
W. P. McNeely, Master of Tug Welcome, . .	Mar. 31, 1889, " Mar. 24, 1893.

NON-RESIDENT STAFF.

E. Gerber, Office Engineer.	
R. Modjeski, Chief Draughtsman, ...	Apr. 30, 1890.
R. Modjeski, Chief Inspector of Superstructure,	Nov. 7, 1890, to Jan. 31, 1892.
Irving Dickinson, Draughtsman.	
O. E. Hovey, "	
E. H. Connor, Inspector of Superstructure, . .	Jan. 27, 1890, to Nov. 30, 1890.
W. S. Macdonald, Inspector of Superstructure, .	Oct. 1, 1891, " Dec. 24, 1891.
W. R. Edwards, Rodman, ...	May 27, 1889, " Apr. 14, 1890.
W. R. Edwards, Asst. Insp. of Superstructure, .	Apr. 15, 1890, " Jan. 2, 1892.
R. Khuen, Rodman, ...	July 16, 1890, " Sept. 4, 1890.
R. Khuen, Asst. Insp. of Superstructure, . .	Jan. 1, 1891, " Aug. 10, 1891.
W. A. Hill, Asst. Inspector of Superstructure, .	Mar. 9, 1891, " Dec. 28, 1891.
W. L. Smith, Asst. Inspector of Superstructure,	Aug. 10, 1891, " Dec. 9, 1891.
F. H. Joyner, Inspector at Limestone Quarries,	May 1, 1889, " Dec. 21, 1890.
N. Joyner, Assistant Inspector at Limestone Quarries, ...	May 19, 1889, " Mar. 31, 1890.
O. T. Geese, Inspector at Granite Quarries, . .	May 13, 1889, " Aug. 31, 1891.

CONTRACTORS.

Lewis M. Loss, ...	Masonry.
Union Bridge Co., ...	Superstructure.
Elmira Bridge Works, ...	Sub-contractor.
Lassig Bridge and Iron Works, . .	" "
Scaife Foundry and Machine Co., .	" "
Keystone Bridge Co., ...	" "
Pittsburg Steel Casting Co., . . .	" "
New Jersey Steel and Iron Co., . .	" "
A. & P. Roberts & Co., ...	Superstructure.
Pittsburg Bridge Co., ...	"
Baird Brothers, ...	Erection.
Pennsylvania Steel Co., ...	Viaduct Superstructure.
Cofrode & Saylor, ...	Sub-contractor.
William Kelley, ...	Earthwork, West Approach.
William O'Mara, ...	" " "
James Saguin, ...	West Approach Trestle.
Speers & Freeman, ...	Sloping and Paving, East Approach.

APPENDIX B.

ACT OF CONGRESS APPROVED FEBRUARY 26, 1885.

AN ACT TO AUTHORIZE THE CONSTRUCTION OF A BRIDGE ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENNESSEE.

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That the Tennessee and Arkansas Bridge Company, a corporation organized and created under and by virtue of the laws of the State of Arkansas, and the Tennessee Construction and Contracting Company, a corporation organized and created under and by virtue of the laws of Tennessee, be, and the same are hereby, jointly authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River from or near Memphis, in the State of Tennessee, to or near the town of Hopefield, in the State of Arkansas. Said bridge shall be constructed to provide for the passage of railway trains, and. at the option of the corporations by which it may be built, may be used for the passage of wagons and vehicles of all kinds, for the transit of animals, and for foot passengers, for such reasonable rates of toll as may be approved from time to time by the Secretary of War.

SEC. 2. That any bridge built under this act and subject to its limitations shall be a lawful structure, and shall be recognized and known as a post-route, upon which also no higher charge shall be made for the transmission over the same of the mails, the troops, and the munitions of war of the United States, or for passengers or freight passing over said bridge, than the rate per mile paid for the transportation over the railroad or public highways leading to the said bridge; and it shall enjoy the rights and privileges of other post roads in the United States.

SEC. 3. That said bridge shall be made with unbroken and continuous spans; two spans thereof shall not be less than five hundred and fifty feet in length in the clear, and no span shall be less than three hundred feet in the clear. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high-water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge. And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States in which any portion of said obstruction or bridge may be located. *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operation of the same.

SEC. 4. That all railroad companies desiring the use of said bridge shall have and be entitled to equal rights and privileges relative to the passage of railway trains or cars over the same, and over the approaches thereto, upon payment of a reasonable compensation for such use; and in case the owner or owners of said bridge and the several railroad companies, or any one of them, desiring such use shall fail to agree upon the sum or sums to be paid, and upon rules and conditions to which each shall conform in using said bridge, all matters at issue between them shall be decided by the Secretary of War, upon a hearing of the allegations and proofs of the parties. *Provided*, That the provisions of section two in regard to charges for passengers and freight across said bridge shall not govern the Secretary of War in determining any question arising as to the sum or sums to be paid to the owners of said bridge by said railroad companies for the use of said bridge.

SEC. 5. That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and to secure that object the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore-line at extreme high and low-water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or brigdes, and shall furnish such other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War the bridge shall not be built; and should any change be made in the plan of said bridge during the progress of construction, such change shall be subject to the approval of the Secretary of War.

SEC. 6. That the right to alter, amend, or repeal this act is hereby expressly reserved; and the right to require any changes in said structure, or its entire removal, at the expense of the owners thereof, whenever Congress shall decide that the public interests require it, is also expressly reserved.

SEC. 7. That it shall be the duty of the Secretary of War, on satisfactory proof that a necessity exists therefor, to require the companies or persons owning said bridge to cause such aids to the passage of said bridge to be constructed, placed, and maintained at their own cost and expense, in the form of booms, dikes, piers, or other suitable and proper structures for the guiding of rafts, steamboats, and other water-craft safely through the passage-way, as shall be specified in his order in that behalf; and on failure of the company or persons aforesaid to make and establish such additional structures within a reasonable time, the said Secretary shall proceed to cause the same to be built or made at the expense of the United States, and shall refer the matter without delay to the Attorney-General of the United States, whose duty it shall be to institute, in the name of the United States, proceedings in any circuit court of the United States in which such bridge or any part thereof is located for the recovery of the costs thereof; and all moneys accruing from such proceedings shall be covered into the Treasury of the United States.

APPENDIX C.

ACT OF CONGRESS APPROVED APRIL 24, 1888.

AN ACT TO AUTHORIZE THE CONSTRUCTION OF A BRIDGE ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENNESSEE.

Be it Enacted by the Senate and House of Representatives of the United States of America in Congress Assembled, That the Kansas City and Memphis Railway and Bridge Company, a corporation created and organized under and by virtue of the laws of the State of Arkansas, its successors and assigns, be and the same are hereby authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River, from or near the town of Hopefield in the State of Arkansas, to or near the taxing district of Shelby County, commonly known as the city of Memphis, in the State of Tennessee. Said bridge shall be constructed to provide for the passage of railway trains and wagons and vehicles of all kinds, for the transit of animals, and, at the option of the corporation by which it may be built, for foot-passengers, for such reasonable rates of toll as may be approved from time to time by the Secretary of War.

Sec. 2. That any bridge built under this act and subject to its limitations shall be a lawful structure, and shall be recognized and known as a post-route, upon which also no higher charge shall be made for the transmission over the same of the mails, the troops, and munitions of war of the United States, than the rate per mile paid for the transportation over the railroad or public highways leading to the said bridge, and it shall enjoy the rights and privileges of other post-roads in the United States.

Sec. 3. That the said bridge shall be made with unbroken and continuous spans. Before approving the plans for said bridge the Secretary of War shall order three engineer officers from the Engineer Bureau to be detailed to the duty of examining, by actual inspection, the locality where said bridge is to be built, and to report what shall be the length of the main channel span and of the other spans. *Provided*, That the main channel span shall in no event be less than seven hundred feet in length, or the other spans less than six hunderd feet each in length; and if the report of said officers shall be approved by the Secretary of War, the spans of said bridge shall be of the length so required. The lowest part of the superstructure of said bridge shall be at least seventy-five feet above extreme high-water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge; and in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States within whose jurisdiction any portion of said obstruction or bridge may be located. *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operation of the same.

Sec. 4. That all railroad companies desiring the use of said bridge shall have and be entitled to equal rights and privileges relative to the passage of railway trains or cars over the same, and over the approaches thereto, upon payment of a reasonable compensation for such use; and in case the owner or owners of said bridge and the several railroad companies, or any one of them, desiring such use shall fail to agree upon the sum or sums to be paid, and upon rules and conditions to which each shall conform in using said bridge, all matters at issue between them shall be decided by the Secretary of War, upon reasonable notice to the parties in interest and upon consideration of such allegations and proofs as may be submitted to him. But the last foregoing provision shall not be held to exclude the ordinary jurisdiction of the courts of the United States in such cases.

Sec. 5. That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river, as the Secretary of War shall prescribe; and to secure that object, the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore-lines at extreme high and low water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or bridges, and shall furnish such other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War, the bridge shall not be built or commenced; and should any change be made in the plans of said bridge during the progress of construction, such change shall be subject to approval of the Secretary of War, and shall not be made or commenced until the same is so approved.

Sec. 6. That it shall be the duty of the Secretary of War, on satisfactory proof that a necessity exists therefor, to require the company or persons owning said bridge to cause such aids to the passage of said bridge to be constructed, placed, and maintained at their own cost and expense, in the form of booms, dikes, piers, or other suitable and proper structures for the guiding of rafts, steamboats, and other water-craft safely through the passage-way, as shall be specified in his order in that behalf; and on failure of the company or persons aforesaid to make and establish and maintain such additional structures within a reasonable time, the said Secretary may cause the said bridge to be removed at the expense of the owners thereof, or may proceed to cause the same to be built or made at the expense of the owners of said bridge, and in that case shall refer the matter without delay to the Attorney-General of the United States, whose duty it shall be to institute, in the name of the United States, proceedings in any circuit court of the United States within whose jurisdiction such bridge or any part thereof is located, for the recovery of the amount so expended by the Government and all costs of such proceedings; and all moneys accruing from such proceedings shall be covered into the Treasury of the United States.

Sec. 7. That if the construction of the bridge hereby authorized shall not be commenced within one year from the time this act takes effect, and be completed within four years after the same date, then this act shall be void, and all rights hereby conferred shall cease and determine.

Sec. 8. That an act entitled "An act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee" approved February twenty-sixth, eighteen hundred and eighty-five, be, and the same is, hereby repealed.

Sec. 9. That the right to alter, amend, or repeal this act is hereby expressly reserved, and the right to require any changes in said structure, or its entire removal, at the expense of the owners, whenever the Secretary of War shall decide that the public interests require it, is also expressly reserved.

APPENDIX D.

CONTRACT WITH WAR DEPARTMENT.

Whereas, By an act of Congress, approved April 24, 1888, entitled "An act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee," it was enacted that the Kansas City & Memphis Railway and Bridge Company, a corporation created and organized under and by virtue of the laws of the State of Arkansas, its successors and assigns, be, and the same are hereby authorized and empowered to erect, construct, and maintain a bridge over the Mississippi River from or near the town of Hopefield, in the State of Arkansas, to or near the taxing district of Shelby County, commonly known as the city of Memphis, in the State of Tennessee; and,

Whereas, It is provided by section 5 of the act of Congress aforesaid, That any bridge authorized to be constructed under this act shall be built and located under and subject to such regulations for the security of navigation of said river as the Secretary of War shall prescribe; and to secure that object, the said companies or corporations shall submit to the Secretary of War, for his examination and approval, a design and drawings of the bridge, and a map of the location, giving, for the space of two miles above and two miles below the proposed location, the topography of the banks of the river, the shore lines at extreme high and low water, the direction and strength of the currents at all stages, and the soundings, accurately showing the bed of the stream, the location of any other bridge or bridges, and shall furnish such other information as may be required for a full and satisfactory understanding of the subject; and until the said plan and location of the bridge are approved by the Secretary of War, the bridge shall not be built or commenced; and should any change be made in the plans of said bridge during the progress of construction, such change shall be subject to approval of the Secretary of War, and shall not be made or commenced until the same is so approved; and

Whereas, The original plans were submitted to a board of Engineer Officers for examination and report, as provided in section 3 of the act of Congress aforesaid; and,

Whereas, The report submitted by said board was not approved by the Secretary of War; and,

Whereas, The Kansas City & Memphis Railway and Bridge Company aforesaid has accepted the provisions of the act of Congress aforesaid, and in compliance therewith has submitted to the Secretary of War for his examination and approval a design and drawing of a proposed bridge across the Mississippi River, the main channel span of which is not less than seven hundred feet in length, and the other spans not less than six hundred feet in length, and the lowest part of the superstructure is seventy-five feet above extreme high-water mark, and has also submitted a map of the location thereof;

Now, therefore, I, William C. Endicott, Secretary of War, having examined and considered the plans of said bridge, and the map of the location thereof, submitted by the Kansas City & Memphis Railway and Bridge Company aforesaid, and which are hereto attached, do hereby approve the same, subject, however, to the following conditions, viz.:

1. That the Kansas City & Memphis Railway and Bridge Company shall provide an independent roadway for wagons and animals on each approach of said bridge, and, for the entire length of the bridge proper, a roadway of sufficient width for wagons to pass each other without inconvenience, to be used by wagons and animals in common with the railroad.

2. That said bridge shall be open for the passage of wagons and animals at all times except when trains are actually crossing.

3. That reasonable signals shall be given when trains are approaching the bridge, and no train shall be permitted to enter the common roadway until the wagons which are on the roadway when the signal is given have passed off of said common roadway.

4. That whenever in the opinion of the Secretary of War the roadway above provided for does not afford ample means for the passage of wagons and vehicles of all kinds, and the transit of animals, the Secretary of War may require the Railway and Bridge Company aforesaid to furnish a Ferry Train, consisting of such a number of large box cars with continuous floor, sides, and top, as he may deem necessary for the transportation of said wagons and vehicles, and the transit of animals across said bridge, and may require said company to receive and land said wagons, vehicles, and animals at such point as he may designate on each side of said river; and may prescribe the intervals at which said Ferry Train shall cross said bridge for the accommodation of said wagons, vehicles, and animals.

5. The right to require changes in said structure, if the public interest demands them, being reserved to the Secretary of War in section 9 of said act.

6. That the Engineer Officer of the United States Army in charge of the district within which the bridge is to be built may supervise its construction so far as may be necessary in order that the plans herein approved shall be complied with and the bridge built accordingly.

Witness my hand this twenty-third day of August, 1888.

WM. C. ENDICOTT,
Secretary of War.

This instrument is also executed by the Kansas City & Memphis Railway and Bridge Company, by George H. Nettleton, its President, thereunto lawfully authorized, this twenty-third day of August 1888, in testimony of the acceptance by said company of the provisions of the act of Congress aforesaid, and of the conditions herein imposed.

KANSAS CITY & MEMPHIS RAILWAY AND BRIDGE COMPANY.

In presence of F. H. DAMON.

By GEO. H. NETTLETON,
President.

APPENDIX E.

REPORT OF FEBRUARY 15, 1887.

New York, Feb. 15, 1887.

George H. Nettleton, Esq.,

Kansas City & Memphis Railway and Bridge Co., Kansas City, Mo.

Dear Sir: At your request I went to Memphis on Nov. 23, 1886, accompanied by my assistant, Mr. E. Duryea, Jr., and made arrangements for Mr. Duryea to begin work as early as possible in making borings on the location of the proposed bridge across the Mississippi River. I returned on the evening of the following day, leaving Mr. Duryea at Memphis, where he still remains. I again went to Memphis on the 28th of December, reviewed the ground and examined specimens obtained from the borings. The borings were continued until stopped by the flood of the present month. While not as complete as I could wish to have them, they are enough to show in all essential features what the character of the bottom is.

The place selected for the crossing of the river is near the foot of Broadway, the axis of the bridge to be at right angles to the current, and the approach from the east being through Alabama Street (Virginia Avenue), the angle between the axis of the bridge and the street line being about 42°.

In our notes the point where the bridge line intersects the center line of Alabama Street is called Station 100, the station numbering running westward from there.

In this report I have assumed that the bridge would be so designed as to give a clear head room of 65 feet above high water, the bottom of tie on the bridge to be 70 feet above high water.

The ground on the Memphis side is a level bluff, the height of which corresponds almost exactly with this required elevation: the track can be laid on the surface of the ground almost as it now is.

The river at this place is practically 2000 feet wide, varying from 1900 feet at extreme low water, to 2100 feet when bank full.

The ground on the west side is a low bottom land, the average elevation of which is about 5 feet below extreme high water.

In our levels we have called the low water of the United States Engineer's gauge zero; high water is 35.15 feet above this gauge, and extreme low water is 0.98 feet below this gauge. The elevation of tie on bridge would be 105.

The elevation of your tracks on the West side of the river is 37, so that the West Approach must descend 68 feet. I should propose to make this descent with a 1.25 grade (66 feet per mile), which will require a distance of 5440 feet, all of which would be on a straight line. Of this, I have estimated on building the 3200 feet next to the bridge in the form of a permanent iron viaduct, and the remainder as a timber trestle to be subsequently filled, unless available material can be found for building an embankment at once.

Although the West Approach is long, its construction is very simple.

All the difficulties of building a bridge at Memphis are concentrated in the bridge itself, 2000 feet long.

The channel of the river is as well fixed here as it is ever found on the Mississippi River, and the work proposed by the Mississippi River Commission for the preservation of the harbor of Memphis, much of which is already completed, will secure the permanency of the channel where it now is.

The long continuance of the channel in one place has probably reduced the width of the river here to that actually required for its discharge, as is always the case when the channel of a silt-bearing river remains fixed for a long period. The main discharge of the river occupies the eastern two thirds of its width, the current in the western one third being decidedly lighter and the depth of water less. The water is deepest and the current strongest about one third of the way over from the east shore.

The east bluff is the east boundary of the alluvial delta of the Mississippi. It is composed of clay and layers of sand and gravel, with a thin stratum of ferruginous sandstone, but practically is entirely without rock. The material below water is generally well adapted to bearing the weight of a foundation, but not wholly safe to resist the erosion of the river without artificial protection. The location of the bridge, a few hundred feet below a projecting point of the bluff, is one in which the necessary artificial protections can be made very cheaply.

The first boring made was on the west shore. This boring found sand to a depth of −52, when a hard blue clay was encountered. This clay changed to a very light-colored clay at a depth of −72, which changed again to a brown clay at a depth of −98, which brown clay changed to a blue clay at −114.5, and this continued to −122, when the boring was abandoned. The lower part of the cream-colored clay was sandier and softer than any of the others. The second boring was made in the river 660 feet east of the first boring, or about at the westerly limit of the strong current. At this boring the upper clay was not found, the light-colored clay being found at −75.6 and the brown clay at −101, the material being evidently identical with that found on the west side. The next boring was made 650 feet farther east, or a little west of the strongest current. In this boring clay was struck at −84, and resembled in character the softer and sandier portion of the cream-colored clay. The boring was discontinued at −104, being then apparently on the surface of the brown clay, though we were driven out by the flood before this could be positively determined.

These clays are in all probability alluvial clays which have been deposited by the river. The two lower clays are evidently continuous for a large distance, and I believe are entirely safe for foundations. The upper clay (found only on the west side) is probably a later pocket much less in extent, but safe for a foundation at the location of the west shore pier. These alluvial clays probably meet the older formation of the east bluff about 200 feet from the east shore, but I have as yet no facts to verify this probability. It is possible that the lower clays are identical with strata which exist under the bluff.

I should propose to found the piers of a bridge at this place on caissons which should be sunk to the clay and a few feet into it, the caissons to be of such size that the fatigue pressure on the base should not exceed $3\frac{1}{2}$ tons per square foot. I should also wish to place on the bottom of the river around each pier a woven mat (such as is used by the Mississippi River Commission for shore protection) about 300 feet square; this woven mat to be sunk upon the bottom of the river and to form the basis of a moderate riprap protection, the object being to prevent scour around the pier, and so give to the foundations the stability due to the lateral support of 40 or 50 feet of sand in addition to that due to the bearing on the base.

The difficulties of building a bridge here would lie in the eastern two thirds of the river. A pier could be built on the western edge of this two thirds without serious difficulty. If piers are to be built in the eastern two thirds there is not much choice of location. As a single pier in the middle of this two thirds would make two spans of about 660 feet, which is not more than an economical length of span, the choice would seem to lie between crossing this portion of the river with two spans or with one. In the former case the bridge would consist of three spans of about 660 feet each, spanning the whole 2000 feet of the river. In the latter case the bridge would consist of one main span of 1300 feet (to be built on the cantilever principle) spanning the eastern two thirds, with anchorage arms extending over the east shore and the western part of the river.

These two plans have been considered separately and estimates made.

THREE SPAN BRIDGE.

The four piers of the Three Span Bridge would be numbered from east to west. Pier I would be located on the bench at the foot of the bluff where the elevation of the ground is about 8 and at station 104; Pier II would be at station 110 + 60, in the deepest water of the river; Pier III would be at station 117 + 25, or at the west edge of the strong current; Pier IV would be at station 123 + 85, close to the west bank and about at the low water shore line.

I have estimated on sinking the foundation of Pier IV to —55, or about three feet into the blue clay; on sinking the foundation of Pier III to —79, or about three feet into the light-colored clay; and on sinking the foundation of Pier II to —105, or through the light clay to the brown clay. The borings at the base of the bluff are not yet complete, but I have estimated on sinking this foundation to the same depth as that of Pier IV.

The foundation of Pier IV offers no special difficulties, it being in very shallow water and the depth being materially less than foundations I have lately put in on the Missouri River. The same may be said of the foundation of Pier I. The depth to which the foundation of Pier III must be sunk is no greater than that of our deep foundations at Omaha, but the foundation and the pier would be very large. At Pier II the difficulties are undoubtedly great, especially if it is found necessary to go as deep as I have estimated, namely, to —105, which is deeper than any foundation I know of which has been carried to any hard material, though by carefully choosing the time of year it might not be necessary to work in any deeper water than was done at the east abutment of the St. Louis Bridge.

For the present I have thought it best to estimate on putting in all four foundations by the pneumatic process, as I feel certain that this can be done. It is possible, however, that after we have put in the foundations of Piers III and IV and thereby learned more than we now know of the character of the clays, a better and cheaper method of handling Pier II may be devised.

The great length of span which it is proposed to use will require large masonry piers, and these piers will require foundations of correspondingly large size, especially as they are to rest on clay and not rock. I have estimated on making Piers II and III 14 feet thick and Piers I and IV 12 feet thick under the coping; the piers to be of limestone and of the form which experience has shown presents the least obstruction to the current and catches the least amount of driftwood, the caissons for Piers I and IV to be of rectangular form 36 feet by 82 feet; the caissons for Piers II and III to be octagonal, the area of base being 3936 feet in Pier II and 3357 feet in Pier III. In pneumatic foundations of ordinary size it is usually desirable to get all the weight possible to facilitate sinking. In foundations of the size we are now considering the reverse will be the case, and it will be desirable to reduce the weight as much as possible. I should propose to build the caisson entirely of oak, to surmount this caisson with a cribwork structure which should terminate at —31, on which the masonry should rest. The cribwork would be built of timber and concrete, with three large wells, which wells would extend up into the masonry; these wells to be filled with concrete after the foundation is completed. In this way the weight on the roof of the caisson and the weight to be handled while sinking would be reduced to very comfortable limits.

Both Piers II and III should have protection mats around them, which mats should be subsequently riprapped. The only protection required at Piers I and IV would be the protection which must at any rate be given to the shores. In my estimates I have provided for all these protections in one item and at a liberal figure.

The superstructure of this bridge would consist of three spans of 656 feet each (200 metres) between end pins, the trusses to be 77 feet deep and 33 feet between centers, and to be built entirely of steel. While these dimensions are greater than those of any trusses yet built, they are entirely within practicable limits and not so great an undertaking now as 400 feet spans were twenty years ago. I have estimated on simple trusses with straight chords, though it is probable it would be expedient to use a curved upper chord. The details of one of these spans have been studied and a careful estimate made of the weights, showing that the weight of such a span will not exceed 3 600 000 pounds, or a little more than 5000 pounds per foot.

To connect the east end of the bridge with the top of the bluff will require a short iron viaduct 240 feet long, the details of which will be similar to that of the longer viaduct on the west side.

The estimated cost of this bridge complete will be as follows:

Pier I.			
3 000 c. y. Masonry at $20	$60 000		
70 000 c. ft. Cribwork " 40 cts	28 000		
60 000 " " Caisson " 80 cts	48 000		
Sinking	15 000	$151 000	
Pier II.			
4 200 c. y. Masonry at $20	$84 000		
163 000 c. ft. Cribwork " 40 cts	65 200		
70 000 " " Caisson " 80 cts	56 000		
Sinking	40 000	245 200	
Pier III.			
4 200 c. y. Masonry at $20	$84 000		
80 000 c. ft. Cribwork " 40 cts	32 000		
57 000 " " Caisson " 80 cts	45 600		
Sinking	35 000	186 600	
Pier IV.			
3 000 c. y. Masonry at $20	$60 000		
70 000 c. ft. Cribwork " 40 cts	28 000		
60 000 " " Caisson " 80 cts	48 000		
Sinking	15 000	151 000	
Outfit for Foundation Work		50 000	
Protection Work, including Mats and Riprap of Piers II and III, and Shore Protection at Piers I and IV		100 000	
TOTAL SUBSTRUCTURE			$883 800
Three 656 ft. Spans, 10 800 000 lbs. at 6 cts		$648 000	
Floor and Painting		15 000	
TOTAL SUPERSTRUCTURE			663 000
TOTAL BRIDGE PROPER			$1 546 800
East Approach.			
240 ft. Iron Viaduct		$12 000	
West Approach.			
2 400 000 lbs. Iron at 5 cts	$120 000		
3 000 c. y. Masonry at $10	30 000		
Floor and Painting	20 000		
3 200 ft. Iron Viaduct	170 000		
Wooden Trestle	25 000	195 000	
TOTAL APPROACHES			207 000
TOTAL BRIDGE AND APPROACHES			$1 753 800
Add 10% for Contingencies			175 380
			$1 929 180
Engineering, etc.			50 000
			$1 979 180

This is the entire estimated cost of the bridge ready for rails from the edge of the bluff at Memphis to the foot of the grade on the west side of the river. It includes nothing for real estate damages, and I do not think these ought to amount to anything. It is perhaps entitled to a credit for tracks, as the amount of track which will be required is very much less than that now used in the connections with the transfer landings.

The prices used for caissons and cribwork are those for which experience has shown me this work can be done on the Missouri River. I think there should be a large reduction in these prices at Memphis. The same may be said of the cost of the masonry, but I have not yet examined any stone quarries.

The price for the superstructure (six cents per pound erected) is at least 20 per cent higher than this work could have been contracted for a year ago.

I should hope that the item of contingencies could be saved, and the actual cash cost of the bridge could be kept within $1 800 000.

If your company should decide to build on this plan the matter of time is an important one. The foundations for Piers III and IV should be put in during the low water season of the present year. These piers should be finished during the Spring of 1888.

The foundation for Pier II should be put in in the Fall, during the low water season of 1888. Pier I can be put in at almost any time. The masonry of Piers I and II should be finished in the Spring of 1889.

The west long span should be raised in the Fall of 1888 and the other two spans in the Fall of 1889.

The approaches should be built in the Spring of 1889.

The bridge could be opened for traffic before the end of 1889.

It might be possible to save one season in the construction of this bridge, but in view of the time required to make preparations for a work of this mag nitude I do not think it would be wise to attempt to do so. It must be remembered that the season which can be depended on for working in the river at Memphis is only five months long.

CANTILEVER BRIDGE.

The main span of the Cantilever Bridge would occupy the portion of the river spanned by the two easterly spans of the Three Span Bridge, the length of this span being 1300 feet. This is one half greater than the span of any railroad bridge now in existence, but 300 feet less than the East River Suspension Bridge and 400 feet less than each of the two main spans of the Forth Bridge now building in Scotland.

I have estimated on making the cantilevers 150 feet deep at the ends and building them with curved upper and lower chords, the masonry to finish ten feet above high water. This arrangement is not strictly in accordance with the requirements of the charter hitherto granted; it gives the required height (65 feet) for a distance of about 400 feet at the center, but this height is reduced at either side. It would, however, accommodate the navigation interests of the river perfectly, as there is abundant room in the center for the upper works of large boats and abundant width for tows which are never high. There can be little doubt that if this design should be decided on there would be no difficulty in getting the authority to build it.

To secure lateral stability I have proposed to put the cantilever trusses 75 feet apart at the base and to build them in inclined planes, these planes to be put 15 feet apart at the highest point. To avoid concentrating too much weight on one point I should put the support of the anchorage span 75 feet from the support of the main span. The result of this arrangement would be that the cantilever structure would be supported on each side of the main span by a group of four piers, these piers to occupy the corners of a 75 feet square. This arrangement is similar to that adopted for the Forth Bridge in Scotland.

In the structure I have estimated on, the center of the easterly group of piers is placed at station 104 + 12.5, and the center of the westerly group of piers at station 117 + 87.5, the length of the span, measured from centers of piers next to the channel being 1300 feet, the distance between centers of towers 1375 feet and the distance between centers of piers including towers 1450 feet. The design provides for shore or anchorage arms 375 feet long, which places the east anchorage 240 feet back of the edge of the bluff and places the west anchorage at station 122, or about 150 feet from the low water shore line. It would probably be economical to shorten the east shore arm and to lengthen the west shore arm. With the arrangement as it is now designed, a 225 foot span will be required to reach from the west anchorage to the end of the iron viaduct.

The substructure of this Cantilever Bridge will consist of (1) the east anchorage pier, (2) the group of piers under the east tower, (3) the group of piers under the west tower, (4) the west anchorage piers and (5) a small pier under the west end of the approach span.

The east anchorage pier will be of the simplest kind, being merely a piece of masonry built in the bluff and of sufficient size to give the weight required for the anchorage. I have estimated on 1200 yards of masonry, but of less expensive character than that of the piers in the river.

The group of piers under the east tower would consist of four piers, each 16 feet in diameter under the coping, resting on caissons 36 feet square and founded at the same depth (— 55) as Pier I of the Three Span Bridge.

The group of piers under the west tower would be similar to those under the east tower, except that the caissons would be 40 feet square and the foundations sunk to — 79.

The west anchorage pier would be founded on a caisson 35 feet by 75 feet at a depth of — 55, and though of considerable dimensions would offer no special difficulties in construction.

A small pier would be required back of the shore line to support the heavy bent at the end of the trestle, which would sustain the shore end of the 225 feet span.

The same shore protection would be required for the east tower as for Pier I of the Three Span Bridge, the same protection around the west tower as around Pier III and the same amount of protection on the west shore as with the other design, the total cost of protection being perhaps two thirds of that required in the Three Span Bridge.

A general plan and strain sheet have been made for this structure, and an approximate estimate of weights. This design, however, has not been worked out with the same degree of detail as the design for the Three Span Bridge, and the estimates, though probably ample, are not as accurate.

The estimated cost of this bridge complete would be as follows:

East Anchorage Pier		$20 000	
East Tower:			
750 c. y. Masonry at $20	$15 000		
16 000 c. ft. Cribwork " 40 cts	6 400		
26 000 " " Caisson " 80 cts	20 800		
Sinking	7 500		
	$49 700		
Group of 4 Piers		198 800	
West Tower:			
910 c. y. Masonry at $20	18 200		
32 000 c. ft. Cribwork " 40 cts	12 800		
32 000 " " Caisson " 80 cts	25 600		
Sinking	10 000		
	$66 600		
Group of 4 Piers		266 400	
West Anchorage Pier:			
3 300 c. y. Masonry at $20	66 000		
27 000 c. ft. Cribwork " 40 cts	10 800		
52 000 " " Caisson " 80 cts	41 600		
Sinking	12 000		
		130 400	
West Approach Pier		5 000	
Outfit for Foundation Work		30 000	
Protection Work		70 000	
TOTAL SUBSTRUCTURE			$720 600
Cantilever Superstructure 14 000 000 lbs.			
One 225 ft. Span 400 000 "			
14 400 000 lbs. at 6 cts.		$864 000	
Floor and Painting		15 000	
TOTAL SUPERSTRUCTURE			879 000
TOTAL BRIDGE PROPER			$1 599 600
West Approach as for Three Span Bridge			195 000
TOTAL BRIDGE AND APPROACHES			$1 794 600
Add 10 per cent for Contingencies			179 460
			$1 974 060
Engineering, etc.			50 000
			$2 024 060

This is the entire estimated cost of the bridge ready for the rails from the bluff at Memphis to the foot of the grade on the west side of the river. Comparing it with the estimate of the Three Span Bridge, there is but a slight difference in the cost. The main cost of this bridge is the great cantilever superstructure, the accurate weight of which can only be determined after working out a careful design in detail. While I fully believe that the estimate now made is ample, I think the chances of saving the 10 per cent contingency allowance are much less in this last plan than in the former, and that it is probable that the Cantilever bridge would cost $200 000 more than the Three Span Bridge.

In the matter of time the cantilever structure could probably be built a little quicker than the Three Span Bridge. The foundations for the east tower and anchorage could easily be put in this year and the east half of the structure erected during the Spring of 1888. The foundations for the west tower and anchorage could be put in in the low water season of 1888, the west half of the superstructure erected immediately thereafter and the bridge opened for traffic in the early Summer of 1889.

CONCLUSION.

Comparing the two structures when once completed, I think the Three Span Bridge would be the better one for the railroads. It would be a perfectly simple structure, the expense for maintaining which would be a minimum. It would involve no complicated details, and as it consists simply of straight trusses resting on masonry piers, would be subject to a minimum degree of disturbance should any slight settlement occur in the foundations. In brief, it would fulfill the universal requirement that the simplest structure is the best.

The Cantilever Bridge, though not conforming to the present requirements of charters, would be the better for the interests of navigation. Both bridges, however, are good enough. The spans of the Three Span Bridge would be nearly 640 feet clear, which is greater than the entire width of many important navigable rivers.

The chief difficulty in building the Three Span Bridge is in the foundation of Pier II. This must be handled at the proper season of the year and handled by men who thoroughly understand their work: that it can be put in satisfactorily admits of no doubt. The next difficulty is the erection of the three great spans. There are several solutions of this. The first is to erect in the usual way on falsework, simply having more powerful machinery than is commonly used. The difficulty of maintaining falsework here during the low water season of the fall months is no greater than at some other points where great bridges have been erected. Another method of erection would be to erect the trusses on floating falsework at a low elevation and then lift them up by hydraulic power into position. I have looked into this matter enough to satisfy myself that it can be done without serious difficulty. Under any arrangement the sinking of the foundations of Piers II and III and the erection of the three long spans must be done during the low water season.

The only real difficulty in the building of the Cantilever Bridge is the manufacture and erection of the superstructure, and the difficulties of this are simply questions of magnitude; the material will have to be handled in very large pieces, requiring powerful machinery and skillful men. As this work will be self sustaining as it goes on, it can be done at any season of the year.

I have directed Mr. Duryea to make careful observation of the high water and should recommend that he continue at Memphis for the present. When I have more full reports of the borings at the site of Pier I and other data concerning the action of floods, I shall have a further communication to make to you.

Mr. Duryea in a letter dated Feb. 11th advises me that the west shore on the bridge line has been cutting rapidly, this being apparently due to the action of waves and surface water rather than a deepening of the bottom. I think it might be expedient to build a short and inexpensive piece of dike work a little above the bridge line very soon, this being designed to prevent further cutting and to form a sand bar at the site of Pier IV.

I hope to visit Memphis again within the next three weeks and shall try to see you very soon thereafter.

Very respectfully,

GEO. S. MORISON.

APPENDIX F.

REPORT OF AUGUST 2, 1888.

New York, Aug. 2, 1888.

Geo. H. Nettleton, Esq.,

President Kansas City & Memphis Railway & Bridge Co.

Dear Sir: On February 15th, 1887, I made to you a report on the proposed bridge to be built by your Company across the Mississippi River at Memphis, Tenn.

In this report it was assumed that a bridge might be built according to the requirements of the charter then in existence, which allowed the construction of spans of a less length than appeared economical and provided for a head room of 65 feet in the clear above high water.

The Act of Congress approved April 24th, 1888, repeals the charter above referred to and authorizes your Company to build a bridge at Memphis on somewhat different conditions, there being three important changes in the requirements.

First. The minimum length of the channel span is fixed at 700 feet, subject to a report to be made by three officers from the Engineer Bureau, such report to be approved by the Secretary of War.

Second. The height in the clear above high water is fixed at 75 feet instead of 65 feet; and

Third. The bridge must be constructed to provide for the passage of wagons and vehicles of all kinds and the transit of animals.

The three engineer officers detailed for this purpose failed to agree, the senior officer recommending a clear span of 700 feet and the two junior officers of 1000 feet. All three agreed that the channel span should be next to the Tennessee shore, that the height should be 75 feet above high water and that the location described in my report of Feb. 15th, 1887, was a satisfactory location. The Secretary of War has added a long indorsement to the report of these engineers, the substance of which is covered by the last paragraph but two, which is as follows:

"Plans may be submitted by the Railway and Bridge Company, giving a main channel span on the Memphis side of the river 730 feet long in the clear at low water, and two other spans 600 feet long in the clear at low water; the end piers to be placed at low water on either shore so that the three spans will cover the entire width of the river at low water. All the necessary aids to navigation in passing under the bridge cannot now be determined; but the Railway and Bridge Company may consider the question of a guiding pier with proper guards to the bridge pier on the Memphis side for protection to navigation, or that of placing the pier on the Memphis side in 9 feet of water at the highest stage, making the long span 770 feet."

For the present, therefore, we will assume that the conditions thus prescribed by the Secretary of War are those under which the bridge will be built.

At first it appeared to me that the wiser method would be to build a 730 feet span and the "proper guards" on the Memphis side of the river. This would require a span of 750 feet between centers of piers on the east side of the river and two spans of 620 feet between centers further west. The arrangement of superstructure which then seemed most advisable was a fixed span between the two central piers, with cantilever arms projecting eastward from Pier II and westward from Pier III, the space between the west end of the west cantilever arm and Pier IV (the west pier) to be occupied by a span of about 400 feet. A similar span would extend eastward from the east end of the cantilever arm east of Pier II; but the east end of this span, instead of resting on Pier I, would be carried on the west end of a cantilever arm projecting from Pier I, this cantilever arm being balanced by an arm east of Pier I held down by an anchorage on the shore.

After laying out the plan, I found that this would involve either the construction of an unnecessarily long shore arm for the East cantilever, or the placing of the anchorage pier on the slope of the bluff, where its construction would be expensive and its security imperfect. It appeared, therefore, that the second alternative provided by the Secretary of War, namely, the 770 feet span, would not only relieve your Company of the necessity of building the guiding pier and guards, but would make the construction of both Pier I and the anchorage pier much less expensive than they would be if the 730 feet span were used.

I have, therefore, prepared a design of a bridge of this character, the east anchorage pier being located at the top of the bluff and a safe distance back from its face. The east pier (Pier I) is located so as to stand in nine feet of water at the maximum stage; that is, at station 103+30 (stations being the same as those used in my report of February, 1887). Pier II would be 790 feet west of Pier I, or at station 111+20, Pier III 620 feet farther west or at station 117+40, and Pier IV 620 feet farther on, at station 123+60, which is practically the west edge of the river. This arrangement places Pier I 70 feet farther east than Pier I of the three span bridge covered in report of February, 1887, which will somewhat reduce the cost of the pier. Pier II will be 60 feet farther west than Pier II of the former plan, which gives very slight advantage in construction. Piers III and IV are virtually unchanged.

Piers I, II and III will carry the equivalent of over 700 feet of superstructure each; but the weight of this superstructure would be concentrated on the axes of the piers, so that the piers may be made of minimum thickness. Pier IV will simply carry one end of a 450 feet span, or 225 feet of superstructure, and may be made thinner than the other piers. I have therefore estimated on making Piers I, II and III 12 feet thick, 36 feet between shoulders and 48 feet long over all under the coping, and building them with a half inch batter throughout; Pier IV to be 10 feet thick, 38 feet between shoulders, 48 feet long over all and built with the same batter. It has seemed to me best to start the masonry of Piers II and III below the ordinary bed of the river, the model form of pier having a minimum scouring effect. The result of this change of plan is to increase somewhat the amount of masonry in Piers II and III and to reduce the amount of masonry in Piers I and IV. After our experience at Cairo it has seemed best to build caissons with vertical sides, surmounted by cribwork of the same dimensions and similar construction. The foundations of Piers I and IV present no special difficulties. I have estimated on making the caisson for Pier I 30 feet by 70 feet and 60 feet high, including cribwork; this caisson to be sunk to elevation −45 (the zero being the U. S. Engineer's Gauge), stopping in a substantial clay. The caisson for Pier IV would be 26 feet by 70 feet and 70 feet high, including cribwork, and would be sunk to an elevation of −55. Piers II and III require larger caissons and much deeper sinking. The caisson for Pier II would be 45 feet by 90 feet and 55 feet high, including cribwork, and would be sunk to an elevation of −100, and that of Pier III, 40 feet by 90 feet, 50 feet high, including cribwork, and sunk to an elevation of −83. In the estimate given hereafter the same prices have been used for this work as in my report of February, 1887.

Pier I would contain 2650 yards of masonry; Pier II, 5400 yards; Pier III, 4800 yards, and Pier IV, 2100 yards, besides which there would be about 750 yards in the Anchorage Pier, making the total amount of masonry 15 600 yards, which has been carried into the estimates at $20 per yard, though I think we could undoubtedly save one dollar and probably two dollars on this price.

It will be observed that the changes in the plans have somewhat increased the cost of Piers II and III, while diminishing that of Piers I and IV.

Approximate estimates have been made of the weight of the superstructure. In these estimates no provision is made for the weight of highway traffic crossing the bridge, as it is assumed that the bridge will be closed to highway traffic while trains are crossing, but the weight of the floor will be 300 pounds more per lineal foot than that of a plain railroad floor. The approximate estimates show that the weight of the entire structure from the anchorage to Pier IV will not exceed 11 000 000 pounds. This is but little more than the weight of the three independent spans of 656 feet each; but being of a more complicated character, the cost of the shopwork would be perhaps a little higher. On the other hand, erection becomes more simple, as no falsework will be required in the channel span. At present prices the cost erected could be safely estimated at $5\frac{6}{10}$ cents per pound, but I have carried it out at the same price as before; namely, 6 cents.

The matter of the arrangement of the highway which you are now required to provide can be settled most economically by putting it on the same floor with the railroad; making this floor wide enough for two teams to pass, providing a substantial railing on each side and excluding carriages, teams and animals when trains are crossing. This arrangement is recommended only on the score of economy, but as the highway travel will be exceedingly light it is not thought that it will give you any serious trouble. I am not at all clear but what the requirements would be met by running a ferry train, but have not thought best to estimate on this. The total estimate shows that the cost of a timber floor adapted to highway traffic, with railings, etc., will be $10 per foot, or just double the cost of a roadway floor, besides which there will be the additional 300 pounds per foot added to the dead weight of the bridge.

In the matter of approaches, the East Approach, which was formerly very simple, being on the surface of the ground, is rendered much more troublesome and expensive by raising the grade ten feet. The difficulties, however, will principally relate to street crossings and the purchase of the property, the grade being generally about eight feet above the surface of the ground. As I am unable to estimate the value of the real estate required for this approach, the entire cost has been placed, as you suggested, at $100 000.

The West Approach has, as before, been supposed to be built on a grade of 1¼ per cent (66 feet per mile). The elevation of the top of the stringer at Pier IV is 114, or 80 feet above extreme high water at the bridge site. I have estimated on using an iron viaduct 4 800 feet long, the grade at the west end of it being 54, or 17 feet higher than the grade of your level track across the bottom land. West of this trestle the approach can be made in the form of an earth embankment and would connect with the present line of the Kansas City, Ft. Scott & Memphis Railroad about two miles from the end of the viaduct. At present I should advise building this viaduct in spans of 30 feet, the construction being of the simplest possible kind. For foundations I have estimated on using small masonry piers four feet square at the smallest place, the top of the masonry to be at the elevation of 39, resting on blocks of concrete nine feet square, the bottom of the concrete being at elevation 24 and being farther supported by nine piles under each pier. The estimated cost of each of these little piers, including iron anchor rods passing from concrete to top, is $285. When the piers are finished I should propose to fill around them to a uniform elevation of 37, or two feet above high water, so as to protect the foundations, piles, etc., from the action of frost and water. This would amount to building an embankment 40 feet wide and averaging perhaps eight feet high under the whole of the trestle.

The roadway approach on the east side would amount to little. On the west side, however, it will be necessary to rise from the level of the bottom land. It seems wise to do this in the cheapest possible way. This would be on a timber trestle, which, if built with a grade of six per cent., need not be more than 1200 feet long, and its cost would not exceed $10 000.

On this basis the following estimate has been prepared of the cost of the bridge as now proposed, this estimate being as nearly as possible in the same form as the estimate accompanying the report of February, 1887:

Pier I.			
2 650 c. y. Masonry at $20	$53 000		
42 000 c. ft. Caisson " 80 cts.	33 600		
84 000 " Cribwork " 40 cts	33 600		
Sinking	15 000		
		$135 200	
Pier II.			
5 400 c. y. Masonry at $20.	$108 000		
81 000 c. ft. Caisson " 80 cts	64 800		
141 750 " Cribwork " 40 cts.	56 700		
Sinking	40 000		
		269 500	
Pier III.			
4 800 c. y. Masonry at $20.	$96 000		
72 000 c. ft. Caisson " 80 cts.	57 600		
108 000 " Cribwork " 40 cts.	43 200		
Sinking	25 000		
		221 800	
Pier IV.			
2 100 c. y. Masonry at $20	$42 000		
31 200 c. ft. Caisson " 80 cts.	24 960		
78 000 " Cribwork " 40 cts	31 200		
Sinking	10 000		
		108 160	
Outfit for Foundation Work		50 000	
Protection Work, including Mats and Riprap of Piers II and III, and Shore Protection at Piers I and IV		100 000	
Anchorage		16 000	
Sloping and Finishing		2 000	
TOTAL SUBSTRUCTURE			$902 660
11 000 000 lbs. steel at 6 cts.		$660 000	
2 200 ft. floor " $10.		22 000	
Painting		6 000	
TOTAL SUPERSTRUCTURE			688 000
TOTAL BRIDGE PROPER			$1 590 660
East Approach		$100 000	
West Approach:			
3 400 000 lbs. of iron at 5 cts	$170 000		
320 Piers " $285.	91 200		
4 800 ft. floor " 5	24 000		
Painting	9 600		
75 000 c. y. Embankment at base	15 000		
Earthwork, 2 miles of road	15 000		
		324 800	
TOTAL APPROACHES			424 800
Highway Trestle on West side, 1200 ft. at $8.			9 600
Four miles of Track.			20 000
TOTAL BRIDGES AND APPROACHES			$2 045 060
Add 10% for Contingencies			204 506
Engineering			50 000
			$2 299 566

This estimate is $320 186 more than the estimate of February, 1887, or, without providing for contingencies, $291 260 more.

Under the present plan the bridge proper reaches to the east anchorage, and its length includes the east approach viaduct of the former plan, so that the cost of the bridge proper as now estimated is $31 860 more than the former estimate.

The former estimate was from the edge of the bluff at Memphis to the foot of the grade on the west side of the river. The present estimate is from a connection with the Kansas City, Fort Scott & Memphis Railroad track in Fifth Street to a Connection with the same railroad on the west side of the river, the present estimate including the following items which were not in the former estimate:

East Approach	$100 000
West Approach: Two miles of Earthwork	15 000
Four miles of Track	20 000
TOTAL	$135 000
Add 10% Contingencies	13 500
TOTAL	$148 500

So that the cost of the bridge as now designed, including all allowances, is $171 686 more than the former estimate. This practically represents the additional cost of the requirements which Congress and the Secretary of War now insist upon.

I have prepared a revised plan of the bridge which I expect to submit personally to the Secretary of War on Friday the 3d inst. A copy of this plan accompanies this report. Of course you will not be ready to begin work until this plan has been formally approved, and it will then be too late to do much work in the river this season. If, however, you have determined on building the bridge, I would ask you to give us the authority to put in the foundation of Pier IV this year, and to purchase the steamer BERTRAM, now furnished with a complete pneumatic outfit, which has been used at Rulo and Nebraska City Bridges. The total amount which would be expended for this foundation and the steamer would be less than $100 000. My idea would be to sink this foundation to the final depth and then sink a test pit within the caisson (as was done at Rulo) and thus determine the character of the lower clays on which the river piers are to be founded. The result of this examination might lead to a very material saving in the cost of the river foundations, as this proved to be the case at Rulo.

If this authority is given, I should propose to do no other work at Memphis until 1889, but to prepare the plans of the two river piers with the utmost possible care, and to put in these two foundations during the low water season in the latter part of 1889. The foundation of Pier I could then be put in at any time and the masonry completed by the summer of 1890. The central span (from Pier II to Pier III) should be erected during the low water season of 1890, and the remainder of the work would be independent of stages of water. I should hope to open the bridge in the early part of 1891.

As to the conduct of the work, my present judgment is that it would not be wise to put in any of the foundations by contract, as the contingencies (that is, in the matter of cost) are so great that any contractor would feel obliged to make his estimates on a basis which would leave him very large profits should everything work well. After the completion of the foundation for Pier IV, it may appear wise to do the work by contract, but my impression is otherwise.

All other parts of the work, including both masonry and superstructure, I should advise letting by contract.

Very respectfully yours,

GEO. S. MORISON.

APPENDIX G.

ARGUMENT FOR AMENDMENT OF CHARTER.

The Kansas City & Memphis Railway & Bridge Co. is now constructing a bridge across the Mississippi River at Memphis, Tenn. The construction of this bridge was authorized by an Act of Congress approved April 24, 1888, and the bridge is being built in accordance with plans which were approved by the Secretary of War in the same year.

The bridge crosses the Mississippi River with three spans, the span next to the Tennessee shore being 770 feet long in the clear and the other two spans 600 feet long. The actual length of the spans between centers of piers is 790 feet and 5 inches and 621 feet. These spans are without precedent for railroad bridges, except in the single case of the Forth Bridge in Scotland and the Suspension Bridge across the Niagara River, both bridges constructed under circumstances so unlike those of the Memphis Bridge that they cannot be considered as precedents. The long span of 770 feet in the clear is about 100 feet longer than the National Capitol at Washington.

The charter requires this bridge to be 75 feet above high water, which is 22 feet higher than has ever been required for any bridge previously built across any of the western rivers, the greatest height being the requirement for the Ohio River, which is 53 feet above high water.

The four piers of the bridge are now in process of construction. The shore pier on the Tennessee side is begun. The caisson for the first channel pier (the deepest foundation) has been sunk more than 84 feet below low water to the hard clay which underlies the alluvial deposit and is now within 12 feet of its final depth. The caisson for the second channel pier is completed and is now being sunk, being already 50 feet below low water. The foundation of the fourth pier near the Arkansas shore is finished and the masonry has been built above high water.

No objection is raised to the length of span required. The plans of the superstructure are nearly completed, and the work has been contracted for on the basis of the length of spans named above. In spite of the extraordinary length of these spans and the consequent additional cost, no attempt will be made to have the lengths reduced. The condition of the foundation work is conclusive evidence of this.

The height of 75 feet above high water seems, however, to be an unnecessary requirement, and it is earnestly desired to have this height reduced from 75 to 65 feet, which last height it is believed will accommodate the river traffic as well as the greater height now required.

The Kansas City & Memphis Railway & Bridge Co. therefore desires that the following amendatory act should be passed:

AMENDATORY ACT.

An Act amendatory of an act to authorize the construction of a bridge across the Mississippi River at Memphis, Tenn., approved April twenty-fourth, eighteen hundred and eighty-eight.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, that Section 3 of the Act entitled "An Act to Authorize the Construction of a Bridge Across the Mississippi River at Memphis, Tenn.," approved April twenty-fourth, eighteen hundred and eighty-eight, be, and the same is hereby amended by striking out the words "seventy-five," and substituting the words "sixty-five," so as to make said section read as follows:

"Sec. 3. That the said bridge shall be made with unbroken and continuous spans. Before approving the plans for said bridge the Secretary of War shall order three engineer officers from the Engineer Bureau to be detailed to the duty of examining by actual inspection the locality where said bridge is to be built, and to report what shall be the length of the main channel span and of the other spans: *Provided*, That the main channel span shall in no event be less than seven hundred feet in length, or the other spans less than six hundred feet each in length; and, if the report of said officers shall be approved by the Secretary of War, the spans of said bridge shall be of the length so required. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstruction; and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge; and in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States within whose jurisdiction any portion of said obstruction or bridge may be located: *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operation of the same."

Sec. 2. The right to amend or repeal this act is hereby expressly reserved.

OBJECTIONS TO 75 FEET HEAD ROOM.

Besides the increased cost involved, there are two very serious objections to the requirement of 75 feet clear head room.

The first of these lies in the fact that it involves the lifting of the entire traffic which will cross the bridge ten feet higher than a head room of 65 feet would require, and that this represents so much increased expenditure for power and fuel, with a corresponding increase in cost, which must ultimately be borne by the shipper and producer.

The second objection, which is a more serious one, lies in the fact that this height will bring the eastern approach to the bridge about ten feet above the level of the bluff on which the city of Memphis is built, which will interfere with the existing arrangement of streets, and also require a grade on the approach up which it will be necessary to work engines in a manner which is objectionable and disagreeable within a city, and is a source of danger to frame buildings, of which there are many in this part of Memphis.

If the height of the bridge could be fixed at 65 feet instead of 75 feet, all these difficulties would be entirely avoided.

FIRST MEMPHIS BRIDGE CHARTER.

The first charter for a bridge across the Mississippi River at Memphis was granted by an act to authorize the construction of a bridge across the Mississippi River at Memphis, Tennessee, approved February 26th, 1885. This charter fixed the length of the channel spans at not less than five hundred and fifty feet and required the height of the lowest part of the superstructure to be at least sixty-five feet above extreme high water mark.

Section 3 of this act reads as follows:

"Sec. 3. That said bridge shall be made with unbroken and continuous spans; two spans thereof shall not be less than five hundred and fifty feet in length in the clear, and no span shall be less than three hundred feet in the clear. The lowest part of the superstructure of said bridge shall be at least sixty-five feet above extreme high water mark, as understood at the point of location, and the bridge shall be at right angles to and its piers parallel with the current of the river. No bridge shall be erected or maintained under the authority of this act which shall at any time substantially or materially obstruct the free navigation of said river; and if any bridge erected under such authority shall, in the opinion of the Secretary of War, obstruct such navigation, he is hereby authorized to cause such change or alteration of said bridge to be made as will effectually obviate such obstructions, and all such alterations shall be made and all such obstructions be removed at the expense of the owner or owners of said bridge. And in case of any litigation arising from any obstruction or alleged obstruction to the free navigation of said river, caused or alleged to be caused by said bridge, the case may be brought in the circuit court of the United States in which any portion of said obstruction or bridge may be located: *Provided further*, That nothing in this act shall be so construed as to repeal or modify any of the provisions of law now existing in reference to the protection of the navigation of rivers, or to exempt this bridge from the operations of the same."

Had the Kansas City & Memphis Railway & Bridge Co. built its bridge under this charter, the longest span which it would be required to build would have been fifty feet shorter than the shortest span in the bridge it is now building, and the head room of the bridge would have been ten feet less than the height now required.

REPORT OF BOARD OF ENGINEERS UPON GENERAL BRIDGE LAW.

A bill was introduced in the Fiftieth Congress known as "Senate Bill 275," to authorize the construction of bridges across the Missouri between its mouth and the mouth of the Dakota or James River, and across the Mississippi River between St. Paul, Minn., and Natchez, Miss., and across the Illinois River between its mouth and La Salle, Ill. This bill was referred to a Board of Engineers who made their report on February 23d, 1888. This report is printed, being Senate Executive Document No. 120, 50th Congress, 1st Session. It is also printed in full in the Report of the Chief of Engineers, U. S. A., for 1888.

In this report (page 9) they say:

"The Board feel well assured that, by the use of well known appliances, the upper portions of steamboat chimneys can be lowered to the level of the pilot houses, and as the clear head room they have recommended will pass the pilot houses of the largest boats on the river, they consider that the slight delay which may accompany this operation of lowering the chimneys will be far less onerous to navigation than the great danger and difficulty which must of necessity attend an attempt to pass through a narrow draw opening at high stages of water."

In other words, the Board recognized the fact that smoke stacks can be so easily lowered that it is unwise to insist on bridges being built so as to give the height necessary for boats to pass without lowering their smoke stacks.

In the same report three lists of boats are given (pages 36, 40 and 41) in which the heights of pilot houses and of smoke stacks are noted.

The first is a list of Ohio River coal tow boats. In this list the greatest height of pilot house is 55 feet, the greatest height of chimney 88 feet. These boats pass through bridges 53 feet above high water, and though complaints have been made of the length of spans, no complaints are made of the height above water.

The second list is a list of the St. Louis and New Orleans Anchor Line boats, the largest passenger packets now running on the Mississippi River. The highest pilot house is 65 feet and the highest smoke stack 92 feet. As a matter of fact the height of the pilot house would be reduced to 60 feet by the removal of unnecessary ornamentation, and the smoke stacks are only four feet higher than the smoke stacks of boats on the Ohio River which pass under 53 feet bridges.

The third list is a list of the tow boats of the St. Louis & Mississippi Valley Transportation Co., the highest pilot house being 52 feet and the highest smoke stack 75 feet. These boats are among the most powerful boats which ever ran on the Mississippi River.

The Board of Engineers returned the proposed General Bridge Law with certain amendments, Section 18 of the bill as recommended by this Board reading as follows:

"Sec. 18. That all bridges authorized by this act over the Mississippi River between the mouth of the Ohio River and Natchez, Mississippi, shall be high bridges with unbroken and continuous spans, having at least one channel span of not less than six hundred and fifty feet clear channel way, all other spans over the water-way to have a clear channel way of not less than five hundred feet; and all said spans shall have a clear head room of not less than seventy feet above high water mark."

It appears to have been the conclusion of this Board that a height of five feet more than the height of the highest pilot house of which they had any record was ample for any portion of the Mississippi River. The Report of this Board of Engineers was based on a height of pilot house measured to the top of ornamentation instead of to the top without ornament, which is the correct measurement. This discrepancy probably occurred from the fact that the Board of Engineers, having a limited time at their command, took the heights as given by the steamboat owners instead of having them specially measured, and the character of the upper five or six feet was thus overlooked.

OBSERVATION OF HEIGHTS OF STEAMBOATS.

With the view of obtaining the most recent information, a special agent was sent down the Mississippi River from St. Louis to New Orleans and return with instructions to examine every boat on the river and report upon her principal dimensions. This trip was made in November and December, 1889.

While the report of this special agent only covers those boats which were in actual service at the time of his trip, it practically includes every boat now running on the Mississippi River except the Ohio River boats, all of which pass under bridges only 53 feet above high water.

A list of the boats measured by this agent with their principal dimensions is given in the Appendix, the boats being arranged in the order of the height of their pilot houses without including ornaments.

The pilot houses of the western river boats as now built are surmounted by a wooden ornament of absolutely no use, several feet higher than the flat roof of the pilot house. The smoke stacks are also ornamented on top, the ornamentation being often in the form of an open work resembling the feathered head dress of an Indian. In some instances this ornamentation is of solid form, and may be considered an extension of the smoke stack; generally it is only ornamental.

The results of this agent's examinations show that there are only about six steamboats on the Mississippi River whose pilot houses including ornamentation are more than 60 feet high, and that there is not a single boat on which the pilot house without ornamentation is 60 feet high, while there are only six boats in which the height of pilot houses without ornamentation is more than 55 feet.

COMPARISON WITH REQUIREMENTS ON TRIBUTARY RIVERS.

The laws under which the two bridges at St. Louis have been built require a head room of 50 feet in the clear above high water, which high water has been interpreted as the height of the St. Louis City Directrix, with an allowance in the case of the new Merchants' Bridge for the slope of the river. The St. Louis City Directrix is 7.6 feet below the extreme high water of 1844, thus making the actual requirement above extreme high water 42.4 feet.

The bridges on the lower Ohio River were built under the provisions of an Act supplementary to an act approved December seventeenth, eighteen hundred and seventy-two, entitled "An Act to authorize the construction of bridges across the Ohio River and to prescribe the dimensions of the same. Approved, February fourteenth, 1883." The closing part of Section 2 of this Act reads as follows:

"*Provided further*, That in lieu of the high draw prescribed above, bridges over the Ohio River below the Covington and Cincinnati Suspension Bridge may be built as continuous bridges with a clear height of fifty-three feet above local highest water, measured to the lowest part of the channel span."

The bridge across the Ohio River at Cairo within four miles of the mouth of the Ohio River, under which every boat passing from the Ohio River to the Mississippi must go, is built in accordance with this law. It is 53 feet above high water, and the range between high and low water at the site of the bridge as determined by the Chief of Engineers is 52.2 feet, making the total height of the bridge 105.2 feet above low water.

At Memphis the range between low and high water is 36 feet, and the requirement of 75 feet head room is not only 22 feet more than is required at Cairo above high water, but corresponds to 5.8 feet more than is required at Cairo above low water.

CONCLUSIONS.

The general conclusions which may be drawn are:

First. It is an established fact that the lowering of smoke stacks is a small matter, which is so easily accomplished that it is unjust to require bridge companies to raise their bridges to a sufficient height to enable boats with high stacks to pass through without lowering.

Second. The boats on the Ohio River are now fitted with hinges for lowering their stacks, and the boats on the Mississippi River could easily adopt the same appliances.

Third. The greatest height of pilot houses is ten feet less than the height required for the Memphis Bridge; and the greatest height of pilot houses without ornamentation, which is the only proper measurement, is fifteen feet less than the height now required.

Fourth. The Kansas City & Memphis Railway & Bridge Co. is building a bridge which from length of its spans and the other general features will form less of an obstruction to navigation than any bridge yet built on any western river.

Fifth. The plan of this bridge in the matter of spans meets the conditions of the General Bridge Law recommended by the Board of Engineers in their Report of February 23d, 1888. The requirements of the act under which the bridge is being built call for five feet more head room than was deemed necessary by such Board of Engineers, and the Report of this Board of Engineers was based on a height of pilot house measured to the top of ornamentation instead of to the top without ornament.

Sixth. A height of SIXTY-FIVE feet would meet all reasonable requirements of navigation and remove from the bridge certain features which are very objectionable both to the bridge company and to the residents of the adjacent portion of the city of Memphis.

GEO. S. MORISON,
Ch. Engr. K. C. & M. R. & B. Co.

CHICAGO, Jan. 4th, 1890.

APPENDIX.

TABLE OF STEAMBOATS ON LOWER MISSISSIPPI RIVER DEC. 1889, ARRANGED ACCORDING TO HEIGHT OF PILOT HOUSE.

ALL HEIGHTS ON BASIS OF BOATS BEING LIGHT.

Name of Boat.	Port.	Line.	When Built.	Kind of Wheel.	Tonnage.	Length.	Height of Stack without Ornament.		Height of Stack with Ornament.		Height of Pilot House without Ornament.		Height of Pilot House with Ornament.	
						FEET.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.
Oliver Bierne	New Orleans	Plan. & Mer. Pk. Co.	1886	Side.	1117.78	267.	78	10	83	10	59	9	94	9
City of St Louis	St Louis	Anchor	1883	"	1565.17	300.	84	2	91	2	59	7	62	7
City of New Orleans	"	"	1881	"	1586 28	290.	83	1	90	1	58	5	62	5
City of Baton Rouge	"	"	1881	"	1603.96	280.	83	3	90	3	57	2	62	2
Jesse K. Bell	New Orleans	Plan. & Mer Pk Co.	1879	"	921.60	219.4	82	6	86	6	56	6	65	6
City of Vicksburg	St. Louis	Anchor	1881	"	1356.52	273.7	79	2	86	2	55	10	60	10
Arkansas City	"	"	1882	"	1236 99	273.7	79	5	86	5	54	8	57	8
City of Providence	"	"	1880	"	1303.81	273.1	79	3	86	3	54	8	57	8
Pargoud	Louisville	Planters Pk. Co.	1884	Stern	711.94	242.	70	11	77	11	54	4	59	3
Paul Tulane	New Orleans	Plan & Mer. Pk. Co.	1888	"	617.03	210.	68	4	73	4	54	3	58	3
Belle of Memphis	St. Louis	Anchor	1880	Side.	1222.80	267.	80	9	87	9	54	3	57	3
City of Monroe	"	"	1887	"	1038.25	275.	79	0	86	0	54	0	57	0
Guiding Star	Cincinnati	U. S. Trans. Co.	1878	Stern.	1121.97	304.	70	10	74	10	53	1	56	1
City of Cairo	St. Louis	Anchor	1887	Side.	1266.12	271.2	81	5	88	5	52	9	55	9
Crystal City	"	"	1887	"	787.43	234.	72	9	78	9	52	4	56	4
James Lee	Memphis	Lee Line	1879	"	747.94	237.	68	0	75	0	52	3	55	3
Kate Adams	"	The Mem. Pk. Co.	1889	"	665.93	247.5	72	1	87	1	50	7	59	7
Warren	New Orleans	Mn. & A. Pk. Co.	1882	Stern.	316.50	184.	67	1	72	1	50	0	56	6
New South	Evansville		1887	Side.	932.95	257.	66	5	71	5	49	7	54	7
Jay Gould	St. Louis	St. L. & Miss. V. T. Co.	1880	Stern.	466.25	189.8	65	7	67	7	49	2	51	2
Laura Lee	New Orleans		1878	"	377.90	209.	71	6	72	6	48	10	52	10
H. M. Hoxie	St. Louis	St. L. & Miss. V. T. Co.	1888	"	622.30	213.	63	1	65	1	48	9	51	9
T. P. Leathers	Cincinnati	The N. & N. O. Pk. Co.	1885	"	458.60	210.	97	2	74	2	48	7	51	7
Chickasaw	Memphis	Mem. & White R. Pk. Co.	1883	"	733 90	187.	65	7	70	7	48	1	56	1
Belle of the Coast	New Orleans		1880	"	480 17	187.4	64	11	67	11	48	1	56	1
La Fanche	"		1888	"	403.	165.	64	8	69	8	48	0	52	0
St. John	Shieldsboro		1878	"	382.33	176.	66	5	72	5	48	0	52	0
Rosa Lee	Memphis	Lee Line	1887	Side	1059.71	210.	68	0	74	0	48	0	52	0
Future City	St. Louis	St. L. & Miss. V. T. Co.	1873	Stern.	589 30	187.4	72	9	74	9	47	7	52	7
De Soto	Cincinnati	Cinn. Pk Co.	1881	"	881.27	261.	58	10	60	10	47	6	50	6
Lady Lee	Memphis	Lee Line	1889	"	289.31	165.	57	5	62	5	46	8	51	8
Golden Rule	Cincinnati		1877	"	881.27	261.	65	4	70	4	46	7	49	7
Mary Z. Comeaux	St. Louis		1883	"	420.06	177.6	64	4	66	4	49	6	49	6
Whisper	New Orleans		1878	Stern.	362.	180.9	97	11	69	11	46	3	51	3
Danube	"	Red R. & Coast	1877	"	250.32	175.1	61	6	94	6	46	1	49	1
Coahoma	Memphis	Lee Line.	1876	Side.	249 51	205.2	71	2	75	2	45	1	50	1
Bald Eagle	St. Louis	St. L. & C. Pk. Co.	1879	Stern.	454.	202.	50	7	55	7	44	10	47	10
Idlewild	"	St. L. & Miss. R. Pk. Co.	1879	"	520.36	207.0	58	2	61	2	44	7	51	7
Assumption	New Orleans		1875	"	238.41	150.	63	10	65	10	44	6	48	6
John Howard	Louisville		1871	"	329.69	180.	64	4	66	4	44	6	47	9
My Choice	St. Louis	St. L. & Miss. V. T. Co.	1872	"	462.23	183.	63	0	66	0	44	0	47	0
City of Florence	"	St. L. & Tenn. R. Pk. Co.	1882	"	358.31	165.	59	6	63	6	43	9	45	9
Cherokee	"	Cherokee Pk. Co	1888	"	931 20		57	4	62	4	43	6	53	6
John Gilmore	"	St. L. & Miss. V. T. Co.	1871	"	563 09	183.	63	1	68	1	43	4	45	4
Gus Fowler	Paducah	P. & C. Pk. Co.	1889	"	309 62	160.	54	1	58	1	43	3	46	3
Sella Wilds	Wheeling		1886	"	289.12	155.	52	4	57	4	43	2	47	2
Ruth	Memphis	Lee Line	1888	"	217.90	166.	53	7	58	7	42	11	45	11
Carnal Goldman	Natchez	N. & V. Pk. Co.	1883	"	172 19		55	11	57	11	42	5	45	5
Teche	New Orleans	N. O. & B. T. Pk. Co.	1886	"	485 90	191.	63	0	67	0	42	4	47	4
Spread Eagle	St. Louis	Eagle Pk. Co.	1881	"	529.34	225.	50	4	55	4	42	1	45	1
E W. Cole	Brashear		1880	"	487.91	202.	53	8	55	8	41	3	44	3
City of Savannah	St. Louis	St. L. & Tenn. R. Pk. Co.	1889	"	335 55		59	10	65	10	41	2	44	2
E. M. Norton	"	St. L. & Miss. V. T. Co.	1875	"	549	174.	57	6	61	6	41	0	43	0
Alto	New Orleans		1879	"	363.16	166.	60	6	62	6	40	7	44	7
Joe Peters	Memphis	Mem. & Ark. Pk. Co.	1883	"	525	175.	57	6	58	6	40	0	45	0
Iron Duke	Pittsburgh		1880	"	421.25	177.	60	11	62	11	39	7	42	7
Chas. D Shaw	Natchez	N. & V. Pk. Co.	1883	"	186.03	186.3	49	10	51	10	39	4	42	4
Mable Comeaux	St. Louis		1883	"	160.06	145.	49	6	51	6	38	2	42	2
H. J. Dickey	New Orleans		1881	"	208.54	167.	56	9	57	9	37	6	39	6
Alvin	" "	N. O. & G. R. R. Co.	1877	"	291.55	143.	52	8	54	8	37	3	41	3
Hallette	" "	Red R. & Coast	1887	"	196 80	165.	53	5	55	5	36	1	39	1
John D. Scully	" "	" " " "	1878	"	285.70	218.	65	0	65	0	34	9	38	9
G W. Sentell	St. Louis	F. A. Str. B. Co.	1882	"	306.76	180.	50	10	53	10	34	8	39	8
Alice Leblanc	New Orleans		1884	"	81 97	135.	46	1	49	1	34	2	38	2
Gen'l Newton	U. S. Steamer		1878	"	263.74	160.	48	11	48	11	35	7	36	7

APPENDIX H.

ORDINANCE OF THE LEGISLATIVE COUNCIL OF THE TAXING DISTRICT OF SHELBY COUNTY, TENNESSEE, PASSED MARCH 23, 1891.

WHEREAS, the Kansas City and Memphis Railway and Bridge Company, a corporation created, organized and chartered under the laws of the State of Arkansas, has petitioned the Legislative Council of the Taxing District of Shelby County, Tennessee, for the right to construct and maintain its tracks and railroad and operate the same with its engines and cars thereon with steam or other motive power across certain streets and across, over and along certain alleys in the said Taxing District, as specified and described in a petition and map filed by the said Kansas City and Memphis Railway and Bridge Company, now on file in the office of the Taxing District of Shelby County, Tennessee; said railroad and tracks being for the purpose of furnishing an eastern approach to the bridge now being constructed by said Kansas City and Memphis Railway and Bridge Company, under an Act passed by the Congress of the United States and approved by the President of the United States, April 24, 1888, pages 92 and 93, Acts of Congress, 1888; and for the right to construct and maintain an incline for an entrance to the wagon way of said bridge, as set forth in said petition and map. Said railroad tracks and approaches are to be located across certain streets and across, over and along certain alleys, as shown by the petition and map aforesaid as follows:

"Beginning at Pier No. one (1) of said bridge near the east bank of the Mississippi River, the said east approach runs southeasterly through said Railway and Bridge Company's property to the north line of Virginia avenue, west of Delaware avenue; thence in the same direction at an angle across the extreme west end of said Virginia avenue into Block No. two (2); thence curving to the left it runs across the extreme northeast corner of said Block No. two (2) to the west line of said Delaware avenue; thence in like manner at an angle across said Delaware avenue into Block No. 3; thence across said Block No. three (3) to the west line of Indiana avenue; thence across Indiana avenue into Block No. five (5), the curve terminating about forty (40) feet east of the west line of said Block No. five (5); thence east to the west line of Arkansas avenue; thence across said Arkansas avenue, at right angles, into Block No. twelve (12); thence east through said Block No. twelve (12) to the west line of Louisiana avenue; thence east across Louisiana avenue, at right angles, into Block No. thirteen (13); thence east across said Block No. thirteen (13) to the west line of Pennsylvania avenue, upon which are located the tracks of the Citizens' Street Railway; thence east across said Pennsylvania avenue, at right angles, into Block twenty-two (22); thence across said Block No. twenty-two (22), and the alleys intersecting the same to the west line of Kansas avenue; thence across Kansas avenue to the west line of Block No. twenty-three (23); thence into and across said Block No. twenty-three (23).

The said approach from Block No. three (3) to Block No. twenty-three (23) inclusive to consist of four tracks. Also a connection line beginning in Pennsylvania avenue near the west line of Block No. twenty-two (22) and curving to the north through said Block No. twenty-two (22), and across the alleys intersecting the same, to the south side of Virginia avenue; thence across the said Virginia avenue to Block No. twenty-one (21); thence across the southeast corner of said block No. twenty-one (21) to the west side of Kansas avenue; then across and along said Kansas avenue to a connection with the tracks of the Kansas City, Fort Scott and Memphis Railroad in said Kansas avenue near the centre line of Broadway, the said connection line to consist of two tracks.

Also a second connection line, beginning in Block No. twenty-three (23) near the east line of Kansas avenue and curving to the north through said Block No. twenty-three (23) and across the alleys intersecting the same, to the west side of Kentucky avenue; thence across and along said Kentucky avenue to a connection with the tracks of the St. Louis, Iron Mountain and Southern Railway in said Kentucky avenue, the said second connection to consist of two tracks. Also a third connection line, connecting with the connection line first aforesaid in or near Virginia avenue and running thence northeastwardly across Kansas avenue to a connection with the tracks of the Kansas City, Fort Scott and Memphis Railroad, east of and near said Kansas avenue, the said third connection line to consist of two tracks." All situated, lying and being in the Tenth (10th) Ward of said Taxing District, commonly known as the City of Memphis.

Now, therefore, be it enacted and ordained by the Legislative Council of the Taxing District of Shelby County, Tennessee, as follows:

SECTION 1.—Be it enacted and ordained, That the Legislative Council of the Taxing District of Shelby County, so far as it has the legal power to do so, grants to the said Kansas City and Memphis Railway and Bridge Company the powers, rights and privileges above named and hereinafter set forth upon the express condition and agreement that the charges and tolls to be charged other railroad companies desiring to use said approaches, connections and bridge for their trains and cars may be fixed and established by the Secretary of War, under Section four (4) of the said Act of Congress, authorizing said Company to build and construct and maintain said bridge for the transportation of freight cars, passenger coaches or trains, foot passengers, etc., over said bridge and over all tracks or approaches thereto as shall be occupied by said Bridge Company, and that the right thereto shall be granted by it to every railroad company now or hereafter entering the Taxing District of Shelby County without discrimination in favor of or against any such railroad company. The word "approaches" shall include all tracks used or owned by said Bridge Company in gaining access to the bridge proper, whether included in the territory covered by the above grant or otherwise.

That in the event the Secretary of War should decline, after a lawful and apt application has been made to him under said Act of Congress by any railroad now or hereafter running into said Taxing District, to fix the rates of tolls over the bridge for the reason that he has no jurisdiction over said approaches, or for any other reason declines to act, or in case the Circuit and District Courts of the United States for the Western District of Tennessee, or the Supreme Court of the United States, or the State Courts of record of competent jurisdiction in Tennessee and having jurisdiction in Shelby County, shall decide that said Act of Congress is inoperative as to the approaches, then this Legislative Council shall have and hereby retains the right to regulate tolls from time to time over all such approaches to said bridge upon a like application by any such railroad.

And for the further consideration of the materials to be furnished, labor performed, work done, and the considerations and obligations agreed to be performed on the part of the petitioner, the Kansas City and Memphis Railway and Bridge Company, as hereinafter set out and specified, and in consideration of the promotion of the public welfare, especially that of this Taxing District, resulting from the construction, maintenance, use and operation of said bridge and said approaches thereto, and the public welfare requiring it, the said Taxing District doth hereby grant, so far as it has the legal power to do so, to the Kansas City and Memphis Railway and Bridge Company, its successors and assigns, for the period of ninety-nine years, or so long as said bridge shall remain where it is now under the sanction of the United States Government, the right and privilege to construct, maintain and operate with steam or other motive power across the streets and across, over and along the alleys above named and shown by said map, and along the route or line above and thereon described, its said railroad tracks and connecting lines, and to operate the same for the purposes stated above and as designated in the petition and map of petitioner now on file in the said office of the Taxing District.

SEC. 2. Be it further enacted and ordained, That said Railroad and Bridge Company shall pave the incline approach to the wagon way of said bridge for vehicles and general traffic with stone placed upon Tishomingo gravel the whole length thereof, being about 150 feet long and to a width of 30 feet, and maintain the same. It shall pave all crossings of streets over which its said tracks pass, between tracks and 18 inches on each side thereof, with not less than three-inch white oak plank to be full width of each street and maintain the same, and shall furnish to the Taxing District free of cost, Tishomingo gravel sufficient to cover from 10 to 12 inches deep, as the Taxing District Engineer may direct, the following four streets: Delaware, Arkansas, Indiana and Louisiana avenues for a width of 40 feet on each from the south line of Virginia avenue to the north side of Iowa avenue or Jackson street, all of which are crossed by said tracks, and also furnish all necessary wood curbing for said distances on said four avenues. All material necessary for the above shall be furnished by the said company at its own cost under the direction and supervision of the Taxing District Engineer, and all work to be done by it under this paragraph shall be under his supervision and direction.

Sec. 3. Be it further enacted and ordained, That the Taxing District is not to be chargeable or liable in any way for any of the expenditures necessary to the construction and operation of these lines of railroad, whether the same be for grading or changing of the street, drainage of the same or for other work or cause whatever in connection therewith. All expenditure, as well as damages, if any, resulting therefrom to property owners by changing, filling or cutting streets, failure to furnish and provide proper drainage or otherwise, shall as between said Taxing District and the Kansas City and Memphis Railway and Bridge Company be assumed by said Railway and Bridge Company, and the said Railway and Bridge Company agrees and hereby obligates itself to hold harmless and indemnify the Taxing District against all damages and expenditures whatever, if any shall accrue therefrom.

Sec. 4. Be it further enacted, That the Kansas City and Memphis Railway and Bridge Company in laying its tracks on and over streets shall so construct and maintain the same as to offer the least possible impediment or obstruction to the use of such streets by the general public.

Sec. 5. Be it further enacted and ordained, That it appearing that the entrance to the wagon way of said bridge is directly in front of Virginia avenue and near to the west end thereof, and that to construct a wagon road for an approach to such entrance, which will best accommodate the public, it is necessary to permanently close said Virginia avenue west of Delaware avenue; and said Railway and Bridge Company, which owns all the land on both sides of that portion of Virginia avenue, having asked that the same be closed, therefore, so far as this body can legally confer such authority, the permanent closing of said portion of Virginia avenue, for the construction therein of said approach and the occupation of said avenue thereby, is hereby authorized.

Sec. 6. Be it further enacted and ordained, That it appearing to be for the convenience of the public and of said Railway and Bridge Company in the construction, use and operation of said wagon road and other approaches, that they occupy a portion of Delaware avenue as now located at and just south of the crossing of Virginia avenue, and that the course of Delaware avenue be changed at that place by turning it northeasterly across the northwest corner of said block three (3) in the manner shown on said map and by said petition filed by said Company as aforesaid, therefore, said Railway and Bridge Company is hereby authorized, so far as this body can legally do so, to occupy said portion of Delaware avenue and to change the course thereof for said approaches, all as shown by said map and petition and as above set forth, upon its first having conveyed to said Taxing District in fee for the use of the public for a street that portion of said block three (3) to be covered by Delaware avenue when changed as aforesaid.

Sec. 7. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally do so, to construct and maintain a bridge or viaduct over said Delaware avenue as it now is and as hereby changed, where its railroad tracks cross said avenue, for the purpose of carrying said tracks, which bridge or viaduct shall be at least twelve (12) feet above the grade of said avenue as established by ordinance, and to which the surface of said street is to be depressed as hereinafter set forth.

Sec. 8. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to grade and depress the present surface of said Delaware avenue where said viaduct and tracks will cross it so as to conform to the grade of said avenue as heretofore established by ordinance.

Sec. 9. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body has the legal power to grant such authority, to construct and build an embankment of earth, eight (8) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Indiana avenue, sloping back north to the south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Indiana avenue, at the point of said crossing, heretofore adopted by said Taxing District; said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 10. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to occupy the south alley (there being two) running east and west through said Block No. 5 with one of its four (4) lines of railway hereby authorized, and may build and construct an embankment or trestle therein so as to conform to the grade of said alley heretofore adopted by said Taxing District and so as to conform to the grade so adopted on Indiana and Arkansas avenues.

Sec. 11. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct and build an embankment of earth, four and one half ($4\frac{1}{2}$) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Arkansas avenue, sloping back north to the south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Arkansas avenue, at the point of said crossing, heretofore adopted by said Taxing District, said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 12. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to build and construct an embankment or trestle, not less than four and one half ($4\frac{1}{2}$) feet, nor to exceed six and one half ($6\frac{1}{2}$) feet high, across both of the alleys running north and south in said Block No. 12, so as to conform to the grade of said alleys heretofore adopted by the said Taxing District and so as to conform to the grade so adopted on said Arkansas and Louisiana avenues.

Sec. 13. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct and build an embankment of earth, six and one half ($6\frac{1}{2}$) feet high at the highest point and forty (40) feet wide, where said bridge lines of railway cross Louisiana avenue, sloping back north to south line of Virginia avenue and south to the north line of Iowa avenue, so as to conform to the grade of said Louisiana avenue, at the point of said crossing, heretofore adopted by said Taxing District. Said embankment shall be of uniform width and constructed so as to give an easy incline from said highest point north to said Virginia avenue and south to said Iowa avenue.

Sec. 14. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to build and construct an embankment or trestle not to exceed six and one half ($6\frac{1}{2}$) feet high across both alleys (there being two) running north and south through said Block 13 so as to conform to the grade of said alleys heretofore adopted by said Taxing District and so as to conform to the grade so adopted on Louisiana and Pennsylvania avenues.

Sec. 15. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to intersect and lay its said four (4) tracks across the Citizens' Street Railway, now laid along and over Pennsylvania avenue, and across said Pennsylvania avenue, and put down all necessary iron or wooden structures in said avenue to effect said crossing, which shall be made on the grade upon which said Citizens' Street Railway is laid and heretofore adopted by said Taxing District.

Sec. 16. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to lay its connection line, which curves northwardly out of the main line and consists of two (2) lines of railway in Bloc No. 22, across the alley running east and west through said Block No. 22, and across Virginia avenue just west of Kansas avenue, and into and across said Kansas avenue so as to intersect and connect with the Kansas City, Fort Scott and Memphis Railroad and to put down all necessary iron or wooden structures to effect said connection in said Kansas avenue: all of which shall be done so as to conform to the grade of said alley and avenues heretofore adopted by said Taxing District and upon which grade said Kansas City, Fort Scott and Memphis Railroad is now laid and constructed upon said Kansas avenue.

SEC. 17. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct a second connection line curving northwardly out of the main line in said Block No. 23, which shall consist of two (2) tracks, across the alley running north and south in the eastern part of said Block No. 23 (there being two (2) such in said block), and across the alley running east and west therein, and across Virginia avenue where it intersects and crosses Kentucky avenue, into and across said Kentucky avenue so as to intersect and connect with the said St. Louis, Iron Mountain and Southern Railway laid in and along said Kentucky avenue, and to put down all necessary iron or wooden structures to effect said connection in said Kentucky avenue: all of which shall be done so as to conform with the grade of said alley and of Virginia and Kentucky avenues heretofore adopted by said Taxing District, and upon which grade said St. Louis, Iron Mountain and Southern Railway is now laid and constructed upon said Kentucky avenue.

SEC. 18. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct the third connection line, connecting with the first connection line herein authorized in or near Virginia avenue, and running thence northeasterly across Kansas avenue to a connection and intersection with the tracks of the Kansas City, Fort Scott and Memphis Railroad east of and near Kansas avenue, which third connection shall consist of two (2) lines of railway tracks, and to put down all necessary iron or wooden structures to effect said connection: all of which shall be done so as to conform with the said grade of Kansas avenue heretofore adopted by said Taxing District.

SEC. 19. Be it further enacted and ordained, That said Kansas City and Memphis Railway and Bridge Company be and it is hereby authorized, so far as this body can legally authorize it, to construct all four (4) of its railway tracks on its main line across both of the alleys running north and south through said Block No. 23, which shall be done so as to conform with the grade of said alleys heretofore adopted by said Taxing District, and upon which grade said Kansas City, Fort Scott and Memphis Railroad and said St. Louis, Iron Mountain and Southern Railroad are constructed and built.

SEC. 20. Be it further enacted and ordained, That the said map filed by the said Kansas City and Memphis Railway and Bridge Company in said office of said Taxing District be and the same is hereby accepted as showing the true line of the tracks for permanent right of way, four (4) in number on the main line and the connection lines aforesaid each consisting of two tracks, for all which rights are hereby granted, and the same is hereby adopted and made part of this ordinance. And it is the true intent and meaning of this grant to give to said Railway and Bridge Company, but only as far as this body has the legal power to do so, and subject to the limitations and restrictions herein set forth, the right to construct, maintain and operate with steam or other motive power said lines of railroad and connections over and across the streets and over, across and along the alleys as shown on said map so referred to and made a part hereof.

SEC. 21. Be it further enacted and ordained, That no sufficient reason or objection having been found or made by any person for rescinding, repealing, amending or modifying the ordinance passed and approved by the Legislative Council on the 12th day of February, 1891, adopting the grade as established by the Taxing District Engineer on Virginia, Delaware, Indiana, Arkansas, Louisiana, Pennsylvania, Kansas and Kentucky avenues and alleys thereby shown at the points therein and thereby designated, and the plat or map or profile of said grades so established and adopted having been on file for more than thirty (30) days in the office of the Taxing District Engineer, and in the office of said Taxing District for the said period of time, all of which was published for more than 30 days in the "Evening Scimitar," a newspaper published daily in the said Taxing District and having a general circulation therein, said grades on said avenues and alleys are now finally adopted, approved, established and made binding.

SEC. 22. Be it further enacted and ordained, That the Taxing District makes the grant and confers the powers and privileges herein specified only so far as it has power to do, and no further, and the Kansas City and Memphis Railway and Bridge Company takes all the risk of the questions of power and agrees to be responsible therefor and to indemnify and hold harmless the Taxing District against all claims against it arising out of the privileges herein granted, if there should be any.

SEC. 23. It is further enacted that said Railway and Bridge Company shall at its own cost, whenever so directed by an ordinance of said Taxing District, put up at any one or all of the street crossings hereby contemplated, an electric light or railroad gate, or station a flagman, and maintain the same at its own cost, but said Taxing District shall not require any two of the above precautionary measures at any one of the said street crossings. This clause shall not, however, be construed as a release of any of the police powers of the said Taxing District now authorized by law, but said police power is by it retained expressly over the entire grant hereby made.

SEC. 24. Be it further enacted and ordained, That as evidence of the assent of said Railway and Bridge Company to the terms of this ordinance it shall execute a contract with said Taxing District embracing the provisions of this ordinance, which contract shall also be executed by the officers of said Taxing District in duplicate, one copy to be held by each of the parties thereto.

SEC. 25. Be it further enacted, That should the said Kansas City and Memphis Railway and Bridge Company fail to comply with all or any of the terms and conditions imposed upon it in this ordinance, then the rights, grants and privileges herein given may be at the option of the Legislative Council of the Taxing District declared cancelled and inoperative and thereafter cease to exist.

Passed March 23, 1891.

J. T. PETTIT,
Vice President.

Attest:
HENRY J. LYNN, Secretary.

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER I.

Date.	Principal Foreman.		Night Foreman.		Sub-Foremen.		Lock Tenders.		Pressure Men.		Coffee House Men.		Coffee.		Sugar.		Candles.		Coal for Heating.		Sacking Out and Clay Hoist Men		Master Mechanic and Day Engineer		Night Engineer	
1890.	Days	Amt.	Days	Amt.	Days	Amount.	Days	Amt.	Hrs.	Amount.	Days	Amt.	Lbs.	Amt.	Lbs.	Amt.	No.	Amt.	200-lb. Boxes.	Amt.	Hrs	Amount.	Hrs.	Amt.	Hrs.	Amt.
Jan. 9	1	5.00	1	4.00	1	3.00	1	3.00	96	24.00	1	1.50	1	.26	...	...	...	...	1	0.28	20	4.00	15	4.80	12	3.60
" 10	1	5.00	1	4.00	3	9.00	2	4.00	328	82.00	2	3.00	7	1.82	4	0.26	12	0.29	2	0.56	88	17.60	15	4.80	12	3.60
" 11	1	5.00	1	4.00	3	9.00	2	4.00	336	84.00	2	3.00	7	1.82	5	0.31	2	0.04	2	0.57	78	15.60	15	4.80	12	3.60
" 12	1	5.00	1	4.00	3	9.00	2	4.00	332	82.80	2	3.00	7	1.82	4	0.26	3	0.07	2	0.56	78	15.60	15	4.80	12	3.60
" 13	1	5.00	1	4.00	3	9.00	2	4.00	336	84.00	2	3.00	9	2.34	5	0.32	3	0.07	2	0.57	78	15.60	15	4.80	12	3.60
" 14	1	5.00	1	4.00	3	9.00	2	4.00	344	86.00	2	3.00	9	2.33	5	0.31	...	...	2	0.56	69	13.80	15	4.80	12	3.60
" 15	1	5.00	1	4.00	3	9.00	2	4.00	336	84.00	2	3.00	6	1.56	5	0.32	2	0.04	2	0.57	78	15.60	15	4.80	12	3.60
" 16	1	5.00	1	4.00	3	9.00	2	4.00	324	81.00	2	3.00	10	2.59	5	0.31	...	...	2	0.56	66	13.20	15	4.80	12	3.60
" 17	1	5.00	1	4.00	2	6.00	2	4.00	240	60.00	2	3.00	6	1.56	5	0.32	2	0.05	2	0.57	50	10.00	15	4.80	12	3.60
" 18	...	...	1	4.00	...	...	2	4.00	...	...	2	3.00	...	...	...	...	...	...	...	...	...	...	15	4.80	12	3.60
" 19	...	...	1	4.00	...	...	2	4.00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17	5.60	...	...
Feb. 14	...	...	1	4.00	2	6.00	2	4.00	220	55.00	2	3.00	7	1.82	1	0.06	3	0.07	1	0.28	43	8.00	15	4.80	12	3.60
" 15	1	5.00	1	4.00	2	6.00	2	4.00	376	94.00	2	3.00	6	1.56	6	0.38	1	0.02	2	0.56	92	17.85	15	4.80	12	3.60
" 16	1	5.00	1	4.00	3	9.00	2	4.00	336	84.00	2	3.00	6	1.56	3	0.19	...	...	2	0.57	92	17.85	17	5.60	12	3.60
" 17	1	5.00	1	4.00	3	9.00	3	6.00	423	105.40	2	3.00	7	1.82	3	0.19	2	0.04	2	0.56	92	17.85	28	8.80	24	7.20
" 18	1	5.00	1	4.00	3	9.00	3	6.00	492	123.00	2	3.00	9	2.34	4	0.26	1	0.02	2	0.57	85	16.85	28	8.80	24	7.20
" 19	1	5.00	1	4.00	3	9.00	3	6.00	520	130.00	2	3.00	7	1.82	4	0.26	...	...	2	0.56	85	16.85	28	8.80	24	7.20
" 20	1	5.00	1	4.00	3	9.00	3	6.00	528	132.00	2	3.00	7	1.82	7	0.44	2	0.04	2	0.57	139	26.15	28	8.80	24	7.20
" 21	1	5.00	1	4.00	3	9.00	3	6.00	532	133.00	2	3.00	7	1.82	6	0.38	3	0.07	2	0.50	92	18.45	28	8.80	24	7.20
" 22	1	5.00	1	4.00	3	9.00	3	6.00	512	128.00	2	3.00	9	2.33	7	0.44	2	0.05	2	0.57	92	18.45	28	8.80	24	7.20
" 23	1	5.00	1	4.00	3	9.00	3	6.00	500	125.00	2	3.00	7	1.82	6	0.38	1	0.03	2	0.56	92	18.45	30	9.60	24	7.20
" 24	1	5.00	1	4.00	3	9.00	3	6.00	512	128.00	2	3.00	7	1.82	6	0.38	1	0.02	2	0.57	87	17.45	28	8.80	24	7.20
" 25	1	5.00	1	4.00	3	9.00	3	6.00	472	118.00	2	3.00	6	1.56	7	0.44	2	0.04	2	0.56	92	18.45	28	8.80	24	7.20
" 26	1	5.00	1	4.00	3	9.00	3	6.00	504	126.00	2	3.00	7	1.82	5	0.31	3	0.07	2	0.57	92	18.45	28	8.80	24	7.20
" 27	1	5.00	1	4.00	3	9.00	3	6.00	264	66.00	2	3.00	7	1.82	6	0.38	3	0.07	2	0.56	92	18.45	30	9.60	24	7.20
" 28	1	5.00	1	4.00	3	9.00	3	6.00	288	72.00	2	3.00	7	1.82	5	0.31	2	0.04	1	0.28	104	21.85	28	8.80	24	7.20
March 1	1	5.00	1	4.00	3	9.00	3	6.00	492	123.00	2	3.00	6	1.56	5	0.32	1	0.02	1	0.29	92	18.45	28	8.80	24	7.20
" 2	1	5.00	1	4.00	3	9.00	3	6.00	520	130.00	2	3.00	9	2.34	7	0.44	2	0.05	1	0.28	92	18.45	28	8.80	24	7.20
" 3	1	5.00	1	4.00	3	9.00	3	6.00	520	130.00	2	3.00	9	2.33	7	0.44	3	0.07	1	0.28	92	18.45	28	8.80	24	7.20
" 4	1	5.00	1	4.00	3	9.00	3	6.00	504	126.00	2	3.00	9	2.34	7	0.44	1	0.03	1	0.28	26	4.90	28	8.80	24	7.20
" 5	1	5.00	1	4.00	3	9.00	3	6.00	520	130.00	2	3.00	6	1.56	3	0.19	1	0.02	1	0.29	...	...	28	8.80	24	7.20
" 6	1	5.00	1	4.00	3	9.00	3	6.00	528	132.00	2	3.00	7	1.82	4	0.26	1	0.02	1	0.28	...	...	28	8.80	24	7.20
" 7	1	5.00	1	4.00	3	9.00	3	6.00	492	123.00	2	3.00	9	2.33	7	0.44	7	0.16	1	0.28	...	...	28	8.80	24	7.20
" 8	1	5.00	1	4.00	3	9.00	3	6.00	496	124.00	2	3.00	9	2.34	7	0.44	...	...	2	0.57	...	...	28	8.80	24	7.20
" 9	1	5.00	1	4.00	3	9.00	3	6.00	464	116.00	2	3.00	9	2.33	7	0.44	4	0.09	1	0.28	...	...	16	5.20	12	3.60
" 10	1	5.00	1	4.00	3	9.00	3	6.00	488	122.00	2	3.00	7	1.82	7	0.44	...	...	1	0.29	...	...	28	8.80	24	7.20
" 11	1	5.00	1	4.00	3	9.00	3	6.00	488	122.00	2	3.00	10	2.59	4	0.20	1	0.03	1	0.28	60	10.95	28	8.80	24	7.20
" 12	1	5.00	1	4.00	4	12.50	3	6.40	495	181.80	3	4.50	9	2.34	6	0.38	4	0.10	1	0.28	96	16.90	28	8.80	24	7.20
" 13	1	5.00	1	4.00	4	13.60	3	7.20	540	216.00	3	4.50	6	1.56	7	0.44	...	...	1	0.29	96	16.90	28	8.80	24	7.20
" 14	1	5.00	1	4.00	5	15.75	2	4.80	567	226.80	3	4.50	6	1.56	7	0.44	...	...	2	0.56	192	33.70	28	8.80	24	7.20
" 15	1	5.00	1	4.00	5	15.75	2	4.80	555	222.00	3	4.50	9	2.33	8	0.50	4	0.09	2	0.57	144	25.30	28	8.80	24	7.20
" 16	1	5.00	1	4.00	5	15.75	2	4.80	552	220.80	3	4.50	10	2.59	8	0.50	...	...	2	0.56	192	33.70	28	8.80	24	7.20
" 17	1	5.00	1	4.00	5	15.75	2	4.80	516	206.40	3	4.50	9	2.34	8	0.50	...	...	2	0.57	153	27.40	28	8.80	24	7.20
" 18	1	5.00	1	4.00	4	13.00	2	4.80	537	214.80	3	4.50	9	2.33	8	0.50	2	0.04	2	0.56	192	34.30	28	8.80	24	7.20
" 19	1	5.00	1	4.00	4	13.00	2	4.80	539	215.60	3	4.50	9	2.34	8	0.50	6	0.14	2	0.57	192	34.30	28	8.80	24	7.20
" 20	1	5.00	1	4.00	4	13.00	2	4.80	528	211.20	3	4.50	7	1.82	8	0.50	6	0.14	2	0.56	192	34.30	28	8.80	24	7.20
" 21	1	5.00	1	4.00	4½	14.12	2	4.80	438	175.20	3	4.50	9	2.33	8	0.50	8	0.19	2	0.57	192	33.70	15	4.80	12	3.60
" 22	1	5.00	1	4.00	5	15.75	2	4.80	426	170.40	3	4.50	9	2.33	4	0.26	1	0.02	2	0.56	192	33.70	15	4.80	12	3.60
" 23	1	5.00	1	4.00	5	15.75	2	4.80	423	169.20	3	4.50	9	2.33	6	0.38	1	0.02	2	0.57	192	33.70	15	4.80	12	3.60
" 24	1	5.00	1	4.00	5	15.75	2	4.80	414	165.60	3	4.50	7	1.82	6	0.38	5	0.12	2	0.56	192	33.70	16	5.20	12	3.60
" 25	1	5.00	1	4.00	5	15.75	2	4.80	420	168.00	3	4.50	7	1.82	5	0.31	3	0.07	2	0.57	192	33.70	15	4.80	12	3.60

Date.	Pump Men.		Firemen.		Coal Passers.		Coal for Boilers.		Black Oil.		Cylinder Oil.		Waste.		Totals for Each Day.	Feet Sunk Each Day.	Material.	Water Pump.			Rev. of Air p'ps.	Remarks.
1890.	Hrs.	Amt.	Hrs.	Amt.	Hrs	Amt.	Tons.	Amount.	Gals	Amt.	Gals.	Amt.	Lbs	Amt				Hours Run.	Rev.	Pres.		
Jan. 9	...	...	24	3.60	18	2.70	2.97	8.54	½	0.05	3	1.11	2	0.12	69.56	2.54	Sand, gravel, clay	6.16	41	45	36	Started air comp. at 10.45 p.m.
" 10	...	...	24	3.60	24	3.60	10.74	30.49	2	0.22	...	...	3	0.18	174.02	0.03	" " "	22.16	38	61	42	Started water pumps at 1 a.m.
" 11	...	...	24	3.60	24	3.60	12.18	34.50	2	0.22	...	...	3	0.18	177.00	0.46	" " "	23.00	38	81	36	
" 12	...	...	24	3.60	24	3.60	12.03	34.13	2	0.22	...	...	2	0.12	176.18	0.31	" " "	23.00	35	83	35	
" 13	...	...	24	3.60	24	3.60	12.03	34.14	2	0.22	...	...	3	0.18	178.04	0.47	" " "	22.33	46	86	30	
" 14	...	...	24	3.60	24	3.60	8.44	23.00	2	0.22	...	...	3	0.18	167.99	0.10	" " "	23.75	43	90	30	
" 15	...	...	24	3.60	24	3.60	13.33	37.80	2	0.22	...	...	2	0.12	180.83	1.33	" " "	23.83	49	86	25	
" 16	...	...	24	3.60	24	3.60	13.47	38.20	2	0.22	...	...	3	0.18	176.86	0.50	" " "	23.50	46	82	25	
" 17	...	...	24	3.60	24	3.60	11.60	32.92	2	0.22	...	...	3	0.18	143.42	1.58	" " "	14.92	41	91	26	
" 18	...	...	24	3.60	24	3.60	4.70	13.43	2	0.22	...	...	2	0.12	40.37	0.48	Sand and gravel	...	...	...	25	
" 19	...	...	24	3.60	24	3.60	3.40	9.75	2	0.22	...	...	3	0.18	30.95	0.13	" " "	...	...	...	26	Air pressure taken off at 2.45 p.m.
Feb. 14	24	4.80	24	3.60	24	3.00	7.43	21.14	2	0.22	...	...	4	0.24	124.23	...	Sand and gravel	14.50	38	99	34	Air pressure applied at 3 p.m.
" 15	24	4.80	24	3.60	24	3.00	19.65	55.66	2	0.22	...	...	3	0.18	212.83	0.47	" " "	22.50	34	99	34	
" 16	24	4.80	24	3.60	24	3.60	11.64	33.03	2	0.22	...	...	4	0.24	183.86	0.08	" " "	24.00	36	97	31	Sacking out gravel.
" 17	24	4.80	48	7.20	48	7.20	20.66	58.52	2	0.22	...	...	3	0.18	246.98	0.69	" " "	39.25	36	93	34	
" 18	24	4.80	48	7.20	48	7.20	17.50	49.58	2	0.22	...	...	3	0.18	255.22	0.31	" " "	35.33	37	93	32	Put on one clay hoist.
" 19	24	4.80	48	7.20	48	7.20	19.08	54.05	2	0.22	...	...	3	0.18	266.14	1.50	" " "	47.33	38	93	34	Started comp. on Lincoln at 7.20 [a m.
" 20	24	4.80	48	7.20	48	7.20	16.06	45.52	2	0.22	...	...	3	0.18	269.14	0.64	" " "	38.82	41	94	36	Sacking out gravel.
" 21	24	4.80	48	7.20	48	7.20	15.34	43.48	2	0.22	...	...	3	0.18	260.36	0.53	" " "	48.00	37	88	35	Started clay hoist.
" 22	24	4.80	48	7.20	48	7.20	26.41	74.76	2	0.22	...	...	4	0.24	287.26	1.93	" " "	46.75	40	85	37	
" 23	24	4.80	48	7.20	48	7.20	24.40	69.08	2	0.22	...	...	3	0.18	278.72	1.62	" " "	47.00	40	78	39	
" 24	24	4.80	48	7.20	48	7.20	19.08	54.05	2	0.22	...	...	3	0.18	264.89	0.62	Sand, gravel, hard- [pan	22.58	38	71	40	
" 25	24	4.80	48	7.20	48	7.20	19.94	56.48	2	0.22	...	...	3	0.18	258.13	1.43	Fine sand	11.25	43	75	38	
" 26	24	4.80	48	7.20	48	7.20	22.24	62.97	2	0.22	...	...	3	0.18	272.79	0.57	Sandy clay or sedi-	46.33	43	80	37	
" 27	12	2.40	48	7.20	48	7.20	14.05	39.85	2	0.22	...	...	3	0.18	188.13	1.23	ment	13.41	41	80	38	Stopped sinking to catch up with planking.
" 28	...	...	48	7.20	48	7.20	20.52	58.12	2	0.22	...	...	3	0.18	212.22	0.21	"	16.91	39	85	34	
March 1	24	4.80	48	7.20	48	7.20	19.94	56.48	2	0.22	3	1.11	4	0.24	263.89	0.58	"	40.24	37	77	35	Water pumps started in night.
" 2	24	5.40	48	7.20	48	7.20	23.39	66.22	2	0.22	...	...	3	0.18	280.98	1.32	"	47.58	40	88	38	
" 3	24	5.40	48	7.20	70	11.05	26.56	75.18	2	0.22	...	...	4	0.24	293.86	1.88	"	46.82	36	84	37	
" 4	24	5.40	48	7.20	70	11.05	15.92	45.13	2	0.22	...	...	4	0.24	246.23	0.20	"	47.00	41	84	33	
" 5	24	5.40	48	7.20	70	11.05	17.07	48.37	2	0.22	...	...	3	0.18	247.48	2.39	"	44.92	41	81	34	
" 6	24	4.90	48	7.20	70	11.05	22.67	64.21	2	0.22	...	...	3	0.18	265.14	0.24	Sandy clay or sedi	46.75	40	85	26	
" 7	24	4.90	48	7.20	70	11.05	21.09	59.73	2	0.22	...	...	3	0.18	252.49	1.74	ment	45.25	38	88	28	
" 8	24	4.90	48	7.20	70	11.05	18.94	53.65	2	0.22	...	...	3	0.18	247.55	0.98	"	43.58	37	84	17	Caisson completed.
" 9	...	...	24	3.60	24	3.60	12.18	34.56	2	0.22	...	...	3	0.18	197.10	0.53	"	27.25	34	82	19	Finished concreting caisson.
" 10	24	4.80	48	7.20	48	7.20	15.48	43.88	2	0.22	...	...	3	0.18	231.03	2.29	"	41.66	38	78	25	Began laying masonry. Put on second clay hoist.
" 11	24	4.80	48	7.20	48	7.20	23.11	65.43	2	0.22	...	...	4	0.24	264.20	0.37	"	43.83	42	85	25	
" 12	24	4.80	48	7.20	48	7.20	16.35	46.33	2	0.22	...	...	3	0.18	316.13	0.36	"	47.92	37	86	33	
" 13	24	4.80	48	7.20	48	7.20	17.93	50.80	2	0.22	...	...	3	0.18	355.29	0.93	"	45.62	39	85	29	
" 14	24	4.80	48	7.20	48	7.20	18.07	51.20	2	0.22	...	...	3	0.18	383.91	2.26	"	48.00	44	82	33	
" 15	24	4.80	48	7.20	48	7.20	17.21	48.76	2	0.22	...	...	3	0.18	369.20	1.17	"	48.00	41	85	31	
" 16	24	4.80	48	7.20	48	7.20	20.09	56.90	2	0.22	...	...	4	0.24	384.70	1.46	"	48.00	43	86	29	
" 17	24	4.80	48	7.40	48	7.20	18.36	52.01	2	0.22	...	...	3	0.18	359.07	0.81	"	46.33	47	87	28	
" 18	24	4.80	48	7.20	48	7.20	20.00	56.90	2	0.22	...	...	3	0.18	376.33	0.18	"	46.01	44	80	31	
" 19	24	4.80	48	7.20	48	7.20	17.93	50.81	2	0.22	...	...	3	0.18	371.16	1.24	"	44.84	40	85	30	
" 20	16	3.20	48	7.20	48	7.20	15.20	43.09	2	0.22	...	...	3	0.18	356.91	1.16	Hard clay	12.00	34	86	32	
" 21	...	...	24	3.60	24	3.60	8.15	23.17	2	0.22	...	...	3	0.18	284.08	0.04	" "	...	...	...	33	
" 22	...	...	24	3.60	24	3.60	4.41	12.61	2	0.22	...	...	3	0.18	269.93	0.79	" "	...	...	...	36	
" 23	...	...	24	3.60	24	3.60	9.16	26.02	2	0.22	...	...	3	0.18	282.27	0.80	" "	10.75	41	76	27	
" 24	...	...	24	3.60	24	3.60	10.59	30.07	2	0.22	...	...	4	0.24	282.76	0.01	" "	24.00	43	76	28	
" 25	...	...	24	3.60	24	3.60	12.32	34.95	2	0.22	...	...	3	0.18	289.47	0.03	" "	24.00	45	77	31	

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER I.—CONTINUED.

Date.	Principal Foreman		Night Foreman		Sub Foreman.		Lock Tenders		Pressure Men		Coffee House Men.		Coffee		Sugar.		Candles		Coal for Heating.
1890.	Days	Amt.	Days	Amt.	Days	Amount.	Days	Amt.	Hrs	Amount	Days	Amt	Lbs	Amt.	Lbs.	Amt	No.	Amt.	200-lb boxes
" 26	1	5.00	1	4 00	5	15.75	2	4 80	411	164.40	3	4.50	10	2.59	7	0.44	2	0.05	2
" 27	1	5.00	1	4 00	5	15.75	2	4.80	414	165 60	3	4.50	9	2.33	6	0.38	5	0.12	2
" 28	1	5 00	1	4 00	5	15 75	2	4 80	410	164 00	3	4.50	10	2.59	8	0.50	8	0.19	2
" 29	1	5.00	1	4 00	4	12.50	2	4 80	393	157.20	3	4.50	9	2.33	6	0.38	2	0.05	2
" 30	1	5.00	1	4 00	5	15.75	2	4 80	417	166.80	3	4.50	11	2 85	6	0.38	1	0.03	2
" 31	1	5.00	1	4 00	6	20.25	2	4.90	520	257 50	3	4 50	11	2.85	8	0.50	4	0.10	2
April 1	1	5 00	1	4.00	6	21 00	2	5.00	420	263.09	3	4.50	13	3.37	9	0.57	3	0.07	2
" 2	1	5.00	1	4.00	6	21.00	2	5.00	410	256 75	3	4.50	14	3.63	9	0.57	8	0.19	2
" 3	1	5.00	1	4.00	6	21.00	2	5.00	408	255.50	3	4.50	11	2.85	9	0.57	4	0.09	2
" 4	1	5 00	1	4 00	6	21.00	2	5.00	392	245.50	3	4.50	11	2.85	8	0.50	7	0.17	2
" 5	1	5 00	1	4.00	6	21.00	2	5.00	411	257.25	3	4.50	11	2.85	8	0 50	7	0.16	2
" 6	1	5.00	1	4.00	5½	19.25	2	5 00	392	245.50	3	4.50	10	2.59	6	0.38	2	0.04	2
" 7	1	5.00	1	4.00	6	21 00	2	5.00	406	254.25	3	4.50	11	2.85	7	0.44	5	0.12	2
" 8	1	5.00	1	4.00	6	21.00	2	5.00	384	240.50	3	4 50	9	2.33	8	0.50	6	0.14	3
" 9	1	5.00	1	4.00	5	17.50	2	5.00	396	248.00	3	4.50	14	3.63	8	0.50	7	0.17	3
" 19	1	5.00	1	4.00	6	21.00	2	5 00	393	245.50	3	4 50	11	2.85	8	0.50	2	0.05	3
" 11	1	5.00	1	4 00	6	21 00	2	5.00	390	244.25	3	4.50	9	2.33	8	0.50	2	0.05	3
" 12	1	5.00	1	4 00	6	21.00	2	5 00	390	244.25	3	4.50	11	2.85	8	0.50	7	0.16	3
" 13	1	5.00	1	4 00	6	21.00	2	5 00	390	244.25	3	4.50	9	2.33	2	0.13	4	0.10	3
" 14	1	5.00	1	4 00	5	17.50	2	5.00	366	229.25	3	4 50	10	2.59	6	0.38	1	0.02	3
" 15	1	5.00	1	4.00	5	17.50	2	5.00	356	222.50	3	4.50	11	2.85	7	0.44	3	0.07	3
" 16	1	5.00	1	4 00	6	21.00	2	5 00	343	214.87	3	4 50	9	2.33	10	0.63	3	0.07	3
" 17	1	5 00	1	4.00	6	21.00	2	5.00	358	224.25	3	4 50	6	1.56	6	0.38	3	0.07	2
" 18	1	5.00	1	4.00	6	21.12	2	5.50	361	243.75	3	4.50	7	1.81	5	0.31	3	0.08	3
" 19	1	5.00	1	4.00	6	22 50	2	6.00	358	268.50	3	4.50	7	1.81	5	0.32	3	0.08	3
" 20	1	5.00	1	4.00	6	22.50	2	6.00	334	250.50	3	4.50	7	1 82	5	0.32	7	0.17	3
" 21	1	5.00	1	4.00	6	22.50	2	6.00	278	208 50	3	4.50	6	1.56	4	0.25	6	0.15	3
" 22	1	5.00	1	4.00	4	15.00	2	6.00	98	73 50	3	4.50	5	1.30	4	0.25	10	0.23	3
		380.00		316.00		1048.74		407.00		12683.62		295.50		167.33		29.43		5.55	153

Date.	Coal for Heating.	Sacking Out and Clay Hoist Men		Master Mechanic and Day Engineer.		Night Engineer.		Pump Men		Firemen.		Coal Passers		Coal for Boilers		Black Oil.		Cylinder Oil.		Waste.	
1890.	Amt	Hrs.	Amount	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt	Tons.	Amount.	Gals	Amt.	Gals.	Amt.	Lbs	Amt.
" 26	0.56	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	11.03	31.31	2	0.23	....	......	3	0.18
" 27	0.57	192	33.70	16	5.20	12	3.60	..	......	24	3.60	24	3.60	13.18	37 38	2	0.22	....	......	3	0.18
" 28	0.56	192	33.70	17	5.60	24	7.20	12	2.40	36	5.40	36	5.40	19.22	54 44	2	0.20	....	......	3	0.18
" 29	0.57	120	21.00	28	8 80	24	7.20	24	4.80	48	7 20	48	7.20	21.81	61.77	2	0.18	....	......	3	0.18
" 30	0.56	96	16.80	29	9.20	24	7.20	24	4.80	48	7.20	48	7.20	18 22	51.62	2	0.18	....	......	3	0.18
" 31	0.57	96	16.80	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	27.29	77.24	2	0.18	....	......	4	0.24
April 1	0.56	134	23.45	28	8.80	12	3.60	...	.....	36	5.40	36	5 40	12.90	36.59	2	0.18	....	......	4	0.24
" 2	0.57	172	30.20	22	6.60	24	7.20	...	....	48	7.20	36	5.40	8.73	24.81	2	0.18	....	......	3	0.18
" 3	0.56	192	33.70	28	8.80	12	3.60	....	......	36	5.40	24	3.00	11.75	33.35	2	0.18	....	......	3	0.18
" 4	0.57	192	33 70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	9.30	26 42	2	0.18	....	......	3	0.18
" 5	0.56	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	12.04	34.16	2	0.18	....	......	3	0.18
" 6	0.57	184	32.50	16	5.20	12	3.60	....	......	24	3 60	24	3.60	12.61	35.77	2	0.18	....	......	3	0.18
" 7	0.56	192	33.70	14	4.40	12	3.60	....	......	24	3.60	24	3.60	10.59	30.06	2	0.18	....	......	4	0.24
" 8	0.84	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	16.63	47.13	2	0.18	....	......	3	0.18
" 9	0.85	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	9.01	25.60	2	0.18	....	......	3	0.18
" 19	0.85	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	5.99	17.07	2	0.18	....	......	3	0.18
" 11	0.85	192	33.70	16	5 20	12	3.60	....	......	24	3.60	24	3.60	4.99	14.24	2	0.18	....	......	3	0.18
" 12	0.84	144	25.30	16	5.20	12	3.60	....	......	24	3.60	24	3.60	9.44	26.81	2	0.18	....	......	3	0.18
" 13	0.85	96	16.90	16	5.20	12	3.60	....	......	24	3.60	24	3.60	7.43	21.14	2	0.18	....	......	3	0.18
" 14	0.85	96	16.90	16	5.20	12	3.60	....	......	24	3.60	24	3.60	7.86	22.35	2	0.18	....	......	3	0.18
" 15	0.85	144	25.30	16	5.20	12	3.60	....	......	24	3.60	24	3.60	9.01	25.60	2	0.18	....	......	4	0.24
" 16	0.84	181	32.30	16	5.20	12	3.60	.	......	24	3.60	24	3.60	8.15	23.17	2	0.18	....	......	3	0.18
" 17	0.57	192	33.70	16	5.20	12	3.60	....	......	24	3.60	24	3.60	8.81	25.04	2	0.18	....	......	3	0.18
" 18	0 61	120	21.05	16	5 20	12	3.60	....	......	24	3.60	34	5.10	9 62	19.63	2	0.18	2	0.74	3	0.18
" 19	0.61	8	1.60	16	5.20	12	3.60	....	......	24	3.60	24	3.60	9 29	18.96	2	0.18	....	......	3	0.18
" 20	0.61	42	7.20	16	5.20	12	3.00	....	......	24	3.60	24	3.60	9.07	18.51	2	0.18	....	......	3	0.18
" 21	0.61	....	....	16	5.20	12	3.60	....	......	24	3.60	24	3.60	4.55	9.29	1	0.09	....	......	2	0.12
" 22	0.62	....	....	16	5.20	12	3.60	....	......	24	3.00	24	3.60	0.03	0.06	1	0.11	....	......	2	0.12
	42.04		1580.70		537.80		410.40		173.90		416.00		435.90	1109.65	3120.22		16.03		2.96		14.64

Date.	Totals for Each Day	Feet Sunk Each Day	Material.	Water Pump: Hours Run.	Rev.	Pres.	Rev of Air p'ps.	Remarks.
" 26	283.50	0.56	Hard clay	24.00	45	78	31	
" 27	290.53	0.94	Silt	24.00	48	77	32	
" 28	316.41	2.03	"	22.50	42	75	40	
" 29	309.64	1.00	Fine sand	48.00	34	72	28	
" 30	309.05	2.38	Clay, ½ sand	48.00	35	75	27	
" 31	429.83	1.90	" " "	48 00	32	76	23	
April 1	390 73	1.01	Clay, hard and pure	5.08	31	54	27	Stopped water pump.
" 2	383.08	0.75	" " " "	......	..	..	29	Hoisting out clay.
" 3	387.88	0.00	" " " "	......	..	..	26	
" 4	365.57	0.00	" " " "	......	..	..	37	
" 5	385.04	1.21	" " " "	......	..	..	40	
" 6	371.40	0.00	" " " "	......	..	..	39	
" 7	377.10	0.01	" " " "	......	..	..	40	
" 8	381.00	0.00	" " " "	......	..	..	40	
" 9	364.81	1.47	" " " "	......	..	..	49	
" 19	356.38	0.01	" " " "	......	..	..	38	
" 11	351.78	0.01	" " " "	......	..	..	40	
" 12	356.57	1.34	" " " "	......	..	..	35	
" 13	341.59	0.00	" " " "	......	..	..	33	
" 14	324.79	1.78	Clay, harder and	......	..	..	34	
" 15	330.03	0.87	tougher	......	..	..	46	
" 16	330.07	0.00	"	......	..	..	40	
" 17	341.43	0.01	"	......	..	..	45	Began sealing at 5 p.m.
" 18	344.96	0.85	"	......	..	..	38	
" 19	359.24	0.00	"	......	..	..	34	
" 20	337.49	0.00	"	......	..	..	26	
" 21	278.57	0.00	"	......	..	..	24	Stopped air pumps at 12.25 a.m., April 23.
" 22	126.69	0.00	"	......	..	..	23	
	22084.36							

COST OF SINKING CAISSON 1.

	Material	Labor	Total.
Amount as tabulated above	$3 398.20	$18 686.16	$22 084.36
Miscellaneous supplies	916.92	....	916.92
Sundry small supplies	130.04	....	130.04
Electric light	287.58	....	287.58
Medical attendance	54 40	....	54.40
Maintenance of plant	1 777.74	1 272.22	3 049.96
Hire of tug	1.17	....	1.17
Labor, not included in table	....	1 342.53	1 342 53
Total	$6 566.05	$21 300.91	$27 866.69

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER II.

Date	Principal Foreman.		Night Foreman.		Sub-Foremen		Lock Tenders.		Pressure Men.		Coffee House Men		Coffee		Sugar.		Candles.		Coal for House Boat		Sacking Out, Clay Hoist, and Elevator Men.		Master Mechanic and Day Engineers.		Night Engineers		Pump Men.		Firemen.		Coal Passers.		Coal for Boilers.		Black Oil.		Cylinder Oil.		Waste.		Totals for Each Day.	Feet Sunk Each Day.	Material.	Water Pump.			Rev. of Air p'ps.	Remarks.
1889.	Days	Amt	Days	Amt.	Days	Amount	Days	Amt.	Hrs	Amount.	Days	Amt.	Lbs	Amt	Lbs	Amt.	No.	Amt.	200-lb. Boxes.	Amt.	Hrs	Amount	Hrs	Amt	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt.	Hrs.	Amt	Tons	Amount	Gals.	Amt.	Gals.	Amt.	Lbs	Amt.				Hours Run	Rev.	Pres.		
May 17																																																Caisson built on shore Placing cutting edge.
" 21																																																Began building caisson.
June 27																																																Caisson ready to launch.
" 29																																																Launched at 4.30 p m.
Sept. 23																																																Towed to position.
" 25																																																Begun concreting at 3 p.m.
Oct. 10	1	5.00	1	4.00	1	3.00	2.5	5.00	150	30.00	1	1.50											17	5.60	12	3.60			24	3.60	24	3.60	9.61	32.12	2	0.15	1	0.37	6	0.33	97.87		Mat				33	Started air compressors on Lincoln at 10.02 a.m.
" 11	1	5.00	1	4.00	2	6.00	3	6.00	300	60.00	2	3.00											17	5.60	12	3.60			24	3.60	24	3.60	12.89	43.10	2	.15			6	.33	143.98	0.11	"				30	
" 12	1	5.00	1	4.00	3	9.00	3	6.00	530	106.00	2	3.00									100	15.30	17	5.60	12	3.60			24	3.60	24	3.60	13.02	43.53	2	.15			6	.33	208.71	0.07	"				32	
" 13	1	5.00	1	4.00	3	9.00	3	6.00	680	136.00	2	3.00									108	16.80	22	7.60	12	3.60			24	3.60	21	3.60	14.87	49.69	2	.15			6	.33	248.37	0.11	"				41	
" 14	1	5.00	1	4.00	3	9.00	3	6.00	880	176.00	2	3.00									78	13.80	17	5.60	12	3.60			24	3.60	24	3.60	16.46	55.02	2	.15			6	.33	288.70	0.24	"				46	
" 15	1	5.00	1	4.00	3	9.00	3	6.00	865	173.00	2	3.00									88	13.20	32	10.40	24	7.20			48	7.20	48	7.20	11.73	39.16	2	.16			6	.33	284.84	0.25	"				57	Started air compressors on Bertram at 8 a.m.
" 16	1	5.00	1	4.00	6	16.50	3	6.00	910	182.00	2	3.00									88	13.20	32	10.40	24	7.20	12	2.40	48	7.20	48	7.20	10.79	36.05	2	.18	1	.37	6	.33	301.02	1.04	"	16.00	35	..	34	" sand pumps at 4. p.m.
" 17	1	5.00	1	4.00	9	24.00	3	6.00	870	174.00	2	3.00									88	13.20	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	18.68	62.46	2	.18			6	.33	328.97	0.42	Clean coarse sand	47.16	35	..	33	
" 18	1	5.00	1	4.00	8	21.50	3	6.00	895	179.00	2	3.00	8	2.01	12	0.82			2	.67	103	15.45	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	15.53	51.92	2	.18			6	.33	326.68	0.71	" " "	48.00	35	....	26	
" 19	1	5.00	1	4.00	12	32.00	3	6.00	1220	214.00	3	4.50	9	2.26	17	1.17	40	1.76	2	.67	103	15.45	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	16.58	55.41	2	.18			6	.33	409.53	0.39	" " "	47.83	36	...	28	
" 20	1	5.00	1	4.00	12	32.00	3	6.00	1290	258.00	3	4.50	13	3.27	18	1.23	29	1.28	2	.67	88	13.20	34	11.20	24	7.20	24	4.80	48	7.20	48	7.20	10.79	36.06	2	.18	1	.37	6	.33	403.69	0.40	" " "	44.20	38	..	22	
" 21	1	5.00	1	4.00	11.5	30.50	3	6.00	1360	272.00	3	4.50	10	2.51	12	0.82	48	2.12	2	.67	90	13.75	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	12.37	41.34	2	.18			6	.33	420.52	0.82	" " "	40.33	40	..	30	
" 22	1	5.00	1	4.00	12	32.00	3	6.00	1380	276.00	3	4.50	17	4.27	22	1.51	48	2.12	2	.67	93	14.32	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	32.24	107.79	2	.18			6	.33	495.49	1.56	" " "	24.00	36	...	31	
" 23	1	5.00	1	4.00	12	32.00	3	0.00	1430	286.00	3	4.50	18	4.52	34	2.34	68	3.00	2	.67	48	7.20	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	24.49	81.83	2	.18			6	.33	474.37	0.80	" " "	48.00	41	....	32	
" 24	1	5.00	1	4.00	12	33.00	3	6.00	1507	301.40	3	4.50	17	4.27	33	2.27	51	2.25	2	.67	35	5.40	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	21.59	72.14	2	.18	1	.37	6	.33	477.58	2.22	" " "	47.66	40	...	29	
" 25	1	5.00	1	4.00	12	32.00	3	6.00	1470	294.00	3	4.50	17	4.27	24	1.65	51	2.25	2	.67	31	4.90	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	21.05	70.37	2	.18			6	.33	466.92	2.49	" " "	24.00	40	....	31	
" 26	1	5.00	1	4.00	12	32.00	3	6.00	1537	307.40	3	4.50	19	4.78	33	2.27	23	1.01	2	.67	78	11.95	32	10.40	24	7.20	21	4.80	48	7.20	48	7.20	22.64	75.67	2	.18			6	.33	492.56	0.55	" " "	40.66	39	...	32	
" 27	1	5.00	1	4.00	12	32.00	3	6.00	1500	300.00	3	4.50	22	5.53	32	2.20	74	3.26	2	.67	30	4.75	34	11.20	24	7.20	24	4.80	48	7.20	48	7.20	23.95	80.05	2	.18			6	.33	486.07	3.00	" " "	44.50	39	...	31	
" 28	1	5.00	1	4.00	12	35.00	3	7.20	1313	315.12	3	4.50	19	4.78	31	2.13	29	1.28	2	.67	30	4.75	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	23.55	78.75	2	.18			6	.36	500.49	2.04	" " "	48.00	41	....	27	
" 29	1	5.00	1	4.00	12	35.00	3	7.20	1443	340.32	3	4.50	19	4.78	30	2.06	40	1.76	2	.67	30	4.25	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	19.75	65.98	2	.18	1	.37	6	.33	519.20	3.23	" " "	48.00	41	....	25	
" 30	1	5.00	1	4.00	12	35.00	3	7.20	1420	340.80	3	4.50	22	5.53	27	1.85	26	1.14	2	.67	20	3.25	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	20.07	69.07	2	.18			6	.33	515.32	3.19	" " "	44.87	42	.	30	
" 31	1	5.00	1	4.00	12	35.00	3	7.20	1475	354.00	3	4.50	17	4.27	24	1.65			2	.67	40	6.25	34	11.20	24	7.20	24	4.80	48	7.20	48	7.20	22.50	75.23	2	.18			6	.33	535.88	2.73	" " "	39.42	47	.	29	
Nov. 1	1	5.00	1	4.00	18	51.00	3	7.20	1475	354.00	3	4.50	17	4.27	24	1.65	42	1.85	2	.67			34	11.20	24	7.20	24	4.80	48	7.20	48	7.20	24.87	83.15	2	.18			6	.33	555.40	1.84	Clean coarse sand	30.50	48	....	27	
" 2	1	5.00	1	4.00	18	51.00	3	7.20	1480	355.20	3	4.50	20	5.03	33	2.27	9	.40	2	.67	40	6.25	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	23.16	77.42	2	.18	1	.37	6	.33	556.58	2.74	and gravel	48.00	47	..	29	
" 3	1	5.00	1	4.00	17	48.25	3	7.20	1635	393.40	3	4.50	20	5.0[illegible]	33	2.27	29	1.28	2	.67	40	6.25	32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	21.96	73.45	2	.18			5	.29	588.53	2.95	"	48.00	49	...	37	
" 4	1	5.00	1	4.00	17	54.00	3	7.50	1600	400.00	3	4.50	19	4.78	31	2.13	29	1.28	2	.67	40	6.25	30	9.60	24	7.20	21	4.80	48	7.20	48	7.20	20.66	69.07	2	.18			5	.29	595.61	1.73	"	46.16	53	....	33	
" 5	1	5.00	1	4.00	17	54.00	3	7.50	1680	420.00	3	4.50	17	4.27	30	2.08	71	3.13	2	.67			32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	21.98	73.44	2	.14			5	.29	610.42	1.67	Mud	42.61	52	...	33	
" 6	1	5.00	1	4.00	18	57.00	3	7.50	1540	385.00	3	4.50	19	4.78	32	2.20	74	3.26	2	.67			32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	23.81	79.61	2	.14			5	.29	590.75	1.96	"	44.33	54	..	32	
" 7	1	5.00	1	4.00	17	53.75	3	7.50	1415	353.75	3	4.50	14	3.52	27	1.85	91	4.01	2	.67			32	10.40	24	7.20	24	4.80	48	7.20	48	7.20	20.26	67.73	2	.14	1	.37	5	.29	543.88	1.93	"	23.50	39	.	31	
" 8	1	5.00	1	4.00	17	59.10	3	8.40	1500	420.00	3	4.50	17	4.27	34	2.34	51	2.25	2	.67			28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	26.72	89.30	2	.14			5	.29	635.46	0.02	Coarse sand and	40.83	47	....	35	
" 9	1	5.00	1	4.00	15	52.50	3	8.40	1420	397.60	3	4.50	18	4.52	33	2.27	9	.40	2	.67	12	3.00	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	21.32	71.27	2	.14			5	.29	589.76	1.84	gravel	45.83	55	....	32	
" 10	1	5.00	1	4.00	17	59.10	4	10.15	1370	383.60	3	4.50	15	3.77	34	2.34	94	4.15	2	.67	24	6.00	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	38.29	128.02	2	.14			5	.29	646.93	1.96	"	48.00	48	...	31	
" 11	1	5.00	1	4.00	17	59.10	4	10.15	1320	369.60	3	4.50	18	4.52	28	1.92	60	2.65	2	.67	24	6.00	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	18.03	60.27	2	.14	1	.37	5	.28	564.37	1.75	"	48.00	50	..	26	
" 12	1	5.00	1	4.00	18	68.00	3	8.40	1003	300.80	3	4.50	15	3.77	34	2.34	51	2.25	2	.67	24	6.00	28	8.80	24	7.20	24	4.80	48	7.20	48	7.20	8.95	29.91	2	.14			5	.28	466.26	0.20	Clay	38.00	47	...	26	
" 13	1	5.00	1	4.00	16.6	60.75	4	10.75	1138	341.40	3	4.50	17	4.27	15	1.03	11	.49	2	.67	24	6.00	30	9.60	24	7.20	24	4.80	48	7.20	48	7.20	9.08	30.37	2	.14			5	.28	505.65	0.86	"	15.50	55	..	30	Stopped water pumps on Lincoln at 2 p.m.
" 14	1	5.00	1	4.00	15	55.00	4	10.75	1115	334.50	3	4.50	14	3.52	28	1.92	74	3.26	2	.67	24	6.00	30	9.60	24	7.20	24	4.80	48	7.20	48	7.20	5.40	18.04	2	.14			5	.28	483.58	0.50	"	24.00	51	...	27	
" 15	1	5.00	1	4.00	16	59.00	4	10.75	1080	324.00	3	4.50	16	4.02	26	1.79	63	2.78	2	.67	24	6.00	30	9.60	24	7.20	24	4.80	48	7.20	48	7.20	5.13	17.14	2	.14			5	.28	476.07	0.23	"	23.50	50	...	27	
" 16	1	5.00	1	4.00	13.5	49.75	4	10.75	815	241.50	3	4.50	14	3.52	23	1.58	43	1.90	2	.67	24	6.00	30	9.60	24	7.20	24	4.80	48	7.20	48	7.20	4.08	13.61	2	.14	1	.37	5	.28	382.57	0.17	"	20.30	50	...	26	Stopped water pumps on Bertram at 4.30 a.m.
" 17	1	5.00	1	4.00	12.5	46.25	3	9.00	825	247.50	3	4.50	16	4.02	20	1.37	23	1.02	2	.67	98	20.80	30	9.60	24	7.20			48	7.20	48	7.20	7.04	25.53	2	.14			5	.28	401.28	0.14	"				25	
" 18	1	5.00	1	4.00	13.7	51.95	4	10.75	897	269.10	3	4.50	15	3.77	21	1.44	23	1.02	2	.67	98	20.80	30	9.60	24	7.20			48	7.20	48	7.20	13.82	46.20	2	.14			5	.28	450.82	0.60	"				26	
" 19	1	5.00	1	4.00	14	53.00	3	9.00	1016	304.80	3	4.50	16	4.02	23	1.58	23	1.01	2	.67	98	20.80	30	9.60	24	7.20			48	7.20	48	7.20	4.34	14.52	2	.14			5	.28	454.52	0.33	"				27	
" 20	1	5.00	1	4.00	14	53.00	3	9.00	867	260.10	3	4.50	15	3.77	23	1.58	8	.35	2	.67	108	22.80	15	4.80	12	3.60			24	3.60	24	7.20	13.69	45.77	1	.07	1	.37	5	.28	430.53	0.10	"				30	Took Bertram ashore.
" 21	1	5.00	1	4.00	12.7	47.45	3	9.00	850	255.00	3	4.50	14	3.52	23	1.58	46	2.03	2	.67	108	22.80	15	4.80	12	3.60			24	3.00	24	3.60	12.37	41.34	2	.14			5	.28	412.91	0.14	"				25	
" 22	1	5.00	1	4.00	14	53.00	4	11.00	1006	301.80	3	4.50	16	4.02	20	1.37	46	2.03	2	.67	108	22.80	15	4.80	12	3.60			24	3.60	24	3.60	15.79	52.78	2	.14			5	.28	478.99	0.15	"				25	
" 23	1	5.00	1	4.00	16	60.00	4	11.00	1023	307.00	3	4.50	16	4.02	26	1.79	31	1.37	2	.67	108	22.80	14	4.40	12	3.60			24	3.00	24	3.60	11.98	40.04	2	.14			5	.28	477.81	0.00	"				30	
" 24	1	5.00	1	4.00	15	56.50	4	11.00	950	285.00	3	4.50	16	4.02	25	1.72			2	.67	108	22.80	14	4.40	12	3.60			24	3.00	24	3.60	7.64	25.52	2	.14			5	.28	430.35	0.04	"				23	
" 25	1	5.00	1	4.00	15	56.50	4	11.00	976	293.00	3	4.50	17	4.27	23	1.58	6	.26	2	.67	108	22.80	15	4.80	12	3.60			24	3.00	24	3.60	19.86	66.43	2	.14	1	.37	5	.28	486.40	0.06	"				29	
" 26	1	5.00	1	4.00	15	56.00	4	11.00	986	296.00	3	4.50	19	4.78	26	1.79	14	.62	2	.67	108	22.80	15	4.80	12	3.60			24	3.60	24	3.60	13.43	44.87	2	.14			5	.28	468.05	0.01	"				27	
" 27	1	5.00	1	4.00	16	57.49	3	9.00	1016	305.00	3	4.50	11	2.77	27	1.85	23	1.01	2	.67	108	22.80	15	4.80	12	3.60			24	3.00	24	3.60	17.76	59.38	2	.14			5	.28	489.49	0.02	"				28	
" 28	1	5.00	1	4.00	16	60.00	3	9.00	983	295.00	3	4.50	15	3.77	37	1.85	40	1.76	2	.67	108	22.80	15	4.80	12	3.60			24	3.00	24	3.60	16.71	55.85	2	.14			5	.28	480.22	0.00	"				28	
" 29	1	5.00	1	4.00	12	44.98	3	9.00	653	196.00	3	4.50	15	3.77	23	1.58	26	1.14	2	.67	66	14.40	15	4.80	12	3.60			24	3.60	24	3.60	11.31	37.82	2	.14	1	.37	5	.28	339.25	0.00	"				31	
" 30	1	5.00	1	4.00			3	9.00			2	3.00	12	3.02	24	1.65	3	0.13	2	.67			15	4.80	12	3.60			24	3.60	24	3.60	8.95	29.91	2	.14			5	.28	72.40	0.01	"				28	
Dec. 1	1	5.00	1	4.00			3	9.00	20	6.50	2	3.00	3	0.75	4	0.27			2	.67			15	4.80	12	3.60			24	3.60	24	3.60	3.69	12.32	1	.07			5	.28	57.53	0.05	"				26	Took off air at 4.40 p.m.
" 2																																										0.51	"					
" 3																																										0.18	"					
Carried forward.		265.00		212.00		2115.93		422.65		14510.19		220.50		179.20		79.55		72.32		30.15		556.12		450.00		320.40		151.20		320.40		324.00		2902.82		8.15		4.44		16.12	23161.13							

APPENDIX I.—CONTINUED.

TIME, COST AND MATERIAL USED IN FOUNDATIONS.

PIER II.—CONTINUED.

Date. 1890.	Principal Foreman Days	Principal Foreman Amt.	Night Foreman Days	Night Foreman Amt.	Sub-Foremen Days	Sub-Foremen Amount.	Lock Tenders Days	Lock Tenders Amt.	Pressure Men Hrs	Pressure Men Amount.	Coffee House Men Days	Coffee House Men Amt	Coffee Lbs.	Coffee Amt	Sugar Lbs	Sugar Amt.	Candles No.	Candles Amt	Coal for House Boat 200-lb. boxes	Coal for House Boat Amt.
Brought forward.		265.00		212.00		2115.92		422.65		14510.19		220.50		179.20		79.55		72.33		30.15
Sept. 1	....	......	....	......	....	......	....	......	....	......	....	......	6	1.51	9	.61	14	.62	......	......
" 2	....	......	....	......	....	......	....	......	....	......	....	......	5	1.26	8	.55	11	.49	......	......
" 3	½	2.50	1	4.50	....	......	1	3.50	112	130.66	..	......	7	1.76	11	.76	46	2.03	......	......
" 4	½	2.50	1	4.00	7	29.25	2	6.50	235	248.00	2	3.00	10	2.51	11	.76	91	4.01	......	......
" 5	1	5.00	1	4 00	11	41.75	2	0.00	340	346.00	3	4.50	10	2.51	17	1.17	122	5.38	1	.33
" 6	1	5.00	1	4.60	11	41.75	2	6.00	357	357.00	3	4.50	11	2.77	18	1.24	54	2.38	1	.33
" 7	1	5.00	1	4 00	11	41.75	2	6.00	367	367.00	3	4.50	11	2.77	19	1.31	14	.62	......	......
" 8	1	5.00	1	4.00	11	41.75	2	6.00	370	370.00	3	4 50	10	2 51	17	1.17	37	1.63	1	.33
" 9	1	5.00	1	4.00	11	41.75	2	6.00	381	381.00	3	4.50	12	3.02	7	.48	94	4 15	1	.33
" 10	1	5.90	1	4.00	10	38.50	2	6.00	389	389.00	3	4.50	10	2.51	17	1.17	23	1.02	......	......
" 11	1	5.00	1	4.00	10	38.50	2	9.00	361	361.00	3	4.50	12	3.02	16	1.10	11	.49	1	.63
" 12	1	5.00	1	4.00	11	41.75	2	6.00	359	359.00	3	4.50	12	3.02	......	......	......	......	1	.33
" 13	1	5.00	1	4.00	11	41.75	2	0.00	358	358.00	3	4.50	13	3.27	18	1.24	......	......	......	......
" 14	1	5.00	1	4.00	10	38.50	2	6.00	392	392.00	3	4.50	8	2.01	11	.79	......	......	......	......
" 15	1	5.00	1	4.00	9	35.25	2	6.00	398	398.00	3	4.50	8	2.01	13	.89	6	.26	1	.33
" 16	1	5.00	1	4.00	10	38.50	2	6.00	306	306.00	3	4.50	9	2 26	13	.89	31	1.37	1	.33
" 17	1	5.00	1	4.00	11	41.75	2	6.00	340	340.00	3	4.50	12	3.02	16	1.10	26	1.14	1	.33
" 18	1	5.00	1	4.00	11	41.75	2	6.00	348	348.00	3	4.50	12	3.02	14	.96	11	.49	1	.33
" 19	1	5.00	1	4 00	11	41.75	2	6.00	338	338.00	3	4.50	12	3.02	17	1.17	8	.35	1	.33
" 20	1	5.00	1	4 00	10	38.50	2	6.00	344	344 00	3	4.50	10	2.51	17	1.17	66	2.91	1	.33
" 21	1	5.00	1	4.00	11	41.75	2	6.00	348	348.00	3	4.50	10	2.51	13	.89	63	2.78	1	.33
" 22	1	5.00	1	4.00	10	38.50	2	6.00	321	321.00	3	4.50	11	2.77	17	1.17	11	.49	1	.33
" 23	1	5.00	1	4.00	11	41.75	2	6.00	323	323.00	3	4.50	14	3.52	16	1.10	51	2.38	1	.33
" 24	1	5.00	1	4 00	11	41.75	2	6.00	331	331.00	3	4.50	11	2.77	15	1.03	11	.49	1	.33
" 25	1	5 00	1	4.00	11	41.75	2	6.00	323	323.00	3	4.50	11	2.77	14	.96	40	1.76	......	......
" 26	1	5.00	1	4.00	11	41.75	2	6.00	330	330.00	3	4.50	12	3.02	15	1.03	17	.75	1	.33
" 27	1	5.00	1	4 00	11	41.75	2	6.00	323	323.00	3	4.50	11	2.77	17	1.17	46	2.03	1	.33
" 28	1	5.00	1	4.00	11	41.75	2	6.00	308	308.00	3	4.50	10	2 51	15	1.03	57	2.51	1	.33
" 29	1	5.00	1	4.00	11	41.75	2	6.00	314	314.06	3	4.50	12	3.02	17	1.17	57	2.51	1	.33
" 30	1	5.00	1	4.00	11	41.75	2	6.00	313	313 00	3	4.50	11	2.77	15	1.03	71	3.13	2	.67
Oct. 1	1	5.00	1	4.00	11	41.75	2	6.00	333	333.00	3	4.50	11	2.77	17	1.17	20	.88	2	.67
" 2	1	5.00	1	4.00	11	41.75	2	6.00	312	312.00	3	4.50	11	2.77	17	1.17	51	2.25	2	.67
" 3	1	5.00	1	4.00	10½	40.42	2	6 00	291	291.00	3	4.50	11	2.77	15	1.03	29	1.28	2	.67
" 4	1	5.00	1	4.00	11	41.75	2	6.00	287	287.00	3	4 50	12	3.02	17	1.17	6	.26	1	.33
" 5	1	5.00	1	4.00	7	25.75	2	6.00	139	139.00	3	4.50	5	1.26	9	.61	6	.26	......	......
" 6	1	5 00	1	4.00	11	41.75	2	6.06	330	330.00	3	4.50	11	2.76	12	.82	23	1.02	1	.33
" 7	1	5.00	1	4 00	11	41.75	2	6.00	335	335.00	3	4.50	11	2.76	15	1.03	6	.26	......	......
" 8	1	5.00	1	4 00	10	38.50	1	3.00	338	338.00	3	4.50	11	2.76	18	1.23	26	1.14	1	.33
" 9	1	5.00	1	4.00	10	38.50	1	3.00	347	347.00	3	4.50	11	2.76	19	1.30	23	1.02	1	.33
" 10	1	5.00	1	4.00	11	41.75	1	3.00	351	351.00	3	4.30	11	2.76	17	1.17	6	.26	1	.33
" 11	1	5.00	1	4.00	10½	39.58	1	3.00	336	336.00	3	4.50	9	2 26	14	.99	23	1.02	1	.33
" 12	1	5.90	1	4.00	10	38.50	2	6.00	329	329 00	3	4.50	9	2.26	14	.96	28	1.23	1	.33
" 13	1	5.00	1	4.00	10½	40.42	2	6.00	328	328.00	3	4.50	11	2.76	15	1.03	6	.26	1	.33
" 14	1	5.00	1	4.00	11	41.75	2	6.00	343	343.00	3	4.50	11	2.76	17	1.17	46	2.03	1	.33
" 15	1	5.00	1	4.00	10	38.50	2	6.00	312	312.00	3	4.60	9	2 26	15	1.03	57	2.51	1	.33
" 16	1	5.00	1	4.50	11	47 25	2	7.00	266	310.34	3	4 50	9	2.26	13	.89	17	.75	1	.33
" 17	1	5.00	1	4.50	10	43.50	2	7.00	293	341.84	3	4.50	14	3.85	20	1.37	6	.30	1	.28
" 18	1	5.00	1	4.50	11	47.25	2	7.00	315	367.50	3	4.50	12	3.30	20	1.37	6	.30	1	.28
" 19	1	5.00	1	4.50	11	47.25	2	7.00	316	368.67	3	4.50	14	3.85	20	1.38	8	.40	1	.28
" 20	1	5.00	1	4.50	11	47.25	2	7.00	320	373.34	3	4.50	14	3.85	21	1.44	12	.60	1	.28
" 21	1	5.00	1	4.50	11	47.25	2	7.00	321	374.50	3	4 50	18	4 86	21	1.65	18	.90	1	.28
" 22	1	5.00	1	4.50	11	47.25	2	7 00	279	325.50	3	4.50	18	4.96	21	1.65	16	.80	1	.28
" 23	1	5.00	1	4.50	11	47.25	2	7.00	261	324 50	3	4.50	14	3.85	21	1.44	15	.75	1	.28
" 24	1	5.00	1	......	0½	3.00	1	3.50	2½	4.67	1.	1.50	......	......	......	......	......	......	......	......
Total.		320.00		420.50		4174 34		736.15		31068 71		445.50		327.49		135.67		140.97		45.02

Date. 1890.	Sacking Out Clay Hoist and Elevator Men. Hrs.	Sacking Out Clay Hoist and Elevator Men. Amount	Master Mechanic and Day Engineers. Hrs.	Master Mechanic and Day Engineers. Amt.	Night Engineers. Hrs	Night Engineers. Amt.	Pump Men. Hrs	Pump Men. Amt.	Firemen. Hrs.	Firemen. Amt.	Coal Passers. Hrs	Coal Passers. Amt.	Coal for Boilers. Tons.	Coal for Boilers. Amount.	Black Oil. Gals.	Black Oil. Amt.	Cylinder Oil. Gals.	Cylinder Oil. Amt.	Waste. Lbs.	Waste. Amt.	Totals for Each Day	Feet Sunk Each Day.	Material.	Water Pump. Hours Run.	Water Pump. Rev.	Water Pump. Pres.	Rev. of Air p'ps.	Remarks.
Brought forward.		556.12		450.00		330.40		151.30		320 40		324.00		2902.82		8.15		4.44		16.12	23161.13							
Sept. 1	......	......	8	2.60	12	3.60	....	......	24	4.00	...	......	95	3.17	2	.15	1	.37	3	.18	16.81	......	Clay	.....	...	..	29	Started air compressors on Lincoln at 11.35 a.m.
" 2	......	......	14	4 40	12	3.60	....	......	24	4.00	.	......	5 02	16.76	2	.18	....	......	3	.18	31.42	......	"	.....	...	....	35	
" 3	......	......	14	4 40	12	3.60	....	....	24	4 00	...	......	3.86	12.88	2	.18	....	......	3	.18	170.95	......	"	.....	...	....	36	[at 2 p.m.
" 4	......	......	14	4.40	12	3.60	....	....	24	4.00	24	3.55	5.09	16.98	2	.18	....	....	3	.18	333.42	0.05	"	16.92	11	64	26	Started water pumps on Lincoln
" 5	48	8.40	14	4.40	12	3.60	....	......	24	4.00	24	3.60	11.72	39.14	2	.18	1	.37	3	.18	480.51	0.00	"	22.87	13	66	30	
" 6	78	15.30	14	4 40	12	3 60	....	......	24	4.00	18	2.70	5.66	18.92	2	.18	...	.....	3	.18	474 25	0.00	"	16.42	15	77	29	Stopped water pumps at 7.15 a.m.
" 7	240	44.00	28	8.80	24	7.30	....	......	48	8.00	48	7.20	11.86	39.60	2	.18	....	......	3	.18	548 11	0 00	"	......	...	...	27	Started air compressors on Bertram at 10 a.m.
" 8	264	48.00	28	8.80	24	7.20	....	....	48	8.00	48	7 20	11.58	38.74	2	.18	....	......	3	.18	555.19	0.00	"	......	...	....	26	
" 9	252	46.00	30	9.60	24	7.20	....	....	48	8.00	48	7.20	12.38	41.33	2	.18	1	.37	3	.18	570.29	0.00	"	......	...	....	29	
" 10	264	48.00	30	9.60	24	7.20	....	....	48	8.00	48	7.20	13.56	45.31	2	.18	...	......	3	.18	568.37	0.00	"	......	...	...	32	
" 11	264	48.00	30	9.60	24	7.20	....	......	48	8.00	48	7.20	12.24	40.89	2	.18	....	.....	3	.18	545.19	0.00	"	......	...	....	32	
" 12	264	48.00	30	9 60	24	7.20	...	.....	48	8.00	48	7.20	12.37	41.33	2	.18	....	......	3	.18	545.29	0.00	"	......	...	....	32	
" 13	264	48 00	30	9 90	24	7.20	....	....	48	8.00	48	7.20	14 22	47.50	2	.18	1	.37	3	.18	551.99	0.00	"	......	...	....	29	
" 14	272	46.00	32	10.40	24	7.20	...	.....	48	8.00	48	7.20	12.50	41.77	1	.09	....	.....	3	.18	473.61	0.00	"	......	...	....	31	
" 15	240	44.00	28	8.80	24	7.20	....	....	48	8.00	36	5 40	10.14	33.87	2	.18	....	......	4	.24	403.93	0.00	"	......	...	....	28	
" 16	216	39 60	28	8.80	24	7.20	....	.....	48	8.00	36	5 40	10.28	34 32	2	.18	....	......	3	.18	472.53	0.25	"	......	...	....	29	
" 17	216	39 60	30	9.90	24	7.20	...	...	48	8 00	36	5.40	11.31	37.81	2	.18	1	.37	3	.18	515.18	0.62	"	......	...	....	27	
" 18	216	39 60	30	9.60	24	7.20	...	..	48	8.00	36	5.40	8.82	29.45	1	.09	....	......	3	.18	513.57	0.14	"	......	...	....	29	
" 19	216	39.60	28	8.80	24	7.20	...	....	48	8.00	36	5.40	8 82	29.45	2	.18	....	......	3	.18	502.93	0.08	"	......	...	....	29	
" 20	216	39 60	28	8.80	24	7.20	....	......	48	8.00	36	5.40	12.10	40.45	2	.18	....	......	4	.24	518.79	0.06	"	......	...	....	29	
" 21	204	37.60	30	9.60	24	7.20	....	.....	48	8.00	36	5.40	11.71	39.15	2	.18	....	......	3	.18	523.44	0.09	"	......	...	....	30	
" 22	216	38 60	30	9.60	24	7.20	....	......	48	8.00	48	7.20	9.87	32 99	1	.09	1	.37	3	.18	487.62	0.18	"	......	...	....	29	
" 23	216	38.60	30	9.60	24	7.20	....	.....	48	8.00	48	7.20	8.43	28 17	2	.18	...	.....	3	.18	490.71	0.00	"	......	...	....	27	
" 24	216	38 60	30	9 60	24	7.20	....	.....	48	8.00	48	7.29	9.87	33.00	2	.18	....	......	3	.18	500.83	0.11	"	......	...	....	27	
" 25	216	38.60	30	9 60	24	7.20	....	......	48	8.00	48	7.20	17.47	58.40	2	.18	1	.37	4	.24	519.53	0.17	"	......	...	....	31	
" 26	264	47.00	30	9 60	24	7.20	....	......	48	8.00	48	7.20	11.06	36.96	1	.09	....	......	3	.18	503.61	0.00	"	......	...	....	35	
" 27	264	47.00	30	9.60	24	7.20	....	......	48	8.00	48	7.20	10.27	34.33	2	.18	....	......	3	.18	504.24	0.00	"	......	...	....	34	
" 28	262	46.60	30	9 60	24	7.20	....	......	48	8.00	30	4.50	11.06	36.96	2	.18	....	......	3	.18	488.85	0.71	"	......	...	....	29	
" 29	246	44.00	30	9.60	24	7.20	....	......	48	8.00	36	5.40	8.03	26.84	2	.18	1	.37	4	.24	484.11	0.00	"	......	...	....	34	
" 30	216	38.60	30	9.60	24	7.20	....	......	48	8.00	48	7.20	13.56	45.32	1	.09	....	......	3	.18	498.04	0.00	"	......	...	....	30	
Oct. 1	264	47.00	28	8.80	24	7.20	....	......	48	8.00	48	7.20	9.87	33.01	2	.18	....	......	3	.18	511.31	1.41	"	......	...	....	32	
" 2	264	47.00	28	8 80	24	7.20	....	......	48	8.00	48	7.20	10.66	35.63	2	.18	1	.37	4	.24	494.73	0.00	"	......	...	....	31	
" 3	168	30.20	28	8 80	24	7 20	....	......	48	8.00	48	7.20	9.61	32.12	3	.18	....	......	3	.18	450.55	1.22	"	......	...	....	27	
" 4	264	47.00	28	8.80	24	7.20	....	......	48	8.00	48	7.20	11.57	38.72	1	.09	....	......	3	.18	470.29	0.00	"	......	...	....	29	
" 5	24	5.00	30	9.60	24	7.20	....	......	48	8.00	48	7.20	7.90	26.40	2	.18	1	.39	3	.18	250.53	0.00	"	......	...	....	28	
" 6	216	38.60	28	8.80	24	7.20	....	......	48	8.00	48	7.20	9.54	31.98	2	.18	....	......	3	.18	498.32	0.00	"	......	...	....	28	
" 7	216	38.60	30	9.60	24	7.20	....	......	48	8.00	48	7.20	12.64	42 23	2	.18	....	......	4	.24	513.55	0.00	"	......	...	....	28	
" 8	216	38.60	28	8.80	24	7.20	....	......	48	8.00	48	7.20	11.98	40.05	1	.09	....	......	3	.18	508.58	0.00	"	......	...	....	28	
" 9	216	38 60	28	8.80	24	7.20	....	......	48	8.00	48	7.20	11.98	40.05	2	.18	1	.39	3	.18	518.01	1.46	"	......	...	....	30	
" 10	216	38.60	28	8.80	24	7.20	....	......	48	8.00	48	7.20	12.37	41.35	2	.18	....	......	3	.18	525.28	0.00	"	......	...	....	30	
" 11	114	20.80	28	8.80	24	7.20	....	......	48	8.00	48	7.20	10.39	34.75	3	.18	....	......	3	.18	483.76	1.67	"	......	...	....	26	
" 12	120	21.80	30	9.60	24	7.20	....	......	48	8.00	48	7.20	10.00	33.44	1	.09	....	......	4	.24	479.35	0.00	"	......	...	....	37	
" 13	120	21.80	28	8 80	24	7.20	....	......	48	8.00	48	7.20	10.14	33.89	2	.18	1	.39	3	.18	479.94	0.00	"	......	...	....	27	
" 14	120	21.80	30	9.60	24	7.20	....	......	48	8.00	48	7.20	10.52	35.19	2	.18	....	......	3	.18	498.80	1.02	"	......	...	....	26	
" 15	168	30.20	30	9.60	24	7.20	....	......	48	8.00	48	7.20	12.61	42.19	2	.18	....	......	3	.18	480.88	0.00	"	......	...	....	27	
" 16	63	11.90	30	9.60	24	7.20	....	......	48	8.00	48	7.20	14 08	47.06	2	.18	....	......	4	.26	474.22	0.85	"	......	...	....	25	Began sealing at 10.30 a.m.
" 17	24	5 00	28	8.80	21	7.20	....	......	48	8.00	48	7.20	10.62	35.50	1	.09	1	.33	4	.26	479.28	0.00	......	......	...	....	25	Sealing.
" 18	24	5.00	28	8.80	24	7 20	....	......	48	8.00	48	7.20	8.89	25.26	1	.18	....	......	3	.18	502.82	0.00	......	......	...	....	24	"
" 19	24	5.00	28	8.80	24	7 20	....	......	48	8.00	48	7.20	9.04	28.20	2	.18	....	......	3	.18	507.50	0 00	......	......	...	....	23	"
" 20	24	5.00	30	9 60	24	7 20	....	......	48	8.00	48	7.20	7 73	22.00	2	.18	....	......	4	.26	507.20	0.00	......	......	...	....	23	"
" 21	24	5.00	30	9.60	24	7.20	....	......	48	8.00	48	7.20	8.32	23.64	2	.18	....	......	3	.18	511.54	0.00	......	......	...	....	25	"
" 22	24	5.00	30	9.60	24	7.20	....	......	48	8.00	48	7 20	9.00	25.58	2	.18	½	.29	3	.18	464.67	0.00	......	......	...	....	28	"
" 23	24	5.00	28	8.80	24	7.20	....	......	48	8.00	48	7 20	4.51	12.83	1	.09	....	......	3	.18	338.37	0.00	......	......	...	....	24	
" 24	3	0.75	5	1.70	....	....	....	......	6	1.20	6	0 90	1.15	3.27	2	.18	....	......	3	.18	25.86	0.00	......	......	...	....	19	Stopped air compressors on Bertram 5.45 a.m. " " Lincoln 5.45 a.m.
Total.		2146.27		912.30		680.40		151.20		721.60		656.05		4683.65		18.94		9.62		26.51	48008.89							

COST OF SINKING CAISSON II.

	Material.	Labor.	Total.
Amount as tabulated above............	$5 385.87	$42 623.02	$48 008 89
Miscellaneous supplies.....................	1 984.47	....	1 984.47
Sundry small supplies.....................	693.15	....	693.15
Electric light.............................	376.01	....	376.01
Medical attendance, etc..................	971.47	....	971.47
Maintenance of plant......................	4 839.24	3 911.80	8 751.04
Hire of tug and derrick..................	381.50	....	381.50
Labor, not included in table............	....	4 496.64	4 496 64
Total..............................	$14 631.71	$51 031.46	$65 663 17

TIME, COST AND MATERIAL USED IN FOUNDATIONS.

PIER III.

Date	Principal Foreman Days	Amt	Night Foreman Days	Amt	Sub-Foremen Days	Amount	Lock Tenders Days	Amt	Pressure Men Hrs	Amount	Coffee House Men Days	Amt	Coffee Lbs	Amt	Sugar Lbs	Amt	Candles No.	Amt	Coal for House Boat 200-lb. Boxes	Amt	Sacking Out Clay Hoist and Elevator Men Hrs	Amount	Master Mechanic and Day Engineers Hrs	Amt	Night Engineers Hrs	Amt
1889.																										
Dec. 16	1	5.00	1	4.00	6½	17.33	2½	5.00	225	81.67	1½	2.25					16	0.77					8	3.20	12	3.60
" 17	1	5.00	1	4.00	12	32.00	3	6.00	501	167.25	3	4.50	6	1.58	11	0.71	35	1.68	1	0.31	88	14.20	16	5.20	12	3.60
" 18	1	5.00	1	4.00	11	29.50	3	6.00	558	186.37	3	4.50	8	2.11	15	.96	15	.72	3	.95	84	13.50	15	4.80	12	3.60
" 19	1	5.00	1	4.00	10	26.50	3	6.00	567	189.50	3	4.50	6	1.58	12	.77	3	.14	3	.95	84	13.50	30	9.00	24	7.20
" 20	1	5.00	1	4.00	12	32.00	3	6.00	600	200.50	3	4.50	7	1.85	14	.90	6	.29	3	.94	108	17.40	30	9.60	24	7.20
" 21	1	5.00	1	4.00	12	32.00	3	6.00	567	189.50	3	4.50	8	2.10	17	1.09	8	.38	3	.95	108	17.40	30	9.60	24	7.20
" 22	1	5.00	1	4.00	11	29.00	3	6.00	513	171.50	3	4.50	7	1.84	15	.96	10	.48	3	.95	108	17.40	30	9.60	24	7.20
" 23	1	5.00	1	4.00	12	32.00	3	6.00	585	195.50	3	4.50	6	1.58	16	1.03	6	.29	3	.94	72	11.72	30	9.60	24	7.20
" 24	1	5.00	1	4.00	10	27.00	3	6.00	588	196.50	3	4.50	7	1.85	16	1.03	10	.48	2	.63	48	8.10	30	9.60	24	7.20
" 25	1	5.00	1	4.00			3	6.80					3	.79	6	.39							30	9.60	24	7.20
" 26	1	5.00	1	4.00	11	32.25	3	7.20	579	231.60	3	4.50	4	1.05	5	.32	3	.14	3	.95	24	6.00	30	9.60	24	7.20
" 27	1	5.00	1	4.00	12	35.00	4	8.70	621	248.40	3	4.50	5	1.32	12	.77			2	.63	24	6.00	30	9.60	24	7.20
" 28	1	5.00	1	4.00	12	35.00	4	8.70	615	246.00	3	4.50	6	1.57	14	.90	1	.05	3	.95	24	6.00	30	9.60	24	7.20
" 29	1	5.00	1	4.00	12	35.00	4	8.70	612	244.80	3	4.50	8	2.11	13	.83	2	.10	3	.94	24	6.00	34	11.20	24	7.20
" 30	1	5.00	1	4.00	6	19.00	4	8.70	331	133.75	3	4.50	9	2.37	16	1.03	7	.34	3	.95	24	6.00	28	8.80	24	7.20
" 31			1	4.00			2	4.00															28	8.80	24	7.20
1890.																										
Jan. 1			1	4.00			2	4.00					1	.26	1	.06							30	9.60	24	7.20
" 2			1	4.00			2	4.00															30	9.60	24	7.20
" 3			1	4.00			2	4.00					1	.26	1	.06							30	9.60	24	7.20
" 4			1	4.00			2	4.00					1	.26	1	.06							30	9.60	24	7.20
" 5	1	5.00	1	4.00	9	28.50	2	4.50	262	163.75	1	1.50	1	.27	1	.06			2	.63	12	3.00	30	9.60	24	7.20
" 6	1	5.00	1	4.00	18	57.00	3	7.50	626	393.75	3	4.50	10	2.64	14	.90	2	.10	1	.32	24	6.00	30	9.60	24	7.20
" 7	1	5.00	1	4.00	17	59.10	3	8.40	590	413.00	3	4.50	9	2.37	23	1.48	6	.29	3	.95	24	6.00	30	9.60	24	7.20
" 8	1	5.00	1	4.00	9	31.20	2	8.40	308	215.60	1	1.50	9	2.36	15	.96	10	.48	3	.94	24	6.00	30	9.60	24	7.20
" 9							2	4.00															15	4.80	12	3.60
" 10							2	4.00															15	4.80	12	3.60
" 11							2	4.00															15	4.80	12	3.60
" 12							2	4.00															15	4.80	12	3.60
" 13							2	4.00															15	4.80	12	3.60
" 14							2	4.00															15	4.80	12	3.60
" 15							2	4.00															15	4.80	12	3.60
" 16							2	4.00															15	4.80	12	3.60
" 17							2	4.00															15	4.80	12	3.60
" 18							2	4.00															15	4.80	12	3.60
" 19							2	4.00															17	5.60	24	7.20
" 20							2	4.00															17	5.60	24	7.20
" 21							2	4.00															15	4.80	24	7.20
" 22							2	4.00															15	4.80	24	7.20
" 23							2	4.00															15	4.80	24	7.20
" 24							2	4.00															15	4.80	24	7.20
" 25							2	4.00															15	4.80	24	7.20
" 26							2	4.00															15	4.80	24	7.20
" 27							2	4.00															15	4.80	24	7.20
" 28	1	5.00	1	4.00	18	66.30	2	6.00	314	314.00	3	4.50	4	1.05	8	.51	5	.24	1	.31	24	6.00	15	4.80	24	7.20
" 29	1	5.00	1	4.00	19	70.00	3	9.00	381	381.00	3	4.50	11	2.89	15	.96	5	.24	1	.33	24	6.00	30	9.60	24	7.20
" 30	1	5.00	1	4.00	20	74.00	3	9.00	374	374.00	3	4.50	10	2.64	27	1.74	2	.10	3	.95	24	6.00	30	9.60	24	7.20
" 31	1	5.00	1	4.00	19¾	72.66	3	9.00	384	384.00	3	4.50	10	2.63	23	1.48	12	.58	3	.95	24	6.00	30	9.60	24	7.20
Feb. 1	1	5.00	1	4.00	20	74.00	3	9.00	379	379.00	3	4.50	11	2.89	23	1.48	10	.48	3	.94	24	6.00	30	9.60	24	7.20
" 2	1	5.00	1	4.00	20	74.00	3	9.00	379	379.00	3	4.50	10	2.63	23	1.48	3	.14	3	.95	24	6.00	30	9.60	24	7.20
" 3	1	5.00	1	4.00	18	67.00	3	9.00	373	373.00	3	4.50	9	2.37	24	1.54	2	.10	3	.95	24	6.00	34	11.20	24	7.20
" 4	1	5.00	1	4.00	20	74.00	3	9.00	376	376.00	3	4.50	10	2.64	23	1.48	6	.29	3	.94	24	6.00	30	9.60	24	7.20
" 5	1	5.00	1	4.00	20	74.00	3	9.00	374	374.00	3	4.50	9	2.37	23	1.48	2	.10	3	.95	24	6.00	28	8.80	24	7.20
" 6	1	5.00	1	4.00	18	66.50	3	9.00	397	397.00	3	4.50	10	2.63	24	1.54	4	.19	3	.95	24	6.00	40	12.40	24	7.20
" 7	1	5.00	1	4.00	19⅝	72.66	3	9.00	404	404.00	3	4.50	10	2.63	29	1.80	7	.34	3	.94	24	6.00	40	12.40	24	7.20
" 8	1	5.00	1	4.00	19⅝	72.66	3	9.00	411	411.00	3	4.50	10	2.63	25	1.61	7	.34	3	.95	24	6.00	40	12.40	24	7.20
" 9	1	5.00	1	4.00	19⅝	72.50	3	9.00	410	410.00	3	4.50	10	2.63	24	1.54	5	.24	3	.95	24	6.00	34	10.60	24	7.20
" 10	1	5.00	1	4.00	20	74.00	3	9.00	382	382.00	3	4.50	8	2.10	26	1.67	2	.10	3	.91	24	6.00	30	9.60	24	7.20
" 11	1	5.00	1	4.00	19¼	71.17	3	9.00	388	388.00	3	4.50	9	2.36	28	1.80	2	.10	3	.95	24	6.00	15	4.80	12	3.60
" 12	1	5.00	1	4.00	20	74.00	3	9.00	372	372.00	3	4.50	2	.52	4	.26	15	.72	3	.95	66	14.40	15	4.80	12	3.60
" 13	1	5.00	1	4.00	9	38.50	2	6.00	196	196.00	2	3.00	10	2.63	23	1.48	18	.87	3	.94	52	10.25	15	4.80	12	3.60
" 14	1	5.00					2	4.00															15	4.80	12	3.60
" 15							2	4.00															15	4.80	12	3.60
" 16							1	2.00															17	5.60	12	3.60

Date	Pump Men Hrs	Amt	Firemen Hrs	Amt	Coal Passers Hrs	Amt	Coal for Boilers Tons	Amount	Black Oil Gals	Amt	Cylinder Oil Gals	Amt	Waste Lbs	Amt	Totals for Each Day	Feet Sunk Each Day	Material	Water Pump Hours Run	Rev	Pres	Rev. of Air p'ps	Remarks
1889.																						
Dec. 16	12	2.40	24	3.60	12	1.80	4.80	14.51	3	0.26	1	0.35	5	0.30	146.04	0.19	Mat	7.00	46	26	26	Started compressors at 12.55 [p.m., pumps at 1.00 a.m.
" 17	24	4.80	24	3.60	24	3.60	5.17	15.62	3	.27			5	.30	274.22	0.16	"	12.00	46	25	26	Sacking out Mat.
" 18	22	4.90	24	3.60	24	3.60	9.13	27.57	3	.27			7	.40	302.35	0.22	"	21.01	40	67	27	[compressors at 4.00 p.m.
" 19	22	4.90	48	7.20	18	2.70	6.97	21.05	3	.27			6	.34	305.70	1.26	"	37.45	51	63	30	Started pumps on Lincoln at 12.15 p.m.,
" 20	22	4.90	48	7.20	24	3.60	17.90	54.07	3	.27			7	.40	360.62	0.52	Fine river sand	36.00	55	61	28	Sacking out Mat.
" 21	22	4.90	48	7.20	48	7.20	17.66	53.34	3	.27			6	.34	352.97	1.64	" " "	47.50	56	61	28	" " "
" 22	22	4.90	48	7.20	48	7.20	24.10	72.96	3	.27			6	.34	354.30	2.44	" " "	48.00	56	72	35	" " "
" 23	22	4.90	48	7.20	48	7.20	25.84	78.03	3	.27	1	.35	6	.34	377.65	3.04	" " "	48.38	53	63	41	Mat all out.
" 24	22	4.90	48	7.20	48	7.20	19.46	58.78	3	.27			7	.40	350.64	2.41	" " "	24.08	52	64	34	Stopped pumps on Lincoln at 4.45 p.m.,
" 25	12	2.40	48	7.20	48	7.20	9.98	30.12	3	.27			6	.34	81.31	1.99	" " "				25	[on Bertram at 11.20 p.m.
" 26	24	4.80	48	7.20	48	7.20	18.51	55.90	3	.27			7	.40	385.58	0.03	" " "	41.61	55	58	37	Started pumps on Bertram and Lincoln
" 27	24	4.80	48	7.20	48	7.20	20.19	60.98	3	.27			6	.34	411.91	1.96	" " "	33.75	57	57	35	[at 8.00 a.m.
" 28	24	4.80	48	7.20	48	7.20	18.15	54.81	3	.27			7	.38	404.13	1.41	" " "	41.83	58	63	35	
" 29	24	4.80	48	7.20	48	7.20	22.59	68.23	3	.27			6	.34	418.42	3.27	" " "	45.00	52	61	34	
" 30	24	4.80	48	7.20	48	7.20	16.34	49.30	3	.27	1	.35	7	.40	271.16	2.67	" " "	20.00	62	61	31	Stopped pumps on Bertram and Lincoln [at 6.00 p.m.
" 31	22	4.40	48	7.20	48	7.20	9.49	28.65	2	.18			6	.34	71.97	0.96	" " "				27	Waiting for Masonry.
1890.																						
Jan. 1			48	7.20	36	5.40	10.10	30.49	3	.27			7	.40	68.88	0.28	" " "				24	" " "
" 2			48	7.20	48	7.20	14.18	42.82	3	.27			6	.34	82.63	0.06	" " "				24	" " "
" 3			48	7.20	36	5.40	15.02	45.35	3	.27			6	.34	83.68	0.06	" " "				21	" " "
" 4			48	7.20	36	5.40	10.94	33.03	2	.18			7	.40	71.33	0.02	" " "				21	" " "
" 5	12	2.40	48	7.20	48	7.20	15.51	46.82	3	.27			6	.34	292.24	0.04	" " "	20.49	65	68	35	Started pumps on Bertram at 8.10 a.m.,
" 6	24	4.80	48	7.20	48	7.20	20.79	62.78	3	.27	1	.35	6	.34	581.45	1.32	" " "	48.00	67	73	33	[on Lincoln at 7.20 p.m.
" 7	24	4.80	48	7.20	48	7.20	14.18	42.83	2	.18			6	.34	584.44	2.88	" " "	44.91	58	69	36	[on Bertram at 6.25 p.m.
" 8	24	4.80	48	7.20	48	7.20	25.47	76.93	2	.18			6	.34	389.89	2.64	" " "	20.74	55	76	21	Stopped pumps on Lincoln at 6.20 p.m.,
" 9			24	3.60	24	3.60	7.69	23.21	3	.27			6	.34	43.42	1.62	" " "				18	Stopped compressors on Lincoln at 8.10
" 10			24	3.60	24	3.60	2.53	7.63	1	.09			4	.22	27.54	0.00	" " "				21	Waiting for masonry. [p.m.
" 11			12	1.80	24	3.60	2.88	8.71	2	.18			4	.23	26.92	0.02	" " "				22	" " "
" 12			12	1.80	24	3.60	4.69	14.15	1	.09			4	.22	32.26	0.01	" " "				23	" " "
" 13			12	1.80	24	3.60	7.45	22.49	2	.18	1	.35	4	.23	41.05	0.01	" " "				25	" " "
" 14			24	3.60	24	3.60	6.85	20.69	1	.09			4	.22	40.00	0.04	" " "				26	" " "
" 15			24	3.60	24	3.60	5.41	16.35	2	.18			4	.23	36.36	0.00	" " "				26	" " "
" 16			24	3.60	24	3.60	5.17	15.62	1	.09			4	.22	35.53	0.00	" " "				26	" " "
" 17			24	3.60	24	3.60	7.21	21.77	2	.18			4	.22	41.77	0.00	" " "				23	" " "
" 18			24	3.60	24	3.60	6.25	18.87	1	.09			4	.23	38.73	0.00	" " "				24	" " "
" 19			24	3.60	24	3.60	5.17	15.62	2	.18			4	.22	40.02	0.00	" " "				24	" " "
" 20			24	3.60	24	3.60	4.33	13.06	1	.09	1	.35	4	.23	37.73	0.00	" " "				23	" " "
" 21			24	3.60	24	3.60	5.41	16.35	2	.18			4	.22	39.95	0.00	" " "				24	" " "
" 22			24	3.60	24	3.60	8.18	24.09	1	.09			4	.23	48.21	0.00	" " "				23	" " "
" 23			24	3.60	24	3.60	5.04	15.24	2	.18			4	.22	38.84	0.00	" " "				24	" " "
" 24			24	3.60	24	3.60	5.29	15.99	1	.09			4	.23	39.51	0.00	" " "				23	" " "
" 25			24	3.60	24	3.60	4.92	14.88	1	.09			4	.22	38.39	0.00	" " "				23	" " "
" 26			12	1.80	24	3.60	3.85	11.63	3	.27			4	.23	33.53	0.00	" " "				22	" " "
" 27			24	3.60	24	3.60	4.80	14.51	4	.36	1	.35	4	.23	38.65	0.00	" " "				24	" " " [pumps at 11.45 a.m.
" 28	24	4.80	24	3.60	24	3.60	5.89	17.78	3	.27			7	.40	450.36	0.00	" " "	28.91	53	75	34	Started comp. on Bertram at 11.05 a.m.,
" 29	24	4.80	48	7.20	48	7.20	19.83	59.90	2	.18			7	.40	580.39	1.21	" " "	36.75	58	70	31	Started compressors on Lincoln at 12.05
" 30	24	4.80	48	7.20	48	7.20	23.20	70.05	4	.36			6	.34	588.68	1.83	" " "	48.00	52	87	28	[a.m.
" 31	24	4.80	48	7.20	48	7.20	28.36	85.64	3	.27			6	.34	613.05	1.89	Coarse sand with gravel	48.00	52	90	30	
Feb. 1	24	4.80	48	7.20	48	7.20	21.87	66.04	4	.36			6	.34	590.03	1.60	"	40.50	53	89	33	
" 2	24	4.80	48	7.20	48	7.20	22.84	68.96	3	.27			6	.34	592.27	1.62	"	44.20	56	86	35	
" 3	24	4.80	48	7.20	48	7.20	16.46	49.70	3	.27	1	.35	7	.40	561.78	1.36	"	39.58	52	82	36	
" 4	24	4.80	48	7.20	48	7.20	21.87	66.05	4	.36			6	.34	586.00	2.81	"	48.00	52	80	36	
" 5	24	4.80	48	7.20	48	7.20	29.68	89.65	4	.36			6	.34	606.95	1.08	"	44.42	48	70	38	
" 6	24	4.80	48	7.20	48	7.20	23.43	70.77	4	.36			6	.34	607.58	0.99	"	40.33	47	67	43	
" 7	24	4.20	48	7.20	48	7.20	19.95	60.26	3	.27			7	.41	610.07	0.21	"	39.42	46	68	38	Clay on west side of cutting edge.
" 8	24	4.20	48	7.20	48	7.20	24.40	73.69	4	.36			6	.34	630.28	1.10	"	42.66	47	69	32	
" 9	24	4.20	48	7.20	48	7.20	16.46	49.71	3	.27			6	.34	609.08	0.33	Coarse sand, gravel and clay	21.08	47	72	33	
" 10	24	4.20	48	7.20	48	7.20	13.22	39.91	3	.27	1	.35	6	.34	565.58	0.86		12.37	46	70	33	Stopped water pumps on Bertram at 6.50 [a.m.
" 11	5	1.25	24	3.60	24	3.60	7.33	22.14	2	.18			7	.42	532.47	0.06	"	0.75	40	50	24	Stopped water pumps on Lincoln at 8.45
" 12			24	3.60	24	3.60	6.97	21.07	4	.36			6	.36	532.74	0.00	"				35	Started clay hoists. [a.m.
" 13			24	3.60	24	3.60	7.45	22.50	3	.27			7	.42	302.46	0.00	"				32	
" 14			24	3.60	24	3.60	3.36	10.15	2	.18			6	.36	35.29	0.01	"				37	Stopped compressors on Bertram at 7.10
" 15			24	3.60	24	3.60	4.33	13.07	2	.18			6	.36	33.21	0.00	"				34	[a.m.
" 16			24	3.00	24	3.60	2.88	8.71	2	.18			7	.42	27.71	0.00	"				33	[a.m. Stopped compressors on Lincoln at 9.30

APPENDIX I.—Continued.

TIME, COST AND MATERIAL USED IN FOUNDATIONS.

PIER III.—Continued.

Date. 1890.	Principal Foreman. Days	Principal Foreman. Amt.	Night Foreman Days	Night Foreman Amt.	Sub Foremen. Days	Sub Foremen. Amount.	Lock Tenders. Days	Lock Tenders. Amt.	Pressure Men. Hrs	Pressure Men. Amount.	Coffer House Men Days	Coffer House Men Amt	Coffee Lbs	Coffee Amt.	Sugar. Lbs.	Sugar. Amt.	Candles. No.	Candles. Amt
June 18			1	4.00														
" 19	1	5.00	1	4.00	1	4.00	1	3.00	24	24.00	1	1.50	1	0.26	3	0.19		
" 20	1	5.00	1	4.00	8	32.00	2	6.00	226	226.00	3	4.50	5	1.32	9	.58	12	0.58
" 21	1	5.00	1	4.00	8	32.00	2	6.00	245	245.00	3	4.50	7	1 84	11	.71	6	.29
" 22	1	5.00	1	4 00	7½	29.34	2	6.00	231	231.00	3	4.50	6	1.58	11	.71	6	.29
" 23	1	5.00	1	4.00	8	32.00	2	6.00	254	254.00	3	4.50	6	1.58	11	.71		
" 24	1	5.00	1	4.00	10	37.75	2	6.00	271	271.00	3	4.50	6	1.58	13	.83	6	.29
" 25	1	5.00	1	4.00	10½	39 91	2	6.00	292	292.00	3	4.50	7	1.84	11	.71	6	.29
" 26	1	5.00	1	4.00	11	41.75	2	6.00	296	296.00	3	4.50	6	1.58	11	.71		
" 27	1	5.00	1	4.00	11	41.75	2	6.00	318	318.00	3	4.50	7	1.84	12	.77		
" 28	1	5.00	1	4.00	10	38.50	2	6.00	310	310.00	3	4.50	6	1.58	12	.77		
" 29	1	5.00	1	4.00	11	41.75	2	6.00	301	301 00	3	4.50	7	1.84	14	.90		
" 30	1	5.00	1	4.00	9	35.25	2	6.00	333	333.00	3	4.50	9	2 36	11	.71	5	.24
July 1	1	5.00	1	4.00	10	38.50	2	6.00	317	317.00	3	4.50	6	1 58	13	.83	3	.14
" 2	1	5.00	1	4.00	10	38.50	2	6.00	309	309.00	3	4.50	7	1.84	13	.83		
" 3	1	5.00	1	4.00	11	41.75	2	6.00	303	303.00	3	4.50	7	1.84	11	.71		
" 4	1	5.00	1	4 00	9	32.91	2	6.00	291	291.00	3	4.50	9	2.37	11	.71	1	.05
" 5	1	5.00	1	4 00	10	38.50	2	6.00	327	327.00	3	4.50	10	2.63	14	.90		
" 6	1	5.00	1	4.00	11	41.75	2	6.00	331	331.00	3	4.50	8	2 10	13	.83	6	.29
" 7	1	5.00	1	4.00	11	41.75	2	6.00	352	352.00	3	4.50	10	2.63	13	.83	1	.05
" 8	1	5.00	1	4.00	11	41.75	2	6.00	354	354.00	3	4.50	9	2.37	14	.90		
" 9	1	5.00	1	4.00	11	41.75	2	6.00	366	366.00	3	4.50	9	2.37	14	.90	2	.10
" 10	1	5.00	1	4.00	11	41.75	2	6.00	385	383.00	3	4.50	10	2 63	13	.83	10	.48
" 11	1	5.00	1	4.00	11	41.75	2	6.00	371	671.00	3	4 50	8	2.11	12	.77	4	.19
" 12	1	5.00	1	4.00	10	38 50	2	6.00	360	360.00	3	4 50	8	2.10	14	.90	2	.10
" 13	1	5.00	1	4 00	10	37.75	2	6.00	351	371.00	3	4.50	9	2.36	13	.84	6	.29
" 14	1	5.00	1	4 00	11	41.75	2	6.00	372	372.00	3	4.50	7	1.84	13	.84	6	.29
" 15	1	5.00	1	4.00	11	41.75	2	6.00	339	339.00	3	4.50	6	1.58	12	.77	1	.05
" 16	1	5.00	1	4.00	9¾	32.43	2	6.00	352	352.00	3	4.50	7	1.84	11	.71	3	.14
" 17	1	5.00	1	4.00	11	41.75	2	6.00	304	364.00	3	4.50	8	2.11	14	.90	6	.29
" 18	1	5.00	1	4.00	11	41.75	2	6.00	360	360.00	3	4.50	8	2.10	12	.77	7	.34
" 19	1	5.00	1	4.00	11	41.75	2	6.00	368	368.00	3	4 50	10	2.63	13	.84	5	.24
" 20	1	5.00	1	4.00	11	41.75	2	6.00	365	365.00	3	4.50	9	2.37	13	.84	6	.29
" 21	1	5 00	1	4.00	10	37.75	2	6.00	396	396.00	3	4.50	8	2.11	13	.84	5	.24
" 22	1	5 00	1	4.00	11	41.75	2	6.00	406	406.00	3	4.50	9	2.30	15	.97	4	.19
" 23	1	5.00	1	4 00	11	41.75	2	6.00	390	390.00	3	4.50	10	2.63	15	.97	5	.24
" 24	1	5.00	1	4.00	11	41.75	2	6.00	373	373.00	3	4.50	8	2.10	14	.90	3	.14
" 25	1	5.00	1	4.00	11	41.75	2	6.00	359	359.00	3	4.50	9	2.37	16	1.08	2	.10
" 26	1	5.00	1	4.00	11	41.75	2	6.00	381	381.00	3	4 50	9	2.36	15	.96	6	.29
" 27	1	5.00	1	4.00	11	41.75	2	6.00	360	360.00	3	4.50	8	2.11	14	.90	3	.14
" 28	1	5 00	1	4 00	11	41.75	2	6 00	383	383.00	3	4 50	9	2.37	14	.90		
" 29	1	5 00	1	4 00	11	41.75	2	6.00	382	382 00	3	4 50	8	2.10	14	.90		
" 30	1	5.00	1	4.00	11	41.75	2	6.00	362	362 00	3	4.50	9	2.37	14	.90	14	.67
" 31	1	5.00	1	4 00	10½	40.42	2	6.00	337	337.00	3	4.50	8	2.11	13	.84		

Date. 1890.	Coal for House Boat. 200-lb. boxes	Coal for House Boat. Amt	Sacking Out, Clay Hoist and Elevator Men Hrs	Sacking Out, Clay Hoist and Elevator Men Amount	Master Mechanic and Day Engineers. Hrs	Master Mechanic and Day Engineers. Amt	Night Engineers. Hrs	Night Engineers. Amt.	Pump Men Hrs	Pump Men Amt	Firemen. Hrs.	Firemen. Amt.	Coal Passers. Hrs.	Coal Passers. Amt	Coal for Boilers. Tons.	Coal for Boilers. Amount.
June 18					16	5.20	12	3.60			24	3.60	24	3.60	1.20	3.66
" 19					16	5.20	12	3.60			24	3.60	24	3.60	9.50	28.68
" 20					16	5.20	12	3.60			24	3.60	24	3.60	8.53	25.77
" 21					16	5.20	12	3.60			24	3.60	24	3 60	5.53	16.70
" 22			36	8.00	16	5.20	12	3.60	24	4.80	24	3.60	24	3.60	8.18	24.68
" 23			120	22.80	16	5.20	12	3.60	24	4.80	24	3.60	24	3.60	12.38	37.39
" 24	1	0.31	120	22.80	16	5.20	12	3.60	24	4.80	24	5.40	24	3.60	12.98	39.20
" 25	1	.32	120	22.80	16	5.20	12	3.60	24	4.80	24	5 40	24	3.60	6.13	18 49
" 26	2	.63	186	34 20	16	5 20	12	3.60	6	1.20	24	5.40	24	3.60	10.22	30.84
" 27			216	38.50	16	5.20	12	3.60			24	5.40	24	3.60	10.69	32.28
" 28	2	.63	216	38.50	16	5.20	12	3.60			24	5 40	24	3.60	9 25	27.93
" 29			216	38.50	16	5 20	12	3 60			24	5.40	24	3 60	10.94	33.03
" 30	1	.31	216	38.50	16	5.20	12	3.60			24	5.40	24	3.60	11.30	34.12
July 1	1	.32	210	37.50	16	5.20	12	3.60			24	5.40	24	3 60	11.30	34 12
" 2	1	.31	216	38.50	16	5.20	12	3.60			24	5.40	24	3.60	12.37	37.30
" 3	1	.32	216	38.50	16	5.20	12	3.60			24	5 40	24	3.60	12.01	36.28
" 4	1	.31	132	25.60	24	8.80	16	4 80	18	3.60	42	7.20	36	5.40	7.69	23.21
" 5	1	.33	168	33.00	28	8.80	24	7.20	6	1 20	48	7.20	48	7.20	18.02	54.43
" 6	1	.31	216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	15.51	46.82
" 7	1	.32	216	38 50	28	8.80	24	7.20			48	7.20	48	7.20	19.34	58.42
" 8			216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	20.30	61.33
" 9	1	.31	216	38.50	28	8 80	24	7.20			48	7.20	48	7.20	24.76	74.77
" 10	1	.32	203	35.90	28	8.80	24	7.20	7	1.40	48	7.20	48	7.20	19.70	59.49
" 11	1	.31	216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	18.75	56.61
" 12			216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	20.07	60.61
" 13	1	.32	216	38.50	34	11.20	24	7.20			48	7.20	48	7.20	18.14	54.78
" 14			216	38 50	28	8.80	24	7.20			48	7.20	48	7.20	15.02	45.35
" 15	1	.31	216	38.50	28	8 80	24	7.20			48	7.20	48	7.20	15.02	45.35
" 16	1	.32	216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	16.22	48 98
" 17	1	.31	216	38.50	28	8.80	24	7.20			48	7.20	48	7.20	12.98	39 20
" 18			216	38.50	28	8 80	24	7.20			48	7.20	48	7.20	12.13	66.64
" 19	1	.32	120	22.60	28	8.80	24	7.20			48	8.00	48	7.20	11.54	34.84
" 20	1	.31	128	22.40	28	8.80	24	7.20			48	8.00	48	7.20	10.10	30.49
" 21	1	.32	216	38.50	28	8.80	24	7.20			48	8.00	48	7.20	12.13	36.64
" 22	1	.31	210	37.50	28	8.80	24	7.20			48	8 00	48	7.20	12.01	36.27
" 23	1	.32	216	38.50	28	8.80	24	7.20			48	8.00	48	7.20	9 13	27.57
" 24	1	.31	216	38.50	28	8.80	24	7.20			48	8.00	48	7.20	14.30	43.10
" 25	1	.33	216	38.50	28	8.80	24	7.20			48	8.00	48	7.20	11.18	33.76
" 26	1	.31	210	38.50	28	8 80	24	7.20			48	8.00	18	7.20	13.10	39.56
" 27	1	.32	216	38.50	30	9.60	24	7.20			48	8.00	48	7.20	12.86	38.84
" 28	1	.31	206	36.50	28	8.80	24	7.20			48	8.00	48	7.20	14.18	42.83
" 29	1	.32	216	38.50	28	8.80	24	7 20			48	8.00	48	7.20	16.64	49.34
" 30	1	.61	214	38.10	28	8.80	24	7.20			48	8.00	48	7.20	21.14	63.84
" 31	1	.32	216	38.50	28	8.80	24	7.20			48	8.00	48	7.20	18.14	54.77

Date. 1890.	Black Oil. Gals	Black Oil. Amt.	Cylinder Oil. Gals.	Cylinder Oil. Amt.	Waste. Lbs.	Waste. Amt.	Totals for Each Day.	Feet Sunk Each Day.	Material.	Water Pump. Hours Run.	Water Pump. Rev.	Water Pump. Pres	Rev. of Air p'ps.	Remarks.
June 18	¼	.03	1	.37	2	.10	24.13						31	Started compressors on Bertram at 11.20 [a m.
" 19	2	.18			3	.15	86.96						30	
" 20	2	.18			2	.10	322.03						36	
" 21	2	.18			3	.15	332.37		Coarse sand gravel	18.58	51	73	37	Started water pump on Bertram at 1.15 [p.m.
" 22	2	.18	1	.37	2	.10	336.55		and clay	24.00	51	89	40	
" 23	2	.18			3	.15	389.11		"	21.58	50	87	38	
" 24	2	.18			2	.10	416.14	0.57	"	24.00	50	70	35	
" 25	2	.18			3	.15	418.79	0.00	"	22.92	79	78	39	
" 26	2	.18	1	.37	2	.10	444 86	0.00	"	3.42	58	95	42	Stopped pump on Bertram at 11.25 a.m.
" 27	2	.18			3	.15	470.77	0.00	"				46	
" 28	2	.18			2	.10	455.49	0 03	"				47	[stopped at 11.25 p.m.
" 29	2	.18			3	.15	454.65	0.14	"	8.00	48	81	52	Started pumps on Bertram at 3.25 p.m.,
" 30	2	.18	1	.37	2	.10	482.44	0 12	"				54	
July 1	2	.18			3	.18	467 65	0.91	"				58	
" 2	2	.18			2	.10	463.92	0.02	"				62	
" 3	2	.18			3	.15	460.03	0.00	"				61	[comp. on Lincoln at 6 35 p.m.
" 4	2	.18	1	.37	2	.10	426 11	0.00	"	15.00	78	98	41	Started pump on Bertram at 5.00 p.m.,
" 5	2	.18			3	.15	508.21	0.36	"	6.33	57	98	37	Stopped pump on Bertram at 2 35 p.m.
" 6	2	.18			2	.10	511.78	1.15	"				33	
" 7	2	.18			3	.15	544 73	0.00	"				35	[stopped at 7.25 p m.
" 8	2	.18	1	.37	2	.10	549.40	0.01	"	8.00	60	101	34	Started pump on Bertram at 11.25 a.m.,
" 9	2	.18			3	.15	574.93	0.97	"				37	[stopped at 4.00 p.m.
" 10	2	.18			2	.10	577 98	0.00	"	6.30	59	91	38	Started pump on Bertram at 9.30 a.m.,
" 11	2	.18			3	.15	561.47	0.86	Clay				41	
" 12	2	.18	1	.37	2	.10	551.26	0.02	"				43	
" 13	2	.18			3	.15	538.47	0.00	"				41	
" 14	2	.18			2	.10	550.75	0.00	"				36	
" 15	2	.18			3	.15	517.54	1.05	"				35	
" 16	2	.18	1	.37	2	.10	525.40	0.00	"				34	
" 17	2	.18			3	.15	537 29	1.03	"				34	
" 18	2	.18			2	.10	530.28	0.00	"				31	
" 19	2	.18			3	.15	522.27	0.00	"				29	
" 20	2	.18	1	.37	2	.10	514.80	0.00	"				33	
" 21	2	.18			3	.15	563.43	0.00	"				41	
" 22	2	.18			2	.10	576.33	0.00	"				41	
" 23	2	.18			3	.15	553.01	0.00	"				39	
" 24	2	.18	1	.37	2	.10	551.24	0.00	"				38	
" 25	2	.18			3	.15	527.86	0.00	"				37	
" 26	2	.18			2	.10	555.71	1.54	"				37	
" 27	2	.18			3	.15	534.39	0.00	"				36	
" 28	2	.18	1	.37	2	.10	559.01	0.00	"				37	
" 29	2	.18			3	.15	565.94	0.00	"	18.00	54	87	37	Started pump on Lincoln at 2.00 p.m.
" 30	2	.18			2	.10	560.92	0.00	Sand and clay	21.75	55	91	38	
" 31	2	.18			3	.15	524.99	1 53	" " "	9.36	49	92	38	Stopped pump on Lincoln at 7.05 p.m.

APPENDIX I.—Continued.

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER III.—Continued.

Date 1890.	Principal Foreman Days	Principal Foreman Amt.	Night Foreman Days	Night Foreman Amt.	Sub-Foremen Days	Sub-Foremen Amount.	Lock Tender Days	Lock Tender Amt.	Pressure Men Hrs	Pressure Men Amount.	Coffee House Men Days	Coffee House Men Amt.	Coffee Lbs.	Coffee Amt.	Sugar Lbs	Sugar Amt.	Candles No.	Candles Amt	Coal for House Boat 300-lb Boxes	Coal for House Boat Amt.	Sacking Out, Clay Hoist and Elevator Men Hrs	Sacking Out, Clay Hoist and Elevator Men Amount.
Aug. 1	1	5.00	1	4.00	11	41.75	2	6.00	342	342.00	3	4 50	6	1.58	13	.83	4	.19	1	.31	216	38.50
" 2	1	5.00	1	4.00	10½	40.42	2	6.00	360	360.00	3	4.50	9	2.36	15	.96	5	.24	1	.32	216	38.50
" 3	1	5.00	1	4.00	10	38.50	2	6.00	338	338.00	3	4.50	9	2.37	14	.90	9	.43	1	.31	216	39.60
" 4	1	5.00	1	4.00	11	41.75	2	6.00	337	337.00	3	4.50	7	1.84	14	.90	4	.19	.....	.....	216	39.60
" 5	1	5.00	1	4.00	11	41.75	2	6.00	342	342.00	3	4.50	7	1.84	15	.96	....	.....	1	.33	144	27.00
" 6	1	5.00	1	4.00	11	41.75	2	6.00	356	356.00	3	4.50	9	2.37	14	.90	1	.05	1	.31	120	22.80
" 7	1	5.00	1	4.00	11	41.75	2	6.00	350	350.00	3	4.50	8	2.10	15	.96	10	.48	1	.32	120	22.80
" 8	1	5.00	1	4.00	11	41.75	2	6.00	331	331 00	3	4.50	9	2.36	14	.90	3	.14	.....	.....	120	22.80
" 9	1	5.00	1	4.00	11	41.75	2	6.00	351	351.00	3	4.50	6	1.58	15	.96	7	.34	1	.31	120	22.80
" 10	1	5.00	1	4.00	11	41.75	2	6.00	329	329.00	3	4.50	8	2.11	15	.96	10	.48	1	.32	120	22.80
" 11	1	5 00	1	4.00	11	41.75	2	6.00	351	351.00	3	4.50	8	2.11	15	.96	2	.10	1	.31	48	10.20
" 12	1	5.00	1	4.00	11	41.75	2	6.00	357	357.00	3	4.50	9	2.37	14	.90	8	.39	1	.32	24	6.00
" 13	1	5.00	1	4.00	11	41.75	2	6.00	363	363.00	3	4.50	8	2.10	12	.77	6	.29	1	.31	24	6.00
" 14	1	5.00	1	4 00	11	41.75	2	6.00	367	367.00	3	4.50	6	1.58	13	.83	6	.29	1	.32	24	6.00
" 15	1	5.00	1	4.00	11	41.75	2	6.00	306	306.00	3	4.50	8	2.11	11	.71	5	.24	1	.31	24	6.00
" 16	1	5.00	1	4.00	10½	40.41	2	6.00	265	265.00	3	4.50	7	1.84	10	.61	16	.77	.....	.....	84	15.70
" 17	1	5.00	1	4.00	11	41.75	2	6.00	299	299.00	3	4 50	11	2.89	10	.64	18	.87	1	.32	120	22.80
" 18	1	5.00	1	4.00	11	45.25	2	6.50	302	628.33	3	4.50	6	1.57	11	.71	14	.68	1	.31	48	10.20
" 19	1	5.00	1	4.50	11	47.25	2	7.00	319	372.17	3	4.50	7	1.84	14	.90	10	.48	1	.32	24	6.00
" 20	1	5.00	1	4.50	11	47.25	2	7.00	322	377.16	3	4.50	6	1.58	11	.71	11	.53	.....	.....	24	6.00
" 21	1	5.00	1	4.50	11	47.25	2	7.00	348	406.00	3	4.50	7	1.85	13	.83	8	.39	1	.31	72	14.40
" 22	1	5.00	1	4.50	11	47.25	2	7.00	324	380.33	3	4 50	6	1.58	12	.77	5	.24	1	.32	48	10.20
" 23	1	5.00	1	4.50	11	47.25	2	7.00	340	396.67	3	4 50	10	2.64	14	.90	6	.29	.....	.....	24	6.00
" 24	1	5.00	1	4.50	11	47.25	2	7.00	338	394.33	3	4.50	9	2.37	13	.84	3	.14	1	.31	24	6.00
" 25	1	5.00	1	4.50	11	47.25	2	7.00	338	394.33	3	4.50	10	2.71	13	.86	12	.58	.....	.....	24	6.00
" 26	1	5.00	1	4.50	11	47.25	2	7.00	329	383.83	3	4.50	9	2.44	16	1.06	1	.05	1	.28	24	6.00
" 27	1	5.00	1	4.50	11	47.25	2	7.00	347	404.83	3	4.50	12	3.25	18	1.19	...	.....	1	.28	24	6.00
" 28	1	5.00	1	4.50	11	47.25	2	7.00	344	401.33	3	4 50	10	2.71	17	1.12	4	.19	1	.28	24	6.00
" 29	1	5.00	1	4.50	11	47 25	2	7.00	351	409.50	3	4.50	10	2.71	17	1.13	...	.....	....	.....	24	6.00
" 30	1	5.00	1	4.50	11	47.25	2	7.00	308	359.33	3	4.50	9	2.44	17	1.13	4	.19	1	.28	24	6.00
" 31	1	5.00	1	4.50	10	43.50	2	7.00	309	360.50	3	4.50	8	2.17	15	.99	6	.29	.....	.....	24	6.00
Sept. 1	1	5.00	1	4.50	11	47.25	2	7.00	335	390.83	3	4 50	9	2.44	17	1.18	9	.43	1	.28	24	6.00
" 2	1	5.00	1	4.50	11	47.25	2	7.00	335	390.83	3	4.50	8	2.17	16	1.06	9	.43	1	.28	24	6.00
" 3	½	2.50	1	4.50	10	42.75	2	7.00	259	302.17	3	4.50	10	2.71	19	1.26	25	1.20	.....	.....	24	6.00
" 4	½	2 50	....	......	4	18.00	1	3.50	115	134.17	1	1.50	5	1.36	10	.66	14	.08	1	.28	....	.....
Total.		570.00		484.00		4946 91		862.60		36660.58		492.75		236.00		105.97		31.50		47.36		2168.27

Date 1890.	Master Mechanic and Day Engineers Hrs.	Master Mechanic and Day Engineers Amount.	Night Engineers Hrs.	Night Engineers Amt.	Pump Men Hrs.	Pump Men Amt.	Firemen Hrs.	Firemen Amt.	Coal Passers Hrs.	Coal Passers Amt.	Coal for Boilers Tons.	Coal for Boilers Amount.	Black Oil Gals.	Black Oil Amt.	Cylinder Oil Gals.	Cylinder Oil Amt.	Waste Lbs.	Waste Amt.	Totals for Each Day.	Feet Sunk Each Day.
Aug. 1	28	8.80	24	7.20	....	......	48	8 00	48	7.20	16.46	49.70	2	.18	1	.37	2	.10	526.21	0.00
" 2	28	8.80	24	7.20	....	......	48	8.00	48	7.20	22.95	69.32	2	.18	....	.....	3	.16	563.16	0.00
" 3	28	8.80	24	7.20	....	......	48	8.00	48	7.20	18.02	54.42	2	.18	....	.....	2	.10	525.51	0.08
" 4	28	8.80	24	7.20	....	......	48	8.00	48	7.20	15.98	48.26	2	.18	....	.....	3	.16	520.58	1.52
" 5	28	8.80	24	7.20	15	3.00	48	8.00	48	7.20	22.83	68.95	2	.18	1	.37	2	.10	537.17	0.00
" 6	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	19.70	59.50	2	.18	....	.....	3	.16	539.52	0.00
" 7	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	19.10	57.70	2	.18	....	.....	2	.10	531.89	0.00
" 8	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	21 87	66.04	2	.18	....	.....	3	.16	520.83	1.66
" 9	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	18.75	56.61	1	.09	1	.37	2	.10	531.41	0.00
" 10	28	8.80	24	7 20	24	4.80	48	8.00	48	7.20	23.79	71.84	2	.18	....	.....	3	.16	525.10	1.74
" 11	30	9 60	24	7.20	24	4.80	48	8.00	48	7 20	20.78	62.78	1	.09	....	.....	2	.10	525.70	1.49
" 12	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	20.31	61.33	2	.18	....	.....	3	.16	525.90	1.52
" 13	28	8.80	24	7.20	24	4.80	48	8.00	48	7.20	15 98	48.26	1	.09	1	.37	2	.10	518.54	1.30
" 14	28	8.80	24	7.20	24	4 80	48	8.00	48	7 20	13.58	40.99	2	.18	....	.....	3	.16	514 60	1.05
" 15	28	8.80	24	7.20	3	0.60	48	8.00	48	7.20	12.13	36.64	1	.09	....	.....	2	.10	445.25	0.90
" 16	28	8.80	24	7.20	....	......	48	8.00	48	7.20	5.29	15.97	2	.18	....	.....	3	.16	391.37	0.00
" 17	28	8.80	24	7.20	....	......	48	8.00	42	6.30	4.68	14.14	1	.09	1	.37	2	.10	432.77	0.00
" 18	28	8.80	24	7 20	....	......	48	8.00	24	3.60	3.60	10.87	2	.18	....	.....	3	.16	445 85	0.00
" 19	28	8 80	24	7.20	....	......	48	8.00	24	3.60	6.97	21.06	1	.09	....	.....	2	.10	498.81	0.00
" 20	28	8 80	24	7.20	....	......	48	8.00	24	3.60	8.65	26.13	2	.18	....	.....	3	.16	508.29	0.00
" 21	28	8.80	24	7.20	15	3.00	48	8.00	48	7.20	10 10	30.48	1	.09	1	.37	3	.15	557.33	0.00
" 22	28	8.80	24	7.20	....	......	48	8.00	48	7.40	8.89	26 85	2	.18	....	.....	3	.15	520.27	0.00
" 23	28	8.80	24	7.20	....	......	48	8.00	36	5.40	5.04	15.22	1	.09	....	.....	3	.15	519.62	0.00
" 24	28	8.80	24	7.20	....	......	48	8.00	36	5.40	5.65	17.08	2	.18	....	.....	3	.15	519.05	0.00
" 25	28	8.80	24	7.20	....	......	48	8.00	36	5.40	23.46	63.55	1	.09	1	.37	3	.15	566.20	0.00
" 26	28	8.80	24	7.20	....	......	48	8.00	36	5.40	22.51	90.96	2	.18	....	.....	3	.16	552.61	0.00
" 27	28	8 80	24	7.20	....	......	48	8.00	36	5.40	33.07	89.57	1	.09	....	.....	3	.15	603.01	0.00
" 28	28	8.80	24	7.20	....	......	48	8.00	36	5.40	31.15	84.37	2	.18	....	.....	3	.16	593.99	0.00
" 29	28	8.80	24	7.20	....	......	48	8.00	36	5.40	30.19	81.74	1	.09	1	.37	3	.15	590.34	0.00
" 30	28	8.80	24	7.20	....	......	48	8.00	36	5.40	22.51	60 97	2	.18	....	.....	3	.15	528.32	0.00
" 31	22	7.00	12	3.60	....	......	30	5.00	36	5.40	10.98	29.73	1	.09	...	.....	3	.15	485.42	0.00
Sept. 1	16	5.20	12	3 60	....	......	24	4.00	24	3.60	18.67	50.55	2	.18	1	.37	3	.15	537.01	0.00
" 2	16	5.20	12	3.60	....	......	24	4 00	24	3.60	14.82	40.14	1	.09	...	.....	3	.15	525.80	0.00
" 3	14	4.40	12	3.60	....	......	24	4.00	24	3.60	12.42	33.65	2	.18	...	.....	3	.15	424.17	0.00
" 4	14	4.40	12	3.60	....	......	24	4.00	12	1.80	8.20	22.19	1	.09	½	.19	3	.16	199.08	0.00
Total.		1100.80		876.00		231.55		390.60		709.40		5808.17		27.47		10.74		30.69	56381.36	

Date 1890.	Material.	Water Pump Hours Run.	Water Pump Rev.	Water Pump Pres.	Rev. of Air p'ps.	Remarks.
Aug. 1	Sand and clay	0.00	00	00	37	
" 2	" " "	24.00	55	92	34	Started pump on Lincoln at 8.00 a.m.
" 3	" " "	11.58	56	93	32	Stopped " " " 7 32 p.m.
" 4	" " "	0.00	00	....	34	
" 5	" " "	37.40	50	90	27	Started pump on Lincoln at 8.10 a.m. " " " Bertram at 3.30 p.m.
" 6	" " "	47.13	48	92	26	
" 7	" " "	47.20	47	93	28	
" 8	" " "	47.30	50	91	27	
" 9	" " "	45.25	48	89	28	
" 10	" " "	47.33	50	91	30	
" 11	" " "	44.74	48	95	28	
" 12	" " "	48.00	50	92	27	
" 13	" " "	46.33	51	90	30	
" 14	" " "	31.33	47	90	26	
" 15	" " "	8.21	48	86	23	Stopped pump on Bertram at 9 05 a.m. " " " Lincoln at 3.28 p.m.
" 16	" " "	......	....	....	23	
" 17	" " "	......	....	....	29	
" 18	" " "	......	....	....	26	
" 19	" " "	......	....	....	25	
" 20	" " "	4.66	49	95	26	Started pump on Bertram at 3.00 a.m. [started Lincoln 8 00 a.m.
" 21	" " "	34.33	50	89	27	Stopped pump on Bertram at 7.00 a.m.,
" 22	Clay	4.42	40	75	26	Stopped pump on Lincoln at 1.40 p.m.
" 23	"	......	....	....	26	Cleaning out caisson and sealing
" 24	"	......	....	....	25	" " " " "
" 25	......	......	....	....	29	Sealing.
" 26	......	......	....	....	26	"
" 27	......	......	....	....	26	"
" 28	......	......	....	....	23	"
" 29	......	......	....	....	27	"
" 30	......	......	....	....	23	"
" 31	......	......	....	....	31	Stopped compressors on Lincoln at [6.00 a.m.
Sept. 1	......	......	....	....	21	Sealing.
" 2	......	......	....	....	19	"
" 3	......	......	....	....	18	"
" 4	......	......	....	....	18	Stopped compressors on Bertram at [6 00 a.m.

COST OF SINKING CAISSON III.

	Material.	Labor.	Total.
Amount as tabulated above	$6 297.90	$50 083.46	$56 381 36
Miscellaneous supplies	1 692.08	....	1 692.08
Sundry small supplies	520.51	....	520.51
Electric light	398.51	....	398.51
Medical attendance, etc.	1 313.98	....	1 313.98
Maintenance of plant	5 570.27	7 016.97	12 587.24
Hire of tug and derrick	1 049.56	....	1 049.56
Labor, not included in table	....	2 672.65	2 672.65
Total	$16 842.81	$59 773.08	$76 615.89

APPENDIX I.—Continued.

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER IV.

Date, 1888.	Principal Foreman, Days	Principal Foreman, Amt.	Night Foreman, Days	Night Foreman, Amt.	Sub-Foremen, Days	Sub-Foremen, Amount.	Lock Tenders, Days	Lock Tenders, Amt.	Pressure Men, Hrs	Pressure Men, Amount.	Coffee House Men, Days	Coffee House Men, Amt.	Coffee, Lbs	Coffee, Amt.	Sugar, Lbs	Sugar, Amt.	Candles, No.	Candles, Amt.	Coal for Heating, 200-lb. Boxes	Coal for Heating, Amt.	Clay Hoist Men, Hrs.	Clay Hoist Men, Amount.
Nov. 24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dec. 15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
" 27	...	...	1	3.22	1½	4 50	1	2.00	96	24.00	...	...	...	...	...	...	...	...	...	...	...	...
" 28	1	5.00	1	3.23	3	9 00	2	4.00	204	51.00	...	...	...	...	...	...	...	...	...	...	...	...
" 29	1	5.00	1	3.22	2½	6.75	2	4.00	168	42.00	...	...	...	...	...	...	...	...	...	...	...	...
" 30	1	5.00	1	3.23	...	...	2	4.00	..	...	...	...	...	...	...	...	...	...	...	...	...	...
" 31	1	5.00	1	3.23	2	6.00	2	4.00	136	34.00	...	...	...	...	...	...	...	...	...	...	...	...
1889 Jan. 1	1	5.00	1	3.22	3	9.00	2	4.00	216	54.00	1	1.50	...	...	...	...	...	...	1	0.37	...	...
" 2	1	5.00	1	3.23	3	9.00	2	4.00	208	52.00	2	3.00	5	1.08	5	0.38	...	...	1	0.37	...	...
" 3	1	5.00	1	3.22	1	3.00	2	4.00	72	18.00	2	3.00	5	1.08	5	0.34	...	...	1	0.37	...	...
" 4	1	5.00	1	3.23	3	9.00	2	4.00	216	34.00	2	3.00	4	0.86	5	0.33	6	0.15	3	1.11	...	...
" 5	1	5.00	1	3.22	½	1.50	2	4.00	27	6.75	2	3.00	4	0.86	6	0.41	...	...	2	0.74	...	...
" 6	1	5.00	1	3.23	3	9.00	2	4 00	216	54.00	1	1.50	4	0.86	3	0.20	6	0.15	1	0.37	...	...
" 7	1	5.00	1	3.22	3	9.00	2	4 00	216	54.00	2	3.00	4	0.86	6	0.40	...	...	2	0.74	...	...
" 8	1	5.00	1	3.26	3	9 00	2	4.00	216	54.00	2	3.00	5	1.07	7	0.47	...	...	2	0.74	...	...
" 9	1	5.00	1	3.23	1	3.00	2	4.00	64	16.00	1	1.50	4	0.86	6	0.41	...	...	1	0.37	...	...
" 10	1	5.00	1	3.23	...	...	2	4.00	...	...	1	1.50	3	0.65	3	0.20	...	...	1	0.37	...	...
" 11	1	5.00	1	3.22	...	...	2	4.00	...	...	2	3.00	...	...	...	...	...	...	1	0.37	...	...
" 12	1	5.00	1	3.23	...	...	2	4.00	...	...	2	3.00	...	...	...	...	...	...	1	0.37	...	...
" 13	1	5.00	1	3.22	3½	11.37	2	4.80	183	73.20	2	3.00	3	0.65	3	0.20	...	...	1	0.37	...	...
" 14	1	5.00	1	3.23	4	13.00	2	4.80	210	84.00	2	3.00	5	1.08	7	0.47	...	...	2	0.74	...	...
" 15	1	5.00	1	3.22	4	13.00	2	4.80	210	84.00	2	3.00	5	1.08	6	0.41	...	...	1	0.37	...	...
" 16	1	5 00	1	3.23	4	13.00	2	4.80	216	86.40	2	3.00	5	1.07	7	0.47	...	...	1	0.37	...	...
" 17	1	5.00	1	3.22	2	6.50	2	4.80	102	40 80	2	3.00	6	1.29	6	0.41	...	...	2	0.74	...	...
" 18	1	5.00	1	3.23	4	13.00	2	4 80	204	81.60	2	3.00	5	1.08	8	0.54	7	0.17	1	0.37	...	...
" 19	1	5 00	1	3.23	4	13.00	2	4 80	192	76.80	2	3.00	5	1.08	6	0.41	...	...	1	0.37	...	...
" 20	1	5 00	1	3.23	2	6 50	2	4.80	102	40.80	2	3.00	6	1.29	6	0.41	...	...	1	0.37	...	...
" 21	1	5.00	1	3.22	1½	5.25	2	4 80	44	27.50	2	3.00	5	1.07	8	0.54	...	...	1	0.37	...	...
" 22	1	5 00	1	3.23	6	21.00	2	5.00	210	131.25	2	3.00	6	1.29	10	0.68	...	...	1	0.37	...	...
" 23	1	5.00	1	3.22	6	21.00	2	5 00	220	137.50	2	3.00	6	1 29	11	0.74	...	...	1	0 37	...	...
" 24	1	5.00	1	3.23	6	21.00	2	5.00	212	132.50	2	3.00	9	1.94	15	1.01	...	...	1	0.37	...	...
" 25	1	5 00	1	3.22	6	21.00	2	5.00	220	141.25	2	3.00	6	1.29	15	1.01	...	...	1	0.37	...	...
" 26	1	5 00	1	3.23	6	21.00	2	5.00	220	137.50	2	3.00	7	1.51	15	1.02	...	...	1	0.37	...	...
" 27	1	5.00	1	3.22	6	21.00	2	5.00	208	130.00	2	3.00	8	1.72	13	0.88	...	...	1	0.37	12	2.10
" 28	1	5 00	1	3 23	6	21.00	2	5.00	222	138.75	2	3.00	7	1.51	13	0.88	...	...	1	0.37	42	7.35
" 29	1	5.00	1	3.22	4½	15.75	2	5.00	149	93.12	2	3.00	6	1.29	5	0.34	...	...	1	0.37	48	8.40
" 30	1	5.00	1	3.23	6	21.00	2	5.00	212	132.50	2	3.00	7	1.51	11	0.74	...	...	1	0.37	72	12.60
" 31	1	5 00	1	3.23	6	21 00	2	5.00	212	132.50	2	3.00	6	1.29	15	1.01	...	...	1	0.37	72	12 60
Feb. 1	1	5.00	1	3.57	6	21.00	2	5.00	224	140.00	2	3.00	8	1.72	15	1.01	12	0.30	1	0.37	72	12.60
" 2	1	5.00	1	3.57	6	21.00	2	5.00	232	145.00	2	3.00	9	1.94	16	1.08	...	...	1	0.37	72	12 60
" 3	1	5.00	1	3.57	6	21.00	2	5.00	232	143.00	2	3.00	8	1.72	15	1.02	...	...	1	0.37	72	12.60
" 4	1	5.00	1	3.57	6	21.00	2	5.00	204	127.50	2	3.00	10	2.15	18	1.22	...	...	1	0.37	72	12.60
" 5	1	5.00	1	3.57	5	17.50	2	5.00	184	115.00	2	3.00	8	1.72	13	0.88	...	...	1	0.37	60	10.50
" 6	1	5.00	1	3.57	5¼	21.56	2	6.00	182	136.50	2	3.00	6	1 64	10	0.67	...	...	1	0.33	...	...
" 7	1	5.00	1	3.57	4	15.00	2	6.00	164	123 00	2	3.00	6	1.64	9	0 60	...	...	1	0.33	...	...
" 8	1	5.00	1	3.57	5	18.75	2	6.00	185	138.75	2	3.00	3	0.82	5	0.34	...	...	1	0.33	...	...
" 9	1	5.00	1	3.57	6	22.50	2	6.00	170	127.50	2	3.00	3	0.82	7	0.47	...	...	1	0.34	...	...
" 10	1	5.00	...	...	1	3.75	½	1.50	36	27.00	1	1.50	3	0.82	3	0.20	13	0.33	...	...	...	...
		225.00		148.26		570.18		209.70		3640.97		115.50		47.50		23.75		1.10		17.24		103.95

Date, 1888.	Master Mechanic and Day Engineer, Hrs.	Master Mechanic and Day Engineer, Amt.	Night Engineer, Hrs.	Night Engineer, Amt	Pump Men, Hrs	Pump Men, Amt.	Firemen, Hrs.	Firemen, Amt.	Coal Passers, Hrs	Coal Passers, Amt.	Coal for Boilers, Tons	Coal for Boilers, Amount.	Black Oil, P'ts	Black Oil, Amt.	Cylinder Oil, P'ts	Cylinder Oil, Amt	Waste, Lbs	Waste, Amt	Totals for Each Day.	Feet Sunk Each Day.	Material.	Water Pump, Hours Run.	Water Pump, Rev.	Water Pump, Pres.	Rev. of Air p'ps.	Remarks.
Nov. 24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Cutting edge placed on launching ways.
Dec. 15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Caisson launched.
" 27	...	...	12	3.60	12	2 40	12	2 40	12	2.10	2 42	9.03	..	...	...	...	2	0.13	53.38	...	Fine river sand	6.00	42	75	...	Put on air at 8 p.m.
" 28	22	7.60	12	3.60	24	4.80	24	4.80	24	4 20	6.24	23 27	1	0.15	...	...	5	0.32	120.97	...	" " "	16.00	44	75	29	Started pump at 2 a.m.
" 29	22	7.60	12	3.60	24	4 80	24	4 80	24	4.20	4.49	16.75	1	0.15	...	...	7	0.45	103.32	3.27	" " "	9.83	49	74	30	
" 30	22	7.60	12	3.60	24	4.80	24	4.80	24	4 20	2.54	9 47	¼	0.07	...	...	4	0.25	47.02	2.82	" " "	...	...	...	30	
" 31	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	7.27	27.12	1	0.15	...	...	5	0.32	104.82	.06	" " "	17.00	59	79	36	
1889 Jan. 1	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	9.03	33.68	1	0.15	...	...	4	0.26	136.18	3.19	...	20.75	48	78	37	
" 2	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	7.40	27.60	1	0.15	...	...	5	0.32	131.08	2.50	Mud	23.66	44	68	37	
" 3	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	4.44	16.56	1	0.15	...	...	7	0.45	80.17	3.01	"	7.00	49	81	26	
" 4	22	7.60	12	3.60	24	4.80	24	4.80	24	4 20	6.94	25.89	1	0.15	...	...	4	0.25	131.97	.65	"	21.50	45	80	28	[of concrete without air holes.
" 5	22	7.60	12	3.60	24	4 80	24	4 90	24	4.20	2.23	8.32	1	0.15	...	...	7	0.45	59.40	2.49	"	1.00	49	87	34	Let off air at 9.20 a.m. to put in last foot
" 6	22	7.60	12	3.60	24	4 80	24	4 80	24	4.20	5.38	20.07	1	0.15	...	...	5	0.32	123.85	1.70	"	21.75	48	82	28	Air compressors started 7 a.m.
" 7	22	7 60	12	3.60	24	4.80	24	4.80	24	4.20	6.50	24.24	1	0 15	...	...	7	0.45	130.06	1.81	"	23.08	43	86	38	
" 8	22	7 60	12	3.60	24	4.80	24	4.80	24	4.20	6.20	23 13	1	0.15	...	...	4	0.26	129.05	2.61	"	14.66	50	90	35	
" 9	22	7.60	12	3.60	24	4 80	24	4 80	24	4 20	3 80	14 17	¼	0.07	...	...	7	0.45	74.06	2.84	"	...	...	...	28	
" 10	22	7.60	12	3.60	24	4.80	24	4.80	24	4 20	2.83	10.63	¼	0.08	...	...	5	0.32	50.98	.01	Coarse sand and gravel	...	...	...	30	
" 11	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	2.67	9.96	¼	0.07	...	...	4	0.25	50.87	.00	"	...	...	...	28	
" 12	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	2.35	8.77	¼	0.08	...	...	5	0.32	49.77	.01	"	...	...	...	31	Let off air at 4 p m. to concrete around
" 13	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	6.00	22.38	¼	0.07	½	0.25	4	0.26	149.77	1.08	"	21 33	52	82	32	Started air pumps at 4 a m. [main shaft.
" 14	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	6.70	24 99	¼	0.08	1	0.50	7	0.45	166.34	.97	"	22.75	57	87	31	
" 15	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	6.64	24.77	¼	0.07	½	0.25	5	0.32	165.29	3.08	"	7.50	36	91	33	
" 16	22	7.60	12	3.60	24	4 80	24	4 80	24	4 20	3.40	12.68	¼	0.08	½	0.25	4	0.25	156.60	1.76	"	6.50	50	88	27	
" 17	22	7 60	12	3.60	24	4 80	24	4 80	24	4 20	6.00	22.38	¼	0.07	½	0.25	7	0 45	113.90	.90	"	9.33	53	88	29	
" 18	22	7.00	12	3.60	24	4 80	24	4.80	24	4 20	6.64	24.77	¼	0.08	½	0.25	5	0.32	163.20	1.64	"	22.08	42	76	33	
" 19	22	7.60	12	3.60	24	4 80	24	4.80	24	4.20	4.74	17.68	¼	0.07	½	0.25	4	0.26	150.95	1.39	Mud	22.75	41	86	34	
" 20	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	6.56	24.46	¼	0.08	½	0.25	5	0.32	115 61	.01	"	19.75	33	86	31	
" 21	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	7 82	29 17	¼	0.07	½	0 25	4	0.26	105.50	.02	"	24.00	30	81	29	
" 22	22	7 60	12	3.60	24	4.80	24	4.80	24	4.20	5.37	20.03	¼	0.08	½	0.25	5	0.32	216.50	.12	"	22.00	45	84	35	
" 23	22	7 60	12	3.60	24	4.80	24	4.80	24	4.20	8.85	33.01	¼	0.07	1½	0.75	4	0.26	236.21	1.29	"	23.66	28	82	33	
" 24	22	7 60	12	3.60	24	4 80	24	4 80	24	4.20	7.60	28.35	¼	0.08	½	0.25	5	0.32	227.05	2.32	"	22.66	34	77	37	
" 25	22	7 60	12	3.60	24	4.80	24	4 80	24	4.30	6.94	25.89	¼	0 07	½	0.25	4	0.26	232.61	.02	"	21.83	33	76	28	Clay hoist placed
" 26	22	7.60	12	3 60	24	4.80	24	4.80	24	4.20	6.38	23.80	¼	0.08	½	0.38	5	0.32	227.21	1.86	"	18.25	42	71	26	
" 27	22	7.60	12	3.60	24	4 80	24	4.80	24	4.20	4.18	15.59	¼	0.07	½	0.25	4	0.26	213.46	1.74	Clay	10.50	36	57	30	Stopped pump at 6.30 p m. Pump [men went on clay hoist.
" 28	22	7.60	12	3 60	24	4.80	24	4.80	24	4.20	3.60	13.43	¼	0.08	¼	0.12	5	0.32	225 04	.26	"	...	...	...	25	
" 29	22	7 60	12	3.60	24	4.80	24	4.80	24	4.20	3.98	14.84	¼	0.07	¼	0.13	4	0.26	175.79	.12	"	...	...	...	30	
" 30	22	7.60	12	3.60	24	4.80	24	4 80	24	4.20	4 68	17.45	¼	0.08	¼	0.12	5	0.32	227 95	.08	"	...	...	...	32	
" 31	22	7.60	12	3.60	24	4 80	24	4 80	24	4.20	4.37	16.30	¼	0.07	¼	0.13	4	0.26	226.76	.11	"	...	...	...	33	
Feb. 1	22	7.60	12	3 60	24	4.80	24	4.80	24	1,20	4 37	16.30	¼	0.08	¼	0.12	5	0.32	235.39	.30	"	...	...	...	32	
" 2	22	7 60	12	3 60	24	4.80	24	4 80	24	4.20	5.10	19.02	¼	0.07	¼	0.13	5	0 32	243.10	.07	"	...	...	...	31	
" 3	22	7.60	12	3.60	24	4.80	24	4 80	24	4 20	4.61	17.19	¼	0.08	¼	0.12	5	0.32	240.99	1.69	"	...	...	...	27	
" 4	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	3.50	13.06	¼	0 08	¼	0.13	5	0.32	220.00	.01	"	...	...	...	24	
" 5	22	7.60	12	3.60	24	4.80	24	4.80	24	4.20	2.92	10.89	¼	0.08	¼	0.12	5	0.32	198.95	.60	"	...	...	...	28	Clay hoist removed.
" 6	22	7.60	12	3.60	...	...	24	4.80	24	4.20	10.98	36.60	2	0.30	¼	0.13	5	0.27	235.77	.00	"	...	...	...	26	Commenced sealing at 10.30 a.m.
" 7	22	7.60	12	3.60	...	...	24	4.80	24	4.20	10.50	35.00	2	0.30	¼	0.12	6	0.33	214.09	.05	"	...	...	...	26	
" 8	22	7 60	12	3.60	...	...	24	4 80	24	4.20	9.69	32.30	1	0.15	¼	0.13	6	0.33	229 67	.00	"	...	...	...	24	
" 9	9	3.10	12	3.60	...	...	6	1.20	6	1.05	5.18	17.27	1	0.15	¼	0.12	6	0.33	196.02	.00	...	...	...	...	22	[stopped at 10.50 a.m.
" 10	...	...	...	...	...	...	...	...	...	...	...	...	1	0.15	¼	0.13	5	0.28	40.66	.00	...	...	...	...	20	Sealing completed and air compressor
		329.90		162.00		194.40		210.00		183.75		918.26		4.88		6.38		14.50	7126.22							

COST OF SINKING CAISSON IV.

	Material.	Labor.	Total.
Amount as tabulated above	$1033.60	$6093 60	$7126.22
Miscellaneous supplies	571.13	......	571 13
Sundry small supplies	267.13	......	267.13
Electric light	70.04	......	70 04
Medical attendance	174 45	......	174.45
Maintenance of plant	858.38	498.07	1356.45
Hire of ferry boat	79.98	......	79.98
Labor not included in table	....	1897.95	1897.95
	$3053.72	$8489.03	$11543.35

TIME, COST AND MATERIALS USED IN FOUNDATIONS.

PIER V.

Date	Principal Foreman.		Night Foreman.		Sub-Foremen.		Lock Tenders.		Pressure Men.		Coffee House Men.		Coffee.		Sugar.		Candles.		Coal for Heating.		Clay Hoist Men.		Master Mechanic and Day Engineer		Night Engineer.	
1890	Days	Amt.	Days	Amt.	Days	Amount.	Days	Amt.	Hrs	Amount.	Days	Amt.	Lbs	Amt.	Lbs.	Amt.	No.	Amt	200-lb boxes	Amt.	Hrs.	Amount.	Hrs	Amt.	Hrs	Amt.
May 7	1	5.00	...	...	2	6.00	...	...	210	42.00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
" 8	1	5.00	1	4.00	2	6.00	1	2.00	160	32.00	1	1.50	2	0.54	2	0.13	5	0.25	1	0.20	...	...	4	1.60	12	3.60
" 9	1	5.00	1	4.00	3	9.00	2	4.00	176	44.00	2	3.00	2	0.54	8	0.52	6	0.30	1	0.21	...	...	16	5.20	12	3.60
" 10	1	5.00	1	4.00	3	9.00	2	4.00	176	44.00	2	3.00	3	0.81	8	0.52	3	0.15	1	0.20	...	...	16	5.20	12	3.60
" 11	1	5.00	1	4.00	2$\frac{3}{10}$	6.90	2	4.00	176	44.00	2	3.00	4	1.08	8	0.52	3	0.15	1	0.21	...	...	10	5.20	12	3.60
" 12	1	5.00	1	4.00	1	3.00	2	4.00	134	33.50	2	3.00	3	0.81	6	0.39	3	0.15	1	0.20	...	...	16	5.20	12	3.60
" 13	1	5.00	1	4.00	...	...	2	4.00	...	...	1	1.50	...	...	...	...	...	...	...	...	...	...	16	5.20	12	3.60
" 14	1	5.00	1	4.00	...	...	2	4.00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16	5.20	12	3.60
" 15	1	5.00	1	4.00	...	...	2	4.00	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16	5.20	12	3.60
" 16	1	5.00	1	4.00	1$\frac{1}{10}$	3.30	2	4.00	62	15.50	2	3.00	6	1.62	8	0.52	2	0.10	1	0.21	...	...	16	5.20	12	3.00
" 17	1	5.00	1	4.00	3	9.00	2	4.00	192	48.00	2	3.00	5	1.35	2	0.13	7	0.35	1	0.20	...	...	16	5.20	12	3.60
" 18	1	5.00	1	4.00	3	9.00	2	4.00	192	48.00	2	3.00	4	1.08	8	0.52	...	...	1	0.21	...	...	16	5.20	12	3.60
" 19	1	5.00	1	4.00	3	9.00	2	4.00	176	44.00	2	3.00	4	1.08	8	0.52	2	0.10	1	0.20	...	...	16	5.20	12	3.60
" 20	1	5.00	1	4.00	3	9.00	2	4.00	184	46.00	2	3.00	2	0.54	8	0.52	1	0.05	1	0.21	...	...	16	5.20	12	3.60
" 21	1	5.00	1	4.00	3	9.00	2	4.00	176	44.00	2	3.00	4	1.08	8	0.52	2	0.10	1	0.20	...	...	16	5.20	12	3.60
" 22	1	5.00	1	4.00	3	9.00	2	4.00	192	48.00	2	3.00	4	1.08	8	0.52	1	0.05	1	0.21	...	...	16	5.20	12	3.60
" 23	1	5.00	1	4.00	3	9.25	2	4.80	192	57.20	2	3.00	4	1.08	8	0.52	...	...	1	0.20	...	...	16	5.20	12	3.60
" 24	1	5.00	1	4.00	4	13.00	2	4.80	186	74.40	3	4.50	6	1.62	14	0.91	...	...	1	0.21	...	...	16	5.20	12	3.60
" 25	1	5.00	1	4.00	4	13.00	2	4.80	177	70.80	3	4.50	4	1.08	10	0.65	1	0.05	1	0.20	...	...	16	5.20	12	3.60
" 26	1	5.00	1	4.00	4	13.00	2	4.80	177	70.80	3	4.50	5	1.35	12	0.78	...	...	1	0.21	...	...	16	5.20	12	3.60
" 27	1	5.00	1	4.00	4	13.00	2	4.80	186	74.40	3	4.50	5	1.35	16	1.04	...	...	1	0.20	...	...	16	5.20	12	3.60
" 28	1	5.00	1	4.00	6	21.00	2	5.00	208	130.00	3	4.50	4	1.08	12	0.78	...	...	1	0.21	...	...	16	5.20	12	3.60
" 29	1	5.00	1	4.00	6	21.00	2	5.00	212	132.50	3	4.50	4	1.08	12	0.78	...	...	1	0.20	...	...	16	5.20	12	3.60
" 30	1	5.00	1	4.00	6	21.00	2	5.00	210	131.25	3	4.50	4	1.08	12	0.78	...	...	1	0.21	...	...	16	5.20	12	3.60
" 31	1	5.00	1	4.00	6	21.00	2	5.00	208	130.00	3	4.50	3	0.81	12	0.78	8	0.40	1	0.20	40	7.25	16	5.20	12	3.60
June 1	1	5.00	1	4.00	6	21.00	2	5.00	198	123.75	3	4.50	3	0.81	12	0.78	...	...	1	0.21	40	7.25	16	5.20	12	3.60
" 2	1	5.00	1	4.00	6	21.00	2	5.00	204	127.50	3	4.50	3	0.81	12	0.78	4	0.20	1	0.20	16	2.90	16	5.20	12	3.60
" 3	1	5.00	1	4.00	6	21.00	2	5.00	208	130.00	3	4.50	4	1.08	10	0.65	2	0.10	1	0.21	16	2.90	16	5.20	12	3.60
" 4	1	5.00	1	4.00	6	21.00	2	5.00	208	130.00	3	4.50	5	1.35	12	0.78	11	0.55	1	0.20	28	5.08	16	5.20	12	3.60
" 5	1	5.00	1	4.00	6	21.00	2	5.00	214	133.75	3	4.50	7	1.89	12	0.78	4	0.20	1	0.21	68	12.12	16	5.20	12	3.60
" 6	1	5.00	1	4.00	6	21.00	2	5.00	194	121.25	3	4.50	8	2.16	16	1.04	1	0.05	1	0.20	88	15.75	16	5.20	12	3.60
" 7	1	5.00	1	4.00	6	21.00	2	5.00	202	126.25	3	4.50	6	1.62	12	0.78	7	0.35	1	0.21	88	15.75	16	5.20	12	3.60
" 8	1	5.00	1	4.00	6	22.02	2	5.50	174	124.75	3	4.50	5	1.35	12	0.78	4	0.20	1	0.20	24	4.35	16	5.20	12	3.60
" 9	1	5.00	1	4.00	6	22.50	2	6.00	182	136.50	3	4.50	5	1.35	12	0.78	2	0.10	1	0.21	...	...	16	5.20	12	3.60
" 10	1	5.00	1	4.00	6	22.50	2	6.00	170	127.50	3	4.50	4	1.08	8	0.52	5	0.25	1	0.20	...	...	16	5.20	12	3.60
" 11	1	5.00	1	4.00	3[illegible]	13.03	2	6.00	105	79.00	1$\frac{3}{10}$	1.95	1	0.27	3	0.19	6	0.30	1	0.21	...	...	16	5.20	12	3.60
" 12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	16	5.20	...	...
		180.00		140.00		469.50		160.50		2764.60		121.95		35.91		20.21		4.50	3.2	6.56		73.85		183.60		126.00

Date	Pump Men.		Firemen.		Coal Passers.		Coal for Boilers		Black Oil.		Cylinder Oil.		Waste.		Totals for Each Day.	Feet Sunk Each Day.	Material.	Water Pump			Rev of Air p'ps	Remarks
1890	Hrs	Amt.	Hrs.	Amt.	Hrs	Amt.	Tons.	Amount.	Gals	Amt.	Gals.	Amt.	Lbs	Amt.				Hours Run.	Rev.	Pres.		
May 7	...	...	12	2.50	...	...	...	...	½	0.05	1	0.37	3	0.15	56.07	0.20	Silt	...	...	...	...	
" 8	...	...	24	3.60	12	2.00	7.02	14.40	½	0.06	...	...	2	0.10	76.98	2.20	"	8.00	39	79	36	Began concreting. Put on air and [started pumps at 11.35 p.m.
" 9	...	...	24	3.60	24	3.60	8.00	16.40	½	0.06	...	...	3	0.15	103.18	2.99	"	19.92	49	80	30	
" 10	...	...	24	3.60	24	3.60	7.34	15.06	½	0.05	...	...	3	0.15	101.94	5.45	"	24.00	45	77	22	
" 11	...	...	24	3.60	24	3.60	5.21	10.68	½	0.06	1	0.37	3	0.15	96.12	5.95	"	9.42	47	81	24	
" 12	...	...	24	3.60	24	3.60	6.53	13.41	½	0.05	...	...	2	0.10	83.61	2.55	Black quick sand	16.75	49	77	24	
" 13	...	...	24	3.60	24	3.60	4.22	8.67	1	0.11	...	...	3	0.15	39.43	4.33	" " "	...	...	...	27	Waiting for air lock.
" 14	...	...	24	3.60	12	1.80	2.42	4.96	½	0.06	...	...	3	0.15	32.37	0.01	" " "	...	...	...	16	" " " "
" 15	...	...	24	3.60	12	1.80	2.43	4.97	½	0.05	1	0.37	3	0.15	32.74	0.00	" " "	...	...	...	18	" " " "
" 16	...	...	24	3.60	12	1.80	4.39	9.00	½	0.06	...	...	2	0.10	60.61	0.14	" " "	7.00	45	79	21	Air lock placed
" 17	...	...	24	3.60	24	3.60	7.68	15.74	½	0.05	...	...	3	0.15	106.97	0.56	" " "	20.33	46	79	28	
" 18	...	...	24	3.60	24	3.60	8.17	16.76	½	0.05	...	...	2	0.10	107.72	2.04	Hard tough silt	21.75	48	80	23	
" 19	...	...	24	3.60	24	3.60	7.18	14.72	½	0.06	1	0.37	3	0.15	102.20	2.39	" " "	22.75	45	88	22	
" 20	...	...	24	3.60	24	3.60	6.85	14.05	½	0.05	...	...	2	0.10	102.52	2.85	" " "	21.16	46	95	22	
" 21	...	...	24	3.60	24	3.60	7.51	15.40	1	0.11	...	...	3	0.15	102.56	3.60	Fine sand	23.42	52	92	24	
" 22	...	...	24	3.60	24	3.60	6.53	13.39	½	0.06	...	...	3	0.15	104.46	5.50	" "	22.25	47	96	19	
" 23	...	...	24	3.60	24	3.60	8.68	17.81	½	0.05	1	0.37	3	0.15	119.43	5.22	" "	24.00	52	99	30	
" 24	...	...	24	3.60	24	3.87	8.33	17.08	½	0.06	...	...	2	0.10	141.95	8.95	" "	22.16	53	100	30	
" 25	...	...	24	3.60	24	3.60	7.03	14.40	1	0.11	...	...	3	0.15	134.74	6.09	" "	15.92	53	98	28	
" 26	...	...	24	3.60	24	3.60	8.49	17.41	½	0.05	...	...	3	0.15	138.05	0.05	" "	23.75	49	99	29	
" 27	...	...	24	3.60	24	3.60	9.33	19.13	½	0.06	1	0.37	3	0.15	144.00	5.20	Coarser sand with gravel	23.33	49	99	35	
" 28	...	...	24	3.60	24	3.60	10.47	21.48	½	0.05	...	...	2	0.10	209.20	4.64		23.33	51	103	42	
" 29	...	...	24	3.60	24	3.60	8.33	17.08	½	0.06	...	...	3	0.15	207.35	1.56	"	23.58	51	104	28	
" 30	...	...	24	3.60	24	3.60	8.00	16.41	½	0.06	1	0.37	3	0.15	205.81	2.38	"	23.16	56	110	27	
" 31	...	...	24	3.60	24	3.60	8.82	18.08	½	0.05	...	...	3	0.15	213.22	2.52	Same streaked with mud	22.92	57	110	32	
June 1	...	...	24	3.60	24	3.90	8.50	17.44	½	0.06	...	...	2	0.10	205.90	2.58	Sand with gravel	20.13	57	109	33	
" 2	...	...	24	3.60	24	3.60	9.48	19.45	1	0.11	1	0.37	2	0.10	207.92	1.93	" " "	23.58	37	110	36	
" 3	...	...	24	3.60	24	3.60	9.47	19.42	½	0.05	...	...	3	0.15	210.06	1.68	" " "	22.25	48	105	43	
" 4	...	...	24	3.60	24	3.60	8.99	18.44	½	0.06	...	...	2	0.10	212.06	0.70	" " "	23.45	56	99	33	
" 5	...	...	24	3.60	24	3.60	7.18	14.72	½	0.05	1	0.37	2	0.10	219.69	1.17	Sandy clay	14.08	57	99	31	
" 6	...	...	24	3.60	24	3.60	9.00	18.45	½	0.05	...	...	3	0.15	214.60	1.03	" "	11.82	57	107	45	Stopped pump at 9 15 p.m.
" 7	...	...	24	3.60	24	3.60	6.85	14.05	½	0.06	...	...	2	0.10	214.67	0.41	" "	...	...	...	43	
" 8	...	...	24	3.60	24	3.60	6.02	12.34	½	0.05	1	0.37	2	0.10	201.51	0.04	" "	...	...	...	44	Began sealing at 3.15 p.m.
" 9	...	...	24	3.60	24	3.60	4.54	9.31	½	0.06	...	...	3	0.15	206.46	0.01	...	...	...	...	35	
" 10	...	...	24	3.60	24	3.60	4.21	8.63	½	0.05	...	...	3	0.15	196.38	0.00	...	...	...	...	33	Supply shaft clogged up.
" 11	...	...	24	3.60	24	3.60	3.72	7.63	½	0.06	1	0.37	2	0.10	134.11	0.00	...	...	...	...	30	
" 12	...	...	12	1.80	12	1.80	0.43	0.88	...	...	...	...	2	0.10	9.78	...	...	...	...	...	31	Finished sealing at 12 m. Stopped all [compressors at 4 p.m.
				130.30		121.07	247.33	507.25		2.20		4.07		4.80	5056.37							

COST OF SINKING CAISSON V.

	Material.	Labor	Total
Amount as tabulated above	$585.50	$4470.87	$5056.37
Miscellaneous supplies	729.94	....	729.94
Sundry small supplies	85.02	....	85.02
Electric light	179.06	....	179.06
Medical attendance	55.05	....	55.05
Maintenance of plant	627.72	767.34	1395 06
Hire of tug	48.58	....	48.58
Labor not included in table	......	1001.31	1001.31
	$2310.87	$6239.52	$8550.39

APPENDIX J.

RECORD OF SINKING CAISSONS.

PIER I.

Date.	Elevations of Cutting Edge, Above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage.	Elevations of Sand. Original Elevation = 199.4.					Average Penetration of Caisson	Water Gauge.	Depth Immersed.	Weights					Air Pressure.		Reaction Due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction	Material.	Remarks.
1890.	N.E.	N.W.	S.E.	S.W.	Average.			N.E.	N.W.	S.E.	S.W.	Average.				Caisson	Masonry.	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons	Tons.	Sq. Ft.	Lbs.		
Dec. 30	....	....	....	....	199.60	....	....	....	....	....	....	....	....	....	....												....	Original elevation of cutting edge = 199.60.
Jan. 9	197.28	197.06	197.27	196.61	197.06	2.54	2.54	....	....	....	....	....	....	....	....	784	....	....	....	784	....	....	....	784	....	....	Sand, gravel, mud and clay	Started air compressors at 10 45 p.m.
" 10	197.19	197.04	197.28	196.60	197.03	0.03	2.57	199.8	201.7	201.2	200.5	200.6	3.57	201.5	4.47	784	....	7	1	792	....	1.94	293	499	703	1419	" " " " "	Started sand pumps at 1 a m.
" 11	196.95	196 60	196.60	196.14	196.57	0.46	3.03	199 5	201.5	199 7	200.6	200.3	3.73	202.9	6.33	810	....	7	3	820	4.50	2.75	415	405	735	1102	" " " " "	
" 12	196.20	196.34	196.35	196.16	196.26	0.31	3.34	200.0	200 1	200.0	200.6	200.2	3.94	204.0	7.74	1129	....	8	4	1141	5.00	3.36	508	633	776	1632	" " " " "	
" 13	195.37	195.45	196.17	196.17	195.79	0.47	3.81	201.3	200.8	200.1	200.9	200.8	5.01	205.0	9.21	1194	....	10	4	1208	6.00	4.00	604	604	987	1224	" " " " "	
" 14	195.23	195.31	196.13	196.11	195.69	0.10	3.91	200.1	200.4	199.7	200.4	200.1	4.41	205.9	10.21	1220	....	9	7	1236	6.50	4 43	669	567	868	1307	" " " " "	
" 15	193.77	193.60	195.19	194.87	194.36	1.33	5.24	200.9	203.5	203.3	201.9	202.4	8.04	207.0	12.64	1615	....	16	5	1636	6.50	5.49	830	806	1584	1018	" " " " "	
" 16	193.15	193.25	194.52	194.51	193.86	0.50	5 74	200.7	203.4	201.0	202 3	201.9	8.04	208.1	14.24	1651	....	16	6	1673	7.00	6.18	933	740	1584	935	" " " " "	
" 17	191.90	192.00	192.65	192.59	192.28	1.58	7.32	204.1	203.1	205.1	205.0	204.1	11.82	209.3	17.02	1991	....	24	5	2020	8.25	7.39	1116	904	2328	777	" " " " "	
" 18	191.89	191 57	192.10	191.63	191.80	0.48	7.80	203.7	201.3	206.9	206.4	204.6	12 80	210.4	18.60	2263	....	26	6	2295	8.00	8.07	1219	1076	2522	853	Sand and gravel	
" 19	191.89	191 53	191.87	191 37	191.67	0.13	7.93	203.6	200.5	207.4	204.6	204.0	12.33	211.2	19.53	2460	....	25	7	2492	9.00	8.47	1279	1213	2429	999	" " "	Air taken off at 2.45 p m.
" 20	191.48	191.07	191.03	190.53	191.01	0.86	8.59	203.8	198.3	206.8	202.8	202.9	11.89	211.8	20.79	....	....	....	....	....	....	....	....	....	....	....	....	
" 21	191.37	191.03	190.95	190.46	190.95	0.06	8.65	203.9	200.6	207 4	206.5	204.6	13.65	213.3	21.85	....	....	....	....	....	....	....	....	....	....	....	....	
Feb. 15	190.87	190.48	190.57	190 00	190.48	0.47	9.12	201.9	195.5	204.8	198.5	200.2	9.72	211.5	21.02	3658	....	19	11	3686	8.00	0.12	1877	2309	1915	2411	" " "	Applied air at 3 p.m., Feb. 14.
" 16	190.77	190.28	190.58	189 96	190.40	0.08	9.20	202.4	195.2	204.4	198.0	200.0	9.60	212.1	21.70	3656	....	19	12	3687	8.00	0.42	1422	2265	1891	2395	" " "	Sacking out gravel.
" 17	189.34	188 94	190.56	189 99	189.71	0.69	9.89	202.7	196.7	204.3	198.5	200.5	10.79	212.5	22.79	3658	....	22	13	3690	8.25	9.89	1493	2197	2126	2067	" " "	
" 18	188.69	188.41	190.49	190.01	189.40	0.31	10.20	202.6	197.8	204.8	199.3	201.1	11.70	212.8	23.40	3856	....	23	12	3691	8.25	10.15	1533	2158	2305	1872	" " "	Put on one clay hoist.
" 19	187.82	187.50	188.36	187.93	187.90	1.50	11.70	202.5	197.8	204.1	200.4	201.2	13.30	213.0	25.10	3656	....	27	12	3695	9.75	10.89	1644	2051	2620	1565	" " "	Started compressors on Lincoln at 7.20 a m.
" 20	187.32	187.38	187.20	187.15	187.28	0.84	12.34	202.2	196.1	204.5	200.6	200.8	13.54	213.1	25.84	3661	....	27	12	3700	11.00	11.21	1693	2007	2667	1505	" " "	Sacking out gravel.
" 21	187.07	187.18	186.40	186.27	188.73	0.53	12.87	205 0	198.2	206.4	201.4	202.7	15.97	213.0	26.27	3661	....	32	10	3703	13.25	11 40	1722	1981	3146	1259	" " "	Started clay hoist. Hoisting out gravel.
" 22	185.06	184.79	184.86	184.48	184.80	1.93	14.80	205.7	200.0	206.9	203.0	203.9	19.10	212.7	27.90	3947	....	38	9	3994	13.25	12 10	1827	2167	3763	1152	" " "	Hoisting out gravel.
" 23	183.21	183.00	183.42	183.09	183.18	1.62	18.42	207.6	200.0	207.1	203.0	204.4	21.22	212.2	29.02	4237	....	42	9	4288	14.00	12.59	1901	2387	4180	1142	" " "	
" 24	182.64	182.50	182.67	182.41	182.56	0.62	17.04	207.5	199.5	207.9	202.7	204 4	21.84	211.4	28.84	4237	....	44	7	4288	18.75	12.51	1889	2399	4302	1115	Sand, gravel and hard pan	
" 25	181.27	181.15	181.17	180.94	181.13	1.43	18.47	207.9	201.2	207.2	202.2	204 6	23.47	210.8	29 67	4355	....	47	6	4408	15.75	12.88	1945	2463	4823	1065	Fine sand	Hoisting out gravel and hard pan.
" 26	180.68	180.41	180.78	180.37	180.58	0.57	19.04	207.3	199.8	207.4	201.2	203.9	23.34	210.4	29.84	4500	....	47	8	4553	19.00	12.95	1955	2598	4598	1130	Sandy clay or sediment	
" 27	179.40	179.17	179.55	179.19	179.33	1.23	20.27	207.1	199.7	207.2	201 4	203.8	24.47	210.6	31.27	4516	....	49	7	4569	16.25	13.57	2049	2520	4820	1046	" " " "	Stopped sand pumps. Waiting for planking.
" 28	179.19	178.97	179.33	178.99	179.12	0.21	20.48	207.5	200.8	206.8	201.9	204.2	25.08	211.5	32.38	4513	....	50	7	4570	18.00	14.05	2121	2449	4940	991	" " " "	Hoisting out material. Started sand pumps during night.
March 1	178.57	178 37	178.78	178.45	178.54	0.58	21.06	205.4	199.1	206.6	200.4	202.9	24.86	212.1	33.56	4532	....	49	9	4590	18.00	14.57	2200	2390	4799	996	" " " "	
" 2	177.24	177.04	177.44	177.14	177.22	1.32	22.38	205.9	200.1	206.9	201.6	203.6	26.34	212.6	35.38	4532	....	53	9	4594	18.50	15.36	2319	2275	5189	877	" " " "	Hoisting out material.
" 3	175.44	175.29	175.44	175.19	175.34	1.88	24 26	206.8	199.8	207.3	200.8	203.4	28.06	213 0	37.66	4550	....	56	10	4616	20.50	16.34	2467	2149	5528	777	" " " "	
" 4	175.22	175.10	175.25	174.99	175.14	0.20	24.46	206 3	199.5	206.4	200 2	203.1	27.98	213.4	38.26	4724	....	55	10	4789	20.75	16 69	2507	2282	5508	828	" " " "	
" 5	172.74	172.84	172.72	172.71	172.75	2.39	26.85	204.5	197.0	206.9	199.5	202.0	29.25	213.7	40.95	5082	....	58	12	5152	17.50	17.77	2683	2480	5762	857	" " " "	
" 6	172.50	172.61	172.46	172 47	172 51	0.24	27.09	202.6	198.5	206.9	199.8	201.9	29.39	214.0	41.49	5082	....	59	12	5153	20.00	18 01	2720	2433	5780	840	" " " "	
" 7	170.71	170.75	170.85	170.76	170.77	1.74	28.83	203.6	196.6	207.0	199.5	201.7	30.93	214.2	43.43	5341	....	62	13	5416	21.75	18.85	2846	2570	6093	843	" " " "	
" 8	169.81	169.82	170.02	169.90	169.79	0.98	29.81	202.4	196.3	207.1	198 8	201.1	31.31	214 5	44.71	5880	....	83	13	5756	23.75	19.40	2920	2827	6168	916	" " " "	Caisson completed.
" 9	169.04	169.00	169.57	169.41	169.26	0.53	30.34	203.2	196.0	206.5	197.7	200.8	31.54	214.7	45.44	5803	....	63	14	5880	20.25	19 72	2978	2902	6213	934	" " " "	Finished concreting caisson.
" 10	166.93	166.93	167.08	166.95	166.97	2.29	32.63	201.9	193.8	206.0	196.4	199.5	32.53	214.9	47.93	5948	10	85	15	6038	22.00	20.80	3141	2897	6408	904	" " " "	Began laying masonry. Put on second clay hoist.
" 11	166.58	166.60	166.67	166.55	166.60	0.37	33.00	203.5	195.1	206.2	198.1	200.7	34.10	215.2	48.60	5948	196	68	15	6227	22.50	21.00	3186	3041	6718	905	" " " "	
" 12	166.20	166.22	166.33	166.22	166.24	0.36	33.36	203.0	195.0	206.3	197.5	200.5	34.26	215.4	49.16	5948	328	68	15	6359	22.00	21.33	3222	3137	6749	928	" " " "	
" 13	165.24	165.27	165.42	165.32	165.31	0.03	34.29	203.1	194.1	205.4	197.6	200.0	34.69	215.6	50.29	5948	494	69	16	6527	23.50	21 82	3296	3231	6834	946	" " " "	
" 14	163.10	163.13	163.02	162.93	163.05	2.26	36.55	202.8	194.3	205.4	199.2	200.4	37.35	215.8	52.75	5948	596	75	15	6634	23 25	22.89	3457	3177	7358	865	" " " "	
" 15	161.89	161.91	161.90	161.82	161.88	1.17	37.72	201.8	194.6	208.5	201.0	200.9	39.02	216.0	54.12	5948	734	78	39	6799	24.00	23.49	3548	3251	7687	846	" " " "	
" 16	160.41	160.42	160.46	160.38	160.42	1.46	39.18	204.8	195.6	206.5	201.8	202.0	41.58	218.0	55.58	5948	792	83	79	6902	24.75	24.12	3643	3259	8191	796	" " " "	
" 17	159.60	159.82	159.63	159.57	159.61	0.81	39.99	203.8	196.8	208.1	200.6	201.7	42.09	216.0	56.39	5948	792	84	89	6913	25.50	24.47	3696	3217	8292	776	" " " "	
" 18	159.42	159.44	159.46	159.39	159.43	0.18	40.17	203.0	194.2	204.8	199.4	200.3	40.87	215.9	56.47	5948	969	82	94	7093	27.50	24.51	3709	3331	8051	842	" " " "	
" 19	158.18	158.22	158.22	158.14	158.19	1.24	41.41	203.3	194.3	206.8	201.0	201.3	43.11	215.9	57.71	5948	1014	88	126	7174	28.00	25.05	3784	3380	8493	798	" " " "	
" 20	157.04	157.08	157.05	156.96	157.03	1.16	42.57	203 2	193.0	205.9	198.7	199.9	42.87	215.9	58.87	5948	1156	86	162	7352	26 50	25.55	3859	3493	8445	837	Hard clay	Stopped sand pumps in afternoon.

APPENDIX J.—Continued.

RECORD OF SINKING CAISSONS.

PIER I.—Continued.

Date.	Elevations of Cutting Edge Above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage.	Elevations of Sand. Original Elevation = 199 4.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights.					Air Pressure		Reaction Due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1890.	N E	N.W.	S.E.	S W.	Average.			N E.	N.W.	S.E	S.W.	Average.				Caisson.	Masonry.	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons	Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs		
Mar. 21	156.99	157.02	157.02	156.93	156.99	0.04	42.61	202.4	194.1	205 6	200.6	200.7	43.71	216.0	59.01	5948	1199	87	166	7400	26.50	25.61	3868	3532	8611	820	Hard clay	
" 22	156.20	156.23	156.26	156.15	156.20	0.79	43.40	202.3	193.4	205.0	200.7	200.3	44.10	216.1	59.90	5948	1200	88	196	7432	27.00	25.99	3926	3506	8688	807	" "	
" 23	155.40	155 42	155.43	155.34	155.40	0.80	44.20	202.9	194.4	204.5	200.2	200 5	45.10	216.2	60.80	5948	1200	90	227	7465	27.00	26.39	3986	3479	8885	783	" "	
" 24	155.39	155.41	155.42	155.33	155 39	0.01	44.21	202.8	194 8	206.7	200.3	201.1	45.71	216.2	60.81	5948	1200	91	227	7466	28.25	26.39	3986	3480	9005	773	" "	Started sand pumps.
" 25	155.36	155.38	155.39	155.30	155.66	0.03	44.24	202.6	194.3	204.8	200.1	200.5	45.14	216.2	60.84	5948	1405	90	227	7670	28.00	26.40	3987	3683	8892	828	" "	
" 26	154.82	154.83	154.81	154.72	154.80	0.56	44.80	202.5	193.7	204.1	199.1	199.9	45.10	216.1	61.30	5948	1495	90	243	7776	28.50	26.60	4018	3758	8885	846	" "	
" 27	153.90	153.92	153.90	153.82	153.88	0.92	45.72	201.6	194.1	204.3	199.9	200.0	46.12	216.0	62 12	5948	1661	92	279	7980	28.50	26.96	4072	3908	9085	860	Sediment	
" 28	151.87	151.90	151.86	151.76	151.85	2.03	47.75	202 4	193 6	204.8	201.1	200.5	48.65	216.0	64.15	5948	1782	97	340	8167	30.50	27.84	4205	3962	9584	828	"	
" 29	150.87	150.90	150.86	150.78	150.85	1.00	48.75	202.6	194.3	204.8	200.9	200.6	49.75	216.0	65.15	5948	1925	100	370	8343	29.25	28.27	4270	4073	9801	831	Fine sand	Commenced blowing out material.
" 30	148.50	148.52	148.45	148.40	148 47	2.38	51.13	201.6	194.0	204 5	200.1	200.1	51 63	216.0	67.53	5948	1973	103	461	8485	27.50	29.31	4427	4058	10171	798	Clay, ¼ sand	
" 31	147.20	147.23	147.15	147.10	147.17	1.30	52.43	200.1	194.6	203.8	201.5	199.8	52.63	216.0	68.83	5948	1973	105	504	8530	27.25	29.87	4512	4018	10368	775	" " "	
April 1	146.19	146.21	146.14	146.09	146 16	1.01	53.44	199.7	194.8	202.8	200.5	199.5	53.34	216.2	70.04	5948	1973	121	550	8592	27.00	30.40	4592	4000	10508	761	Clay, hard and pure	Stopped sand pumps and blow out.
" 2	145.44	145.47	145.39	145 35	145.41	0.75	54.19	200.3	195.7	202.2	200.6	199.7	54.29	216.2	70.79	5948	1973	158	547	8626	28.50	30.72	4640	3986	10695	745	" " " "	Hoisting out clay.
" 3	145.44	145.47	145.39	145.35	145.41	0.00	54.19	200.3	194.4	202.3	200.6	199.4	53.99	216.2	70.79	5948	1973	149	552	8622	30.75	30.72	4640	3982	10636	749	" " " "	
" 4	145.44	145.47	145.39	145.35	145.41	0.00	54.19	200.2	195.8	202.6	202.0	200.1	54.69	216.2	70.79	5948	1973	179	537	8637	30.00	30.72	4640	3997	10774	742	" " " "	
" 5	144.24	144.26	144.17	144.13	144.20	1.21	55 40	199.1	196.8	202.5	202.7	200.3	56.10	216.2	72.00	5948	1973	241	549	8711	31.50	31.25	4720	3991	11052	722	" " " "	
" 6	144.24	144.26	144.17	144.13	144 20	0.00	55.40	200 2	196.8	202.1	203.3	200.4	56.20	216.2	72.00	5948	1973	247	543	8711	30.00	31.25	4720	3991	11071	721	" " " "	
" 7	144.23	144.25	144.16	144 12	144 19	0.01	55.41	199.6	196.6	202 4	203.6	201.3	57.11	216.2	72.01	5948	1973	288	515	8724	29.75	31.25	4720	4004	11251	712	" " " "	
" 8	144 23	144.25	144.16	144.12	144.19	0.00	55.41	198.5	197.5	201.3	203.2	200.1	55.91	216.2	72.01	5948	1973	230	554	8705	30.50	31.25	4720	3985	11014	723	" " " "	
" 9	142.77	142.79	142.68	144.64	142.72	1.47	56.88	200.0	195.8	201.3	202.3	199.8	57.08	216.2	73.48	5948	1973	286	576	8783	31.00	31.89	4817	3966	11245	706	" " " "	
" 10	142.76	142.78	142.67	142.63	142.71	0.01	56.89	198.5	197.4	201.6	204.2	200.4	57.69	216.1	73.39	5948	1973	331	553	8805	31.00	31.85	4811	3994	11365	703	" " " "	
" 11	142.75	142.77	142.66	142.62	142.70	0.01	56 90	198.9	199.1	201.1	203.9	200.7	58.00	216.1	73.40	5948	2121	349	544	8962	32.00	31.86	4813	4149	11436	727	" " " "	
" 12	141.43	141.45	141.31	141.25	141.36	1 34	58.24	198.2	197.6	200.9	203.2	200.0	58.64	216.1	74.74	5948	2300	385	575	9208	32.50	32.44	4900	4308	11552	746	" " " "	
" 13	141.43	141.45	141.31	141.25	141.36	0.00	58.24	197.9	196.4	200.0	202.8	199.1	57.74	216.0	74.64	5948	2300	334	598	9180	33.25	32.39	4893	4287	11375	754	" " " "	
" 14	139.64	139.68	139.52	139.49	139.58	1.78	60.02	198.6	197.8	200.0	203.4	199.9	60.32	216.0	76.42	5948	2300	493	577	9318	33.00	33.17	5011	4307	11883	725	Clay, harder and tougher	
" 15	138.73	138.78	138.69	138.62	138.71	0.87	60.89	197.3	196.6	200.1	201.0	198.7	59.99	215.8	77.09	5948	2300	471	613	9332	31.00	33.46	5054	4278	11818	724	" " " "	
" 16	138.73	138.78	138.69	138.62	138.71	0.00	60.89	197.4	197.0	199.3	200.9	198.7	59.99	215.7	76.99	5948	2300	471	609	9328	31.00	33.41	5047	4281	11818	725	" " " "	
" 17	138.72	138.77	138.68	138.61	138.70	0.01	60.90	197.3	196.2	199.5	201.8	198.7	60.00	215.5	76.80	5948	2300	472	603	9323	33.00	33.33	5035	4288	11820	726	" " " "	Began sealing at 5 p m.
" 18	137.90	137.93	137.82	137.77	137.85	0 85	61.75	197.2	195.6	199.3	203.0	198.8	60.95	215 2	77.35	5948	2300	536	594	9378	33.00	33.57	5071	4307	12007	717		
" 19	137.90	137.93	137.82	137.77	137 85	0.00	61.75	197.4	196.8	199.1	201.8	198.8	60.95	214.5	76.65	5948	2300	536	568	9352	35.00	33.27	5026	4326	12007	721		
" 20	137.90	137.93	137.82	137.77	137.85	0.00	61.75	197.6	196 3	199 3	200.9	198 5	60.65	213.5	75.65	5948	2300	536	540	9324	34.00	32.83	4959	4365	11948	731		
" 21	137.90	137.93	137.82	137.77	137.85	0.00	61.75	195.9	199.3	199.2	205.4	199.9	62.05	212.4	74.55	5948	2300	609	459	9316	33.50	32.65	4886	4430	12224	725		Stopped air pumps at 12.25 a.m., April 23.
" 22	137.90	137.93	137.82	137.77	137.85	0.00	61.75	195.5	199.3	198.3	203.8	199.2	61.35	211.5	73.65	5948	2300	562	442	9252	34.00	31.96	4828	4424	12086	732		

APPENDIX J.—Continued.

RECORD OF SINKING CAISSONS.

PIER II.

Date.	Elevations of Cutting Edge Above Mean Sea Level.					Sunk in 24 Hours	Total Sinkage.	Elevations of Sand. Original Elevation = 151.6.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights					Air Pressure.		Reaction Due to Air Pressure	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1889	N.E	N.W	S.E.	S.W.	Average			N.E.	N.W.	S.E.	S.W	Average.				Caisson	Masonry	Sand.	Water	Total.	Indicated.	Calculated.						
																Tons	Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons	Tons.	Sq. Ft.	Lbs.		
May 17																												Caisson built on shore. Placing cutting edge.
" 21																												Began building caisson.
July 27																												Caisson ready to launch.
" 29																												Caisson launched at 4 30 p m.
Sept. 23																												Caisson towed to position at 1 p.m.
" 25																												Began concreting at 3 p.m.
Oct. 7								149 4	150.9	152.9	153.4	151.6																Original elevation of sand.
" 10	149.19	149 87	148.45	149.30	149.20			150 4	151.0	150.8	151.4	150.9	1.70	187.4	38.20	7892		5	53	7950	17.50	16.58	5160	2790	468	11923		Started air compressors on Lincoln at 10 02 a m
" 11	148.69	149.66	148.45	148.28	149.09	0.11	0.11	149 6	150 4	150.2	150.5	150.2	1 11	187 1	38.01	7892		3	53	7948	18.50	16.51	5138	2810	206	18366		Removing mat.
" 12	148.86	149.54	148.43	149.26	149.02	0.07	0.18	149 7	149.8	149.6	150.2	149.8	0.78	186.7	37.68	8169		2	53	8224	19.00	16.35	5088	3136	215	29172		" "
" 13	148 73	149.32	148.42	149 20	148.91	0.11	0.29	150.9	150.6	150.7	150.9	150.8	1.89	186.4	37.49	8274		5	51	8330	19.50	16.27	5063	3267	521	12541		" "
" 14	148 57	148.80	148.44	148.86	148.67	0.24	0.53	148.9	149.2	150.6	150.3	149 8	1.13	186.1	37.43	8379		3	52	8434	20.00	16.24	5054	3380	311	21736		" "
" 15	148.49	148.72	148.01	148.46	148.42	0.25	0.78	149.0	149.7	149.7	150.4	149 7	1.38	185 7	37.28	8379		3	50	8432	20.50	16.18	5035	3397	353	19246		Started air compressors on Bertram at 8 a m.
" 16	147.46	146.68	148.00	147.39	147.38	1.04	1.83	149.3	150.3	149 5	150.5	149.9	2.52	185.5	38.12	8694		7	50	8751	17.75	16.54	5157	3594	694	10357	Coarse sand	Started sand pumps at 4 p.m.
" 17	146.74	146.40	147.43	147.20	146.96	0.42	2.24	148 8	149.4	148.9	149.9	149.2	2.24	185.1	38.14	8890		6	52	8957	17.75	16.55	5150	3807	617	12340	" "	Hoisting out mat.
" 18	145.60	145.30	147.11	146.98	146.25	0.71	2.95	148.4	148.8	148.5	148.7	148.6	2.35	184.9	38.65	9009		6	52	9067	18.25	16.77	5219	3848	647	11895	" "	" " "
" 19	145.41	145.20	146.44	146.40	145 86	0.39	3.34	149.0	148.1	150.0	149.1	149.0	3 14	184.6	38 74	9114		9	51	9171	18.25	16.81	5231	3943	805	9117	" "	" " "
" 20	145 28	145.27	145.57	145.73	145.46	0.40	3.74	148.3	150.5	148.6	149.6	149 2	3 74	184.5	39.04	9429		10	51	6490	18.25	16.94	5272	4218	1030	8190	" "	" " "
" 21	144.86	144.55	144.86	144.28	144.64	0.82	4 56	146 1	148.9	149.0	150.0	149.2	4.56	184 5	39.86	9429		13	51	9493	18.50	17 30	5384	4106	1256	6543	" "	" " "
" 22	142.81	141.42	144.61	143.46	143.08	1.56	6.12	150.4	152.4	150.2	151.9	151.2	8.12	184.4	41.33	9429		22	48	9499	16.50	17.93	5580	3919	2236	3505	" "	" " "
" 23	141.32	140.39	144.09	143.34	142.28	0.80	6.92	150.8	152.4	150.2	151.8	151.3	9.02	184.2	41.92	9429		25	48	9502	19.75	18.16	5661	3841	2484	3093	" "	Mat all out.
" 24	140.57	139.61	140.40	139 66	140.06	2.22	9.14	150.3	152 5	149 9	154 0	151 7	11.64	184 2	44.14	9129	131	32	47	9639	21.00	19 16	5962	3677	3206	2294	" "	
" 25	137.26	136.31	138.72	137 97	137.57	2.49	11.63	149.3	153.2	150.1	154.9	151.9	14.63	184.1	46.53	9429	349	39	47	9864	21.75	20.19	6283	3581	3947	1815	" "	
" 26	136.47	135.31	138.61	137.69	137.02	0.55	12.18	150 1	153.0	149 0	156.2	152.1	15.08	184 1	47.08	9429	494	42	47	10012	22.00	20.43	6358	3654	4153	1760	" "	
" 27	134.30	133.80	134.11	133.87	134.02	3.00	15.18	149.6	154.3	149.6	158.0	152.9	18.88	184.1	50.08	9429	640	52	46	10167	23.00	21.73	6762	3405	5200	1310	" "	
" 28	131.71	131.44	132.40	132.36	131.98	2 04	17.22	148.4	154.6	147.3	159.0	152.3	20.32	184.2	52.22	9429	640	56	46	10171	23.75	22.66	7052	3119	5597	1114	" "	
" 29	129.09	128.97	128.43	128.52	128.75	3.23	20.45	149.5	154 8	150.1	159.3	153.4	24.65	184.3	55.55	9429	803	68	44	10344	24.75	24.11	7503	2841	6789	837	" "	
" 30	125.27	125.15	125.86	135.96	125.56	3.19	23.64	149.1	154.0	148.0	160.3	152.9	27.34	184.5	58.94	6429	1109	76	44	10658	27.00	25.58	7960	2698	7530	716	" "	
" 31	122.29	122.15	123.40	123.48	122.83	2.73	26.37	149.4	153.1	148 9	160.7	153.0	30.17	184.6	61.77	9429	1226	83	286	11024	27.50	26.81	8343	2681	8310	045	" "	
Nov. 1	120.52	120.32	121.55	121.57	120.99	1.84	28.21	148.6	149.7	152.0	163.2	153.4	32.41	184.6	63 61	9429	1342	88	454	11313	28.50	27.61	8592	2721	8926	609	Coarse sand and gravel	
" 2	117.95	117.71	118.68	118.66	118.25	2.74	30.95	147.7	148.0	149 4	163.1	152.0	33.75	184.7	66.45	9129	1521	93	729	11772	30.00	28.84	8975	2797	9206	602	" " " "	
" 3	115.19	114.95	115.54	115 52	115.30	2.95	33.90	147 8	147.8	155.5	169.8	155.2	39.90	184.8	69.50	9139	1764	110	1137	12470	32 50	30.16	9385	3085	10989	561	" " " "	
" 4	113.50	113.36	113.77	113.75	113.57	1.73	35.63	148.1	147.1	161.1	170 1	156.6	43.03	185.1	71.53	9429	2012	119	1251	12811	33.00	31.04	9659	3152	11851	532	" " " "	
" 5	111.93	111.66	112.04	111.99	111.90	1.67	37.30	147.6	148.6	161.6	167.6	156.4	44.50	185.6	73.70	9439	2117	123	1471	13140	33.75	31.98	9952	3188	12256	520	Sand, gravel and mud	Clean, coarse sand in north and south ends. Mud in middle [chambers.
" 6	109.99	106.76	109.99	110.01	109.94	1.96	39.26	149.9	149.6	163.9	167.9	157.9	47.96	185.9	75.96	9429	2333	132	1704	13598	34 25	32.97	10260	3338	13209	505	Mud	
" 7	108.14	107.97	107.94	107.99	108.01	1.93	41.19	148.4	148.4	165.4	166.4	157.2	49.19	186.4	78.39	9429	2496	136	1941	14002	34.25	34.03	10587	3415	13548	504	"	
" 8	108.12	107.95	107.92	107.97	107.99	0.02	41.21	146 4	148.4	164 4	164.4	155.9	47.91	187.4	79.41	9429	2550	132	2048	14159	36 00	34 46	10724	3435	13196	521	Through mud, coarse sand and [gravel	
" 9	106.24	106.07	106.12	106.17	106.15	1.84	43.05	147.5	149.5	165.5	163.5	156.5	50.35	188.5	83.35	9429	2656	139	2353	14577	37.50	35.74	11132	3455	13868	498	Clean, coarse sand and gravel	
" 10	104 27	104.10	104.17	104.22	104.19	1.96	45.01	146.4	147.4	162.4	162.4	154.7	50.51	189.4	85.21	9429	2831	139	2658	15032	38.25	36.98	11508	3544	13912	509	" " " " "	
" 11	102.43	102 26	102.31	102.56	102.44	1.75	46.76	144 4	145.4	160 4	158.4	152.2	49.76	190.4	87.96	9429	3006	138	2644	15517	37.00	38.17	11878	3639	13705	531	" " " " "	
" 12	102.23	102.06	102.31	102.36	102.24	0.20	46.96	147.2	145.2	158.9	158.2	152.2	49.96	191.2	88 96	9429	3006	139	6049	15623	37.75	38.61	12015	3608	13760	524		
" 13	101.38	101.21	101.44	101.49	101.38	0.86	47.82	146.9	149 9	155.9	155.9	152.2	50 82	191 9	90.52	6429	3176	140	3212	15957	38.25	39.29	12227	3730	13997	533	Clay	Average elevation top of clay 101.8.
" 14	100.84	100.67	100.96	101.01	100.87	0.51	48.33	142.6	144 6	156.6	155.6	149.9	40.03	192.6	91.73	9429	3261	136	3352	16178	38.75	39.81	12388	3790	13504	501	"	
" 15	100.61	100.44	100.73	100.78	100.64	0.23	48.56	148.3	148.3	158.3	158.3	153.3	52.66	193.3	92.66	9429	3344	145	3435	16353	39.75	40.21	12513	3840	14504	529	"	
" 16	100.44	100.27	100.56	100.61	100.47	0.17	48.73	145 4	144 4	158.4	156.4	151.1	50.63	194.4	93 93	9429	3344	140	3604	16517	39.50	40.76	12684	3833	13945	550	"	
" 17	100.30	100.13	100.42	100.47	100.33	0.14	48.87	152.5	147.5	157.5	156.5	153.5	53.17	195.5	95.17	9439	3344	148	3702	16623	39.75	41 30	12852	3771	14644	515	"	
" 18	99.71	99.54	99 81	69.86	99 73	0.60	49.47	151.3	148.3	157.3	161.3	154.5	54.77	196.3	96.57	9429	3344	151	3847	16771	39.50	41.91	13042	3799	15085	494	"	
" 19	99.41	99.19	99.49	69.49	99.40	0.33	49.80	146.3	148.3	156 3	162.3	154.1	54.70	197.3	97 90	9429	3504	151	4021	17105	41.00	42.49	13232	3883	15066	515	"	
" 20	99.31	99.09	69.39	99.39	99.30	0.10	49.90	144.6	143.6	152.6	150.6	147.9	48.60	198.6	99.30	9429	3504	162	4132	17227	40.25	43.10	13412	3815	13386	570	"	Took Bertram ashore in p.m.
" 21	99.19	98 97	69.23	99.23	99.16	0 14	50.04	145 8	143.8	155.8	146.8	148.1	48.94	199 8	100.64	9429	3669	136	4324	17558	41.00	43.68	13593	3965	13479	588	"	
" 22	99.04	98.82	99.08	99.08	99.01	0 15	50.19	148.8	141.8	159.8	143.8	148.6	49 59	200.8	101.79	9429	3666	137	4410	17645	40.25	44.18	13748	3897	13658	571	"	
" 23	99.04	98.82	99.08	99.08	99.01	0.00	50.16	145 7	143.7	146 7	146.7	145.7	46.69	201.7	102.69	9429	3669	129	4511	17738	42.00	44.57	13870	3868	12860	601	"	
" 24	99.00	98.78	99 04	99.04	98.97	0.04	50.23	148.4	144 4	148.4	147.4	147.2	48.23	202.4	103.43	9429	3669	133	4588	17819	42 00	41.89	13969	3850	13284	579	"	
" 25	98.92	98.74	98 97	99.01	98.91	0.06	50.29	141.7	144.7	143.7	143.7	143.5	44.59	202.7	103.79	9429	3669	123	4631	17852	43.00	45.04	14016	3836	12281	624	"	
" 26	98.91	68.73	98.96	99.00	98.90	0.01	50.30	144.3	141.3	144.3	145.3	143.8	44.90	202.8	103.90	9429	3669	124	4643	17865	43 00	45 09	14032	3833	12367	620	"	
" 27	98.89	98.71	98.94	98.68	98 88	0.02	50.32	135.5	140.5	145.5	144.5	141.5	42.62	202.5	103.62	9429	3669	118	4628	17844	43.00	44.97	13994	3850	11739	656	"	
" 28	98.89	98.71	98.94	98 68	98 88	0.00	50.32	139 0	140 0	143.0	145.0	141.7	43.82	202.0	103.12	9429	3669	118	4504	17780	43.00	44.75	13626	3854	11794	653	"	
" 26	98.89	98.71	98.94	98.98	98.88	0.00	50.32	139.6	138 6	141 6	140.6	140 1	41 22	201.6	102.72	9420	3669	114	4322	17734	43.00	44.58	13873	3861	11353	680	"	
" 30	98.88	98.70	98.93	98.97	98.87	0.01	50.33	139.7	140.7	139.7	141.7	140.5	41 63	201.7	102.83	9429	3669	115	4532	17745	43.00	44.63	13888	3857	11466	672	"	
Dec. 1	98.83	98.65	98.88	98.93	98.82	0.05	50.38	139.1	140.1	142.1	143.1	140.8	41.98	202 1	103.28	9429	3669	115	4562	17775	42.50	44.82	13947	3828	11562	662	"	
" 2	98.32	98 14	98.37	98 41	98.31	0.51	50.89	141.7	143.7	144.7	145.7	144.0	45.69	202.7	104.39													Stopped air compressors on Lincoln at 4.40 p m.
" 3	98.16	97.98	98.18	98.22	98.13	0.18	51.07	143.1	146.1	145.1	148.1	145.3	47.17	203.1	104.97													

RECORD OF SINKING CAISSONS.

PIER II.—CONTINUED.

Date.	Elevations of Cutting Edge above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage	Elevations of Sand. Original Elevation = 151.6.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights.					Air Pressure.		Reaction Due to Air Pressure.	Net Weight.	Surface in Contact	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1890.	N.E	N.W.	S.E.	S.W.	Average			N.E.	N.W.	S.E.	S.W.	Average				Caisson.	Masonry	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs.		
Sept. 1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...												...	Started air compressors on Lincoln at 11.35 a.m.
" 4	98.11	97.93	98.13	98.17	98.08	0.05	51.12	149.1	149.5	151.1	152.8	150.6	52.52	191.8	93.72	9429	3669	145	3581	16824	40 50	40.67	12656	4168	14465	576	Clay	Pumping out 6 ft. shaft.
" 5	98.11	97.93	98.13	98.17	98.08	0.00	51.12	150.1	151.4	153.4	153.4	152.1	54.02	192.1	94.02	9429	3669	149	3611	16858	42.00	40.80	12696	4162	14878	560	"	Cleaning out working chamber.
" 6	98.11	97.93	98.13	98.17	98.08	0.00	51.12	150.4	150.4	151.7	154.4	151.7	53.62	192.4	94.32	9429	3669	148	3644	16890	41.00	40.93	12737	4153	14768	502	"	Blowing out mud. Hoisting out clay.
" 7	98.11	97.93	98.13	98.17	98.08	0.00	51.12	149.5	149.4	153.5	155.2	151.9	53.82	192.7	94.62	9429	3669	148	3676	16922	42.00	41.06	12777	4145	14823	559	"	Started air compressors on Bertram at 10 a.m.
" 8	98.11	97.93	98.13	98.17	98.08	0.00	51.12	149.2	149.6	153.9	153.6	151.6	53.52	192.9	94.82	9429	3669	148	3698	16944	42.00	41.15	12805	4139	14741	562	"	
" 9	98.11	97.93	98.13	98.17	98.08	0.00	51.12	150.2	150.2	151 6	156.2	152 1	54.02	192.9	94.82	9429	3669	149	3697	16944	42.00	41.15	12805	4139	14878	556	"	
" 10	98.11	97.93	98.13	98.17	98.08	0.00	51.12	149.3	150.6	150.6	155.9	151.6	53.52	192.6	94.52	9429	3669	148	3665	16913	42.00	41.02	12765	4148	14741	563	"	
" 11	98 11	97.93	98 13	98 17	98 08	0.00	51.12	148.2	148.9	149 5	156.9	150.9	52.82	192.2	94.12	9429	3669	146	3624	16868	42.00	40.85	12712	4156	14548	571	"	
" 12	98.11	97.93	98.13	98.17	98.08	0.00	51.12	150.1	150.8	150.8	150.8	150.6	52.52	191.8	93.72	9429	3669	145	3581	16824	42.00	40.67	12656	4168	14465	576	"	
" 13	98.11	97.93	98.13	98.17	98.08	0.00	51.12	149.9	150.6	148.6	157.9	151.8	53.72	191.6	93.52	9429	3669	148	3558	16804	42.00	40.59	12631	4173	14796	565	"	
" 14	98.11	97.93	98.13	98.17	98.08	0.00	51.12	149.0	149.3	150.3	156.0	151.1	53.02	191.3	93.22	9429	3669	146	3527	16771	41.00	40.46	12591	4180	14603	572	"	
" 15	98.11	97.93	98.13	98.17	98 08	0 00	51.12	149.6	149.6	151.6	150.9	150.4	52.32	190.9	92.82	9429	3669	145	3485	16728	41.25	40.28	12535	4193	14410	582	"	
" 16	97.84	97.66	97.89	97.93	97.83	0.25	51.37	149 6	148.2	150.2	156.2	151.1	53 27	190.9	93.07	9429	3669	147	3510	16755	42.00	40.39	12569	4186	14672	571	"	
" 17	97.27	97.07	97.22	97.26	97.21	0.62	51.99	147.3	149.3	149.3	155.3	150.3	53.09	191.6	94.39	9429	3669	147	3652	16897	41.75	40.96	12746	4151	14622	568	"	
" 18	97.13	96.95	97.08	97.12	97.07	0.14	52.13	150.3	149 6	153.0	151.6	151.1	54.03	193.3	95.23	9429	3669	149	3740	16987	42.25	41.33	12861	4126	14881	554	"	
" 19	97.05	96.87	97.00	97.04	96.99	0.08	52.21	148.2	148 6	150.9	154.9	150.9	53.91	192.9	95.91	9429	3669	149	3814	17061	42.00	41.62	12952	4109	14848	554	"	
" 20	96.99	96.81	96.94	96.98	96.93	0.06	52.27	152.1	149.6	150.4	153.7	151 4	54 47	193.4	96 47	9429	3669	150	3873	17121	42.00	41.87	13029	4092	15002	546	"	
" 21	96.90	96.72	96 85	96.89	96.84	0.09	52.36	150.2	150.2	153.5	154.9	152.2	55.36	194.2	97.36	9429	3669	153	3967	17218	43.50	42.25	13148	4070	15247	534	"	
" 22	96.77	96.59	96.72	96.76	96.71	0.13	52.49	148.5	149.5	149 9	150.2	149.5	52.79	195.2	98.49	9429	3669	146	4093	17337	42.75	42.74	13300	4037	14540	555	"	
" 23	96.77	96.59	96.72	96.76	96.71	0.00	52.49	147.3	146.3	150.0	149.6	148.3	51.59	196.3	99.59	9429	3669	142	4213	17453	42.50	43.20	13443	4010	14209	564	"	
" 24	96.66	96.48	96.61	96.65	96.60	0.11	52.60	149 2	148.2	149.9	147.5	148.7	52.10	197.2	100 60	9429	3669	144	4321	17563	43.00	43.66	13587	3976	14350	554	"	
" 25	96.50	96.32	96 42	96.46	96.43	0.17	52.77	149.6	149.6	152.3	148.9	150.1	53.67	197.6	101.17	9429	3669	148	4381	17627	43.25	43.91	13664	3963	14782	536	"	
" 26	96 50	96.32	96 42	96.46	96.43	0.00	52.77	149.4	148.4	150.0	149.7	149.4	52.97	197 7	101 27	9429	3669	146	4392	17636	42.50	43.95	13677	3959	14589	542	"	
" 27	96.50	96.32	96.42	96.46	96.43	0.00	52.77	147.3	147.7	148.7	149.7	148.3	51.87	198.0	101.57	9429	3669	143	4426	17667	43 00	44.08	13717	3950	14286	553	"	
" 28	95.79	95.61	95.73	95.77	95.72	0.71	53.48	147.7	146.7	149.0	148.0	147.8	52.08	198 0	102.28	9429	3669	144	4503	17745	43 50	44 39	13814	3931	14344	548	"	
" 29	95.79	95.61	95.73	95.77	95.72	0.00	53.48	142.8	143.8	147.5	150.7	146.2	51.48	197.8	102.08	9429	3669	131	4484	17721	43 75	44.30	13786	3935	13903	566	"	
" 30	95.79	95.61	95.73	95.77	95.72	0.00	53.48	144.3	146.6	149.0	151.3	147.8	52.08	197.3	101.58	9429	3669	144	4427	17669	44 25	44.08	13717	3952	14344	551	"	
Oct. 1	94.39	94.21	94.30	94.34	94.31	1.41	54 89	145.3	148.3	153.3	155.6	150.6	56.29	196.6	102.29	9429	3669	155	4498	17751	43.50	44.39	13814	3937	15504	508	Clay	
" 2	94.39	94.21	94.30	94.34	94.31	0.00	54.89	147.2	147.2	152.6	151.9	149 7	55.39	195.9	101 59	9429	3669	153	4424	17675	43.50	44 09	13720	3955	15256	518	"	
" 3	93.17	92.99	93.08	93.12	93.09	1.22	56.11	143.5	145.9	152.9	157.9	150.0	56.91	195.2	102.11	9429	3669	157	4478	17633	43.75	44.32	13792	3841	15674	490	"	
" 4	93.17	92.99	93.08	93.12	93.09	0.00	56.11	147.6	149.6	155.3	158.9	152.8	59.71	194.6	101.51	9429	3788	243	4364	17824	43.00	44.06	13711	4113	16393	502	"	
" 5	93.17	92.99	93.08	93.12	93.09	0.00	56.11	143.2	146.6	153.9	152.6	149.1	56.01	193.9	100.81	9429	3788	155	4338	17710	44.25	43.75	13615	4095	15426	531	"	
" 6	93.17	92.99	93.08	93.12	93.09	0.00	56.11	143.0	146.3	152.3	154.3	149.0	55.91	193.3	100.21	9429	3788	154	4358	17729	42.75	43.49	13534	4195	15399	544	"	
" 7	93.17	92.99	93 08	93.12	93.09	0.00	56.11	145.6	147.2	155.6	155.9	151.1	58.01	192.9	99.81	9429	3788	160	4228	17605	44.00	43.32	13481	4124	15977	516	"	
" 8	93.17	92.99	93.08	93.12	93.09	0.00	56.11	148.4	147.7	155.7	159.0	152.7	59.61	192.7	99.61	9429	3788	227	4168	17612	43.50	43.23	13453	4159	16676	508	"	
" 9	91.71	91.53	91.62	91.66	91.63	1.46	57.57	148.0	149.4	156 0	159.4	153.2	61.57	192.7	101.07	9429	3788	532	4153	17902	43.75	43.86	13649	4253	16713	509	"	
" 10	91.71	91.53	91.62	91.66	91.63	0.00	57.57	146.1	148 8	156.1	149.5	150.1	58.47	192.8	101.17	9429	3788	161	4374	17752	43.25	43.91	13664	4088	16104	508	"	
" 11	90.06	89.88	89.94	89.98	89.96	1.67	59.24	146.8	147.1	147.5	148.5	147.5	57.54	192.8	102.84	9429	3788	159	4556	17932	43.25	44.63	13888	4044	15848	510	"	
" 12	90.06	89.88	89.94	89.98	89.96	0.00	59.24	148.0	147.4	149.0	149.0	148.4	58.44	192.7	102.74	9429	3788	161	4544	17922	44.25	44.59	13876	4046	16096	503	"	
" 13	90.06	89.88	89.94	89.98	89.96	0.00	59.24	144.5	147.5	149.8	148.8	147.7	57.74	192.5	102.54	9429	3788	159	4527	17903	44 00	44.50	13848	4055	15903	510	"	
" 14	89.04	88 86	88.92	88.96	88.94	1 02	60.26	148.6	149 6	149.6	161 0	152.2	63.26	192.3	103.36	9429	3788	876	4339	18432	43.00	44.86	13960	4473	17005	526	"	
" 15	89.04	88.86	88.92	88.96	88.94	0.00	60.26	147.8	150.8	151.1	154.1	150.9	61.96	193.1	103.16	9429	3788	533	4347	18157	43.00	44.77	13932	4225	16781	504	"	
" 16	88.19	88.01	88.07	88 11	88 09	0.85	61.11	148.7	148.3	150.7	157.0	151.2	63.11	192.0	103.91	9429	3788	850	4317	18384	44.25	45.10	14035	4349	16979	512	"	Began sealing at 10.30 a.m.
" 17	88.19	88.01	88.07	88.11	88.09	0.00	61.11	142.7	146.0	150.0	156 7	148.9	60.81	192.0	103.91	...	...	...	...	...	44 00	...	...	...	...	...	...	Sealing caisson.
" 18	88.19	88.01	88.07	88.11	88.09	0.00	61.11	145.9	146 6	151.2	158.6	150.6	62.51	191.9	103.81	...	...	...	...	...	43.50	...	...	...	...	...	...	" "
" 19	88.19	88.01	88.07	88.11	88.09	0.00	61.11	144.1	150 1	151.5	160.8	151.6	63.51	191.8	103.71	...	...	...	...	...	44.50	...	...	...	...	...	...	" "
" 20	88.19	88.01	88.07	88.11	88.09	0.00	61.11	147.2	146.8	152.5	157.5	151.0	62.91	191.5	103.41	...	...	...	...	...	43.00	...	...	...	...	...	...	
" 21	88.19	88.01	88.07	88.11	88.09	0.00	61.11	147.6	148.3	151.0	161.0	152.0	63.91	191 3	103.21	...	...	...	...	...	43 25	...	...	...	...	...	...	" "
" 22	88.19	88.01	88.07	88.11	88.09	0.00	61.11	145.4	150.4	148.8	159.1	150.9	62.81	191.1	103.01	...	...	...	...	...	43.50	...	...	...	...	...	...	" "
" 23	88.19	88.01	88.07	88.11	88.09	0.00	61.11	146.3	147.6	151.6	161.0	151.6	63.51	191.3	103.21	...	...	...	...	...	43.50	...	...	...	...	...	...	" "
" 24	88 19	88.01	88.07	88.11	88.09	0.00	61.11	146.9	150.6	154.9	161.9	153.6	65.51	191.9	103.81	...	...	...	...	...	40.00	...	...	...	...	...	...	Bertram.—Stopped compressors at 6.45 a.m. Lincoln. " " " 9.45 a.m.

APPENDIX J.—Continued.

RECORD OF SINKING CAISSONS.

PIER III.

Date.	Elevations of Cutting Edge. Above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage.	Elevations of Sand. Original Elevation = 156.3.					Average Pene-tration of Caisson.	Water Gauge.	Depth Immersed.	Weights.					Air Pressure.		Reaction Due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1889.	N.E.	N.W.	S.E.	S.W.	Average.			N.E.	N.W.	S.E.	S.W.	Average.				Caisson	Masonry	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs.		
July 30	...	...	...	...	...	...	...	...	...	...	...	...	...	108.1	...												...	Caisson built on shore. Placing cutting edge.
Aug. 8	...	...	...	...	...	...	...	...	...	...	...	...	...	197.2	...	...	...	...	...	...	...	...	...	...	...	...	...	Began building caisson.
Oct. 26	...	...	...	...	...	...	...	...	...	...	...	...	...	184.1	...	...	...	...	...	...	...	...	...	...	...	...	...	Caisson launched at 11.15 a.m.
" 28	...	...	...	...	...	...	...	...	...	...	...	...	...	184.2	...	...	...	...	...	...	...	...	...	...	...	...	...	Caisson towed to position at 11.30 a.m.
Nov. 5	...	...	...	...	...	...	...	...	...	...	...	...	...	185.6	...	...	...	...	...	...	...	...	...	...	...	...	...	Began concreting at 1 p.m.
" 27	...	...	...	...	...	...	...	...	...	...	...	...	...	202.5	...	...	...	...	...	...	...	...	...	...	...	...	...	Finished concreting.
" 28	...	...	...	...	...	...	...	...	...	...	...	...	...	202.0	...	...	...	...	...	...	...	...	...	...	...	...	...	Began building solid timber.
Dec. 11	...	...	...	...	...	...	...	...	...	...	...	...	...	198.2	...	5649	...	...	...	5649	...	...	...	...	...	...	...	Finished building solid timber
" 12	...	...	...	...	...	...	...	...	...	...	...	...	...	196.9	...	5649	...	...	...	5649	...	...	...	...	...	...	...	Began laying masonry.
" 14	154.80	155.59	158.25	159.60	156.99	0.00	...	155.0	154.2	157.8	158.2	156.3	− 0.69	195.0	38.01	5649	349	...	55	6053	...	...	...	...	...	...	...	
" 16	154.36	154.97	158.59	159.27	156.80	0.19	0.19	156.6	156.1	157.9	158.2	157.2	0.40	193.9	37.10	5649	570	1	53	6273	...	...	...	...	...	...	...	Started air compressors on Bertram at 12.55 p.m. Sand [pumps at 1 p.m.
" 17	154.22	154.80	158.48	159.06	156.64	0.16	0.35	156.5	156.1	158.0	158.7	157.3	0.66	194.0	37.36	5649	605	2	53	6309	14.50	16.21	5044	1265	181	13978	...	Sucking out mat.
" 18	154.22	154.63	158.20	158.61	156.42	0.22	0.57	156.2	156.2	158.5	158.0	157.2	0.78	104.4	37.08	5649	642	2	53	6346	14.50	16.48	5128	1218	215	11830	...	" " "
" 19	154.35	152.51	157.80	155.96	155.16	1.26	1.83	157.0	155.3	158.3	158.2	157.2	2.04	195.0	39.84	5649	672	6	54	6381	15.50	17.29	5380	1001	562	3562	...	" " " Started air compressors on Lincoln at 4 p.m.
" 20	154.41	151.79	157.51	154.86	154.64	0.52	2.35	157.2	156.7	158.0	158.8	157.7	3.06	195.3	40.66	5649	878	8	111	6646	16.00	17.65	5492	1154	843	2737	Fine river sand	" " "
" 21	153.53	152.65	153.30	152.52	153.00	1.64	3.99	160.4	160.5	158.4	159.2	159.6	6.60	195.5	42.50	5649	963	15	265	6892	18.00	18.45	5741	1151	1818	1260	" " "	" " "
" 22	151.32	149.67	151.45	149.80	150.56	2.44	6.43	160.3	160.6	158.5	190.1	159.9	9.34	195.6	45.04	5649	1220	23	498	7390	19.50	19.55	6084	1306	2572	1015	" " "	" " "
" 23	147.60	144.71	150.21	147.55	147.52	3.04	9.47	159.0	156.7	161.4	169.0	159.3	11.78	195.7	48.18	5649	1337	32	807	7823	20.75	20.91	6507	1318	3244	812	" " "	Mat all out.
" 24	144.33	143.78	146.33	146.02	145.11	2.41	11.88	160.5	159.9	159.8	160.6	160.2	15.09	195.7	50.59	5649	1348	43	1050	8089	21.00	21.96	9834	1255	4156	604	" " "	
" 25	141.87	141.98	144.33	144.30	143.12	1.99	13.87	158.6	158.6	160.8	160.2	159.6	16.48	195.7	51.58	5649	1565	45	1251	8510	22.00	22.82	7101	1409	4539	620	" " "	Elevator put on.
" 26	141.85	141.97	144.27	144.27	143.09	0.03	13.90	160.6	159.9	159.9	159.3	159.9	16.81	195.6	52.51	5649	1565	46	1250	8510	21.75	22.79	7002	1418	4630	612	" " "	
" 27	140.02	139.69	141.63	142.18	141.13	1.99	15.86	158.7	158.7	158.7	159.3	158.8	17.67	195.6	54.47	5649	1679	48	1446	8822	23.00	23.64	7856	1466	4867	602	" " "	
" 28	138.45	138.73	140.81	140.89	139.72	1.41	17.27	161.0	161.0	162.1	159.6	160.9	21.18	195.7	55.98	5649	1789	58	1599	9095	23.25	24.30	7562	1533	5883	525	" " "	
" 29	135.15	135.32	137.67	137.74	136.47	3.25	20.52	161.2	160.7	163.1	161.2	161.6	25.13	195.7	59.23	5649	2007	69	1926	9651	25.00	25.70	7997	1654	6921	478	" " "	
" 30	132.70	132.60	135.06	134.83	133.80	2.67	23.10	160.5	160.5	158.5	161.7	160.8	26.50	195.7	61.90	5649	2113	73	2208	10043	26.00	26.86	8358	1685	7299	461	" " "	
" 31	131.80	131.69	134.10	133.77	132.81	0.96	24.15	157.7	157.1	160.6	157.6	158.2	25.36	195.6	62.76	5649	2223	72	2303	10247	26.75	27.23	8473	1774	6985	508	" " "	
1890.																												
Jan. 1	131.79	131.43	133.79	133.59	132.61	0.23	24.38	158.1	158.7	160.4	157.4	158.6	25.99	195.4	62.79	5949	2432	72	2302	10455	26.00	27.25	8480	1975	7158	551	Fine river sand	
" 2	131.60	131.38	133.75	133.46	132.55	0.06	24.44	159.1	159.1	165.4	155.4	159.8	27.25	195.4	62.85	5649	2641	77	2308	10675	22.25	27.27	8486	2189	7505	583	" " "	
" 3	131.60	131.28	133.65	133.44	132.49	0.06	24.50	160.0	160.6	160.8	155.1	159.1	26.61	195.5	63.01	5649	2641	73	2323	10686	26.75	27.34	8508	2178	7329	594	" " "	
" 4	131.55	131.28	133.65	133.38	132.47	9.02	24.52	159.1	159.1	161.7	161.7	160.4	27.93	195.7	63.23	5619	2642	77	2341	10709	26.75	27.44	8539	2170	7602	565	" " "	
" 5	131.49	131.21	133.65	133.38	132.43	0.04	24.56	156.7	154.2	158.0	159.8	157.2	24.77	196.8	64.37	5649	2848	68	2464	11029	27.75	27.93	8691	2338	6822	685	" " "	
" 6	130.12	129.81	132.48	132.04	131.11	1.32	25.88	157.6	159.1	159.0	160.0	158.9	27.79	197.8	66.69	5649	3023	77	2699	11448	28.25	28.94	9006	2442	7654	638	" " "	
" 7	127.10	126.02	129.86	129.33	128.23	2.88	28.79	160.6	159.5	159.7	159.7	159.9	31.67	198.5	70.27	5649	3077	87	3080	11893	29.50	30.49	9488	2405	8723	551	" " "	
" 8	124.40	123.96	127.32	126.70	125.59	2.64	31.40	161.1	157.6	158.8	160.4	159.5	33.91	199.2	73.61	5649	3247	94	3429	12419	31.25	31.95	9942	2477	9340	530	" " "	
" 9	122.67	122.20	125.72	125.28	123.97	1.62	33.02	190.0	161.9	158.9	160.9	160.5	36.53	200.1	76.18	5649	3362	101	3623	12635	32.25	33.04	10282	2353	10061	467	" " "	
" 10	122.67	122.19	125.72	125.28	123.97	0.00	33.02	157.5	158.5	162.5	159.5	150.5	35.53	201.5	77.53	5649	3418	98	3841	13006	32.00	33.65	10471	2585	9786	518	" " "	Waiting for masonry. Stopped air compressors on Lincoln [at 8.10 p.m.
" 11	122.65	122.19	125.68	125.26	123.95	0.02	33.04	158.9	158.9	162.9	161.9	160.7	39.75	202.9	78.95	5649	3439	101	3992	13181	32.00	34.26	10661	2520	10122	498	" " "	" " "
" 12	122.64	122.18	125.67	125.24	123.94	0.01	33.05	159.0	160.0	165.0	161.0	161.3	37.36	204.0	80.06	5649	3593	103	4110	13455	32.50	34.75	10814	2641	10290	513	" " "	" " "
" 13	122.63	122.18	125.66	125.23	123.93	0.01	33.06	159.2	160.2	165.1	161.2	161.4	37.47	205.0	81.07	5649	3593	103	4217	13562	33.50	35.18	10948	2614	10320	506	" " "	" " "
" 14	122.62	122.18	125.60	125.18	123.89	0.04	33.10	159.6	160.6	164.5	160.6	161.3	37.41	205.9	82.01	5649	3755	103	4318	13825	34.00	35.59	11075	2750	10304	534	" " "	" " "
" 15	122.62	122.18	125.60	125.18	123.89	0.00	33.10	160.5	160.5	160.5	158.5	159.8	35.91	207.0	83.11	5649	3763	102	4335	13849	34.00	36.07	11224	2625	9890	530	" " "	" " "
" 16	122.62	122.18	125.60	125.18	123.89	0.00	33.10	157.1	157.1	165.1	152.1	157.9	34.01	208.1	84.21	5649	3816	94	4558	14117	35.00	36.55	11274	2743	9367	585	" " "	" "
" 17	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.7	159.7	167.7	156.7	160.9	37.01	209.3	85.41	5649	3828	102	4682	14361	35.50	37.07	11536	2825	10103	554	" " "	" " "
" 18	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.8	159.8	172.4	162.8	163.7	39.81	210.4	86.51	5649	3931	130	4800	14530	36.00	37.54	11682	2848	10945	520	" " "	" " "
" 19	122.62	122.18	125.60	125.18	123.89	0.00	33.10	160.8	160.8	162.8	191.8	161.5	37.61	211.2	87.31	5649	4079	104	4884	14716	36.00	37.89	11791	2925	10839	564	" " "	" " "
" 20	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.3	159.3	164.3	160.3	160.8	36.91	211.8	87.91	5649	4087	102	4949	14787	36.00	38.15	11872	2915	10166	573	" " "	" " "
" 21	122.62	122.18	125.60	125.18	123.89	0.00	33.10	162.5	162.5	162.5	159.8	161.8	37.91	212.3	88.41	5649	4234	105	5002	14990	36.40	38.37	11940	3050	10441	680	" " "	" " "
" 22	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.7	159.7	160.7	163.7	160.9	37.01	212.7	88.81	5649	4237	102	5047	15035	36.50	38.54	11993	3042	10193	597	" " "	" " "
" 23	122.62	122.18	125.60	125.18	123.89	0.00	33.10	160.8	160.8	158.9	161.8	160.6	36.71	213.0	89.11	5649	4286	101	5082	15218	36.50	38.67	12034	3184	10111	629	" " "	" " "
" 24	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.3	159.3	156.3	162.3	159.3	35.41	213.3	89.41	5649	4286	98	5113	15246	37.00	38.80	12074	3172	9753	650	" " "	" " "
" 25	122.62	122.18	125.60	125.18	123.89	0.00	33.10	160.5	160.5	160.5	161.5	160.7	36.81	213.5	89.61	5649	4456	102	5133	15340	37.00	38.89	12102	3238	10138	638	" " "	" " "
" 26	122.62	122.18	125.60	125.18	123.80	0.00	33.10	160.6	160.6	161.6	161.6	161.1	37.21	213.6	89.71	5649	4545	103	5144	15441	37.00	38.93	12115	3326	10248	649	" " "	" " "
" 27	122.62	122.18	125.60	125.18	123.89	0.00	33.10	159.8	159.8	157.8	159.8	159.3	35.41	213.8	89.91	5649	4545	98	5185	15477	37.00	39.02	12142	3315	9753	679	" " "	" " "
" 28	122.62	122.18	125.60	125.18	123.89	0.00	33.10	158.6	158.9	157.6	159.6	158.6	34.71	213.8	89.91	5649	4626	96	5165	15536	37.25	39.02	12142	3394	9560	710	" " "	" " "
" 29	121.56	121.36	124.01	123.81	122.68	1.21	34.31	158.3	159.3	158.5	161.3	159.3	36.62	213.8	91.12	5649	4721	101	5176	15647	38.00	39.55	12307	3340	10086	662	" " "	
" 30	119.71	119.52	123.20	121.98	120.85	1.83	36.14	155.4	159.4	158.4	152.4	156.4	35.55	213.7	92.85	5640	4801	98	5494	16042	39.50	40.30	12541	3501	9791	715	" " "	Started air compressors on Lincoln at 12.05 a.m.
" 31	117.86	117.52	120.32	120.14	118.96	1.89	38.03	152.9	158.7	154.9	158.7	156.3	37.34	213.7	94.74	5649	4801	103	5750	16303	41.00	41.12	12796	3507	10284	682	Coarser sand with gravel.	

RECORD OF SINKING CAISSONS.

PIER III.—CONTINUED.

Date. 1890.	Elevations of Cutting Edge Above Mean Sea Level. N.E.	N.W.	S.E.	S.W.	Average.	Sunk in 24 Hours.	Total Sinkage.	Elevation of Sand. Original Elevation = 156.8. N.E.	N.W.	S.E.	S.W.	Average.	Average Penetration of Caisson	Water Gauge.	Depth Immersed.	Weights. Caisson.	Masonry.	Sand.	Water.	Total.	Air Pressure. Indicated.	Calculated.	Reaction Due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
																Tons	Tons.	Tons.	Tons	Tons.	Lbs.	Lbs.	Tons	Tons.	Sq. Ft.	Lbs.		
Feb. 1	116.31	116.05	118.57	118.50	117.36	1.60	39.63	153.1	157.1	155.1	151.1	154.1	36.74	213 6	96.24	5649	4879	101	5906	16535	41.25	41.77	12998	3537	10119	699	Coarser sand with gravel	
" 2	114 76	114.49	116.87	116.88	115.74	1.62	41.25	154.9	160.7	155.9	153.1	156.2	40.46	213.6	97.86	5949	5001	257	5995	16902	41.50	42.47	13216	3686	11057	666	" " " "	
" 3	113.32	113.13	115.59	115.49	114.38	1.36	42.61	156.9	160.7	153.9	154.9	156 6	42.22	213.3	98.92	5649	5001	546	6008	17204	41.75	42.93	13359	3845	11390	677	" " " "	
" 4	111.01	110.98	112.79	112.95	111.93	2.45	45 06	159.5	161.9	153.6	154.6	157 4	45.47	212.9	100.97	5649	5001	1131	5890	17071	42 75	43.82	13636	4035	11893	678	" " " "	
" 5	110.45	110.60	111.00	111.41	110.87	1.06	46.12	158.8	161.7	155.0	154.0	157.4	46.53	212.2	101.33	5649	5001	1347	5834	17831	42.50	43.98	13686	4145	12057	687	Coarse sand and gravel	
" 6	109.77	109.90	109.77	110.09	109.88	0.99	47.11	155.8	156.7	149.9	155.8	154.5	44.62	211.4	101.52	5649	5001	977	6045	17672	42.75	44.06	13711	3961	11755	674	" " " "	
" 7	109.03	109.00	109.42	109 71	109.29	0.59	47.70	154.9	158.7	147.1	152.9	153.4	44.11	210.7	101.41	5649	5001	874	6113	17637	42.75	44.01	13695	3942	11672	676	Coarse sand, gravel and clay	Clay on west side of cutting edge.
" 8	108.35	108.20	108.80	108.91	108.57	0.72	48.42	157.0	158.0	147.5	148.5	152 8	44.23	210.0	101.43	5649	5001	909	6081	17637	42.75	44.02	13698	3939	11701	673	" " " " "	
" 9	107.91	107.64	107.94	107.04	107.86	0.71	49.13	156.2	157.2	146.6	147.6	151.9	44.04	209.3	101.44	5649	5001	871	6116	17637	43.50	44.02	13698	3939	11660	676	" " " " "	
" 10	107.12	106.72	107.18	106.98	107.00	0.86	49.99	156.6	157.6	144.7	146.7	151.4	44.40	209.3	102.30	5949	5001	987	6182	17769	44.37	44.40	13817	3952	11719	675	" " " " "	
" 11	107.09	106.67	107.15	106.99	106.97	0.03	50.02	157.6	159.4	145.9	147.9	152.7	45.73	209.5	102.53	5649	5091	1180	6083	17913	44.25	44.50	13848	4065	11934	681	" " " " "	
" 12	107.09	106 67	107.15	106.96	106.97	0.00	50.02	155.6	158.6	145.8	147.8	152.0	45.03	209.9	102.93	5649	5001	1051	6090	17791	43.50	44.67	13901	3890	11821	658	" " " " "	
" 13	107.09	109.67	107.15	106.96	106.97	0.00	50.02	150.8	157.6	146.0	148.0	150.6	43.63	210.4	103.43	5649	5001	797	6373	17820	43.75	44.89	13969	3851	11593	664	" " " " "	
" 14	107.08	109.66	107.14	106.95	106 96	0.01	50.03	155.1	158.9	147.4	148.4	152.4	45.44	211.1	104.14	5649	5001	1129	6262	18038	44.00	45.20	14066	3972	11888	698	" " " " "	Stopped air compressors on Bertram at 7.10 a.m.
" 15	197.08	106.66	107.14	106 95	106.96	0.00	50.03	155.0	157.8	141.5	149.2	150.9	43.94	211.5	104.54	5649	5001	853	6588	18091	44.00	45.37	14119	3972	11644	682	" " " " "	Took off air Feb. 16 at 9.30 a.m.
June 18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Coarse sand, gravel and clay	Started air compressors on Bertram at 11 20 a.m.
" 21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	" " " " "	Started sand pumps at 1.15 p.m.; cleaning out shafts; strengthening 6 ft. lock, removing blocking from cutting [edge.
" 24	106.52	106.19	106.51	106.33	106.39	0.57	50.00	148.9	148.9	147.9	154.9	150.2	43.81	201.9	95.51	5649	5001	830	5341	10821	40.00	41.45	12899	3922	11611	675	" " " " "	Hoisting out clay and gravel.
" 25	100.52	106.19	196.51	106.33	106.30	0.00	50.60	148.9	148.9	143.9	149 9	147.9	41.51	201.9	95.51	5649	5001	429	5541	16620	40.00	41.45	12899	3731	11237	662	" " " " "	" " " " "
" 26	106.52	106.19	106.51	106.33	106.39	0.00	50.60	146.7	147.7	147.7	152.2	148.6	42.21	201.7	95.31	5649	5001	546	5459	16655	40.00	41.36	12871	3784	11358	686	" " " " "	" " " " "
" 27	106.52	106.19	106.51	109.33	106.39	0.00	50.60	146.6	146.6	145.6	153.1	148.0	41.61	201.6	95 21	5649	5001	445	5500	16595	40.00	41.32	12858	3737	11255	664	" " " " "	" " " " "
" 28	106.52	106.14	106.46	106.30	106.36	0.03	50.63	149.2	150.7	149.2	152.7	150.4	44.04	201.2	94.84	5649	5001	871	5108	16929	40.00	41.16	12808	4129	11660	708	" " " " "	Hoisting out clay.
" 29	106.38	105.98	106.32	106.18	106.22	0.14	50.77	150.1	150.1	147.1	153.6	150.2	43.98	201.1	94.88	5649	5001	863	5417	16930	40.00	41.18	12815	4116	11631	709	" " " " "	" " "
" 30	106.25	105.85	106.23	106.08	106.10	0.12	50.89	148.7	152.3	148.7	154.3	151.0	44.90	200.7	94.00	5649	5001	1031	5299	16980	40.00	41.06	12777	4203	11900	712	" " " " "	" " "
July 1	105.22	104.87	105.42	105.26	105.19	0.91	51.80	153.0	153.0	149.3	151.8	151.8	46.61	200.3	95 11	5649	5001	1356	5186	17192	40.00	41.28	12846	4346	12069	722	Coarse sand, gravel and clay	Hoisting out clay.
" 2	105.21	104.84	105.37	105.26	105.17	0.02	51.82	147.9	154.9	147.9	149.9	150.1	44.93	200.2	95.03	5649	5001	1037	5343	17030	40.00	41.24	12833	4197	11805	711	" " " " "	" " "
" 3	105.21	104.84	105.37	105.26	105.17	0.00	51.82	149.9	158.6	145.2	148.9	149.4	44.23	200.2	95.03	5949	5001	906	5403	16959	39.50	41.24	12833	4126	11691	706	" " " " "	" " "
" 4	105.21	104.84	105.37	105.26	105.17	0.00	51.82	148.8	151.8	147.8	148.8	149.3	44.13	200.1	94 93	5649	5001	890	5403	16943	39.50	41.20	12821	4122	11975	706	" " " " "	Started air compressors on Lincoln at 6.35 p.m. One compressor on Bertram broke down.
" 5	104.82	104.45	105.04	104.93	104.81	0.36	52.18	150.7	154.7	148.1	153.7	151.8	46.99	200.1	95.29	5649	5001	1432	5153	17235	41.00	41.35	12898	4367	12127	720	" " " " "	Hoisting out clay.
" 6	103.69	103.33	103.85	103.75	103.66	1.15	53.33	151.2	153.2	145.2	151.2	150.2	46.54	200.2	96.54	5649	5001	1347	5346	17343	42.00	41.90	13039	4304	12058	714	" " " " "	" " "
" 7	103.69	103.33	103.85	103.75	103.66	0.00	53.33	153.0	154.0	147.0	151.0	151.0	47.34	200.0	99.34	5649	5001	1442	5234	17326	41.25	41.81	13011	4315	12181	708	" " " " "	" " "
" 8	103.68	103.32	103.84	103.74	103.65	0.01	53.34	152.7	151.7	146.2	152.7	150.8	47.15	199.7	96.05	5649	5001	1404	5226	17280	41.50	41.08	12970	4310	12152	709	" " " " "	" " "
" 9	102.70	102.32	102.89	102.81	102.68	0.97	54.31	148.0	150.3	147.0	151.3	149.9	47.22	199.3	96.02	5649	5001	1428	5276	17354	41.25	41.93	13048	4306	12162	708	" " " " "	" " "
" 10	102.70	102.32	102.89	102.81	102.98	0.00	54.31	152.8	154.8	147.0	151.8	151.6	48.92	198.8	96.12	5649	5001	1763	5060	17473	41.50	41.72	12983	4490	12422	723	" " " " "	" " " Stopped sand pumps at 4 p.m.
" 11	101.81	101.44	102.09	101.96	101.82	0.86	55.17	152.6	154.6	147.8	152.6	151.9	50.08	198.6	96.78	5949	5001	2006	5006	17662	41.75	42.00	13070	4592	12598	729	Clay	" " "
" 12	101.79	101.42	102.05	101.94	101.80	0.02	55.19	150.8	153.8	144.0	149.8	149.6	47.80	198.3	90.50	5649	5001	1501	5202	17356	41.50	41.88	13033	4323	12251	706	"	" " "
" 13	101.79	101.42	102.05	101.94	101.80	0.00	55.19	150.8	153.8	142 0	150.8	149.4	47.60	198.3	96.50	5649	5001	1464	5222	17336	42.00	41.88	13033	4303	12220	704	"	" " "
" 14	101.79	101.42	102.05	101.94	101.80	0.00	55.19	150.1	148.1	141.3	150.1	148 2	46.40	198.6	96.80	5649	5001	1254	5389	17293	42.75	42.01	13073	4220	12037	701	"	" " "
" 15	100.78	100.41	100.97	100.86	100.75	1.05	56.24	151.8	155.2	144.7	149.8.	150.4	49.65	198.2	97.45	5649	5001	1903	5120	17673	43.00	42.29	13160	4513	12533	720	"	" " "
" 16	100.78	100.41	100.97	100.86	100.75	0.00	56.24	153.0	159.0	147.5	151.6	152.0	51.25	198.0	97.25	5649	5001	2176	4909	17735	42.25	42.20	13132	4603	12776	721	"	" " "
" 17	99.79	99.42	99.89	99.78	99 72	1.03	57.27	155.3	153.3	149.6	149.6	151.9	52.18	197.6	97.88	5649	5001	2411	4877	17938	43.00	42.48	13219	4719	12918	731	"	" " "
" 18	99.79	99.42	99 89	99 78	99.72	0.00	57.27	150.3	159.3	148.9	154.3	154.6	54.88	196.6	96 88	5649	5001	2955	4489	18094	42.25	42.05	13085	5009	13326	752	"	" " "
" 19	99.79	99.42	99.89	99.78	99.72	0.00	57.27	155.4	155.4	147.9	149.9	153.2	52.48	196.2	96.48	5649	5001	2471	4953	17774	43.00	41.87	13029	4745	12964	732	"	" " "
" 20	99.79	99.42	99.89	99.78	99.72	0.00	57.27	158.9	159.9	148.9	149.9	154 4	54.68	195.9	96.18	5649	5001	2915	4432	17997	43.00	41.74	12989	5008	13296	753	"	" " "
" 21	99.79	99.42	99.89	99.78	99.72	0.00	57.27	155.4	159.4	148.4	150.4	153.4	58.08	195.4	95.68	5649	5001	2713	4470	17839	42.50	41.52	12921	4918	13143	748	"	" " "
" 22	99.79	99.42	99.89	99.78	99.72	0.00	57.27	150.8	156.8	149.8	154.8	153.1	53.38	194.8	95.08	5649	5001	2953	4444	18047	42.50	41.26	12840	5207	13099	795	"	" " "
" 23	99.79	99.42	99.89	99.78	99.72	0.00	57.27	156.3	158.3	151.3	164.3	157.5	57.78	194 3	94.58	5649	5001	3507	3935	18092	42 00	41.05	12774	5318	13763	773	"	" " "
" 24	99.79	99.42	99.89	99.78	99.72	0.00	57.27	153.5	154.8	152.1	190.1	155.1	55.38	193.8	94.08	5649	5001	3037	4150	17877	42.00	40.83	12706	5171	13401	772	"	" " "
" 25	99.79	99.42	99.89	99.78	99.72	0.00	57.27	153.4	154.1	153.4	161.4	155.6	55.88	193.4	93.68	5649	5001	3158	4060	17868	42.50	40.66	12653	5215	13477	774	"	" " "
" 26	98.20	97.82	98.40	98.30	98.18	1.54	58.81	155.8	153.8	152.1	160.8	155.1	56.92	193.1	94.92	5649	5001	3309	4075	18094	42.00	41.19	12818	5276	13633	774	"	" " "
" 27	98.20	97.82	98 40	98.30	98.18	0.00	58.81	155.7	157.0	153.0	165.7	157.8	59.62	193 0	94 82	5649	5001	3796	3860	18306	41.50	41.15	12805	5501	14038	784	"	" " "
" 28	98.20	97.82	98.40	98.30	98.18	0.00	58.81	152.5	152.5	151.2	160.5	154.2	56.02	193.0	94.82	5649	5001	3185	4171	18006	42.50	41.15	12805	5201	13498	771	"	" " "
" 29	98.20	97.82	98.40	98.30	98.18	0.00	58.81	150.5	152.5	150.5	159.8	153-3	55.12	193.0	94.82	5649	5001	3004	4279	17933	41.50	41.15	12805	5128	13362	797	"	" " " Started pumps on Lincoln at 2 p.m
" 30	98.20	97.82	98.40	98.30	98.18	0.00	58.81	155.0	153.7	154.0	160.7	155.8	57.62	193.0	94.82	5649	5001	3487	4011	18148	41.50	41.15	12805	5343	13739	778	Sand and clay	" " " and pumping sand.
" 31	96.77	99.40	96.77	96.66	96.65	1.53	60.34	157.0	154.0	154.0	162.0	156.9	60.25	193.3	96.65	5649	5001	4069	3921	18637	42.50	41.95	13054	5583	14133	790	" " "	" " " " " "

APPENDIX J.—CONTINUED.

RECORD OF SINKING CAISSONS.

PIER III.—CONTINUED.

Date.	Elevations of Cutting Edge above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage	Elevations of Sand. Original Elevation = 155.3.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights					Air Pressure		Reaction Due to Air Pressure.	Net Weight.	Surface in Contact	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1890.	N.E.	N.W.	S.E.	S.W.	Average			N.E.	N.W.	S.E.	S.W.	Average				Caisson.	Masonry	Sand	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Tons	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs.		
Aug. 1	96.77	96.40	96.77	96.66	96.65	0.00	60.34	155.2	154.5	155.2	160.9	156.5	59.85	193.2	96.55	5649	5001	3964	3965	18579	42.00	41.90	13039	5540	14073	787	Sand and clay	Hoisting out clay and pumping sand.
" 2	96.77	96.40	96.77	96.66	96.65	0.00	60.34	154.4	157.1	154.4	163.4	157.3	60.65	193.1	96.45	5649	5001	4127	3877	18654	42.00	41.86	13026	5628	14193	793	" " "	" " " " " "
" 3	96.69	96.32	96.69	96.58	96.57	0.08	60.42	154.9	153.9	154.9	163.6	156.6	60.03	192.9	96.33	5649	5001	4001	3931	18582	42.00	41.81	13011	5571	14100	790	" " "	" " " " " "
" 4	95.13	94.73	95.23	95.09	95.05	1.52	61.94	154.5	155.5	153.2	161.5	156.2	61.15	192.7	97.65	5649	5001	4230	3953	18833	42.00	42.38	13188	5645	14267	791	" " "	" " " " " "
" 5	95.13	94.73	95.23	95.09	95.05	0.00	61.94	157.5	152.1	154.8	161.2	156.4	61.35	192.4	97.35	5649	5001	4271	3899	18820	42.75	42.25	13148	5672	14297	793	" " "	Started pump on Bertram at 3.30 p m.
" 6	95.13	94.73	95.23	95.09	95.05	0.00	61.94	155.2	155.9	154.5	162.2	156.9	61.85	192.2	97.15	5649	5001	4369	3823	18842	42.00	42.16	13120	5722	14371	796	" " "	Hoisting out clay and pumping sand.
" 7	95.13	94.73	95.23	95.09	95.05	0.00	61.94	156.0	155.3	155.7	163.0	157.5	62.45	102.0	96.95	5649	5001	4493	3737	18880	42.00	42.08	13095	5785	14461	800	" " "	" " " " " "
" 8	93.41	93.01	93.64	93.50	93.39	1.66	63.60	155.2	156.4	154.7	162.9	157.3	63.91	191.7	98.31	5649	5001	4793	3731	19174	42.25	42.67	13278	5896	14678	803	" " "	" " " " " "
" 9	93.41	93.01	93.64	93.50	93.39	0.00	63.60	155.5	156.2	156.2	162.0	157.5	64.11	191.5	98.11	5649	5001	4834	3688	19172	42.25	42.58	13250	5922	14708	805	" " "	" " " " " "
" 10	91.71	91.29	91.90	91.71	91.65	1.74	65.34	154.3	155.2	153.6	161.9	156.2	64.55	191.2	99.55	5649	5001	4925	3797	19372	42.00	43.20	13443	5929	14773	808	" " "	" " " " " "
" 11	90.19	89.78	90.45	90.23	90.16	1.49	66.83	155.0	156.0	152.3	160.7	156.0	65.84	191.0	100.84	5649	5001	5189	3815	19654	42.50	43.76	13618	6036	14964	807	" " "	" " " " " "
" 12	88.70	88.30	88.90	88.66	88.64	1.52	68.35	154.9	156.6	152.9	160.6	156.2	67.56	190.9	102.26	5649	5001	5542	3805	19997	43.00	44.38	13811	6186	15219	813	" " "	" " " " " "
" 13	87.40	87.00	87.59	87.36	87.34	1.30	69.65	155.1	155.7	151.4	160.4	155.6	68.26	190.9	103.56	5649	5001	5686	3871	20207	43.75	44.94	13985	6222	15322	812	" " "	" " " " " "
" 14	86.31	85.91	86.54	86.39	86.29	1.05	70.70	151.2	153.2	149.8	157.5	152.9	66.61	191.0	104.71	5649	5001	5347	4142	20139	44.00	45.44	14140	5999	15078	796	" " "	" " " " " "
" 15	85.37	85.02	85.67	85.51	85.39	0.90	71.60	152.8	155.4	151.5	159.2	154.7	69.31	191.0	105.61	5649	5082	5901	3980	20612	45.00	45.83	14262	6350	15477	821	" " "	" " " " " "
" 16	85.37	85.02	85.67	85.51	85.39	0.00	71.60	155.0	156.0	151.8	159.2	155.5	70.11	191.0	105.61	5649	5163	6066	3893	20771	45.00	45.83	14262	6509	15594	835	" " "	" " " " " Ditching along cutting edge.
" 17	85.37	85.02	85.67	85.51	85.39	0.00	71.60	155.1	156.3	151.8	161.8	156.2	70.81	191.1	105.71	5649	5163	6210	3827	20849	44.50	45.88	14277	6572	15697	837	" " "	" " " " " " " " "
" 18	85.37	85.02	85.67	85.51	85.39	0.00	71.60	152.2	153.9	151.5	160.5	154.5	69.11	191.2	105.81	...	...	...	...	...	44.50	...	...	...	...	...	" " "	" " " " " Sealing along cutting edge.
" 19	85.37	85.02	85.67	85.51	85.39	0.00	71.60	150.7	156.0	151.0	160.0	154.4	69.01	191.2	105.81	...	...	...	...	...	45.75	...	...	...	...	...	" " "	" " " " " " " " "
" 20	85.37	85.02	85.67	85.51	85.39	0.00	71.60	154.0	152.9	152.7	159.2	154.7	69.31	191.2	105.81	...	...	...	...	...	46.50	...	...	...	...	...	" " "	" " " " " " " " "
" 21	85.37	85.02	85.67	85.51	85.39	0.00	71.60	152.9	152.6	150.9	159.4	154.0	68.61	191.3	105.91	...	...	...	...	...	47.00	...	...	...	...	...	" " "	" " " Stopped pump on Bertram at 7 a.m.
" 22	85.37	85.02	85.67	85.51	85.39	0.00	71.60	153.0	152.7	153.0	159.5	154.6	69.31	191.4	106.01	...	...	...	...	...	46.50	...	...	...	...	...	Clay	" " " " " " Lincoln at 7.40 a m.
" 23	85.37	85.02	85.67	85.51	85.39	0.00	71.60	152.6	151.0	152.6	159.1	153.8	68.41	191.0	105.61	...	...	...	...	...	47.00	...	...	...	...	...	"	Cleaning out caisson and sealing.
" 24	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.4	147.2	151.9	157.5	151.5	66.11	190.7	105.31	...	...	...	...	...	47.00	...	...	...	...	...	"	" " " " "
" 25	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.0	147.1	150.8	157.4	151.1	65.71	190.8	105.21	...	...	...	...	...	46.00	...	...	...	...	...	...	Sealing. Cutting edge 2 ft. below clay in north end Sand cleaned out to clay, which is 2.5 ft. below cutting edge in [south end.
" 26	85.37	85.02	85.67	85.51	85.39	0.00	71.60	152.8	147.9	152.1	159.7	153.1	67.71	190.5	105.11	...	...	...	...	...	47.00	...	...	...	...	...	...	Sealing.
" 27	85.37	85.02	85.67	85.51	85.39	0.00	71.60	153.1	148.1	153.1	160.3	153.7	68.31	190.5	105.11	...	...	...	...	...	46.00	...	...	...	...	...	...	"
" 28	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.3	148.4	150.6	159.1	151.8	66.41	190.7	105.31	...	...	...	...	...	44.00	...	...	...	...	...	...	"
" 29	85.37	85.02	85.67	85.51	85.39	0.00	71.60	150.2	155.2	150.9	160.9	154.3	68.91	190.9	105.51	...	...	...	...	...	46.75	...	...	...	...	...	...	"
" 30	85.37	85.02	85.67	85.51	85.39	0.00	71.60	151.9	155.9	153.9	161.6	155.8	70.41	190.9	105.51	...	...	...	...	...	46.00	...	...	...	...	...	...	"
" 31	85.37	85.02	85.67	85.51	85.39	0.00	71.60	148.7	153.3	152.0	161.3	153.8	68.41	191.0	105.61	...	...	...	...	...	45.00	...	...	...	...	...	...	" Stopped air compressors on Lincoln at 6 a.m.
Sept. 1	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.3	154.0	152.0	162.0	154.3	68.91	191.0	105.61	...	...	...	...	...	43.50	...	...	...	...	...	...	Sealing.
" 2	85.37	85.02	85.67	85.51	85.39	0.00	71.60	150.0	149.8	151.3	159.7	152.7	67.31	191.0	105.61	...	...	...	...	...	44.00	...	...	...	...	...	...	"
" 3	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.1	151.4	152.4	160.1	153.2	67.81	191.4	106.01	...	...	...	...	...	43.50	...	...	...	...	...	...	"
" 4	85.37	85.02	85.67	85.51	85.39	0.00	71.60	149.5	156.1	150.1	162.1	154.5	69.11	191.8	106.41	...	...	...	...	...	44.00	...	...	...	...	...	...	" Stopped air compressors on Bertram at 6 a m.

RECORD OF SINKING CAISSONS.

PIER IV.

Date.	Elevations of Cutting Edge above Mean Sea Level.					Sink in 24 Hours.	Total Sinkage.	Elevations of Sand. Original Elevation = 175.85.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights.				Air Pressure.		Reaction due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1888.	N.E.	N.W.	S.E.	S.W.	Average.			N.E.	N.W.	S.E.	S.W.	Average.				Caisson.	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs.		
Nov. 24																											Caisson built on shore; cutting edge placed.
" 26																											Began building
Dec. 15																											Caisson launched.
" 17					175.85			176.1	176.1	175.6	175.6	175.85		189.6													Caisson placed in position.
" 23																											Began concreting.
" 27																										Fine river sand	Put on air at 8 p.m.
" 28	171.36	170.02	174.17	172.80	172.09		3.76	172.9	170.4	174.4	175.4	173.28	1.19	191.4	19.31	1823			1823	5.5	8.38	941	882	204	8647	" " "	Started sand pump at 2 a.m.
" 29	168.92	168.40	169.17	168.79	168.82	3.27	7.03	171.7	168.7	172.7	178.7	172.95	4.13	191.7	22.88	2416			2416	8.0	9.93	1115	1301	710	3665	" " "	
" 30	166.72	166.14	165.80	165.34	166.00	2.82	9.85	173.5	174.0	179.0	169.0	173.88	7.88	192.0	26.00	2498			2498	9.0	11.28	1267	1231	1355	1817	" " "	
" 31	166.58	166.04	165.80	165.34	165.94	.06	9.91	170.6	166.6	173.6	177.6	172.10	6.16	192.6	26.66	2622			2622	9.5	11.57	1300	1322	1059	2497	" " "	
1889.																											
Jan. 1	161.74	163.03	162.43	163.79	162.75	3.19	13.10	171.2	170.2	173.7	176.7	172.95	10.20	193.2	30.45	2918			2918	13.0	13.22	1485	1433	1754	1634	Fine river sand	
" 2	160.06	160.84	159.30	160.49	160.25	2.50	15.60	167.6	167.6	173.6	177.6	171.60	11.35	193.6	33.35	3232			3232	14.0	14.47	1625	1607	1952	1646	Mud	
" 3	156.92	156.84	157.63	157.56	157.24	3.01	18.61	168.7	167.7	173.7	178.7	172.20	14.96	193.7	36.46	3272			3272	14.5	15.82	1777	1495	2573	1162	"	All timber of caisson proper in place.
" 4	156.66	156.28	156.87	156.54	156.59	.65	19.26	167.7	167.7	174.7	178.7	172.20	15.61	193.7	37.11	3518			3518	15.0	16.11	1809	1709	2685	1273	"	
" 5	154.09	154.09	154.11	154.15	154.10	2.49	21.75	167.5	166.5	180.0	176.5	173.62	18.52	193.5	39.40	3943			3943	15.5	17.10	1921	2022	3186	1268	"	Let off air at 9.30 a.m to put in last foot of concrete without [air holes. Began building crib.
" 6	151.84	151.87	152.91	152.96	152.40	1.70	23.45	167.1	168.6	173.1	173.1	169.98	17.58	193.1	40.70	4092			4092	15.0	17.66	1984	2108	3024	1394	"	
" 7	150.10	150.21	150.98	151.02	150.59	1.81	25.26	163.8	172.8	166.8	184.3	172.42	21.83	192.8	42.21	4112			4112	17.0	18.32	2058	2054	3755	1094	"	
" 8	147.76	147.99	147.96	148.21	147.98	2.61	27.87	167.6	163.6	176.6	182.6	172.60	24.62	192.6	44.62	4129			4129	18.0	19.37	2176	1953	4255	921	"	
" 9	144.87	144.91	145.35	145.44	145.14	2.84	30.71	166.9	166.9	176.9	186.9	174.40	29.26	192.9	47.76	4133			4133	19.5	20.73	2328	1805	5033	717	"	
" 10	144.87	144.91	145.32	145.43	145.13	.01	30.72													20.0						Coarse sand and gravel	Crib completed.
" 11	144.87	144.91	145.32	145.42	145.13	.00	30.72	165.2	164.2	174.7	185.7	172.45	27.32	194.2	49.07	4165			4165	20.0	21.30	2392	1773	4699	755	" " " "	
" 12	144.86	144.90	145.30	145.42	145.12	.01	30.73	165.1	165.1	179.1	183.6	173.22	28.10	195.1	49.98	4190			4190	20.0	21.69	2436	1754	4833	725	" " " "	Let off air at 4 p.m to concrete around main shaft.
" 13	143.19	143.23	143.60	143.74	143.44	1.68	32.41	167.6	163.6	168.6	185.6	170.83	27.41	196.6	53.16	4190		117	4307		23.07	2591	1716	4714	728	" " " "	Started air pumps at 4 a.m.
" 14	142.18	143.23	142.67	142.82	142.47	.97	33.38	165.0	167.0	173.0	183.0	172.00	29.53	198.0	55.53	4190		212	4402	22.5	24.10	2707	1695	5079	667	" " " "	
" 15	139.11	139.18	139.53	139.72	139.39	3.08	36.46	164.0	166.5	171.5	181.5	170.87	31.48	199.5	60.11	4190		400	4590	24.0	26.09	2930	1660	5414	613	" " " "	
" 16	137.31	137.38	137.82	138.01	137.63	1.76	38.22	163.7	165.7	171.7	181.7	170.70	33.07	200.7	63.07	4190		520	4710	25.0	27.37	3074	1636	5688	575	" " " "	
" 17	136.45	136.52	136.89	137.07	136.73	.90	39.12	163.4	169.4	174.4	181.4	172.15	35.42	201.4	64.67	4198		587	4785	26.0	28.07	3153	1632	6092	536	" " " "	
" 18	134.90	135.00	135.14	135.33	135.09	1.64	40.76	162.7	165.7	168.7	187.7	171.20	36.11	201.7	66.61	4206		664	4870	27.0	28.91	3247	1623	6211	523	" " " "	
" 19	133.55	133.64	133.71	133.90	133.70	1.39	42.15	160.4	164.4	171.4	180.4	169.15	35.45	202.4	68.70	4206		742	4948	27.0	29.82	3349	1599	6097	524	Mud	
" 20	133.54	133.61	133.71	133.90	133.69	.01	42.16	161.9	164.9	168.9	178.9	168.65	34.96	202.9	69.21	4213		773	4986	27.0	30.04	3374	1612	6013	536	"	
" 21	133.54	133.61	133.67	133.87	133.67	.02	42.18	165.4	163.4	168.4	178.4	168.90	35.23	203.4	69.73	4217		793	5010	28.5	30.26	3399	1611	6060	531	"	
" 22	133.48	133.56	133.49	133.68	133.55	.12	42.30	161.1	165.1	168.1	177.1	167.85	34.30	204.1	70.55	4217		825	5042	29.0	30.62	3439	1603	5899	543	"	
" 23	132.23	132.24	132.23	132.36	132.26	1.29	43.59	161.6	164.6	168.6	176.6	167.85	35.59	204.6	72.34	4219	146	840	5205	30.0	31.40	3527	1678	6121	548	"	
" 24	129.98	129.96	129.86	129.96	129.94	2.32	45.91	161.8	164.8	162.8	174.8	166.05	36.11	204.8	74.86	4219	179	933	5331	31.0	32.49	3649	1682	6211	541	"	
" 25	129.98	129.94	129.82	129.94	129.92	.02	45.93	161.6	163.6	165.6	175.6	166.60	36.68	204.6	74.68	4224	212	908	5344	31.0	32.41	3640	1704	6309	540	"	
" 26	128.19	128.14	127.89	128.02	128.06	1.86	47.79	160.2	163.2	164.2	175.2	165.70	37.64	204.2	76.14	4232	224	1001	5457	32.0	33.04	3711	1746	6474	539	"	
" 27	126.35	126.30	126.21	126.33	126.32	1.74	49.53	160.5	162.5	160.7	170.0	163.37	37.05	203.5	77.18	4232	260	1049	5541	31.5	33.50	3763	1778	6373	558	Clay	Stopped sand pumps at 6.30 p.m. Pump men went on clay [hoist. Started well.
" 28	126.06	126.13	126.00	126.07	126.06	.26	49.79	161.6	163.6	160.6	171.6	164.35	38.29	202.6	76.54	4234	260	967	5461	31.5	33.22	3731	1730	6586	525	"	
" 29	125.94	126.02	125.90	125.94	125.94	.12	49.91	161.5	163.0	163.5	170.5	164.62	38.68	201.5	75.56	4234	260	922	5416	31.5	32.79	3683	1733	6653	521	"	
" 30	125.84	125.91	125.80	125.87	125.86	.08	49.99	161.0	161.5	168.5	171.0	165.50	39.64	201.0	75.14	4234	260	902	5396	32.0	32.61	3663	1733	6818	508	"	
" 31	125.70	125.83	125.72	125.73	125.75	.11	50.10	161.3	160.8	169.3	169.8	165.30	39.55	200.8	75.05	4234	260	898	5392	32.0	32.57	3658	1734	6802	509	"	
Feb. 1	125.46	125.59	125.34	125.39	125.45	.30	50.40	161.9	161.4	168.9	169.9	165.52	40.07	200.9	75.45	4234	260	917	5411	32.0	32.75	3678	1733	6898	503	Clay	
" 2	125.35	125.45	125.34	125.39	125.38	.07	50.47	162.3	161.8	169.3	169.3	165.68	40.30	201.3	75.92	4234	260	939	5433	33.0	32.95	3701	1732	6932	499	"	
" 3	123.62	123.72	123.68	123.76	123.69	1.69	52.16	162.8	162.8	171.8	168.8	166.57	42.86	201.8	78.11	4234	260	1040	5734	32.5	33.90	3808	1726	7372	468	"	
" 4	123.61	123.71	123.67	123.73	123.68	.01	52.17	162.4	163.4	171.9	169.4	166.77	43.09	202.4	78.72	4234	260	1008	5502	33.0	34.16	3837	1735	7411	465	"	
" 5	122.90	123.03	122.98	123.05	122.99	.69	52.86	162.9	162.4	169.9	169.9	166.28	43.29	202.9	79.91	4230	260	1124	5614	32.5	34.68	3895	1719	7446	461	"	Took off clay hoist.
" 6	122.90	123.03	122.98	123.05	122.99	.00	52.86	161.2	161.2	177.2	169.2	167.20	44.21	203.2	80.21	4230	260	1138	5628	33.0	34.81	3910	1718	7004	452	"	Began scaling at 10.30 a.m.
" 7	122.90	122.96	122.88	123.03	122.94	.05	52.91	159.1	161.1	169.1	169.1	164.60	41.66	203.1	80.16	4230	260	1135	5625	33.0	34.79	3908	1717	7164	479	"	
" 8	122.90	122.96	122.88	123.03	122.94	.00	52.91	159.8	158.8	171.8	168.3	164.68	41.74	202.8	79.86					32.0							
" 9	122.90	122.96	122.88	123.03	122.94	.00	52.91	161.1	160.1	167.6	167.6	164.10	41.16	202.1	79.16					30.0							
" 10	122.90	122.96	122.88	123.03	122.94	.00	52.91							201.1	78.16												Stopped air pumps at 10.50 a.m.

APPENDIX J.—Continued.

RECORD OF SINKING CAISSONS.

PIER V.

Date	Elevations of Cutting Edge above Mean Sea Level.					Sunk in 24 Hours.	Total Sinkage.	Elevations of Sand. Original Elevation = 211.3.					Average Penetration of Caisson.	Water Gauge.	Depth Immersed.	Weights				Air Pressure.		Reaction due to Air Pressure.	Net Weight.	Surface in Contact.	Average Weight per Sq. Ft. of Surface Exposed to Friction.	Material.	Remarks.
1890.	N.E.	N.W.	S.E.	S.W.	Average.			N.E.	N.W.	S.E.	S.W.	Average.				Caisson.	Sand.	Water.	Total.	Indicated.	Calculated.						
																Tons.	Tons.	Tons.	Tons.	Lbs.	Lbs.	Tons.	Tons.	Sq. Ft.	Lbs.		
Apr. 25	211.82	211.82	211.82	211.82	211.82																						Set up cutting edge.
" 26																											Began building caisson.
May 7	211.72	211.68	211.48	211.59	211.62	0.20		211.7	210.9	211.3	211.4	211.3															Began taking out blocking.
" 8	209.32	209.39	209.51	209.48	209.42	2.20	2.40	211.7	210.9	211.3	211.4	211.3	1.88														Began concreting. Put on air and started sand pumps at [11 55 p.m.
" 9	206.72	206.37	206.41	206.15	206.43	2.99	5.39	210.8	210.9	210.6	210.9	210.8	4.37	211.1	4.67	168	5		173	4.00	2.03	128	45	530	170	Top soil	
" 10	201.64	201.25	200.70	200.31	200.98	5.45	10.84	209.8	209.6	210.1	210.1	209.9	8.92	209.6	8.62	612	10		622	5.77	3.74	236	386	1183	653	" "	
" 11	104.89	194.89	195.16	195.17	195.03	5.95	16.79	210.2	208.8	209.6	210.2	209.7	14.67	210.1	15.07	821	17		838	9.00	6.54	413	425	1781	477	" "	
" 12	193.01	192.92	192.03	191.[illegible]	192.48	3.55	19.34	209.6	209.7	210.3	210.3	210.0	17.52	210.3	17.82	853	20		873	9.75	7.73	488	385	2127	362	Black quick sand	
" 13	188.17	188.18	188.15	188.1[illegible]	188.16	4.32	23.66	209.3	209.1	209.1	209.1	209.1	20.94	210.4	22.24	1012	25	1	1038	11.00	9.65	610	428	2542	337	" " "	Waiting for air lock.
" 14	188.14	188.16	188.14	188.16	188.15	0.01	23.67	209.3	209.1	209.1	209.1	209.1	20.95	210.9	22.75	1012	25	1	1038	9.00	9.87	624	414	2543	326	" " "	" " " "
" 15	188.14	188.16	188.14	188.16	188.15	0.00	23.67	211.2	209.9	210.2	210.2	210.4	22.25	210.6	22.45	1012	26	0	1038	10.00	9.74	616	422	2701	312	" " "	
" 16	188.01	188.02	188.01	188.02	188.01	0.14	23.81	211.2	209.9	210.2	210.2	210.4	22.39	210.2	22.19	1012	26	0	1038	10.00	9.63	609	429	2718	316	" " "	Air lock received and placed.
" 17	187.38	187.44	187.47	187.53	187.45	0.56	24.37	210.6	209.7	210.4	209.5	210.0	22.55	210.3	22.85	1376	26	0	1402	12.00	9.91	626	776	2738	566	" " "	
" 18	184.85	185.74	185.68	185.90	185.41	2.04	26.41	207.8	202.7	208.7	209.5	207.2	21.79	210.6	25.19	1437	25	2	1464	13.00	10.93	691	773	2645	577	Hard, tough top soil	
" 19	183.51	182.48	183.55	183.53	183.02	2.39	28.80	210.3	208.8	209.0	206.2	208.6	25.38	210.8	27.78	1673	29	1	1683	14.50	12.06	762	921	3105	593	" " " "	
" 20	179.78	179.77	180.55	180.59	180.17	2.87	31.65	209.0	208.6	209.0	210.0	209.1	28.93	211.3	31.13	1917	34	1	1952	15.50	13.51	854	1098	3512	625	" " " "	
" 21	176.51	176.42	176.70	176.67	176.57	3.60	35.25	209.1	207.5	207.4	208.5	208.1	31.53	210.4	33.83	1966	37	1	2004	16.75	14.68	929	1075	3828	562	Fine sand	
" 22	171.08	171.09	171.04	171.07	171.07	5.50	40.75	207.4	208.1	205.4	206.2	206.8	35.73	210.7	39.63	2246	42	2	2290	17.50	17.20	1087	1203	4338	555	" "	
" 23	165.95	165.91	165.76	165.76	165.85	5.22	45.97	207.7	207.4	207.4	207.8	207.6	41.75	210.7	44.87	2486	49	2	2537	18.50	19.46	1230	1307	5068	516	" "	
" 24	157.05	157.03	156.77	156.77	176.90	8.95	54.92	207.6	208.3	208.7	208.4	208.7	51.80	209.4	52.50	2631	59	1	2691	24.00	22.78	1440	1251	6289	398	" "	
" 25	150.82	150.78	150.84	150.79	170.81	6.09	61.01	208.9	209.0	207.9	208.8	208.6	57.79	210.2	59.39	2987	67	1	3055	27.00	25.78	1630	1425	7016	406	" "	
" 26	150.79	150.74	150.78	150.74	150.76	0.05	61.06	208.7	209.6	209.1	209.1	209.1	58.34	210.0	59.24	3015	68	1	3084	27.00	25.71	1625	1459	7082	412	" "	
" 27	145.61	147.54	145.58	145.51	145.56	5.20	66.26	209.9	210.0	209.6	208.6	209.5	63.94	210.3	64.74	3353	74	1	3428	28.50	28.09	1776	1652	7762	425	Sand coarser with gravel	
" 28	140.08	140.91	140.92	140.86	140.92	4.64	70.90	209.4	208.0	209.1	208.2	208.7	67.78	209.7	68.78	3622	79	1	3702	29.50	29.85	1887	1815	8228	441	" " " "	
" 29	139.40	139.33	139.39	139.33	139.36	1.56	72.46	209.4	209.4	209.0	208.4	209.0	69.64	209.6	70.24	3588	81	0	3669	30.00	30.48	1927	1742	8454	412	" " " "	
" 30	137.02	136.95	136.99	137.07	137.00	2.36	74.82	207.3	208.1	208.0	208.6	208.0	71.00	209.3	72.30	3812	83	1	3896	31.00	31.38	1984	1912	8619	444	" " " "	
" 31	134.70	134.42	134.55	134.47	134.48	2.52	77.34	207.0	207.5	207.8	208.6	207.7	73.22	209.3	74.82	3863	85	1	3949	32.70	32.47	2053	1896	8889	427	Same, streaked with mud	
June 1	131.90	131.82	131.98	131.90	131.90	2.58	79.92	206.8	207.7	207.2	207.9	207.4	77.50	209.0	77.10	3863	88	1	3952	34.00	33.46	2115	1837	9166	401	Sand with gravel	
" 2	130.00	129.92	130.01	129.93	129.97	1.93	81.85	205.6	206.6	207.9	207.9	207.0	77.03	208.9	78.93	3863	91	1	3954	34.50	34.26	2166	1788	9351	382	" " "	
" 3	128.33	128.19	128.39	128.25	128.29	1.68	83.53	207.6	207.5	206.0	206.1	206.3	78.01	208.5	80.21	3863	129	5	3997	[illegible]	34.81	2201	1796	9470	379	" " "	
" 4	127.63	127.57	127.60	127.54	127.59	0.70	84.23	205.6	206.4	204.6	205.9	205.6	78.01	207.8	80.21	3863	136	5	4004	35.00	34.81	2201	1803	9470	381	" " "	
" 5	126.47	126.40	126.43	126.36	126.42	1.17	85.40	205.9	206.7	205.9	206.0	206.1	79.68	207.9	81.48	3863	138	34	4035	37.00	35.36	2235	1800	9673	372	Sandy clay	
" 6	125.43	125.29	125.48	125.35	125.39	1.03	86.43	205.1	206.5	204.7	206.2	205.6	80.21	208.1	82.71	3863	139	63	4065	37.50	35.90	2269	1796	9737	369	" "	
" 7	125.02	124.93	125.03	124.94	124.98	0.41	86.84	205.1	206.5	204.5	205.3	207.3	80.32	206.3	81.32	3863	138	23	4024	37.50	35.29	2231	1793	9751	368	" "	
" 8	124.98	124.91	124.98	124.89	124.94	0.04	86.88	206.8	207.9	205.5	206.3	206.6	81.66	206.2	81.26	3863	140	15	4018	36.50	35.27	2230	1788	9014	361	" "	Began sealing at 3.15 p.m.
" 9	124.97	124.89	124.97	124.89	124.93	0.01	86.89	207.1	209.0	205.2	206.2	206.9	81.97	207.2	82.37					38.50	35.71						Sealing.
" 10	124.97	124.89	124.97	124.89	124.93	0.00	86.59	206.8	208.1	205.9	206.3	206.8	81.87	207.5	82.57					37.50							Supply shaft choked up.
" 11	124.97	124.89	124.97	124.89	124.93	0.00	86.89	207.0	208.5	205.9	206.4	207.0	82.07	207.6	82.67					36.00							Sealing.
" 12	124.97	124.89	124.97	124.89	124.93	0.00	86.89	206.7	208.2	205.8	206.5	206.8	81.87	208.3	83.37					35.00							Finished sealing at 12 m.

APPENDIX K.

SPECIFICATIONS FOR MASONRY.

PIERS.

There will be four piers numbered from east to west and an Anchorage Pier.

The Anchorage pier will stand on the east bluff and back of the present face of that bluff. It will contain approximately 700 cubic yards.

Pier I will be on the East side of the river, standing in nine feet of water at high water. It will contain approximately 2 300 cubic yards.

Piers II and III will be in the river. They will each contain approximately 4 400 cubic yards.

Pier IV will be near the west bank. It will contain approximately 2 800 cubic yards.

Piers I, II and III will finish 12 feet thick, 35 feet long between shoulders and 47 feet long over all under the belting course.

Pier IV will finish 10 feet thick, 37 feet long between shoulders and 47 feet long over all under the belting course.

The lower portions of Piers II and III will not be solid, but will contain three hollow spaces extending from the bottom of the masonry to high water.

The piers shall be built in all respects to conform to the plans which will be furnished by the Engineer.

The Anchorage Pier must be built around the anchor rods, which will extend from the bottom to the top of the masonry.

FOUNDATIONS.

The foundations will be put in by the company.

The foundation for Pier I will finish at elevation 201, or 20 feet above low water, and the masonry will be started after the foundation is completed.

The foundation for Piers II and III will finish at elevation 141, or 40 feet below low water.

The contractor will be required to lay the masonry for these piers while the pneumatic foundations are being sunk, and to keep up with the rate of sinking, and must be prepared to lay four feet of vertical masonry per day.

The foundation of Pier IV is now finished at elevation 173, or eight feet below low water mark.

It is surmounted by a water-tight curb, and the contractor will begin laying masonry on the completed foundation.

STONE.

The masonry below elevation 180 and the footing courses of Pier I may be of limestone. The masonry of Pier I above the footing courses, and of Piers II, III and IV above 180 and in each case below elevation 229 shall be of granite with limestone backing. The masonry above elevation 229 shall be of limestone or of granite with limestone backing, as may be directed by the Engineer.

The limestone used shall be that known as Bedford limestone from the quarries near Bedford, Indiana, unless some other limestone is expressly accepted by the Chief Engineer. The granite shall be a granite specially accepted by the Chief Engineer. All stone of each class shall be subject to the approval of the Engineer.

MASONRY.

The masonry shall be first class work, laid in regular courses.

Copings, starling copings included, shall have the upper beds, wash, face and a width of six inches from face on lower beds six cut with true lines and surfaces. Belting shall have a like proportion of the lower bed bush hammered and shall have a face margin draft of four inches along the lower edge. The face of the upstream starling of Piers II and III shall be fine pointed with no projection exceeding one half inch. There shall be a draft of four inches on each side of the point of the pier on both the upstream and downstream ends of all piers below the starling coping. All other parts of the work shall have a rock face with no projections exceeding three inches from the pitch line of the joint and no hollows back of that pitch line.

The interior faces of the walls in the hollow portion of Piers II and III shall have no projections exceeding six inches and no hollows exceeding two inches from the true dimensions of the plans.

The stones shall be cut and coursed out at the quarries, every dimension stone being marked for its place, and full course plans shall be furnished to the Resident Engineer before shipment.

No course shall be less than 20 inches thick nor more than 36 inches thick, and no course, except the main belting and coping, shall be thicker than the course below it. The backing shall be of the same thickness as the dimension work and with beds of precisely the same character.

The bottom beds of the face stones shall never be less than 36 inches in either direction. Headers shall be at least six feet deep measuring from pitch line of the face, and stretchers shall measure at least five feet long in the wall. Every header shall retain a width of at least 24 inches at the full specified depth from the face. Every stretcher shall retain a length of at least four feet 36 inches back from the face. The beds of the principal pieces of backing in each course shall average at least eight square feet. The bottom bed shall always be the full size of the stone. The top bed shall nowhere be more than six inches less than the bottom bed. There shall be not less than three nor more than four headers between the shoulders on each side in each course. In the hollow portions of Piers II and III there shall be at least one stone in each course bonding three feet each way between the cross walls and the face walls of the pier.

The upper and lower beds shall be parallell and dressed closely to true planes with no projections above those planes.

The face edges shall be pitched to true lines. The cutting of joints for a distance of 12 inches from the face shall be the same as that of the beds.

Joints shall be at right angles with face and beds unless otherwise shown on special plans. The hollows due to plugging must not exceed eight per cent of the surface of the bottom bed nor fifteen per cent of the surface of the top bed of any stone. No plug hole to be more than nine inches across nor more than one inch deep. Hollows due to plugging will not be allowed in limestone.

Joints shall be broken at least 15 inches on the face.

The stones for the coping shall be cut according to special plans to be furnished by the Engineer; all the beds shall be the full size of the stones, and special pains shall be taken with the bearings on the belting course below the coping.

All stones shall be laid in full mortar beds. They shall be lowered on the bed of mortar and be brought to a bearing with a maul, no spawls being allowed. Thin mortar joints will not be insisted on, but the joints shall be properly cleaned on the face to a depth of one inch and a half and pointed in mild weather, the pointing to be driven in with a calking iron. The openings in the backing shall never exceed a maximum of six inches or an average of two inches between adjacent stones; these openings shall be filled with small stones thoroughly bedded and well packed in mortar.

The face stones of every seventh course shall be dowelled into those of the course below with round dowels of one and one eighth inch iron, extending six inches into each course; the dowels shall be placed from eight to twelve inches back from the face and eight inches on each side of every joint. The stones of the upper course shall be drilled through before setting, after which the drill hole shall be extended six inches into the lower course; a small quantity of mortar shall then be put into the hole, the dowel dropped in and driven home and the hole filled with mortar and thoroughly rammed.

The four courses under the coping shall have the joints bonded with cramps of one inch round iron twenty inches long between shoulders, the ends being sunk four inches into each stone.

MORTAR.

The cement used in masonry will be furnished by the Bridge Company, but the contractor will be required to take care of the cement and will be held responsible for any waste. The mixture of mortar and the selection of the cement shall be directed by the Resident Engineer.

The contractor will be required to furnish his own sand, which shall be subject to the approval of the Resident Engineer.

CONDITIONS.

The contractor will be required to furnish all necessary tools and materials of every description whatsoever excepting only cement.

No material shall be measured or paid for which does not form a part of the permanent structure.

No free transportation will be furnished on the lines belonging to the Kansas City, Ft. Scott and Memphis R. R. system. The freight rates for this work will be at the rate of four mills per ton per mile. On other railroads contractors will make their own arrangements for freight.

Approximate estimates will be made monthly as the work proceeds. In these approximate estimates the cost of the freight will be deducted from the contract price on all material not yet delivered at the bridge site.

Stone quarried but not cut shall be estimated at one third the price of finished masonry. Stone quarried and cut shall be estimated at two thirds the price of finished masonry. Payment shall be made on these approximate monthly estimates deducting ten per cent as security for the completion of the work.

TIME.

The contractor must be prepared to begin laying the masonry on Piers II and III by August 1st, 1889, and to lay up at least 5000 yards of the lower portion of these two piers as fast as the foundation work proceeds. He will be held responsible for any delays in sinking these foundations which may be due to his failure to lay four vertical feet of masonry per day whenever required.

The remainder of the masonry shall be completed during the winter and spring of 1890, and the entire masonry shall be finished by July 1st, 1890, unless otherwise ordered.

The right is reserved to suspend the work, and no stone shall be prepared for any portion of the masonry above elevation 229 until special orders to this effect are given by the Chief Engineer.

(Signed) LEWIS M. LOSS.

(Signed) KANSAS CITY AND MEMPHIS RAILWAY AND BRIDGE COMPANY.
By GEO. H. NETTLETON,
President.

APPENDIX L.

SPECIFICATIONS FOR SUPERSTRUCTURE.

I. GENERAL DESCRIPTION.

1. The superstructure is divided into two parts: First, the Continuous Superstructure of the main bridge; Second, the Deck Span at the west end.

2. The Continuous Superstructure will consist of a central span (resting on Piers II and III), 621 feet 0⅜ inches long, from each end of which will project a cantilever arm, 169 feet 4½ inches long; of an anchorage span (from the Anchorage Pier on the Tennessee shore to Pier I), 225 feet 10 inches long, from which will project a cantilever arm precisely like those projecting from the central span; of two intermediate spans 451 feet 8 inches long (one of which will be suspended from the cantilever arms projecting from Piers I and II, and the other will be suspended at the east end from the cantilever arm projecting from Pier III and will rest at the west end on Pier IV), the entire continuous superstructure being 2258 feet 4 inches long, divided into one span of 225 feet 10 inches, one of 790 feet 5 inches and two of 621 feet 0⅜ inches.

3. This Continuous Superstructure will be rigidly fastened to Piers I, III and IV, but will rest on expansion rollers on Pier II. Slip joints will be provided for expansion at the suspended ends of the independent spans.

4. The trusses will be placed 30 feet between centers and will be divided into panels 28 feet 2¾ inches long, the right being reserved to shorten the panels by an amount not exceeding one half inch at any time before the work is actually manufactured.

5. The Deck Span at the west end will be 338 feet 9 inches long from the center of Pier IV to the center of the pin on Pier V, divided into twelve panels of 28 feet 2¾ inches each, the trusses being placed 22 feet between centers. The east end of the span will be carried in niches on the west side of Pier IV; the west end will have roller bearings over the center of Pier V. This span will include a vertical bent which will carry the west end of the west pair of stringers.

6. The estimated approximate weight of the Continuous Superstructure is 13 000 000 pounds; that of the Deck Span 1 000 000 pounds, making the total estimated weight of the superstructure of the bridge proper 14 000 000 pounds.

PLANS.

7. Full detail plans showing all dimensions will be furnished by the engineer. The work shall be built in all respects according to these plans. The contractor, however, will be expected to verify the correctness of the plans and will be required to make any changes in the work which are necessitated by errors in these plans, without extra charge, where such errors could be discovered by an inspection of the plans.

II. MATERIAL.

8. All parts, except nuts, swivels, clevises and wall-pedestal plates, will be of steel. The nuts, swivels and clevises may be of wrought iron, but shall have sufficient strength to break the bodies of the members to which they are attached. The pedestal plates will be of cast iron.

9. All material shall be subject to inspection at all times during its manufacture, and the engineer and his inspectors shall be allowed free access to any works in which any portion of the material is made. Timely notice shall be given to the engineer so that inspectors may be on hand.

STEEL.

10. Steel will be divided into three classes: first, High Grade Steel, which shall be used in all the principal truss members; second, Medium Steel, which shall be used in the floor system, laterals, portals, transverse bracing and the lacing of the truss members; third, Soft Steel, which shall be used only for rivets and at the option of the contractor where wrought iron is permitted.

11. The bolsters which carry the large pin bearings on Piers I, II and III shall be of cast steel.

12. In any case where it seems doubtful what quality of steel is required, High Grade Steel shall be used.

13. Steel may be made by the open hearth or by the Bessemer process, but no steel shall be made at works which have not been in successful operation for at least one year.

14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt certified by a chemist satisfactory to the Chief Engineer.

15. In the finished product of open hearth steel the amount of phosphorus shall not average more than $\frac{8}{100}$ of one per cent and never exceed $\frac{1}{10}$ of one per cent.

16. In the finished product of Bessemer steel, the amount of phosphorus shall not average more than $\frac{4}{100}$ of one per cent and never exceed $\frac{1}{20}$ of one per cent.

17. A sample bar three quarters of an inch in diameter shall be rolled from every melt, the method of obtaining the piece from which this bar is rolled to be the same in all cases, and the amount of work on this sample bar to be as nearly as practicable the same as on the finished product. The first laboratory test shall be made on this sample bar in its natural state without annealing.

18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion.

21. The first laboratory test shall meet the following requirements:

	High grade Steel.	Medium Steel.	Soft Steel.
Maximum Ultimate Strength, pounds per sq. inch....	78 500	72 500	63 000
Minimum " " " " "	71 500	65 500	57 000
" Elastic Limit, " " "	42 000	38 000	32 000
" Percentage of Elongation in 8 inches	20	24	28
" " " Reduction at Fracture	40	45	50

22. The second laboratory test shall meet the following requirements:

	High Grade Steel.	Medium Steel.	Soft Steel.
Maximum Ultimate Strength, pounds per sq. inch....	78 500	72 500	63 000
Minimum " " " " "	69 000	64 000	55 000
" Elastic Limit, " " "	40 000	37 000	30 000
" Percentage of Elongation in 8 inches	18	22	28
" " " Reduction at Fracture	38	44	50

23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

24. Every melt which does not conform with these requirements shall be rejected.

25. A full report of the laboratory tests shall be furnished certified by an inspector accepted by the Chief Engineer.

26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.

27. Three notices of the acceptance of each melt shall be mailed on the day of such acceptance, stating the number of the accepted melt and quality of steel. Two of these notices shall be sent to the Chief Engineer at his Chicago and New York offices respectively and one to the shop inspector at the works.

28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the mill inspector, who will forward them to the Chief Engineer.

29. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office not later than the end of the week succeeding the week in which such tests are made.

30. Three notices of the shipment of manufactured material identifying the melts and dimensions shall be mailed on the day after such shipments are made, in the same manner as the notices of acceptance of material.

31. Every finished piece of steel shall be stamped on one side near the middle of the bar and also on both ends of the bar with a number identifying the melt.

32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

33. The cross sections shall never differ more than two per cent from the ordered cross sections as shown by the dimensions on the plans.

34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

35. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be drilled through the axis.

CAST STEEL.

36. A sample bar $1\frac{1}{4}$ inches in diameter and 16 inches long shall be cast from every melt. This sample bar shall then be turned down to three quarters of an inch in diameter and the laboratory tests made upon it.

37. These laboratory tests shall show an ultimate strength of at least 70 000 pounds, an elastic limit of at least 40 000 lbs., an elongation of at least 15 per cent. in 8 inches and a reduction of 18 per cent. at point of fracture.

38. Steel castings shall be sound and as free as possible from blow holes.

39. If on the finished surface the blow holes cover more than $\frac{1}{10000}$ part of the entire surface, and if any blow hole exceeds one eighth of an inch in diameter, the casting shall be rejected.

CAST IRON.

40. Cast iron shall be the best quality of dark gray charcoal iron of a quality suitable for car wheels, the castings to be entirely sound and free from blow holes.

III. MANUFACTURE.

41. The work shall be done in all respects according to the detail plans furnished by the Chief Engineer.

42. Where there is room for doubt as to the quality of work required by the plans or specifications, the doubt shall be decided by using the best class of work which any interpretation would admit of.

43. All workmanship, whether particularly specified or not, must be of the best kind now in use. Past work done for the same chief engineer will never be recognized as a precedent for the use of other than the best kind of work.

44. Ragged edges or any kind of irregularities or unnecessary roughness will be sufficient ground for rejection.

45. All surfaces in contact shall be cleaned and painted before they are put together.

46. All work shall be finished in the shop and ample time given for inspection.

47. No material shall be loaded on cars until accepted by the inspector.

48. The finishing of work after loading will not be permitted.

SOLID DRILLED WORK.

49. All riveted members which are made of High Grade Steel and all other pieces connecting with such members shall be solid drilled, no punching whatever being allowed, excepting lacing bars which may be punched and reamed.

50. All plates, angles and shapes shall be carefully straightened at the shops before they are put together. Mill straightening will not be considered to meet this requirement.

51. The pieces shall be then assembled and held in position by clamps and bolts.

52. Where bolts passing through the metal are used, the holes shall be drilled in all metal more than three quarters of an inch thick, the diameter of the drilled hole to be at least one eighth of an inch less than the diameter of the finished hole.

53. In metal not more than three quarters of an inch thick punched holes may be used for fitting up, the diameter of the punched hole not to be more than three quarters the diameter of the finished hole, and the number of punched holes never to exceed eight in any one plate or four in one flange of any one angle.

54. After assembling, the work shall be drilled, the rivet holes being carefully spaced in truly straight lines and at the exact distances shown on the plans.

55. After the drilling is completed a special reamer shall be run over both edges of every hole, so as to remove the sharp edges and make a fillet of at least $\frac{1}{16}$ of an inch under each rivet head.

56. The assembled parts shall then be riveted up without taking apart, unless specially directed by the Chief Engineer.

57. In general, all holes which are to pass through several thicknesses of metal shall be drilled with all those pieces of metal assembled in the exact relative position they are to hold in the bridge.

58. In the case of connections between members having four webs, one member may be finished complete with the splice plates riveted on. The two inside webs of the adjoining member, one end being already faced, may then be fitted up separately in their true position and the rivet holes in the splices drilled. These inside webs may then be removed; the member to which they belong shall be assembled, riveted up complete and the ends faced, the facing to agree exactly with the two ends already faced. (See § 67.) The member shall then be fitted to the adjoining member and the rivet holes in the splices connecting the outside webs shall be drilled.

59. The size of rivets shown on the plans is the size of the cold rivet before heating.

60. The diameter of the finished hole shall not be more than $\frac{1}{16}$ of an inch greater than the diameter of the cold rivet. It is intended that the heated rivet shall not drop into the hole, but require a blow from a hammer to force it in. If it is found that rivets will drop easily into the holes, the inspector will condemn those rivets and order a larger size.

61. In all cases where riveting is to be done in the field, the parts so to be riveted shall be fitted together in the shops and the rivet holes drilled while they are so assembled.

62. The riveted connections of the portals, cross frames and floor beams with the posts and chords shall be drilled with the several parts fitted together, excepting in the case of interchangeable floor beams.

63. An iron templet not less than two inches thick may be used instead of the floor beams when drilling the holes in the chords, and the same templet instead of the chords when drilling the holes in the floor beams; a templet may be used in the same manner in drilling the connections between the floor beam and the supported upright at panel points where two inclined members come together; but the connection between the floor beam and the vertical suspenders at panels point L, and L, of the intermediate spans shall be drilled with the parts actually assembled and marked. With this arrangement two floor beams at each end of the intermediate spans, making eight in all, become special; the other floor beams are classed as interchangeable.

64. All rivets shall be driven by power wherever this is possible.

65. All rivets shall be regular in shape, with hemispherical heads concentric with the axis and absolutely tight. Tightening by calking or recupping will not be allowed. This applies to both power driven and hand driven rivets.

66. All pin holes and holes for turned bolts passing through the whole width of a riveted member shall be bored or drilled after all other work is completed.

67. All surfaces in contact shall be carefully faced, the facing to be done after the entire member is assembled and riveted up, except that in the case of chord sections with four webs, the inside webs may have one end faced before they are assembled, these two faced ends to be carefully held against a plane surface when assembled and the corresponding ends of the other two webs to be faced after riveting and to agree with the ends already faced.

68. When two chord pieces are fitted together complete in the shop there shall be no perceptible wind in the length of the two sections. The chords are generally made in two panel lengths, or 56 feet $5\frac{1}{8}$ inches long. In the case of shorter lengths a sufficient number of pieces shall be put together to make a continuous length equal to two of the long sections.

69. All chord sections shall be stamped at each end on the outside with letters and numbers designating the joints in accordance with the diagram plan furnished by the Chief Engineer.

70. The posts shall be fitted together for their entire length and bolted up and when so fitted shall be perfectly straight and free from wind.

71. The same rule shall apply to the marking of the posts as to the marking of the chords.

72. Pin holes shall be bored truly and at exact distances, parallel with one another and at exactly right angles to the axis of the member.

73. Pin holes in the posts shall be truly parallel with one another and shall be at right angles to the axis of the post.

74. Pin holes shall be bored with a sharp tool which will make a clean, smooth cut. Two cuts shall always be taken, the finishing cut never to be more than $\frac{1}{8}$ inch. Roughness in pin holes will be sufficient reason for rejecting a whole member.

75. Measurements shall be made from an iron standard of the same temperature as the member measured.

PUNCHED AND REAMED WORK.

76. All riveted members which are composed entirely of Medium Steel may be punched and reamed, but this does not apply to the connections between such members and High Grade Steel members, which connections shall be solid drilled throughout.

77. All plates, angles and shapes shall be carefully straightened at the shops before they are laid out. Mill straightening will not be held to meet this requirement.

78. The rivet holes shall be marked from templets and these templets shall lie flat without distortion when the marking is made.

79. The angles of stringers must be square and straight. The web plate must not project above the angles and the top surfaces of the top angles must be such that the outside edges are never above a true plane and never more than one-sixteenth of an inch below a true plane coincident with the roots of the angles.

80. The outside angle at the root of the angles connecting the stringers with the floor beams or the floor beams with the posts, chords or other members, shall never be less than a right angle, and the excess over a right angle shall never be greater than $\frac{1}{8}$ of an inch in the longer leg of the angle; the angle shall be perfectly straight.

81. In fitting these angles to stringers or floor beams they shall be so fitted that the exact length is measured to the root of the angle, the two roots being in exactly the same plane; the entire end of the assembled member shall then be faced. The effect of these requirements will be to prevent any reduction of area of the angle at the root by facing and to secure a true surface of the whole width of the connection which will require no strain in the rivets to draw the parts together.

82. After laying out with templets, the rivet holes may be punched with a punch at least $\frac{3}{32}$ of an inch smaller than the diameter of the rivets as given on the plans and working in a die only $\frac{1}{64}$ of an inch larger than the punch.

83. The several parts of the member shall then be assembled and the holes reamed so that at least $\frac{1}{16}$ of an inch of metal is everywhere taken out.

84. After the reaming is completed a special reamer shall be run over both edges of every hole so as to remove the sharp edges and make a fillet of at least $\frac{1}{16}$ of an inch under each rivet head.

85. The pieces shall be riveted together without taking apart.

86. All requirements as to size and quality of rivets and manner of riveting and measuring shall be the same as the requirements for Solid Drilled riveted work.

87. All bearing surfaces shall be truly faced.

88. All sheared edges shall be planed off and all punched holes shall be drilled out so that none of the rough surface is ever left upon the work.

FORGED WORK.

89. The heads of eye bars shall be formed by upsetting and forging into shape by a process acceptable to the Chief Engineer. No welds will be allowed.

90. After the working is completed the bars shall be annealed in a suitable annealing furnace by heating them to a uniform dark red heat and allowing them to cool slowly.

91. The form of the heads of the steel eye bars may be modified by the contractors to suit the process in use at their works, but the thickness of the head shall not be more than $\frac{1}{16}$ inch greater than that of the body of the bar, and the heads shall be of sufficient strength to break the body of the bar.

92. The heads and the enlarged ends for screws in laterals, suspenders and counters shall be formed by upsetting and shall be of sufficient strength to break the body of the bar.

93. Nuts, swivels and clevises, if made of steel, shall be forged without welds; whether made of steel or wrought iron, one of each size shall be tested and be of sufficient strength to break the bars to which they are attached.

94. Eye bars shall be bored truly and at exact distances, the pin holes to be exactly on the axis of the bar, and at exactly right angles to the plane of the flat surfaces.

95. When six bars of the same billed length are piled together the two pins shall pass through both pin holes at the same time without driving. Every bar shall be tested for this requirement.

96. Pin holes shall be bored with a sharp tool that will make a clean smooth cut. Two cuts shall always be taken, the finishing cut never to be more than $\frac{1}{8}$ inch. Roughness in pin holes will be sufficient reason for rejecting bars.

97. Twenty full-sized steel eye bars shall be selected from time to time from the bars made for the bridge, by the inspector for testing.

98. No bars known to be defective in any way shall be taken for test bars, but the bars shall be selected as fair average specimens of the good bars which would be accepted for the work.

MACHINE WORK.

99. All bearing surfaces shall be faced truly.

100. Chord sections and half-post sections shall be faced after they are riveted up complete, the facing to be perfectly true and square. In the case of four web chords, one end of the two inside webs only may be faced before riveting up.

101. The ends of the stringers and of floor beams shall be squared in a facer.

102. All surfaces so designated on the plans shall be planed.

103. All sheared edges shall be planed off, and all punched holes shall be drilled or reamed out.

104. All pins shall be accurately turned to a gauge, and shall be of full size throughout.

105. Pin holes shall be bored to fit the pins with a play not exceeding $\frac{1}{50}$ of an inch. These requirements apply to lateral connections as well as to any other pins.

106. The plans show the distances between centers of pin holes. Shop measurements, however, shall be made between the bearing edges of the pin holes, that is, between the inside edges of compression members and the outside edges of tension members, with a proper allowance for the diameter of the pin. An iron standard of the same temperature as the piece measured shall always be used.

107. All screws shall have a truncated V thread, United States standard sizes.

108. Special pains shall be taken with the roller bearings on Pier II. The castings shall be accurately fitted together and when bolted up, the top surface shall be a perfectly true plane.

109. The rail plates shall be planed on the bottom after being riveted up, then planed on the top and the surface polished. Any roughness or irregularity which prevents an uniform opening between the rail heads shall be planed out.

110. The rollers shall have the hollow sides planed and the bearing surfaces turned to a perfectly true cylinder and polished

111. The rods passing through the rollers shall fit the holes with a play not exceeding $\frac{1}{32}$ of an inch.

112. The side bars connecting the rods shall be drilled to fit the rods with a play not exceeding $\frac{1}{32}$ of an inch, and the upper and lower surfaces of these side bars shall be planed.

113. The lower side bar in each instance shall be fitted with a graduated bronze scale, so divided as to register inches of motion of the top bearing, and the upper bar shall be fitted with a German silver vernier, so divided as to read to sixteenths of inches as graduated on the scale.

114. The two bearings, including everything between the masonry and the fourteen inch pin, shall be set up complete in a level position at the Athens shops and shall not be shipped before they have been examined and approved by the Chief Engineer. They shall be ready for his inspection on or before January 1, 1891.

115. Special pains shall be taken with the slip joints at the suspended ends of the intermediate spans; the surface of the joints shall be polished and fitted exactly.

MISCELLANEOUS.

116. All material shall be cleaned, and, if necessary, scraped and given one heavy coat of Cleveland iron-clad paint, purple brand, put on with boiled linseed oil, before shipment. This applies to everything except machine finished surfaces.

117. The same paint shall be used wherever painting is required.

118. All machine surfaces shall be cleaned, oiled and given a heavy coat of white lead and tallow before shipment. The inspector must see that this is a substantial coat, such as is used on machinery, and not a merely nominal covering.

119. All small bolts, all pins less than six inches in diameter, the expansion rollers and everything with special work on it, shall be carefully boxed before shipment.

120. The contractor will be required to furnish the field rivets for erection, furnishing 20 per cent. in excess of each size over and above the number actually required, but this excess will not be estimated, but considered as taking the place of the work which is not done on these rivets.

IV. INSPECTION.

121. The mill inspection shall be performed at the expense of the contractor, by an inspector accepted by the Chief Engineer.

122. This inspector will be required to furnish the certificates and notices in the manner specified above.

123. The mill inspector shall from time to time check the manufacturers' analyses by analyses made by an independent chemist.

124. The acceptance of material by such inspector will not be considered final, but the right is reserved to reject material which may prove defective or objectionable at any time before the completion of the contract.

125. The inspection at the shops will be under the charge of an inspector appointed by the Chief Engineer, with such assistants as may be required.

126. Such inspector will be considered at all times the representative of the Chief Engineer, and his instructions shall be followed in the same manner as if given by the Chief Engineer.

TESTS OF FULL SIZED BARS.

127. The tests of full-sized eye bars shall be made in the large testing machine at Athens.

128. These bars will be required to develop an average stretch of twelve per cent. and a minimum stretch of ten per cent. before breaking. The elongation shall be measured on a length of not less than twenty feet, including the fracture.

129. The bars will be required to break in the body.

130. They shall also show an elastic limit of not less than 32 000 lbs. and an ultimate strength of not less than 62 000 lbs., as indicated by the registering gauges of the testing machine at Athens.

131. In the case of bars too long for the machine, the bars shall be cut in two, each half reheaded, and both halves tested in the machine, the two tests, however, to count as a single test bar.

132. If the capacity of the machine (estimated at 1 200 000 lbs.) is reached before the bar is broken, the bar shall be taken out of the machine and the edges shall be planed off for a length of 10 feet at the center until the section is reduced to the equivalent of 16 square inches of section of the original bar. The bar shall then be placed in the machine and broken; when this is done the elongation shall be measured on a length of eight feet and an ultimate strength of 60 000 lbs. computed on the 16 inches of original section will be considered satisfactory.

133. In these tests, a failure to meet the required elongation will be considered fatal and be a sufficient cause for condemning the bars represented by the bars so tested, but the Chief Engineer shall examine carefully into the cause of the breakage of any bar which does not meet the requirements and may order additional tests if he sees fit.

134. The failure of a bar to break in the body shall not be considered sufficient reason for rejection, provided the required elongation is obtained and not more than one quarter of the bars break in the head.

135. In all requirements and tests the qualities given are minimum or maximum requirements and not averages unless expressly so stated.

V. TERMS.

136. The work will be paid by the pound of finished work loaded on cars at Buffalo.

137. On riveted work and other material shipped from Athens, the difference between the freight rates from Athens to Memphis and from Buffalo to Memphis will be borne by the contractor.

138. No material will be paid for which does not form a part of the finished superstructure.

139. All expenses of testing shall be borne by the contractor.

140. All riveted work shall be manufactured at the Athens shop, unless by special permission of the Chief Engineer.

141. Prices will be per pound at separate rates for High Grade Steel and for Medium Steel.

142. To avoid complications, all members the principal parts of which are High Grade Steel shall be estimated as wholly of High Grade Steel, and all members the principal parts of which are of Medium Steel shall be estimated as wholly of Medium Steel.

143. Cast Steel shall be estimated as High Grade Steel.

144. Cast and wrought iron shall be estimated at the same price as Medium Steel.

145. The anchorage span, the east cantilever arm and one half the east intermediate span shall be completed and shipped on or before October 1st, 1890.

146. The Deck Span shall be completed and shipped on or before December 1st, 1890.

147. The central span and the two adjoining cantilever arms shall be shipped complete on or before June 1, 1891.

148. The west intermediate span and the second half of the east intermediate span shall be shipped complete on or before August 1st, 1891.

149. Approximate estimates shall be made at the end of each month of the material received and work performed up to that time.

150. In these estimates material received at the shops but not manufactured shall be estimated at 65 per cent of the contract price for finished material.

151. Material manufactured but not shipped shall be estimated at 85 per cent of the contract price.

152. Material completed and shipped shall be estimated at the full contract price.

153. Payments shall be made on these estimates on or about the middle of the following month, deducting therefrom 10 per cent., which shall be held as security until the completion of the entire contract.

154. In these monthly estimates no material will be estimated as received at the shop more than six months before the date set for the completion and shipment of such material.

155. In these monthly estimates no material will be estimated as manufactured more than four months before the date set for the completion and shipment of such material.

156. The contractors will be required to keep the material at their shops insured from injury by fire to the full amount of the payments made on such material by the Bridge Company.

VI. ERECTION.

157. The contractor will be expected to receive all material as it arrives on the cars, to unload this material and store it in a material yard until ready for erection.

158. He will be held responsible for the custody and care of all superstructure material after its arrival.

159. The material of the main Continuous Superstructure will be delivered on cars on the east side of the river.

160. When ready for erection, the Bridge Company will switch any cars on which this material has been loaded, to a point where it can be transferred to barges, no charge being made for such switching.

161. All material for the Deck Span at the west end will be delivered on cars on the west side of the river.

162. A track will be laid to a convenient position for unloading material, near Pier V, and no switching will be done after the material has once been unloaded.

163. The contractor will be required to keep all the material in good condition, and in case of its becoming dirty or rusty, will be expected to clean it before erecting.

164. The contractor will be required to paint all surfaces which will be inaccessible for painting after erection, the paint being furnished by the Bridge Company.

165. The contractor will be required to furnish all tools, barges and false work of every description, excepting power riveters.

166. The contractor will be required to remove all work which he may put in the river so that there will be nothing left either to interfere with navigation or to catch drift.

167. No holes shall be drilled or bolts placed in the piers without the express permission of the engineer.

168. All bolts so put in shall be removed and the holes carefully filled with Portland cement mortar, and any damages done shall be charged to the contractor.

169. The contractor will be required to erect the superstructure complete in every respect including riveting.

170. Everything is to be completed ready to receive the timber floor.

171. The erection shall include the placing and riveting of the iron hand rail.

172. The contractor will be expected to raise the ties for the central span and the adjoining cantilever arms and distribute them without charge. This does not include any framing, fitting or bolting. The ties will be delivered to the contractor loaded on barges.

173. The central span will be raised on false work.

174. The west intermediate span will be raised on false work.

175. The east intermediate span may be raised on false work, or without, at the option of the contractor.

176. The anchorage arm east of Pier I will be raised on false work.

177. The three projecting cantilever arms will be built out without false work.

178. It is expected that the anchorage arm and the cantilever arms projecting from Pier I can be raised in the fall of 1890. That the deck span at the west end can be raised in the following winter. That the false work for the central span can be put in in August and September of 1891, and the erection of this span completed in the following month. That the cantilevers can be built out and the entire bridge completed by January 1, 1892.

179. All erection shall be done under the direction of the Chief Engineer and in conformity with his requirements.

180. The wall-plate castings shall be set on Piers II and III before the bottom chord is placed.

181. The expansion rollers and the bolster complete shall be set on Pier III. The bottom chords shall then be put together and riveted up complete. The expansion end shall then be adjusted so that the axis of the rollers will be exactly vertical at a temperature of 70 degrees Fahrenheit. This adjustment shall be made at a time when there has been no sun on the steel work for ten continuous hours, and when there has been no sudden change of temperature. The span shall be erected complete and the end rollers shall be examined again, and if any error is found, shall be corrected, the correction being made under the same conditions as to sunshine and sudden changes of temperature as the original adjustment. Special care shall be taken with the rollers while the span is being swung, and if by any accident they get out of place, the span shall be wedged again and the rollers be readjusted.

182. The eye bars in the end panel of the top chord shall be stiffened so as to resist compression by fitting planks between the bars and bolting the whole together.

183. When the erection of the central span is completed, the two cantilever arms shall be built out and the two intermediate spans erected, thus completing the bridge.

184. All rivets shall be regular in shape with hemispherical heads concentric with the axis and absolutely tight. Tightening by calking or recupping will not be allowed.

185. All riveted joints which have to resist tension, this including all joints in both chords of the central span and all joints in the bottom chord of the intermediate spans, shall be riveted by power, except in such special cases as the engineer may authorize hand-driven rivets. This authority will never be given for rivets in splices of web plates.

186. A power riveter, with air pump or with hydraulic pump and accumulator, will be furnished by the Bridge Company. The contractor will be required to keep the same in repair and will not be relieved from any responsibility in this connection, the Bridge Company only agreeing to bear the cost of the machine.

187. No extra bills are to be rendered by the contractor, except for new work not embraced in the contract. Charges for reaming holes, fitting bolts in place of rivets and other small work of this class will not be allowed.

188. The setting of the wall plate castings, including the drilling of holes in masonry for the anchor bolts, the packing of rust cement or lead under the castings and all other work connected therewith, is to be done by the contractor.

189. The contractor will be responsible for any damages which the Bridge Company may be held liable for in consequence of any of his work.

GEO. S. MORISON,
Chief Engineer.

January 4th, 1890.

APPENDIX M.

SUPPLEMENTARY SPECIFIACTIONS, MAY 6, 1890.

MODIFICATIONS OF SPECIFICATIONS FOR SUPERSTRUCTURE OF BRIDGE ACROSS THE MISSISSIPPI RIVER, AT MEMPHIS, TENN., ACCEPTED APRIL 22d, 1890.

STEEL.

10. Steel will be divided into three classes: first, High Grade Steel, which shall be used in all the principal truss members; second, Medium Steel, which shall be used in the floor system, laterals, portals, transverse bracing and the lacing of the truss members; third, Soft Steel, which shall be used only for rivets, and at the option of the contractor where wrought iron is permitted.

11. The bolsters which carry the large pin bearings on Piers I, II and III, shall be of cast steel.

12. In any case where it seems doubtful what quality of steel is required High Grade Steel shall be used.

13. Steel shall be made by the open hearth process, but no steel shall be made at works which have not been in successful operation for at least one year.

14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt, certified by a chemist satisfactory to the Chief Engineer.

15. In the finished product of acid open hearth steel the amount of phosphorus shall not average more than $\frac{8}{100}$ of one per cent and never exceed $\frac{1}{10}$ of one per cent.

16. In the finished product of basic open hearth steel the amount of phosphorus shall not average more than $\frac{6}{100}$ of one per cent and never exceed $\frac{7}{100}$ of one per cent.

17. A sample bar three-quarters of an inch in diameter shall be rolled from a four-inch ingot cast from every melt. The first laboratory test shall be made on this sample bar in its natural state without annealing.

18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion. Two successful tests out of a total of three will be accepted as satisfactory.

21. The first laboratory test shall meet the following requirements:

	High Grade and Medium Steel.	Soft Steel.
Minimum Ultimate Strength, pounds per square inch	65 000	57 000
Minimum Elastic Limit, pounds per square inch	38 000	32 000
Minimum Percentage of Elongation in 8 inches	20	28
Minimum Percentage of Reduction at Fracture	40	50

22. The second laboratory test shall meet the following requirements:

	High Grade Steel.	Medium Steel.	Soft Steel.
Maximum Ultimate Strength, pounds per square inch	78 500	72 500	63 000
Minimum Ultimate Strength, pounds per square inch	69 000	64 000	55 000
Minimum Elastic Limit, pounds per square inch	40 000	37 000	30 000
Minimum Percentage of Elongation in 8 inches	18	22	28
Minimum Percentage of Reduction at Fracture	38	44	50

23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

24. Every melt which does not conform with these requirements shall be rejected. Cases in which the tests are thought not to give fair representations of the character of the material shall be referred to the Chief Engineer.

25. A full report of the laboratory tests shall be furnished, certified by an inspector accepted by the Chief Engineer.

26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.

27. Three notices of the acceptance of each melt shall be mailed on the day of such acceptance, stating the number of the accepted melt and quality of steel. Two of these notices shall be sent to the Chief Engineer at his Chicago and New York offices respectively and one to the Shop Inspector at the works.

28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the Mill Inspector, who will forward them to the Chief Engineer. The phosphorus and carbon analyses shall always be made. Analyses for silicon and manganese shall be made whenever called for by the Inspector. Copies of all analyses, whether made by request of the Inspector or by the desire of the manufacturer, shall be furnished to the Chief Engineer.

29. Weekly reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office not later than the end of the week succeeding the week in which such tests are made.

30. Three notices of the shipment of manufactured material, identifying the melts and dimensions shall be mailed on the day after such shipments are made, in the same manner as the notices of acceptance of material.

31. Every finished piece of steel shall be stamped on one side near the middle of the bar and also on both ends of the bar, with a number identifying the melt. If it is found impossible to stamp any particular piece on the ends, the Inspector may authorize the two end stamps to be put on the surface, within one-half inch of each end, the fact of the stamping being done in this way to be specified distinctly on all notices and invoices; this may be done, however, by an agreed character.

32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

33. The cross sections shall never differ more than two per cent. from the ordered cross sections as shown by the dimensions on the plans.

34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

35. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes.

GEO. S. MORISON,
Chief Engineer.

May 6th, 1890.

APPENDIX N.

SUPPLEMENTARY SPECIFICATIONS, JANUARY 1. 1891.

MODIFICATIONS OF SPECIFICATIONS FOR SUPERSTRUCTURE OF BRIDGE ACROSS THE MISSISSIPPI RIVER AT MEMPHIS, TENN., ACCEPTED DECEMBER 29TH, 1890.

STEEL.

10. Steel will be divided into four classes: first, High Grade Steel, which shall be used in all the principal truss members except eye bars; second, Eye-bar Steel, which shall be used only in eye bars; third, Medium Steel, which shall be used in the floor system, laterals, portals, traverse bracing and the lacing of the truss members; fourth, Soft Steel, which shall be used only for rivets, and at the option of the contractor where wrought iron is permitted.

11. The bolsters which carry the large pin bearings on Piers I, II and III shall be of cast steel.

12. In any case where it seems doubtful what quality of steel is required, High Grade Steel shall be used.

13. Steel shall be made by the open-hearth process, but no steel shall be made at works which have not been in successful operation for at least one year.

14. All steel shall be made from uniform stock low in phosphorus, and the manufacturer shall furnish reports of the analysis of every melt, certified by a chemist satisfactory to the Chief Engineer.

15. In the finished product of acid open-hearth steel the amount of phosphorus shall not average more than $\frac{8}{100}$ of one per cent. and never exceed $\frac{1}{10}$ of one per cent.

16. In the finished product of basic open-hearth steel the amount of phosphorus shall not average more than $\frac{6}{100}$ of one per cent. and never exceed $\frac{7}{100}$ of one per cent.

17. A sample bar three-quarters of an inch in diameter shall be rolled from a four-inch ingot cast from every melt. A laboratory test shall be made on this sample bar in its natural state without annealing, but this test may be made subsequent to the acceptance of the material and shall be for record only.

18. A second sample bar having a cross section of one square inch shall be cut from the finished product of every melt. The second laboratory test shall be made on this sample bar in its natural state without annealing.

19. In the laboratory tests all observations as to elastic limit, ultimate strength, elongation and reduction shall be made on a length of eight inches.

20. A piece of each sample bar shall be bent 180 degrees and closed up against itself without showing any crack or flaw on the outside of the bent portion. Two successful tests out of a total of three will be accepted as satisfactory.

21. The first laboratory test shall meet the following requirements:

	High Grade Eye Bar and Medium Steel.	Soft Steel
Minimum Ultimate Strength, pounds per square inch	65 000	57 000
Minimum Elastic Limit, pounds per square inch	38 000	32 000
Minimum Percentage of Elongation in 8 inches	20	28
Minimum Percentage of Reduction at Fracture	40	50

22. The second laboratory test shall meet the following requirements:

	High Grade Steel.	Eye-bar Steel.	Medium Steel.	Soft Steel
Maximum Ultimate Strength, pounds per square inch.	78 500	75 000	72 500	63 000
Minimum Ultimate Strength, pounds per square inch.	69 000	66 000	64 000	55 000
Minimum Elastic Limit, pounds per square inch	40 000	38 000	37 000	30 000
Minimum Percentage of Elongation in 8 inches	18	20	22	28
Minimum Percentage of Reduction at Fracture.	38	40	44	50

23. If the ultimate strength comes within five hundred pounds of the maximum or minimum limit, a second test will be made, and both tests will be required to come within the limits.

24. Every melt which does not conform with these requirements shall be rejected. Cases in which the tests are thought not to give fair representations of the character of the material shall be referred to the Chief Engineer.

25. A full report of the laboratory tests shall be furnished, certified by an inspector accepted by the Chief Engineer.

26. The broken and bent specimens shall be preserved subject to the orders of the Chief Engineer.

27. Notices shall be sent in duplicate to the Chief Engineer at his Chicago office and to the Shop Inspector at the works.

28. Analyses shall be made by the manufacturer of every melt, showing amount of phosphorus, carbon, silicon and manganese, and certified copies of these analyses shall be furnished to the Mill Inspector, who will forward them to the Chief Engineer. The phosphorus and carbon analyses shall always be made. Analyses for silicon and manganese shall be made whenever called for by the Inspector. Copies of all analyses, whether made by request of the Inspector or by the desire of the manufacturer, shall be furnished to the Chief Engineer.

29. Duplicate reports in full detail, including reports of chemical analyses, shall be sent to the Chief Engineer at his Chicago office, and also to the shop Inspector at the works, not later than the day on which the accepted material is shipped.

30. Two notices of shipment of manufactured material, identifying the melts and dimensions, shall be mailed on the day after such shipments are made, one to be sent to the Chief Engineer at his Chicago office, and one to the Shop Inspector at the works.

31. Every finished plate, bar or angle shall be stamped on one side near the middle with a number identifying the melt, and this stamp shall be surrounded by a heavy circle of white paint. Steel for pins shall have the melt numbers stamped on the ends. Rivet and lacing steel and small pieces for pin plates and stiffeners may be shipped in bundles securely wired together with the melt number on a metal tag attached.

32. The finished product shall be perfect in all parts and free from irregularities and surface imperfections of all kinds.

33. The cross sections shall never differ more than two per cent from the ordered cross sections as shown by the dimensions on the plans.

34. All sheared edges shall be planed off so that no rough or sheared surface shall ever be left on the metal.

35. Steel for pins more than four inches in diameter shall be hammered steel, and tests shall be made on this steel in accordance with the requirements of Section 22. In such tests an elongation of fifteen per cent. and a reduction of area of thirty per cent, given in each of two test bars tested separately, will be accepted as satisfactory, provided the character of the fracture is satisfactory. The bending test required in Section 20 shall be made on pin steel, but pin steel will not be rejected, provided the bar will bend around a circle of a diameter equal to twice the thickness of the bar without cracking. Steel for pins shall be sound and entirely free from piping. All pins in the main trusses shall be annealed before they are turned and shall be drilled through the axes.

GEO. S. MORISON,
Chief Engineer

January 1, 1891.

APPENDIX O.

TESTS OF STEEL EYE BARS.

Remarks.	Span.	Tests on Full-size Eye Bars: Dimensions, Inches: Original: Nominal: Width.	Nominal: Thickness.	Actual: Length C. to C.	Actual: Gauged Length.	Actual: Width.	Actual: Thickness.	After Test: Width.	After Test: Thickness.	Results of Mechanical Tests: Reduction of Area, Per cent.	Elongation: Inches.	Elongation: Per cent.	Elastic Limit, Lbs. per sq. in.	Max. Load, Lbs. per sq. in.	Place of Fracture.	Tests on Sample Bars from Same Melts: Melt Number.	Areas: Original, Inches	Areas: After Testing, Inches.	Reduction, Per cent	Elongation, Per cent.	Elastic Limit, Lbs per sq. in.	Max Load, Lbs. per sq. in.	Phosphorus, Per cent.	Kind of Steel.	Made by	Forged by
	Experimental.	10	1½	160.63	120	10.07	1.50	8.00	1.14	39.6	20.2	16.8	35 100	67 490	Body	6 552	.9500	.4994	47.5	27.5	41 580	73 050	.027	Basic open-hearth	Carnegie, Phipps & Co	Union Bridge Co.
Flaw in bark of eye		10	1½	158.07	120	10.16	1.46	......	......	......	10.75	8.96	30 030	65 190	Head	6 552										
High steel.		10	1¾	353.93	324	9.95	1.73	7.86	1.32	39.7	26.6	8.2	37 680	70 160	Body	10 747	.9918	.4593	52.6	24.4	42 650	75 620	.015	" " "	" " "	" " "
		10	1¾	361.23	312	9.98	1.75	7.77	1.25	44.4	36.8	11.8	39 700	65 500	"	10 647	.9520	.4957	47.9	28.8	40 280	70 280	.062	" " "	" " "	" " "
	Anchorage.	10	1½	162.38	120	10.05	1.50	8.06	1.15	38.5	38.5	17.3	33 140	65 060	Body	6 552	.9500	.4992	47.5	27.5	41 580	73 050	.027	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.
		6	1⅛	291.26	252	6.08	1.13	4.62	0.64	56.9	33.7	13.4	29 690	56 700	"	10 830	.9750	.5330	45.4	28.1	40 490	69 700	.026	" " "	" " "	" " "
		6	1⅛	314.18	288	6.09	1.12	4.83	0.82	41.9	39.6	13.8	30 800	59 210	"	10 830										
		10	$1\frac{11}{16}$	287.37	240	10.07	1.67	8.07	1.25	40.0	32.5	13.5	32 860	65 600	"	09 099	1.1590	.6474	44.5	20.0	43 750	75 000	.021	" " "	" " "	" " "
		10	$1\frac{15}{16}$	284.28	240	9.92	1.95	7 97	1.47	39.4	36.8	15.3	31 110	61 060	"	5 798	1.0140	.5814	42.7	28.8	42 210	69 730	.046	" " "	" " "	" " "
		10	1	287.88	240	9.94	0.99	8.05	0.80	34 6	32.9	13.7	33 990	63 220	"	10 886	.9808	.4719	52.2	28.1	40 230	69 720	.025	" " "	" " "	" " "
Bar cut in two, reheaded, not reannealed. First half: stretched to full capacity of machine, then planed to a section equivalent to 16 sq. in. original.		10	$2\frac{3}{16}$	222 88	96	10.05	2.20	6.09	1.77	32.6	13.0	13.5	29 330	63 100	"	015 014	.9635	.4983	48.3	28.8	38 090	71 300	.017	" " "	" " "	" " "
Second half treated same as above.		10	$2\frac{3}{16}$	222.48	96	10.05	2.18	5.75	1.63	41.4	14.6	15.2	28 660	63 860	"	015 014										
Piping in fracture		10	1⅞	464.03	420	10.12	1.86	9.99	1.80	4.5	10.4	2.5	31 970	53 860	"	015 090	1.0201	.6084	40.4	27.0	40 200	71 860	.017	" " "	" " "	" " "
Retest of above. Reheaded, not reannealed. Broke in new head. Elongation is total for both tests.		10	1⅞	198.03	144	......	......	......	......	......	4.7	3.2	......	58 950	Head	015 090										
Soft steel suspender.		7	$1\frac{3}{16}$	314.04	270	7.12	1.17	5.14	0.77	52.5	59.3	21.5	30 270	51 500	Body	11 045	1.0180	.4941	51.5	28.8	33 400	57 170	.014	" " "	" " "	Keystone " "
Foreign substance in fracture.	Central.	10	$2\frac{3}{16}$	338.73	300	10.07	2.20	9.73	2.11	7.3	20.8	6.9	28 030	55 160	Body	11 063	1.1220	.6371	43.2	24.2	38 320	70 220	.023	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.
Retest of above. Reheaded, not reannealed, planed to equivalent of 16 sq. in. original area.		10	$2\frac{3}{16}$	......	96	......	......	5.83	1.70	37.5	18.4	19.2	......	62 590	"	11 063										
First half of bar cut in two; reheaded, not reannealed.		10	$1\frac{13}{16}$	251.58	204	10.03	1.81	8.08	1.39	38.1	28.9	14.1	29 670	62 140	"	015 094	1.0200	.4121	59.6	26.3	40 200	71 080	.028	" " "	" " "	" " "
Second half of above.		10	$1\frac{13}{16}$	250.08	204	10.05	1.81	......	......	......	5.7	2.8	29 270	49 340	Head	015 094										
Above reheaded, not reannealed.		10	$1\frac{13}{16}$	194.88	144	......	......	......	......	......	5.2	3.6	......	53 930	"	015 094										
First half.		10	1⅜	250.28	204	9.97	1.37	8 39	1.11	31.8	24.0	11.8	32 700	65 400	Body	015 093	1.0670	.6374	40.3	25.0	39 300	69 360	.041	" " "	" " "	" " "
Second half of above. One head buckled; rebored, and then test finished.		10	1⅜	247.78	204	9 99	1.37	8 15	1.07	36.3	23.0	11.3	31 290	64 510	"	015 093										
Soft steel suspender.		7	$1\frac{5}{16}$	385.73	348	7.02	1.31	5.16	0.92	48.4	78.3	22.5	28 980	52 010	"	8 303	1.1700	.5133	34.2	31.3	34 190	58 460	.039	" " "	" " "	Keystone " "
	Cantilever.	7	1¼	335.78	348	7.01	1.26	5.13	0.83	51.8	47.3	13.6	28 410	54 740	Body	6 901	1.0170	.5220	48.7	28.1	41 400	67 840	.010	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.
First half.		10	1⅝	249.98	204	9.99	1.62	7.49	1.11	48.6	39.4	19.3	30 500	58 870	"	40 411	.9338	.5572	40.3	25.0	40 910	70360	.014	" " "	" " "	" " "
Second half. Spot of foreign matter in fracture.		10	1⅝	250.23	204	10.02	1.63	9.49	1.53	11.1	19.6	9.6	29 980	56 950	"	40 411										
Bar strained to 59 30 lbs. per sq. in., then planed to equivalent of 16 sq. in. original section. Area 1 foot from fracture, reduced 12 per cent.		10	$2\frac{1}{16}$	341.28	96	9.96	2.05	7.52	1.91	10.3	11.8	12.3	33 300	73 550	"	5 868	.9700	.4792	51.5	25.5	40 410	69 900	.063	" " "	" " "	" " "
Bar cut in two, first half.		10	$1\frac{5}{16}$	249.48	204	10.13	1.30	7.92	0.92	44.6	32.0	15.7	32 520	60 710	"	40 435	.9504	.5363	43.6	27.0	40 400	70 490	.023	" " "	" " "	" " "
Second part of above.		10	$1\frac{5}{16}$	249 58	204	10.13	1.30	7.77	0.94	44.6	35.3	17.3	31 900	59 470	"	40 435										
		10	$1\frac{13}{16}$	284.82	240	9.98	1.81	7.62	1.28	40.0	35.8	14.9	28 000	58 720	"	013 091	1.0000	.5557	44.4	29.5	40 000	66 800	.008	" " "	" " "	" " "
First part.		10	$1\frac{13}{16}$	221.98	180	10.15	1.83	8 06	1.34	41.8	23.5	13.1	32 290	62 270	"	40 409	.9746	.5574	42 8	21.3	40 530	72 240	.056	" " "	" " "	" " "
Second part.		10	$1\frac{13}{16}$	221.98	180	10.13	1.81	......	......	......	11.1	6.2	31 910	58 050	Head	40 409										
Retest of above, reheaded, not reannealed.		10	$1\frac{13}{16}$	172.43	120	10.13	1.81	8.43	1.38	36.6	15.7	13.1	......	65 170	Body	40 409										
		10	1	361.68	312	10.04	0.99	8.22	0.71	41.2	47.1	15.1	29 970	58 680	"	40 414	1.1720	.6371	45.7	27.0	40 610	70 480	.060	" " "	" " "	" " "

APPENDIX O.—CONTINUED.

TESTS OF STEEL EYE BARS.

REMARKS.	SPAN	Tests on full-size eye bars. Dimensions, Inches. Original. Nominal. Width.	Nominal. Thickness.	Actual. Length C. to C.	Actual. Gauged Length.	Actual. Width	Actual. Thickness.	After Test. Width.	After Test. Thickness.	Results of Mechanical Tests. Reduction of Area, Per cent.	Elongation Inches.	Elongation Per cent	Elastic Limit, Lbs. per sq. in.	Max. Load, Lbs. per sq. in.	Place of Fracture	Tests on sample bars from same melts. Melt Number.	Areas. Original, Inches.	Areas. After Testing, Inches.	Reduction, Per cent.	Elongation, Per cent.	Elastic Limit, Lbs. per sq. in.	Max Load, Lbs. per sq. in.	Phosphorus, Per cent	Kind of Steel	Made by	Forged by
	East Intermediate.	7	1¼	258.68	228	7.01	1.27	5.31	0.90	46.3	38.2	16.8	28 640	56 830	Body	11 072	1.0200	.5402	47.0	28.1	40 790	68 730	.030	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.
High steel. After test, bar cut in two, reheated, not reannealed, test completed as below.		8	1¾	478.88	432	8.03	1.75	....	....	....	52.7	12.2	32 220	61 260	Not broken	10 770	1.0020	.6013	40.0	28.1	40 920	76 150	.042	" " "	" " "	" " "
First half above. Broke in unannealed end near heat line of new head.		8	1¾	236.28	168	8.03	1.75	0.22	1.18	47.8	22.1	13.2	....	54 720	Body	10 770										
Second half. Broke like above. Area between fracture and new head reduced 24.1 per cent.		8	1¾	240.28	180	8.03	1.75	7.44	1.60	15.3	20.1	11.2	....	57 190	"	10 770										
After test. Bar cut in two, reheaded, not reannealed, retested as below.		8	1¼	478.88	432	8.00	1.26	....	....	....	51.7	12.0	32 380	62 930	Not broken	10 770										
First part of above		8	1¼	236.99	156	8.00	1.26	6.29	0.94	41.37	25.8	16.5	....	68 590	Body	10 770										
Second part of above. Broke in unannealed part of bar on heat line of new head.		8	1¼	238.18	168	8.00	1.26	0.41	0.85	45.9	18.2	10.8	....	58 880	"	10 770										
		8	1 3/16	254.63	216	7.98	1.20	6.14	0.92	41.0	33.2	15.4	31 930	63 870	"	10 828	1.0100	.4108	59.3	21.9	40 900	69 800	.024	" " "	" " "	" " "
		8	2 5/16	338.58	300	8.03	2.32	6.34	1.77	39.8	34.6	11.5	32 840	62 400	"	10 660	1.0620	.5946	44.0	23.1	41 710	71 000	.066	" " "	" " "	" " "
Soft steel suspender.	West Intermediate.	7	1 3/16	258.68	216	7.00	1.18	5.27	0.85	45.8	36.8	17.0	27 870	53 520	Body	20 816	1.0560	.4995	52.7	31.9	32 480	58 050	.027	Basic open-hearth	Carnegie, Phipps & Co.	Pencoyd B. & C. Co.
" " Full capacity of machine reached.		9	2 5/16	338.58	300	9.00	2.31	....	....	10.5	35.3	11.8	27 730	54 400	Not broken	09 257	1.0900	.5416	50.3	29.5	39 900	66 780	.013	" " "	" " "	Keystone Bridge Co.
" " First part.		9	1¼	206.58	168	9.09	1.25	6.81	0.83	50.3	39.1	23.3	32 590	57 410	Body	09 405	.9734	.4488	53.8	28.7	38 110	60 920	.014	" " "	" " "	" " "
" " Second part.		9	1¼	205.38	168	9.09	1.25	6.94	0.94	42.6	34.8	20.7	32 820	58 440	"	09 405										
Lower lateral. Broke at back end of upset for screw, disclosing piece of iron welded in.		6	1 3/16	409.08	348	6.07	1.18	....	....	....	19.5	5.6	35 480	60 390	In upset for screw	3 055	.830	.435	47.6	23.0	39 760	74 340	.069	Acid "	Pencoyd I. & S. Co.	Pencoyd B. & C. Co.
Lower lateral.		6	1 3/16	416.78	360	6.04	1.18	....	....	....	21.6	6.0	39 190	63 220	Sleeve nut	3 327	.672	.303	54.9	27.5	41 670	71 740	.082	" "	" " "	" " "
" "		4	13/16	422.18	372	4.03	0.80	3.25	0.57	42.6	39.2	10.6	40 540	71 580	Body	3 095	1.026	.436	58.5	31.3	39 280	66 090	.084	" " "	" " "	" " "
" "		4	1	421.88	372	4.02	1.00	3.10	0.75	41.8	45.1	12.1	39 570	68 490	"	3 095	....	....	....	....	....	....	....	" " "	" " "	" " "
" "		4	1⅛	423.08	372	4.04	1.13	3.08	0.79	46.8	47.8	13.8	39 720	69 180	"	3 095	....	....	....	....	....	....	....	" " "	" " "	" " "
First part.	Deck Span.	8	1 13/16	279.98	240	8.11	1.79	6.26	1.34	42.2	37.1	15.5	28 940	58 010	Body	11 150	1.114	.5960	46.5	23.0	40 480	66 880	.030	Basic open-hearth	Carnegie, Phipps & Co.	Union Bridge Co.
Second part.		8	1 13/16	279.88	240	8.11	1.79	6.13	1.24	47.7	38.8	16.2	28 660	58 290	"	11 150										
First part.		7	1	289.23	252	7.02	1.00	5.53	0.75	40.9	44.9	17.8	31 380	59 850	"	11 072	1.020	.5402	47.0	28.1	40 790	68 730	.030	" " "	" " "	" " "
Second part.		7	1	249.48	252	7.00	1.00	5.51	0.67	47.3	42.7	16.9	31 470	59 730	"	11 072										

The first four bars were entirely experimental and did not represent bars which it was intended to use in the structure. They were generally of rather too high a steel, and the result of these tests led to the adoption in the specifications of a special eye-bar steel, midway between the medium and high grade steel.

Tests Nos. 5 and 6 were 6 inch bars which showed a weak steel below the requirements of the specifications, and led to the substitution of 7 inch bars for 6 inch bars for all floor-beam suspenders, the 7 inch bars being made of soft steel.

Tests 13 and 14 were both of the same bar. The first test was unsatisfactory and showed a flaw in the steel. The second test was a test of a stretched bar reheaded after stretching, and not reannealed; as was to be expected, it broke in the new head.

Test No. 16 showed a flaw. Test No. 17, of the same bar, when reheaded and planed down to a reduced section, showed that the steel was excellent.

Test No. 18 was good. Tests Nos. 19 and 20 of the same bar broke in heads which had been forged but not reannealed, the last having been forged on a stretched bar.

Test 26 falls a little below the requirements of the specifications, and this was explained by a slight flaw at the fracture, the fracture taking place in the head.

Test 48 led to the rejection of the bars represented by it.

APPENDIX P.

REPORT OF TESTING COMMITTEE.

GEO. S. MORISON, ESQ.
Chief Engineer K. C. & M. Ry. & Bridge Co.

DEAR SIR: The committee appointed to report on the results of the testing of the Memphis Bridge on the 12th of May, 1892, submits the accompanying tabulated statement of deflections observed in the different spans of the bridge, under the several test loads applied:

The sign — indicates a downward deflection.

The sign + indicates an upward deflection.

The statement gives the deflections for the north and south trusses of each span, and also movements eastward and westward of the north and south roller bearings on Pier II, the other bearings being all fixed.

The testing was done with 18 locomotives weighing in the aggregate 1405.7 tons.

Load I was applied to the cantilever arm east of Pier I. It consisted of four locomotives covering the entire length of cantilever and weighing 342 tons.

Load II was applied to the span between Piers I and II. It consisted of 15 locomotives covering the entire distance between piers and weighing.. 1190.3 tons.

Load III was applied to the span between Piers II and III and to the cantilever arm east of Pier I. It consisted of 12 locomotives covering the entire span (II–III) and weighing.................................. 944 tons; and of four locomotives covering the entire length of cantilever and weighing.. 320.3 tons.

Load IV was applied to the adjacent spans of span (II–III) and consisted of nine locomotives from Pier II eastward, weighing.............. 690.2 tons; and of nine locomotives from Pier III westward, weighing......... 715.5 tons.

Load V was applied to the span between Piers III and IV, and consisted of 11 locomotives covering the entire length of span and weighing....825.2 tons.

Load VI consisted of 18 locomotives coupled together, weighing 1405.7 tons.

This train, moving at a speed of 30 miles per hour, entered the bridge at the west end and was stopped at the east end within a distance as short as practicable. The deflections under the rapidly moving load did not exceed the maximum deflections under static load.

Observations taken on the empty structure immediately after the test showed that no permanent deflections had taken place.

The vibrations under the running test were as moderate as could be expected, even from such massive spans.

The behavior of the entire structure under the different tests made was altogether very satisfactory.

Respectfully submitted,
ROBERT MOORE,
C. L. STROBEL,
G. BOUSCAREN,
The Committee.

LOCOMOTIVES USED IN TESTS.

Position in Train.	Railroad.	Number.	Kind.	Weight in Tons.
1	K. C., M. & B. R. R.	34	10 wheel	85.5
2	"	23	10 "	85.5
3	"	35	10 "	85.5
4	"	31	10 "	85.5
5	"	32	10 "	85.5
6	"	30	10 "	85.5
7	K. C., Ft. S. & M. R. R.	96	Switch	67.5
8	"	97	"	67.5
9	"	89	"	67.5
10	"	23	"	67.5
11	I. C. R. R.	1159	8 wheel	78.5
12	L. N. O. & T. R. R.	55	10 "	82.5
13	N. N. & M. V. R. R.	605	10 "	92.3
14	M. & C. R. R.	198	8 "	71.0
15	T. M. Ry.	201	10 "	83.0
16	St. L., I. M. & S. Ry.	475	8 "	74.0
17	L. R. & M. R. R.	14	8 "	68.4
18	L. & N. R. R.	321	Switch	73.0
			Total.........	1405.7

TABULATED STATEMENT OF RESULTS OF TESTS MADE ON THE MEMPHIS BRIDGE, MAY 12, 1892.

DEFLECTIONS IN FEET.

POINTS OBSERVED.		1st Load, 342 tons.	2d Load 1190 3 tons	3d Load, 944 tons. 320.3 "	4th Load, 690.2 tons. 715 5 "	5th Load, 825.2 tons.	6th, Running Load, 1405.7 tons
Centre of cantilever span...	N.	— 0.015	+ 0.025	— 0.020	0.000	— 0.010	
	S.	— 0.010	+ 0.025	— 0.020	0.000	— 0.010	— 0.200
West end of 1st cantilever, span (I–II).............	N.	+ 0.030	— 0.200	+ 0.030	— 0.060	+ 0.020	
	S.	+ 0.020	— 0.200	+ 0.020	— 0.060	+ 0.020	
Centre of intermediate span (I–II).................	N.	+ 0.010	— 0.350	+ 0.070	— 0.270	0.000	— 0.350
	S.	+ 0.010	— 0.380	+ 0.050	— 0.280	— 0.020	
East end of 2d cantilever, span (I–II).............	N	0.000	— 0.240	+ 0.100	— 0.250	— 0.040	
	S.	0.000	— 0.240	+ 0.100	— 0.250	— 0.040	
Centre of span (II–III).....	N.	0.000	+ 0.090	— 0.170	+ 0.160	+ 0.080	— 0.130
	S	0.000	+ 0.090	— 0.170	+ 0.160	+ 0.080	
West end of cantilever, span (III–IV)...............	N.	0.000	— 0.040	+ 0.120	— 0.270	— 0.200	
	S.	0.000	— 0.050	+ 0.110	— 0.270	— 0.200	— 0.240
Centre of intermediate span (III–IV)................	N.	— 0.010	— 0.030	+ 0.090	— 0.220	— 0.210	
	S.	0.000	— 0.040	+ 0.070	— 0.270	— 0.210	

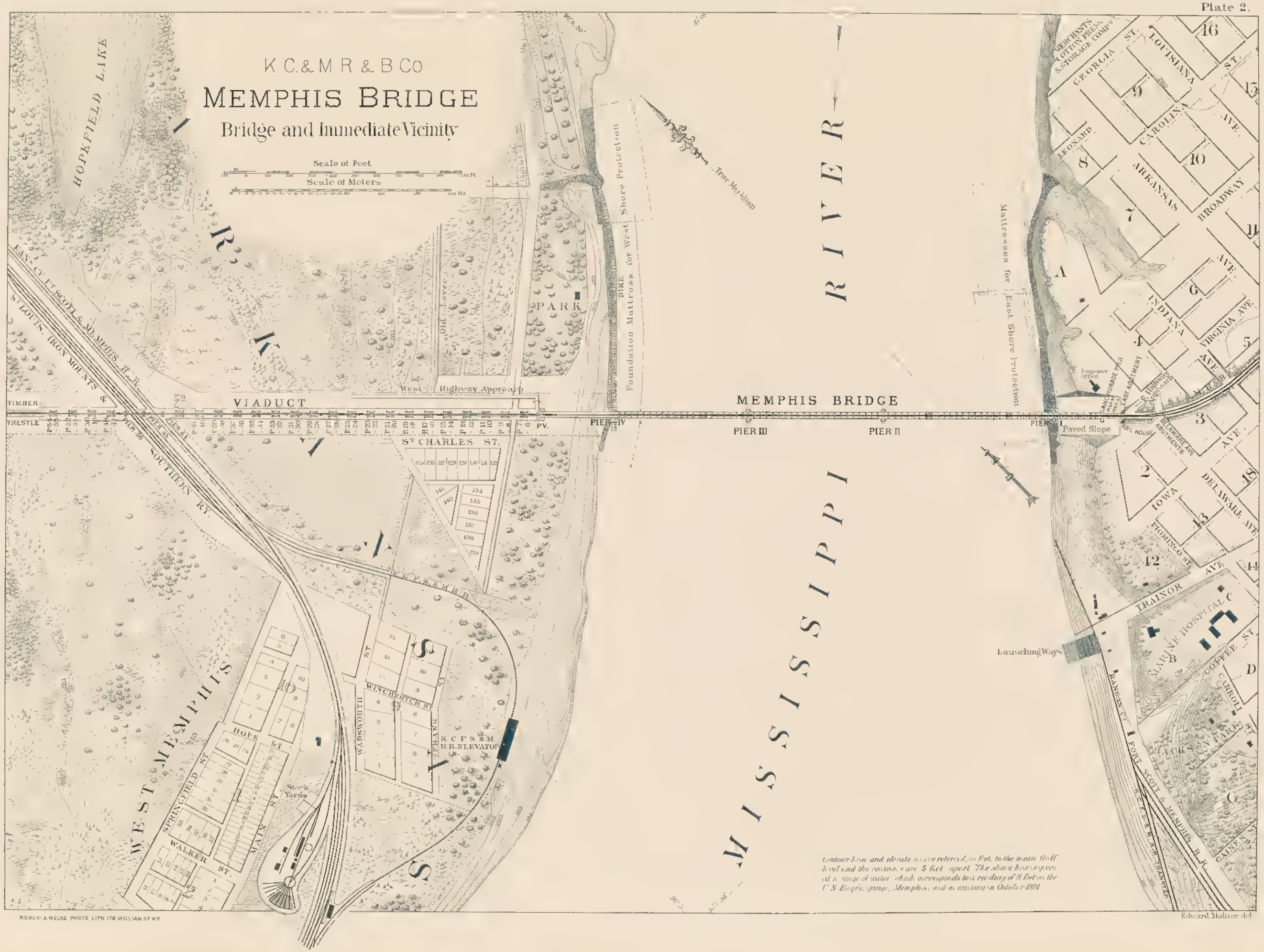
MOVEMENTS OF ROLLER BEARINGS, IN FEET.

POINTS OBSERVED.	1st Load.	2d Load.	3d Load.	4th Load.	5th Load.
North rollers on Pier II.........	0.003 E.	0.023 W.	0.048 E.	0.039 W.	0.008 E.
South " " " ".........	0.003 E.	0.025 W.	0.047 E.	0.040 W.	0.010 W.

Plate 1.

ROBERT A. WELKE PHOTO-LITH. 178 WILLIAM ST. N.Y.

Edward Molitor, del

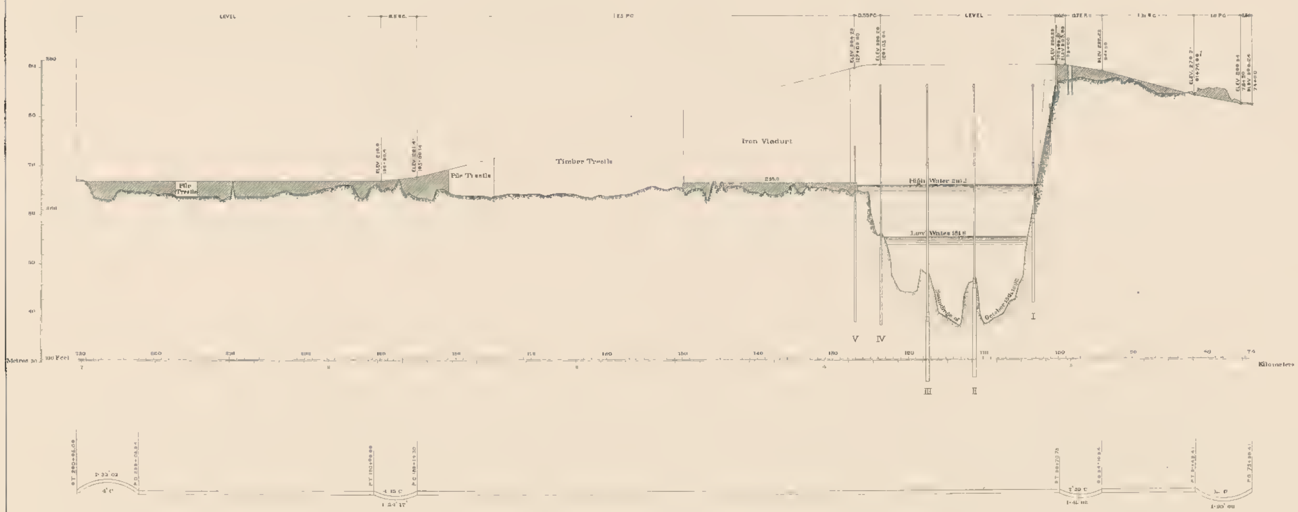


Edward Molitor del.

Moerch & Welke Photo Lith. 178 William St. N.Y.

Plate 3.

K.C.&M.R.&B.Co.
MEMPHIS BRIDGE
PROFILE AND ALIGNMENT.



Geo. S. Morison
Ch. Engr.

ROBERT A WELKE PHOTO LITH 178 WILLIAM ST N.Y.

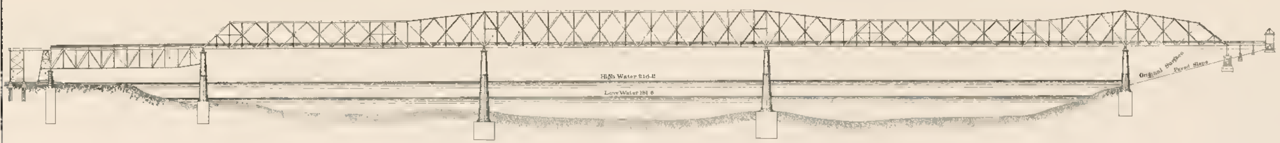
K.C.&M.R.&B.Co.

MEMPHIS BRIDGE.

GENERAL ELEVATION AND PLAN.

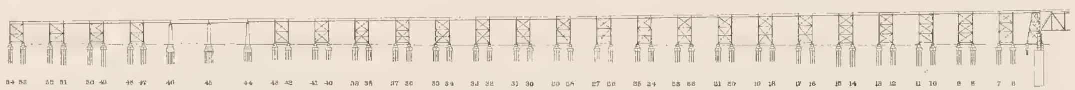
Scale.

Elevation.



Plan.

Elevation.



Plan.

G. S. Morison
Ch. Engr.

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K.C.&M.R.&B.Co.

MEMPHIS BRIDGE

PROFILE SHOWING STRATIFICATION ON BRIDGE LINE.

G. S. Morison
Ch. Engr.

Scales
Horizontal — Vertical
Feet
Metres

Heavy vertical lines indicate borings.

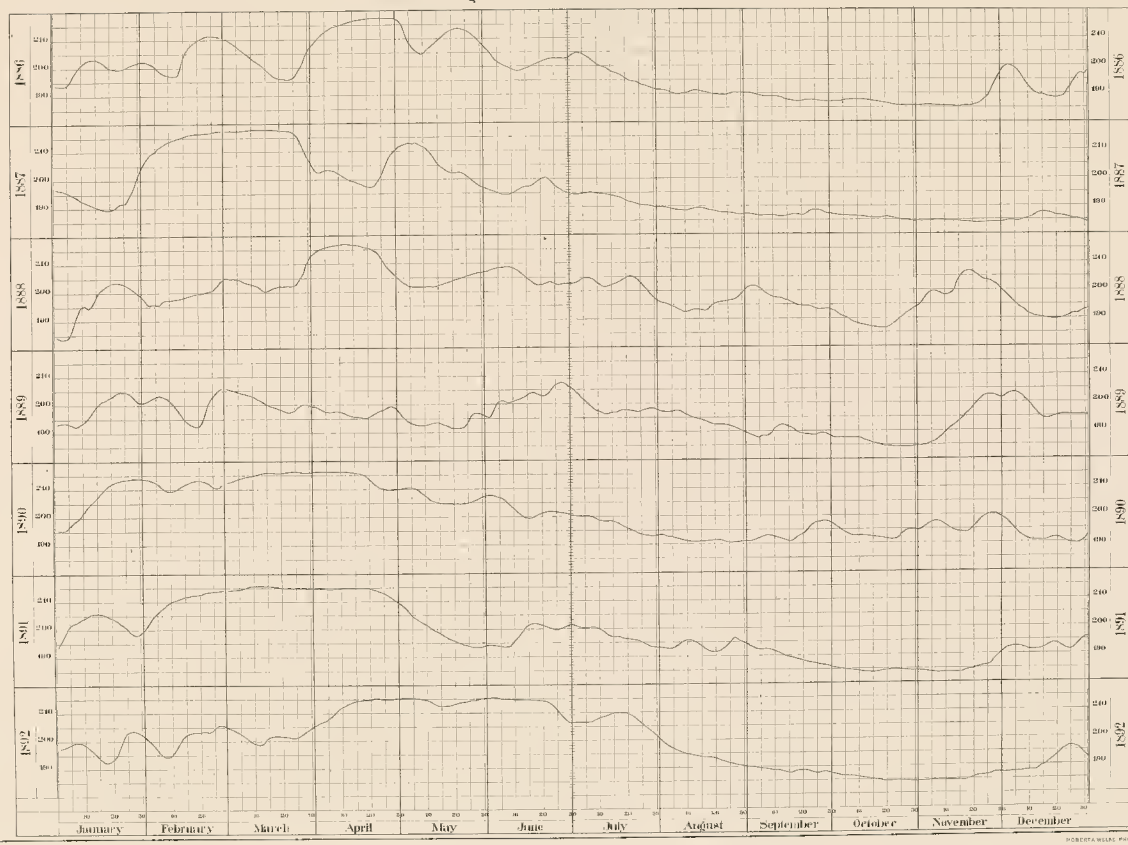
ROBERTA WELKE PHOTO-LITH 173 WILLIAM ST NY

K. & M. R. & B. Co

MEMPHIS BRIDGE

Water Gauge Record at foot of Jefferson St.

G. S. Morison
Ch. Engr.



ROBERTA WELKE PHOTO LITH 176 WILLIAM ST N.Y.

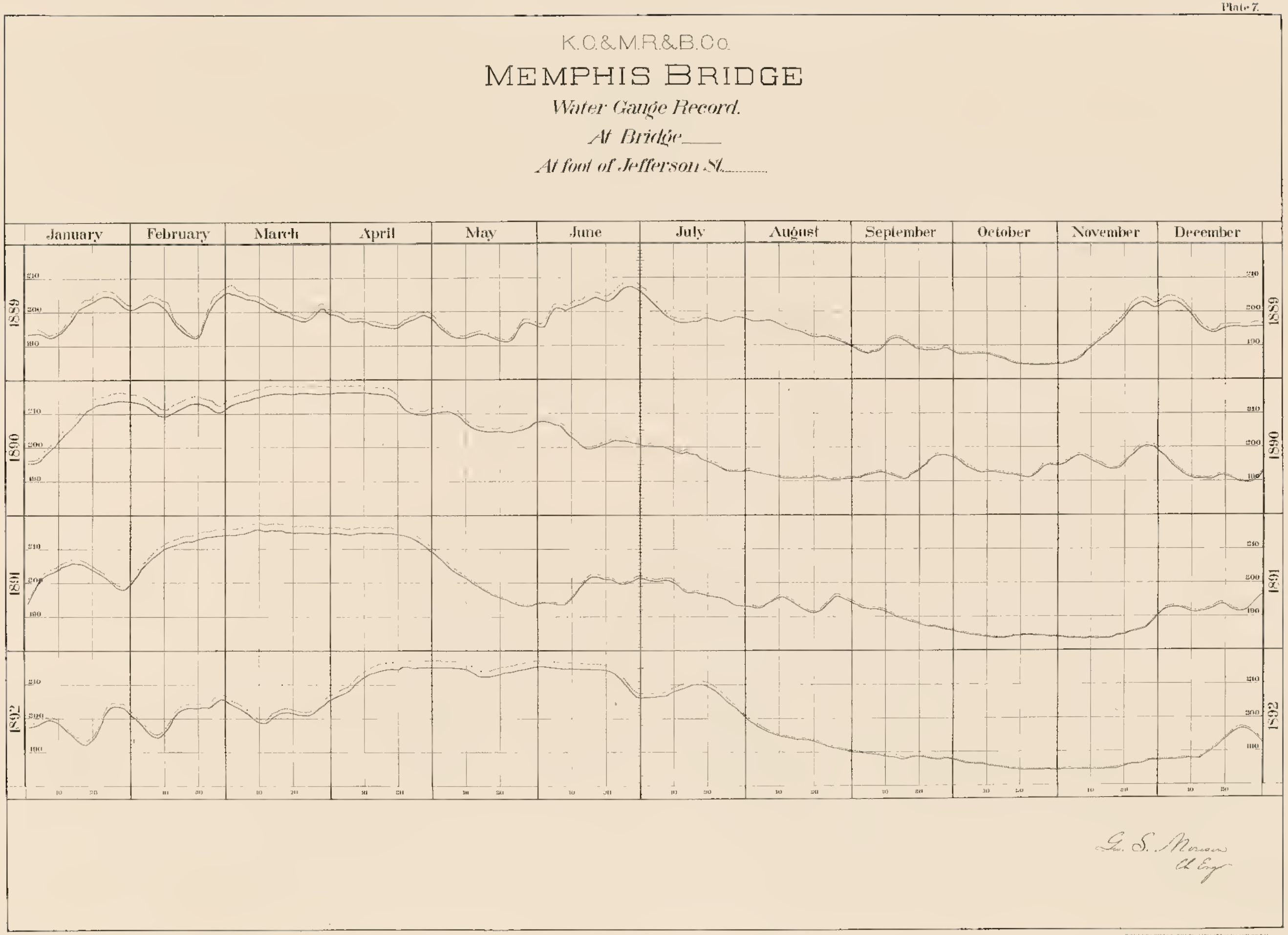
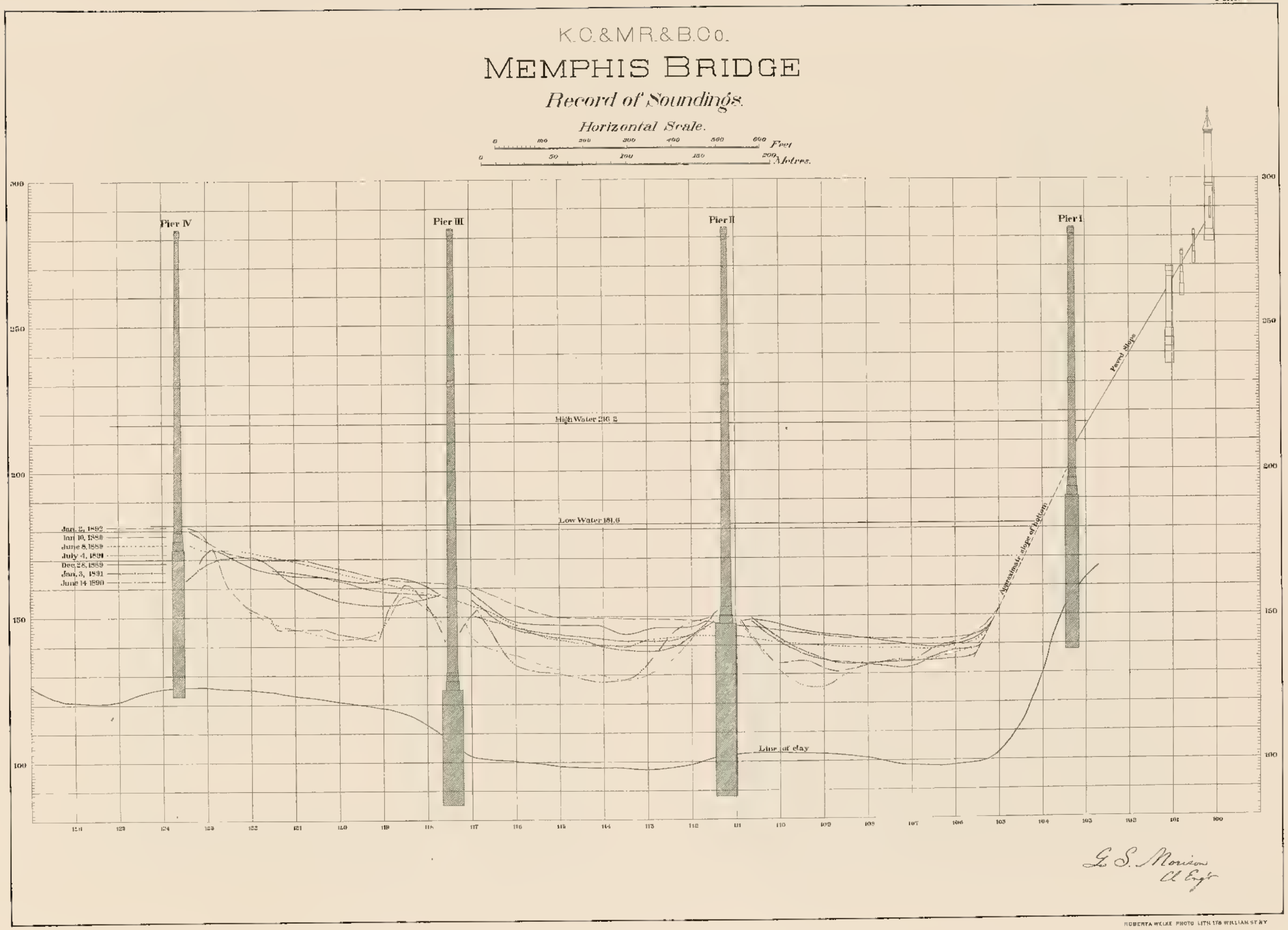
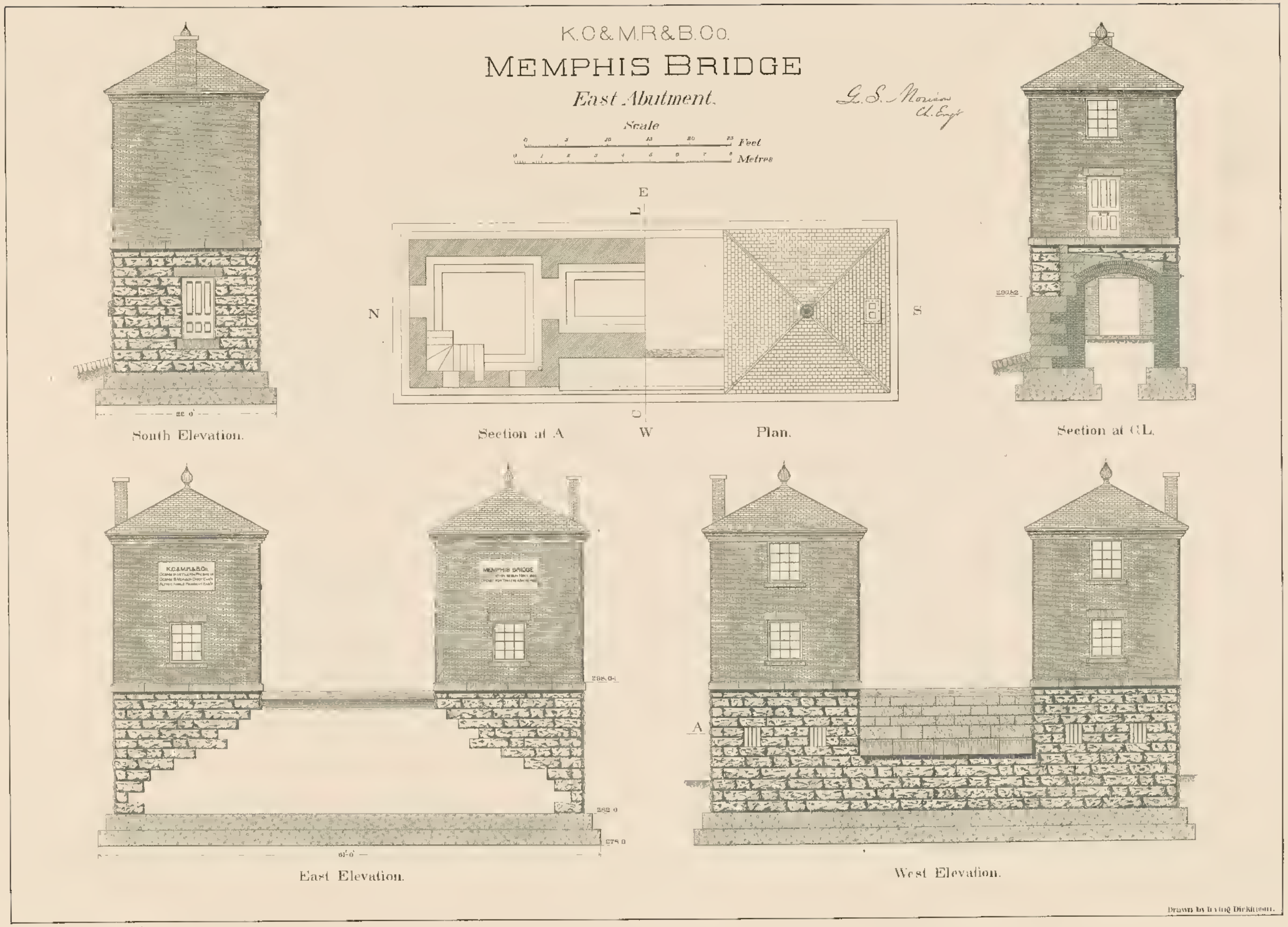

K.C.&M.R.&B.Co.
MEMPHIS BRIDGE
Water Gauge Record.
At Bridge
At foot of Jefferson St.
January
February
March
April
May
June
July
August
September
October
November
December
1889
1890
1891
1892
Geo. S. Morison
Ch. Engr.

Plate 8



ROBERTS & WELKE PHOTO LITH 178 WILLIAM ST N.Y.

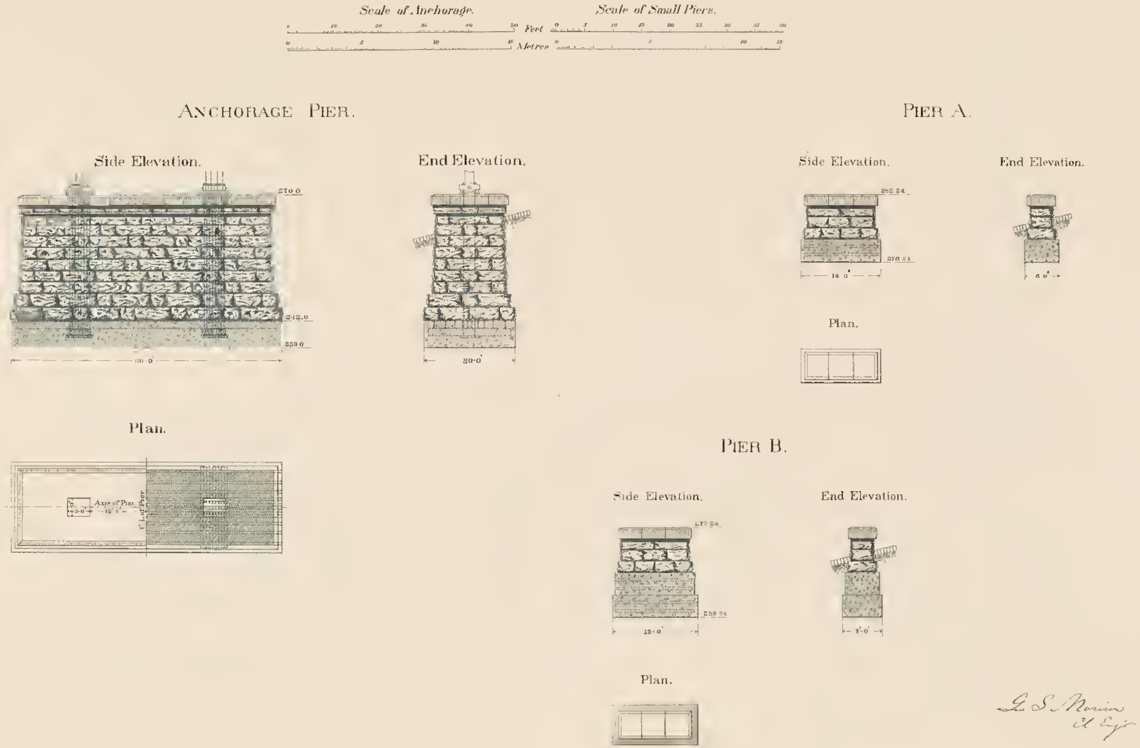


GOBLE & WELKE PHOTO LITH 178 WILLIAM ST N.Y.

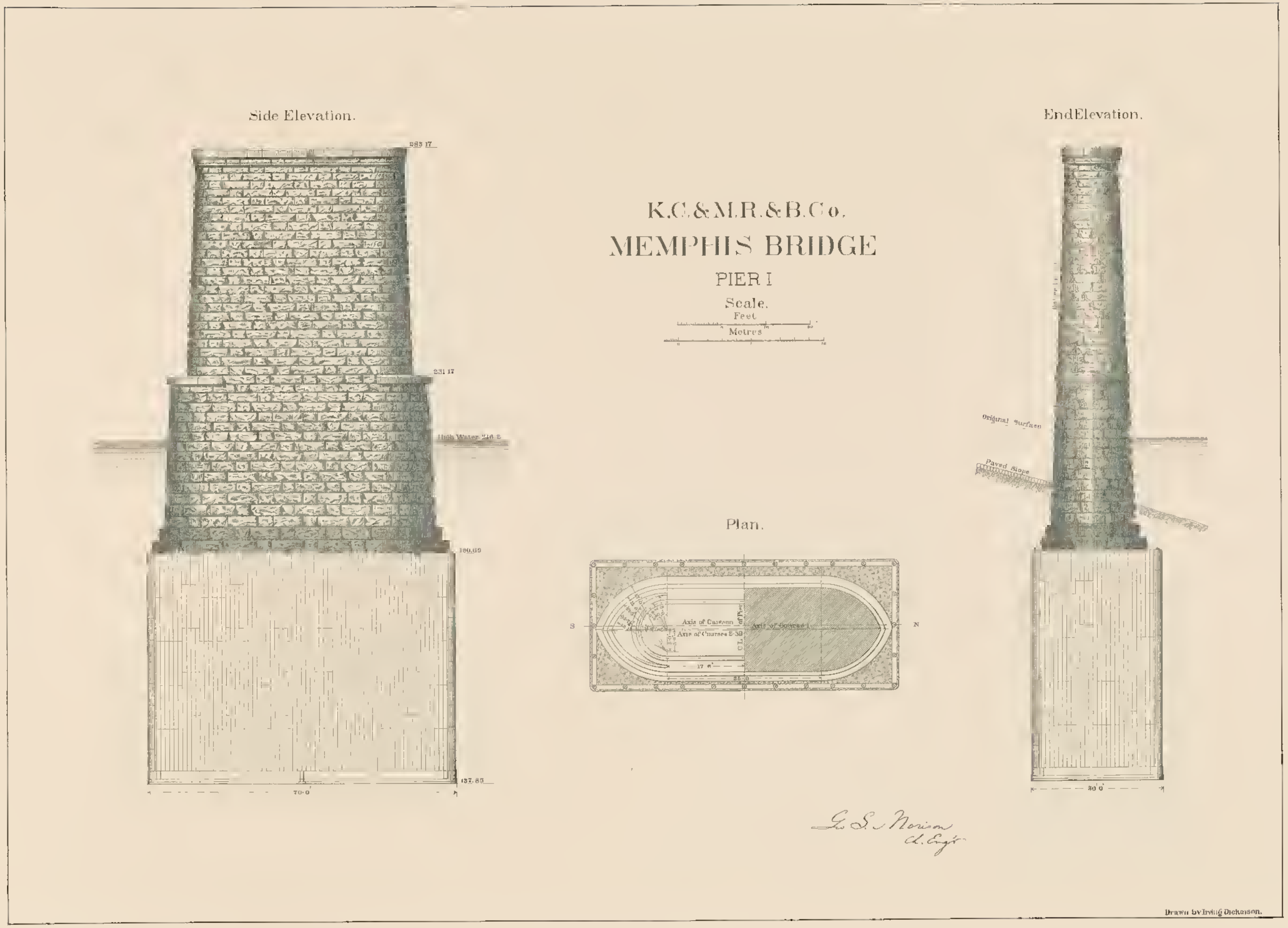
K.C.& M.R.& B.Co.

MEMPHIS BRIDGE

ANCHORAGE AND SMALL PIERS.



G. S. Morison
Ch. Engr.



ROBERTS & WELKE PHOTO LITH 170 WILLIAM ST NY

K C & M R & B Co

MEMPHIS BRIDGE

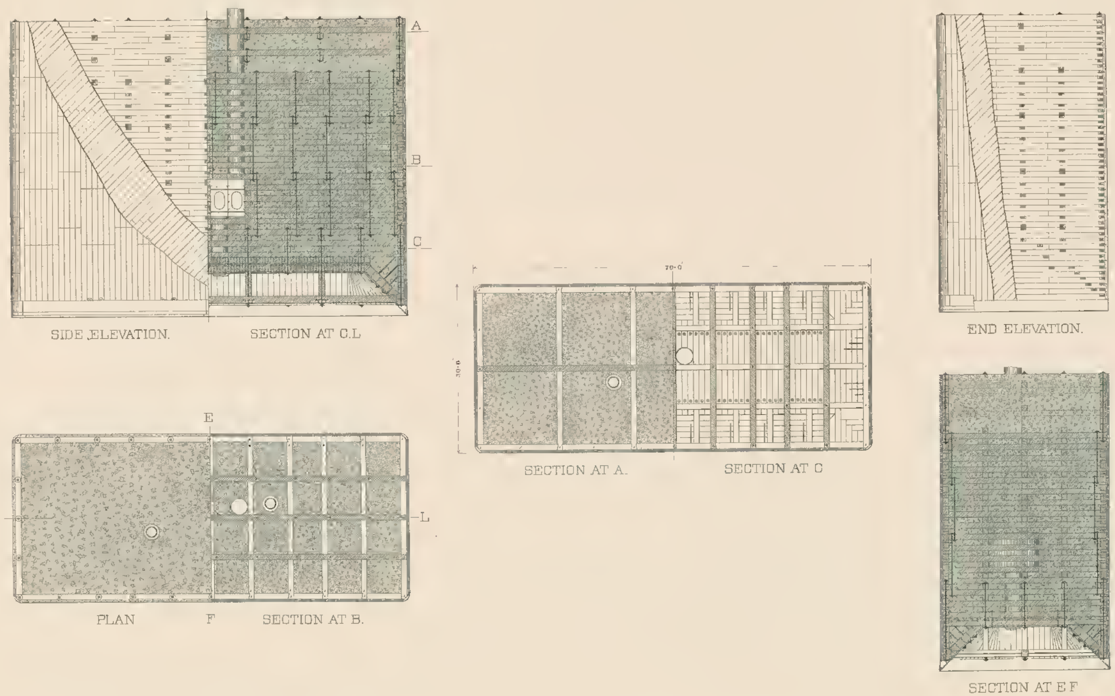
Caisson - Pier I

Scale

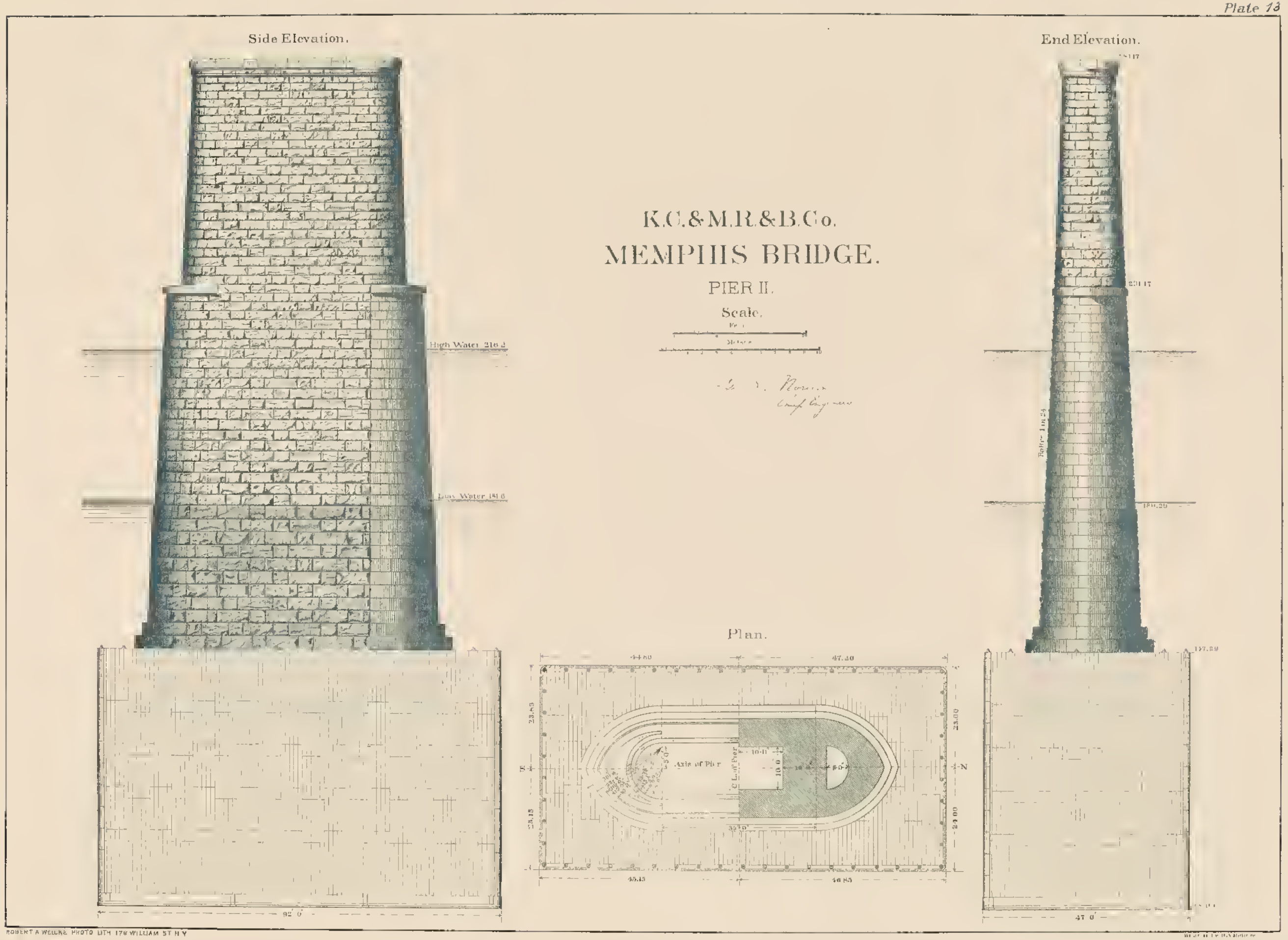
0 5 10 15 20 25 30 Feet

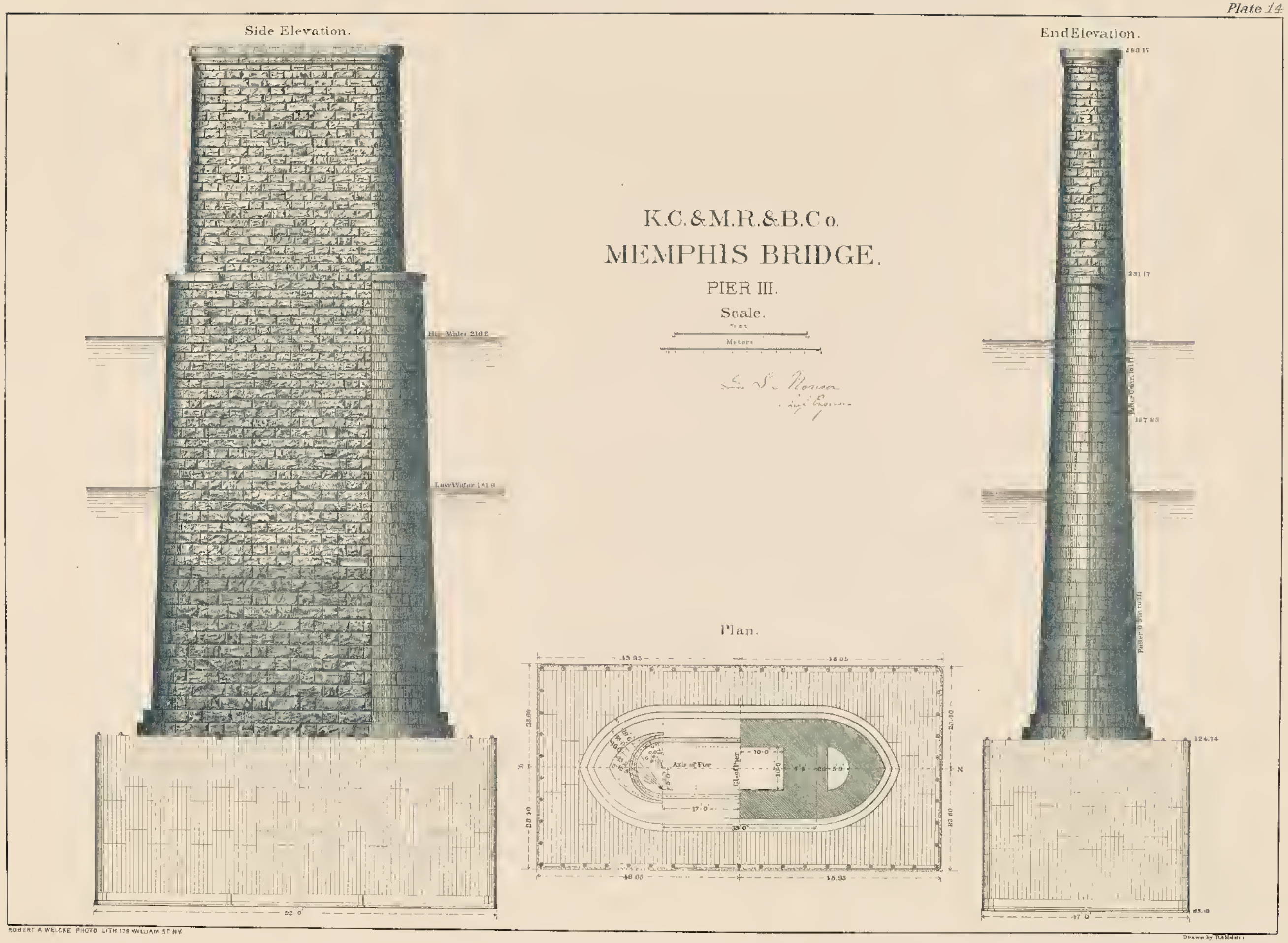
0 5 10 Metres

G. S. Morison
Ch. Engr.



ROBERTS & WELKE PHOTO LITH 178 WILLIAM ST NY

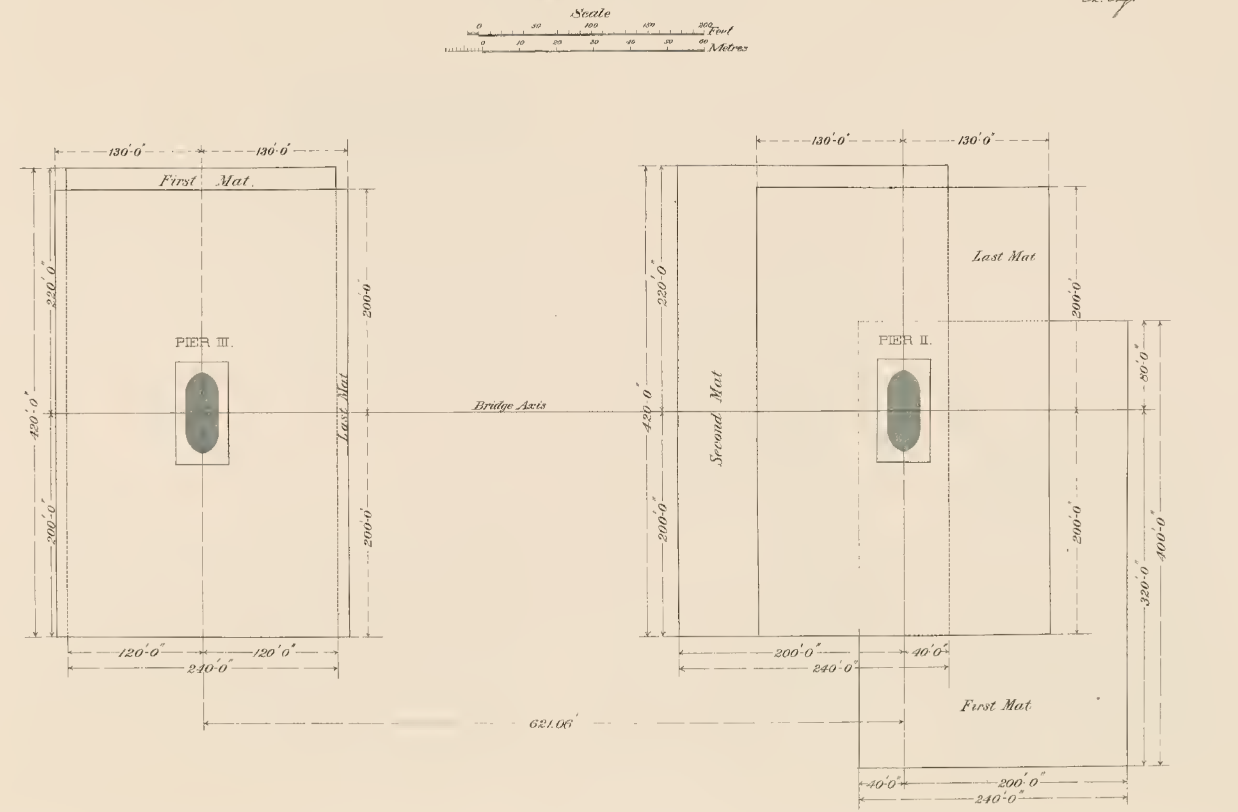

Side Elevation.
End Elevation.
K.C.&M.R.&B.Co.
MEMPHIS BRIDGE.
PIER II.
Scale.
High Water 216.2
Low Water 180.0
Plan.
Axis of Pier
92' 0"
47' 0"
44.60
47.30
45.15
46.85
23.00
24.00


Side Elevation.
End Elevation.
K.C.&M.R.&B.Co.
MEMPHIS BRIDGE.
PIER III.
Scale.
Meters
Plan.
Axis of Pier
Low Water
52' 0"
37' 0"
124.14
ROBERT A. WELCKE PHOTO. LITH 178 WILLIAM ST N.Y.

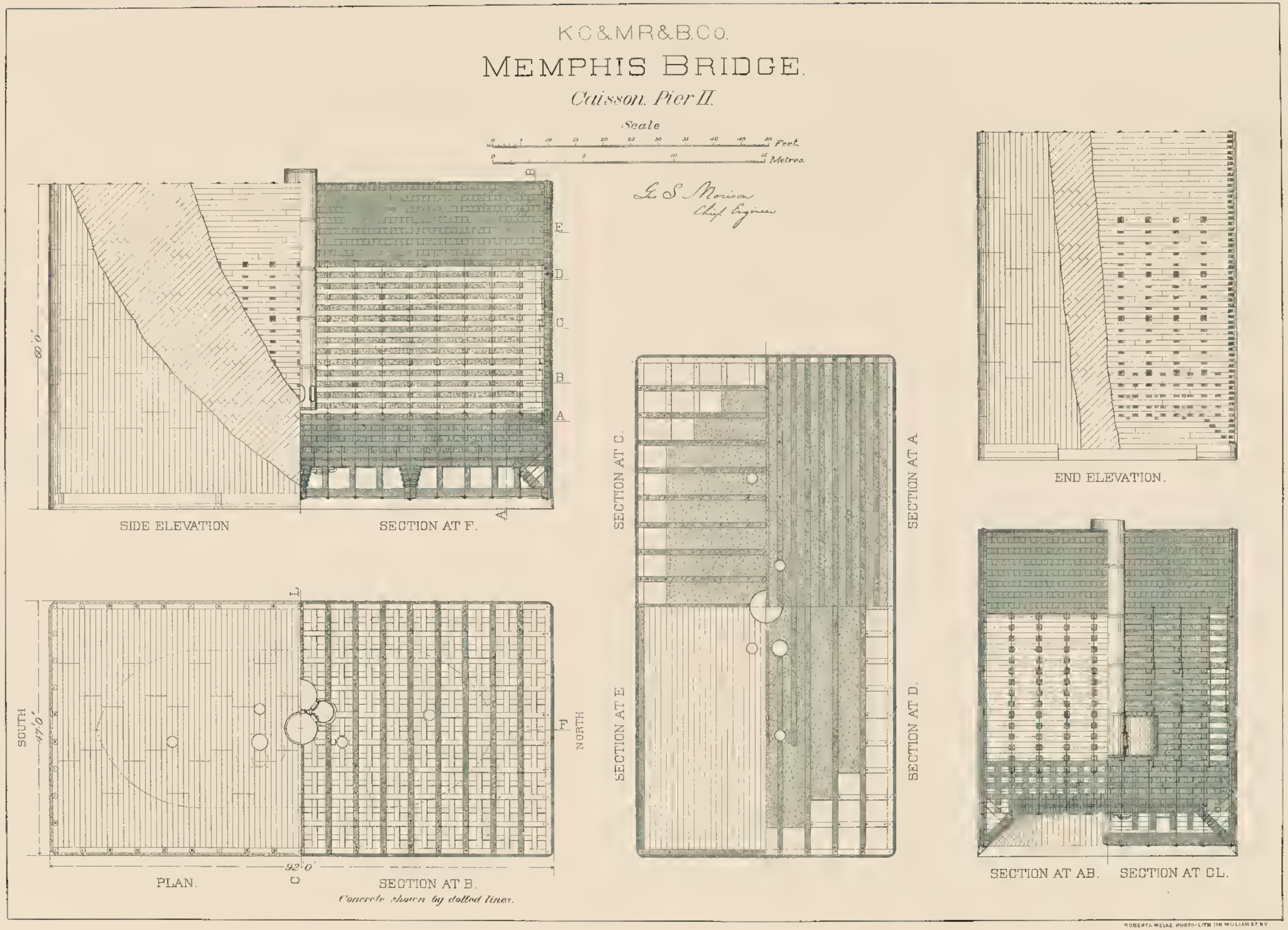
K.C.&M.R.&B.Co.

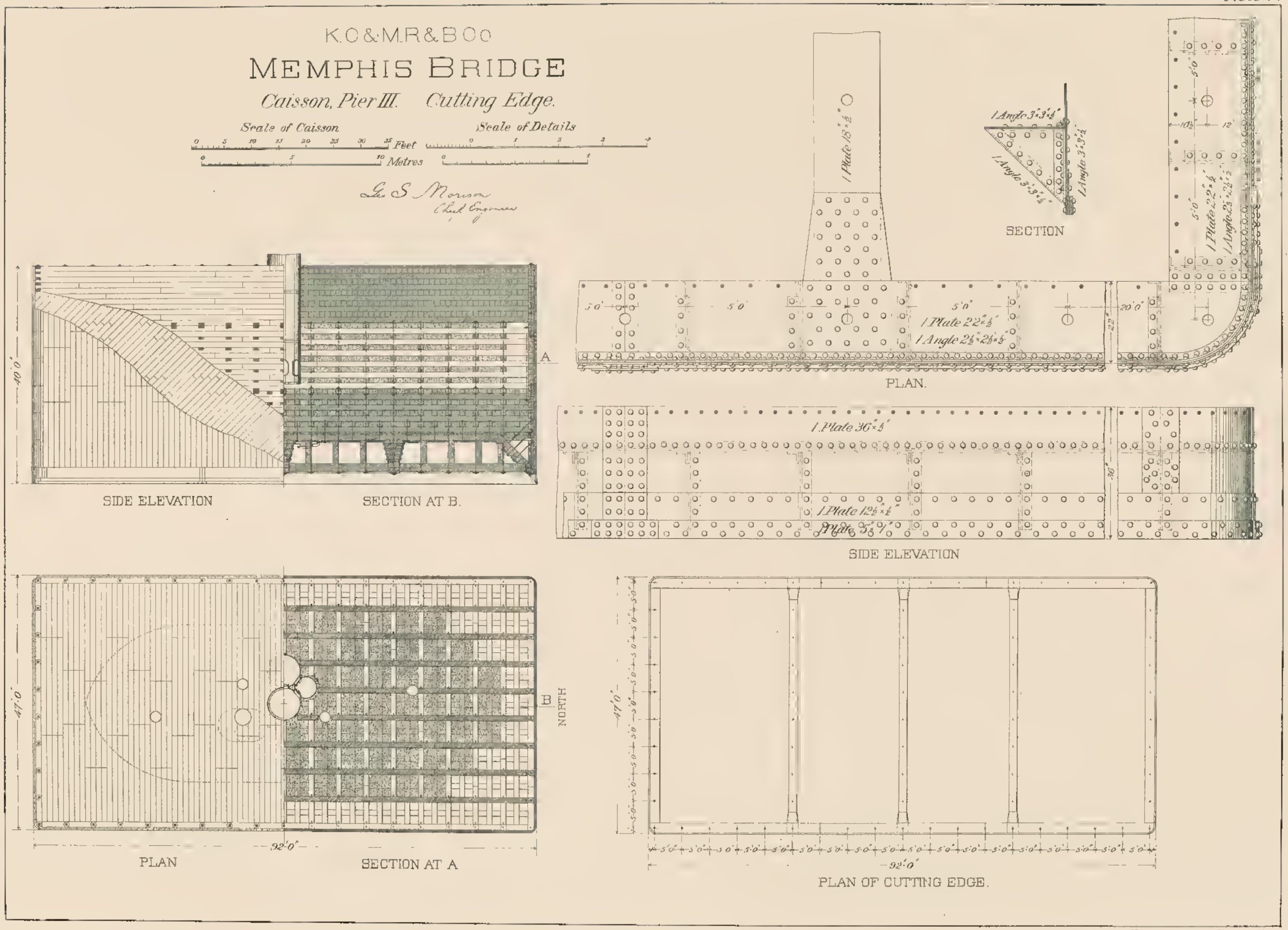
MEMPHIS BRIDGE

Position of Mats at Piers II and III.



ROBERTA WELAE PHOTO-LITH 175 WILLIAM ST NY


K.C.&M.R.&B.Co.
MEMPHIS BRIDGE.
Caisson. Pier II.
Scale
Feet.
Metres.
G. S. Morison
Chief Engineer
SIDE ELEVATION.
SECTION AT F.
END ELEVATION.
SECTION AT C.
SECTION AT A.
SECTION AT E.
SECTION AT D.
PLAN.
SECTION AT B.
Concrete shown by dotted lines.
SOUTH
NORTH
SECTION AT AB.
SECTION AT CL.
ROBERTS & WELKE PHOTO-LITH 138 WILLIAM ST N.Y.

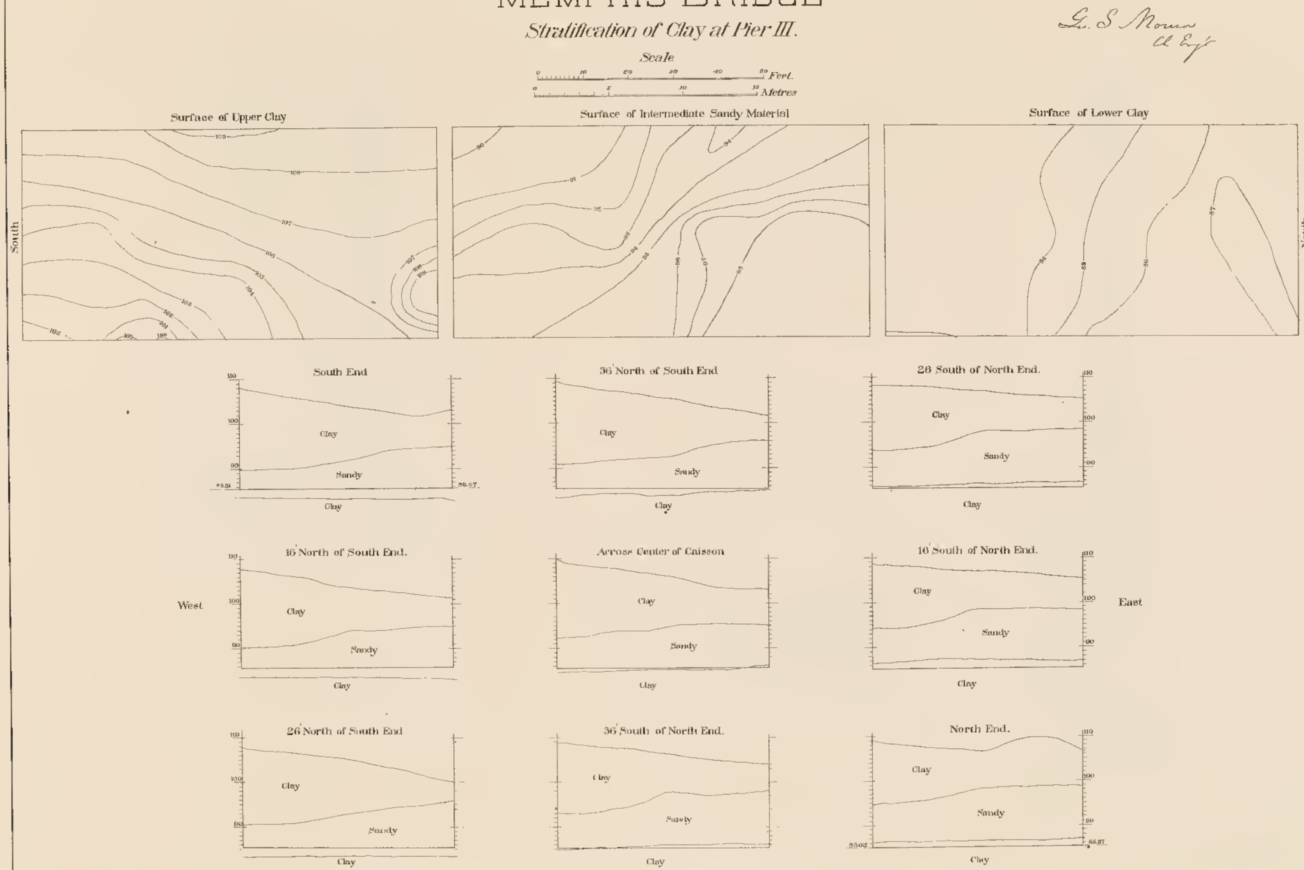


ROBERTS & WELKE PHOTO. LITH. 115 WILLIAM ST. N.Y.

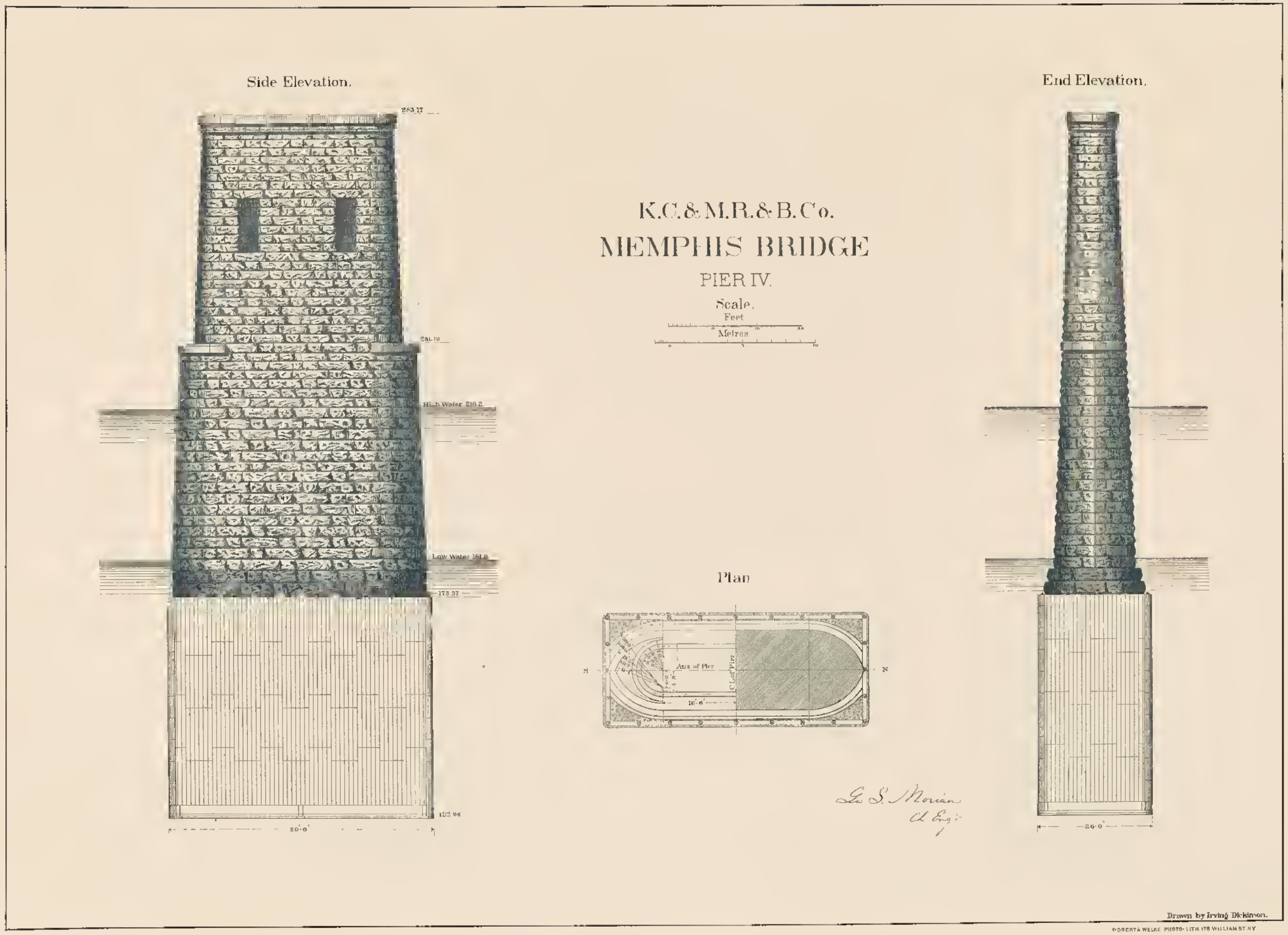
K.C.&M.R.&B.Co

MEMPHIS BRIDGE

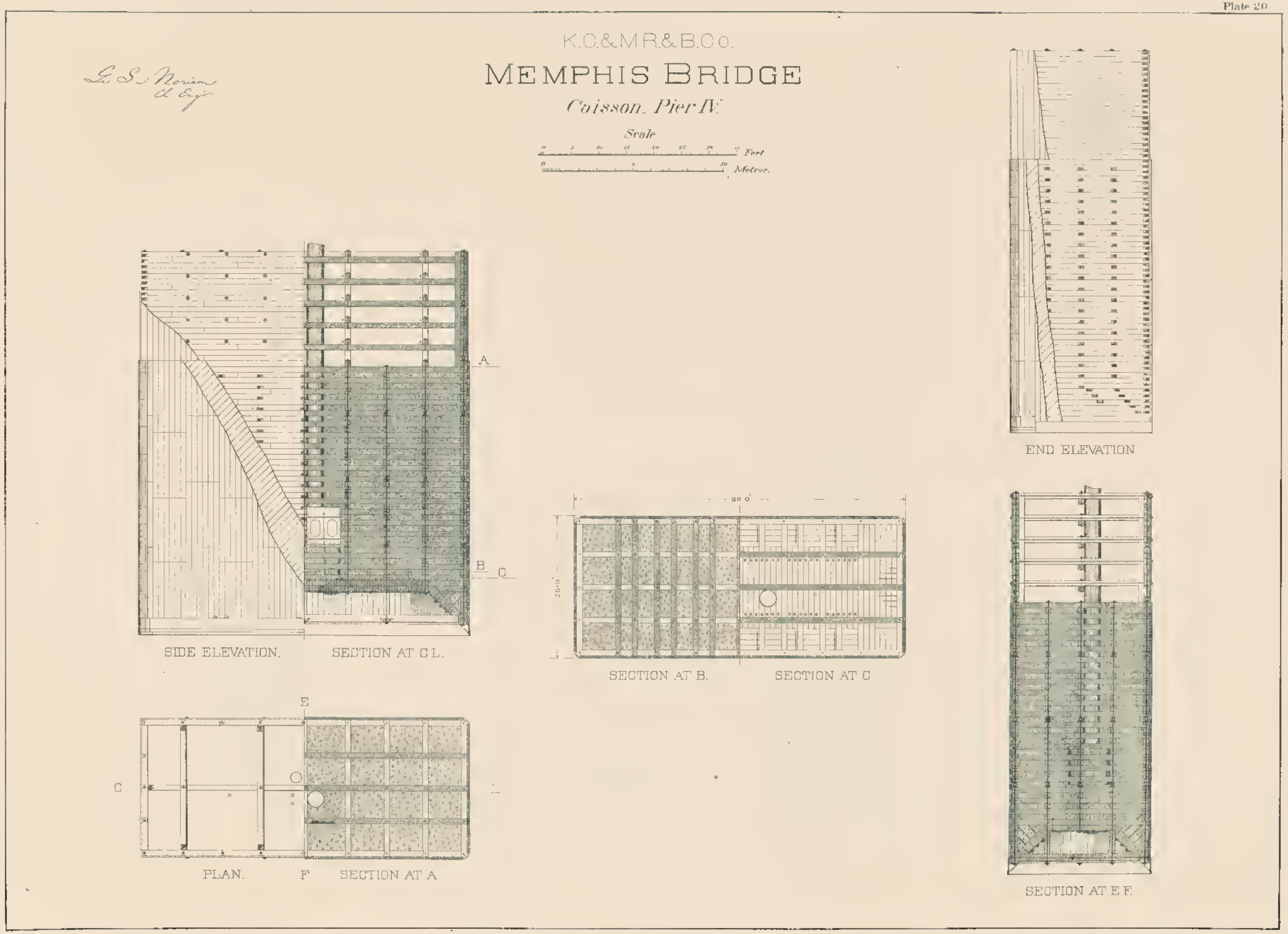
Stratification of Clay at Pier III.



ROBERTS & WEALE PHOTO LITH 178 WILLIAM ST N Y



ROBERTA WELKE PHOTO-LITH. 178 WILLIAM ST. NY



ROBERTS & WELKE PHOTO. LITH. 178 WILLIAM ST. N.Y.

K.C.&M.R.&B.

MEMPHIS BRIDGE

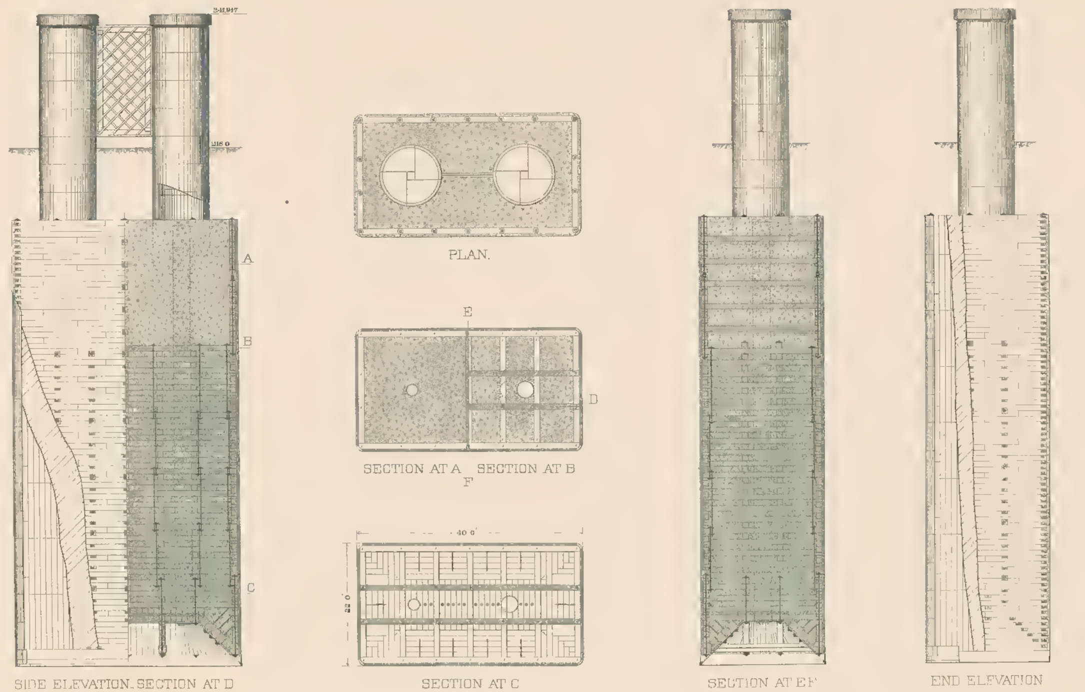
Pier V.

Scale

Feet

Metres

G. S. Morison
Ch. Eng'r



K.C.&M.R.&B.Co.

MEMPHIS BRIDGE

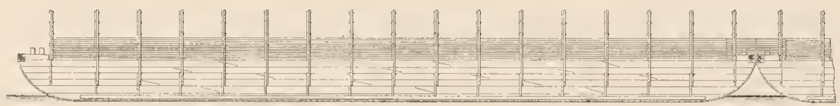
Weaving Barges.

Scale

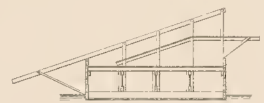
0 5 10 15 20 25 30 35 *Feet*

0 5 10 *Metres*

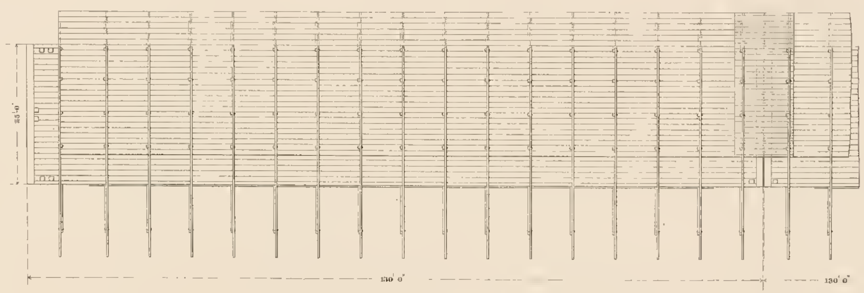
G. S. Morison
Ch. Engr.



Side Elevation.



Section.



Plan.

ROBERT A. WELKE PHOTO-LITH 178 WILLIAM ST N.Y.

K.C.&M.R.&B.Co.

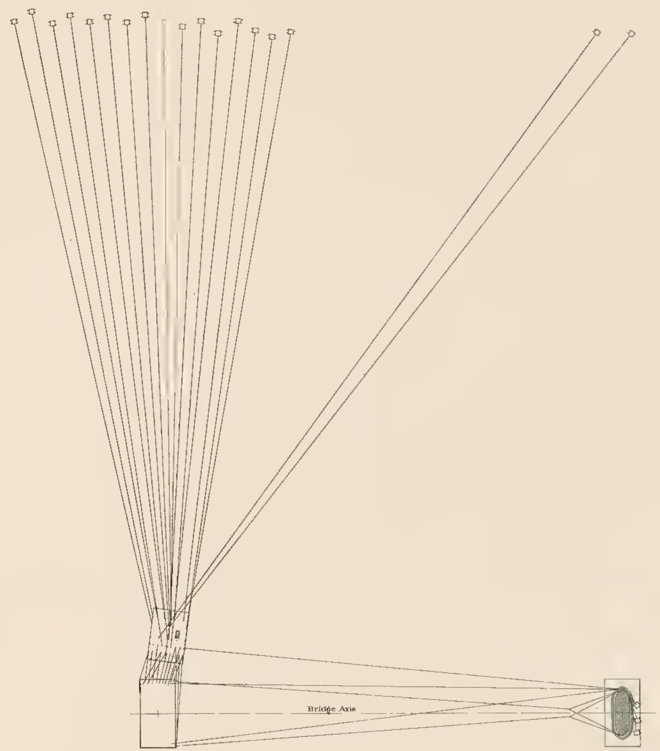
MEMPHIS BRIDGE

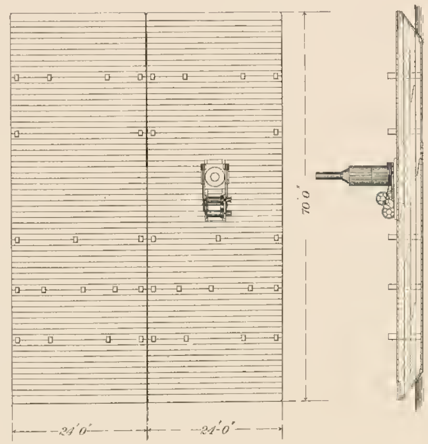
Anchorage of Caisson III.

Scale of Anchorage. — Feet 0–300; Metres 0–100

Scale of Barges. — Feet 0–30; Metres 0–10

Geo. S. Morison
Ch. Engr





ROBERT A. WELCKE PHOTO-LITH 178 WILLIAM ST. N.Y.

K C & M R. & B. Co

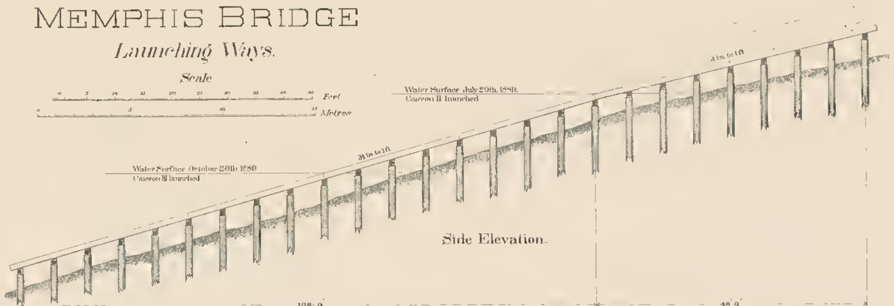
MEMPHIS BRIDGE

Launching Ways.

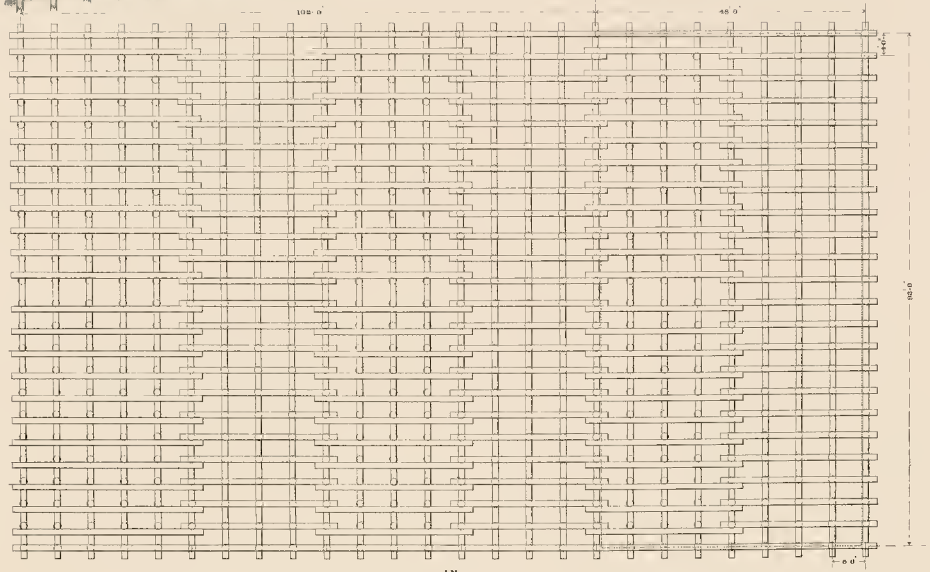
Scale

Feet

Metres



Side Elevation.



Plan.

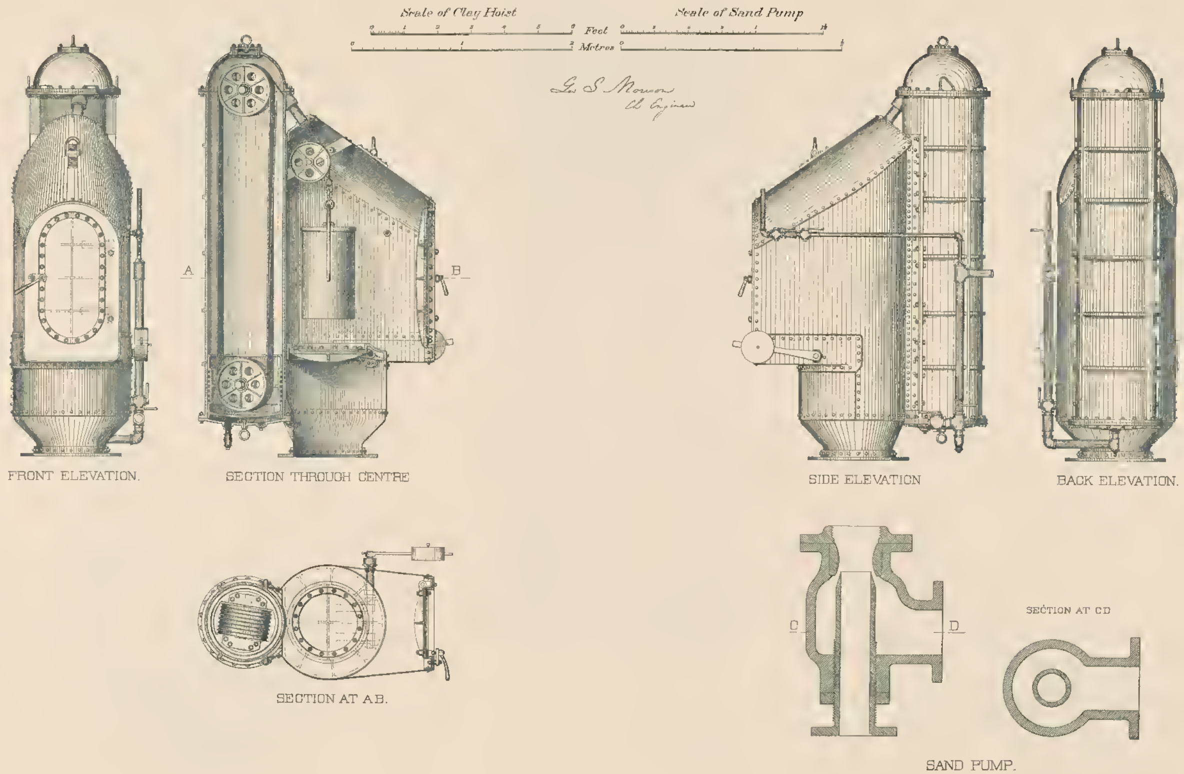
Geo. S. Morison
Ch. Eng'r

ROBERTA WELKE PHOTO LITH 178 WILLIAM ST NY

K.C.&M.R.&B.Co.

MEMPHIS BRIDGE.

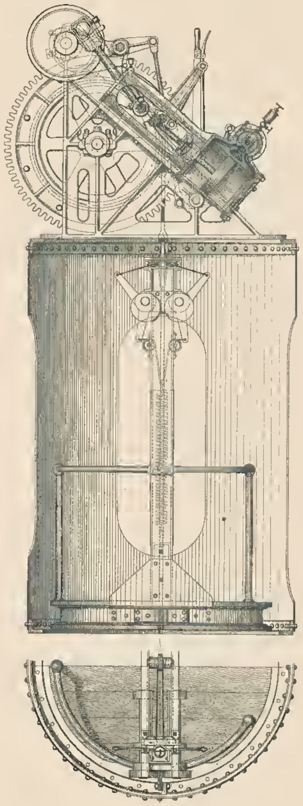
Clay Hoist and Sand Pump

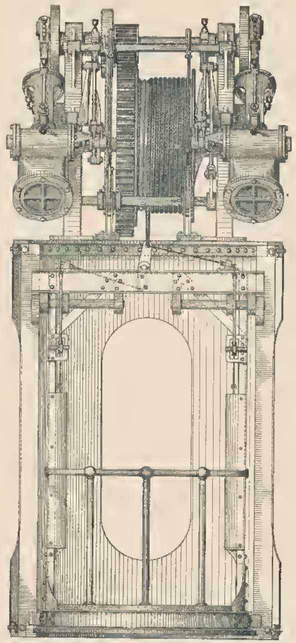


ROBERTS & REAL PHOTO LITH 178 WILLIAM ST N.Y.

ELEVATOR ENGINE AND GAGE

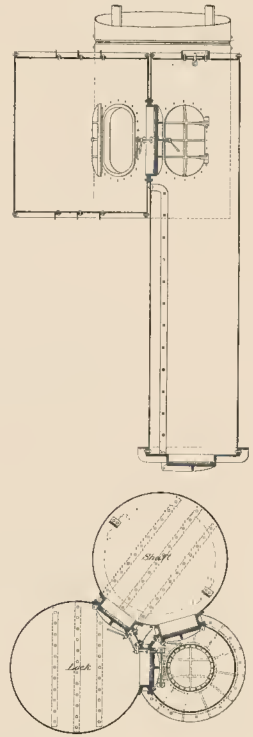
Scale 1 in. = 1 ft.





AIR LOCK AND SHAFT.

Scale ½ in. = 1 ft.



K.C.&M.R.&B.Co.

MEMPHIS BRIDGE.

Special Hoist and Lock used at Piers II and III

Geo. S. Morison
Chief Engineer

GEORGE S. MORISON,
CIVIL ENGINEER
THE TEMPLE. CHICAGO.
June 30th 1892

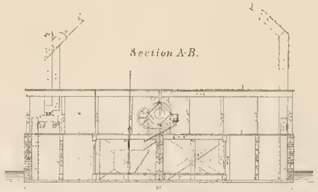
ROBERT A. WELCKE PHOTO-LITH 178 WILLIAM ST NY

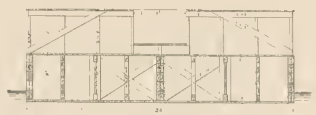
K.C.&M.R.&B.Co.

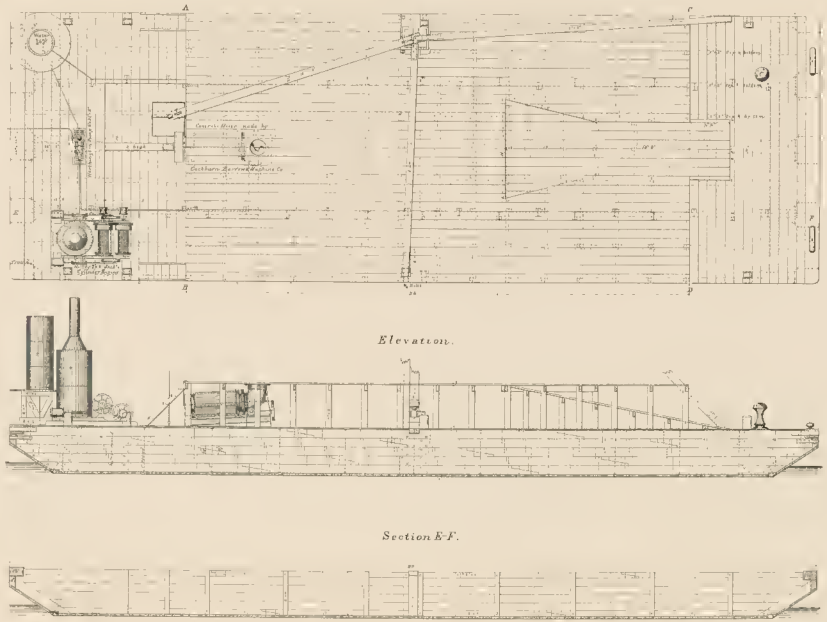
MEMPHIS BRIDGE

Concrete Mixing Plant.

Scale $\frac{1}{8}$"=1'.







Geo. S. Morison
Ch. Engr.

ROBERTS & WELKE PHOTO-LITH 178 WILLIAM ST N.Y.

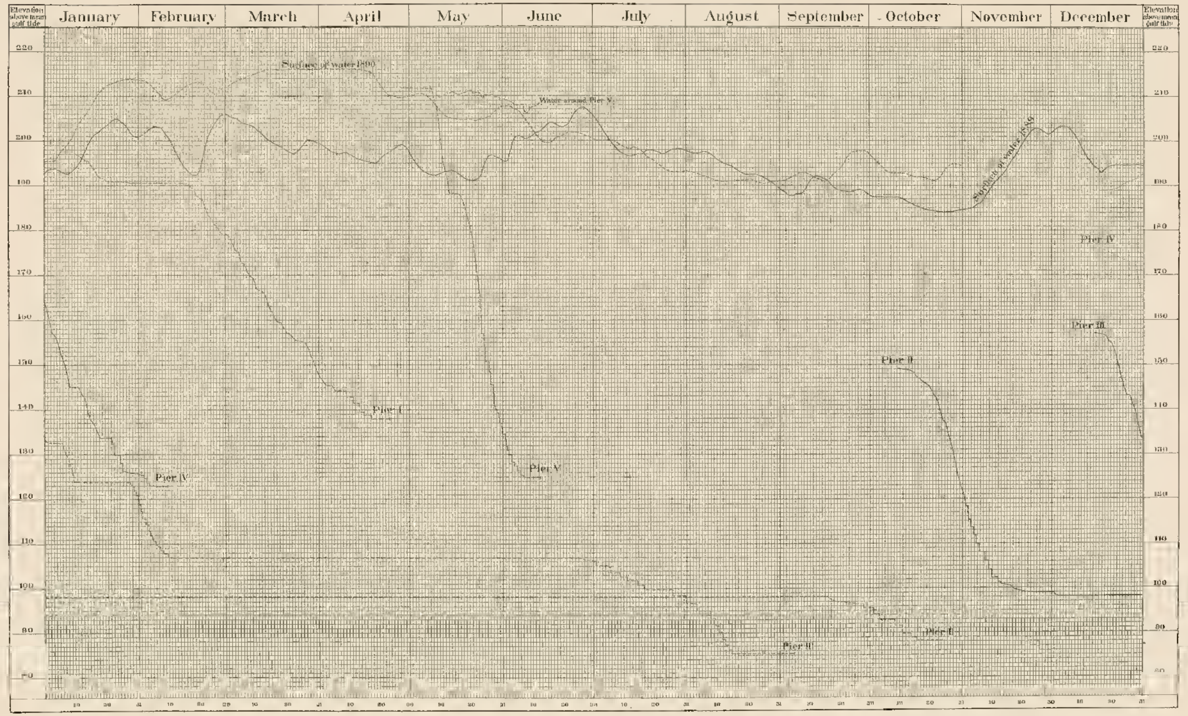
K. C. & M. R. & B. Co.

MEMPHIS BRIDGE

Diagram showing rate of progress in sinking caissons.

1888
1889 ___
1890 . . . .

G. S. Morison
Ch. Eng.

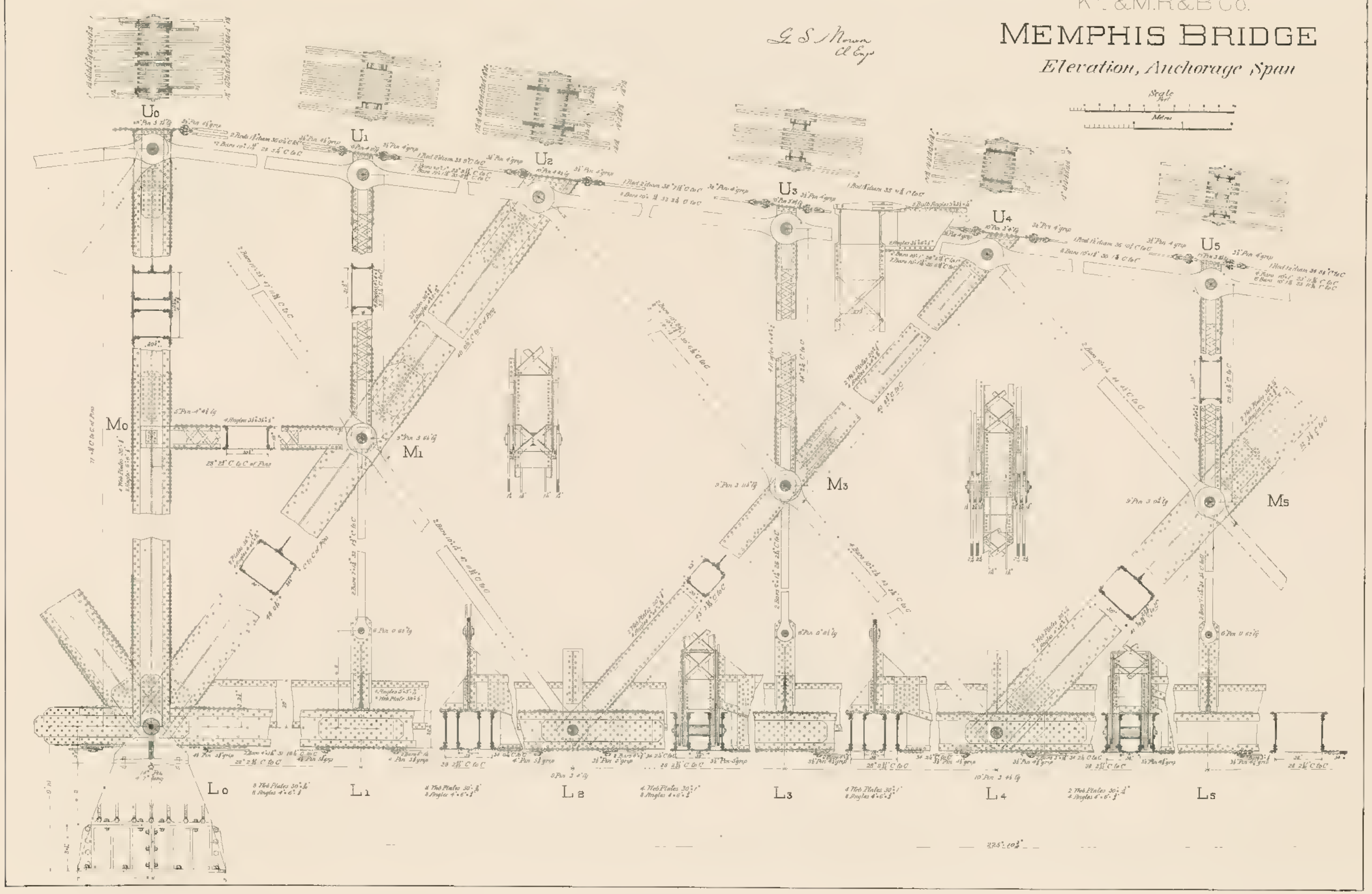


ROBERTS & WELSE PHOTO-LITH. 176 WILLIAM ST. N.Y.

K. &M.R.&B.Co.

MEMPHIS BRIDGE

Elevation, Anchorage Span

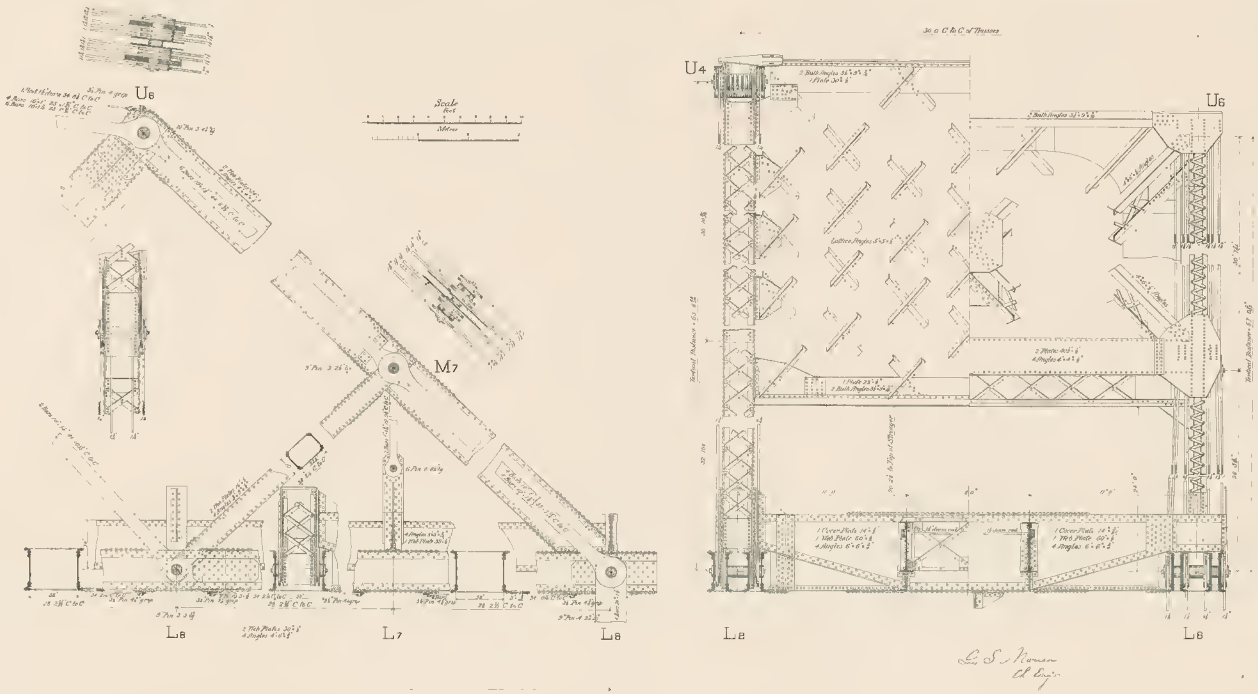


ROBERT A. WELKE PHOTO-LITH 178 WILLIAM ST NY

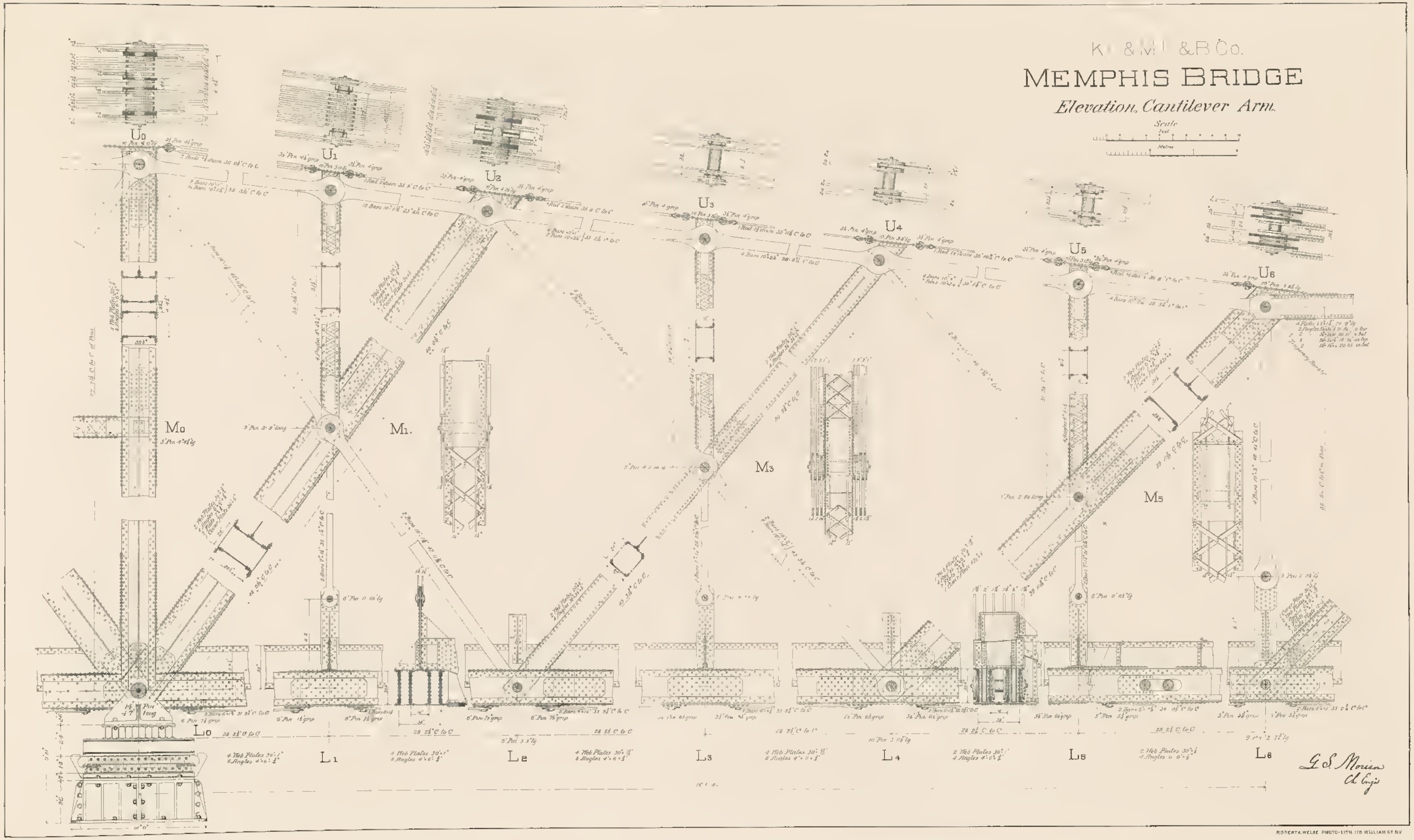
K.C.&M.R.&B.Co.

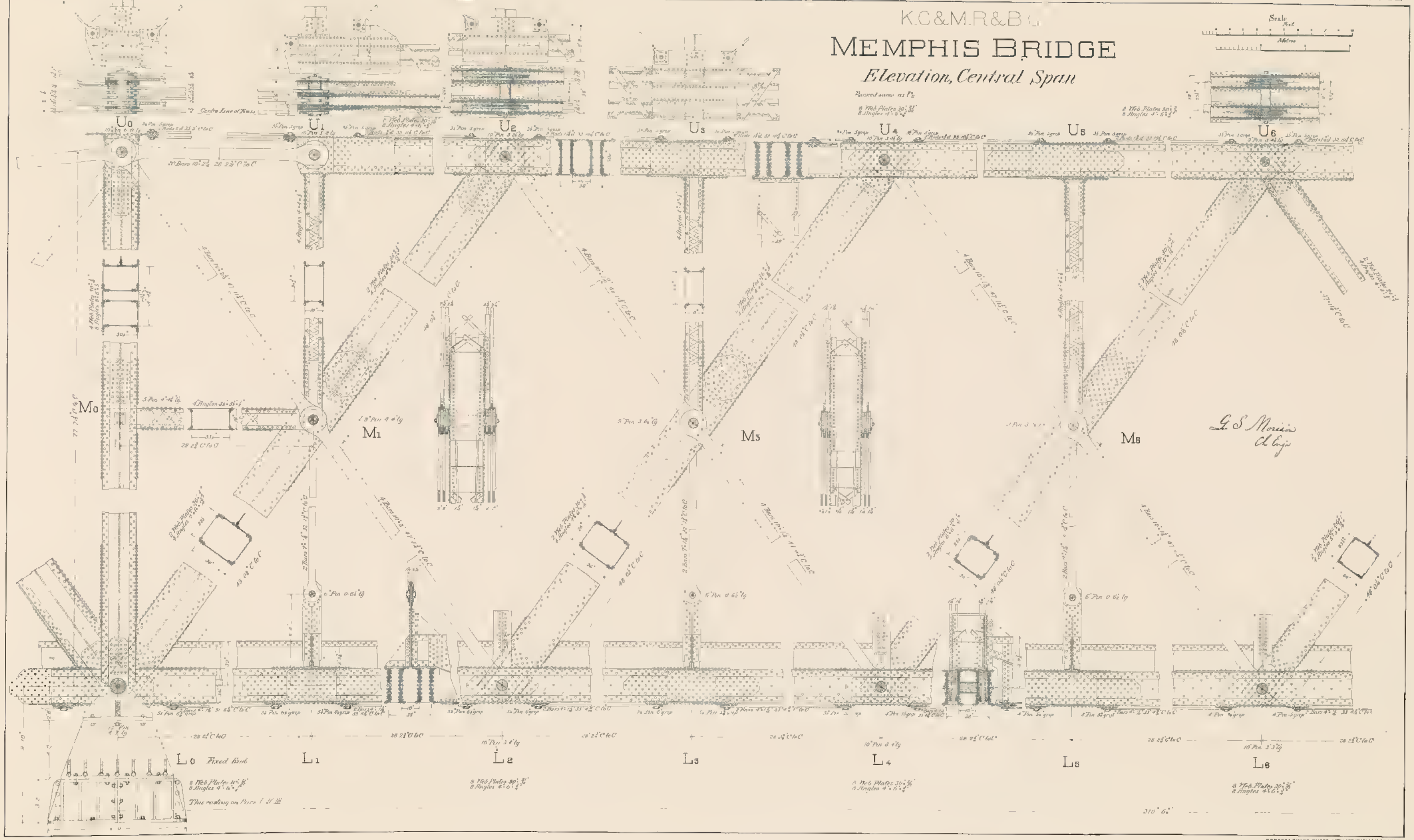
MEMPHIS BRIDGE

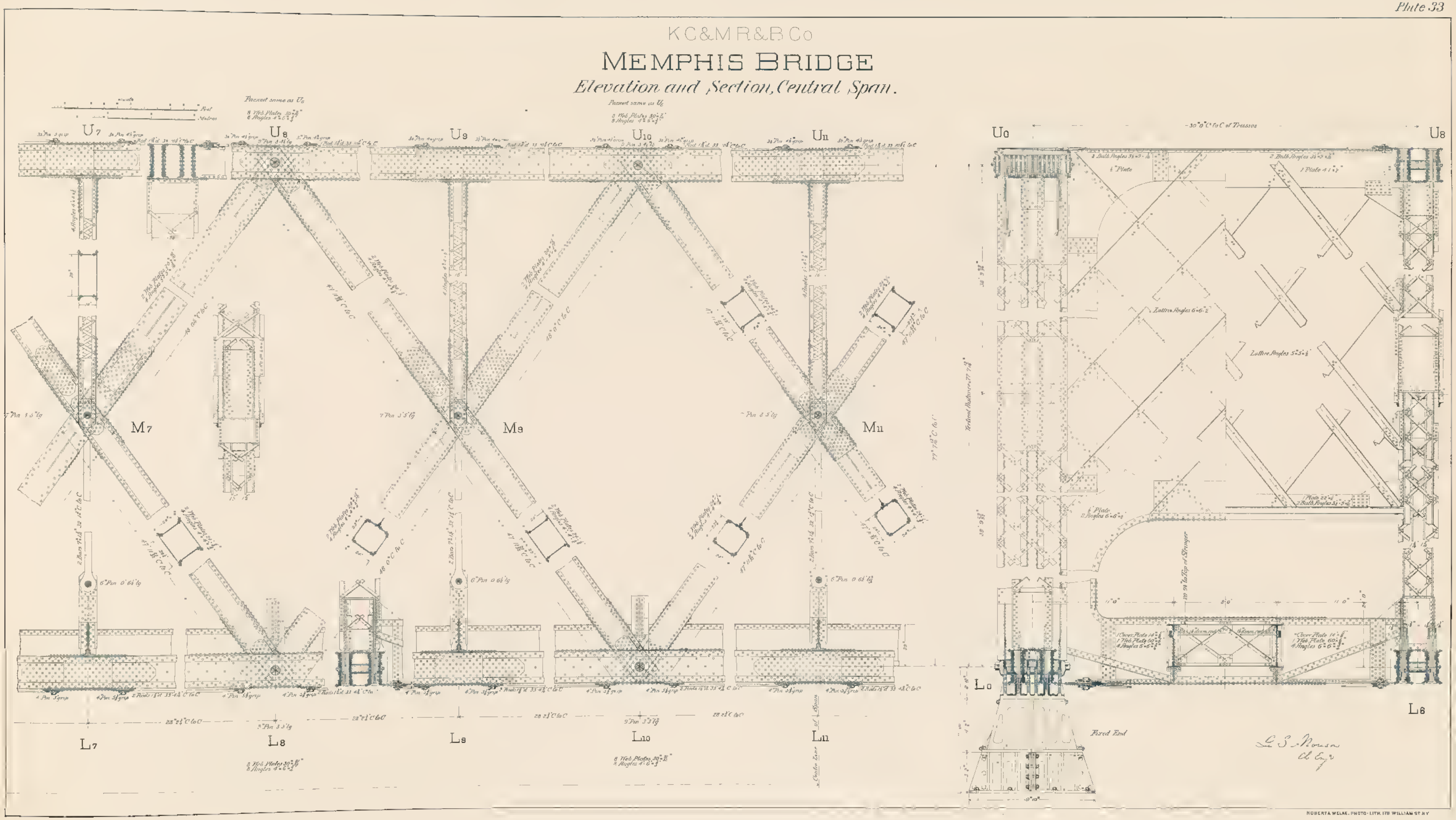
Elevation and Section, Anchorage Span.

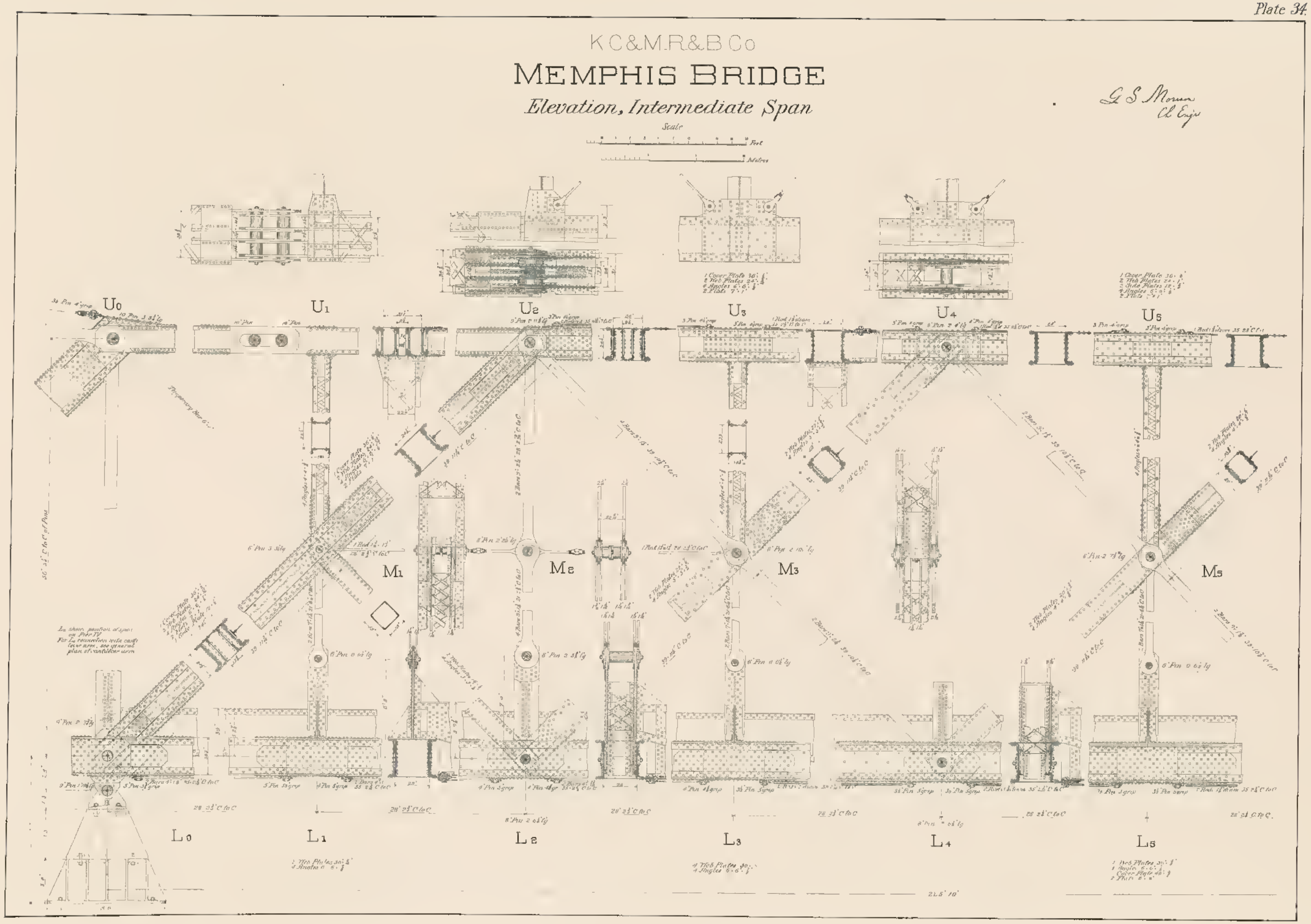


ROBERTA WELKE PHOTO LITH 174 WILLIAM ST NY


MEMPHIS BRIDGE
Elevation, Cantilever Arm.
Scale
U0
U1
U2
U3
U4
U5
U6
M0
M1
M3
M5
L0
L1
L2
L3
L4
L5
L6


K.C.&M.R.&B.Co
MEMPHIS BRIDGE
Elevation, Central Span
Scale
U0
U1
U2
U3
U4
U5
U6
M0
M1
M5
M8
L0 Fixed End
L1
L2
L3
L4
L5
L6
G. S. Morison
Ch. Engr.


K C & M R & B Co
MEMPHIS BRIDGE
Elevation and Section, Central Span.
U7
U8
U9
U10
U11
M7
M9
M11
L7
L8
L9
L10
L11
U0
U8
L0
L8
Fixed End
ROBERTA WELAE, PHOTO-LITH. 170 WILLIAM ST. N.Y.

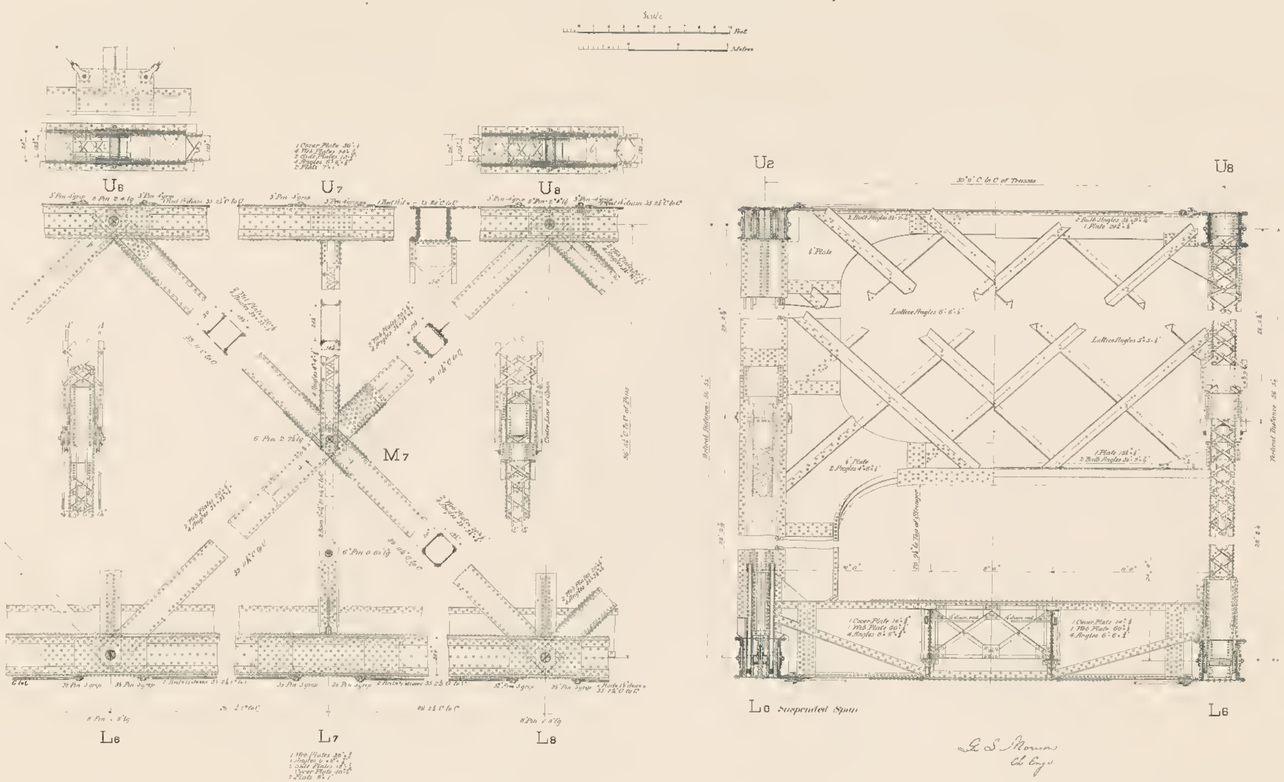


ROBERTA.WEISS PHOTO-LITH. 128 WILLIAM ST. N.Y.

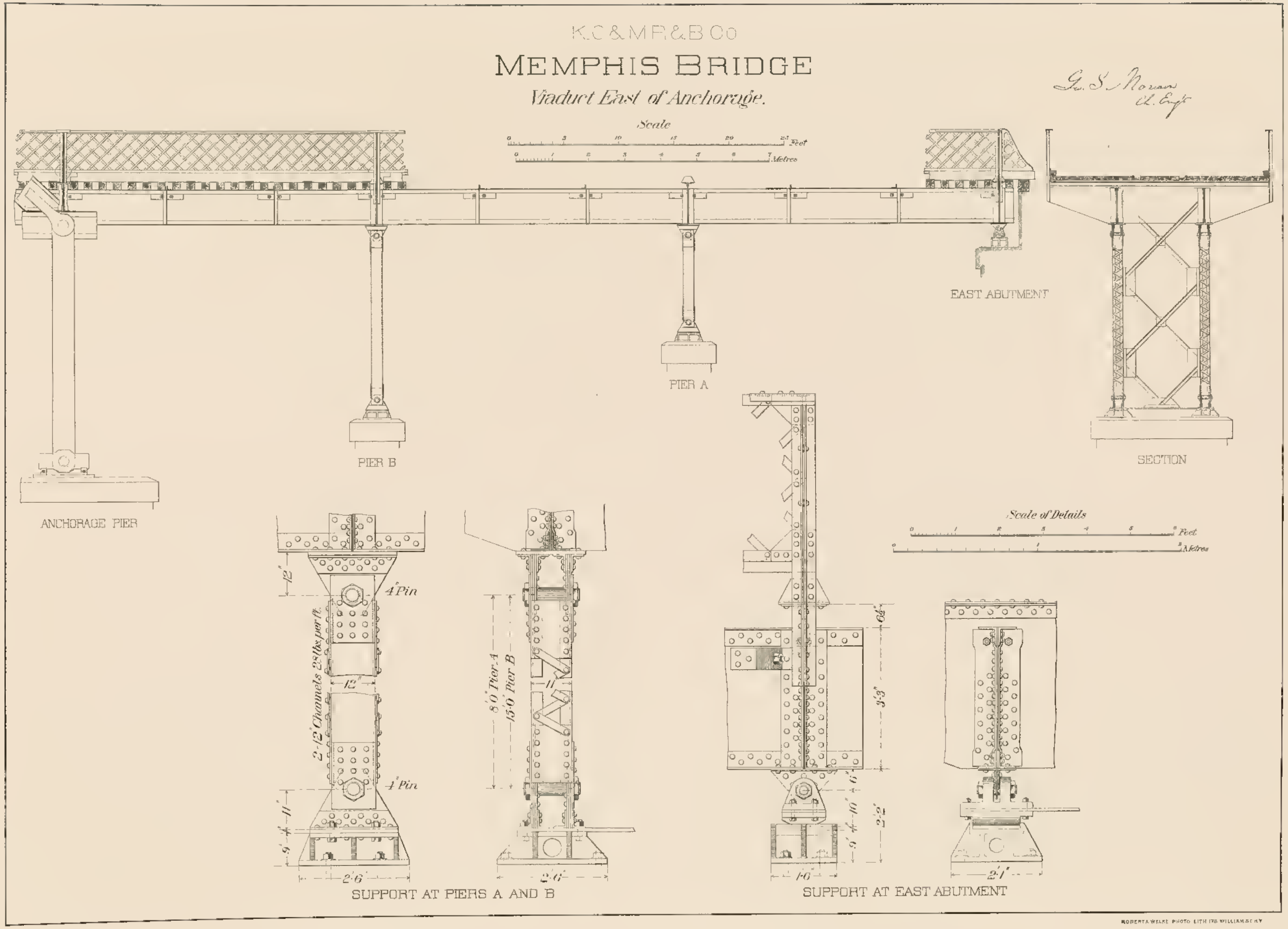
K.C.&M.R.&B.Co.

MEMPHIS BRIDGE

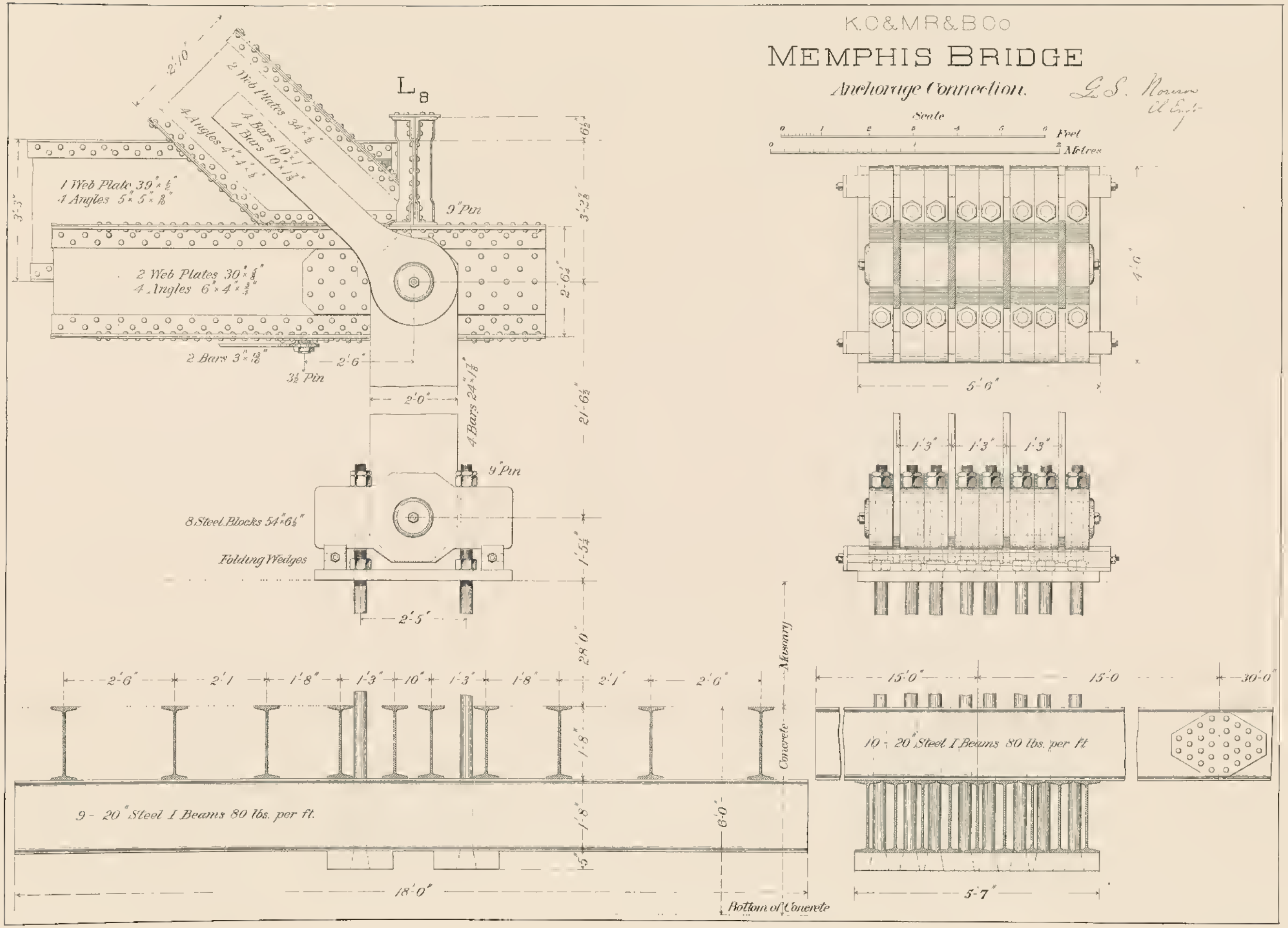
Elevation and Section, Intermediate Span



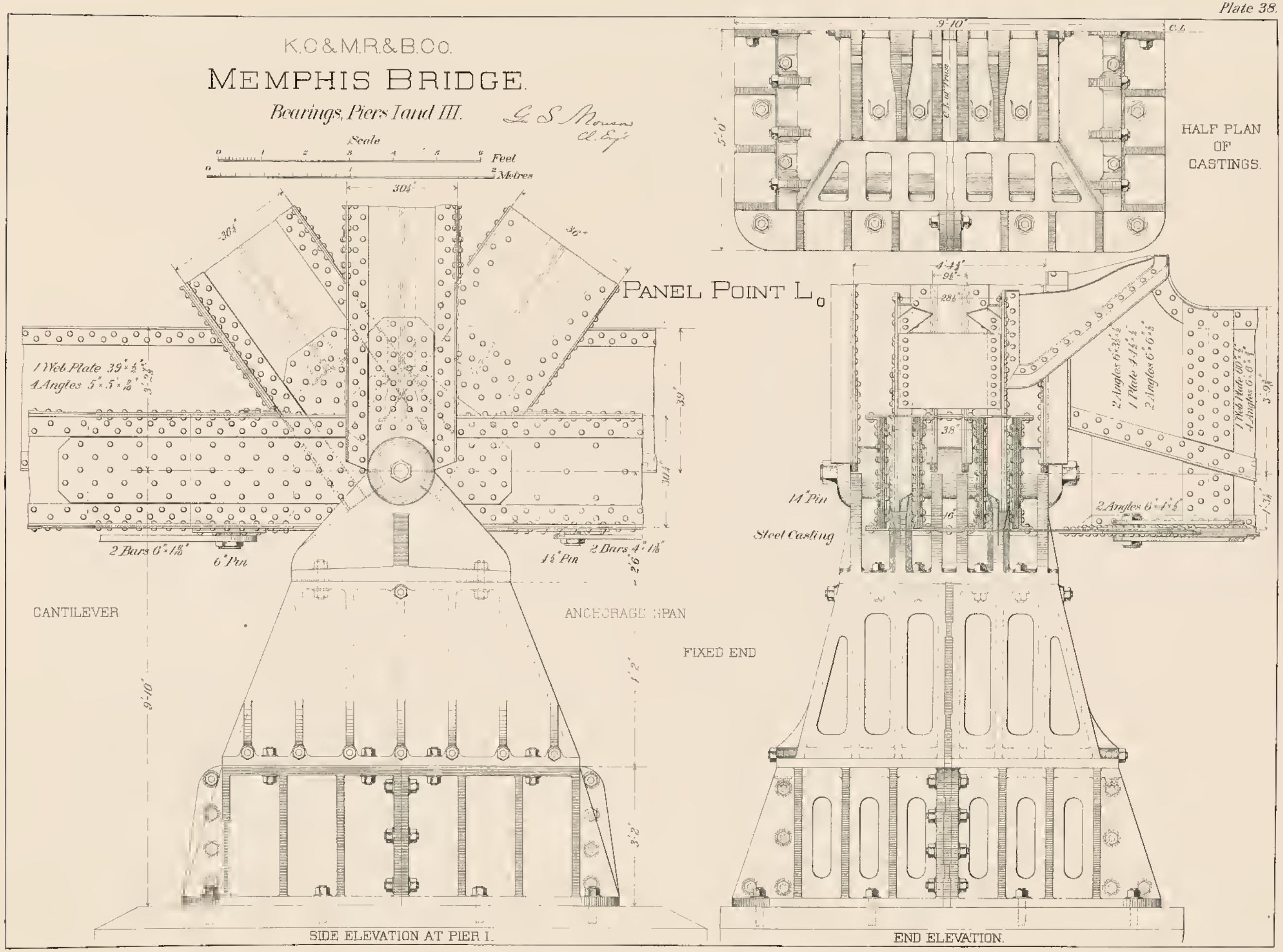
ROBERTA WELKE PHOTO-LITH 126 WILLIAM ST NY



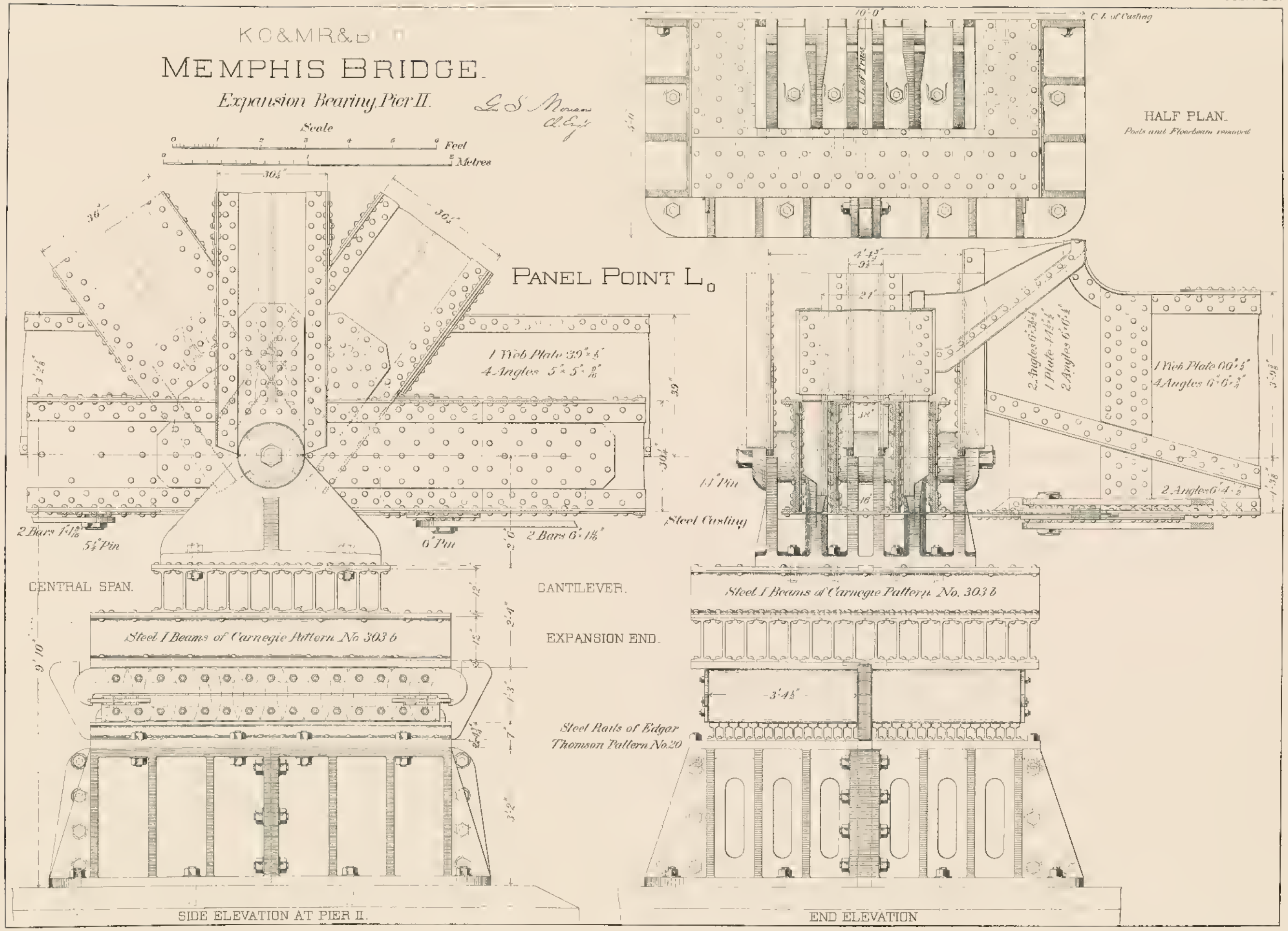
ROBERTA WELKE PHOTO. LITH. 178 WILLIAM ST. NY



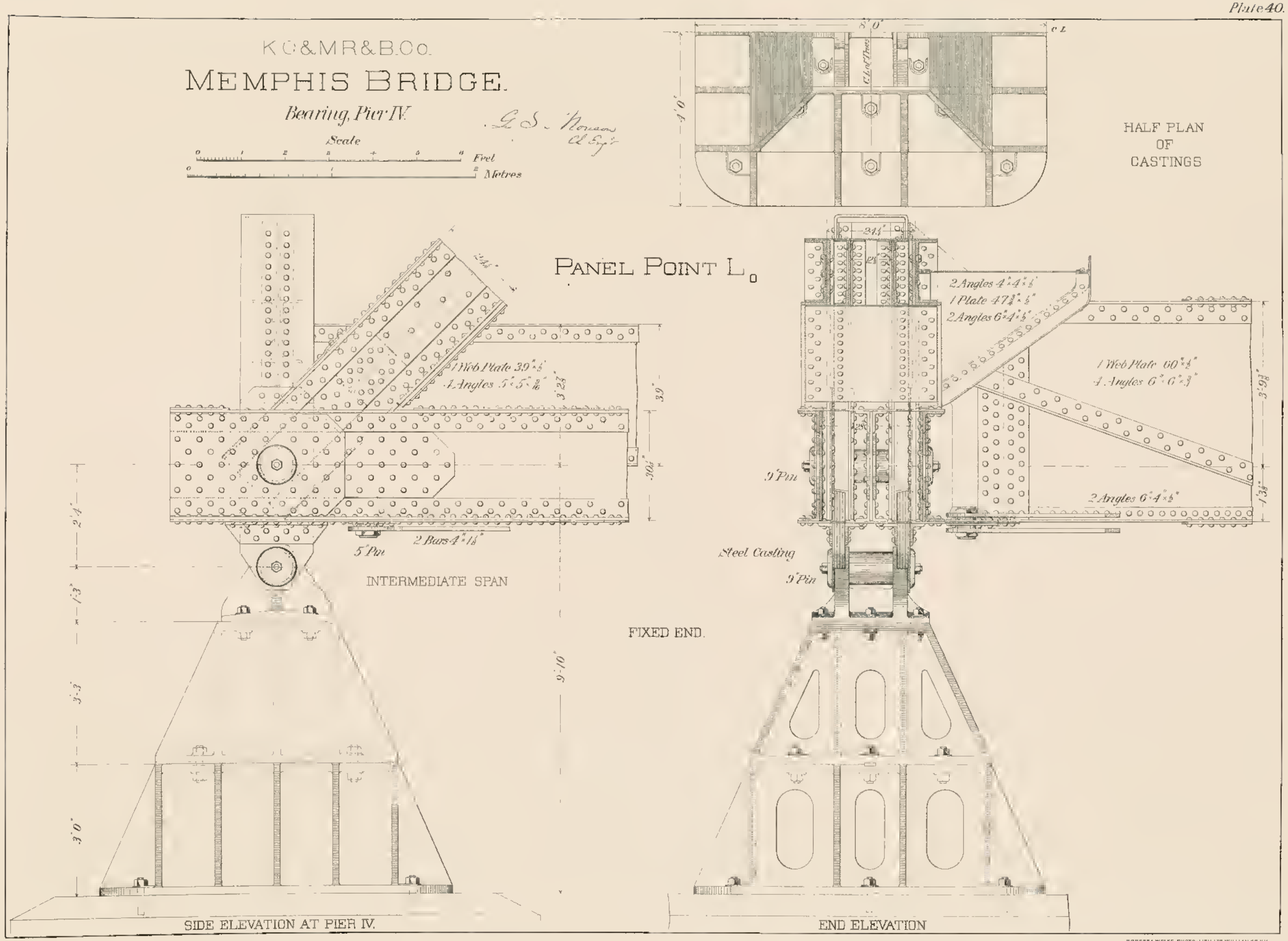
ROBERTA WEIBE PHOTO LITH 178 WILLIAM ST. N.Y.

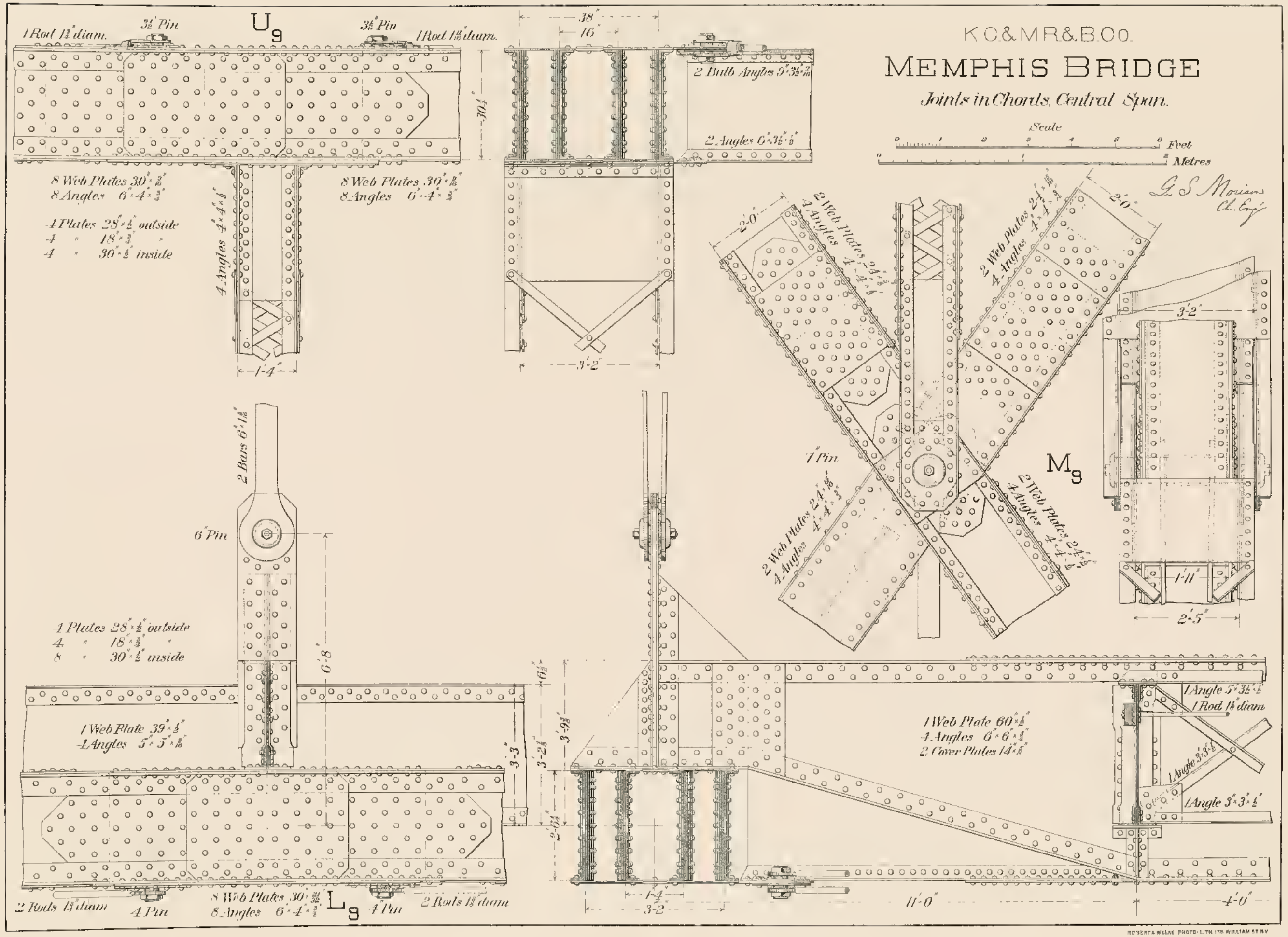


ROBERT A. WELKE PHOTO-LITH 174 WILLIAM ST. N.Y.



ROBERT A WELKE PHOTO-LITH. 178 WILLIAM ST. N.Y.


K.C.&M.R.&B.Co.
MEMPHIS BRIDGE.
Bearing, Pier IV.
Scale
Feet
Metres
HALF PLAN
OF
CASTINGS
PANEL POINT L_0
1 Web Plate 39" x ½"
4 Angles 5" x 5" x 9/16"
2 Angles 4" x 4" x ½"
1 Plate 47½" x ½"
2 Angles 6" x 4" x ½"
1 Web Plate 60" x ½"
4 Angles 6" x 6" x ⅜"
2 Angles 6" x 4" x ½"
9" Pin
5" Pin
2 Bars 4" x 1½"
Steel Casting
9" Pin
INTERMEDIATE SPAN
FIXED END.
SIDE ELEVATION AT PIER IV.
END ELEVATION
ROBERTA WELKE PHOTO-LITH 178 WILLIAM ST. N.Y.



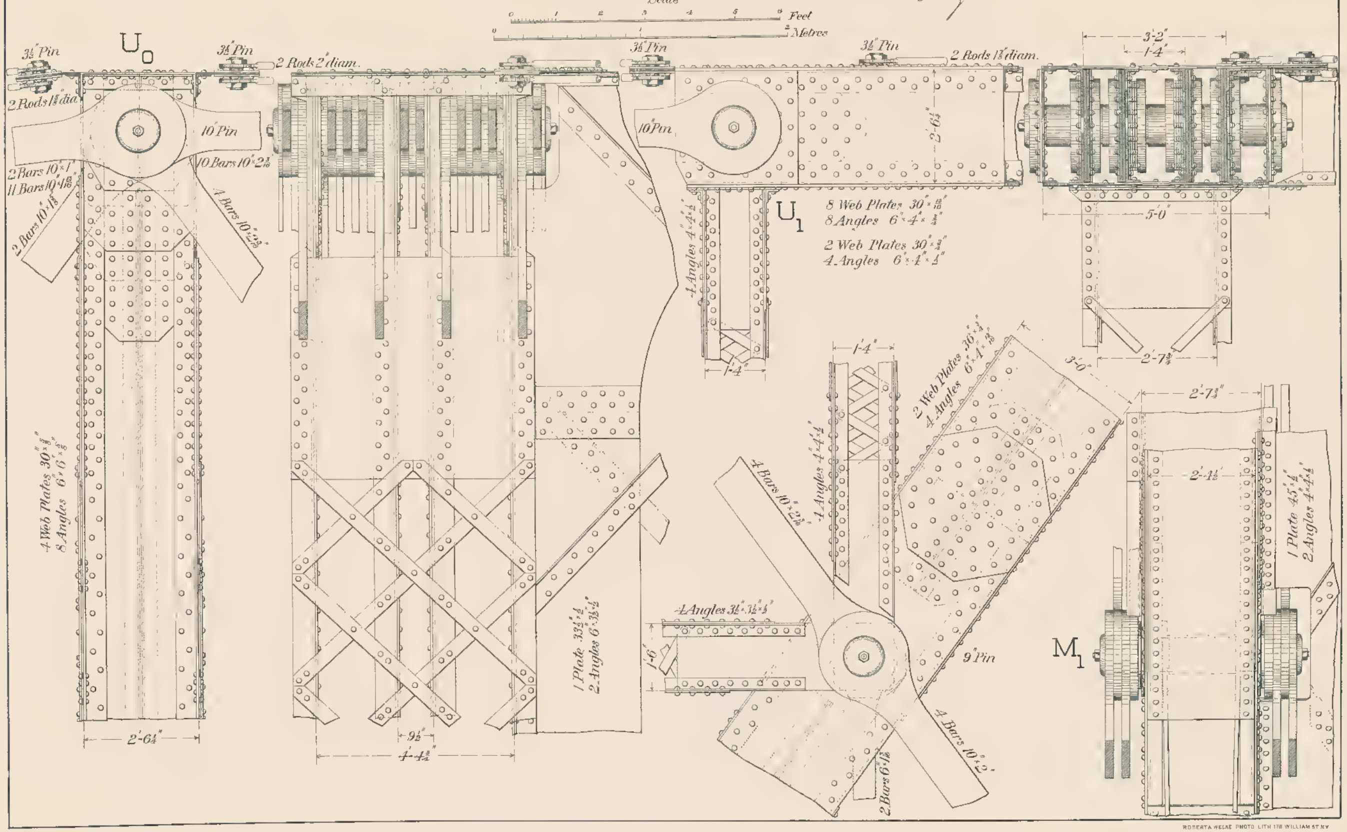
ROBERTS & WELKE PHOTO-LITH. 178 WILLIAM ST. N.Y.

K.C.& M.R.& B.Co.

MEMPHIS BRIDGE

U_0 Panel Point, Central Span.

Geo. S. Morison
Ch. Eng.



ROBERTA HELKE PHOTO. LITH 178 WILLIAM ST. N.Y.

K.C.&M.R.&B.Co.

MEMPHIS BRIDGE

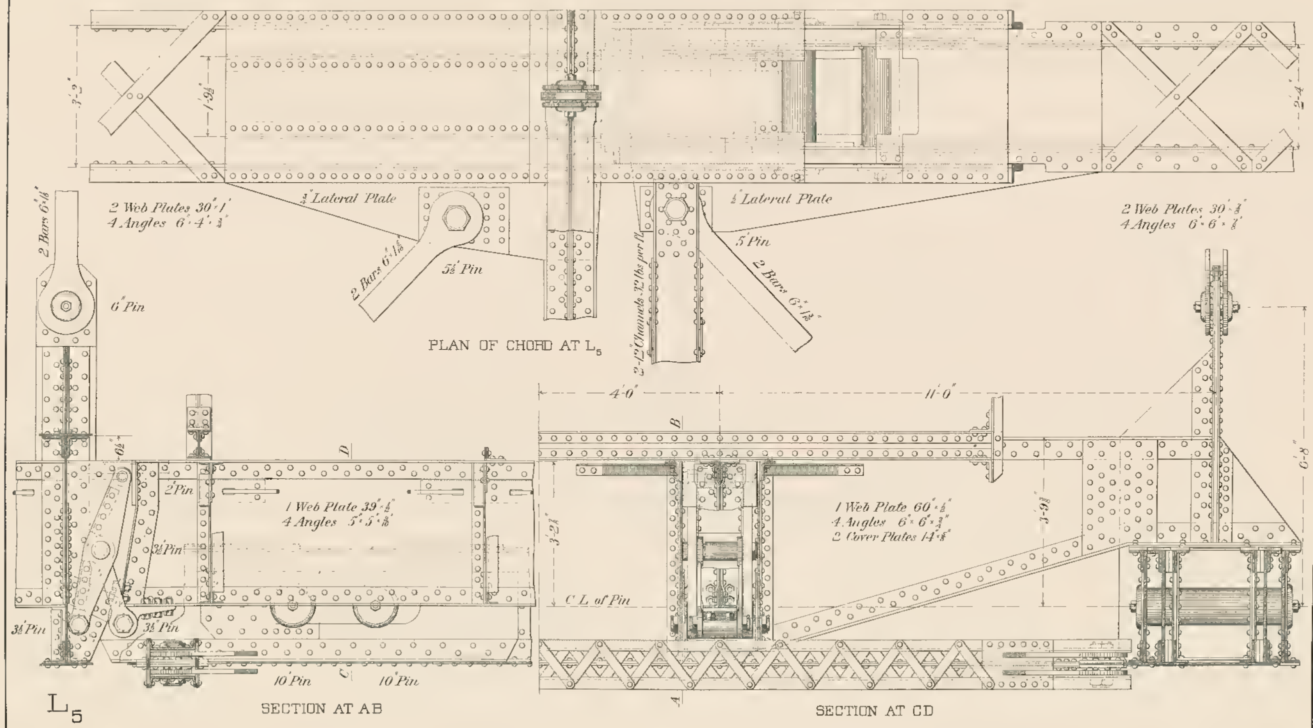
Expansion Joints: Lower Chord and Stringers, Intermediate Span.

Scale

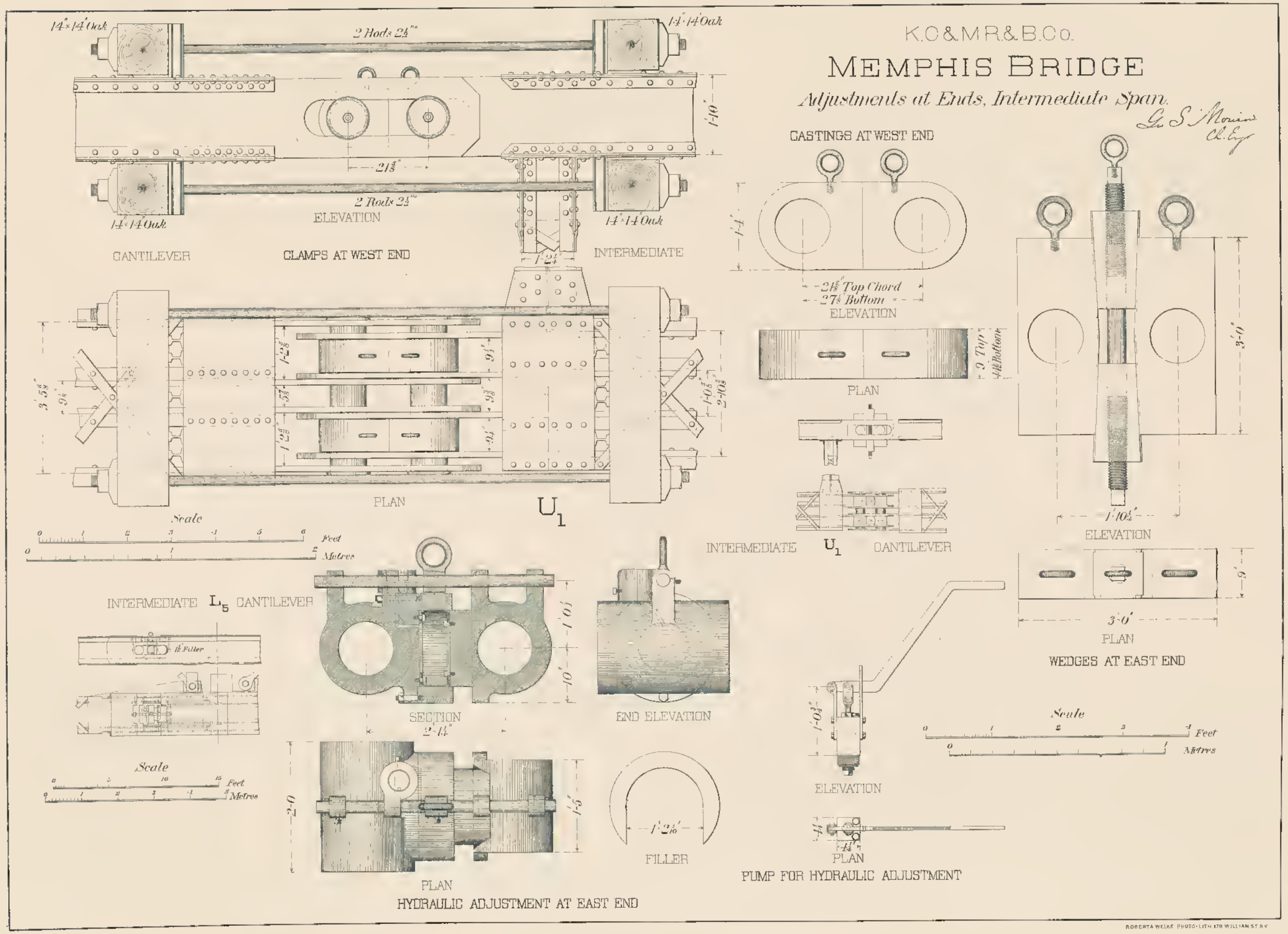
0 1 2 3 4 5 6 Feet

0 1 2 Metres

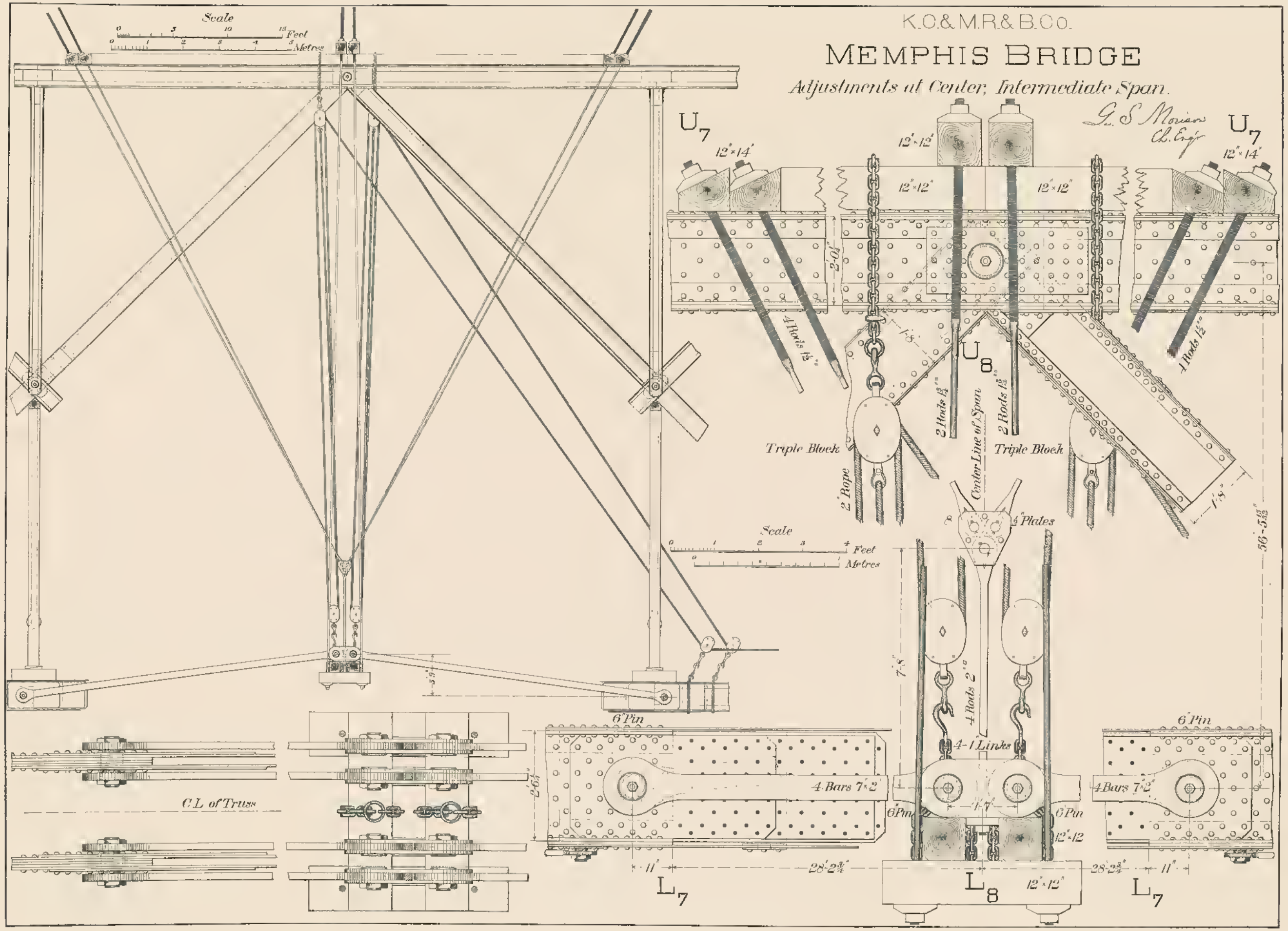
G. S. Morison
Ch. Engr.



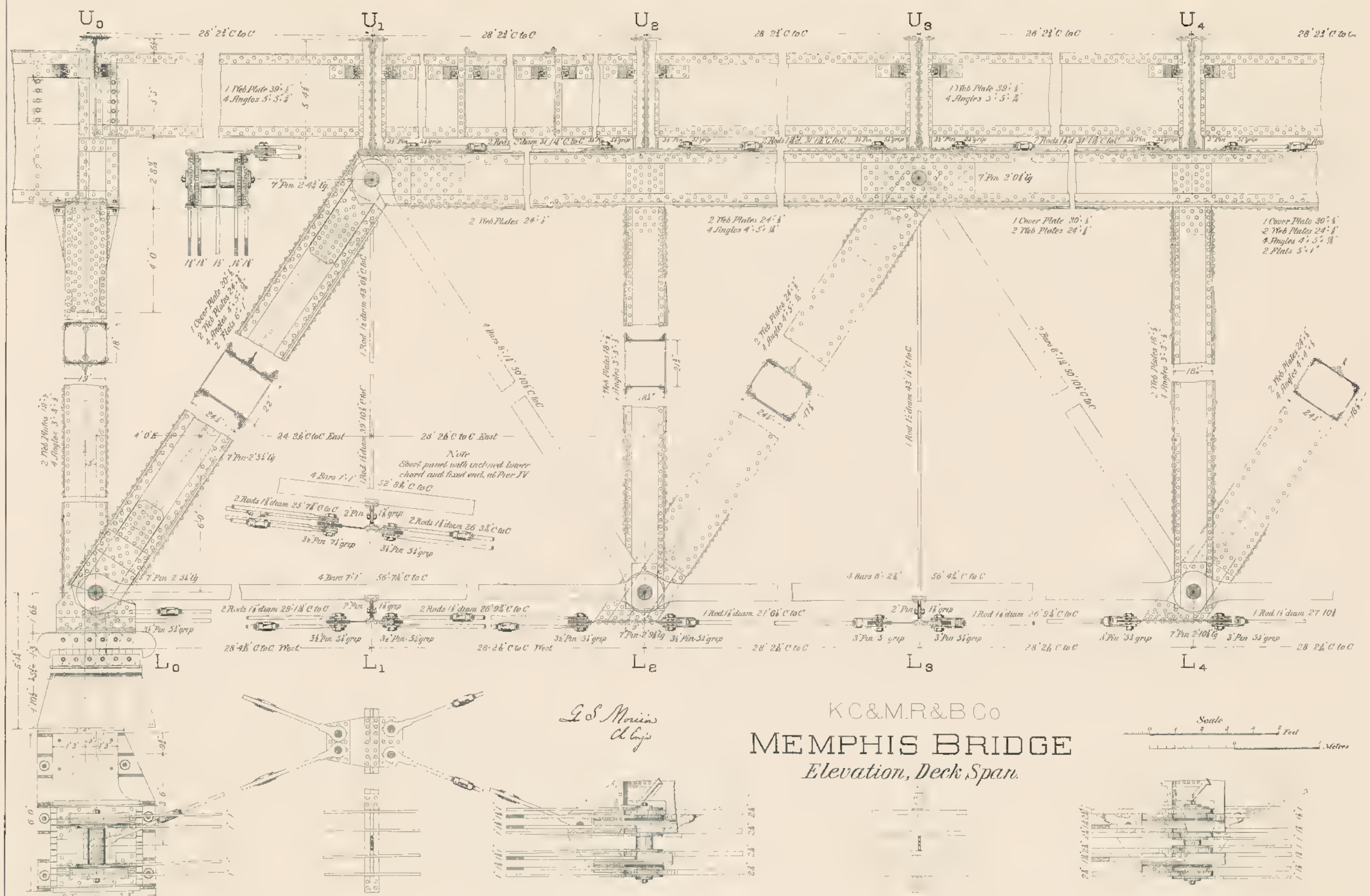
ROBERTA WEIAE PHOTO-LITH 178 WILLIAM ST. N.Y.



ROBERTA WELKE PHOTO-LITH 179 WILLIAM ST N.Y.



ROBERTA WELKE PHOTO LITH 178 WILLIAM ST N.Y.

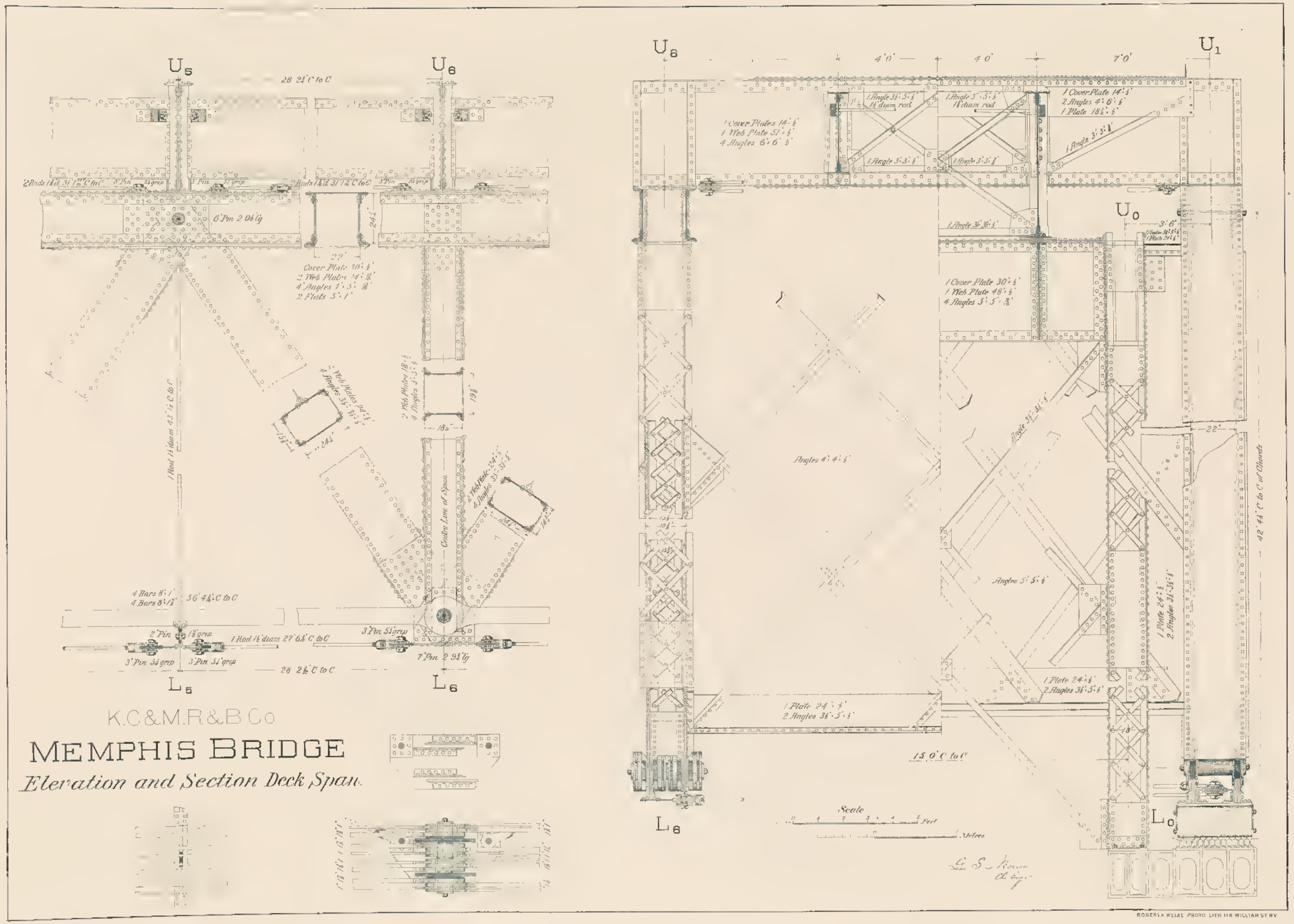


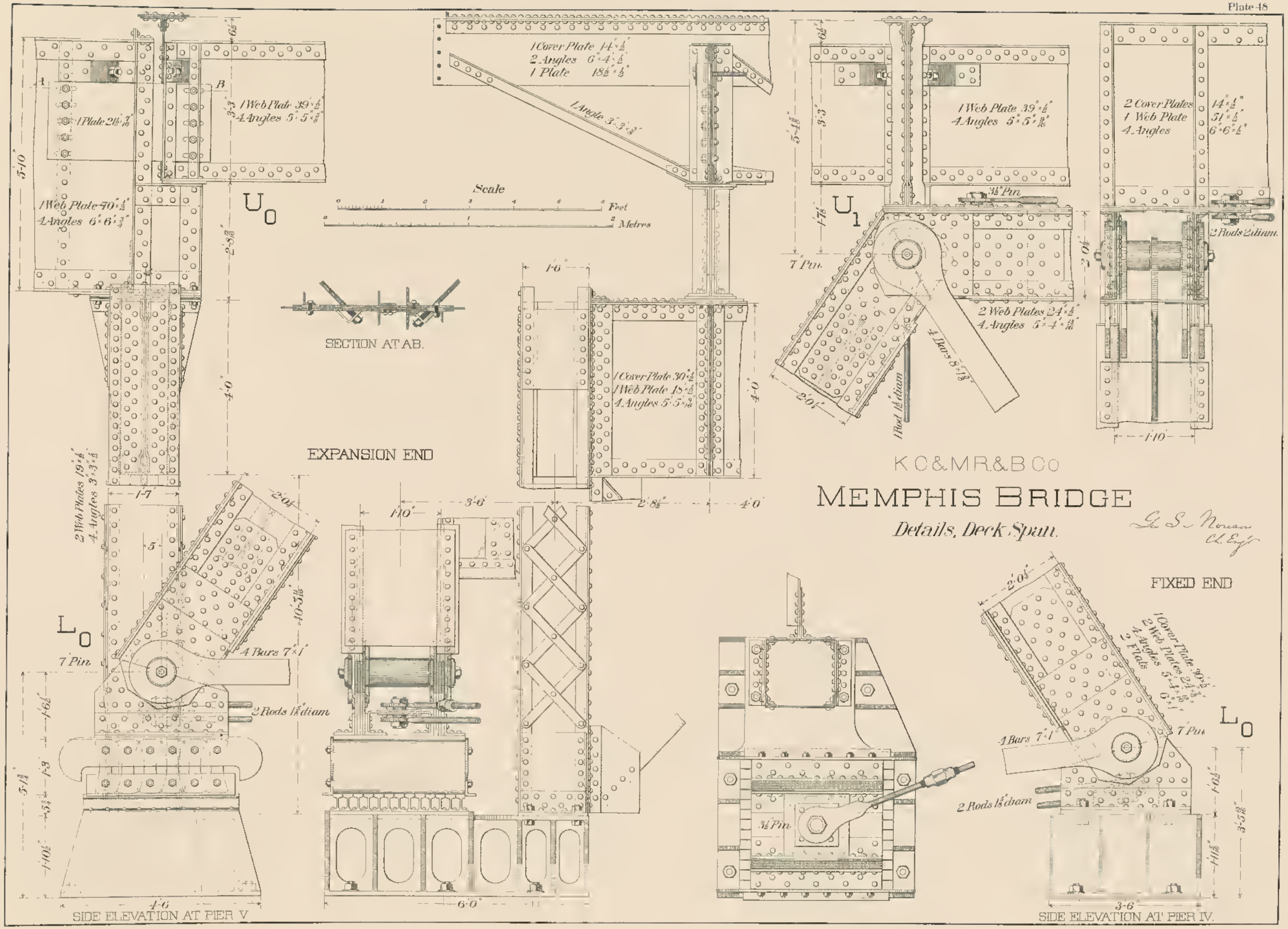
K.C.&M.R.&B.Co.

MEMPHIS BRIDGE

Elevation, Deck Span.

ROBERTS & WELKE PHOTO LITH 118 WILLIAM ST N.Y.


U5
U6
L5
L6
U1
U0
L0
Centre Line of Span
Scale
K.C.&M.R.&B.Co
MEMPHIS BRIDGE
Elevation and Section Deck Span.


K.C.&M.R.&B.Co.
MEMPHIS BRIDGE
Details, Deck Span.
EXPANSION END
FIXED END
SECTION AT A.B.
Scale
Feet
Metres
SIDE ELEVATION AT PIER V.
SIDE ELEVATION AT PIER IV.
1 Cover Plate 14"×½"
2 Angles 6"×4"×½"
1 Plate 18½"×½"
1 Web Plate 39"×½"
4 Angles 5"×5"×⅜"
1 Web Plate 40"×½"
4 Angles 6"×6"×⅜"
2 Cover Plates 14"×½"
1 Web Plate 51"×½"
4 Angles 6"×6"×½"
2 Web Plates 24"×½"
1 Cover Plate 30"×½"
7 Pin
2 Rods 1⅝" diam
4 Bars 7"×1"
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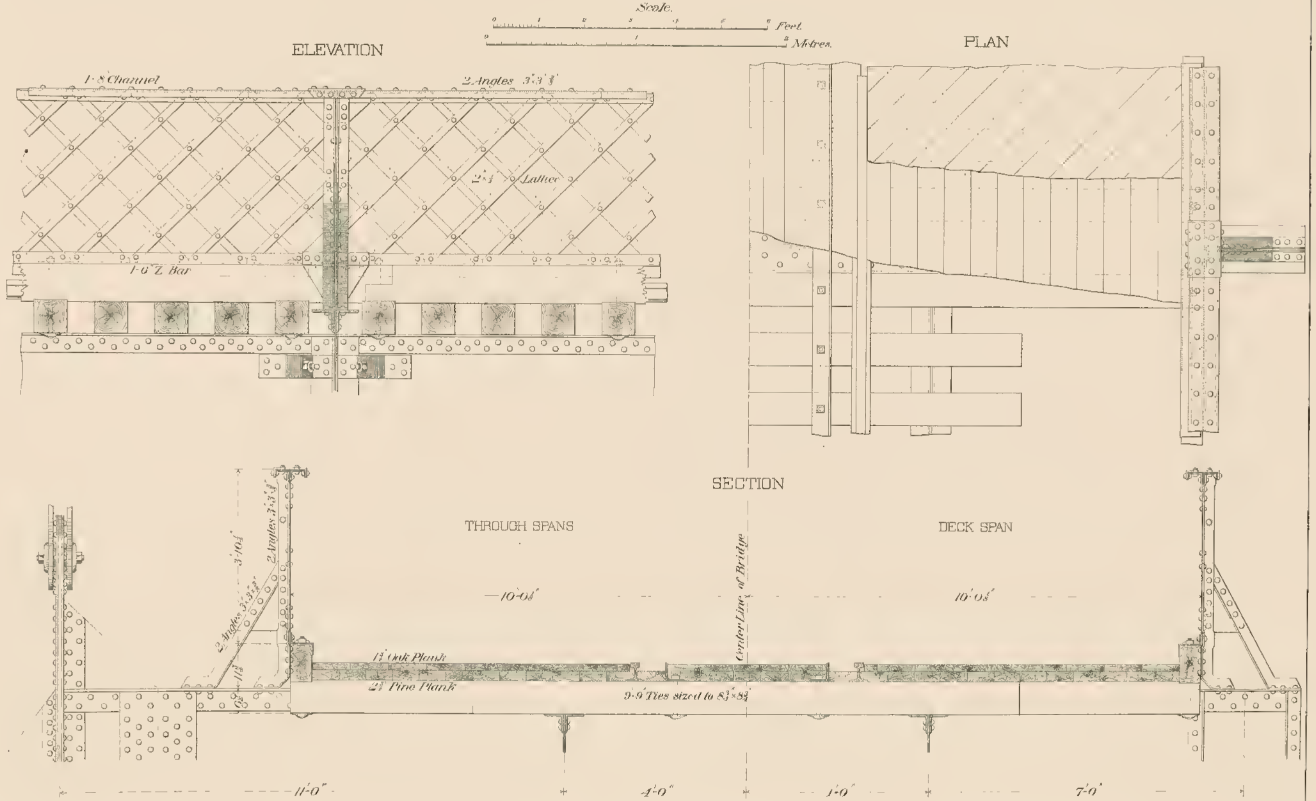
MEMPHIS BRIDGE

Floor.



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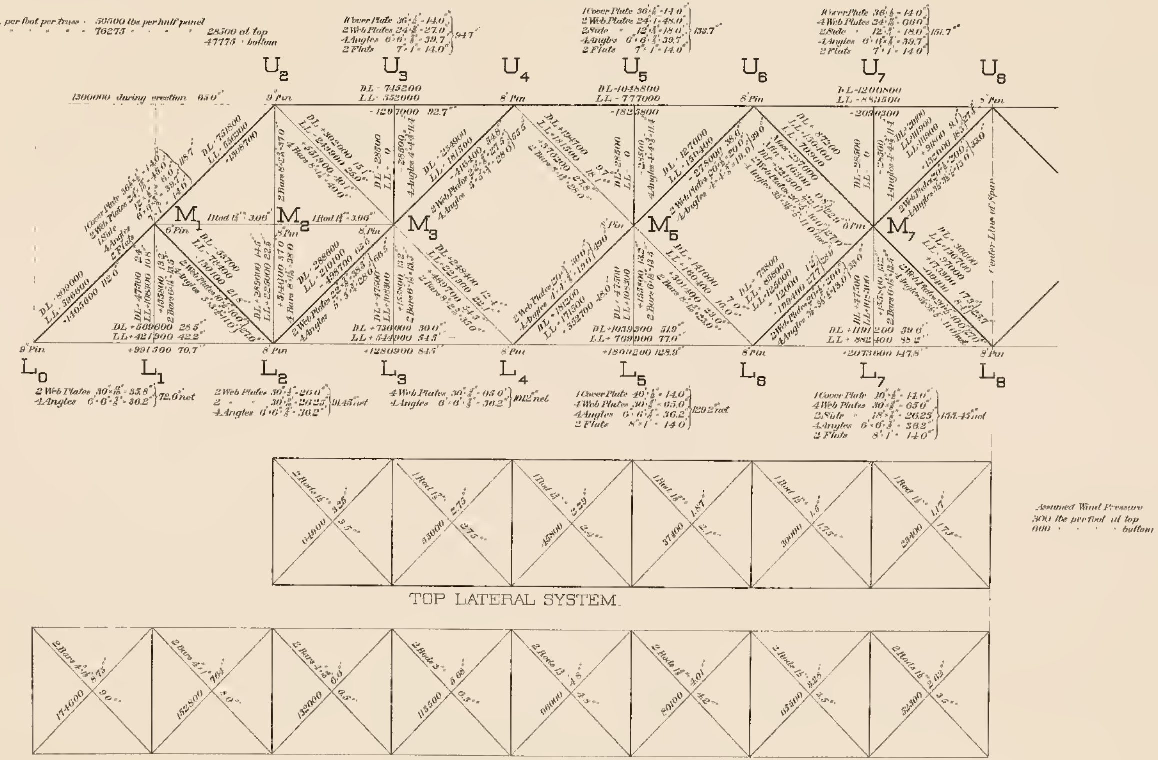
MEMPHIS BRIDGE

Strain Sheet, Intermediate Span.

G. S. Morison
Ch. Engr.

Intermediate Span 451'-8" C to C End Pins, equal sixteen (16) half panels of 28'-2¼" each; 30-0 C to C Trusses; 56'-5½ C to C Chords

Live Load 2000 lbs. per foot per truss = 56500 lbs per half panel
" " 2700 " " " " " = 76275 " " " " 28500 at top, 47775 " bottom



TOP LATERAL SYSTEM.

BOTTOM LATERAL SYSTEM

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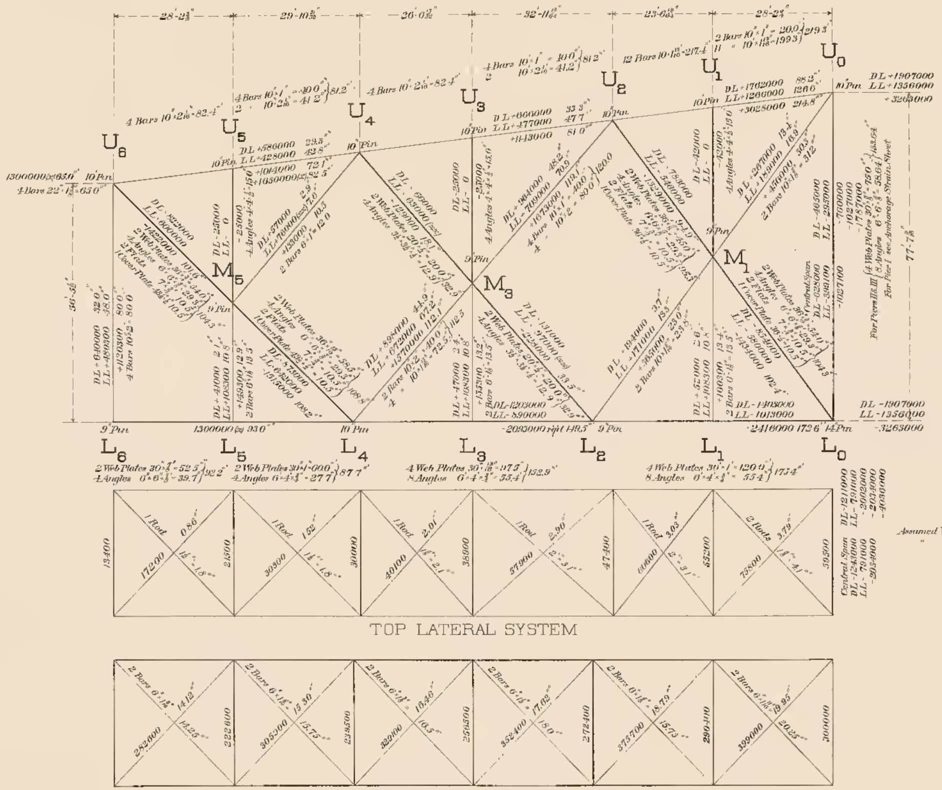
MEMPHIS BRIDGE

Strain Sheet, Cantilever Arm

G. S. Morison
Ch. Engr.



Cantilever Arm 169'-4½" C to C End Pins; equal six (6) half panels of 28'-2¾" at Bottom Chord, 30'-0" C. to C. of Trusses

Actual Dead Load taken in Strain Sheet.					
L_0	52000			U_0	31000
L_1	52000	M_1	25000	U_1	42000
L_2	56000			U_2	40000
L_3	47000	M_3	27000	U_3	25000
L_4	64000			U_4	17000
L_5	41000	M_5	12000	U_5	25000
L_6	15000 625000			U_6	15000

(x) Occurs only during erection
(xx) Assuming LL of 108300 applied at L_5

Live Load per Truss
2000 lbs. per foot - 56500 lbs. per one half panel.

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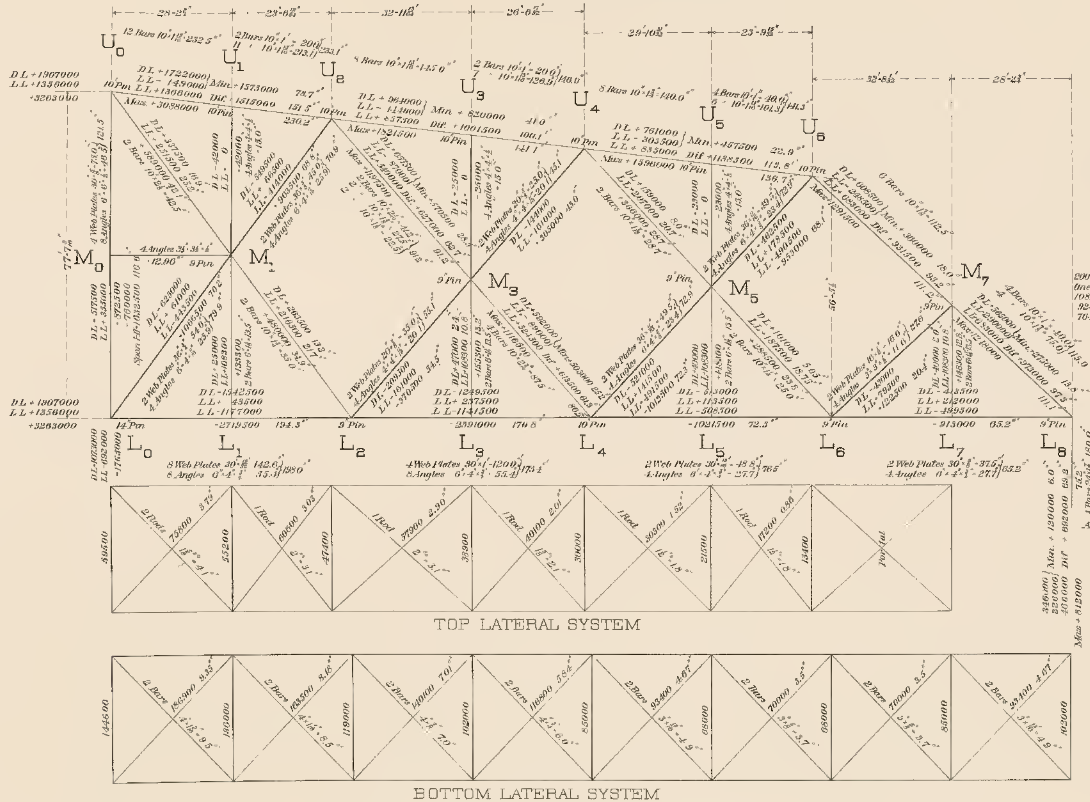
Strain Sheet, Anchorage Arm.

Geo. S. Morison
Ch. Engr



Anchorage Span 225'-10" C to C End Pins equal eight (8) half panels of 28'-2¼" at Bottom Chord. 30' 0" C to C of Trusses

Dead Load per Truss					
L_0	52000			U_0	31000
L_1	52000	M_1	25000	U_1	42000
L_2	56000			U_2	40000
L_3	47000	M_3	27000	U_3	25000
L_4	64000			U_4	17000
L_5	40000	M_5	23000	U_5	23000
L_6	45000			U_6	21000
L_7	40000	M_7	19000		
L_8	40000				

Live Load per Truss

2000 lbs per foot = 56500 lbs per one half panel
One half panel load (=56500 lbs) at L_8
108300 lbs. applied at L_7 for strain in L_8M_7
92400 " " " L_7L_8 " " M_7L_8
76400 " " " $L_7L_8L_6$ " " $U_6M_5M_5U_4L_5M_5$

Assumed Wind Pressure 300 lbs. per ft. at top
" " " 600 " " " bottom

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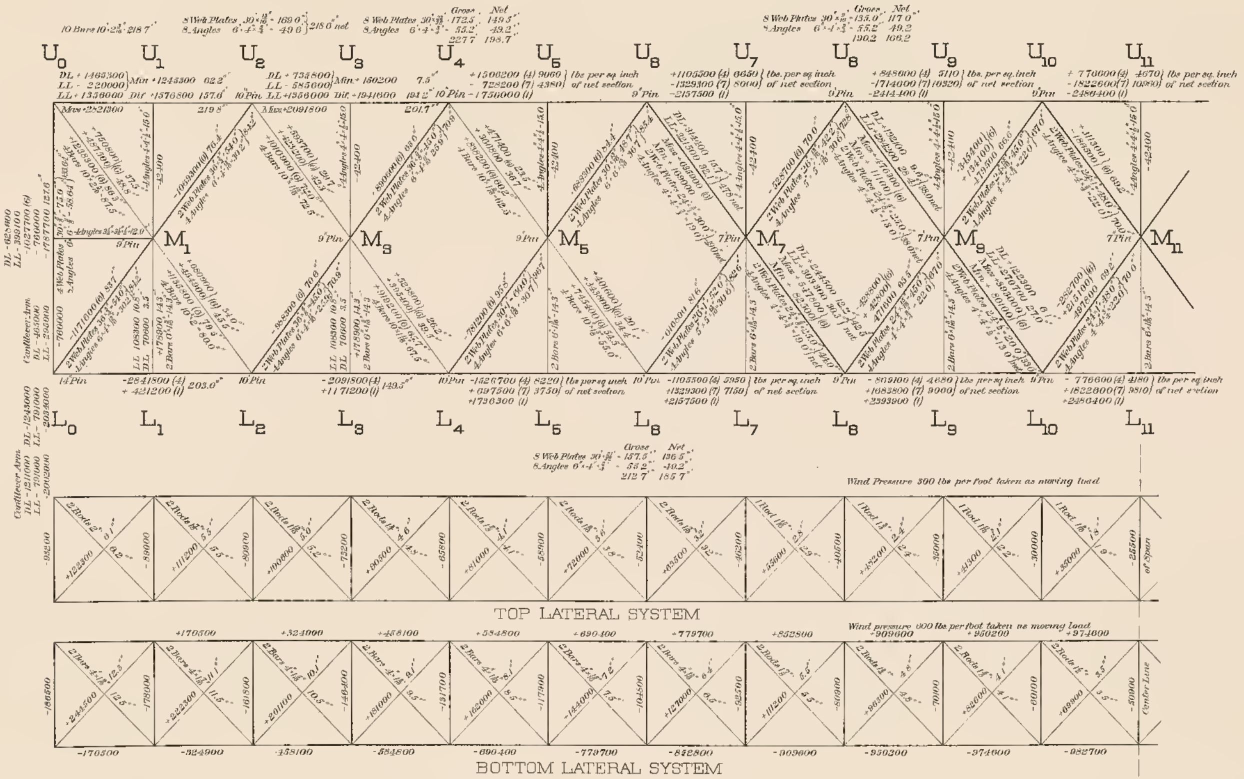
Strain Sheet. Central Span.

G. S. Morison
Ch. Engr.



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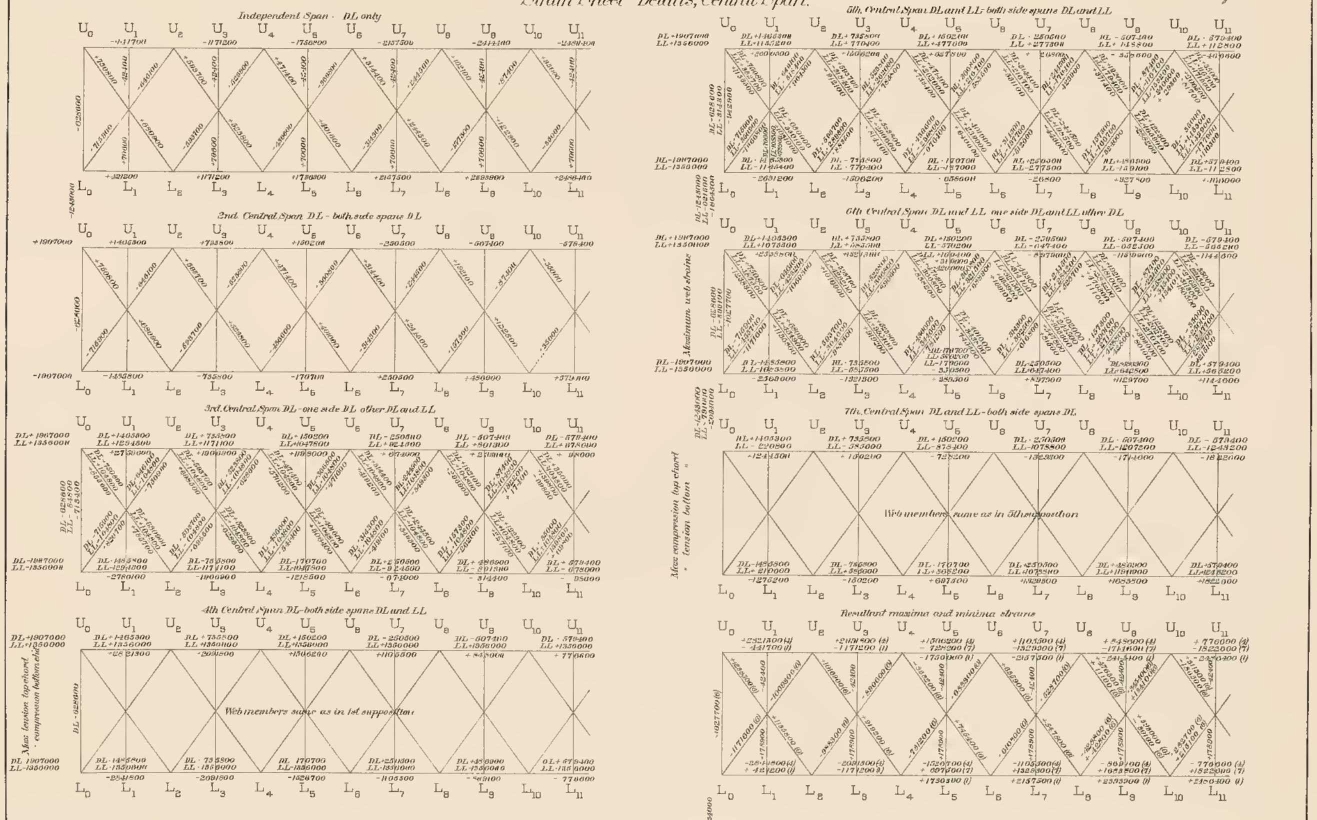
Strain Sheet Details, Central Span.

Central Span 621'-0½" C to C End Pins; equal twenty two (22) half panels of 28'-2⅝" each
30'-0" C to C Trusses, 77'-7⅛" C to C Chords

DL - 4000 lbs. per foot per truss - 113000 lbs per ½ panel {42400 lbs at top, 70600 " " bottom
LL - 2000 " " " " - 56500 " ½ "
EL - 3000 " " " " - 84750 " ½ "

G. S. Morison
Ch. Eng.



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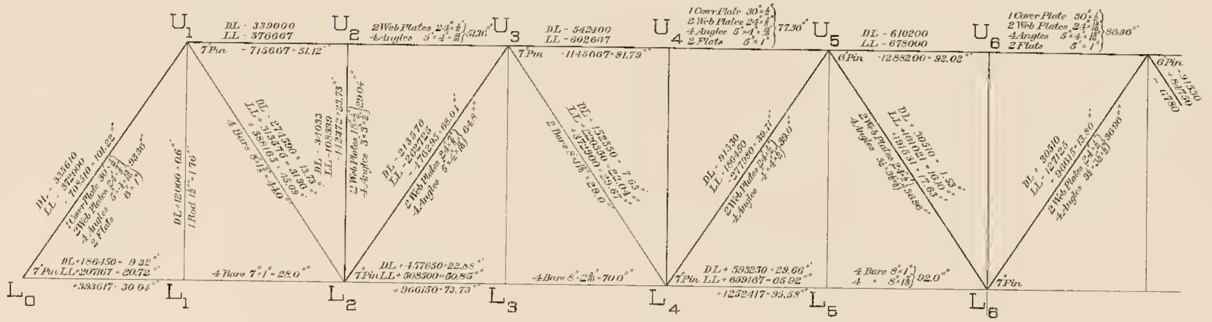
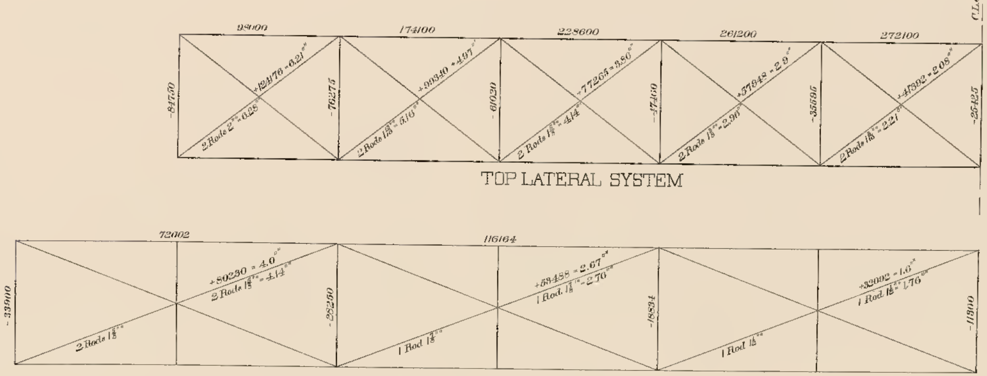
Strain Sheet, Deck Span.

G. S. Morison
Ch. Eng.





Deck Span 338'-9" C. to C. End Pins, twelve equal half panels of 28'-2¼" each; 22'-0" C. to C. Trusses; 42'-4½" C. to C. Chords.

Assumed Loads

Dead Load per panel per truss - 50850 lbs.
Live " " " " " - 56500 "

Camber 8"

Wind Pressure

200 lbs. per lineal foot on Lower Chord
600 " " " " " Upper "

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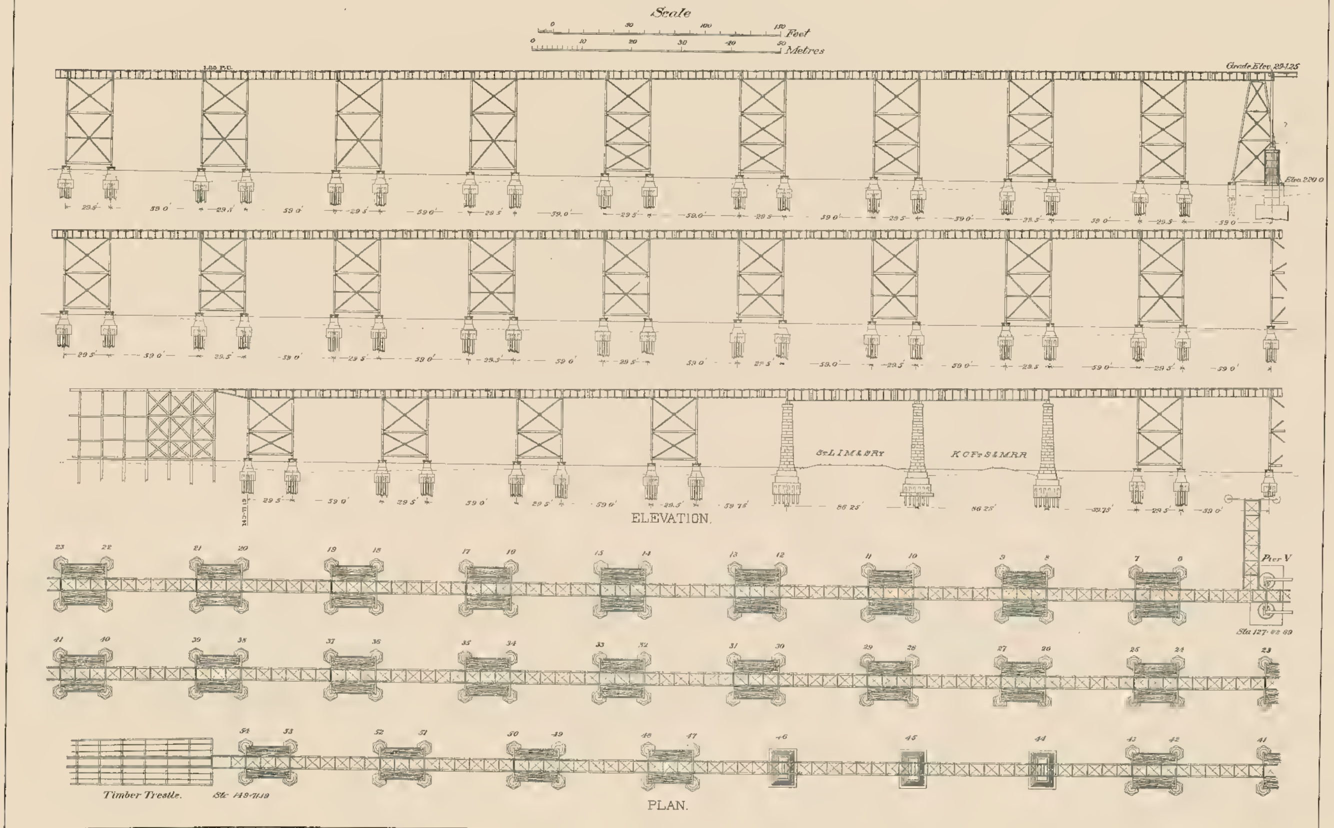
West Approach Viaduct.

G. S. Morison
Ch. Eng'r



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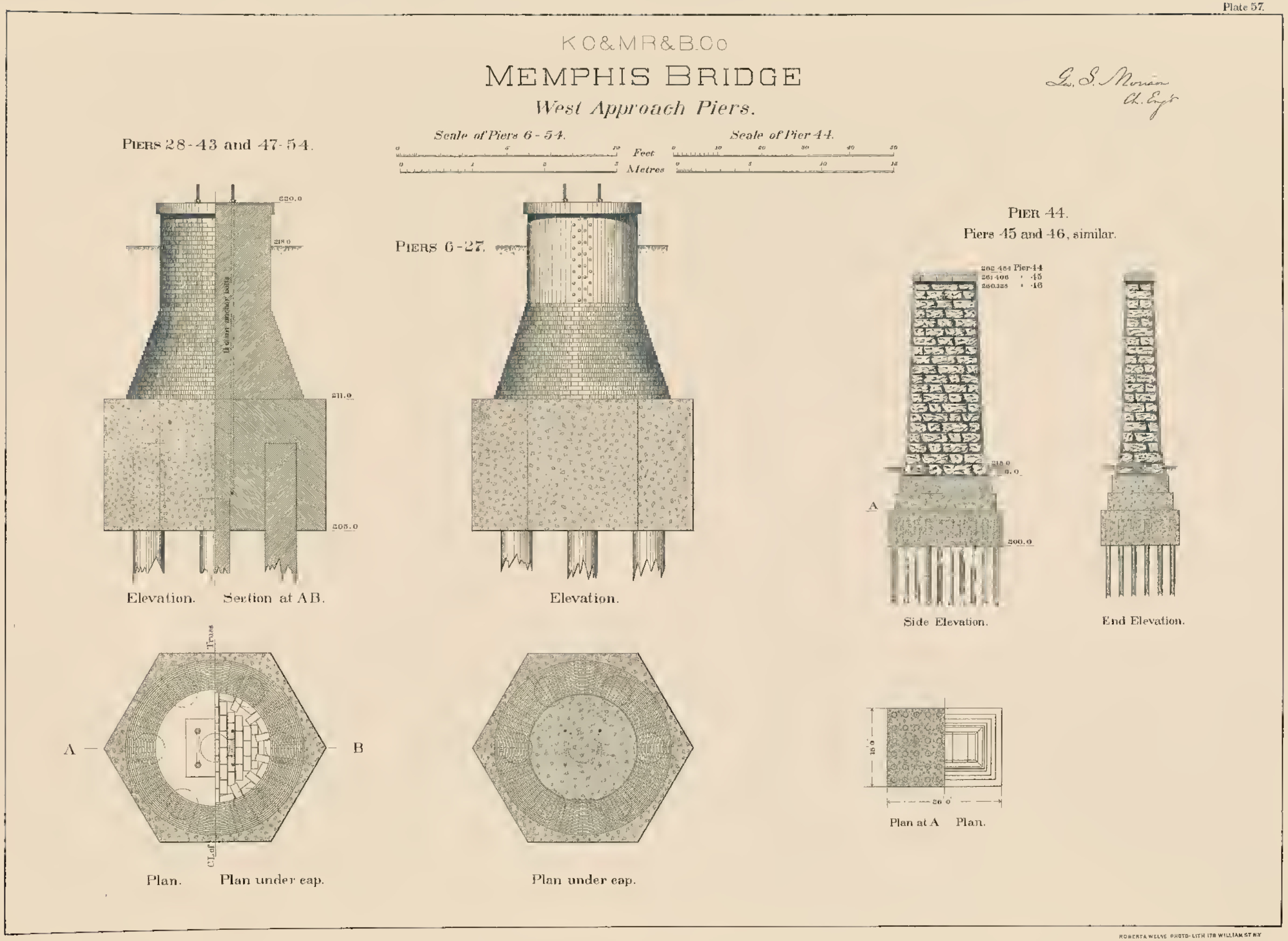
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MEMPHIS BRIDGE
West Approach Piers.
G. S. Morison Ch. Engr.
Scale of Piers 6 - 54.
Scale of Pier 44.
Feet
Metres
Piers 28 - 43 and 47 - 54.
220.0
211.0
205.0
Elevation.
Section at A B.
Piers 6 - 27.
Elevation.
Pier 44.
Piers 45 and 46, similar.
262.484 Pier 44
261.406 " 45
260.328 " 46
300.0
A
Side Elevation.
End Elevation.
A
B
Truss
Plan.
Plan under cap.
Plan under cap.
Plan at A
Plan.

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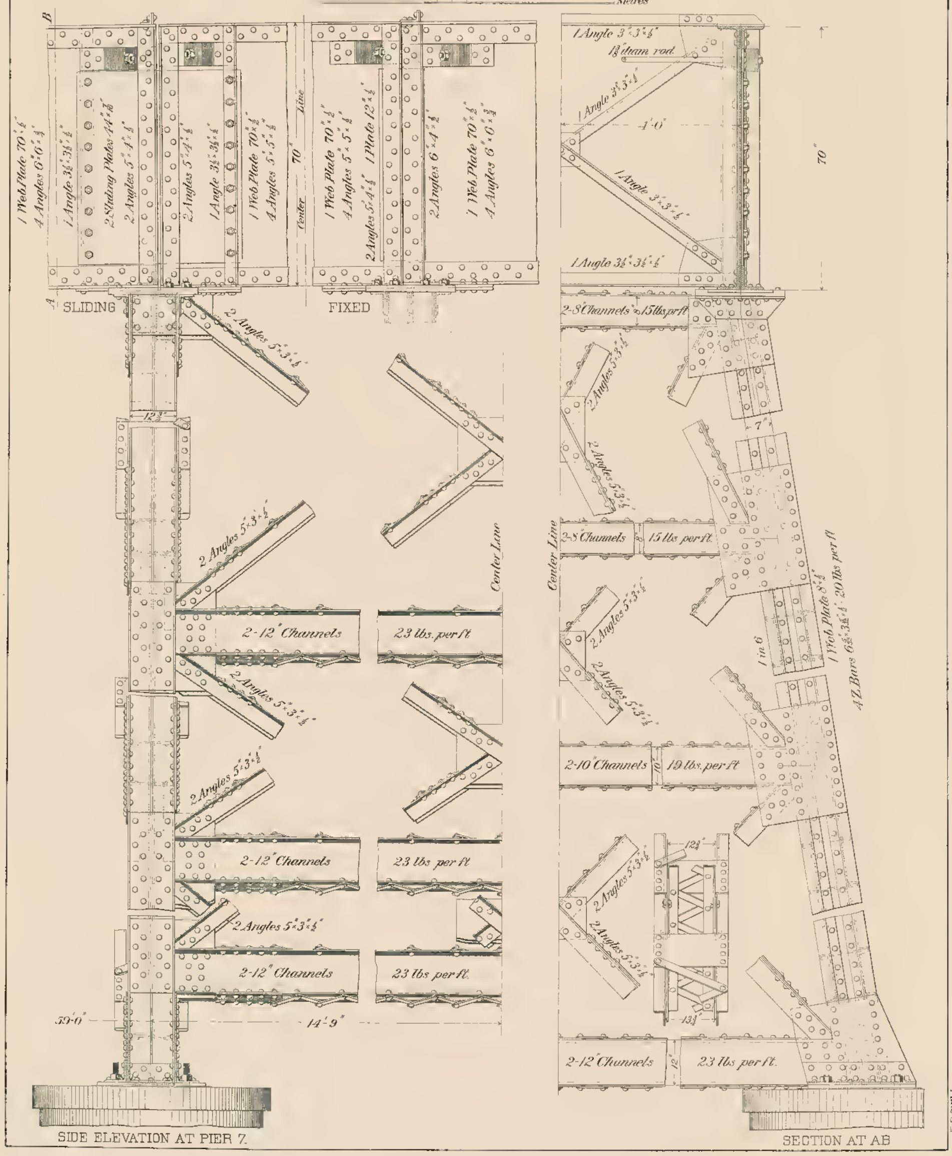
MEMPHIS BRIDGE

Details, West Approach Viaduct.

G. S. Morison
Ch. Eng.



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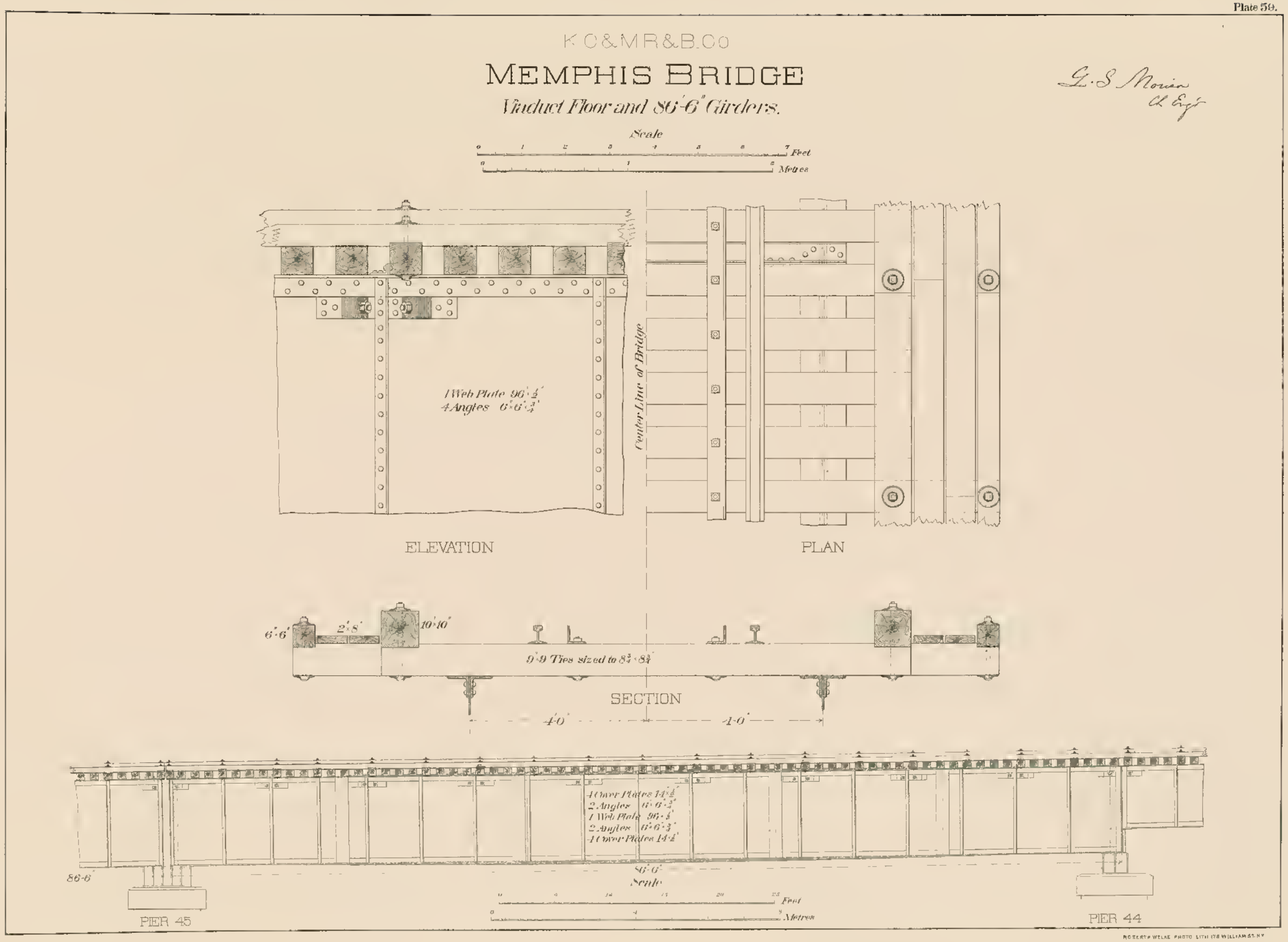

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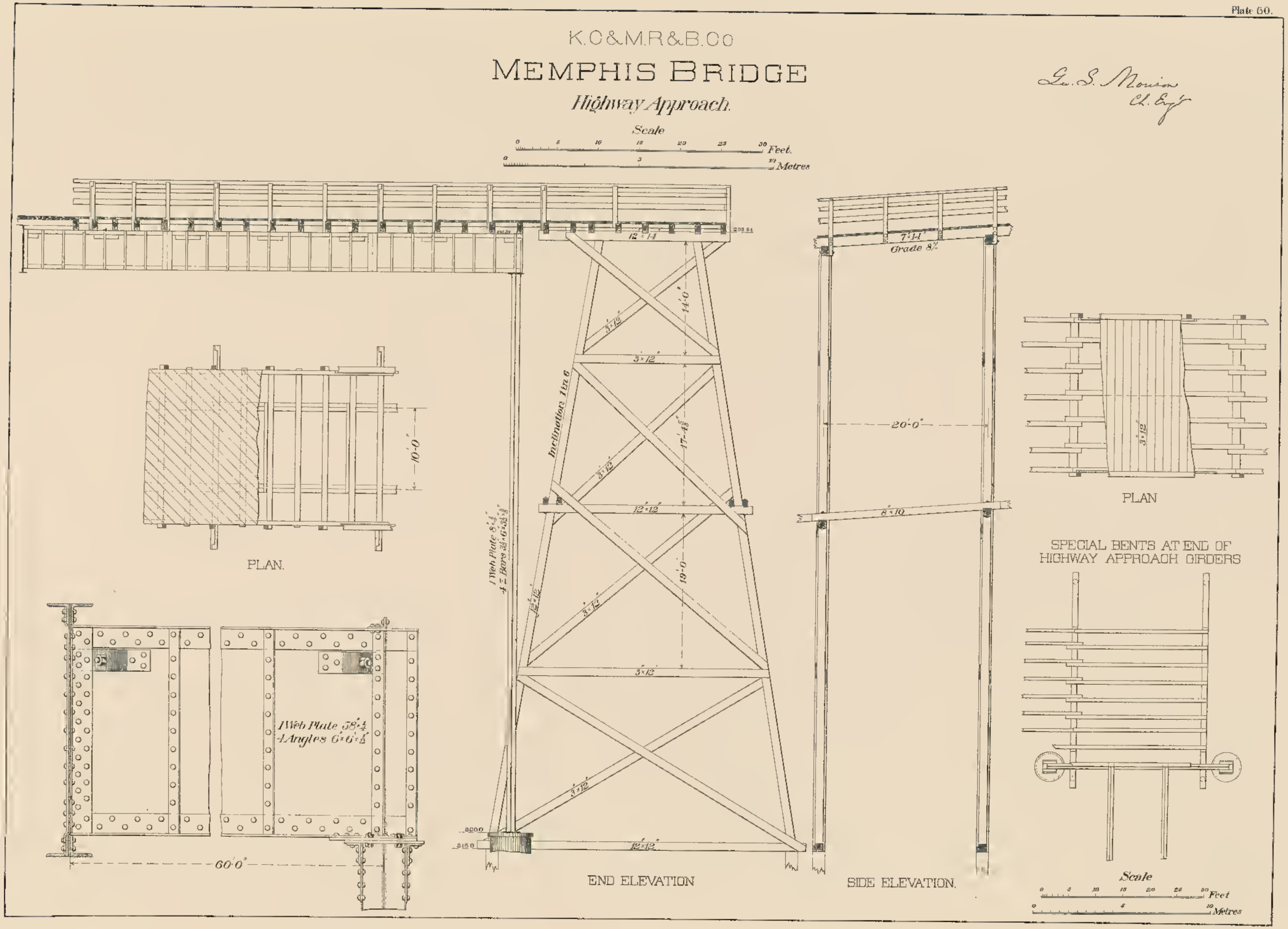

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