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FOL.

ALBUM OF DESIGNS

THE PHŒNIX BRIDGE COMPANY

THE PHŒNIX BRIDGE CO. PHILADELPHIA

PHŒNIXVILLE BRIDGE WORKS

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PHILADELPHIA AND READING RAILROAD BRIDGE,

OVER FRENCH CREEK, AT PHŒNIXVILLE, PA.

ALBUM OF DESIGNS

OF

THE PHŒNIX BRIDGE COMPANY

SUCCESSORS TO CLARKE, REEVES & CO.

Phœnixville Bridge Works.

OFFICES:

No. 410 Walnut Street, Philadelphia. No. 49 William Street, New York.

At Works, Phœnixville, Pa.

PHILADELPHIA:
J. B. LIPPINCOTT & CO.
1885.

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PHILADELPHIA.

6—42089

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ADOLPHUS BONZANO, Vice-President and Chief Engineer.
WILLIAM H. REEVES, General Superintendent.
WILLIAM H. BURR, Assistant to Chief Engineer.
GEORGE GERRY WHITE, Secretary.
FRANK T. DAVIS, Treasurer.
DANIEL W. BOWMAN, Assistant Engineer.
MORITZ G. LIPPERT, Chief of Drawing-Room.

PHŒNIXVILLE BRIDGE WORKS.

OFFICE OF

THE PHŒNIX BRIDGE COMPANY,

Successors to CLARKE, REEVES & CO.,

Engineers, Contractors, and Builders of Bridges, Viaducts, Roofs, etc., of Iron and Steel,

No. 410 WALNUT STREET, PHILADELPHIA.

SINCE the presentation of our last album in 1873, the rapid increase in the variety and amount of our business, in the design and manufacture of bridges and of all kinds of structures of iron and steel, renders it necessary for us to exhibit to the public, and to our friends and customers particularly, the present state of constructive engineering as existing at the works of The Phœnix Bridge Company.

By a recent reorganization the Phœnixville Bridge Works, heretofore known under the firm-name of Clarke, Reeves & Co., are conducted under the corporate title of The Phœnix Bridge Company. By this reorganization we have assumed the entire business of that firm, and have perfected arrangements with The Phœnix Iron Company, which give us additional facilities for concentrating the productive plant of that company upon the construction of our bridges, roofs, viaducts, piers, etc. Our present capacity thus reaches a yearly amount of 30,000 to 35,000 tons of finished material, with facilities which permit of further increase, if required by any unusual demand.

With machinery of the most improved character and an experience extending back almost to the very commencement of iron bridge-building in this country, it is believed that The Phœnix Bridge Company has unexcelled, if, indeed, equalled facilities for meeting the demands of the most advanced engineering practice.

It is our intention at the present, as it has been in the past, in the first place, to admit no material in our constructions except that of the very best quality, and which, by its nature, is best adapted to the resisting of the stresses acting upon it; and, in the second place, by a careful study of the circumstances of each case, to so design all parts, both main and detail, as to enable them to exert the resisting capacity of the metal in the simplest, most direct, and consequently most advantageous manner, thus attaining that greatest desideratum in all correct constructive design, viz., combined economy of material and expense.

Our situation is such that the quality of the material entering into our constructions is completely under our control. Essentially, all of our material is produced by The Phœnix Iron Company, whose resources are so extensive and plant so complete that every stage of manufacture from the ore to the finished bar or shape is included within their works and performed on their premises. Thus every part of the process of production may be so adjusted and co-ordinated to the others, that any quality or grade of material best adapted to any particular construction may be secured with certainty. The high reputation of "Phœnix" iron for constructive purposes is undoubtedly due to this unity of design governing the effects of the different stages of production for the purpose of securing a definite end.

CHARACTER OF TRUSS.

Each individual type of truss possesses some particular merit of its own; but long experience in American bridge-practice has shown that the type originally developed by Pratt in wood and Whipple in iron, when designed in proper proportions, combines the greatest number of advantages for all usual circumstances. Our early selection and development of this truss for the great majority of ordinary cases, together with its later almost universal adoption in American practice, constitute gratifying evidences of the correctness of the general principles on which we have developed our designs.

Extraordinary circumstances, such as those of unusual length of span, difficulties of erection, etc., render advisable other types of truss, like the cantilever, or those with varying contours, or those having chords wholly or partially continuous.

Our varied facilities and extensive experience with such unusual structures, both in designing and erecting, enable us to meet the exigencies of those cases where they are

required, without loss of time and with the greatest economy, and by methods based upon the most advanced engineering practice.

DETAILS.

The design of details has received from us especial attention. We have regarded it as one of the most important departments of bridge design, and have given it careful and continuous study in connection with the constantly varying and increasing demands of modern bridge-practice. It has been our endeavor to give the greatest possible simplicity to details, and so to dispose the material in them as to transfer stress in the most direct and simple manner, and by such a method to give to each main member precisely and only that kind of stress which it is intended to take.

All increments of chord stress are brought to bear directly and symmetrically upon the full chord section, thus completely avoiding all bending and cumulative stresses. This result we deem of great importance in constructive design, though it frequently fails of that consideration which its importance demands.

By the attainment of these ends we are enabled in tension members to concentrate the metal truly along the centre lines of stress, and in compression members to so dispose the sectional area as to enable it to act in the most advantageous manner possible, and thus to secure the most economical design.

Our forms of cross-section for compression members, chief among which is the well-known "Phœnix" section, have been developed on the basis of the latest and most comprehensive column tests, in combination with the results of many years of experience in American practice with open and closed columns.

Whenever "Phœnix" columns are used, effective preservative processes are employed, before the column is closed, on all surfaces that are not afterwards open to inspection and painting, the columns are then closed absolutely tight. Such columns have been examined after fourteen to twenty years' use, and found to be not in the slightest degree affected by oxidation, though in some cases the columns had occupied most exposed positions in respect to extreme hygrometric changes in the atmosphere, and, in fact, had at times been under water for several days.

In open columns built of plates and angles, or of channels and plates, we dispose the metal in the most judicious manner, in view of the duties which it has to perform. By the use of well-designed latticing the requisite stiffness is secured, with ample facilities for constant inspection and painting at proper intervals.

In all cases, whether of closed or open columns, we aim to form a member in which the metal is placed far from the neutral axis, and whose parts shall be so self-supporting as to cause the column to fail as a whole, thus avoiding a weakness quite common to many latticed or other columns. The "Phœnix" column is, however, the only form which entirely fulfils this condition.

Although much yet remains to be done in the empirical determination of the resistance and proportions of long columns with various end conditions, yet sufficient tests have already been made upon full-size "Phœnix" and upon latticed and other forms of columns on the Government machine at Watertown, Mass., and at Phœnixville and elsewhere, to obtain correct ideas of the relative merits of some of the principal forms of section.

The following formulæ are expressive of those experimental results, which can be relied upon by engineers:

P = ultimate resistance in pounds per square inch of section.
l = length of column in inches.
r = radius of gyration in inches in direction of failure.

	Flat Ends.	*Pin Ends.*
Phœnix Column.	$P = \dfrac{42{,}000}{1 + \dfrac{1}{50{,}000}\dfrac{l^2}{r^2}}$	$P = \dfrac{42{,}000}{1 + \dfrac{1}{30{,}000}\dfrac{l^2}{r^2}}$
Latticed, or Common Column.	$P = \dfrac{39{,}000}{1 + \dfrac{1}{40{,}000}}$	$P = \dfrac{39{,}000}{1 + \dfrac{1}{30{,}000}\dfrac{l^2}{r^2}}$
Angle-Iron Struts.	$P = \dfrac{39{,}000}{1 + \dfrac{1}{30{,}000}\dfrac{l^2}{r^2}}$	$P = \dfrac{39{,}000}{1 + \dfrac{1}{16{,}000}\dfrac{l^2}{r^2}}$

The great superiority of the "Phœnix" column in resisting capacity is well shown by a comparison of these formulæ. They give results a little too low where the lengths become less than about 30 radii of gyration, with the exception of the last two, and a little too high when the lengths exceed 135 to 150 radii.

The formula for pin-end angle-struts is to be used only when the length exceeds 120 radii of gyration, as below that length the values of P for pin and flat ends are shown by experiment to be the same,—*i.e.*, for the pins used in the tests.

EYE-BARS.

In order to bring the design of eye-bar heads to a state of perfection, we have made many hundred tests on full-sized bars, and secured such a contour of head that the full resistance of the body of the bar will always be developed if it be tested to failure.

We are now prepared to die-forge the eye-bar head under the steam-hammer, or to form it by hydraulic pressure, as may be preferred.

RIVETED WORK.

In the design of riveted work we aim to produce results of the same general character as those obtained in the best pin-work. This is accomplished by placing the metal truly along the centre lines of stress, and causing the latter to intersect as nearly as possible at a single point at each joint.

The influence of the bearing pressure of the rivets against the intrados of the rivet-hole on the tensile resistance of the bars and plates, as well as the shearing of the rivets and other methods of rupture of the joints, are carefully considered in all designs. Bending and other secondary stresses, so prevalent in nearly all riveted work, and constituting, to some extent, at least, unavoidably inherent defects, are thus reduced to a minimum.

FLOOR SYSTEM.

There is probably no part of a railway bridge subjected to such destructive effects from the moving load as the floor system and its attachments to the truss proper at the chord-joints. The design of these parts has, therefore, received the care required by the difficult character of the duty which they have to perform. Our floor systems combine that degree of flexibility which enable them to sustain, with the least fatigue of the metal, the shock of a rapidly-passing train with such a judicious rigidity as to secure complete lateral stability and a perfect attachment to the truss proper. This attachment consists of two suspension loops at each panel point, by means of which the floor-beams are drawn tightly up against the posts, materially increasing the lateral stability of the truss, and effectually preventing any motion of the floor system as a whole or in any of its parts.

WIND PRESSURE.

During the past few years American experience has shown that high-wind pressures cannot be safely neglected in the design of any bridge structure. All our lateral and transverse systems of bracing are carefully designed both in reference to the highest recognized wind pressure and the lateral vibration caused by rapidly-passing trains.

ROLLING LOADS.

The steady increase in railway rolling loads, which has taken place during the past ten years, has now caused it to reach a value of 96,000 pounds on a wheel-base of 14 feet 9 inches, or 111,000 pounds on a wheel-base of 22 feet 10 inches; or, again, 171,000 pounds on a base of 45 feet 3 inches. This corresponds to about the heaviest pattern of "consolidation" engine at present in use.

The moving or rolling load, however, should depend on the length of span, for the following simple reasons: If the span is very short, the four drivers (or a less number) of a consolidation engine may cover it, and thus subject it to an enormously heavy load, which will take a very high value per foot,—perhaps 5000 or 6000 pounds.

If, on the other hand, the span has a length of 100 feet and upwards, the general rolling load per foot will fall to an average of 3200 pounds, even if loaded with a train of consolidation locomotives. Hence it is that the rolling load varies from a very high value per foot for short spans to a comparatively low one for long spans.

But, again, a recognition of this difference is not sufficient. The stresses in many of the truss members will be very much reduced below their proper value if the loads on the drivers and at other points be considered uniformly distributed. A correct system of computation, therefore, demands that the actual moving load, concentrated at drivers and other points, should be so placed as to give the greatest possible stress to the different truss members. This is of special importance in connection with the floor system and its attachments to the chords. Our system of designing is based upon a correct recognition of these conditions.

GREATEST ALLOWABLE STRESS.

The greatest stress to which it is permissible to subject any portion of a bridge structure varies much both with its position in a given truss and the length of span.

The floor system and its attachments to chords are subjected to sudden loads and, comparatively speaking, violent shocks. The fatigue of the metal is correspondingly greater, and the greatest allowable stress should be correspondingly lower.

In the chords and main-web members the variations are much more gradual and less in relative amount; hence the working stress may be larger. Again, the fixed load or weight of structure is much less in proportion to the moving load on short spans than for long ones. Hence the variation of stress, both relative and absolute, in passing from a loaded to an unloaded state, or *vice versa*, will be much greater in short spans than in long ones, thus necessitating the smaller working stress for short spans.

The effects of these indirect influences, the importance of which has only been more fully developed by late investigations, have had almost their earliest application by this Company, which has, consequently, been among the first to be in position to utilize the advantage of investigations in the fatigue of metals.

UPSET SCREW-ENDS.

All of our upset screw-ends are from one-sixteenth of an inch to one-eighth of an inch larger at the bottom of screw-threads than the diameter of the rods, the ends of the rods being upset before the threads are cut. Many tests have shown the necessity of this arrangement, in order to develop the full strength of the body of the bar.

PLATE GIRDERS.

In the design of plate girders, it is to be borne in mind that the connection between the web and chords or flanges is not so intimate as in the case of rolled beams, and, further, that the stress in the cover-plates must be carried from the web to those plates first through the rivets between the web and chord angles, then through the chord-angles to the rivets between the angles and cover-plates, and finally through the latter rivets to the cover-plates; hence, if there are a number of cover-plates, it will be essentially impossible to produce a satisfactory action in those farthest from the web, however accurately and solidly the riveting may be done. At the same time considerations of economy frequently forbid carrying the full centre section of the chord to the ends of the beam. The most judicious design is that one which avoids piling a number of thin plates at the centre of the span, but at the same time makes such a proper selection of angle-iron for chords that reduction to their section at and near the ends of the girders will produce the most economical construction.

Tests on full-sized girders have shown that, when the riveting is properly done, part of the web may be included with the chords in the resistance to bending. Parties, however, may specify whether they wish to have the web included or not.

Experiments on full-sized girders have also shown that a comparatively thin web will safely resist a much greater shear than is frequently allowed by many engineers. Indeed, it is a question whether there is not frequently a waste of material in the webs of large girders. Very thin webs are not permissible, on the ground that a very little deterioration, from corrosion or other cause, produces the destruction of a relatively large amount of metal; but web-plates of moderate thickness are not open to that objection, and if well stiffened at the ends, as well as at intervals of about one and a half times the depth, are sufficient for the heaviest girders.

The number and pitch of rivets should be determined by the amount of stress they have to carry from the web-plate to each part of the chord. This will usually necessitate a much smaller pitch near the ends than in the vicinity of the centre.

SPECIFICATIONS AND TESTS.

In cases where specifications are not furnished by the parties ordering of us, we use the General Specifications given elsewhere in this album. We may say here, however, briefly, that we design our structures for rapidly-passing loads, consisting of the heaviest consolidation locomotives, with a weight of 96,000 pounds on a wheel-base of 14 feet 9 inches, or 171,000 pounds on a wheel-base of 45 feet 3 inches. This corresponds to about the heaviest locomotive now in use.

All machine and other work is of that high degree of excellence which has ever characterized the bridge-work of this Company.

We have three testing-machines of large capacity at the works of the Phœnix Iron Company, which are always in readiness for testing full-sized pieces or prepared specimens.

GENERAL DIRECTIONS.

Invitations for tenders and estimates should be accompanied by exact information on the following points:

Length of span in the clear, or from centre to centre of piers, or to back of abutments.

Angle between centre line of bridge and centre line of piers.

Whether on tangent or curve, and, if on the latter, the radius of the same.

Clear width between trusses.

Dimensions of tops of piers and abutments.

Height from base of rail to top of masonry.

Height from base of rail to extreme high water.

Whether floor system is on upper or lower chord.

Soundings along centre line of bridge, with the character of the bottom.

Specifications covering character and amount of moving load and limiting stresses.

A general statement of the character of the structure.

The nearest point of delivery to site of bridge by rail or water, and distance of haul, if any.

Whether railway company will furnish staging for erection or not.

LIST OF

WROUGHT-IRON BRIDGES, VIADUCTS, AND PIERS,

BUILT AND NOW BUILDING BY

THE PHŒNIX BRIDGE COMPANY

Successors to CLARKE, REEVES & CO.,

FROM 1869 TO 1885.

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Chicago, Burlington & Quincy	Burlington, Mo.	1	125	125
Illinois Central	La Salle, Ill.	18	160	2880
Chicago & North Western	Clinton, Iowa	2	150	300
Philadelphia, Wilmington & Balt.	Chester, Pa. 2 tracks	1	154	308
" " "	" " Draw. 2 tracks	2	127	508
Reading R. R.	Flowertown	1	82	82
" "	"	1	55	55
Bridgeton, N. J.	Bridgeton. Draw	1	139	139
North Pennsylvania R. R.	Saucon Creek	2	77	154
U. S. Arsenal	Rock Island, Ill. Highway	4	150	600
Portland & Kennebec R. R.	Augusta, Me.	7	4—174 1—154 1— 70 1— 55	975
Connecticut Air Line R. R.	Viaduct	3	17	51
" " "	"	...	.....	48
" " "	North Pond	1	120	120
" " "	Baileyville	1	79	79
" " "	Saddle Hill	1	56	56
" " "	Pistol Factory	1	112	112
" " "	Lyman Viaduct. 2 tracks	...	.....	2224
" " "	Rapallo " "	...	.....	2756
Hudson River Bridge Co.	Albany. 2 tracks	15	7— 73 4—185 1—274 1—110 1— 48 1— 65	3496
Portland & Ogdensburg R. R.	Hiram, Me.	1	185	185
Cambria Iron Co.	Johnstown	4	85	340
North Pennsylvania R. R.	Saucon Creek	5	3— 50 2— 47	248
Chesapeake & Ohio R. R.	New River	4	2—255 2— 75	660
Portland & Ogdensburg R. R.	Conway	2	158	316
Catawissa R. R.	Viaduct	...	.....	226
Intercolonial Railway Co.	Miramichi	11	210	2310
" " "	Restigouche	5	212	1060
Wheelock Bridge Co.	Terre Haute. Highway	1	50	50
West Chester R. R.	Glen Mills	1	83	83
North Pennsylvania R. R.	Ft. Washington Station	5	1— 41 4— 27	149
Camden & Amboy R. R.	Hightstown	1	139	139
Alex. T. Stewart	Long Island	2	1— 54 1— 84	138
Chesapeake & Ohio R. R.	Greenbrier River	8	4—104 4—123	908
Maine Central R. R.	Brunswick, Me.	4	2—183 2—182	730
Chesapeake & Ohio R. R.	Rivanna Creek	1	97	97
A. Schofield	Manayunk. Highway	1	93	93
Ohio & Mississippi R. R.	Cochran	1	145	145
" " "	No. 11	1	147	147
" " "	Medora	2	1—147 1—163	310
Ohio & Mississippi R. R.	Scottsville	3	177	531
" " "	West Fork	2	207	414
" " "	Big Sugar	1	116	116
" " "	Little Sugar	1	33	33
" " "	Little Wabash	1	96	96
Grand Trunk Railway of Canada	St. Hyacinthe	3	1—124 1—124 1—124	372
" " "	Black River	1	155	155
" " "	White River	2	1—156 1— 78	234
" " "	St. Francis	2	155	310
" " "	Magog	2	124	248
" " "	Massawippi	1	122	122
" " "	Coaticoke	1	122	122
" " "	Island Pond	1	114	114
" " "	N. Stratford	1	124	124
" " "	Gorham	1	156	156
" " "	W. Paris	1	132	132
" " "	S. Paris	1	138	138
" " "	Mechan's Falls	1	156	156
" " "	N. Yarmouth	1	108	108
" " "	Boundary Line	1	75	75
" " "	Waterville	1	122	122
" " "	Northumberland	2	84	168
" " "	Little Androscoggin	1	123	123
" " "	Big Androscoggin	3	2—152 1—102	406
" " "	Dummer No. 1	1	83	83
" " "	" No. 2	2	75	150
" " "	Windsor Creek	1	75	75
" " "	Willow Brook	1	74	74
" " "	West Paris	1	84	84
" " "	Moose River	1	65	65
" " "	Lewistown Canal. 3 tracks	1	65	195
" " "	Royal River at Yarmouth	1	125	125
Philadelphia, Wil. & Balt. R. R.	Ridley Park	2	1— 63 1— 31	94
Rock Island Arsenal	Moline, Ill.	5	142	711
Central R. R. of New Jersey	Parampo. 3 tracks	1	96.3	289
North Pennsylvania R. R.	Sellersville	6	1— 73 5— 31	228
Geneva & Ithaca R. R.	Tanghannock	1	102	102
" "	Sheldrake Ferry	1	104	104
" "	Trumansburg Viaduct	...	.....	300
" "	Seneca Canal	1	88	88
Costa Rica Railway	Costa Rica	4	1—132 1— 68 1— 74 1— 16	310
City of Philadelphia	Girard Ave., 100 ft. wide. 7 trusses, equal to 6 railroad tracks	3 2	197 137	5190
Philadelphia, Wil. & Balt. R. R.	Gray's Ferry. Roadway	1	120	120
" " "	2 tracks	1	142	284
" " "	"	1	109	218
Philadelphia, Wil. & Balt. R. R.	2 tracks	1	56	112
" " "		1	22	22
" " "	Havre de Grace	7	6—255 1—307	1837
Ohio & Mississippi R. R.	Laughry Creek	3	58	174
Millville	Millville. Roadway Draw	1	130	130
Utica, Ithaca & Elmira R. R.	Deep Gorge Viaduct	...	.....	480
" " "	Block House Gorge	...	.....	570
Balt. & Ohio R.R., Valley R.R. Br.		4	150	600
" " "	Wolf Creek	3	50	150
Washington Chain Bridge	Washington	8	6—172 2—160	1352
Maine Central R. R.	Waterville	4	2—200 1—100 1—113	613
" "	Biddeford Branch	5	2—100 3—133	599
Phœnix Iron Co.	Phœnixville	2	1—165 1— 97	262
Chupichaca Viaduct	Peru	3	1—156 2—105	366
Philadelphia & Reading R. R.	Richmond St., Phila. 205 ft. wide.	1	60	1344
North Pennsylvania R. R.	2 tracks 2 tracks	7	1— 37 1— 55 2— 26 1— 18 2— 34	285
Peru, Lima & Oraya R. R.	Rio Remac	1	204	204
" " "	Capa Crossing	1	125	125
" " "	" Viaduct	...	.....	150
" " "	Anche Crossing	1	120	120
" " "	" Viaduct	...	.....	180
" " "		3	1— 83 1— 78 1— 33	194
Cuzco R. R.	Peru	16	23	368
"	"	2	46	92
"	"	2	42	84
Maine Central R. R.	Ticonic	2	175	350
" "	"	1	172	172
" "	"	1	115	115
Sao Paulo & Rio de Janeiro R. R.		2	70	140
W. W. Harding	Manayunk. Roadway	1	90	90
Philadelphia, Wil. & Balt. R. R.	Lamokin	1	58	58
" " "	Sharon Hill	1	61	61
Washington, D. C.	Anacostia	12	99	1188
" "	" Draw	1	30	30
Philadelphia, Wil. & Balt. R. R.	Culverts. 2 tracks	2	15	60
" " "	" "	2	8	32
Eastern & Maine Central R'y	Lewiston	2	1—164 1—153	317
Quebec, Montreal, Ottawa & C. R'y	Riviere des Mille Isles	5	154	770
" " "	" " Prairies	3	2—155 1—203	513
" " "	Mill Race	1	55	55

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Chimbote & Huarez Railway	Santa River, No. 7	1	140	140
" " "	" No. 6	1	100	100
Great Western Railway	Thamesville, Ontario. 2 tracks	1	184	368
Intercolonial Railway	Roof for Halifax Passenger Station. 24 trusses	...	80	400
New Orleans & Mobile Railway	Chef Menteur	8	110	880
" " "	Rigolets	18	110	1980
" " "	"	1	110	110
" " "	"	2	110	220
" " "	Pearl River	2	100	200
" " "	"	1	110	110
" " "	"	3	120	360
" " "	Pascagoula	2	80	160
" " "	"	16	100	1600
" " "	"	2	120	240
Philadelphia, Wil. & Balt. R. R.	Culverts. 2 tracks	2	.....	47
" " "	Red Clay Creek. 2 tracks	1	.....	101
" " "	Culvert. 2 tracks	1	.....	33
New London & Northern Railway	Norwich Falls	1	148	148
Allison & Sons	Philadelphia	1	58	58
Great Western Railway	Bridge No. 1	1	23	23
" "	" No. 2	1	22	22
" "	" No. 4	1	33	33
" "	" No. 10	1	26	26
" "	" No. 7	8	41	328
" "	" No. 8	5	41	205
" "	" No. 3	1	40	40
" "	" No. 5	3	22	66
" "	" No. 6	1	16	16
Philadelphia, Wil. & Balt. R. R.	Eddystone Bridge. 3 tracks	1	51	153
" " "	Havre de Grace Br., No. 36. 2 tracks	1	15	30
" " "	Belleview Bridge, No. 53. 3 "	1	9	27
" " "	" " No. 23. 2 "	1	11	22
" " "	" " No. 22. 2 "	1	10	20
" " "	" " No. 21. 2 "	1	7	14
" " "	North East. 3 tracks	1	12	36
" " "	Havre de Grace Br., No. 37. 2 tracks	1	10	20
Passenger Railway Co.	Ridge Avenue, Phila. 5 trusses	...	70	101
Kent Co. Bridge	Canada	1	205	205
Great Western Railway	" No. 9	3	41	123
" "	"	2	22	44
" "	"	1	50	50
Philadelphia, Wil. & Balt. R. R.	Coaling Bridge	1	104	104
" " "		1	21	21
North Pennsylvania R. R.	Oreland Bridge	1	38	38
Great Western Railway	Bear Creek	3	41	123
" "	" "	1	88	88
" "	Bridge No. 12	1	103	103
Philadelphia, Wil. & Balt. R. R.	Moore's Station	2	10	20
" " "	Lamokin	1	40	40
Maine Central Railway	Gardiner Bridge	1	31	31
Philadelphia, Wil. & Balt. R. R.	Havre de Grace	1	254	254
" " "	" "	1	307	307
" " "	Gray's Ferry	2	8	16
" " "	Roof for Round-House, Gray's Ferry. 7 trusses	...	67	150
" " "	Roof for Freight Depot, Philadelphia. 21 trusses	...	97	359
Marietta & Cincinnati R. R	Cincinnati, Ohio	2	145	290
Fairmount Park, Philadelphia	Observatory Towers, 10 Stories	...	.....	217
Philadelphia, Wil. & Balt. R. R.	Stanton	3	24	72
" " "	Kirkwood	1	36	36
" " "	Roof for Engine-House, Wilmington. 18 trusses	...	68	343
" " "	Front for Passenger Depot, Phila.	1	150	.....
Intercolonial Railway	Halifax, N. S.	1	22	22
N. Y., N. H. & H. Railway	North Haven. 2 tracks	4	33	264
Toledo, Wabash & Western R'y	Danville, Ill., Viaduct	...	.....	330
Great Western Railway	Bridge No. 1	1	60	60
" "	" No 2. 2 tracks	1	22	44
Philadelphia, Wil. & Balt. R. R.	Big Elk Creek. 2 tracks.	1	104	208
Great Western Railway	Bridge No. 3	3	41	123
" "	" No. 4	3	41	123
Philadelphia & Reading R. R.	Shur's Lane. G. & N. 2 tracks	2	40	160
" " "	Washington St. G. & N. 3 tracks.	3	40	360
" " "	Nicetown Lane. G. & N. 2 tracks.	2	34	136
Mr. Dempsey (Thos. Holt, Agent).	Lewiston, Me	1	49	49
Great Western Railway	Hamilton, Ont. Bay Street	3	39	117
Philadelphia, Wil. & Balt. R. R.	Wilmington, Del. 3 tracks	1	24	72
Quebec, Montreal, Ottawa & O. R'y	Belle River	1	55	55
" " "	1 Span West, 2 Spans North River.	3	104	312
Great Western Railway	Stony Creek Station, Can.	1	24	24

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Toledo, Wabash & Western R'y	Logansport, Span I	1	95	95
" " "	" " II	1	158	158
" " "	" " III	1	146	146
" " "	" " IV	2	1—159, 1—149	308
Portland & Rochester Railway	Portland, Me.	2	1—86, 1—93	179
" " "	" Span II	1	87	87
" " "	" " III., IV., V.	3	87	261
Baltimore Central Railway	Avondale Station	1	13	13
Quebec, Montreal, Ottawa & O. R'y	Batiscan Bridge	4	162	648
" " "	Ste. Anne's River	6	5—152, 1—150	910
" " "	Gatinean Bridge	4	204	816
" " "	Rouge "	3	150	450
" " "	An Lievre "	2	1—150, 1—100	250
" " "	Blanche "	1	100	100
" " "	Salmon "	1	100	100
" " "	Nation "	1	100	100
" " "	Upper Blanche "	1	100	100
" " "	Calumet River "	1	100	100
" " "	North Nation "	2	1—150, 1—200	350
" " "	Little Upper Blanche	4	50	200
" " "	Salmon Creek			
" " "	Little Blanche			
" " "	Pointe au Chene			
Missouri Pacific Railway	Morean River	2	108	216
Great Western Railway		2	22	44
Wabash Railway	Bridge 198, Wabash River	2	1—166, 1—148	314
Grand Trunk Railway	Stark Grade Bridge	1	127	127
" "	Nulhegan	1	103	103
Quebec, Montreal, Ottawa & O. R'y	Batsican Draw	1	129	129
" " "	Ste. Anne's Bridge	1	129	129
" " "	Ste. Maurice	5	219	1095
Philadelphia, Wil. & Balt. R. R.	Newark, Del.	3	2—6, 1—16	28
Grand Trunk Railway	Worthley Creek	1	31	31
" "	Swift's Creek	1	43	43
" "	Oxford	1	39	39
" "	Compton	1	37	37
" "	At 239¾ Mile Board	1	26	26
New London Northern Railway		2	1—147, 1—93	240
Grand Trunk Railway	Port Britain	1	46	46
Quebec, Montreal, Ottawa & O. R'y	Aux Lievres	2	148	296
Great Western Railway of Canada	Galt Branch	1	44	44
" " "	At 65¼ and 67¾ M. P. Main Line.	2	18	36
" " "	Baptiste Creek	1	41	41
" " "	Cayuga	1	97	97
Philadelphia, Wil. & Balt. R. R.	2 tracks	6	8	96
" " "	2 tracks	1	37	74
" " "	Harford Run, Baltimore. 4 tracks.	1	32	128
Caibarien & Santo Espirito R'y	Manacas River, Cuba	1	152	152
Gilbert Elevated Railway, N. Y.	New Church St., from Morris to Dey Sts. 3 tracks	...	.....	5793
	From Dey St., along New Church St., through Little Church St. to Murray, along Murray to College Place, along West Broadway to Grand St. 2 tracks	...	.....	9164
Great Western R'y of Canada	Jarvis	1	27	27
New London Northern Railway		1	28	28
Houston & Texas Central Railway		1	128	128
Philadelphia, Wil. & Balt. R. R.	Cattle Guards. 2 tracks	12	8	192
Phila. & Read. R. R. G. & N. Br'h.	Duy's Lane. 2 tracks	1	48	96
Caz'via, Canas'a & De Ruyter R. R.		1	40	40
Pittsburgh, Cin. & St. Louis R'y	Raccoon Creek	3	122	366
New London Northern Railway	Palmer.	1	17	17
Caze'via, Canas'a & De Ruyter R'y.		1	16	16
" " " "		1	40	40
" " " "		1	95	95
" " " "		2	35	70
New London Northern Railway	Bridge Nos. 1, 7, and 10	3	12	36
" " "	" No. 2	1	6	6
" " "	" No. 3	1	7	7
" " "	" Nos. 4, 5, 8, and 9	4	11	44
" " "	" No. 6	1	8	8
" " "	" No. 11	1	14	14

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Seaboard & Roanoke R. R.	Weldon, N. C.	6	4—160, 2—100	840
Camden & Atlantic R. R.	Kirkwood, N. J.	1	25	25
Philadelphia, Wil. & Balt. R. R.	Cattle Guards on line. 2 tracks	2	6	24
Great Western Railway of Canada.	Over Welland Canal	2	38	76
" " "	Desjardins C'l, Hamilt'n, Ont. 2 Tr.	1	66	132
" " "	Brandford, Norfolk & Port B. Div.	3	99	297
Boston & Hoosac Tunnel Railway.	Mechanicsville, N.Y., Canal. 2 Tr.	1	83	166
" " "	Hudson River. 2 tracks	1	50	100
" " "	" " 2 "	9	130	2340
" " "	Wrought Iron Viaduct. 2 tracks.	...	.....	1386
Great Western Railway of Canada.	Thames River Bridge	1	163	163
" " "	Kettle Creek Bridge	1	163	163
" " "	Bridge Nos. 2, 5, and 9	3	40	120
" " "	" No. 3	1	22	22
" " "	" No. 4	1	70	70
" " "	" Nos. 6 and 7	2	30	60
" " "	" No. 8	1	24	24
Seaboard & Roanoke R. R.	Weldon, N. C.	2	79	158
New Orleans & Mobile R. R.	Pearl River. Draw	1	69	69
New London Northern		1	35	35
Philadelphia & Reading R. R.	Schuylkill River, Reading. 2 Tr.	2	145	580
" " "	" " "	1	157	314
" " "	" " "	1	174	348
Boston Hoosac Tunnel & W'n R'y	Schaghticoke. 2 tracks	7	66	924
" " "	Tomhanock Creek. 2 tracks	1	66	132
" " "	Anthony's Kill, Mech'ville. 2 Tr.	1	66	132
" " "	Near Valley Falls. 2 tracks	3	107	642
Philadelphia, Wil. & Balt. R. R.	Iron Hill. Roadway	1	42	42
Metropolitan Elevated R'y, N. Y.	53d St., fr'm 6th Av. to 9th Av. 2 Tr.	...	.....	5400
Central Vermont Railway	Winooski River Bridge No. 5	1	162	162
" "	" " No. 4	2	1—140, 1—128	268
" "	" " Trestle	2	21	42
Mobile & Ohio Railway	Tombigbee River Bridge	1	206	206
" "	" "	1	174	174
" "	" "	1	67	67
Central Vermont R. R.	Winooski River Bridge	2	137	274
Camden & Atlantic R. R.	On line of Camden & Atlantic R'y	2	1—15, 1—20	35
Portland Water Co.	Portland, Me.	1	31	31
Quebec, Montreal, Ottawa, & O. R'y	Terrebonne Bridge	4	150	600
" " "	L'Assomption "	1	215	215
" " "	Mascouche "	1	100	100
" " "	Bayonne "	1	120	120
" " "	L'Achigan "	1	120	120
" " "	St. Esprit "	1	80	80
Canada Central R. R.	Petewawa	3	1—138, 2—61	260
New London Northern Railway		1	35	35
Boston Hoosac Tunnel & W'n R'y.	Pownall. 2 tracks	1	135	270
" " " "	" "	1	155	310
Great Western Railway of Canada.	26¾ M. P.	1	40	40
" " "	Over Waterdown Road	1	26	26
" " "	57¾ and 60½ M. P.	2	22	44
" " "	Dundas Gorge, 48¾ M. P.	3	2—36, 1—33	105
Metrop'n & Greenwich St. El. R'ys	9th Av., from 53d to 59th Sts., N. Y.	...	.....	1600
Wabash Railway	Georgetown Crossing	7	26	182
City of Brantford, Ont.	Grand River Highway, N. Y.	1	254	254
Great Western Railway of Canada.	Nanticoke Bridge	1	93	93
" " "	Mimico Creek	2	84	168
Wabash Railway	Trestle-work at Sagamon River	...	.....	480
Philadelphia, Wil. & Balt. R. R.	Port Deposit	1	40	40
Boston Hoosac Tunnel & W'n R'y.	Walloomsic River. 2 tracks	2	75	300
Central Vermont Railway	Lull Brook Bridge No. 1	1	70	70
" "	" " No. 2	1	150	150
" "	" " No. 3	1	109	109
Guatemala Central Railway	Naranjo River Viaduct	4	3—20, 1—30	90
Great Western Railway of Canada.	Jeannette's Creek, No. 7	1	41	41
Philadelphia, Wil. & Balt. R. R.	Bellevue	1	10	10
Fralick, Murphy & Co.	Puira River	2	75	150
Western R. R. of Cuba	Rio San Diego	1	197	197
Philadelphia, Wil. & Balt. R. R.	Chester. 2 tracks	1	13	26
Phœnix Iron Co.	French Creek, Phœnixville	1	96	96
Philadelphia & Reading R. R.	Broad St. Crossing. 2 tracks	1	187	374
" " "	" " 2 "	1	122	244
" " "	" " 2 "	3	25	150
Boston, Hoosac Tunnel & W'n R'y.	Stations 800, 776, 630, and 990	4	3—12, 1—13	49
" " " "	" 708 and 390	2	23	46

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Great Western Railway of Canada.	St. George Viaduct	8	50	400
Quebec and Lake St. John Railway	Jacques Cartier Bridge	2	120	240
Sobral R. R., Brazil	Rio Camocim Bridge	2	185	370
Philadelphia & Reading R. R.	Mahanoy Plane. 2 tracks	1	16	32
Great Western Railway of Canada.	Copetown	1	63	63
" " "	Grand River at Cayuga	4	93	372
Baltimore & Harford Turnpike Co.	Gunpowder River	1	122	122
Great Western Railway of Canada.	Thames River, Ont	2	80	160
" " "	91½ M. P., Cedar Creek	2	46	92
Harlem Extension for Metropolitan Elevated R'y, N. Y.	9th Ave., from 83d to 91st Sts. 2 Tr.	...	.....	4224
	9th Av., fr'm 91st to 104th Sts. 3 Tr.	...	.....	10296
	9th Av., from 104th to 109th Sts., thence in a reversed curve to 8th Ave. and 111th St.; along 8th Av. from 111th to 133d Sts. 2 tracks	...	.....	16704
	Along 8th Av. from 133d to 137th Sts. 3 tracks	...	.....	3168
	Along 8th Avenue from 137th to Harlem River. 4 tracks	...	.....	23392
East Side. 2d Ave. Line for Manhattan Railway Co., N. Y.	Chatham Square, running up Division St. to Allen, to Houston. 2 tracks	...	.....	9842
	Houston, up 1st Ave. to 23d St., al'g 23d St. to 2d Av. (proportioned to carry 3 t'ks). 2 T'ks.	...	.....	12688
	2d Ave. to 129th St., or Harlem River (proportioned to carry 4 tracks). 2 tracks	...	.....	55884
	Between 59th and 67th Sts., and between 85th and 86th Sts.	...	.....	1943
Oscar von Nostitz	Coban, Guatemala, C. A.	1	130	130
Hibernia Mine R. R., N. J.	Rockaway, N. J.	1	65	65
Great Western Railway of Canada.	Wortley St. Bridge, London, Ont.	1	32	32
Philadelphia & Reading R. R.	Nicetown. 2 tracks	1	145	290
Boston, Hoosac Tun. & Wes'n R'y	Hoosac Falls Bridge. 2 tracks	1	32	64
" " " "	" Junction Bridge. 2 tracks.	1	36	72
" " " "	" " Y	1	43	43
Great Western Railway of Canada.	Dundas Bridge	1	67	67
Wabash Railway	Illinois River Bridge	3	160	480
Great Western Railway of Canada.	Oakville Bridge, 17⅛ M. P.	5	90	450
" " "	Bronte Bridge, Toronto Div.	6	84	504
Hoosac Tun & Troy & Gr'nf'ld R'y	North Adams	1	26	26
Great Western Railway of Canada.	Public Road Bridge, 130 M. P.	1	22	22
Hoosac Tun. & Troy & Gr'nf'ld R'y	Braytonville, Hoosac River. 2 Tr.	4	76	608
Philadelphia, Wil. & Balt. R. R.		1	40	40
Wabash, St. Louis & Pacific R'y	Toledo, O.	1	30	30
Hibernia Mine Railway, N. J.		2	1—10, 1—15	25
" " "	Rockaway Bridge, N. J.	4	50	200
Caibarien & Santo Espiritus R'y	Cuba. Bridge No. 65	1	27	27
" " "	" " No. 66	1	24	24
" " "	" " No. 70	1	13	13
" " "	" " No. 88	1	23	23
Hibernia Mine Railway, N. J.		1	26	26
North Pennsylvania R. R. P. & R.	Sandy Run Bridge No. 2. 2 tracks.	2	26	104
Great Western Railway of Canada.	1st Crossing Fairchild's Creek	1	150, Viaduct.	150, 405
" " "	2d " " "	1	77, Viaduct.	77, 420
" " "	Grand River Crossing	3	80	240
" " "	" "	2	37	74
Harlem River Bridge	New York. Draw span. 2 tracks.	1	360	600
" "	" Spans 5 and 6. 2 Tr.	2	100	400
" "	" 2 tracks	1	89	178
" "	" Span 1. 2 tracks	1	60	120
" "	" Spans 2, 3, 4, 7 & 8. 2 Tr.	5	58	580
" "	" Span 9. 2 tracks	1	62	124
" "	" Span 10. "	1	91	182
" "	" Approaches. 2 tracks.	11	25	550
Quebec & Lake St. John Railway.	Jacques Cartier	6	43	258
Mexican Central Railway		5	20	100
" "		5	25	125
" "		5	30	150
" "		2	40	80
" "		2	50	100
Quebec, Montreal, Ottawa & O. R'y	Chaudiere Bridge	10	150	1500
" " "	" "	1	160	160
" " "	" "	1	135	135
" " "	" "	1	255	255
Great Western Railway of Canada.	Tilsonburg Viaduct	...	1—150, 1—133	283

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Great Western Railway of Canada.	Delhi Viaduct	...	1—150, 1—133	283
Philadelphia, Wil. & Balt. R. R.		3	12	36
" " "	Back River Bridge. 2 tracks	37	14 to 22	1320
" " "	Roof for Eng. House, Wil. 9 tru's.	...	67	170
Mexican Central Railway		2	65	130
Hoosac Tun. & Troy & Gr'nf'ld R'y.	2 tracks	1	6	12
Quebec & Lake St. John Railway.	Portneuf River	1	60	60
" " "	Over Lake St. John Discharge	1	80	80
Wabash Railway	Vermilion River	2	200	400
Mexican Central Railway		2	1—150, 1—100	250
Philadelphia, Wil. & Balt. R. R.	Bay View Round House. 9 trusses	...	67	170
Boston & Maine R. R.	Haverhill Bridge. 2 tracks	4	147	1176
" " "	" " "	1	117	234
Mexican Central Railway		3	30	90
" " "		3	40	120
" " "		5	50	250
" " "	Goods Shed. 12 trusses	...	62	300
Great Western Railway of Canada.	Tilsonburg Viaduct	29	33⅓	967
" " "	Delhi Viaduct	23	33⅓	767
Philadelphia, Wil. & Balt. R. R.	Coaling Bridge at Bay View	1	86	86
Mexican Central R. R.	San Bartolo Bridge	1	43	43
" " "		1	28	28
" " "	Tlalnepantla Bridge	1	33	33
Wallkill Valley R. R.	Springtown Bridge	2	146	292
New York, Lack. & Western R. R.	Susquehanna Bridge. 2 tracks	6	160	1920
A. G. Menocal's	Nicaragua Bridge, C. A.	1	128	128
Philadelphia, Wil. & Balt. R. R.	Bellevue Station	1	13	13
" " "	Havre de Grace	1	18	18
" " "	Bay View Station	1	18	18
Wabash, St. Louis & Pacific R. R.	Bridge No. 396, over L. N. A. & C. R. R.	1	54	54
City of Winnipeg	Louise Bridge over Red River	2	1—205, 1—203	408
Boston, Hoosac Tun. & Wes'n R'y.	Bridge at Station 202+50. 2 T'ks.	1	22	44
" " " "	" " 241+66. 2 T'ks.	1	20	40
" " " "	" " 272. 2 tracks	1	20	40
" " " "	" " 219+34. 2 T'ks.	1	10	20
" " " "	" " 122	1	17	17
" " " "	" " 410+30. 2 T'ks.	1	22	44
Philadelphia & Reading R. R.	Over Penna. C'l at Harrish'g. 2 Tr.	1	108	216
Mexican Central Railway	Roof for Eng. Repair S'p. 6 trusses.	...	83	138
" "	" " " 3 "	...	31	66
Philadelphia, Wil. & Balt. R. R.	Bridge at Quarryville. 2 tracks	1	15	30
" " "	" " 2 tracks	1	27	54
" " "	" at Perkins' Creek. 2 T'ks.	1	29	58
" " "	" at Quarryville. 2 tracks	1	43	86
Morgan's La. & Tex. R. R. & S. S. Co.		4	33	132
" " "	Berwick's Bay Bridge. Draw	1	270	270
" " "	" "	5	158	790
Philadelphia, Wil. & Balt. R. R.	Bridge No. 35, at Havre de Grace	1	15	15
" " "	Claymouth Station. 2 tracks	1	10	20
Morgan's La. & Tex. R. R. & S. S. Co.		1	33	33
Old Colony R. R.	Bridge at Braintree. 2 tracks	1	41	82
Great Western Railway of Canada.	16-Mile Creek Bridge	6	4—92, 1—100, 1—63	531
Philadelphia, Wil. & Balt. R. R.	Bridge No. 9, at Darby, Roadway	1	32	32
" " "	" No. 10, at Sharon Hill. "	1	38	38
" " "	" No. 11, at Norwood. "	1	38	38
New York, Lack. & Western R'y.	Smith's Creek Bridge	1	50	50
Brighton Pier & Nav. Co., N. Y.	Landing Pier at Brighton Beach, Coney Island, 50 ft. wide	...	.....	1000
Mexican National Construct'n Co.	Dos Rios Viaduct	...	.....	183
" " "	Ferrocarril Manzanillo y Laredo	22	43⅓	953
Galv'n, H'sb'g & San Antonio R'y.	Bridge over Medina River	2	150	300
" " "	" Hinda "	1	150	150
" " "	" Medina "	3	130	390
" " "	" Hinda "	2	130	260
" " "	" Chacin "	1	75	75
" " "	" Francisco "	1	70	70
Albany & Greenbush Bridge Co.	Albany Bridge. 2 tracks	2	249	996
" " "	" Drawbridge. 2 tracks	1	397	794
Great Western Railway	Thames River Bridge	3	1—165, 2—125	415
New York, Lack. & Western R'y.	Ellis Creek Bridge	1	50	50
Mexican National Construct'n Co.	Ferrocarril Manzanillo y Laredo	1	29	29
" " "	" " "	1	33	33
Morgan's Louisiana & Texas R. R.		1	33	33
G. H. & S. A. R. R.	Hondo River Bridge	1	160	160
Oregon Navigation Co.	Snake River Draw	1	333	333

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Mexican Nat'l Construct'n Co.	East Sec., Toluca Div., Bridges Nos. 7, 29, 30, 31	4	23	92
" " "	W. Sec., Toluca Div., B'dge. No. 32.	1	24	24
" " "	East " " No. 12.	1	53	53
Great Western Railway of Canada.	Irvine River Bridge	1	150	150
" " "	Conestoga River Bdge. at Drayton.	1	150	150
Galv'n, H'sb'g & San Antonio R. R.		4	160	640
" " "		14	130	1820
" " "	Nueces River Bridge	4	225	900
" " "	" "	1	200	200
" " "	Main Frio River	1	180	180
Petersburg R. R. Co., Va.	Nottoway River Bridge	1	93	93
Mexican National Construct'n Co.	Bridge No. 8	1	65	65
" " "	Pipe Line Viaduct	...	.....	150
County Roadway Bridge	Burlington, N. J.	1	120	120
Boston, Hoosac Tunnel & W'n R'y	Over Highway east of Hudson R.	2	23	46
" " "	Bridge at Station 122	1	17	17
N. Y., L. Erie & W'n Coal & R. R. Co.	Kinzua Viaduct	...	...	2050
Albany & Greenbush Bridge Co.	East Approach of Albany Bridge	3	36	108
" " "	" " " 2 Tr.	2	150	600
Galv'n, H'sb'g & San Antonio R'y.	B'dg's over Chacin & Franc'o Riv's	2	80	160
" " "	San Felipe River	1	130	130
" " "	Sycamore West Creek	2	150	300
" " "	Saco R., Blanco R., Lindsey's Cr.	3	120	360
" " "	Main Elm River and Pinto River	2	100	200
Albany Bridge	West Approach	3	36	108
Great Western Railway of Canada.	Kettle Cr. Viaduct at St. Thomas	...	.....	133
" " "	" " "	...	.....	687
Morgan's La. & Tex. R. R. & S. S. Co.	Berwick's Bay Bridge	3	158	474
" " " "	East end of Berwick's Bay Bridge.	1	140	140
Rich'nd, F'd'ksb'g & Potomac R'y.	Rappahannock Bridge	3	123	369
" " " "	" " "	2	109	218
New York, Ontario & West'n R. R.	Moodna Creek Viaduct	...	.....	690
" " " "	" " "	...	.....	160
Great Western Railway of Canada.	Cayuga Bridge	8	48	384
Mexican National Construct'n Co.	Armeria River Bridge No. 3	4	200	800
" " "	Chinos River Bridge	1	151	151
" " "	Comala " "	1	135	135
" " "	Periquillo River Bridges	1	135	135
" " "	Colima River Bridge	1	102	102
New York, West Shore & Buf. R'y.	Catskill Bridge. 2 tracks	6	167	2004
" " "	" " "	1	104	208
" " "	" " "	1	100	200
Kentucky Central Railway	Kentucky River Bridge	1	300	300
New York, West Shore & Buf. R'y.	Schoharie Bridge. 2 tracks	3	163	678
" " "	Glenarie "	1	163	326
" " "	Over Black Creek. "	1	98	196
" " "	Glenarie Bridge. "	2	98	392
" " "	" " "	1	84	168
Kentucky Central Railway	Kentucky River Bridge	1	304	304
" " "	" " "	1	254	254
Galv'n, H'sb'g & San Ant'io Ext.	Dev. Riv., P'd Cave C'on, 1st C'g. P'd Cave C'n, 2d C'g, Pecos Riv.	9	150	1350
" " "	Over Pecos River	1	225	225
" " "	Painted Cave Cañon, 1st Cross'g, Main Elm C'ing, Pinto C'ing.	3	100	300
" " "	Painted Cañon, 3d Crossing, Station 11,482, Station 11,550	3	225	675
" " "	Painted Cave Cañon, 3d Crossing Seminole Cave Creek.	3	150	750
" " "	At Station 11,590	1	120	120
" " "	Over Pecos River	1	150	150
New York, West Shore & Buf. R. R.	Rondout Creek Viaduct. 2 Tr.	6, 5, 1, 1, 3	50½, 29⅔, 19¾, 60, 18	1166
" " "	Rondout Creek Bridge. 2 tracks	1	264	528
" " "	" " "	1	241	482
" " "	" " "	1	163	326
Galv'n, H'sb'g & San Antonio R. R.	At Station 11,892	1	150	150
" " "	At Stations 11,939 and 11,988	2	200	400
" " "	At Station 11,968	1	225	225
" " "	" 12,061	1	260	260
" " "	" 12,013	1	300	300
Great Western Railway	Grand River Bridge	4	82	328
" "	Over McGregor's Creek. 2 tracks.	1	126	252
Ode F. de Muriahe	Rio de Janeiro, Brazil	2	185	270
S. S. & L. R. R.	Sunbury Bridge	10	192	1920
" "	" Span No. 11	1	156	156
" "	" " No. 12	1	156	156
" "	" " No. 13	1	156	156

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
S. S. & L. R. R.	Sunbury Bridge, Span No. 14	1	156	156
D., G., H. & M. R. R.	Crockery Creek	1	123	123
" " "	Stony Creek	1	80	80
W., St. L & P. R. R.	Approaches to St. Charles Bridge	130	16	2080
Central Pacific R. R.	Bear River, Utah	1	224	224
Great Western Railway of Canada	Paisley Bridge	1	133	133
" " "	Viaduct for Paisley Bridge	22	30	660
" " "	Wingham Bridge	1	133	133
" " "	" Viaduct	8	30	240
" " "	Catfish Creek Bridge	1	150	150
" " "	" Viaduct	8	7— 30, 1— 20	230
" " "	Mimico Bridge	1	94	94
" " "	Viaduct at 65½ M. P.	7	30	210
Galv'n, H'sb'g & San Antonio R'y.	San Felipe Bridge	2	80	160
" " "	Leona Bridge	1	75	75
Petersburg R. R. Co.		2	37	74
" "		1	29	29
Chesapeake & Ohio R. R.	Guyandotte Bridge	2	154	308
" "	" "	1	146	146
" "	Coal River Bridge	1	152	152
" "	" "	2	102	204
Morgan's Louisiana & Tex. R. R.	Bayou Ramos Bridge	8	34	272
R. & P. R. R.	Near Ellicotty'e, Cat'gus Co., N.Y.	3	63	189
" "	" " "	1	77	77
Phœnixville & West Chester R. R.	French Creek Bridge	1	110	110
" " "	Pickering Creek Bridge	1	110	110
Memphis & Vicksburg R. R.	Yazoo River Bridge	2	300	600
" "	" "	1	271	271
New York, West Shore & Buf. R.R.	Erie Canal, at Station 346. 2 tracks	1	166	332
" " " "	" " 403. "	1	207	414
" " " "	" " 558. "	1	114	228
P. & W. C. R. R.	Over P. V. R. R.	1	76	76
New York, West Shore & Buf. R.R.	Seneca River Bridge. 2 tracks	20	54	2160
" " " "	Onondago Creek	4	69	276
New York, West Shore & Buf. R. R. All in Syracuse, N. Y.	Marsh Road Station, 1497. 2 Tr.	1	41	82
	Smith Street " 1523. "	1	40	80
	Geddas " " 1140. "	1	59	118
	Sand " " 1132. "	1	38	76
International Construction Co.	Rio Escondido Crossing	1	200	200
" " "	" "	1	120	120
New York, West Shore & Buf. R.R.	Station 1473, Onondago Co. 2 Tr.	1	164	328
" " " "	Skaneateles Creek. 2 tracks	3	1— 38, 2— 28	188
" " " "	Carpenter Creek. 2 tracks	1	33	66
S. S. & L. R. R.		3	123	369
Chesapeake & Ohio R. R.	Dunlap's Creek	2	80	160
New York, West Shore & Buf. R. R	O. & S. R. R. Crossing. 2 tracks	1	78	156
Galv'n, H'sb'g & San Antonio R. R.	Rio Grande Bridge	3	230	690
" " "	" "	2	120	240
Seaboard & Roanoke R. R.	Weldon Bridge	10	80	800
Yuza R. R., Cuba	Cuba	1	58	58
New York, West Shore & Buf. R. R.	Cold Spring Brook Bridge. 2 T'ks	1	54	108
" " "	1st Crossing of Clyde River. 2 Tr.	1	217	434
" " "	S. C. R. R. Crossing, Station 435	1	82	82
" " "	Owasco Creek	1	89	89
Wabash & St. Louis & Pac. R'y.	Charley Creek Viaduct	33	16	528
	Helms " "	16	16	256
New York, West Shore & Buf. R. R.	New York Central R.R. C'ng. 2 Tr.	1	130	260
" " "	Station 383, Cayuga Co. 2 tracks.	1	28	56
" " "	Lyons Mill Race. 3 tracks	1	33	99
Seaboard & Roanoke R. R.	Goose Creek	1	23	23
" " "	Canal at Weldon	1	33	33
New York, West Shore & Buf. R. R.	2d Crossing of Clyde River. 2 T'ks.	1	187	374
State Line & Sullivan R. R.		1	154	154
Cumberland Valley R. R. Co.	Ap'ches to Susquehanna Riv. B'ge.	4	3— 43, 1— 39	168
New York, West Shore & Buf. R. R.	Station 591, Cayuga Co. 2 tracks.	1	33	66
Richmond & Petersburg R. R.	James River Bridge	7	151	2063
" " "	" "	4	148	
" " "	" "	3	138	
Great Western Railway	Credit River	1	200	200
" "	Puce River Bridge	3	41	123
" "	Ruscom River Bridge	3	41	123
" "	Baptista Creek Bridge	5	41	205
Philadelphia & Reading R. R.	Canal at Phœnixville. 2 tracks	1	140	280
International Construction Co.	Sabinas River, Mexico	1	100	100

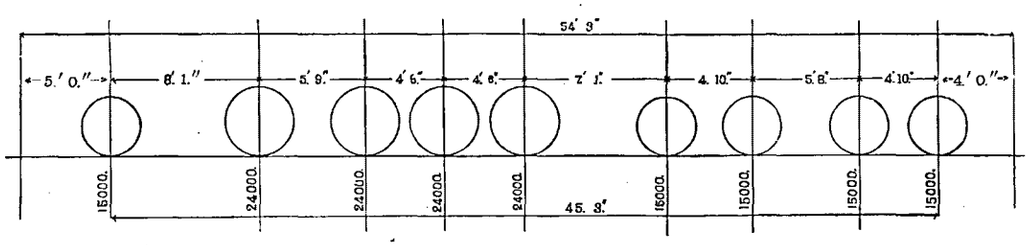
FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
International Construction Co.	Sabinas River, Mexico	3	250	750
New York, West Shore & Buf. R'y.	3d Crossing of Clyde River. 2 Tr.	2	190	760
" " "	Over G. & L. R. R. 2 tracks	1	155	310
Louisville Elevated Railway	2 tracks	174	.....	9376
New York, West Shore & Buf. R. R.	Station 207, East Wayne Co. 2 Tr.	1	33	66
" " "	" 250, " " 2 Tr.	1	34	68
G. B. & L. R. R.	Devil's Gate, Colorado	9	8— 30, 1— 60	300
B., C. C. & S. W. R. R.	Bald Eagle Creek	2	132	264
" " "	Fishing Creek	3	50	150
Gettysburg & Harrisburg R. R.		1	100	100
" " "		1	110	110
Philadelphia & Reading R. R.	Port Richmond Branch. 2 tracks.	1	115	230
Commissioners of Chester Co., Pa.	Gay St. Bridge, Phœnixville	1	165	165
" " "	South Approach of Gay St. Bridge.	1	367	307
" " "	North " " "	1	450	450
R. & P. R. R.	James River, Va	1	138	138
New York, West Shore & Buf. R. R.	Station 457, Cayuga Co	2	1— 18, 1— 20	38
Central Pacific R. R.	Truckee River	1	208	208
Philadelphia & Reading R. R.	Perth Amboy Br., Sum B'ge. 2 Tr.	1	38	76
Phila., Ger'n & Chestnut Hill R. R.	16th St. & Indiana Ave. "	1	71	278
Penna. Schuylkill Valley R. R.	" " "	2	21	
" " "	" " "	2	13	
" " "	17th St. Trestle. "	8	195	390
" " "	Crossing Phila ,G'n & N'n R R. "	1	163	326
" " "	Alleghany Ave. Crossing. "	...	2— 69, 1—111	360
Wilmington & Northern R'y Co.	Kennet Pike	1	24	24
Philadelphia & Reading R. R.	Montgomery Station, on Catawissa and Williamsport Br'ch.	1	34	34
" " "	C'l R. R. N.J. D'n o'r Mid. B'k. 4 Tr.	1	128	512
Houston & Texas Central R'y		2	100	200
W. & N. R. R. Co.	Public Road	1	44	44
Philadelphia & Reading R. R.	Over Creek. E. of Bound Br'k. 4 Tr.	3	1— 55, 2— 51	628
Boston, Hoosac Tunnel & W. R'y.	Hoosac River at Eagle Bridge	2	82	164
Philadelphia & Reading R. R.	Newark Bridge. 2 tracks	1	164	328
" " "	" "	1	94	188
Wilmington & Northern R. R.	Poplar Neck Bridge	2	163	326
New Orleans and Miss. Val. R. R.	Sunfl'r R., Hushp'kana R., Yazoo Pass, B. Bl'k R., H'm'chitto R.	5	147	735
" " " "	Sunflower River Bridge	2	123	246
" " " "	Hushpuckana " "	2	98	196
" " " "	Big Black " "	2	73	146
Penna. Schuylkill Valley R. R.	Schuylkill River Bridge. 2 tracks.	1	163	326
" " "	" "	4	164	656
" " "	" "	4	95	380
Seaboard & Roanoke R. R.	Blackwater Bridge	1	144	144
Southern Pacific R. R.	San Jacinto River	1	154	154
Oregon Extension of C. P. R. R.	4th Crossing of Sacramento River.	2	130	260
" " "	3d " " "	2	1—152, 1—109	261
Carolina Central R. R.	Buffalo Bridge	3	127	381
Guatemala Central R. R	Rio Michatoya	1	52	52
Juragua Iron Co.	Wharf at Santiago, Cuba. 3 Tr.	3	122	1098
Philadelphia & Reading R. R.	Clegg's Mill Road. 2 tracks	1	34	68
Raleigh & Augusta R. R.	Crane's Creek Bridge	2	1— 20, 1— 45	65
Philadelphia & Reading R. R.	Canal Bridge at Coplay	1	106	106
Chesapeake & Ohio R. R.	Christian's Creek	1	85	85
Penna. Schuylkill Valley R. R.	Approach to Schuylkill R. Bridge.	1	69	69
Philadelphia & Reading R. R.	Grove St. Cr's'g, E'zab'h, N.J. 4 Tr.	1	32	128
" " "	Bayway St. " 2 Tr.	1	32	64
" " "	Clinton Ave., Plainfield, N.J. "	1	32	64
" " "	Richmond St., " 4 Tr.	1	32	128
" " "	Park Ave., " "	1	32	128
" " "	Berckman St., " "	1	32	128
" " "	Plainfield Ave., " "	1	32	128
" " "	Madison Ave., " "	1	32	128
" " "	Leland Ave., " 2 Tr.	1	32	64
" " "	Central " " 4 Tr.	1	32	128
" " "	New St., " "	1	32	128
" " "	Liberty St., " "	1	32	128
" " "	Peace " " "	1	32	128
" " "	Washington St., " "	1	32	128
" " "	Grant Ave., " 2 Tr.	1	32	64

FOR WHOM BUILT.	LOCATION.	Spans. No.	Spans. Length, Feet.	Total Lineal Feet, Single Track.
Penna. Schuylkill Valley R. R.	Main St. C'ng, Phœnixville. 2 Tr.	2	1— 23, 1— 63	172
Norfolk & Western Railway	9th Crossing of Peak Creek	2	68	136
" "	4th " Holston Creek	1	85	85
C. P. Huntington, New York	Lake Amatillan, Guatemala	1	98	98
Seaboard & Roanoke R. R.		7	5— 16, 2— 17	114
" "	Shingle Creek Bridge	3	44	132
Wabash, St. Louis & Pac. R. R. Co.	Lagro Creek Viaduct	...	.....	421
Norfolk & Western R. R.	Little Otter Viaduct	5, 10	40, 50⅞, 52⅞	716
" "	1st Crossing of New River	5	168	840
Seaboard & Roanoke R. R.	Crossing over Petersburg R. R.	1	39	39
Recife & Caruaru R. R.	Capibaribe River	1	192	192
La compañia de Almacenes de deposito de la Habana	4 Iron Piers at Havana, Cuba. 33 feet wide	...	.....	1314
Cape May Pier Co.	Mar. P'r at C. May, N.J. 30 ft. w'e.	...	.....	900
Norfolk & Western R. R.	2d Crossing of New River	4	140	560
I. H. Todd	Port Kennedy	1	7	7
G. W. Div. G. T. R.	Jeannette Creek Bridge	3	41	123
Seaboard & Roanoke R. R.	Meherrin Bridge	25	40	1000
" "	" "	1	159	159
G. W. Div. G. T. R.	Belle River Bridge	3	41	123
Norfolk & Western R. R.	Reed Island Crossing	2	120	240
Mr. George Harding	Foot Bridge between two Hotel Buildings, Catskill Mount'ns.	4	25	100
Philadelphia & Reading R. R.	2d Bridge, South of Pencoyd	1	28	28
" " "	Lovers' Leap Bridge	3	170	510
Juragua Iron Co.	Cuba	1	53	53
Alf. P. Bollar, Engineer, N. Y.		1	31	31
Coplay Branch Phila. & Read. R. R.	Over Lehigh Valley R. R.	1	107	107
W. H. Crosman & Bro., N. Y.	Rio Parabyba, Brazil	4	141	564
Southern Pacific R. R.	Santa Clara Creek Bridges	7	100	700
" "	" "	2	120	240
" "	" "	2	90	180
" "	" "	3	80	240
" "	" "	3	57	171
Royer's Ford Bridge Co.	Sch'k'l Riv. Br. at Royer's F'd, Pa.	3	2—117, 1—119	353
L. & S. Branch C. R. R. of N. J. Div. Phila. & Read. R. R.	Coal Port Bridge over Lehigh Valley R. R. 2 tracks	1	125	250
Philadelphia & Reading R. R.	Over Lehigh R. at Turnhole. 2 Tr.	2	122	488
Trenton City Bridge Co.	Delaware Riv. Br. at Trenton, N. J.	7	180	1260
Gay Manufact'ng Co, Suffolk, Va.	Over S. & R. R. R.	1	15	15
P. & O. R. R.	Centre Conway Trestle	16, 1	28½, 29 7/16	495
Richmond & Alleghany R. R.	Reid's Creek Bridge	1	54	54
S. G. R. R., Huntingdon Co., Pa.	Bridge No. 1	1	54	54
" " "	" No. 2	1	23	23
" " "	" Nos. 3 and 4	2	33	66
" " "	" Nos. 5 and 6	2	23	46
John W. Berry	Pittston, Pa	2	87	174
Grand Trunk Railway of Canada	Brock St. Bridge	1	167	167
Portland & Rochester R. R	On line of P. & R. R. R.	1	13	13
Philadelphia & Reading R. R.	Lehigh Gap. 2 tracks	1	90	180
The Allison Manufacturing Co.	Flue Mill, Phila. 10 trusses	...	79	219
Central Vermont R. R.	Barron's Road Crossing, White River Junction	8	4—108, 4— 40	592
" "	Davis Road Crossing	1	44	44
Thos. Ricart, Agent	P'n R'f for Th'tre, Hav., C. 6 tr'ses.	...	70	105
Pottstown Bridge Co.	Sch'yl River Br'ge at Pottst'n, Pa.	2	180	360
W. B. Wilkins, Agent, N. Y.	Rio Pyranga, Brazil	1	134	134
" " "	Braco do Rio, "	1	53	53
Philadelphia & Reading R. R.	Near Spring Mill	2	30	60
E. P. & H. N. Almy	Footway Bridge	1	35	35
Seaboard & Roanoke R. R.	Meherrin Slough Bridge	1	60	60
New London Northern R. R.	Stafford Bridge	1	73	73
Louisville, New Orl's & Tex. R. R.	Bayou Perre Bridge	2	123	246
W. H. Crossman & Bro., N. Y.	Brazil	2	115	230
Central Pacific R. R.	Cape Horn Bridge	1	120	120
Baldwin Locomotive Works	Footway Bridge	1	51	51
Cincinnati, Wash. & Balt. R. R.	Muskingum River Bridge	2	187	374
Glendon Iron Co.		1	57	57
Phila. Branch of Balt. & Ohio R. R.	Over Watson's Island, Va	...	.....	1942
" " "	East Approach to Susquehanna B.	1	242	242
John W. Berry	Wash. Ave. Bridge, Scranton, Pa.	1	110	110

SUMMARY:
- Total number Single-Track Railway Spans ..... 370,400 lineal feet = 70 miles.
- Total number of square feet of Iron Roofs 187,546
- Total number of square feet of Ocean Piers 164,880

GENERAL SPECIFICATIONS FOR RAILWAY BRIDGES.

THE moving load for each track shall consist of two consolidation locomotives, each with weights distributed according to the following diagram, followed by a train



weighing 3000 pounds per lineal foot. In the case of double-track bridges, this moving load shall be taken as moving in either direction on either track.

The lateral bracing between the chords which do *not* carry the moving load shall be designed to resist a wind pressure of 150 pounds per lineal foot of span.

The lateral bracing between the chords which carry the moving load shall be designed to resist a wind load of 450 pounds per lineal foot of the span, 300 of which shall be treated as a moving load.

In all viaducts and trestle towers the wind load shall be taken as follows:

On the unloaded structure, 50 pounds per square foot of surface projected on the vertical plane through its axis.

On the loaded structure, 30 pounds per square foot of the same surface, in addition to an equal amount per square foot of train surface; the latter to be treated as a moving load.

In all cases the projected surface of two trusses and two sides of towers is to be taken as the surface of action of the wind. The overturning effect of the latter on both trusses and train shall be considered.

The weight of ties, guard timbers, rails, spikes, etc., shall be taken at 400 pounds per lineal foot.

The greatest working stresses in all tensile members of railway bridges shall be taken as follows:

In counter-web members	8,000 pounds per square inch.
In long verticals	8,000 " " "
In main web members (eye-bars)	10,000 " " "
In suspension loops	7,000 " " "
In tension members of lateral and transverse bracing (including 10,000 pounds for initial tension)	15,000 pounds per square inch.
In counter-rods and long verticals of lattice-girders (net section)	7,000 " " "
In lower chords and main tension members of lattice-girders (net section)	8,000 " " "
In bottom flange of plate-girders (net section)	8,000 " " "
In bottom flange of rolled beams	8,000 " " "

The greatest working stresses in compression members shall be the following, in which P is in pounds per square inch:

	Flat Ends.	*Pin Ends.*
Phœnix Column.	$P = \dfrac{8400}{1 + \dfrac{l^2}{50{,}000\, r^2}}$	$P = \dfrac{8400}{1 + \dfrac{l^2}{30{,}000\, r^2}}$
Latticed, or Common Column.	$P = \dfrac{7800}{1 + \dfrac{l^2}{40{,}000\, r^2}}$	$P = \dfrac{7800}{1 + \dfrac{l^2}{30{,}000\, r^2}}$
Angle-Iron Struts.	$P = \dfrac{7800}{1 + \dfrac{l^2}{30{,}000\, r^2}}$	$P = \dfrac{7800}{1 + \dfrac{l^2}{16{,}000\, r^2}}$

l is the length of column, and r the radius of gyration of section in direction of failure; both are to be taken in feet, or both in inches.

The formula for pin-end angle-struts is to be used only when the length exceeds 120 radii of gyration; below that value, the formula for flat ends is to be used in all cases.

In the compression flange of plate girders and rolled beams, the working stress shall not exceed 8000 pounds per square inch of gross section.

If the web-plate or plates in the upper chord of latticed girders are not both supported by angles and latticed, their working stresses shall be determined by the formula for angle-struts; if, on the other hand, they are so supported, the formula for common columns shall be used, the gross section being taken in both cases. In all cases the length, l, shall be taken either between points of attachment of lateral bracing, or between panel points, as may make $l \div r$ the greatest possible.

If the upper chord of a deck structure supports the ties (or its own weight) as a

transverse load, such a member shall be designed to sustain the combined stresses arising under such circumstances of loading.

All members sustaining alternate tension and compression shall be designed to carry the largest stress added to six-tenths, the smallest.

The greatest shearing stress in any rivet or pin shall not exceed 7500 pounds per square inch.

The greatest bearing stress allowed on any rivet shall not exceed 12,000, multiplied by its diametrical bearing area before driving. This clause shall also apply to the bearing of pins.

The bending stress of tension or compression on the extreme fibres of pins shall not exceed 15,000 pounds per square inch for wrought iron, nor 20,000 pounds per square inch for steel.

All structures whatsoever shall be provided with complete and efficient systems of lateral and transverse bracing.

QUALITY OF MATERIAL.

Wrought iron shall be uniformly tough and fibrous in character, and shall possess a limit of elasticity of not less than 26,000 pounds per square inch.

The ultimate resistance of prepared specimens of 1 square inch in sectional area for a length of 10 inches, taken from full-sized bars of not more than 4 square inches in area of section, shall be not less than 50,000 pounds per square inch. A reduction of 500 pounds per square inch for each additional square inch of full-sized bar area will be allowed in similar specimens taken from bars of greater sectional area than 4 square inches, down to a minimum ultimate resistance of 48,000 pounds per square inch. In all cases the stretch shall be not less than 18 per cent. in 10 inches.

Specimens not over 1 square inch in area of cross-section, taken from shapes and plates under 24 inches wide, shall give an ultimate resistance of not less than 48,000 pounds per square inch, and a final elongation of 15 per cent. in 8 inches; all tests being made in the direction of the fibre.

Similar specimens from plates over 24 inches in width shall give a resistance of not less than 46,000 pounds per square inch, and an elongation of not less than 12 per cent. in 8 inches; tests being made, as before, in direction of the fibre.

All iron used in tension must bend cold 90 degrees without cracking to a curvature whose radius is about the thickness of the metal, and not less than one-third of such specimens shall bend to 180 degrees under the same conditions. Plate and shape specimens must bend cold 90 degrees to a radius one and a half times the thickness without cracking.

All iron, when nicked and bent by blows from a hammer, must show a structure nearly all fibrous.

HIGHWAY BRIDGES.

All highway bridges shall be proportioned to carry their own weight, added to 80 pounds per square foot of clear roadway and sidewalk, as moving load for spans of less than 125 feet, or 60 pounds per square foot for spans over 125 feet. In all cases the floor system shall be designed for a moving load of 100 pounds per square foot of clear roadway or sidewalk.

The greatest allowable stresses of the various kinds shall be determined by increasing those for railway structures to the extent of 20 per cent.

The general excellence of the work and material shall fully equal that required for railway structures.

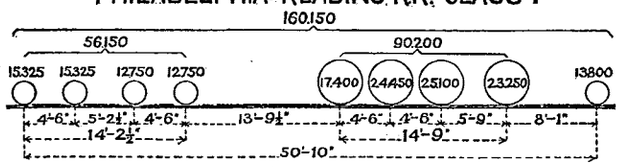
THE WEIGHTS OF LOCOMOTIVES AND CARS.

Although the weights of locomotives and loaded cars vary widely according to circumstances of location and traffic, the more common values found in connection with the heaviest as well as the ordinary traffic carried by either the standard or narrow-gauge roads are completely given on the adjoining plate. These values are not only of very considerable interest in themselves, but are of the greatest importance in the design of bridge structures. The old method of a uniform moving load with locomotive excess in front no longer meets the requirements of the best structural design. The wheel concentrations must be taken as they are, and that position assumed which will give the greatest value to the stresses sought. These observations possess special force in connection with the design of the floor systems of railway bridges.

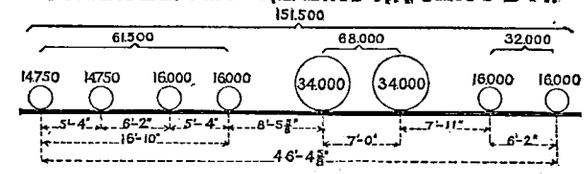
The wheel concentrations shown on the plate give correct ideas of the proper weights or loads to be taken, in addition to the weights of structures, within the ordinary limits of the best practice for either standard or narrow-gauge roads.

ACTUAL WEIGHTS of ENGINES & TENDERS.

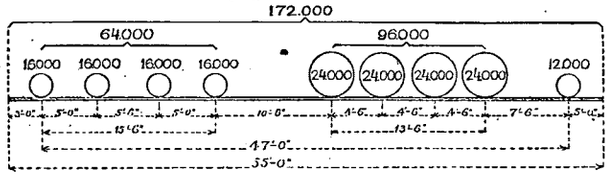
PHILADELPHIA & READING R.R. "CLASS 1"



PHILADELPHIA & READING R.R. "CLASS D44"



PENNA. R.R. CONSOLIDATION.



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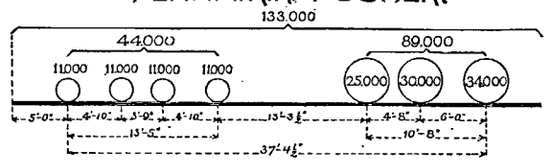
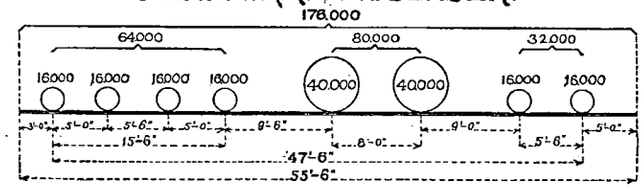
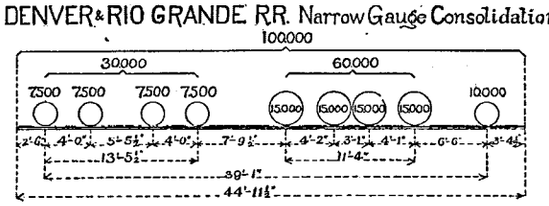


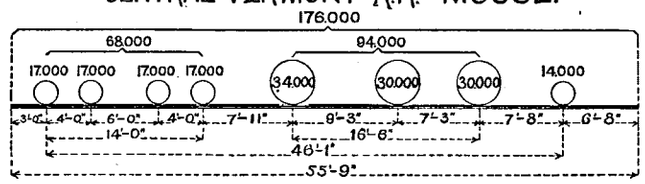
PENNA. R.R. PASSENGER.



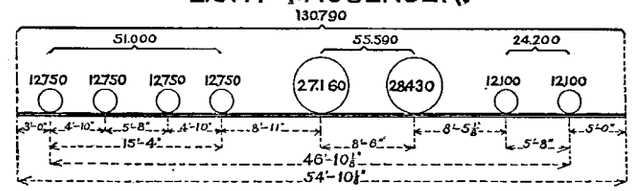
DENVER & RIO GRANDE R.R. Narrow Gauge Consolidation.



CENTRAL VERMONT R.R. "MOGUL".

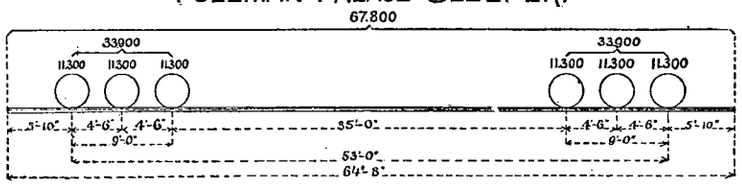


LIGHT PASSENGER.

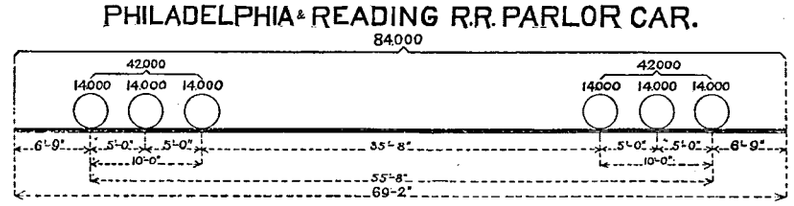


WEIGHTS of LOADED CARS.

PULLMAN PALACE SLEEPER.



PHILADELPHIA & READING R.R. PARLOR CAR.



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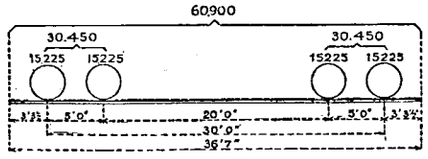

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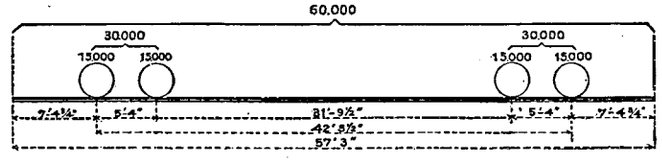

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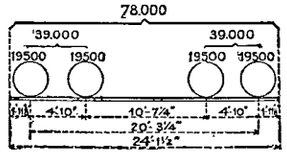

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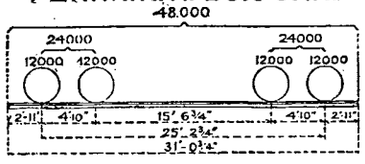

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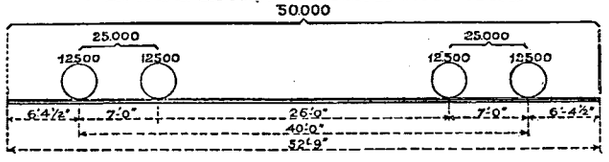

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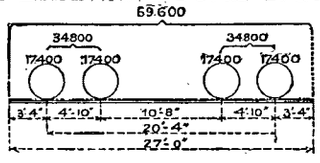


PHŒNIXVILLE BRIDGE WORKS.

THE Works of the Phœnix Iron Company, at Phœnixville, Pa., are conveniently situated with respect to the ore-beds and coal-fields of the eastern part of that State, and within easy reach of the markets of the country by means of the admirable systems of transportation afforded by the Philadelphia and Reading and the Pennsylvania Railroads. Not only because of the quantity and high quality of their product have these Works won a world-wide reputation, but also by reason of the large extent and the well-planned arrangement of the many furnaces, mills, and shops that constitute the plant of the Company. Beginning on a small scale in the year 1790, these works were materially enlarged in 1827. In 1842 very extensive additions were made in the shape of a complete puddling-mill with six single furnaces, a Burden rotary squeezer, and a train of rolls, this being the first establishment in the Schuylkill Valley to begin the puddling of iron on a large scale. In 1845 two blast-furnaces 15 by 59 feet were built, and in 1846 a third blast-furnace 15 by 59 feet was put up. These furnaces are still in operation, but have been very greatly improved by the addition of such modifications as have been brought forward from time to time and approved by the usage of the best iron-workers. In 1846 a large mill for manufacturing railway iron was erected and equipped with a complete set of furnaces, engines, and rolls requisite for the production of such material.

In this mill was rolled much of the railway iron that was used in the construction of the pioneer railroads of this country, and its products were well known in every State of the Union. In 1855 the ownership of the works was merged into a stock company under the title of "The Phœnix Iron Company," and the manufacture of beams, channels, tees, and a variety of shapes of iron was begun. The capacity of their shops and foundry having been enlarged, they entered upon the construction of bridges, roofs, and other varieties of structural iron-work, and this department of their business has steadily increased in importance since its establishment. During the civil war many hundred wrought-iron field-guns were made at these works, as well as large quantities of material for ordnance service and naval stores.

In 1862 the Phœnix column was introduced to the market, and in 1866 the manufacture of eye-bars forged by hydraulic pressure for bridge-links was begun.

These two important factors in the construction of bridge-work, in furnishing engineers with their material arranged in the most perfect forms for resisting the strains of compression and tension, have performed signal service in developing the American type of bridge, and have made practicable the rapid and economical manufacture of engineering structures adapted to a great variety of purposes. In 1870 the works occupied an area of about 30 acres, but so steady had been the demand for their product, and so wide was the field for its employment, that it was then considered advisable to make provision for such enlargement of their capacity as would enable them to meet the requirements of their business in a more satisfactory manner. A large building, covering about 6¼ acres under a single roof, was erected, and a complete outfit of gas producers, regenerative furnaces, compound engines, and trains of rolls planned for its equipment in the most thorough manner. This building served as a model for the architects of the Centennial Exhibition buildings, and is admirably adapted to the special requirements of a large rolling-mill. It is 928 feet long, 288 feet wide, and 30 feet high to the square. It is built almost wholly of iron and glass. Two long parallel sheds connected by four spacious transepts, and enclosing three interior courts, will convey, in brief description, some idea of the general plan.

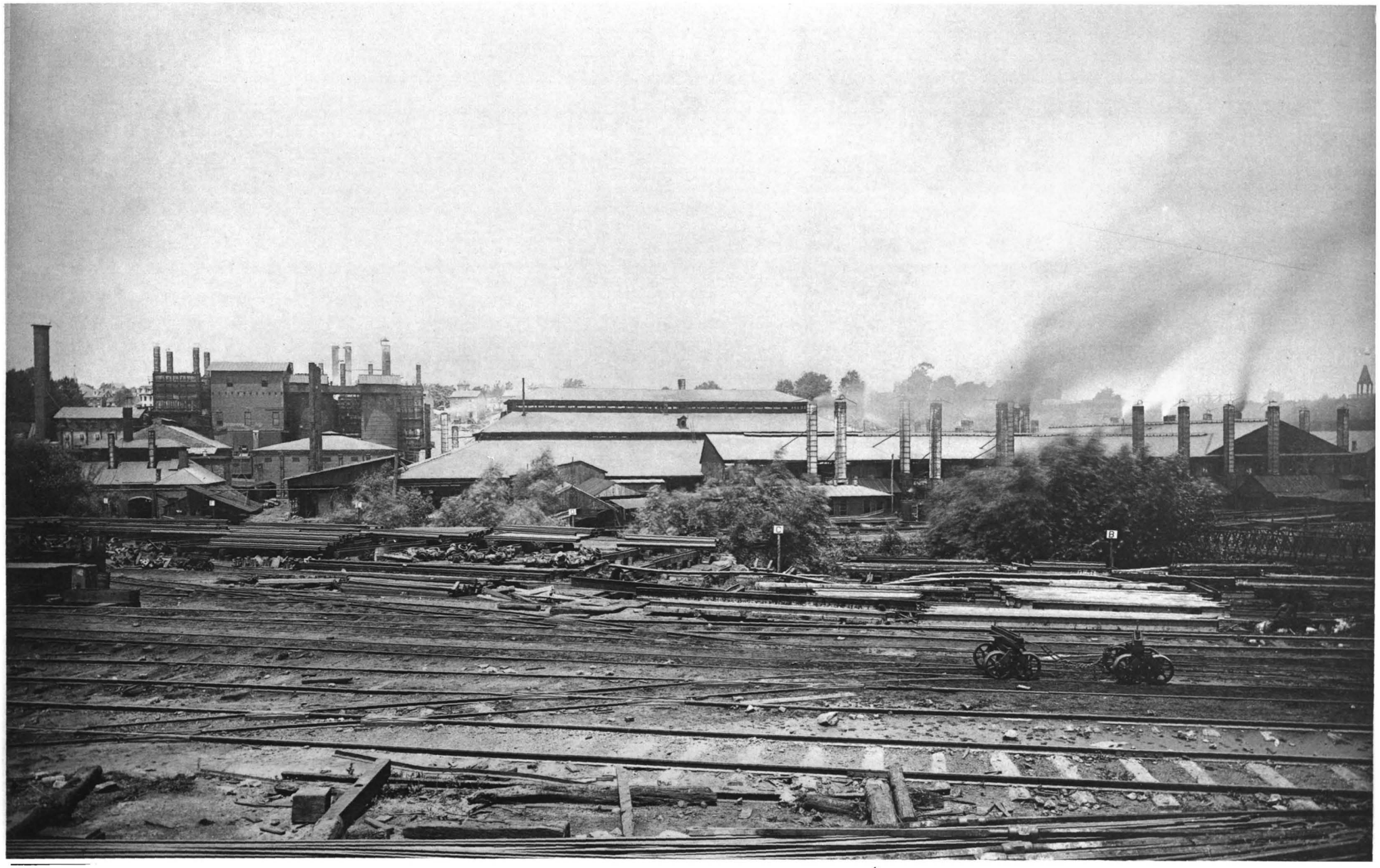
Two views of the Works are presented in this album, from photographs, which give some idea of the general arrangement of the plant, but necessarily omit much, and but inadequately represent its magnitude. One of them shows, in part, the new rolling-mills. Back of this building is that of the gas-producers, 60 feet wide, running the length of the main building and separated from it by a passage-way of 150 feet. The second view represents the blast-furnaces, puddling- and old rolling-mills. On the opposite side of the creek, in front of them, but not shown, are the various shops, foundry, and other buildings used in the manufacture of bridges.

The drains, water-pipes, steam-pipes, and gas-passages form an intricate system under the iron floor that is quite hidden from the visitor, but, like the circulation of a living organism, a system most essential to the vitality and action of the body that is dependent upon it. The recent adoption of gaseous fuel has enabled manufacturers to regulate much more satisfactorily the quality of their iron by keeping it clean and free from ashes or dust during the process of heating, as well as by giving a thorough control of the temperature desired in the furnace, and these advantages are obtained in this mill by the use of all of the appliances yet devised for the purpose.

From these furnaces the iron is rolled into the various forms required in the construction of buildings, bridges, and ships by passing it between rolls having in them grooves of the form it is desired to give to the bars. From the mills such bars as are to be further worked up into the construction of bridges or buildings are taken to the machine-shops.

These buildings, the largest covering about an acre and a half of ground, contain

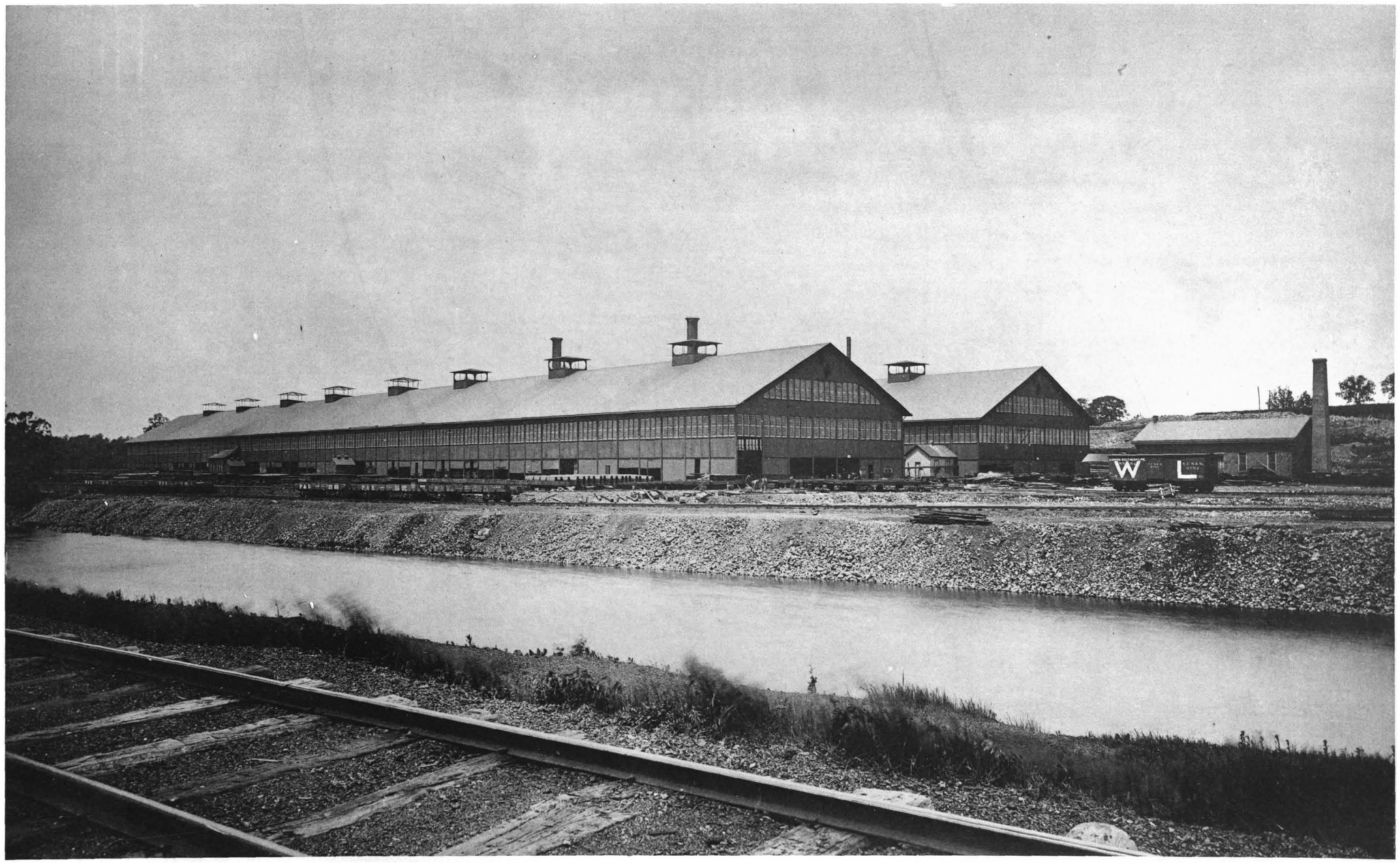
THE PHŒNIX BRIDGE COMPANY.



Blast Furnaces. Rolling Mills. Puddle Mills.

WORKS OF THE PHŒNIX IRON COMPANY,

PHŒNIXVILLE, PA.



Length, 930 Feet. New Rolling Mills. Front, 430 Feet.

WORKS OF THE PHŒNIX IRON COMPANY,

PHŒNIXVILLE, PA.

the various machines and tools by which the iron is planed, turned, drilled, and handled with expedition and accuracy. Steam-riveting and air-riveting machines replace the din of the hand-hammers and sledges of a decade ago, and do more than double the amount of work almost noiselessly. In an adjoining building special attention is given to the riveting of the Phœnix columns, large numbers of which in a great variety of sizes can be very quickly produced by means of the tools specially adapted for the purpose. The heavy links for bridge eye-bars are forged by hydraulic pressure in another shop which is set apart for this particular work. The heads upon these bars are made by a process that insures the development of the full strength of the bar when under strain in a structure. The end of the bar having been heated to a white heat is upset by pressure between dies, and then shaped by reheating and further pressure into the desired form. After cooling and trimming, the pin-holes are bored, both holes at one operation, thus insuring an accuracy in the distances from centre to centre of holes that is essential in the manufacture of work of this character. Powerful testing-machines stand ready to prove by actual pull the strength of the bars thus made, and to enable inspectors to determine the elasticity and ductility, as well as the ultimate strength of the material called for by their specifications. Adjoining the hydraulic forge a hammer-shop, with a 6-ton steam-hammer and gas-heated furnace, has recently been put up, and will greatly add to the power and capacity of the forge. Here can be handled and made any parts of a bridge requiring heavy and accurate die-forging, and the use of gas for heating the material will give the same advantages of clean work and control of temperature that is obtained in the mill-furnaces.

The foundry of the Company is a spacious stone building with iron roof-frame and ample light from all sides. It is served with steam-cranes and all modern appliances for producing the best material at the lowest cost, and is kept constantly busy in turning out the various forms and shapes of iron that the ingenuity of the millwright delights to design and the skill of the workman takes pleasure in constructing.

The old frame building that was used for foundry purposes was destroyed by fire April 23, 1882, and the first casting made in the new foundry was in the afternoon of June 16, 1882. The numerous and valuable patterns belonging to the works are stored in a brick building put up expressly for the purpose of affording protection against the risk of their destruction by fire. It is four stories high and is lighted from a skylight in the roof by a central shaft, about which the shelves and passages are arranged in such a way as to afford the greatest amount of storage room with easy access to the patterns and ample light in every corner. The distribution of material from the mills to the shops and about the yards is effected by a system of narrow-gauge railway that ramifies throughout the yards and reaches every part of the works. Four locomotives are constantly employed in the service of this system of distribution, and have with great economy taken the place of the many mules and horses that formerly attended to this very necessary duty.

A large stock of beams and shape-iron of every variety of size and weight is kept on hand for supplying promptly orders for such material, and telegraphic orders from New York, Boston, Chicago, or Baltimore can in this way be filled with accuracy and despatch, and the iron loaded and shipped in a few hours after the receipt of specifications.

For supplying the many boilers, for cooling the furnace sides, for the service of the condensers, and for a great many other purposes, an abundant supply of excellent water is obtained from the Saukanac, or French Creek, along the valley of which the works extend for nearly a mile. A Worthington pump of 2½ million gallons capacity raises this water to a storage reservoir on the hill-side, whence it is distributed by a system of mains and service pipes to all parts of the newer works.

Thus the whole establishment is arranged for the production of iron of high quality on a large scale in a great variety of shapes by means of the most modern and improved appliances, and claims to occupy a place among the foremost American mills.

DESCRIPTION OF DESIGNS.

DESIGN "A."

THE general style of girder shown in this design is well adapted to spans under 18 or 20 feet. It is composed of two eye-beams, 15 inches deep in the present case, weighing 200 pounds to the yard. These beams are thoroughly braced in two panels, so as to secure perfect lateral stability.

The lateral struts are 6-inch eye-beams, and the ties are rods 1⅛ inch in diameter.

This simple structure is specially adapted to locations in which the head room is very limited.

The plate represents a girder placed on the line of the Seaboard and Roanoke Railroad, at Suffolk, Va.

DESIGN "B."

This design shows the adaptation of our plate-girder system to a span of about 40 feet. In the vicinity of the ends the chords are each composed of a pair of angles, which are reinforced for somewhat more than the central half of the span by a heavy plate. As there is only one cover-plate, it may be depended upon to perform its functions with the greatest efficiency.

The stiffness of the intermediate portion of the web is secured by pairs of angles (one angle on each side of web) riveted at sufficiently frequent intervals. As the ties are placed on the top chords, the ends of the girders are subjected to very severe shocks and consequent fatigue. This is amply provided against by extra heavy vertical end-stiffeners riveted over fillers reaching from upper to lower chord-angles.

Transverse stiffness is secured by latticed struts of equal depth of the girders, which take hold of the angle-stiffener throughout the entire depth of the main girder. These transverse struts also serve as the compression members of the lateral system, the latter being completed by the ties as shown. The most thorough lateral and transverse stiffness is thus secured, and the girders enabled to sustain in the most efficient manner that severe use under rapidly-passing heavy loads to which all short spans are unavoidably subject.

This particular structure was built for the Seaboard and Roanoke Railroad, and forms a part of the "Meherrin Bridge."

These plate-girders may be advantageously used under ordinary circumstances for spans running from 20 to 50 feet, although they have been constructed for spans of about 70 feet.

DESIGN "C."

The general character of our deck lattice-girders is well illustrated by this plate, which represents the 60-feet span of the Kinzua Viaduct. The upper and lower chords are alike, and are composed of two angles and a deep web-plate extending throughout the length of the span, reinforced over about the central half by a cover-plate. A sufficient depth of web-plate in the chords was taken to properly resist the bending action of the moving load in combination with the direct compression, as well as to secure sufficient bearing surface for the rivets uniting the web members to the chords.

All the web-braces are arranged in pairs, so as to take hold of both sides of the chord-plate, thus securing double shear in the rivets, and completely avoiding all twisting of the chords. Both the rivet shear and the bearing capacity of rivets against the plate and angles are carefully considered in all our riveted work; and when, as in the present instance, the ties rest directly on the chord, the latter is designed to resist the combined stresses arising under such circumstances.

By our system of construction we are enabled to make the centre lines of stress of members meeting at one place intersect as nearly as possible in one point, thus essentially avoiding those secondary stresses which frequently constitute such an objectionable feature in riveted work.

The vertical end-posts are made very heavy, as they are exposed to very severe duty. The transverse and lateral systems of bracing are of heavy angle-iron and in short panels, and so attached to the chords as to develop the full resistance of cross-section in the most direct and effective manner.

At and near the centre of the span, where the web members take both kinds of stress, both bars and angles are provided, the former to take the tension and the latter to resist the compression.

All intersections of web members are riveted, in order to shorten the struts and give general stiffness.

DESIGN "D."

Our type of ordinary through bridge for railway traffic is well exemplified by these trusses of 120-feet span, built for the Norfolk and Western Railroad, and forming a part of the bridge at Reed Island crossing. In each span there are six panels of 20 feet, and the trusses are 21 feet deep. The chief characteristics are the single system of triangu-

lation with long panels, and consequently small number of parts, great simplicity of details, and the use of "Phœnix" columns as compression members. The long panels reduce the number of parts, and hence the tendency to vibration, to a minimum, while the economy of inclined end-posts is considerably increased.

The top and bottom lateral bracing is designed for a total wind pressure of 550 pounds per lineal foot, in addition to which there are heavy transverse knee-braces. The lateral stability is still further materially increased in an incidental manner, both by the floor-beams being drawn tightly up against and into recesses at the bottom of the posts, and by the ties and struts between the stringers, which really constitute an independent lateral system. These latter give the requisite lateral stiffness to the long track-stringers. Both the truss and floor system are thus seen to be peculiarly well adapted to a heavy and rapidly-moving traffic.

DESIGN "E."

The adaptation of our system of construction to an extraordinarily heavy structure is shown by this span of a two-truss double-track railway bridge, with a span of 264 feet and ¾ of an inch from centre to centre of end-pins. It forms one span of the Rondout Bridge, on the line of the New York, West Shore and Buffalo Railway; the complete structure will receive a full description on another page.

As the total load is divided between two trusses only, the members of each are unusually heavy; consequently, the economic depth of truss takes a comparatively high value.

The depth of 45 feet fixed upon in the design involves the incidental but important advantage in such a length of span of a small deflection and correspondingly increased stiffness.

Heavy upper and lower lateral systems of bracing are provided, in connection with transverse bracing, in the vertical planes of each pair of opposite panel-points, besides portals of unusual stiffness. The general stability of the bridge is still further increased by bracing the upper half of the third panel from either end in each truss, and connecting the lower transverse bracing-points of all the posts.

There are fifteen panels of 17 feet 7¼ inches each, which, in connection with the three systems of triangulation, unites the advantages of an economical angle for the ties with those of long panels.

The converging of a large number of eye-bars at the upper extremity of the end-post presented a problem which is effectually solved in a very simple manner by a massive plate hung on the end-pin in the manner shown.

The transverse floor-beams are necessarily of unusual depth, and their lower chords are held rigidly in place by tie-rods reaching from each pin to the lower extremity of each adjacent pair of hanger-loops.

In the centre panel of each truss there are ten eye-bars, giving rise, unless properly designed and arranged, to excessive pin bending. As in all our designs, the eye-bars and pins were here so proportioned that the extreme fibre stress does not exceed 15,000 pounds per square inch.

DESIGN "F."

In many cases it is desired to connect masonry piers across an opening where the clear space below is not limited. Under such circumstances this type of truss can be most economically employed.

There are six panels of 13 feet 4 inches each, and the depth of truss is equal to the panel length. The trusses are placed 10 feet apart centres, so that the ties rest directly on the upper chord. The latter is so proportioned as to resist the consequent bending in combination with the direct compression. A judicious selection of panel length enables the proper balance to be maintained between chord-bending on the one hand and the advantage of a long panel on the other. Effective systems of upper and lower lateral and transverse bracing are easily secured in such a bridge, and give the requisite general stability.

This bridge carries the line of the Chesapeake and Ohio Railway over Dunlap's Creek.

DESIGN "G."

The application of our system of construction to a long deck span is well shown by this bridge, built for the Galveston, Harrisburg and San Antonio Railroad. The length of span, which is 300 feet, necessitates such a distance between the trusses that it is impracticable to place the ties directly on the upper chords. The usual transverse floor-beams are placed directly at and over the panel-points, and held rigidly in place by inverted loops.

Two lines of longitudinal stringers, 6 feet apart centres, carry the single line of rails, while two other lines over the two trusses make ample provision for the sidewalks.

The stringers are placed on the floor-beams, and braced firmly in position and stiffened by the heavy brackets, as shown.

The depth of the truss is 37 feet 8 inches, and length of panel 17 feet 8 inches. The advantages of a long panel, combined with an economical angle of ties, are thus secured by employing two systems of triangulation.

Complete transverse and lateral stability, both upper and lower, are effectually obtained in the usual manner.

Although there are eight lower chord eye-bars in the centre panel of each truss, they are so proportioned and arranged that the stress on the extreme pin-fibre does not exceed the proper limit.

DESIGN "H."

The distribution of material in a long span drawbridge, so as best to subserve the purposes of its construction, is a problem requiring the most careful consideration in all its details. It may be safely asserted, however, that the object of structural design has rarely, if ever, been accomplished in a more satisfactory manner than in this particular case.

The heavy bending over the centre pier is controlled by a comparatively small amount of metal, in consequence of the increased depth of the truss at that point; while the stresses in the web members in the vicinity of the centre are materially relieved by the greater chord inclination at the same place. The outer portions of the two arms, in which the stresses change in kind under the passage of the moving load, possess a depth of comparatively small and nearly uniform value. This meets in a most rational and effective manner the requirements of the relatively small stresses existing in these parts

of the structure. The curved upper outline of the trusses thus combines the excellencies of an economic system with a remarkably graceful appearance.

As the bridge carries a double-track railway, with two trusses 26 feet apart between centres, it is readily seen to be a very heavy structure. The end and centre depths (20 and 40 feet respectively) are so taken in connection with the panel length of 17 feet 5½ inches, however, that the greatest economy is attained.

The turn-table is wholly rim bearing, and the drum, 28 feet 2 inches in diameter, is carried on forty-two 24-inch rollers.

This type of structure is peculiarly adapted to the purpose of securing that degree of economy in construction and ease and stability in turning which are so essential in a long and heavy drawbridge.

A further description of this bridge will be found on another page.

DESIGN "I."

The most economical method of carrying a railway across a wide gorge in which firm pier foundations are easily secured at all points, is illustrated in a remarkable manner by this structure. The total width of gorge is divided into twenty-one open spans and twenty tower spans, the former of about 60 feet, and the latter of about 40 feet. The greatest height is about 300 feet.

Each of the towers are thoroughly braced longitudinally and transversely in order to resist not only the wind pressure, which acts with great severity on a structure of such extreme height, but also the thrust and vibrations caused by the moving loads.

The lateral pressure of the wind against a passing train at great elevations produces an overturning effect of unusual magnitude, which in this case has been amply provided for by the inclination of the columns and the anchorage at their feet.

The wind pressure on the structure and its train-load was taken at 30 pounds per square foot, and 50 pounds per square foot for the unloaded structure. Subsequent tests on large surfaces, at the site of the Forth Bridge, have demonstrated that these values give abundant security against wind stresses.

The towers are divided into stories of about 33 feet each, at the extremities of which the column sections are joined by interior wrought-iron sleeves, forming a complete cylinder. By means of these cylindrical sleeves each column is made absolutely continuous from the top of the tower to the masonry at its base.

The lattice-girders forming the superstructures are of the deck variety and 10 feet apart centres, but possess no special characteristics other than being remarkably substantial structures.

DESIGN "J."

This design shows a highway bridge built by us for the Pottstown Bridge Company, of Pottstown, Pa., and the structure crosses the Schuylkill River at that place. There are two spans of 179 feet each from centre to centre of end-pins. The trusses are 21 feet 4 inches apart centres, with two sidewalks about 5 feet each in the clear. This bridge is typical of our usual highway construction.

It will be observed that the marked advantages of long panels and a single system of triangulation are secured by the use of a system of intermediate transverse iron beams, one resting at the centre of each panel on a pair of main longitudinal iron stringers. The latter are supported on the main floor-beams a short distance from the points of support of the latter, thus adding very little to their bending movements. 6-inch eye-beams and the two main stringers just mentioned form the joists which carry the floor-plank. Two lines of light timber joists, one outside of each main stringer, receive the spikes which hold the plank in place.

The sidewalk railing acts as a truss, with a span of one panel length, for half the sidewalk and its load. The sidewalk plank are spiked to the top of the guard-timber as shown; in this manner the footwalk is raised an agreeable distance above the roadway.

By this method of construction a permanent, light, and economical iron-floor system is obtained, the only inflammable portion being the necessary plank floor.

Efficient systems of upper and lower lateral and transverse bracing give in themselves complete stability against moving-load vibrations and the wind, though they are very materially reinforced by our system of floor construction.

DESCRIPTION OF PLATES.

PLATE I.

MIDDLE BROOK BRIDGE.

THIS structure carries the four tracks of the New Jersey Central and Bound Brook Divisions of the Philadelphia and Reading Railroad across Middle Brook, near Bound Brook, N. J. The trusses are 28 feet apart between centres, and the span is 128 feet, divided into seven panels of 18¼ feet. The depth of 32 feet is so taken as to preserve the proper balance between economy of material in the bridge as a whole and judicious design and arrangement of the individual truss members. The extraordinarily heavy load carried by the centre truss, as well as the somewhat unusual characteristics of the traffic, give to the design of this structure more than ordinary interest. The anthracite coal region finds one of its main outlets over the New Jersey Central Division, and thus puts upon the bridge a continuous and very heavy traffic, while the New York and Philadelphia express trains over the Bound Brook route move at a speed certainly not surpassed in this country. There is thus combined in the duty performed by the structure essentially the highest limits of requirements respecting rapidity of movement and weight of passing loads. The floor system, composed of twelve lines of longitudinal stringers rigidly secured between the transverse floor-beams, admirably fulfils the requirements of such exceptional conditions. The depth of trusses gives very stiff transverse bracing, and the construction of the floor system increases very materially the lateral stability.

The heavy loads carried by this bridge involve the use of the eight segment Phœnix column and a number of heavy eye-bars of 12 square inches in sectional area.

PLATE II.

SUNBURY BRIDGE.

The single track of the Mahanoy and Susquehanna Division of the Philadelphia and Reading Railroad crosses the Susquehanna River at Sunbury, Pa., on the through structure shown in this plate. Ten spans of 192 feet each are on a tangent, while four of about 156 feet each are on an eight-degree curve, making a total length of about half a mile. All the trusses are 32 feet deep, but a separation of 16 feet between truss centres for the spans on the tangent is changed to 21 feet for those on the curve. The 192-feet spans have each eleven panels of 17 feet 5½ inches, while each of the other spans are composed of ten panels 15 feet 7 inches in length. The bridge was designed to meet the requirements of the heavy traffic of the Philadelphia and Reading Railroad, and its general proportions are such as not only to fulfil those conditions, but also to form a most graceful structure, adding a very agreeable feature to its picturesque location. The pleasing effect is increased by the ornamental character of the Phœnix column.

The principal features of the construction are sufficiently well shown by the phototype to render unnecessary a detailed description. Perfect lateral and transverse stability are secured, and the floor system meets the highest requirements of the best practice. It is an excellent illustration of the most modern form of single track through bridge.

PLATE III.

CHAUDIERE BRIDGE.

The Ottawa River is spanned at Ottawa, Ontario, by this bridge, which was built for the Quebec, Montreal, Ottawa and Occidental Railway, now forming a portion of the Canadian Pacific system. Although the plate shows but six spans, there are thirteen, seven of which are separated by an island from the six that are shown. In all the spans the trusses are 16 feet 6 inches apart centres, but the depth of 34 feet 6 inches of the 255-feet spans is reduced to 30 feet for the others. The panel length of 17 feet 1 inch is uniform for all the spans except the longest, in which it changes to 17 feet 3 inches.

It is a "through" structure carrying a single track, and is nearly 2100 feet in length. The method of securing the floor-beams to the posts, by riveting just over the lower pins, is the only peculiar characteristic of the construction, and was required by the Railway Company. This feature. in connection with the placing of the stringers between the floor-beams, gives rise to a very stiff floor system, and materially increases the lateral stability.

The track rests on ties carried by a system of four longitudinal stringers, constituting a floor of sufficient continuity and strength to provide for any ordinary derailment. These stringers are 4 feet apart between centres; the two adjacent to the centre of the track are, therefore, heavier than the others.

The track is about 25 feet above the water at ordinary stage.

PLATE IV.

CATSKILL BRIDGE.

Of the many picturesque locations along the line of the New York, West Shore and Buffalo Railroad, there is, probably, none in which the art of the engineer combines more harmoniously with the quiet beauty of the natural scenery than at the site of this structure. The village of Catskill, prettily located on the bank of the Catskill Creek, and at a considerable elevation above it, in one of the most charming portions of the valley of

the Hudson, looks down upon this bridge as it carries the railway line over the creek and adjacent valley.

As the plate shows, the bridge is a double-track deck structure in eight spans,—six of 170 feet, and one each of 100 and 106 feet, with a total length of 1250 feet. The depth of the long spans is 26 feet, and panel length 16-feet 8 inches, while the depth and panel length of the short spans are 21 and 17¼ feet respectively. The trusses are 20 feet apart centres in all the spans, and the track is 85 feet above the water. Like all constructions for the New York, West Shore and Buffalo Railway, it was required to meet in all respects specifications based on the demands of the most advanced bridge practice of the present day. By the use of an independent floor system, with transverse floor-beams resting at the upper chord-panel points, a length of panel could be selected which would be productive of economy in trusses, and leave all stresses well defined.

As the two trusses are 20 feet apart centres, with depths of 21 and 26 feet, excellent proportions for effective transverse bracing are secured. The economy of oblique end-posts is attained by using vertical columns at the feet of the end-posts, which carry a panel moving load.

This bridge meets the requirements of a heavy and rapidly moving traffic, with a high degree of constructive economy.

PLATE V.

HARLEM RIVER BRIDGE.

The graceful outline of this drawbridge indicates that the demands of the location involved not only considerations of structural economy, but those of an æsthetical character as well. It is a double-track structure, crossing the Harlem River at Eighth Avenue, New York City, and connects the West Side and Yonkers Railway with the Eighth Avenue Elevated Road.

With a centre depth of 40 feet, and 20 feet at the end, the intermediate depths are so taken as to secure both beauty of outline and a proper regard for economic considerations. In fact, the varying inclination of the upper chord not only produces an agreeable impression on the eye, but is in reality a true expression of a correct distribution of material. No structure could be more admirably adapted to the complex requirements of the location. There are sixteen panels of 17 feet 5½ inches, and one of 18 feet 5 inches.

The trusses are 26 feet apart centres, and carried at the pivot pier by a wholly rim-bearing turn-table fitted with the proper appliances for steam as the motive power. The diameter of the drum is 28 feet 2 inches, and turns on forty-two 24-inch rollers. Although a single system only of triangulation is used, by proper trussing the entire weight of the bridge and its load is equally divided between eight points of support on the drum, equidistant from each other.

The locking-gear and turning machinery, with engine and boiler, are of the most approved character. They are located in the turn-table, and operate with great expedition and efficiency.

PLATE VI.

ALBANY AND GREENBUSH BRIDGE.

The Albany and Greenbush bridge shown on this plate is the second one built by this Company across the Hudson River at Albany; it connects the village of Greenbush with the city of Albany at a point just south of the freight station of the A. and S. Division of the Delaware and Hudson Canal Company.

The necessities of this particular case are a combination of those usually found in separate structures; the difficulties presented, therefore, were of a correspondingly complicated character. A roadway with sidewalk on either side is carried along the lower chord, while a double-track railway is placed 19 feet above the lower chord-pins. The structure is, therefore, obliged to do double duty, and, with the length of spans required, it becomes unusually heavy.

The trusses are 28 feet apart centres, and the entire structure is composed of four "through" fixed spans of 150 and 250 feet in length, combined with a "through" draw span 400 feet long, and three plate-girders at each end of 36-feet span, making the total length 1430 feet. The depth of the 250-feet spans is 45 feet, and that of the 150-feet spans 22 feet. The panel length is 16 feet 7 inches for the fixed spans, and 18 feet 3 inches for the draw, except at the drum, where there are two panels of 16 feet each.

The problem of placing a double-track railway platform midway of the depth of the long span trusses and draw presented some interesting points of design not usually encountered in bridge construction. All vertical compression members in the bridge are of the ordinary latticed channel species above the railway platform, but below the latter eye-beams take the place of the latticing, and furnish points of support at their upper extremities for the railway floor-beams. The end-posts of the 250-feet spans are eight segment Phœnix columns of the heaviest section ever rolled; they possess a cross-sectional area of 104 square inches.

The draw span has a depth of 25 feet at the ends and 50 feet at the centre. The resulting inclination of the chords produces considerable relief of stress in the web members. The four main posts at the pivot pier, with the double cancellation, made it necessary to consider each main truss as composed of two separate trusses, each continuous in itself, with one system of triangulation and two points of support at the centre.

The weight of the trusses and superincumbent load is distributed at ten points on the drum of the combined centre and rim-bearing turn-table.

This drum has a diameter of 34 feet, and depth of 42 inches.

The entire mass of drawbridge and turn-table weighs about 1000 tons, and is turned by steam in less than two minutes.

PLATES VII. AND VIII.

KINZUA VIADUCT.

The structure from which the views in these two plates were taken has attained celebrity from its great height, and stands as one of the most remarkable examples of modern construction. It carries the single track of the New York, Lake Erie and Western Coal and Railroad Company across the Kinzua Valley, in Bradford County, Pa. The superstructure is composed of latticed deck-trusses, 10 feet apart centres, and alternately of 61- and 38½-feet spans. The towers vary in height from 20 to 280 feet. To this latter height is to be added the depth of the latticed trusses and height of masonry, making a total elevation of 301 feet above the surface of the water in Kinzua Creek.

The towers are each composed of Phœnix columns for the main compression members and transverse struts, with longitudinal struts of four latticed angles and diagonal

tension-rods arranged in pairs as shown. Both longitudinal and transverse bracing were designed in view of the extraordinary circumstances of the location. Very high winds sweep through the gorge and produce conditions requiring the most careful consideration in connection with such an elevated structure, while its vibrations, caused by moving trains, call for scarcely less attention.

A train of consolidation engines formed the moving load under which the viaduct was designed.

The following is a recapitulation of the main data:

Number of iron towers	20
Number of columns	110
Number of spans	41
Total length of iron-work	2053 feet.
Length of each clear span	61 "
Length of each tower span	38½ "
Highest tower	297 "
Average height of towers	170 "
Width of top	10 "
Width of base (widest part)	103 "
Pounds of iron in viaduct	3,500,000
Pounds of steel in track and fastenings	100,000

Besides the railway track, the viaduct is provided with a sidewalk on each side.

PLATE IX.

RONDOUT BRIDGE.

One mile south of Kingston, N. Y., on the line of the New York, West Shore and Buffalo Railroad, the railway pierces the rocky ridge just north of Rondout, then emerging from the tunnel, it is carried over the creek by the viaduct and through spans shown on this plate. The viaduct is adjacent to the tunnel, and the southern portion of it consists of eleven lattice deck-girders, alternately of 51- and 30-feet spans, with one exception of 20 feet and another of 60.

The northern portion consists of a series of three pin-connected spans, and the entire superstructure is carried on the top of towers varying from 32 to 140 feet in height. As shown on the plate, the two longer spans are over Rondout Creek, and at an elevation of 155 feet from base of rail to surface of water.

The separation of trusses in each through span is 29 feet, and the depth of the two longer spans 45 feet; the length of panel is 18 feet.

The general design of the structure is such as to secure the greatest economy of material, in combination with the requisite stability at such an elevation. As there are two trusses only to each pin-connected span, and a double track to be carried, the conditions to be fulfilled were such as are not ordinarily found.

The construction of the towers is admirably adapted to the requirements of stability and economy. Phœnix columns are used in compression, and all details are so formed as to act in the most direct and effective manner. The three through spans are so placed on the towers that their weights are equally distributed on the four legs.

The viaduct is 531 feet long, while the whole structure has a length of 1244 feet. The total weight of iron is about 2000 tons.

PLATE X.

METROPOLITAN ELEVATED RAILWAY.

This plate shows some features in the construction of the Metropolitan Elevated Railway of New York City. The requirements of this work were certainly most unique, and at its inception the difficulties of design were unusual in engineering experience. The construction of an entire railway line on an elevated iron structure, to be subject to the demands of steam traffic, would give rise to more than ordinary engineering problems, but when these conditions are coupled with others, required by an almost absolutely continuous use of the structure, the difficulties encountered are very materially increased. Although the speed of the trains on the elevated railways of New York are not high, yet the short intervals of time between them permit scarcely any rest to the metal of the viaduct. Hence the fatigue of the iron becomes an important consideration.

This incessant use also gives rise to very wearing demands on the connections of the lateral and transverse systems of bracing, especially on the curved portions of the line, some of which are reversed.

This plate shows a portion of the road where the design was such as to meet the difficulties arising from a combination of greatly-increased height with a reversed curve. The inherent stiffness of the Phœnix column in all directions, as well as its superior capacity for resisting compression, render it peculiarly adapted to such extraordinary conditions as these. The transverse and lateral bracing, as well as the longitudinal bracing of the towers, were made sufficiently heavy to permanently meet the requirements of the circumstances. The whole amount of elevated railway built by this company in New York City up to the present time is 30.3 miles of single track.

PLATE XI.

METROPOLITAN ELEVATED RAILWAY.

This plate shows the general character of the same structure as the preceding, but on the tangent along Ninth Avenue.

The superstructure is composed of lattice-girders of a heavy type, carrying the railway lines, while a very firm system of transverse bracing is secured by the pairs of latticed struts in combination with the curved knee-braces at the tops of the columns. The latter, as shown, are of heavy Phœnix section. In short, this structure is built to secure that unusual degree of strength and stiffness that is necessary to withstand the extraordinary demands upon it.

The general methods employed in the erection of the structure were also somewhat peculiar to its character. After the vertical columns were firmly anchored in place the longitudinal girders were raised into position from the traveller resting on the portion already constructed. The transverse and lateral bracing were then completed. The structure was thus made to serve the purpose of its own false works.

PLATE XII.

GIRARD AVENUE BRIDGE.

The Girard Avenue bridge is one of the most celebrated roadway structures of its kind. It spans the Schuylkill River, in the city of Philadelphia, on the line of the main avenue of approach to Fairmount Park, and it is remarkable as the first attempt in this country to combine the American system of pin-connection bridges with a solid roadway of stone constructed in the most massive and substantial manner.

There are seven lines of trusses placed 16 feet apart centres, and united by horizontal and vertical bracing. All compression members are Phœnix columns. Upon the top of the posts, and transversely, are laid heavy 15-inch eye-beams, and on these are placed longitudinally 9-inch beams 2 feet 8 inches apart centres. Transverse corrugated plates rest on the latter and support four to five inches of asphalt concrete, making a water-tight surface. The roading is 100 feet wide and paved with granite blocks in the usual manner, except that it is divided into seven ways by two lines of iron tracks, adjacent to the sidewalks, for horse-cars, and five lines of carriage tramways made of cut granite blocks 1 foot wide and laid to a 5-feet gauge. The total width of 100 feet is divided into one carriage-way of 67½ feet and two 16¼ feet sidewalks.

The moving load of 100 pounds per square foot, in addition to the weight of the structure, constitutes a total load of 30,000 pounds per lineal foot of bridge.

PLATE XIII.

TRENTON CITY BRIDGE.

This roadway bridge was built for the Trenton City Bridge Company, of Trenton, N. J., and crosses the Delaware River at that place. There are seven spans with a total length of 1280 feet. Each span contains nine panels of 20 feet each, and the depth of truss is 26 feet. There is a clear width of 20 feet for the roadway, and 6 feet for each of the two sidewalks.

The design of this structure represents the most advanced system of construction as applied to the ordinary roadway bridge. Two lines of iron stringers extend the entire length of the seven spans, and carry at the centre of each panel an intermediate transverse beam, on which rest iron joists of half a panel length. All the economic and other advantages of long panels were thus made available, besides eliminating everything combustible, with the unavoidable exception of the floor-plank and three lines of light-timber stringers to which they are spiked.

The sidewalk railing serves the double purpose of a guard and trussed stringer for a portion of the sidewalk load. With its lines plainly expressive of the purpose of its construction, it materially contributes to the light and graceful, yet most substantial, appearance of the entire structure.

PLATE XIV.

CAPE MAY PIER.

During the past few years the field of engineering construction has been extended so as to cover ocean piers built entirely of wrought iron, with the exception of the timber floor, and that at Cape May is one of the finest examples to be found on the Atlantic coast. With its length of 1000 feet, and pavilion located at the outer extremity on an extent of 26,000 square feet of floor, there is ample space not only for the demands of business, but for the gratification of the crowds of people who delight to make the pier a promenade. Its adaptability to the latter purpose makes it one of the principal attractions of this popular summer resort.

The width of the stem of the pier is 30 feet, and the size of the head 130 by 200 feet, while the centre bay is 60 by 80 feet. The entire floor is elevated 21 feet above low water.

The columns are all of the Phœnix section and fitted at the lower extremity with cast-iron feet 24 inches in diameter. These were sunk 10 feet into the sand, and so rigidly braced together, both longitudinally and transversely, that the pier would stand firmly in position with no support but its own bracing.

The columns were sunk to the required depth by the water-jet process.

FRONTISPIECE.

PHILADELPHIA AND READING RAILROAD BRIDGE,

OVER FRENCH CREEK, AT PHŒNIXVILLE, PA.

This bridge carries the double track, main line of the Philadelphia and Reading Railroad, across both the canal of the Phœnix Iron Company and French Creek, at the confluence of the latter with the Schuylkill River. The span of 140 feet is divided into seven panels of 20 feet each. The centres of the trusses are 28 feet apart, while the depth of truss is 32 feet. Each track is carried on three lines of iron stringers resting on transverse floor-beams.

The proportions of the bridge and its various parts are thus seen to fulfil the requirements of the heaviest traffic, and at the same time answer every demand of economy. The location of the structure at a short distance from the Phœnixville depot is such as to constantly subject its floor system to the traction of the locomotives of all outgoing trains to the north, and the violent thrusts induced by the air-brakes of all trains bound south. These circumstances, in connection with the high speed of the passenger trains and the extraordinarily heavy coal traffic of this road, render the service of this bridge very trying in its character. But its design was undertaken in view of these conditions, and its remarkable stiffness and stability under moving loads in every variety of motion show how perfectly the end was accomplished.

The depth of trusses was so taken that the requisite systems of upper and lower lateral bracing could be supplemented by the transverse system shown in the plate. That degree of stability necessary to the circumstances of the location was thus effectually secured.

Shortly after its completion the resistance of the floor system was severely tested by a derailed locomotive and car, which ran nearly half-way across the span on the ties, but eventually came to rest without material injury to the structure.

The bridge was designed to carry, in addition to its own weight, a moving load on each track of two coupled locomotives, each weighing 177,800 pounds, in 54 feet 2 inches, or 106,000 pounds on a driving-wheel base of 14 feet 9 inches, followed by a uniform train of 2240 pounds per lineal foot.

DESIGNS

SHOWING

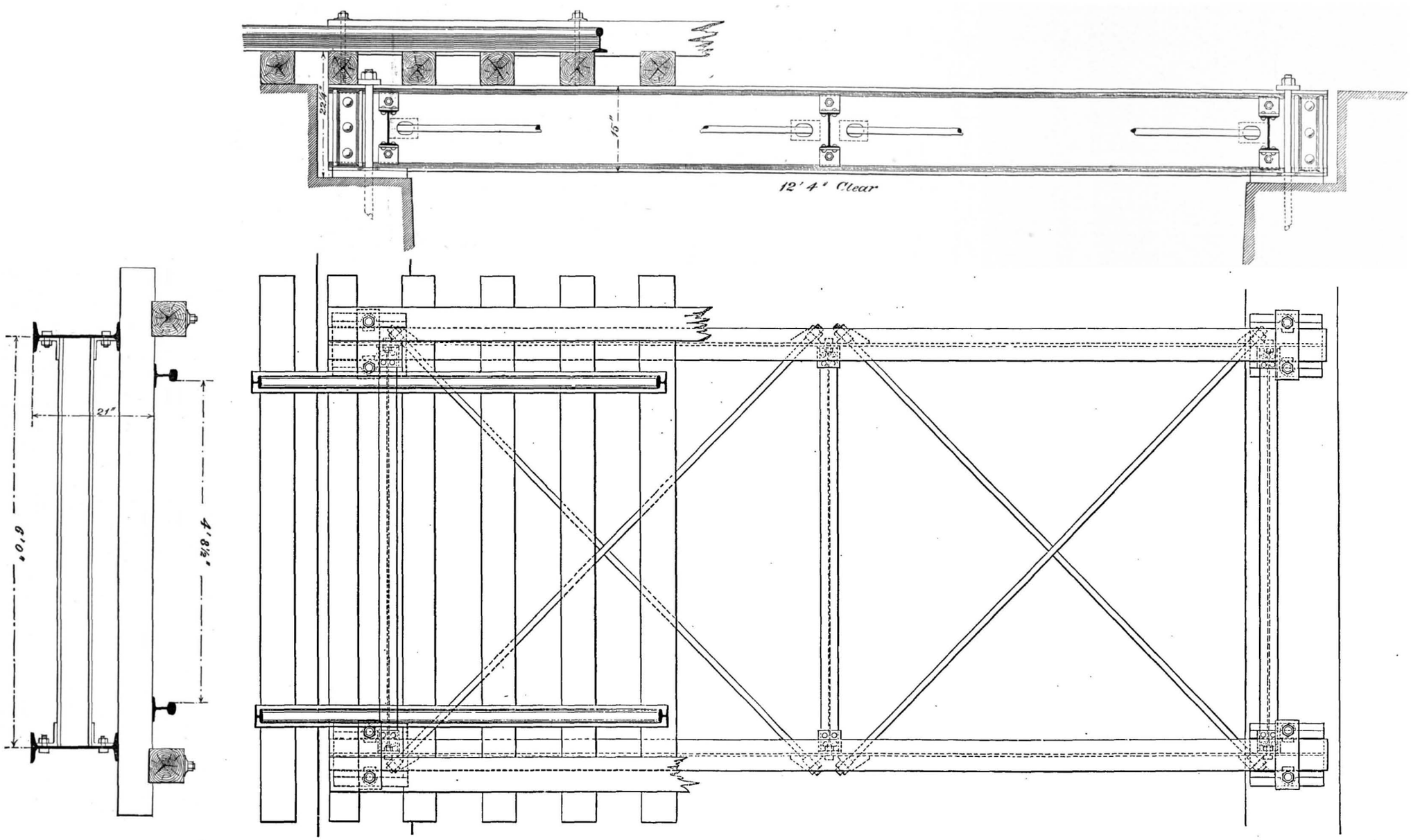
USUAL FORMS OF BRIDGES

BUILT BY

THE PHŒNIX BRIDGE COMPANY

FOR

VARIOUS LENGTHS OF SPANS.



EYE BEAM SPAN,

FOR PORTLAND AND ROCHESTER RAILROAD.

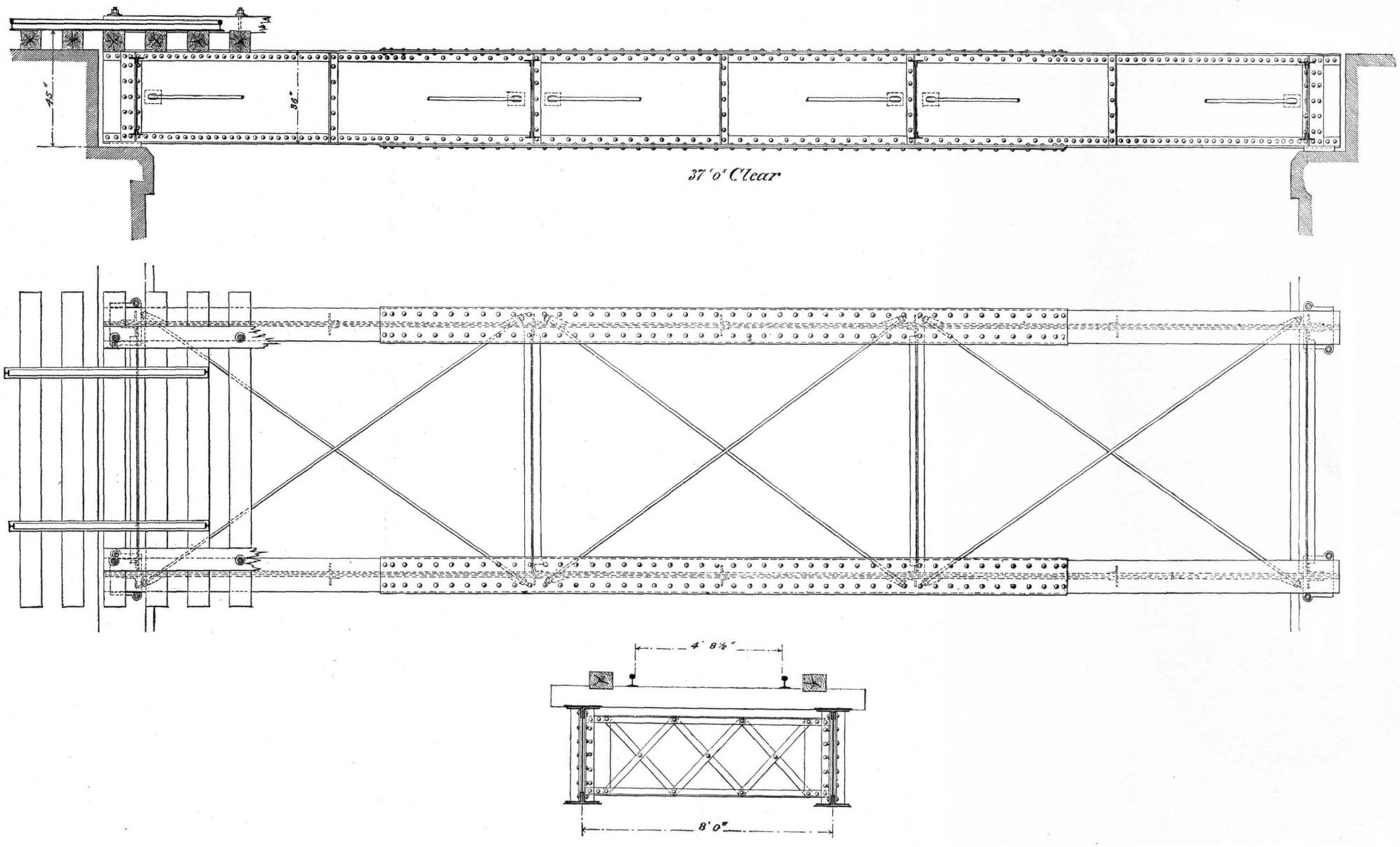
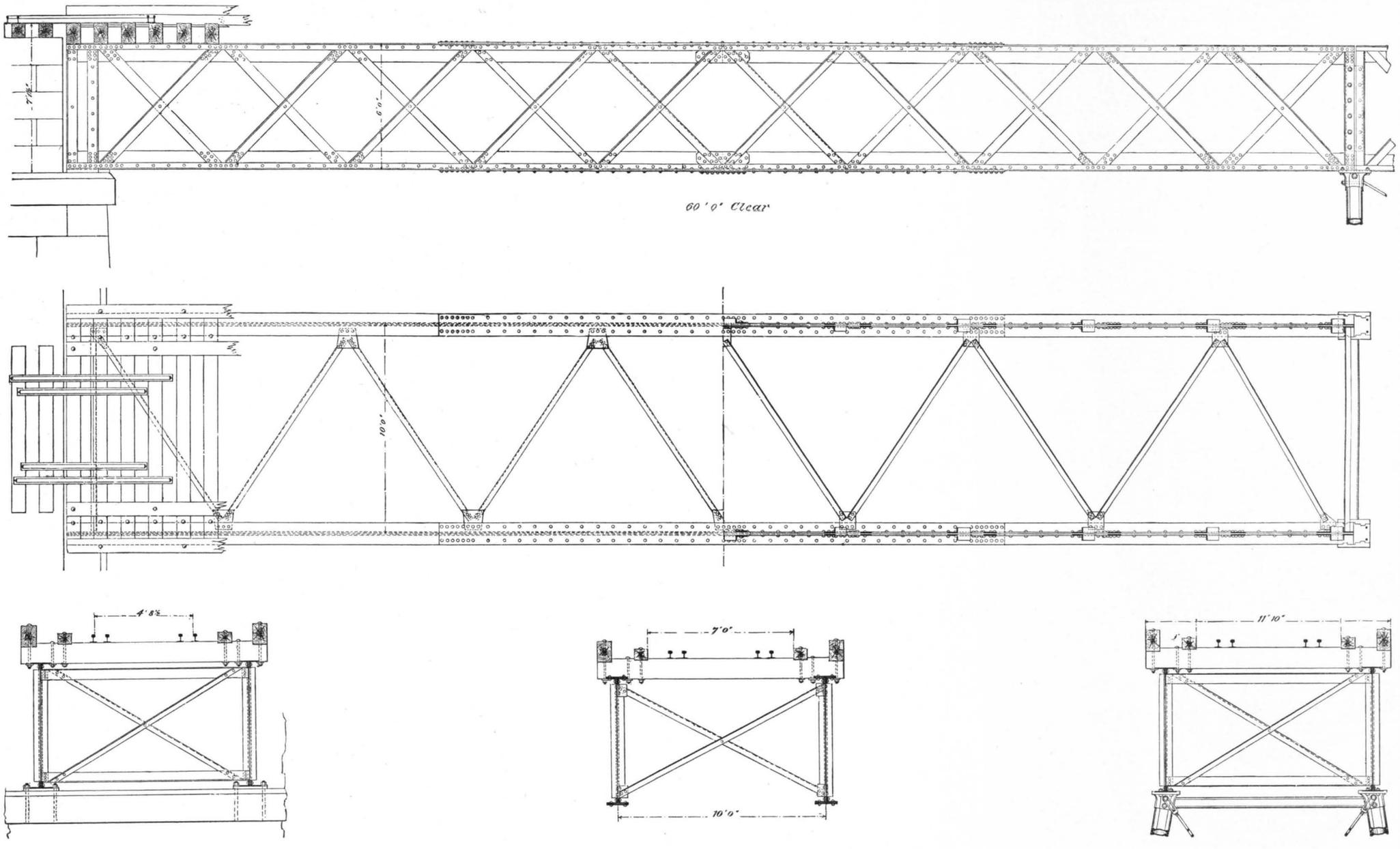


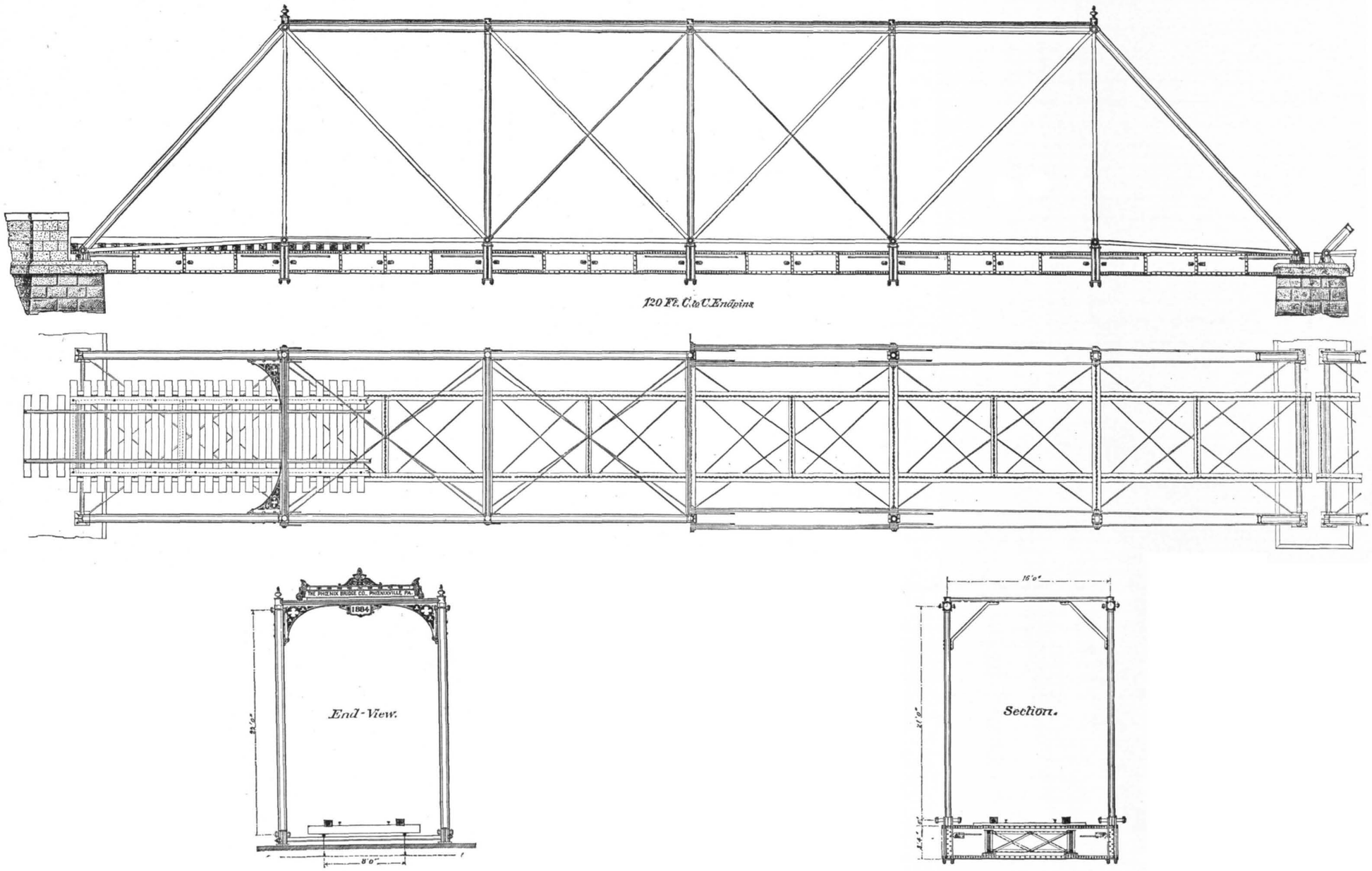
PLATE GIRDER SPAN,

FROM MEHERRIN BRIDGE, SEABOARD AND ROANOKE RAILROAD.



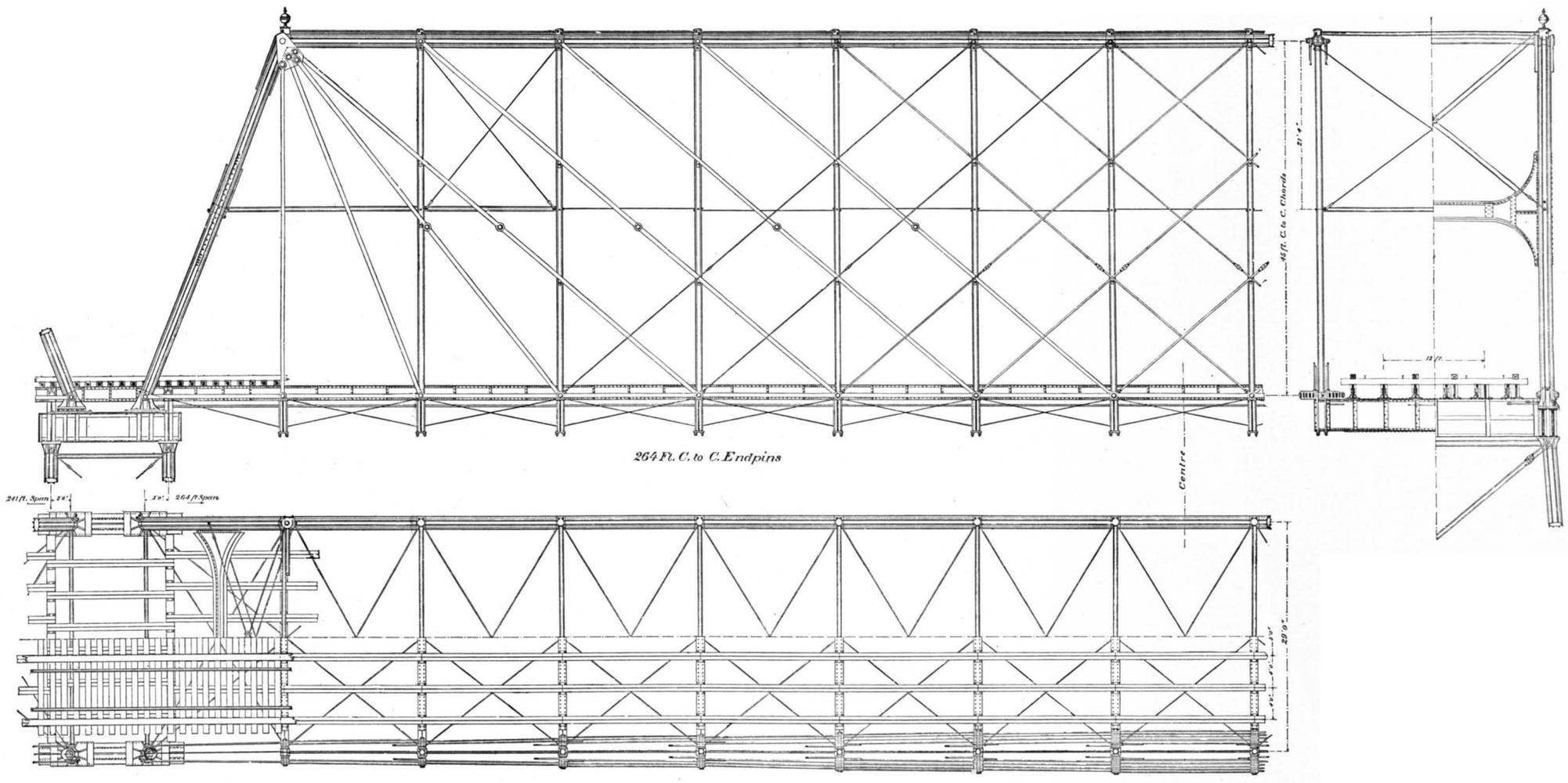
LATTICE GIRDER SPAN.

KINZUA VIADUCT. NEW YORK, LAKE ERIE AND WESTERN RAILWAY.



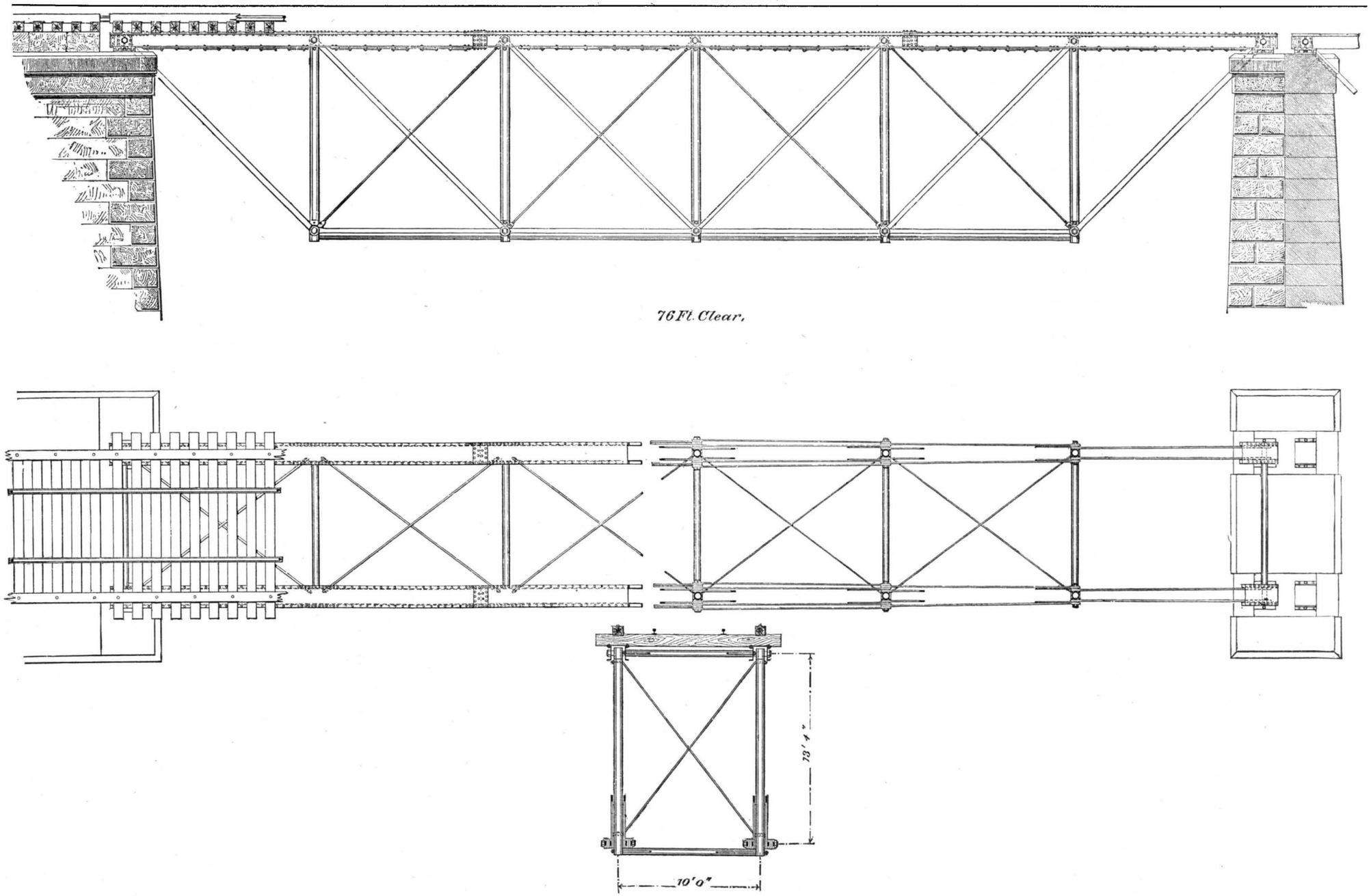
SINGLE TRACK THROUGH SPAN, SINGLE INTERSECTION.

REED ISLAND BRIDGE, NORFOLK AND WESTERN RAILROAD, 2-120 FEET SPANS.



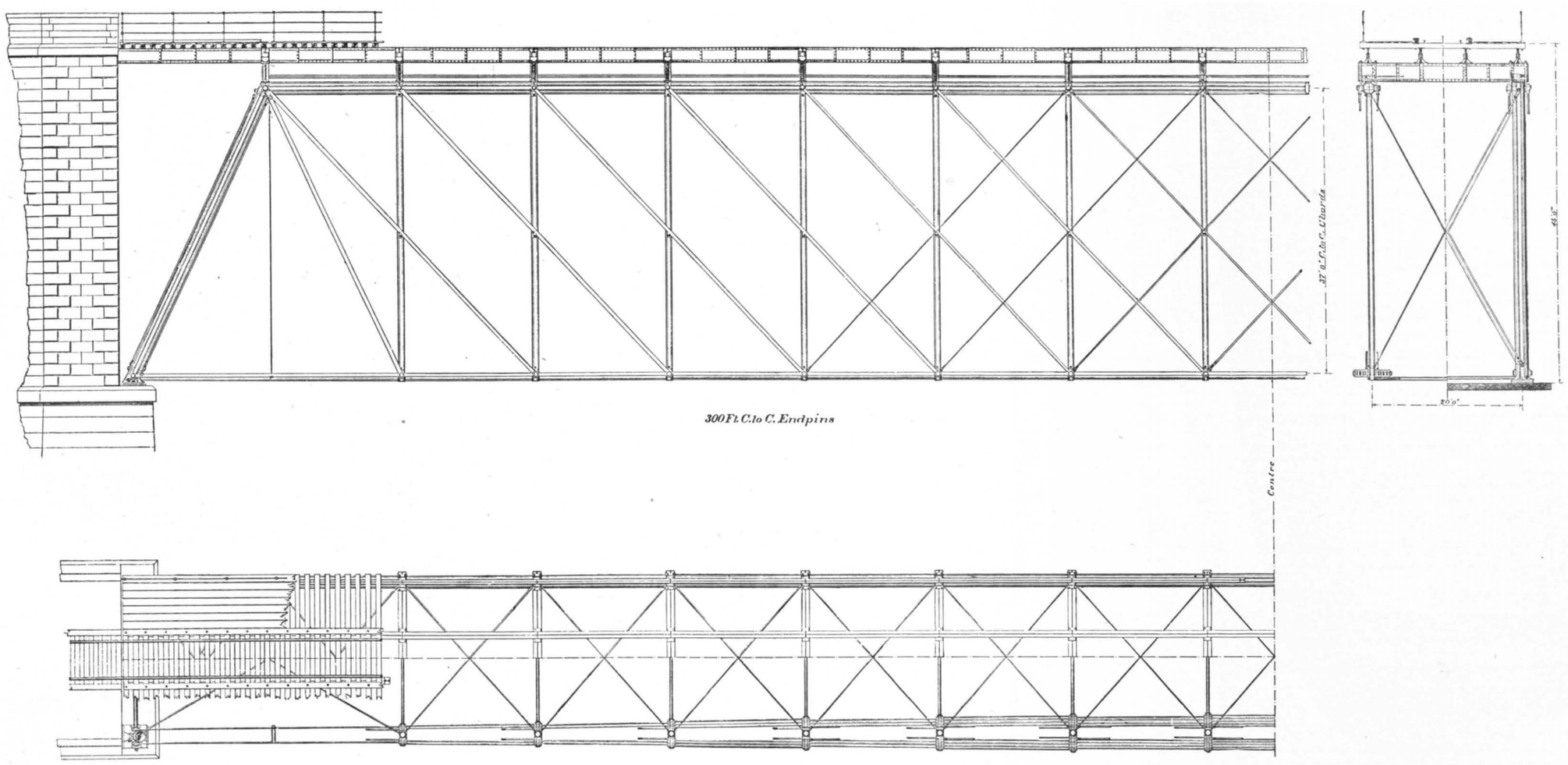
DOUBLE TRACK THROUGH SPAN.

264 FEET SPAN OF RONDOUT BRIDGE, NEW YORK, WEST SHORE AND BUFFALO RAILWAY.



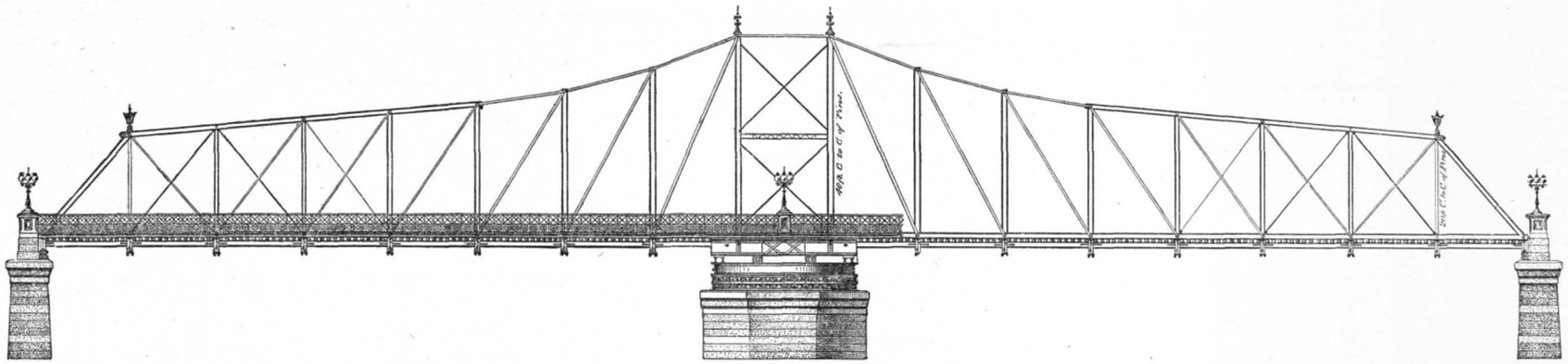
SINGLE TRACK DECK SPAN.

DUNLAP'S CREEK BRIDGE, CHESAPEAKE AND OHIO RAILWAY.

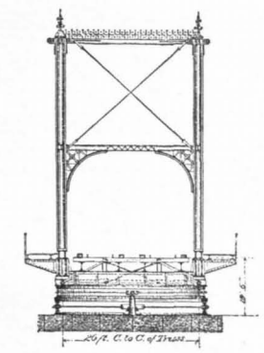


300 FEET SPAN.

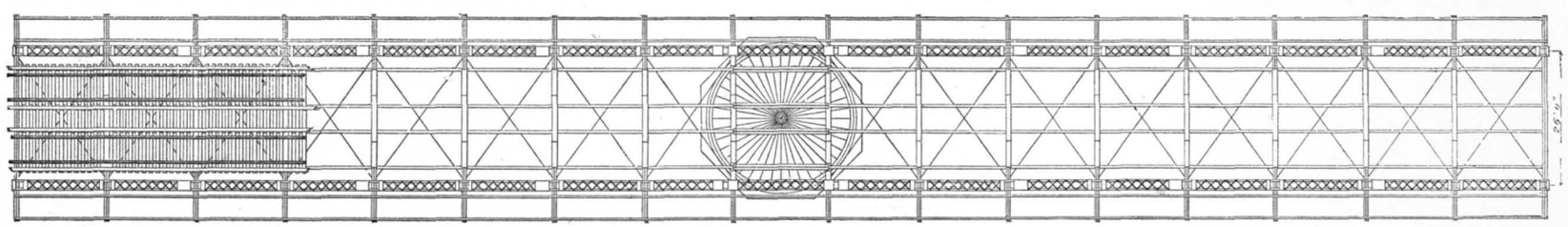
BUILT FOR GALVESTON, HARRISBURG AND SAN ANTONIO RAILROAD.



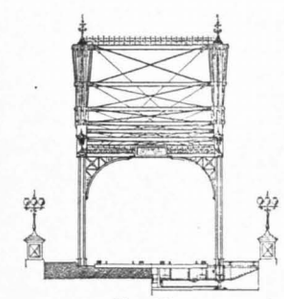
297'-8⅝" C. to C. of Endpins



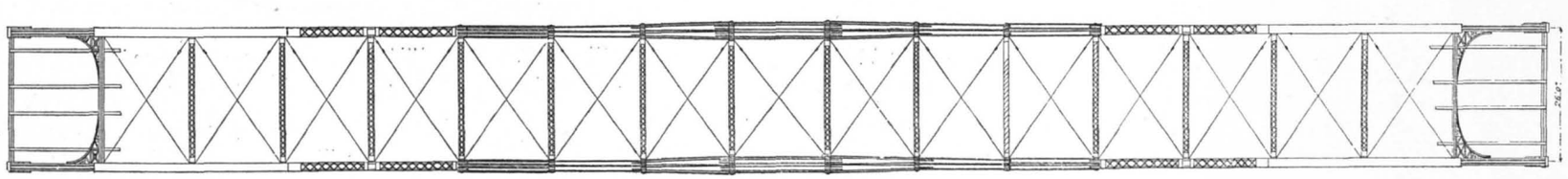
Section at Centre.



Plan of Floorsystem and Lower Lateral Bracing.



End View.

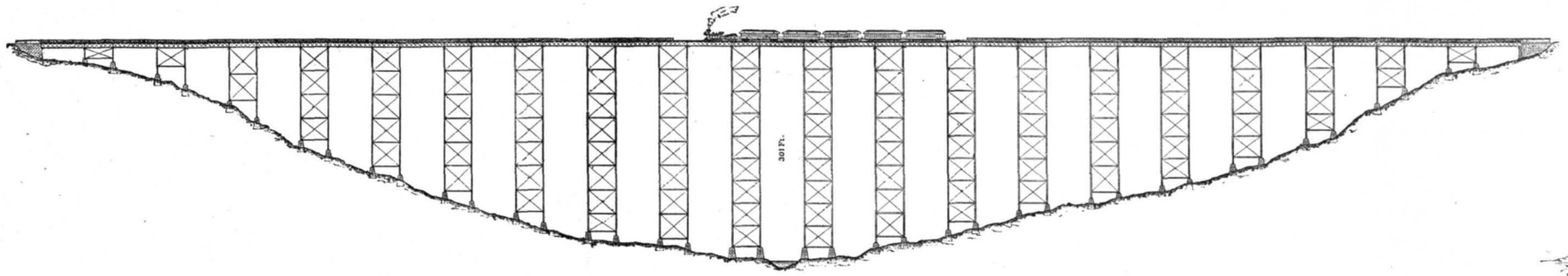


Plan of Upper Lateral Bracing.

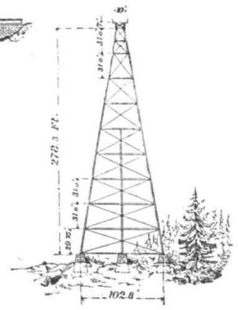
Design H.
297 Ft. Double-Track-
Draw Bridge.

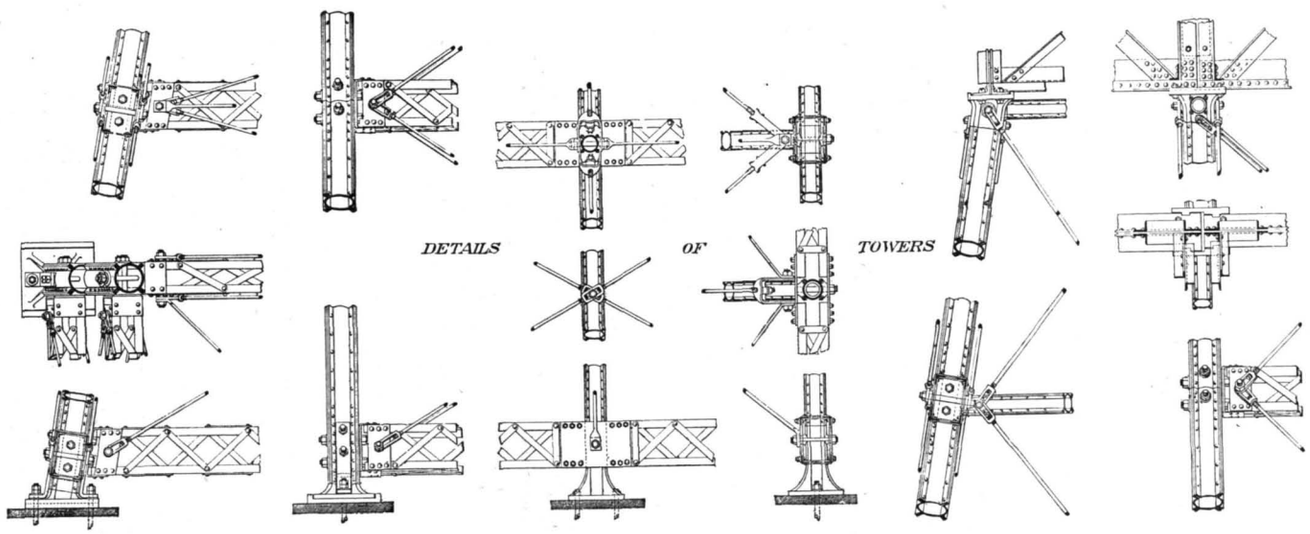
LONG SPAN DRAWBRIDGE.

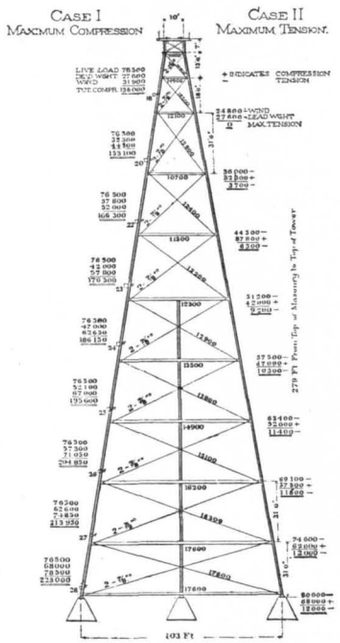
WEST SIDE AND YONKERS RAILWAY.



Total Length 2052 Ft.







DATA FOR STRESSES.

Live Load: Consolidation engines having 88,000 lbs. on drivers in a space of 14 ft. 9 in. Total weight of engine and tender, 161,310 lbs. Length over all, 54 ft. 3 in.

Dead Load: 1000 lbs. per lin. ft.

CASE I.

Gives maximum compression. Structure loaded. Wind pressure, 30 lbs. per sq. ft Wind pressure at top, 20,000 lbs.; on each story, 64 lbs. per vertical ft., or 1980 lbs. per story.

CASE II.

Gives maximum tension. Structure unloaded. Wind pressure at top, 15,000 lbs.; on each story, 106 lbs. per vertical ft, or 3300 lbs. per story.

Stresses in diagonals and struts are the maxima which can arise from either case.

All longitudinal rods, 7/8 in.—2 rods.

All struts (except S_1 S_2 S_3) of 4 angles, 2½ x 2½ x 15 lbs. per yard latticed.

S_1 S_2 S_3 of B^1 column. Area, 6 sq. in.

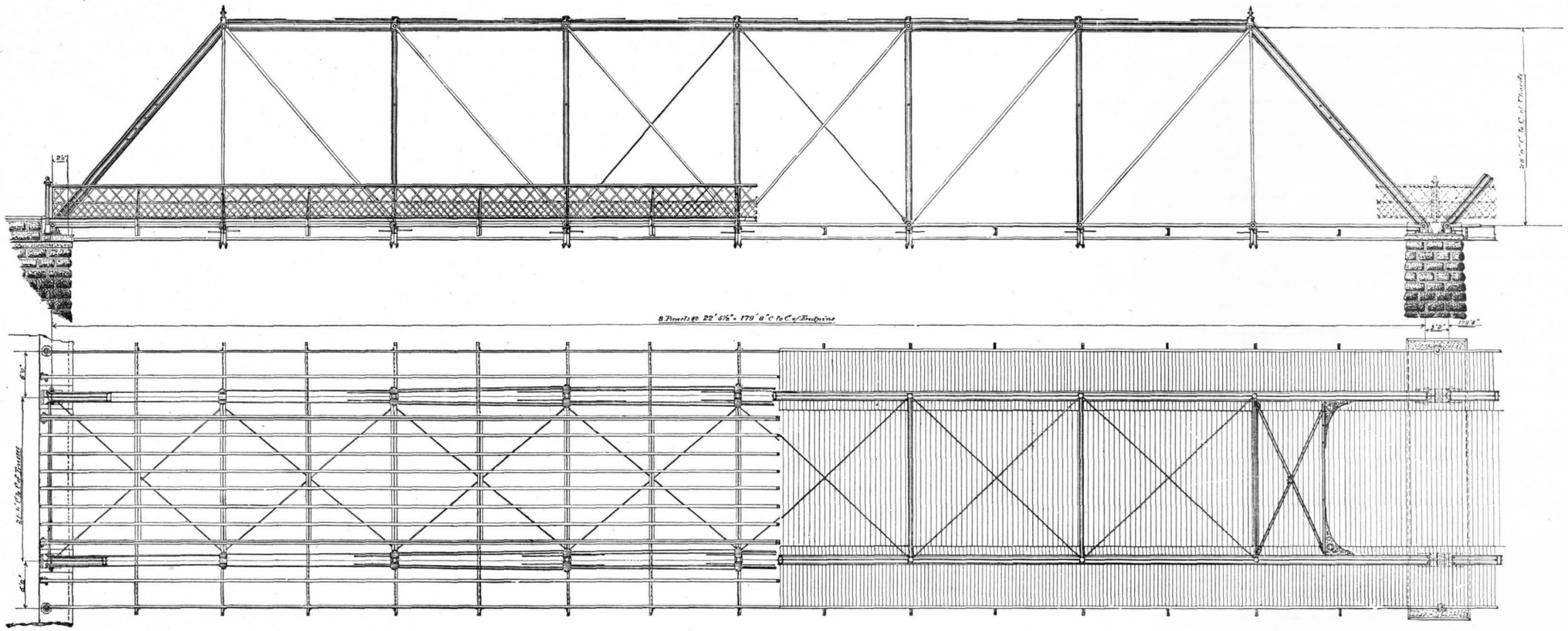
Ultimate strength of Phœnix columns, 35,000 lbs. per sq. in., as per experiments at United States Arsenal, Watertown, Mass.

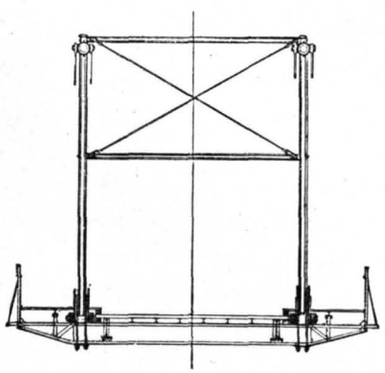
Factor of safety for live and dead loads = 5, equivalent to 7000 lbs. per sq. inch.

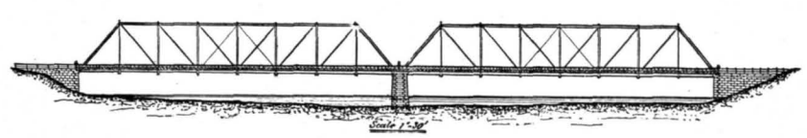
Factor of safety for wind pressure, 3½, equivalent to 10,000 lbs. per sq. inch. Diagonals strained 15,000 lbs. per sq. inch.

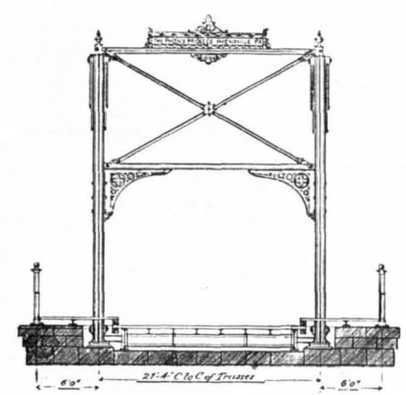
KINZUA VIADUCT.

NEW YORK, LAKE ERIE AND WESTERN RAILWAY.









HIGHWAY BRIDGE,

POTTSTOWN, PA.

PLATES

SHOWING

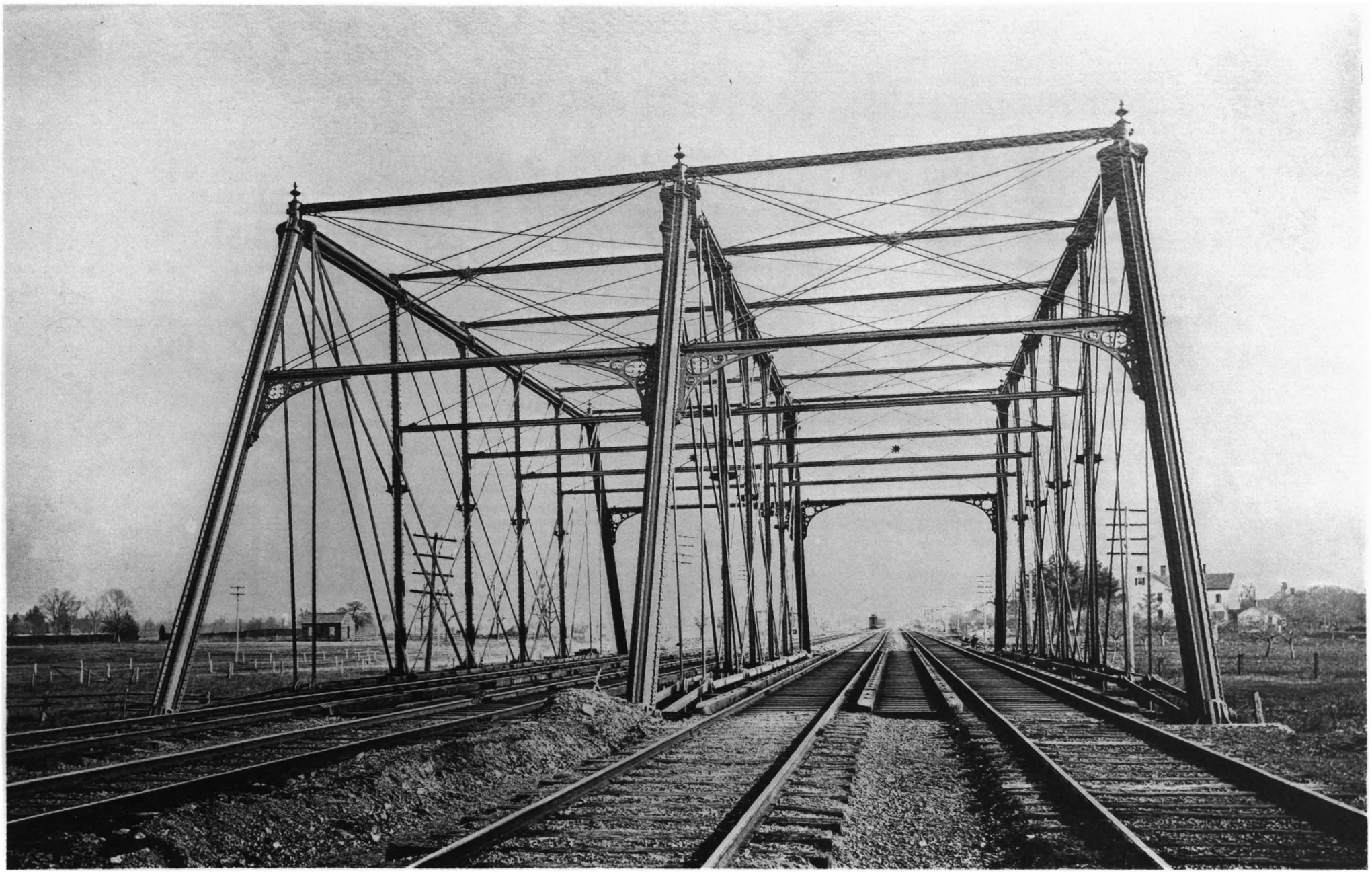
PHOTOGRAPHIC VIEWS OF BRIDGES

AND

OTHER STRUCTURES

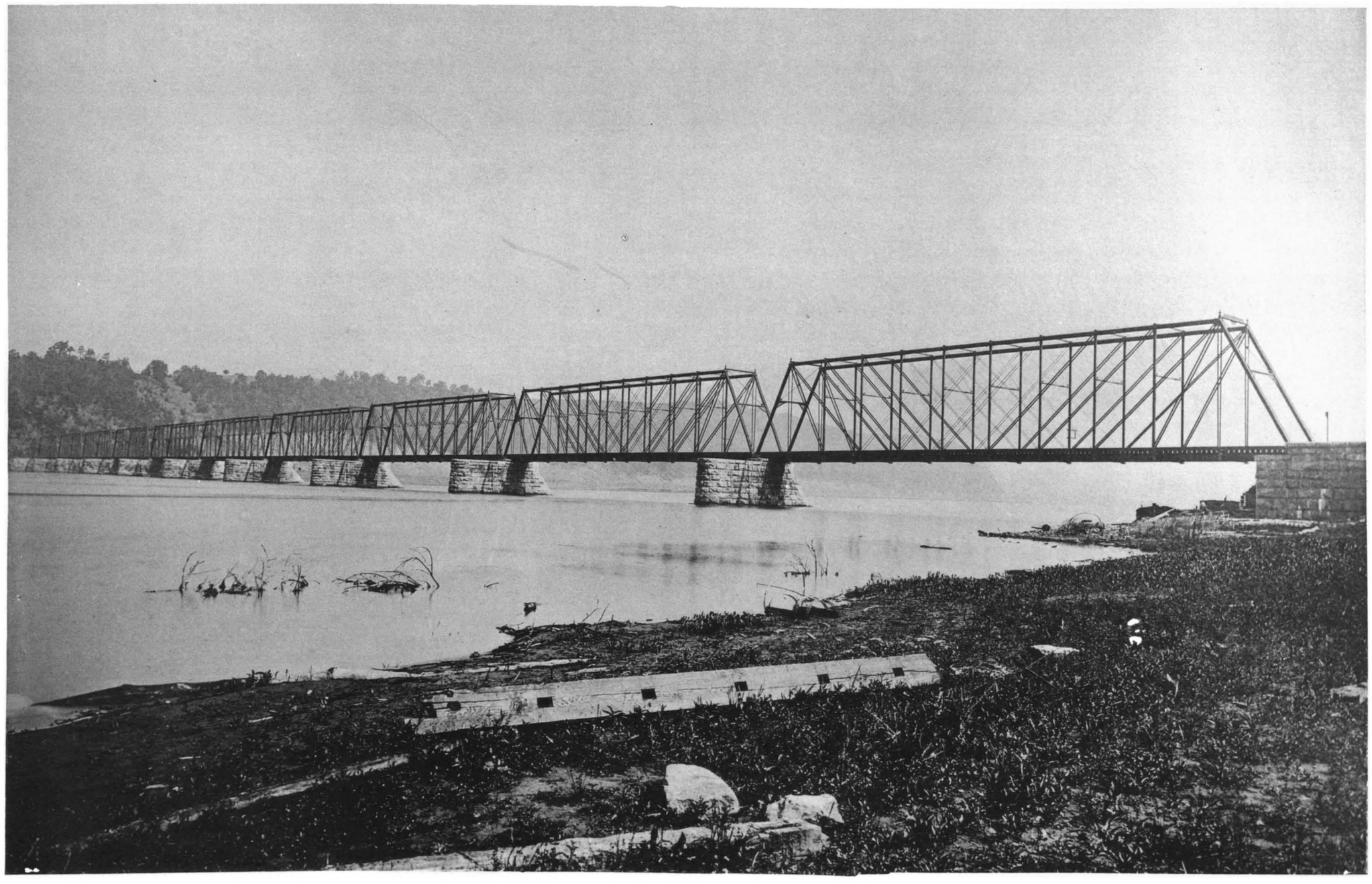
DESIGNED, CONSTRUCTED, AND ERECTED BY

THE PHŒNIX BRIDGE COMPANY.



FOUR-TRACK RAILWAY BRIDGE OVER MIDDLE BROOK,

CENTRAL RAILROAD OF NEW JERSEY DIVISION PHILADELPHIA AND READING RAILROAD.



SUSQUEHANNA RIVER BRIDGE,

SUNBURY, PA.

SINGLE-TRACK THROUGH BRIDGE OF FOURTEEN SPANS.

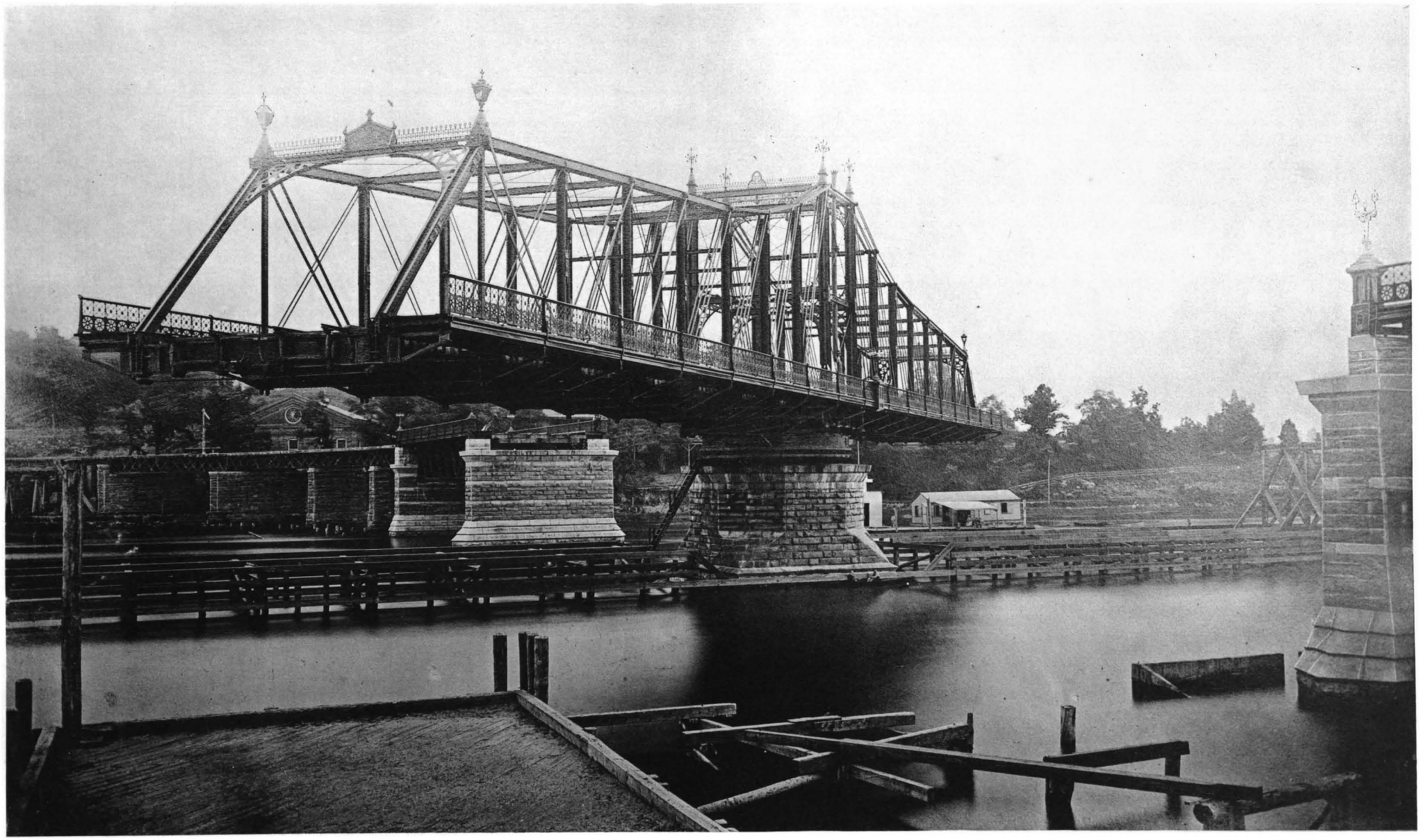
CHAUDIERE BRIDGE,

ACROSS OTTAWA RIVER, OTTAWA, ONTARIO.

CATSKILL BRIDGE,

NEW YORK, WEST SHORE AND BUFFALO RAILROAD COMPANY.

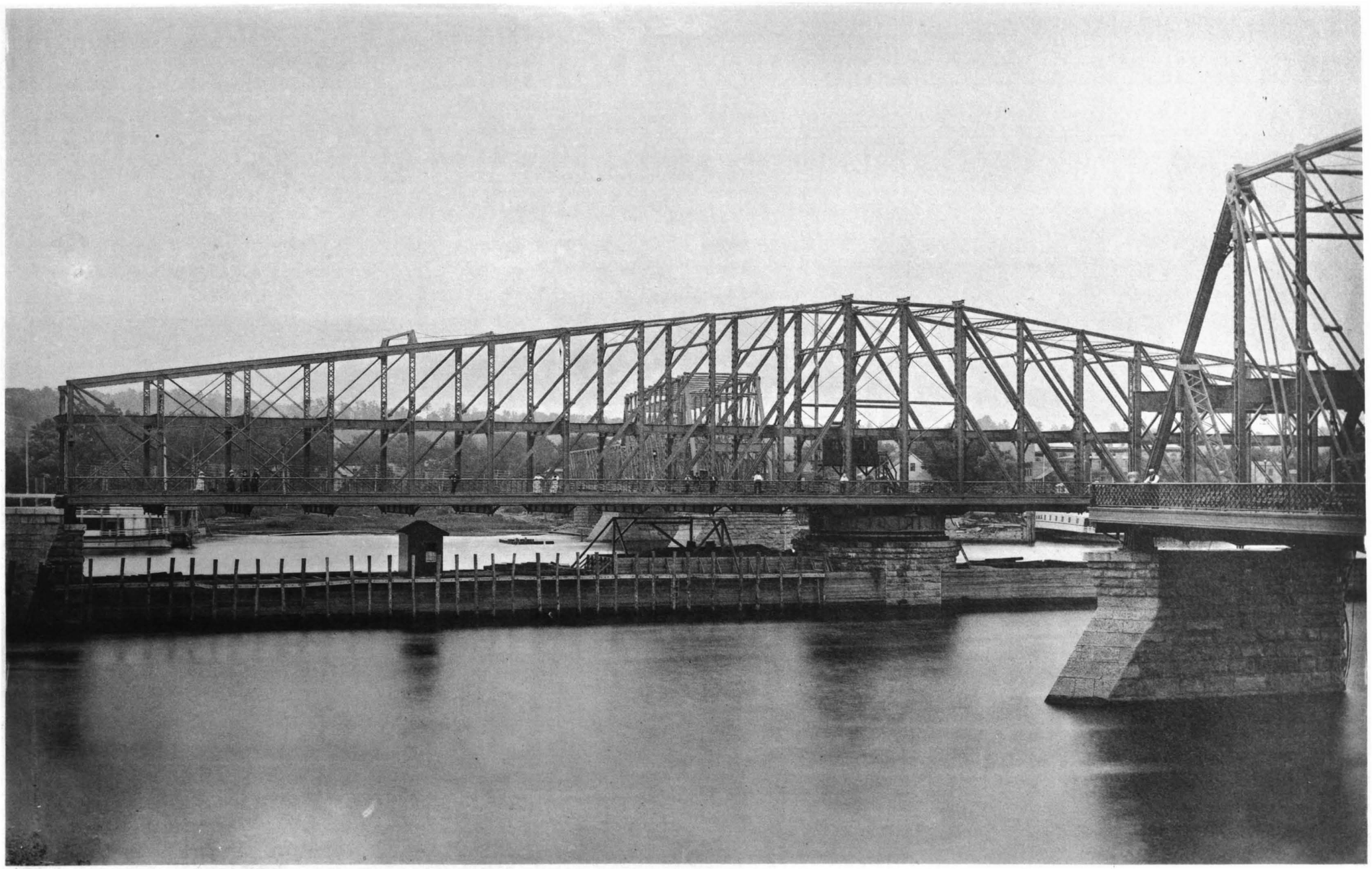
DOUBLE TRACK DECK BRIDGE OF EIGHT SPANS.



HARLEM RIVER BRIDGE,

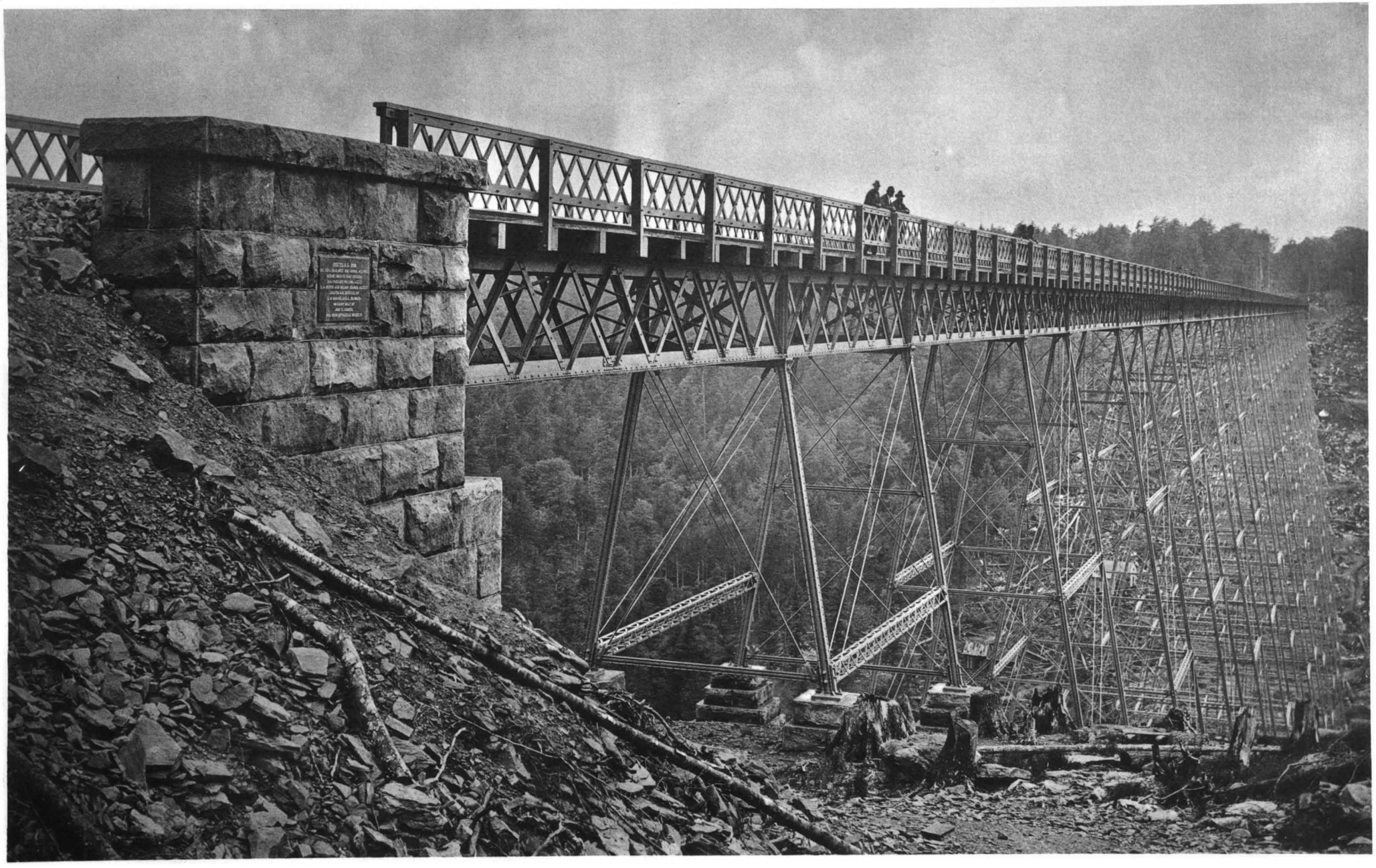
WEST SIDE AND YONKERS RAILWAY,

EIGHTH AVENUE, NEW YORK.



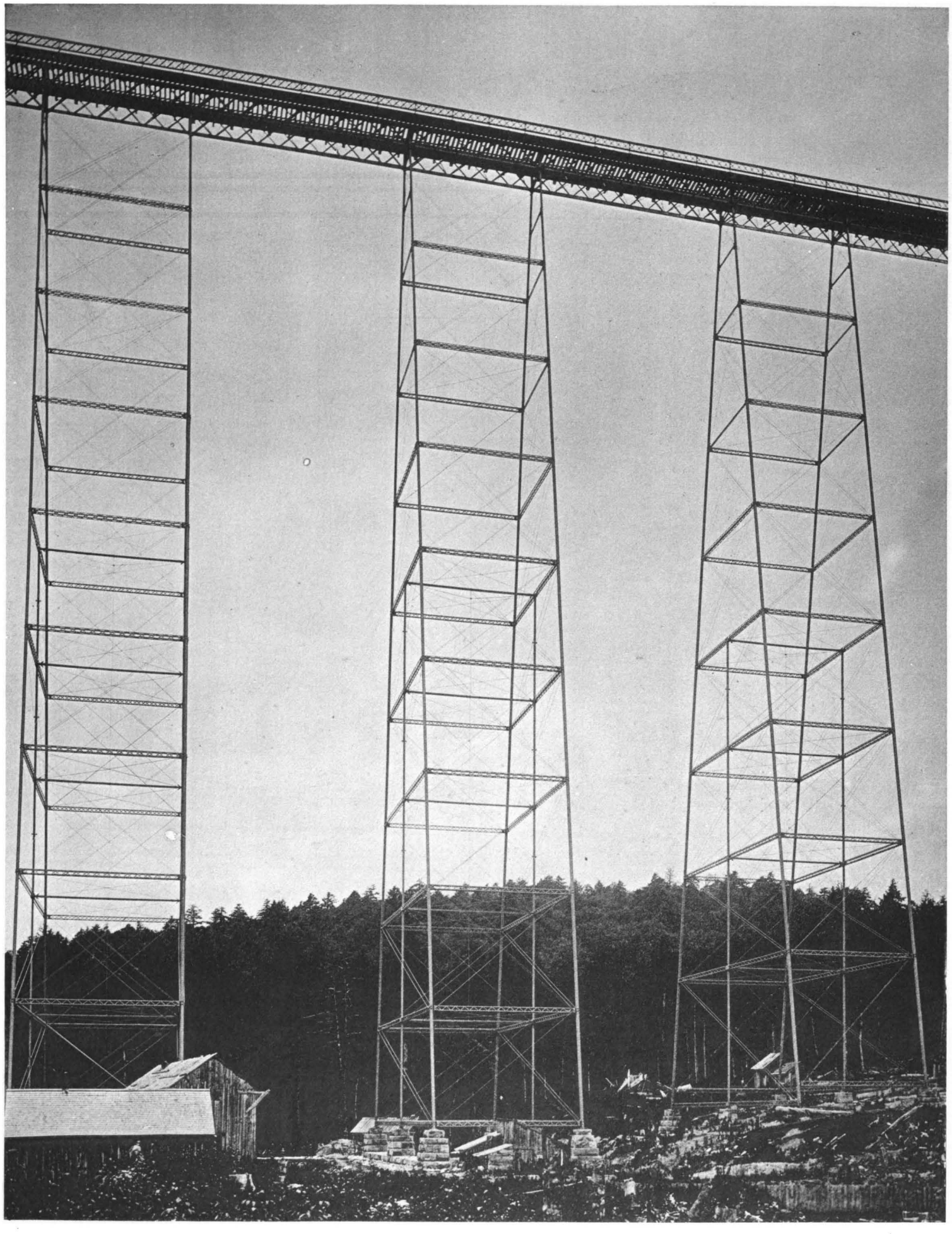
ALBANY AND GREENBUSH BRIDGE.

DOUBLE-TRACK RAILROAD ABOVE. ROADWAY AND TWO SIDEWALKS BELOW.



KINZUA VIADUCT,

NEW YORK, LAKE ERIE AND WESTERN COAL AND RAILROAD COMPANY.



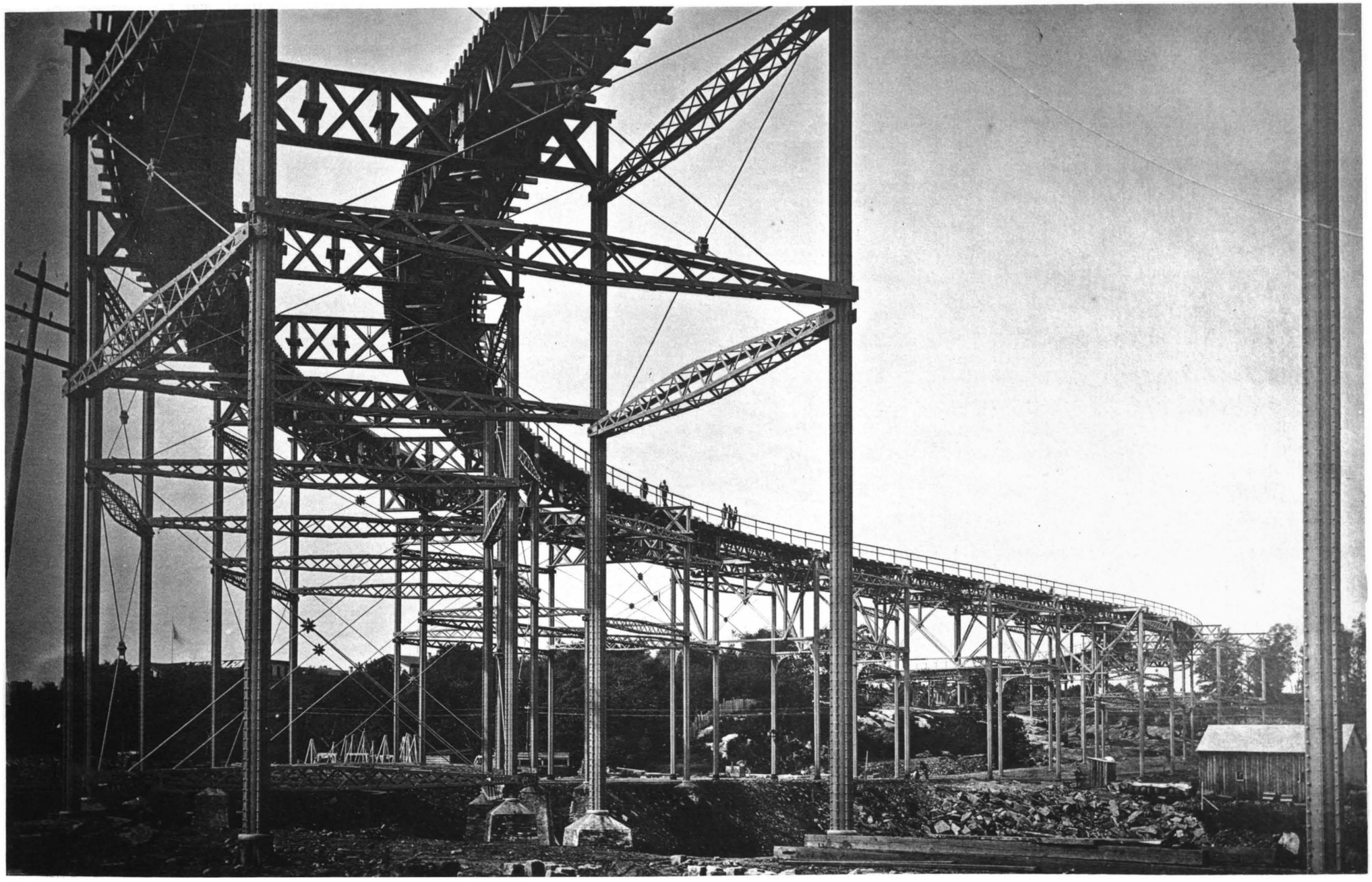
KINZUA VIADUCT,

NEW YORK, LAKE ERIE AND WESTERN COAL AND RAILROAD COMPANY.

RONDOUT BRIDGE,

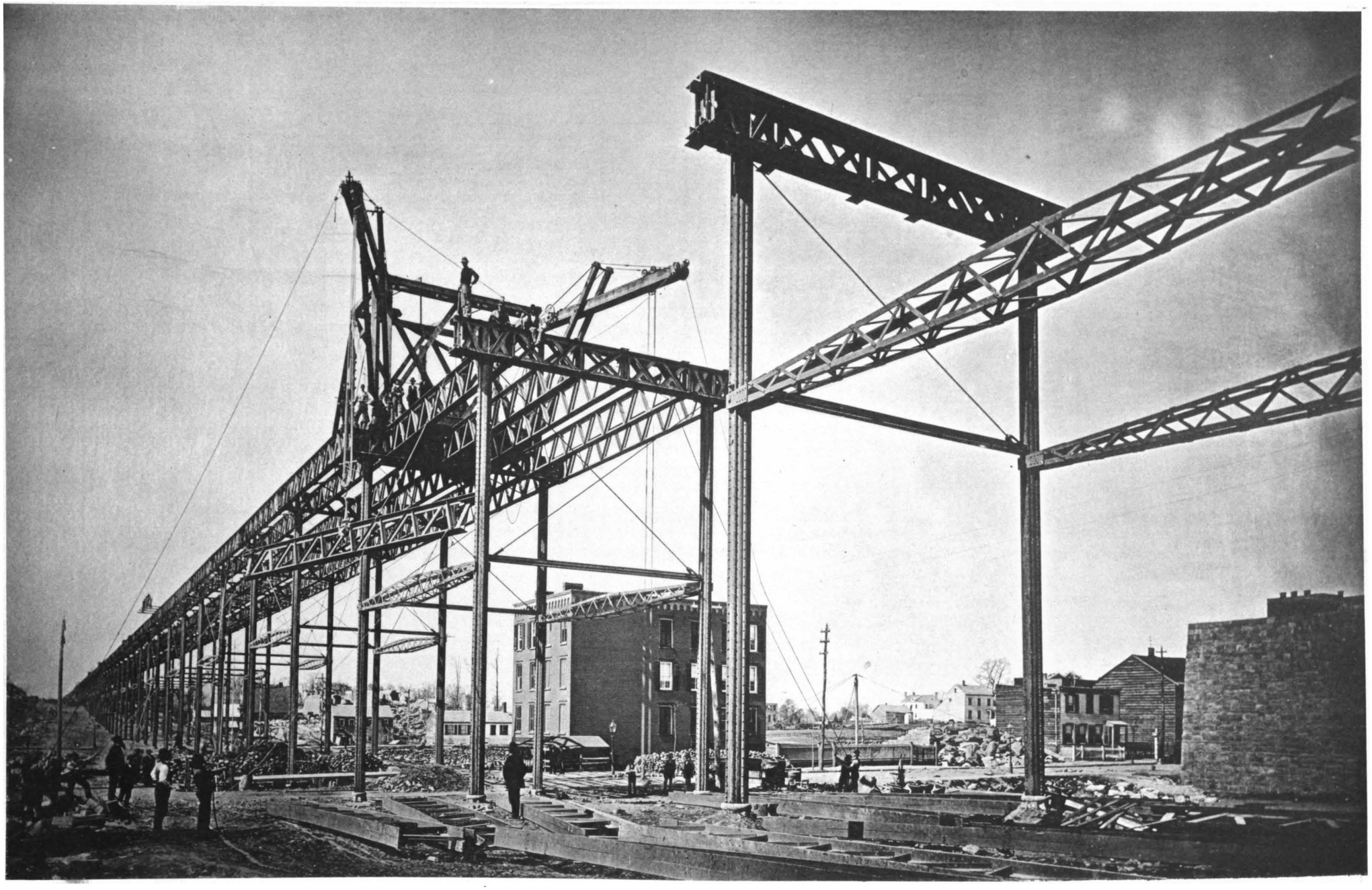
NEW YORK, WEST SHORE AND BUFFALO RAILROAD COMPANY.

DOUBLE TRACK THROUGH BRIDGE AND VIADUCT.



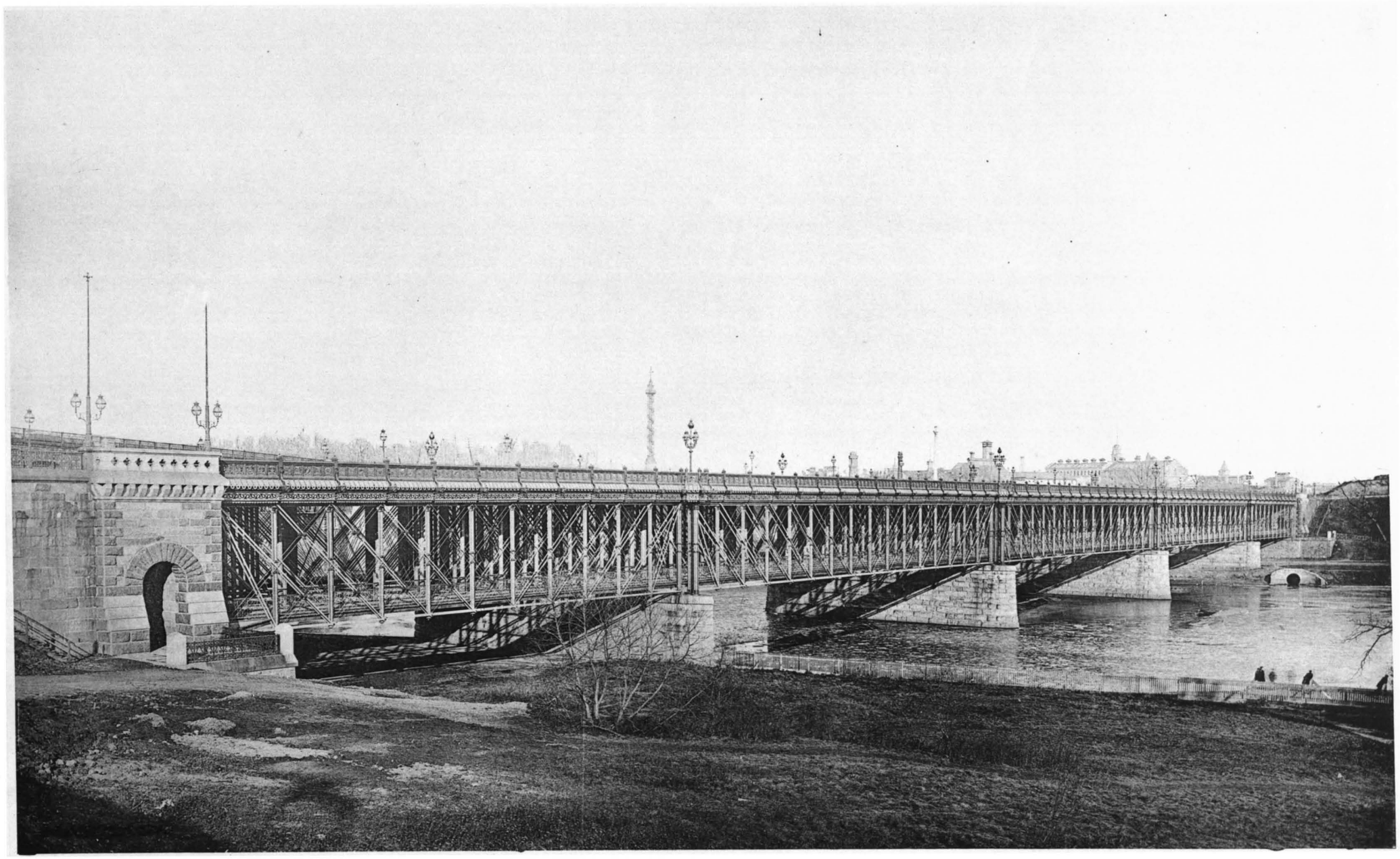
METROPOLITAN ELEVATED RAILWAY,

NEW YORK.



METROPOLITAN ELEVATED RAILWAY

NEW YORK.



GIRARD AVENUE BRIDGE,

PHILADELPHIA, PA.

HIGHWAY BRIDGE,

ACROSS DELAWARE RIVER, TRENTON, N. J.

OCEAN PIER AT CAPE MAY, N. J.

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