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MISSISSIPPI RIVER BRIDGES.

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THE MISSISSIPPI RIVER BRIDGES.

Historical and Descriptive Sketch of the Bridges over the Mississippi River.

Mr. F. B. Maltby, U. S. Asst. Engr.*

The subject of "Bridging the Mississippi River between St. Paul and St. Louis" is exhaustively treated in a report with that title, made by G. K. Warren, Major of Engineers and Brevet-Major General, U. S. A., and printed in the annual report of the Chief of Engineers, U. S. A., for the year 1878. This report is a voluminous and complete one, covering the bridges in existence up to 1876 — 15 in number — and is generally considered the best authority on the subject covering the period up to that date. Since that time the number of bridges over the river below the Falls of St. Anthony has increased some three-fold, and the object in view in the preparation of this paper has been to bring the history of the subject down to date.

As Major Warren's report is now out of print, and not readily obtainable, and in order to make this description as complete as possible, the subject matter of his report is included in this paper in a somewhat condensed form.

1 MINNEAPOLIS; HENNEPIN AVENUE.

Highway.

The first bridge of importance completed over the Mississippi river was built at Minneapolis in 1855, though it is possible that the old Rock Island bridge was commenced at a prior date. It was a suspension bridge of about 620 feet span and was located in about the same position as that occupied at present by the steel arch bridge at the foot of Hennepin Avenue. This bridge was a very light structure, but stood remarkably well the increasing loads put on it for 20 years. The cables — 4 in number — contained about 2,000 strands of No. 10 soft iron wire. The cables were supported by wooden towers and the anchorage was formed by links running entirely through a ledge of limestone about 10 feet thick which overlies the soft sandstone.

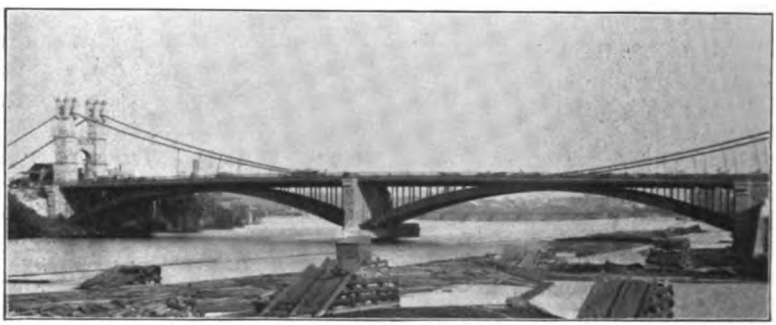
The bridge was replaced with another suspension bridge built in 1876–77, which had a span of about 675 feet. It had 4 cables, each containing 3,648 strands of No. 9 iron wire, supported on masonry towers about 111 feet high.† This bridge has again been replaced, by a steel arch.

* This paper was prepared in 1900, and some changes in some of the bridges have been made since then.

† *Engineering News*, 1878, page 85.

It is proposed to confine this paper to a description of the bridges below the falls, and this bridge is only mentioned on account of its historical importance.

It is thought that the first railroad bridge over the Mississippi river was the draw bridge at Rock Island built in 1853-56, and torn down in 1872, and described further on.



Hennepin Ave., Minneapolis. Highway. Transition of Suspension to Steel Arch.

Prior to 1866 it does not appear that the authority of Congress was deemed necessary before commencing the erection of a bridge over the river. This year was, however, a prolific one in bridge legislation by the national legislature. Seven bridges were authorized and built within a few years: namely at Winona, Dubuque, Burlington, Keokuk, Quincy, Hannibal and the St. Louis "Eads" bridge. In addition a bridge was authorized at Prairie du Chien in the same act, but was not built at that time.

The general provisions of the act were "That if built as high "bridges they should be 50 feet above extreme high water, with "spans not less than 250 feet in length, and one main or channel span "not less than 300 feet in length; if built as draw bridges they should "have two draw openings of 160 feet in the clear, and the next ad-"joining spans should not be less than 250 feet and should be 10 "feet above high water and 30 feet above low water." It provided "that the bridge at St. Louis should not be a suspension or draw "bridge, but should be of continuous or unbroken spans with the "bottom chord, at its greatest span, 50 feet above the city directrix; "that it should have at least one span 500 feet in the clear, or two "spans of 350 feet in the clear; that no span over the water at low "water stage should be less than 200 feet in the clear.

The River and Harbor act of the same year provided for "ex-"amining and reporting upon the subject of constructing railroad "bridges across the Mississippi between St. Paul and St. Louis upon

"such plans of construction as will offer the least impediment to the "navigation of the river." The report of Major Warren referred to is the outcome of this provision.

In considering the bridges at different points it has seemed impracticable to take them up in chronological order without confusion, and they are therefore described in the order in which they are found in proceeding down the river beginning at the Falls of St. Anthony.

The information concerning the various structures has been obtained through a thorough search of the files of technical periodicals, by correspondence with those persons who are, or have been, connected with the bridges in an official capacity, and by a personal inspection of the structures.

It is impossible to acknowledge in each instance the source of information, and the writer desires to express here his appreciation of the kindness and courtesy of those who have so promptly and cheerfully furnished much of the data contained herein.

It has been the desire of the writer to state facts only and to make the descriptions strictly accurate, and he has, so far as possible, corroborated them, but undoubtedly some errors have crept in, and it is hoped that they may be corrected by such members as may be in possession of more definite and positive information than was obtainable by the writer.

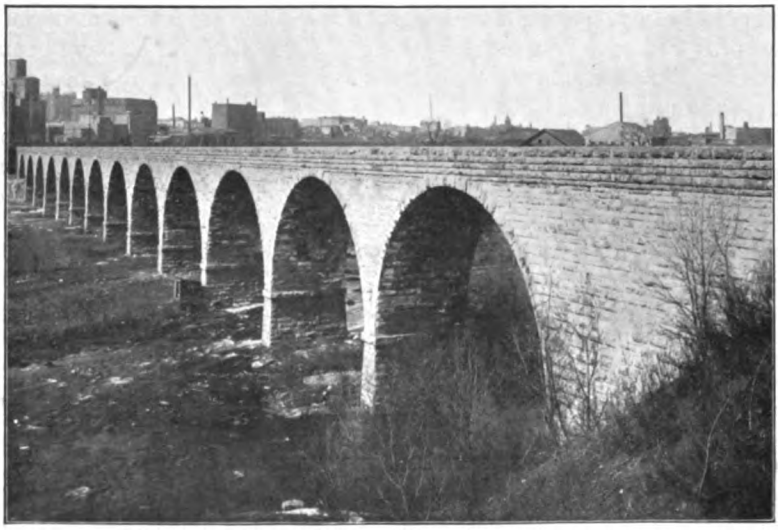
2 MINNEAPOLIS; STONE ARCH.

Railway Viaduct—Built in 1882-83.

The first bridge below the falls is a magnificent stone arch viaduct, built and owned by the Minneapolis Union Railway. It is located immediately below the falls, the west end in fact passing above them. The river at this point is about 1,000 feet wide, with steep banks, rocky bottom and is not navigable at any stage. The bridge crosses the river diagonally and has a total length of 2,490 feet; the eastern 1,033 feet is on a straight line and the remainder is on a 6-degree curve to the right.

Commencing at the east abutment the structure consists of first nine stone arches with a span of 80 feet each. They are semicircular and have a key of 2 feet 8 inches; then four arches with a span of 100 feet each, segmental, with a rise of 39 feet 8 inches, and with a depth of key of 3 feet; then six arches with the same dimensions as the first mentioned, then one arch with 71.36 feet span, the east half being semicircular and the west half segmental with a rise of 15 feet, depth of key 2 feet 8 inches, then a 40-foot arch, segmental, with a rise of 5 feet 4 inches, and a key 2 feet 8 inches in depth, then an arch with a span of 43.86 feet, segmental,

with a rise of 13 feet, and a key 2 feet 6 inches in depth, to the stone dam at the falls. Thence across this dam to the structure across the water power canal above the dam, forming a continuation of the viaduct. The latter structure consists of two skew iron girder spans aggregating 85 feet in length, two through pin connected iron spans each 130 feet in length, resting on tubular piers made of boiler iron filled with concrete, then a 40-foot iron girder reaching to the west abu tment.



Stone Arch Railway Viaduct, Minneapolis.

The size of the piers commencing at the east end is as follows:

No. 1, the abutment.

Nos. 2, 3, 4, 5, 6, 7, 8 and 9, 7 x 26 feet under the coping.

No. 10, 14 x 26 feet under the coping.

Nos. 11, 12 and 13, 10 x 26 feet under the coping.

No. 14, 13 feet $4\frac{5}{16}$ inches on inside, and 14 feet $7\frac{7}{8}$ inches on outside of curve by 26 feet under the coping.

Nos. 15, 16, 17, 18 and 19, 7 feet $1\frac{1}{3}$-inch on inside, 9 feet 6 inches on outside of curve by 26 feet under the coping.

No. 20, 10 feet $8\frac{1}{4}$ inches on inside, 13 feet $1\frac{1}{10}$-inch on outside of curve by 26 feet under the coping.

No. 21, 8 feet 9 inches x 26 feet under the coping.

No. 22, 10 feet 2 inches x 26 feet under the coping.

No. 23, abutment in dam.

The piers are Minnesota granite up to the spring line, and all above that is magnesian limestone. The foundations below the dam

are on soft sandstone which underlies the limestone at the falls. The deepest foundation is at Pier No. 13 and is 17 feet below low water. The bridge is a double track structure and is 28 feet wide. over the parapet walls; the grade line is 65 feet above low water,

The bridge was designed under the charge of Col. Chas. C. Smith, at that time Chief Engineer of the St. Paul, Minneapolis & Manitoba Ry. and its proprietary line the Minneapolis Union Ry. It was built by Darragh & Haviland, and contains 30,554 yards of masonry, and about 10,000 yards of stone filling. It cost approximately $650,000.

This magnificent structure is the only stone bridge on the river below the falls.

A photograph and profile of this structure are shown.*

3 MINNEAPOLIS; SIXTH AVENUE.

Highway—Built in 1872.

The second bridge below the falls is a highway bridge at the foot of Sixth Avenue in Minneapolis. The east end is only a few feet from the end of the stone viaduct just described. It is a deck

Sixth Avenue, Highway, Minneapolis, with Stone Arch Railway Beyond.

structure and consists of six spans, the western three being about 200 feet long, center to center of piers, and the other three having a length of about 166 feet each. The eastern span is over ground entirely above high water, while on the west end the bank slopes very rapidly to the water's edge. Both ends of the bridge rest on solid rock and the abutments consist only of retaining walls to support the earth filling.

The bridge is supported on masonry piers throughout, which rest on a foundation of limestone debris which rests on the "St. Peter"

* I am indebted to Mr. Jno. F. Stevens, Chief Engineer, Great Northern Ry., for the above information.

sandstone, being a part of the crest of St. Anthony Falls in its recession. The piers are of limestone and have no cutwater or ice breaker on the upstream end and the outer stones have disintegrated to a considerable extent. The trusses are of single intersection and have vertical end posts. The panel length of the long spans is 12 feet 4 inches, and that of the short spans 13 feet 8 inches; the trusses are about 18 feet apart, center to center. The posts are channels with plate covers and they are provided with castings at the top and bottom through which the pins for chord and lateral connection pass. The pins at the foot of the end posts pass through a slotted hole in the bed casting to provide for expansion. It is evident that this pin does not move in the slot and that it serves as a rocking bearing for the end posts. In consequence the rods in the end panels of the bottom chords, which are mere idlers, have been buckled by being thrown into compression.

The floor beams are a pair of trussed I-beams, and one of each pair extends beyond the chord and forms a support for the sidewalks. The stringers are of wood. The roadway is of plank, 17 feet wide, with two sidewalks of 5½ feet each. The height of the roadway above the water surface is 67 feet. The bridge was built by the King Bridge Co., and cost $160,000.

4 MINNEAPOLIS; GREAT NORTHERN RY.

Built 1891.

This bridge is located a short distance below Tenth Avenue, Minneapolis, and was built by and belongs to the Minneapolis Western R. R., which is operated by the Great Northern Railway Co.

The river in this locality has steep rocky banks, about 80 to 90 feet above the ordinary low water surface. The banks are somewhat more abrupt than indicated on the profile, owing to the fact that the axis of the bridge is at an angle of 40 degrees with the river bank on the west side, while on the east side the bridge is very nearly tangent with the top of the bluff.

The structure is a deck bridge throughout and consists, commencing on the east side, of first 11 plate girder spans of 60 feet each, alternating with the same number of 30-foot tower spans, also plate girders, then two spans of 150 feet each, a tower span of 30 feet, then a span of 141.756 feet, and one of 158 feet to a tower span of 30 feet, then a 60-foot span, a 30-foot span, one of 60 feet, and then a 30-foot span to the west abutment — 32 spans altogether, and with a total length of 1,830 feet. The 30 and 60 foot spans are all plate girders, while the longer spans are single intersection trusses. The latter are placed 14 feet apart, center to center, while the short spans, except where adjacent to long piers, are 10 feet apart, center to center. The superstructure, with the

exception of the 141 and 158 foot spans, the adjacent ends of which rest on a masonry pier extending to the bottom chord, rests on iron towers, which in turn rest on low piers extending only a short distance above high water. The axes of all the piers and towers are at right angles to the axis of the bridge, except the high masonry pier mentioned above, which is in the main channel of the river and

Great Northern Railway, Minneapolis.

whose axis is at an angle of 40 degrees with the axis of the bridge. This fact accounts for the peculiar appearance of the truss over this pier as shown in the profile. The masonry is of Kettle River sandstone, put in by McMullen & Morris of Minneapolis.

The railway is about 82 feet above low water. The short spans at the west end of the bridge and about 600 feet of the east end of the bridge is on a 6-degree curve, while the intervening portion is on a tangent.*

5 MINNEAPOLIS; NORTHERN PACIFIC R. R.

Built 1884-85.

This bridge is located about one mile below the falls and a very short distance above Washington Avenue, Minneapolis. The low water channel of the river is near the east side and at the foot of an abrupt rocky bluff. The bank on the west side has a much more gentle slope.

* Mr. C. J. A. Morris was engineer of the bridge, and the iron work was furnished and erected by the Shiffler Bridge Co., of Pittsburg.

I am indebted to Mr. Jno. F. Stevens for the above information.

It was built by the St. Paul & Northern Pacific R. R. Co., a corporation which owned the line of railroad from St. Paul to Brainard. It was afterwards turned over to the Northern Pacific R. R., and is operated by that company.

It is a double track deck bridge, and beginning at the east end consists of two spans of 245 feet each, then a viaduct 750 feet in length composed of alternate 30 and 60 foot spans, the shorter spans being tower spans, the longer being inverted "A" trusses with two equal panels of 30 feet. The west end of the viaduct passes over a street and has a span, with very shallow truss, 64 feet

Northern Pacific Railway, Minneapolis.

long. A large portion of the viaduct is over ground somewhat above high water. The first two piers from the east abutment are in water. They are of limestone with granite coping and with granite facing to their upstream ends, which are triangular in shape to above high water. The masonry in these two piers extends to the bottom chords and the piers are about 60 feet high and they rest on the sand rock which forms the river bed. The piers under the steel towers extend just above ground, some of them go down to the rock and some of them rest in gravel and boulders. It was found that the surface of the bed rock under the earth on the west side of the river is lower than in the present river channel.

The main spans are single intersection trusses and are divided into 8 panels. It is believed that at the the time the bridge was built the panel length of about 30 feet was greater than in any truss built in this country. The trusses are 42 feet deep, center to cen-

ter, and are 24 feet apart. The floor beams are placed on top of the top chord, and the stringers are of uniform depth over the trusses and viaduct.

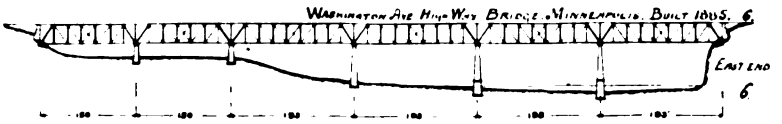
The roadway is about 101 feet above the water surface.

The bridge is entirely of steel and is one of the earliest of steel bridges.*

6 MINNEAPOLIS; WASHINGTON AVENUE.

A highway bridge built for the City of Minneapolis in 1885.

The river has the same characteristics as at the Northern Pacific bridge only a short distance above it.



The structure consists, commencing on the east side, of four spans of 193 feet each and two spans of 150 feet each, center to center of piers, a total length of 1,072 feet. The first two spans cross the river proper, the remaining spans being over the ground above high water.

The substructure is masonry throughout and the piers are built of limestone faced with granite on the upstream side. The foundation is rock. The piers are about 25 feet long on top and the top of the highest is 74 feet 4 inches above the bottom or about 55 feet above high water. They have triangular ends upstream with semicircular downstream ends extending above high water. Both ends of the bridge rest on solid rock with abutments for retaining walls only.

The superstructure originally consisted of Pratt Deck trusses 32 feet high and set 20 feet 5 inches apart, center to center. The roadway was 18 feet wide with two sidewalks each 6.5 feet wide.

In 1890, owing to the increased loads due to the growing traffic of the street railways, the bridge was strengthened by adding a center truss with top chord supporting the floor directly. The floor system was also strengthened by the addition of iron stringers.†

The roadway is paved with cedar blocks and has two street car tracks. The posts supporting the trolley wires are outside the trusses and run down to and are supported on the piers. The floor is about 97 feet above the water surface. The bridge was built by the Canton Bridge Co.

* It was designed by Mr. C. F. Loweth. The chief engineer for the railroad was J. W. Kendrick. The Edgemoor Bridge Co. was the contractor, with Onward Bates in charge of erection.

† See *Engineering Record*, July 18, 1896.

7 MINNEAPOLIS; FRANKLIN AVENUE.

Highway Bridge.

The river at this place, as well as at the next two bridges, is narrow with a swift current and with steep rocky bluffs on each shore.

The structure consists of a channel span of 300 feet and two spans of 172½ feet at each end reaching to the top of the bluff. The center or channel span is a half through span with the floor at about the center of the height of the truss. The end spans are deck spans, their shore ends being supported on masonry abutments near the top of the bluffs. The channel piers are both near the low water line, the length of the channel span very nearly representing the low water width of the river. They are of limestone and rest on solid rock and have triangular ends upstream to about the height of high water; they extend up to the bottom chord of the center span, the ends of the side spans resting in recesses in the sides of the piers. The roadway is about 18 feet wide and is paved with cedar blocks. There are two sidewalks 6 feet wide outside of the trusses, with the roadway 100 feet above the water.

The bridge was built in 1889 by the King Bridge Co., Cleveland, O.

8 MINNEAPOLIS; C., M. & ST. P. RY., (SHORT LINE).

Built 1879-80.

This structure is about one-half mile below Franklin Avenue and about one mile above the Marshall Avenue bridge, and as at these two bridges, the river is narrow, has a rocky bottom, swift current and steep bluffs on each side rising from the water's edge.

C. M. & St. P. Railway (Shortline), Minneapolis.

The structure consists of three main spans, the center one having a length of 324 feet and the end spans 272 feet each. At the west end there is a 40-foot and a 60-foot deck span, and on the east

end there are three 60-foot deck spans reaching from the ends of the main spans to the abutments at the top of the bank.

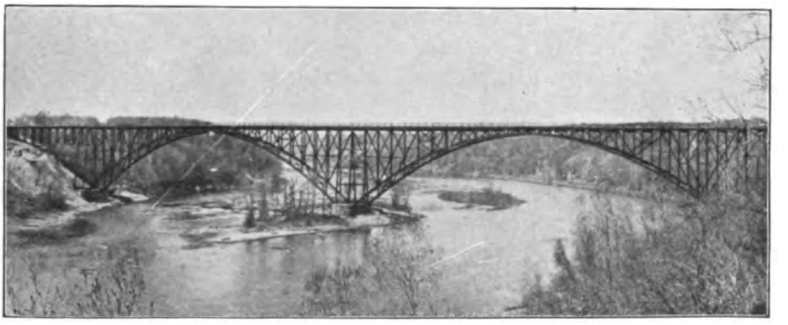
The piers under the main channel span are in the river and extend a short distance above high water, and are surmounted by single iron bents, which in turn support the superstructure. The west end of the west span rests on a masonry pier on the side of the bluff, while the east end of the east span is supported on iron cylindrical piers. The approach spans rest on iron trestle bents supported on smaller cylindrical piers. Considering the trusses in the main bridge, there are only two spans instead of three, as the trusses are continuous over the channel piers and project to the center of the channel opening, the chords being cut at this point. They are, therefore, true cantilevers.

The structure is a single track deck bridge, both chords of the main span are horizontal, and of the same depth throughout. The truss in detail is of the double intersection type with vertical posts. The end spans were erected on false work while the center span was projected without its use. The track is about 150 feet above low water. The bridge was designed and built by C. Shaler Smith. Plans have been made for a structure to replace the present one, having spans of somewhat different length and for a double track.

9 MINNEAPOLIS; MARSHALL AVENUE.

Highway—Built 1888-89.

This bridge joins Marshall Avenue, Minneapolis, and Lake Street, St. Paul. The river at this point is narrow and rapid, with rocky bluffs rising to a height of about 120 feet, and with a width at this



Marshall Avenue, Highway, Minneapolis.

elevation of 1,273 feet measured along the axis of the bridge. It was authorized by an act of the legislature of Minnesota which fixed the location and limited the cost to $150,000.

The structure consists of three low piers supporting the ends of two 456-foot arch spans and three tall towers which carry the floor between the arches. There are two deck trusses 133 and 95 feet long respectively, connecting the arch spans with short girder and trestle approaches. The center pier is on a small island, and rests on gravel at a depth of about 4 feet below low water. A bed of concrete about 3 feet thick rests directly on the gravel. The side piers rest on rock. The masonry is Mankato limestone with granite skewbacks and bearing stones. The roadway is 20 feet wide with 6-foot cantilever sidewalks on each side. The panel length is 19 feet throughout the structure.

The bridge was built under Mr. J. S. Sewall, M. W. S. E., as engineer, for the joint board of commissioners of Hennepin and Ramsey counties, by the Wrought Iron Bridge Co., of Canton, O. It was built under the general specifications of Mr. Sewall and, excepting the floor system which has 7 x 16-inch wooden stringers, was entirely of iron--no steel being allowed in its construction.

The main arches have triangular trussing between the lower chord and arch and the horizontal top chord, and is practically a three-hinged arch, as the top chord has no connection with the adjacent structure. The floor is paved with cedar blocks.*

10 FORT SNELLING.

Highway—Built 1879-80.

The Sundry Civil appropriation bill passed by the national Congress in 1878 contained an item appropriating $65,000 for aiding the construction of a free wagon bridge at the military reservation of Fort Snelling, Minn. The bridge was built by commissioners appointed for this purpose by the legislature of Minnesota, and Mr. J. S. Sewall, M. W. S. E., was their engineer.

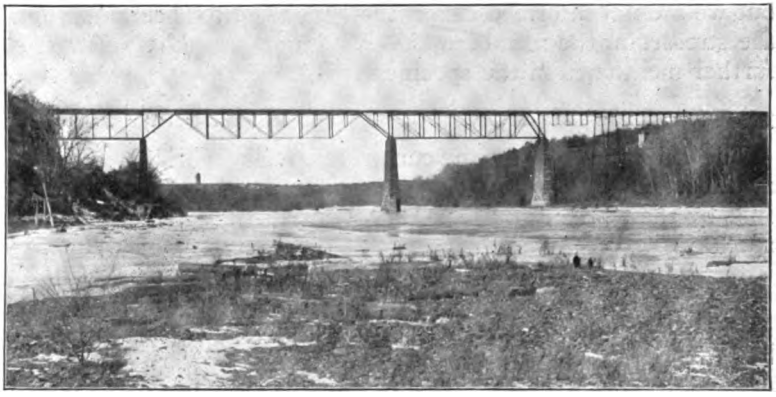
The river valley at this point has a width of about 800 feet, with steep rocky bluffs 80 to 90 feet in height, on each side. The low water channel is only about one-half this distance in width.

Beginning on the west side, the structure consists of a span reaching from the top of the bluff to the first pier, which is at the edge of the water; this span also crosses over a railroad track and is 135 feet long; then the main channel span of 270 feet; then a span of 181½ feet; then 5 spans of about 65 feet, each supported by four intermediate tower spans of about 18 feet, to an abutment at the top of the bluff. All are deck spans.

The three main spans are of somewhat peculiar design. The shore end of the first is supported at the top chord, the opposite end is supported on the pier at the bottom chord. The channel

* See *Engineering Record*, Dec. 7, 1895, for details.

ends of each of the two side spans have a single projecting inclined post, forming a cantilever, and supporting a suspended span over the channel. The east end of the third span has an inclined end post, the inclination, however, covering only half the ordinary panel length. The trusses are single intersection, but with intermediate



Fort Snelling—Highway.

supports for the chords. Both the top and bottom chords of the side spans are of latticed channels, the bottom chord of the channel span is of eye bars. The floor beams rest on top of the chord and are of iron; the stringers are of wood. The roadway is about 18 feet wide, with a single sidewalk 5 feet in width.

The piers supporting the main spans extend to the bottom chord, the lower part is of limestone, and the upper portion of sandstone quarried in the immediate neighborhood. The first or west pier rests on rock about 20 feet below the water surface, the other two were sunk in caissons onto pile foundations, The piers have triangular ends upstream, faced with granite, and extending above high water. The towers are supported on low piers of masonry.

The superstructure was built by Mr. H. E. Horton, the contract having been awarded to him after a competition in which 32 bids, (all on competitive designs) were received. The original specifications required that the iron superstructure be so proportioned and constructed that with a load of 1,800 lbs. per lineal foot upon the whole or any part thereof, there should be no tensile strain upon any part of the structure exceeding 12,000 lbs. per square inch, and no compressive strain exceeding one-fourth the breaking load of the part as calculated by Gordon's formulæ.

Specifications also provided for a wind pressure of 50 lbs. per square foot, shearing strains on rivets and pins 8,000 lbs. per

square inch, and iron in tension "to have an elastic limit exceeding 25,000 lbs. per square inch."

The bridge was completed in January, 1880, and was tested by the engineer having general supervision for the government, by loading it with ice to 1,800 lbs. per lineal foot, as provided in the specifications. The bridge successfully stood up under the load, but we are not informed of any methods used to ascertain whether the stresses in the members did or did not exceed the limits still further mentioned in the specifications.*

11 ST. PAUL; C., ST. P., M. & O. RY. AND C. M. & ST. P. RY.

The only authority for the construction of this bridge was granted by the territorial legislature of Minnesota in 1855. The bridge was built by the St. Paul & Sioux City Railroad Co., and was completed in 1869.

C., St. P., M. & O. R. R. and C., M. & St. P. Ry., St. Paul.

The left bank of the river at this point is a low bluff, while on the right bank there is a narrow bottom extending to the bluffs which are somewhat higher than on the left bank. The low water width was at this time about 1,300 feet with a high water width of 3,000 feet, the difference between high and low water was about 22 feet.

The original structure consisted of a trestle approach on the right bank, then a span of 150 feet, then a draw span 270 feet long over all, with clear openings of 114 feet, then six spans of 150 feet each. All the spans rested on masonry piers, which, with the exception

*Report of Chief of Engineers, U. S. A., 1880, p. 1869.

of the draw pier, were 22 feet long and 7 feet wide on top, with a batter of ½ inch per foot. All except the one on the right bank had triangular ends upstream. The piers to the right of the draw, the draw, and the two piers to the left, rested on piles cut off below the water. The others rested on the bed of the river and were protected by rip-rap. The draw pier was 30 feet in diameter, and the guard pier was a rock filled crib.

The superstructure was a Howe truss throughout. The short spans were 22½ feet high and the draw was 9 feet high at the ends and 26 feet at the center, and were built by the railroad company. The bridge was rebuilt with the same kind of trusses in 1876–77. The draw was rebuilt in iron in 1885 and the first span from the right bank in 1887. Both spans were built by the Lassig Bridge Co., and both are riveted lattice trusses. The remaining six spans were rebuilt in 1888 by the Keystone Bridge Co., and are Pratt trusses.

The old piers were used, and after 31 years of use are in remarkably good condition, showing very little deterioration.

12 ST. PAUL; SMITH AVENUE.

Built 1887-88.

This is a highway bridge built by the City of St. Paul, and situated about half-way between the C., St. P., M. & O. R. R. bridge and the Wabasha Street bridge. It extends from the bluffs on the St. Paul side to the bluffs on the right bank, and has a length between abut-

Smith Avenue—Highway—St. Paul, Minn.

ments of 2,770 feet. It is a deck structure throughout, with a roadway 24 feet wide and with two sidewalks each 8 feet in width, the total width between railings being 41.5 feet. The roadway is paved with cedar blocks and the structure has a clear height above low water of about 118 feet.

The structure consists, commencing with the abutment on the south side, of first two 60-foot spans, a 170-foot span to a 50-foot tower span, then four 250-foot spans with a 50-foot tower span between the second and third, then a 50-foot tower span, three 90-foot spans to a 40-foot tower span, then nine 80-foot spans, between each three of which there is a 40-foot tower span, then two 90-foot spans to the abutment.

The substructure consists of the two abutments and 27 small piers on which rest the legs of the towers or bents. With the exception of those piers in the side of the bluffs, they extend a short distance above high water and rest on a pile foundation.

The superstructure is of wrought iron throughout, the trusses are 22 feet apart, center to center. The four 40-foot tower spans and the 60-foot spans are plate girders, the 80 and 90 foot spans are riveted lattice, while the three 50-foot tower spans, with the 170 and 250 foot spans, are pin connected. The adjacent ends of spans between towers rest on single trestle bents, which form rocker bearings, and which, with sliding joints at about every third span, provide for expansion in the short spans. The highest bent is 129 feet.*

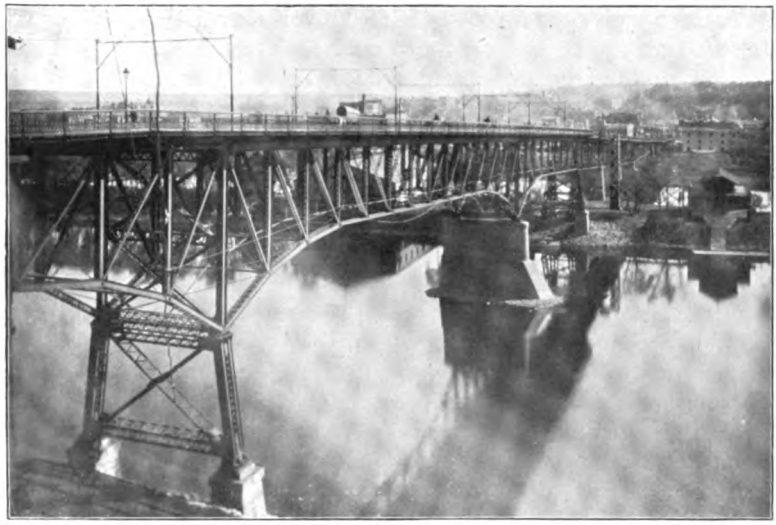
13 ST. PAUL; WABASHA STREET.

One of the first bridges built over the river was a highway bridge at what is now the foot of Wabasha Street, St. Paul, completed in 1858. The only authority for its construction was granted by the territorial legislature of Minnesota in 1854. The act provided for a main span 300 feet long, between piers. This span was, however, made only 240 feet.

The river at the site of the bridge is divided into two channels by an island, the width between main banks at the time the bridge was built being about 1,200 feet. The original structure consisted of a trestle approach 375 feet long, on the right bank, to the first pier, then 7 spans 140 feet long, center to center, then a channel span 240 feet long, and lastly an 80-foot span, the outer end of which rested on the rock bluff. The first pier on the right bank rested on a grillage of timber below low water, and was 20 feet long and 5 feet wide on top, with a batter of ½ inch to the foot. The others were 7 feet wide on top. Those in the channel had triangular ends up to above high water, and rested on piles cut off as near the bottom as possible, and the masonry sunk onto them in caissons. The two piers on the island had no triangular end and no piles under them, the masonry resting on a timber grillage sup-

* The superstructure was furnished by the Keystone Bridge Co., and erected by Mr. Horace E. Horton. Mr. A. W. Munster was engineer. Complete details of the superstructure can be found in the *Engineering Record* for February 16, 1889, et. seq.

ported on a bed of rip-rap. The channel piers were 30 feet long and 7 feet wide on top, with a batter of ½ inch to the foot, and were 86 feet high above low water. They were built of limestone quarried in the neighborhood.



Wabasha Street—Highway—St. Paul.

The pier under the St. Paul end of the channel span was near the water's edge and at the foot of the steep rocky bluff, and it was supposed that it would rest on rock. It was found, however, that the rock sloped off so rapidly that it was necessary to drive piles under about one-third of the base of the pier. Timbers 24 inches square were used as grillage, one end of them resting on the piles and the other end on the rock.

The original superstructure was of a peculiar pattern, and was designed and built of wood by J. S. Sewall, M. W. S. E., and is described by him as follows:

"The trusses were Howe trusses with wooden suspenders in the "place of iron rods. The suspenders were notched onto iron angle "blocks which were set into daps in the chords like the angle blocks "of a Howe truss; chords were bolted to angle blocks. The 240-"foot span was a through span, the others deck spans. The chords "were level; the vertical members of the deck spans were carried "to the proper height above chord and capped by the floor beams. "At the ends of spans the posts stood on cast-iron shoes, there were "no corbels, but the truss stood on the end posts. At one end of "each 140-foot span these end members extended a few inches

"below chord, at the other end seven feet and a few inches. The "panels were 10-foot. I think the 140-foot trusses were 16 feet "high.

"The long span had three trusses, panels 10-foot, double inter-"section, height probably 26 feet, lower chord sticks 7x20 inches "with 6x16-inch caps on lower chord over four-fifths of the span. "It stood on the end posts, the piers being but a few inches below "bottom of lower chords. The floor beams were 5 feet apart, "supported by lower chord, with blocking or short posts to get the "proper height. The span was further strengthened by arch "braces at each end extending from iron shoes 10 feet from ends "of chords to seats cut in the masonry of piers. The sketch shows "the connection of braces, suspensions and chords for the 140-foot "spans, the end posts being same as suspensions. The long span "detail is the same except the size of the chords. I have forgotten "how the counters were arranged in the 140-foot spans, but in the "long span they were cut in between the braces, with little bearing "plates. Thus each counter was cut into four lengths. They soon "became loose and useless. Very likely there never was a condi-"tion of loading that produced a strain on them. The other web " members were properly proportioned to the strains. The lateral " and diagonal systems were as usual and good. These trusses "never sagged. The 240-foot span lasted eleven years, when the "lower chord was found to be badly decayed. It was replaced by "a Howe truss of the usual type."

The roadway over the short spans was on a 5 per cent grade and over the channel span was about 3½ per cent.

The bridge was built by a company and toll charged. It was acquired by the City of St. Paul sometime prior to 1875, just when I have not learned, and since then has been a free bridge.

The bridge when completed was very little, if any, obstruction to navigation, and as at that time the only means of reaching St. Paul was by river, steamboat navigation was flourishing, and this fact probably explains the satisfactory provision for it. The first railroad communication to St. Paul was not opened till 9 years after the opening of the bridge.

The main span was rebuilt of wood, ordinary Howe truss, in 1869-70 and the others in 1872 on original plans. In 1879 the main channel span was replaced with iron. This span was of Whipple trusses of 16 panels, 30 feet in depth, and 20 feet 9 inches wide, center to center of trusses, giving a clear roadway of 17 feet and two sidewalks each 4.5 feet wide. The wooden spans, Nos. 3, 4, 5 and 6, counting from the St. Paul end, were rebuilt in 1883 with iron Pratt trusses 23.5 feet in depth and 17-foot centers, iron floor beams and wooden stringers. The first three spans were built

by the Missouri Valley Bridge Co. and the other by Horace E. Horton, the old piers being used. The remaining wooden spans were replaced in 1884-85 with Pratt trusses, piers 8 and 9 were used, but the last three spans were shortened to 110, 125 and 100 feet respectively, two new piers and an abutment were built and the pile approach filled up.

In 1889 the spans over the main channel were again replaced by a new structure. As it was desirable to have a deck bridge throughout and to very materially widen the roadway, and as the masonry of the old piers was not fit for rebuilding, an entirely new structure was designed. The new bridge, commencing at the bluff, consisted of a span 135 feet long, a channel span of 280 feet and a span of 187 feet. New piers were built resting on a pile foundation; the new spans are of the cantilever order. The end spans were erected on false work while the channel span was erected without it, the material being partly supported by the old bridge during erection. The roadway is 36 feet wide and is paved with brick. There are two sidewalks each 10 feet in width. The new spans were built by the Keystone Bridge Co. and were erected by Horace E. Horton and only 40 days elapsed after the receipt of the material until the bridge was again thrown open to the public. (*Engineering Record*, 1891-92, p. 58, for details of the new span.)

This year (1900) the remaining portion of the structure is being rebuilt to the full width of 56 feet. The arrangement of the spans, as well as that built in 1889, is shown on the profile, also the position of the piers in the original bridge. The new piers are all on pile foundations. The total length has been shortened to 1,200 feet by an embankment at the south end.*

To provide for the use of the bridge during the erection of the new one, the old spans were moved bodily to one side of their old position and supported on temporary pile piers.†

14 ST. PAUL; ROBERT STREET.

Highway—Built 1885-86.

This bridge is just below the Chicago, St. Paul & Kansas City Railway, and, in fact, it crosses over the latter bridge so that the end on the left bank is on the upstream side of it. The structure consists, commencing on the left side, of first five 18-foot plate girder spans, one 17.41-foot plate girder, one deck pin-connected span of 180 feet, then one through pin-connected inclined top chord channel span of 352 feet, then three deck pin-connected spans of 200 feet

* The new bridge is being built by the Wisconsin Bridge Co. on the design made by Mr. A. Munster, of St. Paul.

† This proceeding is described and illustrated by Mr. Munster in the *Jour. Engr. Societies*, Jan. 1900, and to him I am indebted for a large amount of the information concerning the history of this structure.

each, one deck pin-connected span of 150 feet, and two 55-foot plate girders to the abutment, the total length, center to center of abutments, being 1540.65 feet. The grade of the north end is 3.5 per cent and the south end 3.8 per cent, rising in each case toward the channel span which is level. Ths sub-structure consists of 14 pedestal masonry piers, 6 river piers and 2 abutments.

The chords of the trusses are 35 feet apart, center to center, and carry a roadway 32 feet wide, paved with cedar blocks, and two sidewalks, each 10 feet in width. The height of the roadway at the channel span is about 75 feet above low water. The channel span is single intersection, with intermediate supports for the chords. The end posts are about 30 inches square, and with the heavy portal bracing give the structure a very massive appearance.* It was built by the Morse Bridge Co., of Youngstown, Ohio.

15 ST. PAUL; CHICAGO GREAT WESTERN RY.

Built 1885.

This is a single track railroad bridge, located only a short distance below the Wabasha Street bridge. It crosses the river diagonally downstream from the right bank at an angle of about 55 degrees with the general direction of the river, and consists, com-

Robert Street Bridge and Chicago Great Western Draw Span, St. Paul.

mencing on the right bank, of 4 spans 222 feet long, center to center of piers, then a draw span 411 feet long on the center line, with clear openings of 175 feet, originally. These openings have been reduced by the construction of the piers of the Robert Street bridge, which passes over the draw span, to clear widths of 123 and 147 feet.

The bridge is supported throughout on masonry piers of Mankato limestone, which rests on pile foundations cut off at the bot-

* I am indebted to Mr. O. Claussen, City Engineer of St. Paul, for the above information.

tom of the river. The masonry in foundations was laid by the use of open cofferdams, except the main channel pier, which was sunk in open caissons. The draw pier is 30 feet in diameter, the others are about 7 feet wide on top by 30 feet long; the guard pier is a pile structure planked. The piers have triangular ends upstream, with a slope on the nose of about 1 to 1. The coping of the draw pier is just above extreme high water.

The fixed spans are double intersection trusses with horizontal top chords. The draw is single intersection with the usual inclined top chord. The piers are parallel with the current and all the spans are thus on a skew. The fixed spans are 29 feet high, the draw 29 feet at the ends and 44 feet at the center; fixed spans are 17 feet wide, center to center, the track on a part of the draw is on a 6-degree curve and it is 25 feet wide, center to center, and its axis is set at an angle of about 2 degrees with the axis of the fixed span. Panel lengths in the draw are 18 feet 9 inches, while on the fixed spans they are 17 feet 6 inches. The draw is operated by steam.*

16 SOUTH ST. PAUL BELT RAILWAY BRIDGE.

This structure crosses the river near Newport, Minn., about 9 miles below the business center of St. Paul, and 3 miles below the Union Stock Yards. It forms a part of the South St. Paul Belt Ry., a line of road about 4 miles in length and connecting the Union Stock Yards on the west side of the river in South St. Paul with the main lines of the C., M. & St. P. Ry. and C., B. & Q. R. R. at Newport. In consideration of a bonus from the City of South St. Paul and Newport Township, provision was made for highway traffic.

Construction was begun in the summer of 1894, and the bridge was opened for traffic in April, 1895.

The structure has a double deck, the upper for railroad and the lower for highway traffic. To accommodate the latter the trusses were spaced so as to make a clear roadway 18 feet in width; no sidewalk is provided. The railroad grade on the east bank was so high as to necessitate placing the tracks on the upper deck. The highway is designed to accommodate an electric street railway, if ever desired, and has a clear head-room of about 13 feet.

Beginning at the east side the structure consists of a viaduct approach of 30 and 40 foot spans with an upper deck 440 feet long, and a highway floor 416 feet long; then a draw span 442 feet in length, center to center of piers; then 5 spans each of 140 feet in

* The bridge was designed by C. Shaler Smith, the draw was built by the Passaic Rolling Mills and the fixed spans by the Edgemoor Bridge Co., with Mr. Onward Bates in charge of erection. G. W. Sherwood & Co., of St. Paul, built the substructure.

length, center to center of piers; then a 50-foot girder span; then 1,039 feet of pile and trestle approach.

The highway floor is deflected from the axis of the bridge under the 50-foot girder span and by a short pile trestle is landed on earth embankment. The substructure throughout is of masonry piers; those in and adjoining the river have pile foundations. Generally the piles were sawed off at or below the river bottom and timber grillage used, of such thickness as each individual case would permit; the pier near the west side has no grillage, concrete over and about the piles being substituted. The masonry is built of magnesian limestone from Mankato, Minn. The protection or fender

South St. Paul Belt Railway and Highway.

piers for the draw span are of pile and timber with a rock filled timber crib at the upstream end. The east end of the draw span is at the river bank, and from this pier, upstream, there is a pile and timber sheer-boom located along the water's edge and 800 feet in length, designed to facilitate the passage of log rafts through the opening.

The superstructure is of steel. The viaduct approach has at each third span a braced tower with a 30-foot span, the two intermediate spans being 40 feet and supported on rocking bents. All posts are vertical. Floor beams of the upper deck are rigidly connected to the posts and in addition have heavy brackets underneath, so as to take care of the lateral forces; below the lower deck are diagonal braces as in the usual construction.

The draw span is of the usual type, of two independent spans supported from a central tower, the top chords being curved. The trusses are 44 feet deep at ends and at the tower, 72 feet—the excessive end depth being necessary to give the required head-room

of 22 feet above the railroad track. The span is 440 feet in length over all, with a central panel of 18 feet 7⅜ inches and 7 panels of 30 feet ¼ inch in each arm. The span has a rim-bearing turntable. Between the trusses and the drum are four large girders, placed transversely to the axis of the bridge, and connected together in pairs by twin girders under each central tower post; these four girders are so spaced as to distribute the load evenly at 8 equidistant points on the drum.

The turntable has 56 cast steel wheels, 18¼-inch diameter and 10½-inch face; the track is of cast iron, securely bolted to the masonry, and the upper tread is of forged steel, bolted to the lower flange of drum. The rack is of cast iron, secured with turned bolts to the lower track, with all bearing or contact surfaces between the two machines finished. The ends of span are supported on large double cast steel rollers, moving transversely to the axis of the bridge, and the track rails are raised and lowered by the same mechanism. The draw span was at first provided with a 50 H. P. gasoline engine, but this power proved unsatisfactory and last year was replaced with steam.

The five 140-foot spans are of the usual Pratt type of truss, divided in 7 equal panels. The upper floor beams are riveted into the truss posts below the top chords, and the lower floor beams above the bottom chords with bottom flange flush with bottom of truss posts, the same as in the draw span. Each panel of wind pressure at upper deck is supposed to go through the truss posts directly to the bottom lateral system, and thence to piers, the posts being proportioned on this basis, but in addition there is a supplemental but light lateral system along the upper deck.*

17 HASTINGS, MINNESOTA.

C. M. & St. P. Ry.—Built 1871.

The only authority for the construction of this bridge was granted by the Minnesota legislature in 1867.

The river in this vicinity crosses the valley from the left bank and strikes the low bluffs on the right bank, and there makes a sharp bend of nearly a right angle, only a short distance above the bridge; a location similar to that of the Hannibal bridge. The low water channel was about 400 feet wide, with a high water width extending from bluff to bluff of about 4,000 feet. The depth

* The Pittsburgh Bridge Co., Pittsburgh, Pa., was the contractor for the entire structure' and sub-let the substructure and protection piers to Mr. Chas. Stone of St. Paul. Mr. W. W. Curtis, M. W. S. E., as the representative of the Pittsburgh Bridge Co., secured the contract and generally had charge of its construction for the contractors. The structure was designed and built under the supervision of Mr. Chas. F. Loweth, M. W. S. E., of St. Paul, Minn., to whom I am indebted for the above information.

of water was from 18 to 22 feet, the current gentle and with a rise from low to high water of about 22 feet. The bridge was completed in 1871 by the Hastings & Dakota Railroad Co., afterwards acquired by the C. M. & St. P. Ry.

The structure originally consisted, beginning on the right bank, of 235 feet of trestle approach; then a draw span 300 feet long over all with clear openings of 120 feet and 135 feet; then two spans of about 150 feet each and one of 106 feet; then about 2,286 feet of trestle to a bridge of two spans of 105 feet each; then 700 feet of trestle to the embankment. The main bridge was on a straight line.

The piers were built of limestone quarried in the vicinity and rest on piles, with the exception of the first one, which is on rock about 6 feet above low water and about 15 feet back from the shore line. The draw pier was 26¾ feet in diameter on top with a batter of ½ inch per foot. The piers at the ends of the draw span were 7 feet wide on top, the others 6 feet. Piers Nos. 3 and 4 were 30 feet long on top with triangular starlings extending about 18½ feet above low water, with a slope on the nose of 1 to 1. Piers 5 and 6 were of the same dimensions but had no starlings. The piers under the short spans near the bluffs were 5½ by 25½ feet on top with semi-circular ends. The guard piers were rock-filled cribs resting on the bottom of the river.

SUPERSTRUCTURE.—The draw and two adjoining spans (150 feet) were of the "Post" pattern, built by the American Bridge & Iron Co. The three 105-foot spans were a combination of wood and iron, built by the railroad company, and of the same form of truss. The draw was operated by hand. The lowest part of the structure was not over 6½ feet above high water (Warren). The 105-foot span over the river was rebuilt in 1880, and the draw and two remaining spans in 1891; all are of iron throughout and, as is the custom of this company, were built by the railway company itself. The old piers were used, their tops only being changed to meet the requirements of the new spans. The approach on the south or west side has been partly filled, while most of the trestle on the east side has been maintained, and was rebuilt in 1890. The spans and trestle near the north bluffs have been filled.

The new spans are all single intersection and have horizontal top chords. The short span has all the stringers riveted to the web of the floor beams and the bottom chord is of the ordinary eye bars; the longer fixed spans have stiff continuous bottom chords made of plates and angles and the floor beams are below the stringers and suspended from the chord. The new "draw" is operated by steam.

18 HASTINGS, MINN.

Highway—Built 1895.

Authorized by act of Congress in 1894. This bridge is located only about 1,000 feet downstream from the railroad bridge just described, and is a high bridge, the bottom chord of the channel span being about 55 feet above high water. Owing to the fact that the river is comparatively narrow and all confined to one channel, and that the banks are low, especially those on the north side, the greater part of the length of the structure is contained in the approaches, which are of steel trestle bents and plate girders with wooden joists and plank floor. Beginning with the trestle approach on the north or left bank, the structure consists of a deck span of about 135 feet; then the main channel span of about 375 feet to a tower span on the south bank; then two deck plate girder spans to the trestle approach. The south end of the main channel span is supported by two legs of the tower, which in turn rest on low piers extending above high water, and they in turn rest on the exposed solid rock and a few feet back of the low water line. The north end of the span

Hastings—Highway.

and the adjacent end of the deck span rest on a single bent resting on a masonry pier extending above high water and which is in the water some 25 or 30 feet from the low water line. The trestle approach rests on low stone piers only a foot or two above the surface of the ground.

The main span is a through truss of single intersection with curved top chords, the five central panels only being horizontal. The trusses are spaced 24 feet apart, center to center, and are —— feet high. The roadway is 19 feet and one sidewalk 5 feet in width,

both being inside the trusses. Owing to the height of the truss, the posts, which appear very light, are braced by longitudinal struts between alternate posts and at about the center of their height; they are also braced by lateral struts placed at about one-third and two-thirds of their vertical height. This bracing is in addition to the ordinary top lateral bracing. The deck span is divided into 5 panels and the bottom chord is curved, the center panel only being horizontal. The approach on the north end at a distance of about 75 feet from the end of the deck span makes a turn of about 45 degrees upstream. The south approach is peculiar in the fact that it is almost circular in plan and makes a complete turn of 360 degrees, the end where it reaches the street level being underneath and having a direction and position on the axis of the bridge prolonged. The length of the girders in the north approach is about 33 feet, while in the south approach, owing to the arrangement of bents, they vary in length, but are generally somewhat shorter. This is a free bridge belonging to the city.*

19 RED WING, MINNESOTA.

Highway.

Built by the City of Red Wing, Minn. Begun in the summer of 1894 and opened for traffic May 1st, 1895

It is a highway bridge and the city charges toll for passage over it. It was built for the purpose of increasing the city's trade with the adjoining country in Wisconsin, and supplanted a ferry.

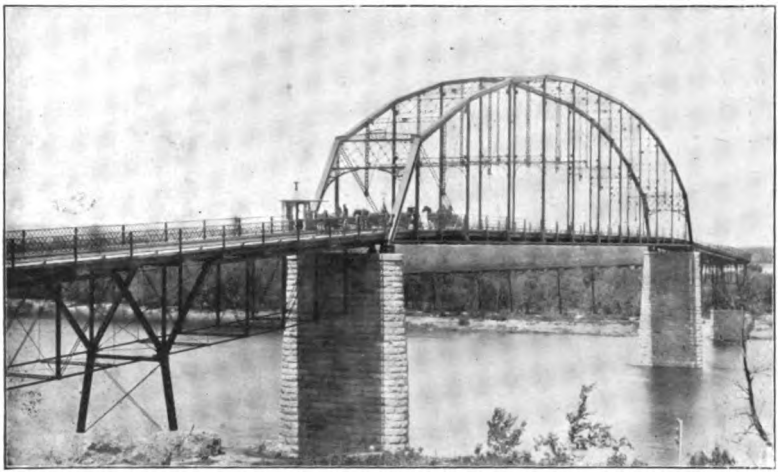
The Minnesota end of the structure begins near the foot of the large bluff known as Barn Bluff and opposite the end of Bluff street in the city of Red Wing. The line of the bridge crosses the river squarely and immediately over the east or Wisconsin bank of the river the bridge turns up stream at an angle of 77 degrees 46 minutes by a short curve.

The main structure and its approaches are all substantially and permanently built. The general dimensions are as follows: Beginning at the intersection of Bluff and Main streets, there is an earth approach about 400 feet in length; then two 94-foot deck spans, the second one crossing over the tracks of the C., M. & St. P. Ry.; then a 430-foot channel span; then a 220-foot deck span; the shore end of which projects as a cantilever an additional distance of 37 feet; then a steel viaduct 839 feet in length then an earth embankment about 400 feet in length. On the earth em-

*The bridge was built by the Wisconsin Bridge & Iron Co., and John Geist was the engineer.

bankments there is one 6-foot sidewalk and a 24-foot roadway, and over the spans and trestle there is one 6-foot sidewalk and a roadway 17 feet wide in the clear. The main channel span, which is the only through span, has trusses spaced far enough apart so as to be outside both roadway and sidewalk. Character of trusses in the several spans is shown on the photograph.

The higher portion of the Wisconsin approach trestle is made as is outlined in the sketch herewith. The two 94-foot spans on the city side are suported by a rocking bent between them.



Red Wing, Minn., Highway.

SUBSTRUCTURE.—The substructure is of substantial masonry work throughout: the abutments and piers for the two 94-foot spans are founded upon natural bed-rock. The two piers for the channel span are each of stone masonry and are 69 feet in height above low water mark of the river. The form of these piers is shown on the photograph herewith. The pier at the west side of the channel is near the edge of the river, while that at the east end of the span is well out into the river. The piers have pile foundations surmounted with timber grillage which extends to one foot below low water level. The easterly one of these large piers was in water 16 feet deep. The piles were cut off near the surface of the bottom of the river, and the timber grillage consists of 14 courses of 12-inch timbers. The top and bottom courses were laid solid, but the intermediate courses were approximately three-quarters solid. The piles were driven to a firm foundation and were from 40 to 60 feet in length below the level at which

they were cut off. The foundation for the west one of these high piers was similar but in shallower water. The grillage was about 4 feet in thickness and much shorter piles were required.

The pier at the Wisconsin shore is upon a pile foundation; concrete being placed over and about the piles nearly to the ground surface.

The small piers for trestle approach have concrete footings, and above that are of large size stone masonry. The stone used throughout the work, except for starlings of river piers, is a hard magnesian limestone, quarried two and one-half miles from the bridge site, and is a hard, durable stone quite suitable for the purpose. The starlings of river piers from low to high water level are of granite from St. Cloud, Minn.

The superstructure was proportioned for live loads as follows:—

For floor system and secondary members throughout, including the viaduct approach, 100 lbs. per square foot, over both roadway and sidewalk.

The trusses of 94-foot spans, 1,680 lbs. per lineal foot.

For 220-foot span, 1,430 lbs. per lineal foot.

For 430-foot span, 1,200 lbs. per lineal foot.

All of the metal work is of steel excepting small rods, which were of iron. Flooring was three inches thick for the roadway, two inches for the sidewalks, and of white pine. Since construction, the roadway floor has been renewed with oak. The joists were of white pine, 15 lines of joists being used 4x14 inches for the channel span and for portion of the trestle, and 4x12 inches elsewhere.*

20 REED'S LANDING.

Pontoon Railway Bridge—Built 1882.

This bridge is located about one and one-half miles below the lower end of Lake Pepin, and a short distance below the mouth of the Chippewa River. It was built and is operated by the C. M. & St. P. Ry. Co. The river has a low water width of about 2,400 feet.

The bridge consists of an ordinary pile trestle with a pontoon draw about 400 feet in length, which gives a clear opening of about 350 feet. There were three openings in the trestle bridge which were spanned by Howe trusses 40, 70 and 90 feet in length.

*The small piers for Wisconsin approach trestle were built by the city by day labor. All other substructures were built under contract by Mr. D. D. Smith of Minneapolis. The superstructure was built by the Toledo Bridge Company, Toledo, Ohio. The work was designed and construction supervised by Mr. Charles F. Loweth, M. W. S. E., of St. Paul, assisted in the field work by Mr. L. P. Wolff, city engineer.

I am indebted to Mr. Loweth for the above information.

A large amount of the trestle has been filled with rock to a little above low water. A description and discussion of the Prairie du Chien bridge, which is of the same type, will answer for this and will not be repeated here.

The bridge was rebuilt in 1891, and only two Howe trusses were built, one of 114 and one of 50-foot span.

21 WINONA.

C. & N. W. Ry.

Built under act of congress in 1886, and opened to traffic in 1871. The town of Winona was situated on an isolated gravel terrace only a few feet above high water, and, originally, during high stages, there was water behind the town. Opposite the town there was an island with a channel about 700 feet wide on the opposite side; the main channel, about 10,000 feet in width, was next to the town. The whole bottom between bluffs in this vicinity is quite low and subject to overflow to several feet in depth. The distance between bluffs is about 3 miles; the range between high and low water is about 17 feet; the low water slope is 0.7 feet per mile, with a current of about 3 miles per hour.

The original structure consisted, commencing on the Winona side, of about 2,100 feet of trestling on a 1 per cent grade, and crossing two streets on 40-foot spans. The first span was 80 feet long; then a draw of 360 feet with clear openings of 160 feet each; then two spans of 250 feet each, to the island; then about 1,000 feet of trestle across the island; then four spans of 160 feet each; then about 400 feet of trestle to an embankment 487 feet long; then 360 feet of trestle to an embankment. There was also two spans of 132½ feet and 420 feet of trestle over a slough about one-half mile back from the river, making the original high water opening about 3,988 feet in width.

SUBSTRUCTURE.—The piers under the four spans over the main river, except the one under the east end of the fourth span, are masonry resting on piles cut off at low water. The first pier came inside the water line, Nos. 2 and 4 were 8x30 feet on top, with a batter of ½ inch to the foot. They had triangular ends up-stream beginning about 8 feet below the top, with a slope on the nose of about 4 inches per foot. Pier No. 5 was 7 feet wide, but otherwise of the same dimensions. The draw pier was 33 feet in diameter on top; the guard piers were timber cribs with a row of piles running from them to each side of the draw pier. Pier No. 6 under the east end of the fourth span was of timber 11x37 feet and resting on a rock filled crib. The piers under the 160-foot

spans were of piles with the lower part surrounded by a rock-filled crib.

SUPERSTRUCTURE.—Spans 1, 3 and 4 were Howe trusses, as were also the 160-foot spans. The draw was of iron of the Post pattern and was turned by steam. In 1876 the trestle across the island was replaced by 7 spans of Howe truss 142½ feet long, resting on three bent pile piers. This change was found necessary on account of the scour around the old trestle occasioned by the lodgement of driftwood against it. The trestle beyond the 160-foot

Highway and Railway Bridges, Winona, Minn.

spans over the east channel was replaced about 1875 by nine 45-foot queen post trusses resting on pile piers, and about the same time the 360-foot of trestle over the slough was replaced by two Howe trusses of 142½ feet and one 45-foot span, all resting on pile piers. (Warren.)

Mr. Edw. C. Carter, Chief Engineer of the C. & N. W. Ry. writes that there were no queen post trusses in this structure. The Howe truss spans were replaced in 1886 by riveted lattices built by the Lassig Bridge & Iron Co. of Chicago. The draw span was replaced in the winter of 1898-99 by a pin connected span built by the Detroit Bridge & Iron Works. The original trestling outside the spans above mentioned has all been filled.

22 **WINONA.**

Highway Bridge.

This bridge was authorized by act of congress in 1890, and constructed in 1894. It is located only a very short distance below the C. & N. W. Ry. bridge. Owing to the location and the condition of traffic requirements at the Winona end, the approach

could not be built in line with the channel spans. The approach starts at the intersection of Second and Main streets, with an embankment running to the alley between Front and Second streets on a grade of 4.22 per cent, then on a viaduct approach to Front street and across the tracks of the C. & N. W. Ry. Here the viaduct makes a right-angle turn with a radius of 50 feet and extends up Front street parallel with the river for about 300 feet, where with another right-angle turn with the same radius it enters the main structure. The latter consists of first a span of 200 feet; then the channel span of 360 feet; then a span of 250 feet; these three spans forming cantilevers over the intermediate piers; then comes a span of 250 feet to the timber trestle approach of the Wisconsin side.

The main structure rests on masonry piers which extend about 5 feet above high water and rest on pile and grillage foundations; piers 7x39 feet under coping. On piers 2 and 3, which support the channel span, iron towers were erected to give the spans the necessary height. At piers 1 and 4 the spans, which are of peculiar shape, rest directly on the piers. The bottom chord of the fourth truss is only about 5 feet above high water, and the roadway crosses it in a half-deck manner between the trusses and on a grade of about 4.5 per cent. The grade of the roadway on the first and third spans is also on a grade of 4.5 per cent, while on the channel span it is level and is 55 feet above high water. Spans 1, 3 and 4 were erected by mean of false work, while the main channel was projected from each end and was self-supporting. The trusses are pin connected with solid riveted floor connections. The roadway is 18 feet wide with a sidewalk 5 feet wide on one side only. The viaduct approach on the Winona side is of pin connected deck trusses set 40 to 60 feet apart, each end being supported by two braced iron posts forming a bent. The top chord was extended one panel length and braced to the bottom chords, thus forming a cantilever. The space between their extremities was bridged by the regular floor stringers.*

28 WINONA.

C. B. & N. R. R.—Built 1890.

This bridge was authorized by an act of congress in 1888, and is located near the east end of the city; and consists, beginning on the Minnesota side, of first, a draw span 440 feet long between end pins with clear openings of 200 feet; then one 360-foot span

*The bridge was built for the city of Winona by the Chicago Bridge and Iron Company from designs by Horace E. Horton, president and engineer. Mr. George T. Baker, Davenport, Ia., was consulting engineer. See Engineering Record, August 25, 1894, for further particulars.

and two spans of 240 feet each. On the Minnesota side there was a trestle approach of 300 feet, and on the opposite side one of 1,200 feet.

The first pier was a rectangular one 6x26 feet under the coping, with a batter of ½ inch per foot; the draw pier was 30 feet in diameter with no batter; the other piers are 8x22 feet under the coping, with a batter of ½ inch. The up-stream end is triangular in plan with a slope of 1 to 2 on the nose. All rest on timber grillage at least 2 feet under low water, and from 2 to 6 feet thick; this is in turn supported on piles which were driven with a steam hammer. The masonry is of limestone quarried in the vicinity.

The 240-foot spans are 17 feet wide; the 360-foot span and the draw are 20 feet wide. The panel length throughout is 30 feet, except over the center of the draw. The superstructure is generally of steel. The draw is 25 feet high at the ends and 50 feet high at the center.*

24 LA CROSSE.

C. M. & St. P. Ry.

The river in this vicinity flows at the foot of a sand terrace from 10 to 40 feet above high water, on the left bank of which is situated the city of La Crosse, Wis. There is a similar terrace on the opposite side of the river and about 2 to 2½ miles away, the intervening bottoms being overflowed in high water to a considerable extent. The bluffs are some distance farther back. The river has a flat slope and a gentle current, and the channel is divided by numerous islands. The range between high and low water is about 16 feet.

A bridge at this place was authorized by Congress in 1868, but was not built. The act of 1872 authorized the Milwaukee & St. Paul Ry. Co. to build a bridge at any point they might select between the counties of LaCrosse, Wis., and Houston, Minn. Considerable discussion arose over the location of the bridge, but in 1875 the railroad company was allowed to proceed with the construction at their own site across the lower end of Minnesota island and about two miles above La Crosse. It was opened to traffic in December, 1876.

The original structure consisted of a draw span 310 feet long over the Black River, then about 4,000 feet of trestle over French Slough to the east channel, which was crossed by 5 spans of 148 feet each; then 650 feet of trestle across the island; then two spans of 164 feet each, one of 250 feet, and a draw 360 feet.; then nearly

*The bridge was built by the Union Bridge Company. D. M. Wheeler was chief engineer, with George S. Morison as consulting engineer. See Engineering News, October 17, 1891.

5,000 feet of trestle. The total length of bridge and trestle work was about 12,120 feet.

The pier of the draw over Black River is of masonry 27 feet in diameter and resting on piles, while the piers at the ends of the draw are of piles. The five spans over the east channel rested on six masonry piers, the two outside ones are 5 feet wide on top, the others 6 feet, and 22 feet long resting on a grillage of timber 2 feet below water which in turn rested on piles. The upstream ends of these piers have triangular starlings with a slope of 1 to 1 on the nose. The piers under the west or main channel, except the draw, are 6x21 feet on top, and with the exception of the east one had triangular starlings with a slope of 1 to 1 on the nose, to a point about 10 feet above low water; above that it had the same slope as the batter on the walls—½ inch per foot. The draw pier was 30 feet in diameter on top and 33 feet on the bottom. All rest on a grillage 2 feet thick, two feet below water and are supported on piles. The piles under the main channel spans are 40 feet long and were driven with a steam hammer.

SUPERSTRUCTURE.—The span over Black River was of iron with wooden floor beams; the spans over the east channel and the two short spans over the west channel were single intersection trusses and at that time were the only single intersection trusses over the river except at Louisiana. The draw and the 250-foot span were double intersection.*

All of the spans are still in use except the second short span over the west channel, which was destroyed in a collision in 1882, and was replaced with a Howe truss; this was again replaced with a single intersection truss in 1890, built by the railroad company.

The draw span over the Black River is to be renewed this year (1900).

The trestle across the island has been maintained and was rebuilt in 1886. All but about 270 feet of the west approach has been filled, a considerable part of the east approach over French Slough has also been filled, a portion of it being replaced by a span 163 feet long built in 1877. The total length of the bridge and trestle is at present a little over 5,000 feet.

25 LA CROSSE.

Highway.

This bridge is located directly opposite the city of La Crosse and some distance below the railroad bridge. It was built and is owned by the city of La Crosse. There are two islands in the

*All were of iron throughout, and were built by the American Bridge Company.

river opposite the city, the main channel being next to the town. There are pile bridges across the chutes back of the islands and the west one has a pontoon draw in it. This draw has never been operated, and probably never will be, as the chute has been entirely closed to navigation at the upper end by controlling works built by the Government.

The main bridge, commencing on the LaCrosse side, consists of a span of 116 feet; then a draw span 448 feet long over all with clear openings of 200 feet each; then a span of 302 feet and one of 120 feet. The short spans are Pratt trusses while the draw and the long fixed span are double intersection. The draw is operated by steam and is the only draw bridge on the river used exclusively for highway purposes and it is said to be the longest highway draw bridge in the country. The piers are masonry on pile foundations.*

26 PRAIRIE DU CHIEN.

C., M. & St. P. Ry.

The river at this locality flows at the foot of the high rocky bluffs on the west side. It is divided by a large island, which is below high water with nearly the same amount of water flowing in the channel on either side. The town is on a sand terrace, above overflow, forming the east bank of the river. The total width, including the island, is about 1¼ miles. The current is gentle and the range between high and low water about 22 feet. The act of 1866 authorized a bridge at this point, but it was not built. Before the building of the bridge freight cars were transferred by ferry. In the winter of 1868-69, after the river had frozen over, a pile trestle was erected across both channels of the river and trains ran over it till the ice broke up in the spring when the ferry was again resorted to. This method was continued until 1874, when the first pile and pontoon bridge was completed. It was legalized by act of congress the same year.

In the original structure the approaches and fixed portions across the channels and the island were pile trestles, the opening

*This bridge was built by the Clinton Bridge and Iron Works, Clinton, Ia.

or draw was filled with a deck barge or pontoon which supported the track, the latter being laid lengthwise with the barge. The barges were 408 feet long, about 30 feet beam and 6 feet deep. The first one had a stiffening truss extending the whole length of the boat and resting on its bottom, later ones have longitudinal bulkheads between the bottom and deck. In opening the draw one end of the boat is kept secured to the fixed bridge, the other is allowed to swing free with the current. It is closed by hauling the free end back to the pile structure by means of a small hoisting engine and a chain lying on the bottom of the river.

In the west channel the track on the pontoon was on blocking which was added to or removed, as the river fell or rose, to adjust the track to the level of that on the trestle. In the east channel small changes were provided for by short adjustable sections of track forming inclines, but to provide for greater changes two approaches were built, one for high and one for low water, the latter being submerged at high water. The total length of the bridge was about 7,000 feet. Sheer booms were built extending from each end of the draw opening on an inclined line up stream to the shore. The cost was about one-sixth of the estimated cost of the ordinary draw bridge at the time it was built.*

The original bridges were repaired from time to time as required, and in 1888 were practically rebuilt and in a slightly different position. In 1898 the bridge over the eastern or Prairie du Chien channel was again rebuilt and the location of this part of the bridge was changed to one lower down and directly opposite the portion over the west channel. The portion over the west or McGregor channel is being rebuilt this year. The pile portion of the bridge is of the ordinary kind of this class of structures. The pontoon recently built is 396 feet long and about 41 feet wide over all. It is 6.5 feet deep at the center and the deck has a crown of about 12 inches. It has flaring sides and the floor beams are 6x10 inches and the deck beams of the same size, the sheathing is 4 inches thick, and the deck is 3 inches in thickness. There are three longitudinal bulkheads, those on the sides being 16 inches thick, while the center one is 12 inches thick. The track is laid lengthwise of the boat and is supported on stringers resting on cross beams, made of channel irons, every 12 feet. These cross beams are held against the lateral and longitudinal motion at each end by four 8x10-inch posts which extend from the bottom of the boat, and are bolted to the side bulkheads, to about 20 feet above

*It was designed and constructed by Mr. John Lawler, who describes it in Trans. Am. Soc. C. E., Vol. XIII., page 67. See, also, Major Warren's report and report of chief of engineers, U. S. A., 1874, part 1, p. 681.

the deck. They are braced to the deck on the outside and are tied together longitudinally at their tops by a cap running the full length of the boat. The cross beams are free to move in a vertical direction between the posts and the elevation of the track for various stages of water is adjusted by blocking under them, the posts holding the track rigidly against horizontal movement. The stringers at the ends of the pontoon are 36 feet long and slight changes in stage are taken up in their length. A cross section of the pontoon is shown.

This bridge and the one at Read's Landing are of a distinctly different type from any others on the river, and as such, especially considered as permanent structures, deserve more than a passing mention.

We are led to believe from the description of the original structure that the principal consideration in deciding upon its use was one of first cost, and one conversant with the fate of the ordinary wooden railroad structures would have expected that it would have been replaced with a permanent structure of the ordinary character. The fact, however, that it is owned and operated by one of the most progressive roads in the west, that it has been maintained for 26 years, and that the third structure is being built at this place, would indicate the belief, of the officials of the road operating it, that it is an economical *permanent* structure.

The use of this class of structures is, of course, limited to a very few locations on the river, as it can only be used where there is a gentle current, and where the ice can be taken care of without much trouble. I have not been able to ascertain the cost of this bridge, but it would seem that the first cost should not exceed 20 per cent of that of an ordinary draw bridge at the same point. From the above history it is safe to say that the life of the structure is from 12 to 15 years, which is at least one-half as much as the ordinary so-called permanent structures built at the time of the original bridge. If the annual repairs amount to 5 per cent of the first cost, the total cost, at the end of the 26 years of its life, is still considerably less than that of the ordinary structure, omitting interest charges which at the time of building were very much more serious in amount than at present.

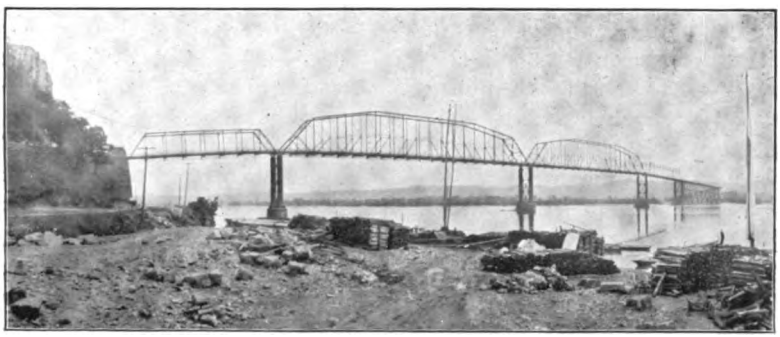
27 EAGLE POINT, DUBUQUE, IOWA.

Highway Bridge—Built in 1901.

This is a toll bridge and was built to enable the farmers in Grant County, Wisconsin, to do their trading in Dubuque. The project has been up at various times for many years past.

In 1894 a bill authorizing its construction passed both houses of Congress. Nothing was done, however, until the summer of 1899, when several different plans and estimates were made. Early in 1900 a new bill passed Congress. Contracts were let for sub and superstructure in April, 1900. Erection was started in July, 1900, and the bridge was opened for traffic in May, 1901.

The bridge has 4 steel spans: two 380-ft., one 200-ft., one 150-ft., and 1,860 feet of wooden trestle. The trusses are 20 feet apart, center to center, and are supported on steel cylinders filled with concrete which rest on masonry piers with concrete interior. The piers rise to a height of 2 feet above high water. The structure is 55 feet in the clear above extreme high water, or about 78 feet above ordinary low water. The masonry piers rest on a timber grillage supported on piles.



Eagle Point, Dubuque, Highway.

The bridge is owned by a stock company composed of Grant County, Wisconsin, farmers and Dubuque, Iowa, merchants. There are no bonds, and the stock is held mostly in very small amounts, the only three holdings of any size being $5,000, $3,000 and $2,000, respectively.

Before bids were asked for, an estimate of cost was prepared and given the directors. This estimate was a little less than $105,000. The total cost, excluding engineers' services, was $97,000. The city of Dubuque, in lieu of making an appropriation, built the west abutment and the west approach. The cost of this is not included in above figures.*

*This description of this lately built bridge was contributed by the engineers, Messrs. C. E. and R. M. Shankland.

28 DUBUQUE.

Illinois Central R. R.

This bridge, authorized by act of Congress in 1866, was built by the Duluth & Dunleith Bridge Co. and opened to travel in December, 1868. The river at this point flows at the foot of the high rocky bluffs on the Illinois shore. The low water width at the time the bridge was built was 1,700 feet and the high water width about 4,000 feet. The width has been greatly reduced by the encroachments of lumber yards and later by the bridge approaches as will be mentioned later. The current was comparatively slow and the range between high and low water was about 22 feet.

The approach to the bridge from the Iowa side was a high timber trestle 2,400 feet long, part of which was on a curve of about 1,400 feet radius. The first pier stood on what was originally an old levee. The first four spans were 225 feet long, center to center; then one span 250 feet long; then a draw span 360 feet long over all with clear openings of 160 feet; then a span 250 feet long resting on the Illinois abutment.—150 feet back of this abutment was the entrance to a tunnel 835 feet long which is on a curve of about 625 feet radius. The piers were masonry resting on a grillage placed on piles which were sawed off about 10 feet below water where the water was deep enough to permit it. The piers in the water were 24 feet long, 7 feet wide on top, with a batter of ½ inch per foot. About 12 feet below the bridge seat is a band course projecting about 4 inches and below that the up-stream end is finished as a starling with a slope of 4 inches to the foot on the nose.

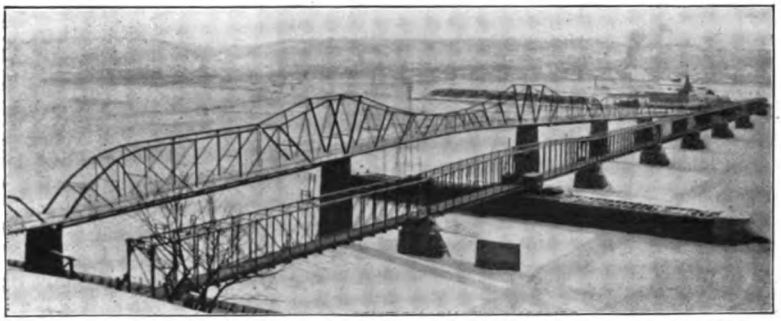
The horizontal section of this starling is an equi-lateral triangle. The lower end of the piers, below the band course, is semi-circular in plan. The piers are about 43 feet high, 50 feet long by 12 feet wide on the bottom. Rip rap was placed around them to prevent scour.

The superstructure was of iron built by the Keystone Bridge Co. The draw span was of wrought iron throughout. In the other spans the top chords were of wrought iron. The heads and feet of the posts in both the draw and fixed spans are of cast iron. The draw was operated by steam power. It is noticed that this bridge is one of the few built strictly in accordance with the provisions of the act authorizing it.

The draw span was replaced by a new one built by the Keystone Bridge Co. in 1893. The trestle approach has long since been replaced by an earthen embankment. Just when the filling was

done I have been unable to ascertain. In 1899, by authority of the Secretary of War, the first span, 225 feet long, on the Iowa side was replaced by a solid earth embankment. The high water area of discharge has, therefore, been reduced from one with an original width of 4,000 feet to 1,535 feet including the obstruction offered by the piers. What effect this reduced width has had on the height of high water above and below the bridge, the velocity of the current, and the scour of the bottom, presents an interesting problem, but it is one that I have been unable to investigate.

The three remaining 225-foot spans were rebuilt in 1899 and the two 250-foot spans are now being rebuilt. The new spans are being built by the American Bridge & Iron Works of Chicago, and have sloping top chords, the center panel only being hori-



Railway and Highlevel Highway, Dubuque, Ia.

zontal. Panels are about 25 feet long. The trusses are built for a single track and are designed for a loading of two 160-ton engines followed by a train load of 4,600 lbs. per foot. It will be noticed that these old spans were in use somewhat over thirty years.

29 DUBUQUE.

Highway.

A wagon bridge was authorized at this place in 1865 and the plans which contemplated a pontoon bridge with a draw opening of about 520 feet were approved. This bridge, however, was not built and nothing was done towards actual construction till the erection of the present bridge, completed in 1887. It was built by

the Dubuque Pontoon Bridge Company immediately below the railroad bridge and with the piers in the same line. The two structures are parallel and 75 feet apart, center to center and the draw of the railroad bridge swings under the main channel span.

The structure consists, beginning on the Illinois side, of first, two spans of 120 feet over the tracks of the C. B. & N. R. R.; then a span of 248.5 feet; then a span of about 363 feet which is the main channel span and is 54 feet above the high water of 1880; then a span of 248.5 feet and then 4 spans of 225 feet each. The channel span and two adjoining spans are cantilevers, while the remaining spans are through trusses. The four spans from the Iowa shore, as well as the span on the west of the channel are on a grade of 4 feet per 100, while the channel span has a grade in a vertical curve towards its center from each direction tangent to grade on side spans. The east spans have a grade of 4 feet per 100. The roadway is 18 feet wide in the clear and there are two sidewalks each 5 feet in width. The floor system is of wood; the channel span was erected without the use of false work.

The piers are of masonry carried up to the full height and are 7x24 feet on top except the channel piers, which are 7x25 feet. All have semi-circular ends and a batter all around of ½ inch per foot. The foundations are piles cut off 5 feet below low water, and surmounted by a timber grillage 2 feet thick. The channel piers are about 75 feet high and there are about 150 piles under each pier.*

80 SABULA.

C., M. & St. P. Ry.

Authorized by act of Congress in 1872, and built in 1881. The river in this locality is nearly straight for about three miles above the bridge and flows diagonally across the bottom. At Sabula it flows at the foot of the terrace on which the town is situated. The low water width is not over 1,300 feet, while the high water width, if not confined by the levees or railroad embankments, would be several miles. The range between high and low water is about 20 feet.

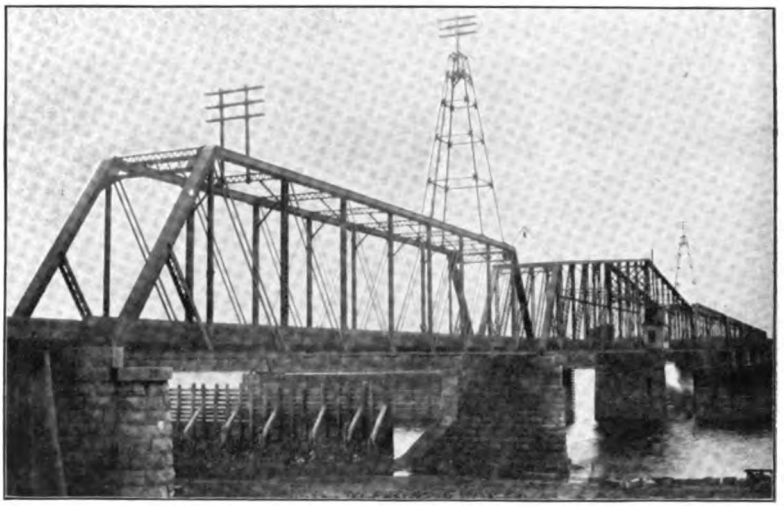
The structure, commencing on the west or Iowa side, consists of 82 feet of trestle approach to a span of 160 feet, then a draw 361 feet long over all with two clear openings of 160 feet each; then a span of 259 feet; then three spans of 217½ feet and one of 217 feet to the trestle approach on the island.

*The bridge, sub, and superstructure were designed and constructed by Horace E. Horton, M. W. S. E., and to him I am indebted for the above information.

This was the first highway bridge across the "Father of Waters" below St. Paul, and marked an epoch in bridge matters, in the fact that the lesser commercial interests of a wagon bridge justified the outlay.—H. E. H.

The piers are of masonry throughout and rest on pile foundations. The piles were cut off at the river bed and the masonry was built in open caissons. The stone is limestone from Anamosa, Ia. The guard piers are rock filled cribs.

It is a single track through bridge; the first span is a single intersection truss, the draw also is single intersection and with-



C. M. & St. P. Railway, Sabula,

out counters. The other spans are Whipple trusses. The depth of the fixed spans is 29 feet; the width for the 160 and 217-foot spans is 16 feet; for the 259-foot span 16 feet 3 inches, and for the draw 18 feet. Wrought iron was used for all of the fixed spans. The draw is 25 feet high at the ends and 40 feet at the center; mild steel was used in the bottom chords and it is operated by steam.

The floor system is worthy of attention; the ties are 6x8 inches and spaced 12 inches center to center, 6x8-inch guard rails shod with angle iron, placed on each side of each rail, while 10x10-inch guard rails are laid on each side of the track and 10 feet 4 inches apart.

The trestle approach over the island is now a double track structure 404 feet long, and was built in 1895-99. There is also a double track pile trestle 458 feet long over the slough back of the island.

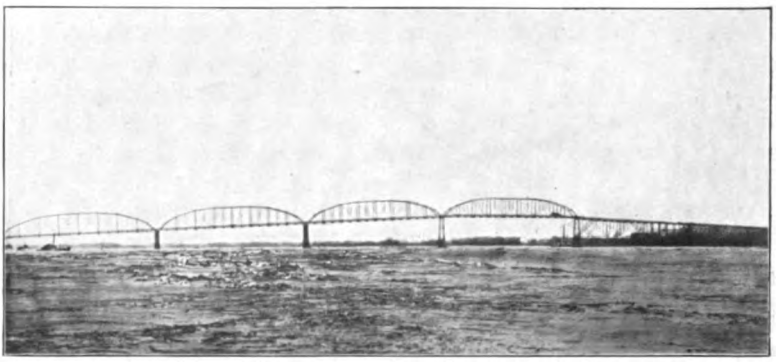
Mr. C. Shaler Smith was the engineer, and the superstructure was built by the Edgemoor Iron Company.

A full description of the draw, with details of construction and specifications, can be found in "The Sabula Draw by Graphics," by M. A. Howe.

31 LYONS AND FULTON.

Highway.

This highway bridge was built in 1890 by the Lyons and Fulton Bridge Company, and connects the town of Fulton on the Illinois shore with the town of Lyons (a part of Clinton) on the Iowa shore. Contracts for the work were entered into July 21st, 1890, and the bridge was opened for traffic with elaborate ceremonies July 4th, 1891. It is a toll bridge.



Lyons and Fulton, Highway.

At the site of the bridge, the river is the narrowest for many miles, and the entire flow of the river is at all times confined to one deep channel. The banks on either side are of rock. The river at ordinary stage of water is only about 1,540 feet in width. The towns are almost opposite each other, and the bridge is located so as to make the shortest distance practical between their business centers. The bridge crosses the river squarely and at the Iowa shore the approach is deflected up stream at an angle of 92 degrees with the axis of the bridge.

The structure with its approaches are substantially and permanently built. General dimensions are as follows: Beginning at the Illinois side there is a short earth-work approach not exceeding 200 feet in length. Then three spans of 330 ft. centers of piers; then a channel span 361 feet 6 inches centers of piers; then a deck span 201 feet 6 inches, centers of piers; then a combined pile and timber trestle, and earth embankment about 910 feet in length, and extending up stream along the shore to the foot of Main street in Lyons.

Beginning at the Illinois shores, the grade of roadway rises at the rate of 4.635 per cent; over the channel or 361 feet 6 inches span, the grade is level; thence over the 200-foot span and to the foot of trestle approach the grade descends at the rate of 5 per cent. This gives a clear head room under the channel span of 55 feet

above extreme high water level, allowing for the passage of boats at any stage of water. During ordinary stages of water, boats frequently pass under the span adjoining the channel span on the Illinois side.

SUBSTRUCTURE.—The substructures are all of first-class dimension stone masonry, excepting the pier on the Iowa shore; this is an iron cylinder pier and carries the shore end of the 201-foot deck span. The pier on the Illinois shore was founded upon natural bed rock and all others upon piling; the piles were sawed off at the river bottom and surmounted with timber grillage of such thickness as to bring them about one foot below low water level; the grillage for one of the channel piers being 16 feet in thickness. The top and bottom courses of the grillages were made solid and the intermediate courses, approximately three-quarters solid.

The two piers under the channel span are built up to about 5 feet above high water level, and the spans carried by steel towers. The stone is magnesian lime-stone from the well known quarries at Anamosa, Ia., about 70 miles from the bridge site.

Extending up-stream from the pier under the Iowa end of the channel span is a floating sheer boom 700 feet in length, for the purpose of facilitating the passage of log rafts under the channel opening. This boom is made up of several thicknesses of heavy planking, laid alternately in longitudinal and diagonal courses, securely drift bolted together and anchored at intervals to submerged cribs.

SUPERSTRUCTURE.—The superstructure is of steel, with the exception of a few members of iron. The 330 and 360-foot spans are of Pratt trusses, while the 200-foot deck span has horizontal bottom chords, and the top chords inclined parallel with the roadway grade. These is a roadway 18 feet wide in the clear between trusses and one sidewalk, outside of the down-stream truss, and 5 feet in width, with a substantial iron railing. The superstructure was proportioned generally in accordance with Cooper's specifications for highway bridges, and for a live load of 1,600 lbs. per lineal foot for the trusses of 200-foot spans, and 1,200 lbs. for the trusses of 330 and 360-foot spans, while the floor system and secondary members of trusses were proportioned for a live load of 80 lbs. per square foot over the roadway and two 5-foot sidewalks. Only one sidewalk was built, but provision was made for the other at any future time when desired.*

*The contract for the entire structure was awarded to the Chicago Bridge and Iron Company, H. E. Horton, M. W. S. E., president, on the basis of specifications for the structure prepared by the engineer. Detailed plans for superstructure were later prepared by the contractor, and checked and approved by the engineer. The metal work was all made by the Chicago Bridge and Iron Company.

32 CLINTON, IOWA.
C. & N. W. Ry.

This is one of the very early bridges, having been completed in 1865. The only authority for its construction was granted by the legislatures of Illinois and Iowa. It was legalized by being declared a post route in 1867.

At the site of the bridge the river is divided by Little Rock Island, the main channel being on the Iowa side. The portion over the east channel was built and operated sometime before the part over the west channel, the transfer over the latter being by ferry.

The main bank on the Iowa side is of rock, but not above high water; the island is stratified limestone a little above ordinary high water. The Illinois side is of alluvial formation and subject to overflow. The width of the valley submerged at high water was about 2 miles. The current was gentle, varying from 1¾ to 3 miles per hour between high and low water, and the range between high and low water was about 19 feet. As first built the structure over the Illinois channel consisted of 1,390 feet of trestle approach; then 7 spans of 200 feet each to an embankment on the island. The 200-foot spans were McCallum trusses and rested on masonry piers with concrete cores founded on piles. The structure over the Iowa channel built in 1864-65 consisted, beginning at the island end, of one span 174 feet and one 200 feet of wood, then a draw span 300 feet long over all and consisting of two Bollman trusses suspended by hog chains from a central tower, then a wooden span 128 feet long to the abutment. The trusses were about 6 feet above high water.

The guard pier was originally a rock-filled crib 400 feet long and 35 feet wide, on which the pivot pier was built. The pier at the east end of the draw was also a crib, while the pier at the west end was of masonry. The draw was the first one on the river to be operated by steam power. All the piers except the pivot pier have since been built of masonry resting on piles. The portion of the structure over the Illinois channel was entirely rebuilt in 1868-69. The first span from the east end was replaced with one of iron of the same length. The remaining length of 1,200 feet was replaced with eight spans of 150 feet each, all of iron, the piers rested on piles. The 200-foot span and the two adjoining 150-foot spans were built by the American Bridge Company of Chicago, and of the Post pattern; the next two by the Detroit Bridge Company; the next two by the Phoenix Bridge Company; the next two by the Keystone Bridge Company; the last six being Pratt trusses.

The Howe truss spans over the west channel were replaced in 1874 by iron spans of Whipple trusses built by the American Bridge Works. The draw span was replaced by a pin connected Pratt truss in 1887, built by the Detroit Bridge Company.

The reconstruction of this draw presented some novel features in bridge erection. Owing to the danger of placing false work in the river, the new span was erected up and down stream on the guard pier, leaving the old draw span intact for carrying the railroad traffic. When the new span was completed it was supported by the old span and swung into position in line with the track, the old one then being over the guard pier where it was taken down.

The east 200-foot span over the east channel was replaced by a Whipple truss in 1880, built by Rust & Coolidge. In 1882-85 the eight 150-foot spans over the east channel were replaced by pin connected Pratt trusses built by the Lassig Bridge & Iron Works. In 1898 the 200-foot Whipple truss over the east channel and the three spans over the west channel were replaced by Pratt trusses built by the Detroit Bridge Company, the Railroad Company building the false work. The old masonry was used throughout. Some very rapid work was done in the erection of these last spans, the four old trusses being taken down and the new ones erected between January 19 and February 26. This time does not, however, include time erecting false work. The new spans are 30 feet high and 19 feet 3 inches wide center to center.*

33 CLINTON.

Highway—Built 1891.

This structure starting from the Illinois side crosses the east channel below the railroad bridge just described, and nearly parallel with it. On the island it turns up-stream and crosses the C. & N. W. Ry. tracks, and thence across the main or west channel up-stream from the railroad bridge and at an angle with it The structure consisted, beginning with a trestle approach on the Illinois side, of a span 220 feet long; one 210 feet and six of 150 feet each, across the east channel; then 250 feet of iron trestle to the first river span; then a span of 210 feet, a channel span of 420 feet, which is 55 feet above high water in the clear; then a span of 210 feet and one of 290 feet to the approach on the Iowa across the island to a 290-foot span crossing the railroad tracks side.

The piers in the east channel are steel cylinders filled with concrete, except the first one, which is masonry. The piers in the

*See Railroad Gazette, May 20, 1898, Vol. XXX., page 355.

main or west channel are of stone from Anamosa, Ia., and are carried above high water and the two channel piers are surmounted by iron bents, supporting the superstructure. The bottom chords rest directly on the two side piers. All rest on pile foundations, which were cut off near the bottom of the river and surmounted by a timber grillage. One of the piers was placed in 46 feet of water, the piles cut off about 8 feet from the bottom and a grillage used to bring it up to about 3 feet below low water. The character and arrangement of the superstructure is shown in the profile. The roadway is 18 feet wide with a sidewalk of 4 feet, both inside the trusses.

The west pier of the main span is on line with the draw pier of the railroad bridge and a sheer boom connects them and extends for some distance up-stream from the highway bridge, the west draw opening is thus cut off entirely from use.*

34 ROCK ISLAND.

Railway and Highway.

The original bridge at this point was located a little less than one-half mile above the present bridge, and was built to connect the Chicago & Rock Island Railroad with the Mississippi and Missouri Railroad in Iowa, the latter extending from Davenport to Iowa City, a distance of about fifty-five miles.

The only authority for its construction seems to have been granted by the legislature of Illinois in 1853. The bridge was completed in 1856. The route of the approach to the bridge extended over the island of Rock Island, which was then, as now, owned by the Government as a military reservation. The United States district attorney applied for an injunction to prevent the building of the bridge and approach over the property owned by the Government, but it was denied by the United States Supreme Court, and the bridge was completed. It was probably the worst obstruction to navigation of all the bridges built over the river, but the owners successfully resisted all efforts to have it removed until the completion of a new bridge.

The piers as first built were very weak structures, mostly timber cribs filled with stone, and were not of sufficient weight and strength to withstand the impact of ice, though they were founded on bed rock. They were replaced by stone piers built in 1859.

The structure consisted of 5 spans of Howe truss 250 feet long, and a draw span of about 270 feet with clear openings of 112 and

*The bridge belongs to the Clinton Bridge Company, and toll is charged. It was built by the Clinton Bridge and Iron Works. George T. Baker was the chief engineer.

117 feet. It was 20 feet above ordinary high water. The trusses had wooden arches bolted to the outside of them. The stone piers were 35 feet by 7 feet wide on top and 53 feet long by 11 feet wide on the bottom. The draw pier was 35 feet in diameter on top and a guard pier of rock filled crib work 355 feet long and 40 feet wide extending above and below it. The piers were not built parallel with the current and were badly located, and in consequence serious delays and accidents occurred to vessels.

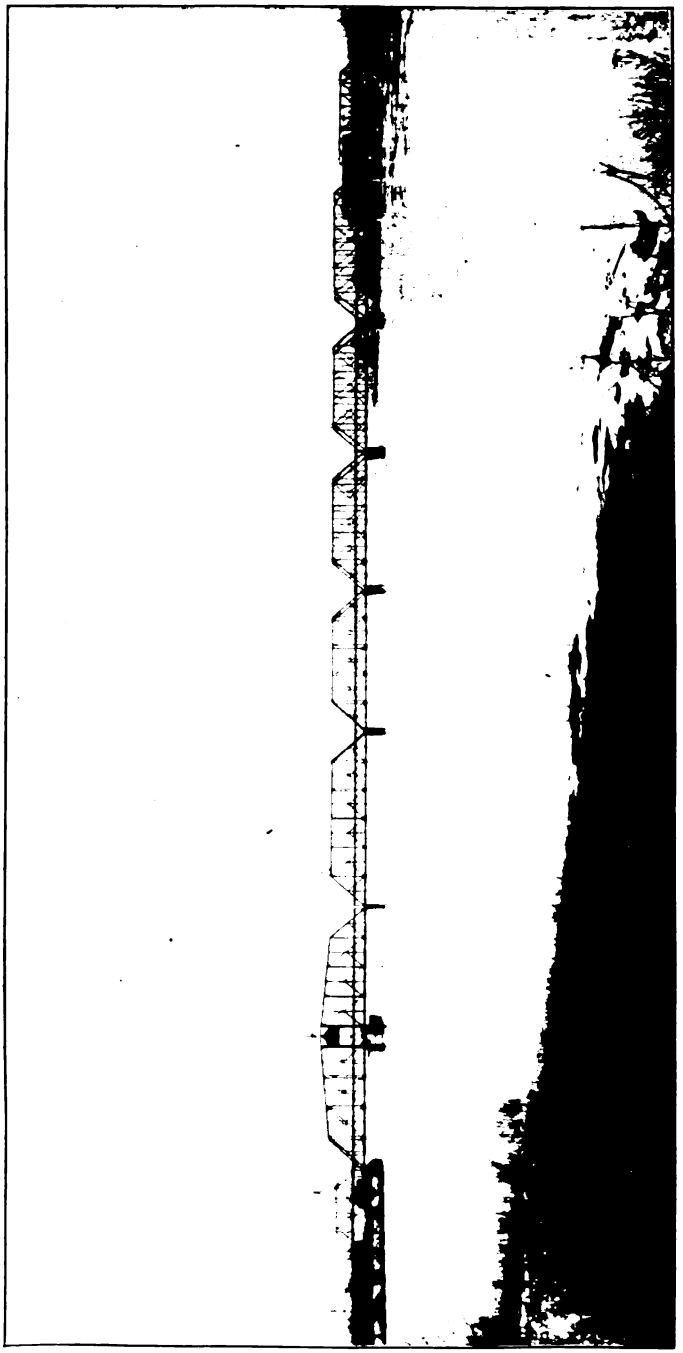
In May, 1856, the first span east of the draw was destroyed by fire communicated by the Steamer Effie Afton, which collided with one of the piers and burned. In the suit for damages that followed Abraham Lincoln appeared as counsel for the Railroad Company.

In 1868 the first pier on the Iowa side was shoved bodily down stream for 20 or 30 feet by the ice, and in April of the same year the draw span was blown over in a wind storm. In the debates of Congress of 1866 Mr. Washburn made the statement that, up to that time, 64 steamboats had been wrecked or damaged on this bridge.

A new bridge was authorized by Congress in 1866, and on its completion in 1872 the old one was torn away. The new bridge was located in the position occupied by the present structure and was built by the Government, partly at the expense of the Railroad Company. During the preliminary work connected with the location of the bridge, its dimensions, etc., various plans were suggested and estimates made of the cost. A notable incident in connection with these estimates was that the engineer who made the estimate of the cost of a structure for a single track railroad with a roadway 17 feet wide below it, afterwards, when a proposition was submitted to him for an estimate on a structure with a 26 foot roadway and a double track railroad, saw no reason for changing his original estimate.

The construction of the bridge was first placed in the hands of the Ordinance Department, but was transferred to the Engineer Department in 1869 and placed under the charge of Major G. K. Warren, who made the plans and retained charge till 1870 when he was superseded by Col. Macomb.

The bridge is situated at the foot of Rock Island, the greater portion of the island being above high water. The width of the river between the Iowa shore and the Island was at that time about 1,650 feet. The channel on the Illinois side of the Island is merely the tail race for the water power at the head of the Island. The location is at the lower end of what is known as the Rock Island Rapids, and the rise between high and low water is about



The New Rock Island Railway and Highway Bridge

16 feet, though this may be increased by ice gorges to 21 feet. The maximum velocity of the current was about 4½ miles per hour.

The bridge was approached, from the Davenport side, by the railroad on a curve of 1,700 feet radius over a span of 196 feet at the intersection of Second and Front streets to the main bridge.

The main bridge had one span of 260 feet, then three of 220 feet center to center of piers, then one of 260.5 feet, and then the draw of 370 feet over all, with two clear openings of 160 feet each. A span of 80 feet then carried the railroad track to the embankment on the island. This embankment extended on a grade of 30 feet to the mile across the island. Then comes a span of 80 feet over the Island wagon road; then the embankment continued 700 feet further to the abutment of the slough bridge. The latter had four spans of 150 feet each.

The piers were built 32 feet long and 7 feet wide on top, the up-stream end had a slope of one to one. The horizontal section of this starling was formed by describing arcs of circles whose radii equal the width of the pier at the section and with centers at the opposite sides. The draw pier was 36½ feet in diameter under the coping with a batter of ½ inch per foot. The upper and lower end of the guard pier was of masonry with the space between the masonry ends and the circular pier filled with rock cribs.

The piers in the Iowa channel are all founded on rock, which lies at a depth of 10 feet to 14 feet below low water. Their construction was let by contract, but owing to inefficient methods employed by the contractor, the contract was terminated and the work finished by the Government by hired labor. The piers in the Illinois channel were of masonry resting on piles.

SUPERSTRUCTURE.—The bridge was of wrought iron throughout. The upper chords were of rolled channels and the lower chord of eye-bars in the fixed spans. In the draw span both upper and lower chords were of channels. The draw was operated by hydraulic power, the pumps being driven by steam. The posts were of Phoenix pattern. The railroad track was above the wagon roadway and was attached to the posts. The head room between the two roadways was 12 feet, and both were constructed of wood. The part of the bridge over the Illinois channel, across the island and the approaches were built by the railroad company. The whole was finished and opened to the public in October, 1872. The wooden floor system was replaced with iron in 1891.

The bridge over the main river was built by the Baltimore Bridge Company, C. Shaler Smith, Chief Engineer.

A new superstructure was authorized by Congress in 1894, and $490,000 was appropriated for the purpose. The bridge was built by the United States Government and by agreement 60 per cent of the cost was charged to the C. R. I. & P. Ry. The new spans rest on the old piers and are the same length as the old, all are 29 feet wide center to center of trusses. The draw span is 62 feet high at the center and 50 feet at the ends. The long spans are 50 feet high at the centers. All carry a roadway at the lower chord line with a railroad on the upper deck. The roadway is about 26 feet wide in the clear and carries two lines of rails for street cars. There are two sidewalks each 6 feet wide outside the trusses. The roadway has a clear height of 12 feet 6 inches. The railroad deck is double track; the floor beams are attached to the posts and carry a solid floor of trough sections. The trusses were designed to carry a live load of 100 lbs. per square foot on the roadway and two 125-ton locomotives followed by a train of 4,000 lbs. per foot on the railroad. The wind pressure was assumed at 650 lbs. per foot of bridge.

It was decided to use the old piers, but as the new bridge is considerably wider than the old, it was necessary to lengthen the piers on top. To do this the coping and upper portion was removed to a point where by interrupting the batter of the old cut water and extending it upward and vertically, the necessary length was obtained. The old piers were of Joliet limestone; the new work is faced with Kettle River sandstone with backing of Anamosa limestone, all laid in Portland Cement.

The new turning machinery has some novel features, among them being the connection between the rack on the drum and the operating shaft by means of sprocket wheels and chains with 12-inch pitch instead of the usual gearing. It is operated by an electric motor, power being furnished by the street railway company.

In erecting the bridge the railroad was kept open for traffic except for a short time after the false work and part of the iron work for the new draw had been destroyed by the movement of the ice in the river.*

35 ROCK ISLAND.

Railway.

This is a railroad bridge built for the Davenport, Rock Island

*A detailed description of this accident and the novel means adopted for erecting a temporary bridge, also a more detailed description of the bridge, can be found in a paper by Mr. Ralph Modieski in the Journal of the Western Society of Engineers, April, 1897, Vol. II., page 135.

The bridge was erected under the direction of Col. A. R. Buffington, Ordnance Department, U. S A., with Ralph Modjeski, M. Am. Soc. C. E., chief engineer. The Phoenix Bridge Company were the general contractors for the new work.

& North Eastern Ry., a belt line connecting Davenport, Rock Island and Moline, and is located about 1½ miles below the C. R. I. & P. Ry. bridge and near the lower limits of the cities of Rock Island and Davenport, and is the last bridge to be completed over the river up to the present time (1900). The main channel of the river is about 2,200 feet wide, from the Rock Island side to an island about 300 feet in width, at the point crossed by the bridge and is below high water. There is a slough about 600 feet wide on the west side of the Island.

Davenport and Rock Island Railway.

The bridge was authorized by act of congress in 1885, but nothing was done towards actual construction till 1895. Work on the portions of the substructure was begun in 1896, but not till 1897 was the construction pushed continuously. It was opened to traffic in 1899.

The structure consists, commencing on the Illinois side, of a viaduct approach over existing tracks and a street, and a short embankment to the main bridge, then 3 spans each 200 feet long; then a draw span 442 feet long over all; then one span of 361 feet; three spans of 300 feet each; one 56-foot girder to a pile trestle 380 feet long across the island; then 7 deck plate girders across the slough to a pile trestle approach. The Rock Island approach is on an 8 degree curve and the three 200-foot spans are on a 7 and 6 degree 30 minute curve, while the draw and remainder of the

main bridge is straight. The trestle across the island and part of the spans over the slough are on a 6 degree curve. The curves are all in the same direction and give the bridge as a whole the shape of a crescent. The piers for the main bridge are built of limestone from Stone City, Ia., except the starlings, which were faced with granite. The main piers are 7 feet 6 inches wide and 31 feet long under the coping and have a batter of ½ inch to the foot, and have starlings on the up-stream ends extending to high water with a batter of 9 inches to the foot. The lower ends of the piers are semi-circular. The draw pier is 32 feet in diameter under the coping. The up-stream guard pier is a rock filled crib resting on a bed of rip rap and the up-stream end is protected with old iron rails, the spaces between them being filled with cement mortar. The down-stream guard pier is a pile and timber structure. The piers under the slough spans are steel cylinders filled with piles and concrete. The abutment and first three piers from the Rock Island side rest on solid rock. The other piers are on piles cut off at the river bed. The foundations for the three next the island were placed in open coffer dams, concrete being placed around and over the piles. The three mid-channel piers rest on a timber grillage on the piles.

The superstructure is a single track structure and is of rolled steel throughout, except some minor details. The trusses have inclined top chords except the 200-foot spans which are horizontal. The latter are 23 feet wide, while the former are 18 feet 6 inches wide, center to center of trusses. The draw span is operated by electric motor and all the signal lights about the bridge are electric lights.*

86 MUSCATINE, IOWA.

Highway.

In this vicinity the river flows at the foot of the bluffs on the Iowa side on which the town is situated, and is all confined to one channel. The bridge is a high bridge and used for highway purposes only. Beginning on the Illinois side the structure consists of 260 feet of trestle approach; then four spans of 160 feet each, of which two rest on cylindrical piers; one span of 240 feet, one 360 feet, one 442 feet, one 360 feet, two of 160 feet each, three girders 45, 58 and 55 feet in length respectively and about 120 feet of iron trestle work.

*The engineer was Mr. C. F. Loweth. The superstructure was built by the Phoenix Bridge Company. Mr. Charles Stone was contractor for the main piers, while the slough piers were constructed by the railroad company by day labor. Engr. News, January 11, 1900, contains very full details of the superstructure.

The original plans contemplated masonry piers throughout, but to save expense the first three piers were made of iron cylinders filled with concrete and resting on piles which extend up into the cylinders for some distance. They are respectively 5 feet 5 feet 6 inches and 6 feet in diameter. The remaining piers are all of masonry and have pile foundations. The piles were cut off at the

Muscatine, Iowa, Highway.

bed of the river and were surmounted by a grillage of 12x12 timbers of sufficient thickness to bring it within one foot of low water except under the two main channel piers, which are 3 feet below low water. The grillage varied from 4 feet to 16 feet in depth. It was caissoned on top, towed to position and sunk into position by weighting with stone. The masonry is of limestone from Cedar Valley, Iowa. Most of the piers are of masonry extending a short distance above high water only, and are surmounted by iron bents which support the superstructure. A few of the piers, as shown in the profile, are of masonry extending to the superstructure.

The main channel spans are of the cantilever type, while the others are of the ordinary single intersection. The roadway is 18 feet wide with one sidewalk 4 feet wide on the down stream side.*

In the winter of 1898-99 the ice attained a very great thickness along the Illinois shore and in the breakup it exerted sufficient force to move the third cylindrical pier (from the Illinois shore) a distance great enough to let the river end of the second span drop down. Contracts have been let for replacing the cylindrical piers with masonry.

*Mr. George F. Baker was chief engineer. The Milwaukee Bridge and Iron Works were the contractors. The bridge is owned by the Muscatine Bridge Company, and is a toll bridge.

37 KEITHSBURG.

Railway.

This bridge was authorized by act of Congress April 26, 1882, and built for the Iowa Central Railroad Company in 1886. The river at this point flows at the foot of a low sand terrace which is above high water, on the Illinois side. The banks on the Iowa side are low and the bottom extending to the Iowa bluffs is subject to overflow. The river is divided by a large island, the channel on the Illinois side being the main one. The low water width is about 2,000 feet, while the high water width extends to the Iowa bluffs—some five miles. The structure as built, beginning on the Illinois side, consisted of a trestle approach of 800 feet, then draw span 360 feet long over all; then a span of 255 feet, then 7 spans of 250 feet each, and a trestle of 900 feet. The masonry piers are 6 feet 6 inches by 26 feet under the coping and rest on a pile foundation, which, with the exception of the draw pier, extends above the river and to within about 3 feet of low water. In order to stiffen the pier foundations an open crib was sunk around them and filled with rip rap. The piers have triangular ends extending to 6 feet below the coping.*

38 BURLINGTON.

C. B. & Q. R. R.

This bridge is one of those authorized by the act of Congress in 1866, and it was opened to traffic in July, 1868. It is located near the lower limits of the city of Burlington, Iowa. The river at this point and for some considerable distance above and below flows along the bluffs, on the Iowa shore, which are of rocky formation. The slope of the river at low water was only about 0.27 feet per mile, and in consequence the current was very gentle. The low water width was about 2,100 feet, with a high water width extending from bluff to bluff—about 5 miles. The range between high and low water was about 20 feet.

The structure, as originally built, consisted of an earth embankment on the Iowa side, which was on a curve of about 720 feet radius. Then from an abutment, a span of 175 feet, with a second one of 200 feet. The curve on the approach extended over

*The superstructure is of the Phoenix pattern, and was built by the Phoenix Bridge Company, who were also general contractors for the entire structure. Mr. George A. Lederle was the engineer in charge.

The work of the erection of the superstructure was very much delayed by accidents, one of which was the fall of the traveler, used in erecting the second span, and in which three men were killed and five injured. A derrick boat partly loaded with iron was sunk in a gale of wind, and, in addition, the ice carried away the false work for four spans. (Engr. News, December 19, 1885.)

these first two spans and in consequence they were made wider than the remainder of the bridge. Then a draw span of 360 feet over all with clear openings of 160 feet; then 6 spans of 250 feet each to a trestle approach.

The piers are of masonry resting generally on piles. Piers No. 1 and No. 2 are on rock and were put in with coffer dams. Pier No. 3 had about 170 piles under it; pier No. 4, the draw, about 333. The piles under these piers reached to the rock; pier No. 5 had 174 piles and the remainder from 133 to 140; their lengths averaged from 22 to 32 feet, and they were driven with a drop hammer. The sand was washed out from among the piles after they had been cut off as near the bottom of the river as possible and the space thus formed filled with loose rock. The masonry was laid in floating caissons with bottoms, which formed the grillage, two feet thick and sunk by the weight of the masonry. The sides of the caissons were afterwards removed. The stone came from Lamont, Ill., Point Pleasant, Ia., and LeClaire, Ill., and was laid in Utica cement mortar. The draw pier is 34 feet in diameter at the top and 44 feet at the bottom. The piers at each end of the draw span were 9 feet wide on the top and 19 feet at the bottom. The others were 7 x 23 feet on top, the rectangular part extending down about 10 feet with a batter of 1 inch per foot, where the length increased to 36 feet 10 inches. The sides and down stream end, the latter semi-circular in plan, continued with the same batter. The up-stream end was formed, in plan, by arcs of circles with a radius equal to the thickness of the wall, and with centers at the opposite sides. The nose has a batter of 6 inches per foot.

Many interesting incidents of the construction of the substructure of the original bridge are given by Mr. C. H. Hudson, who was Resident Engineer, in The Journal of Associated Engineering Societies, Vol. 13, p. 257, 1894.

The superstructure was built by the Detroit Bridge & Iron Co. The fixed spans were quadrangular trusses with cast iron top chords, Phoenix posts and bottom chords of open links. Both chords of the draw were of channels and were carried on a wrought-iron drum. This was the first iron bridge completed on the river, though its completion antedates by a few months only the Dubuque and Quincy bridges which were under construction at the same time. In 1887 the first span (175 feet) was removed and replaced by an embankment, the trestle approach to the Illinois side had been filled up some time previous. The entire superstructure was replaced in 1890-93 by a double track structure, with spans of the same length, except the western one

(the second one in the original structure) which was replaced by two spans about 71 feet long. The old piers were used, the upper portion only being remodeled to provide for the additional width required.*

39 FORT MADISON.

Railway and Highway.

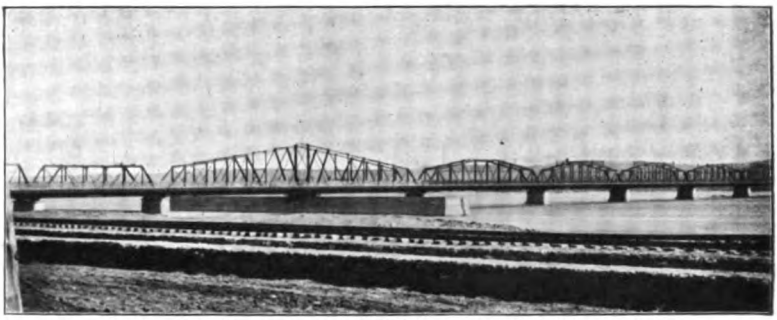
A charter for a bridge at this place was obtained in 1872 for a proposed railroad from Peoria, Ill. The road, however, was not built and nothing was done towards the construction of the bridge till the extension of the "Santa Fe" system to Chicago was determined on in 1887, when it was surrendered to that company. It was stipulated in transferring the charter that the structure to be built should be a combined railroad and wagon bridge.

The river valley at this point is about two miles wide with rather low banks on either side. The low water width was about 1,350 feet, with a high water width of at least 4,000 feet. No rock was found in the river bed, but on the Iowa side blue clay was found and also formed the bed of the river to about the position occupied by pier No. 4. Beyond that it seems to dip rapidly and is covered with sand.

The structure consists, commencing on the Iowa side, first, of an abutment, then two 150-foot spans, then a draw span 400.5 feet long over all, then a span 274.5 feet long, then four spans 237.5 feet long, center to center of piers, then a trestle approach. The bridge rests on masonry piers throughout, built of stone from Stone City, Iowa. The backing of masonry in the draw pier is concrete. The abutment on the Iowa side rests on piles driven into the clay and cut off about 8 feet below water and about 4 feet below the surface of the clay. Piers Nos. 2, 3 and 4 are on piles cut off at the bottom of the river, which at these points is of blue clay and not likely to scour. The piles are surmounted by a timber grillage 4 feet 3 inches in thickness, which also formed the bottom of open caissons used in laying up the masonry. The draw pier is circular and the caisson was built in the same form. The grillage was carefully brought to a circle at its edge and to this was fastened vertical plank, which were banded on the outside in the same manner as large water tanks; the inside was strengthened with circular braces. The caissons

*The details of this work were very fully given in a paper by Mr. George S. Morison, who was the engineer, in the Journal of the Associated Engineering Societies, Vol. 12, page 599, 1893. The chief engineer of the original bridge was Max Hjortsberg. The superstructure of the new bridge was manufactured by the New Jersey Steel and Iron Company, and erected by hired labor under the charge of the resident engineer, Mr. E. P. Butts, till his unfortunate death, and afterwards by Mr. George A. Lederlee.

were towed to position and sunk by loading them with concrete on which the masonry rests. Piers Nos. 5 and 6 were sunk through the sand to the blue clay by the use of pneumatic caissons, while piers Nos. 7, 8, 9 and 10 rest on piles cut off about 12 feet below the bottom of the river by means of bottomless cribs. These cribs were built with double walls and the necessary weight given them by filling between the walls with concrete. They were sunk by their own weight and by removing the sand from the



Ft. Madison, Iowa, Railway.

area covered by their interior by the use of centrifugal pumps. After the cribs had reached the desired depth piles were driven about 25 feet into the sand below the bottom of the cribs and cut off level and surmounted by a timber grillage of the same thickness used in the other piers. The guard pier for the draw was a pile and timber structure.

The superstructure was built by the Union Bridge Co. The trusses are for single track and are single intersection, with long panels and inclined top chords. They are designed for a loading of two 86-ton engines followed by a train load of 3,000 lbs. to the foot; this loading was increased 25 per cent. for the flooring system. No increase was allowed for the loading of the wagon road, as it was thought impossible to bring a concentrated load on the wagon way at the same time the bridge was occupied by a train; the unit stresses allowed in the members were, however, reduced 10 per cent to allow for this increased load. The wagon road is 8 feet wide and is carried on brackets outside the trusses on each side.*

40 KEOKUK.

Railway and Highway.

This was built under act of Congress of 1866 and completed in

*Mr. O. Chanute was chief engineer, with Mr. W. W. Curtiss, resident engineer. (Engr. News, June 2 and 9, 1888.)

1871. The bridge is located at the foot of the Des Moines Rapids, and the bed of the river is rock. The low water width was, before the construction of the bridge, about 2,600 feet, with a high water width of about 5,500 feet. The slope of the river over the rapids above the bridge averages about 2.2 feet per mile, while in the lower part it is as much as 3 feet per mile. Immediately below the bridge the slope is much less, and the bed of the river is of rock for one mile below the bridge. The average range between high and low water is about 21 feet.

The bridge consisted of 11 spans of the following lengths, measuring from center to center of piers, and commencing on the Iowa side: First a draw span 380 feet long over all, then come spans of 258 feet, 256.3 feet, 162.6 feet, 162.5 feet, 163 feet, 151.5 feet, 164.9 feet, 165.1 feet, 164.3 feet, and 165 feet, making the total length of the bridge 2,190 feet.

The Illinois approach is an embankment, about 500 feet of which is in the former high water channel way. There was a span of 95 feet, which has been lengthened 45 feet over a slough some distance back from the Illinois shore, but with this exception both the high and low water width of discharge was confined to the width of the bridge as given above, instead of an original width of 5,500 feet and 2,600 feet respectively. As the bed of the river is rock it cannot scour, and the height of the water above the bridge must necessarily be increased sufficiently to give an additional velocity sufficient to carry the volume of water.

The Iowa approach was on a masonry structure and on a curve of about 850 feet radius, the abutment being about 160 feet out from the shore line. The bridge is on a straight line and is about 1,000 feet only below the lower lock of the Des Moines Rapids Canal, which was being constructed at the time the bridge was built. The draw pier is on a line with the eastern or river bank of the canal. The piers were built of limestone quarried in the immediate neighborhood, and rest on the rock, though some of them have a timber grillage intervening.

The draw pier was circular and was provided with slots in which the ends of floats, extending from the pier to the guard piers, rose and fell with the water. These floats have since been replaced with a fixed timber structure. The guard piers were detached cribs filled with rock. The piers were built with their axes at an angle of 72 deg. 45 min. with the axis of the bridge, so that the openings between them is not represented by the length of the spans, neither are the piers parallel with the current, thus further reducing the available space. On a trial resulting from

the sinking of the "War Eagle" and destruction of a span of the bridge, the legality of the bridge was affirmed in a U. S. Court. Also Report of Secy. War Robt. T. Lincoln, who reports to Congress on legality of the bridge sometime about 1882-83. This available space was only 125 feet in the west draw after the completion of the bridge.

SUPERSTRUCTURE.—The bridge was built by the Keystone Bridge Co., of Pittsburgh. It was of wrought iron throughout, except the head and foot of posts and angle plates of upper chords, which were of cast iron. The trusses are 21 feet high, except the draw, which is about 35 feet high in the center and 21 feet at the ends. The trusses are 23 feet wide from out to out with a sidewalk 5½ feet wide on each side. The floor beams were of two channels trussed and extended outside the trusses to support the sidewalk. The bridge was built for rail and wagon traffic on the same floor, and the whole was planked over at the same level. The draw was turned by steam.

The bridge was constructed without supervision of any officer of the Government and was a marked violation of the provisions of the act authorizing its construction, inasmuch as the piers were not placed parallel with the current, and it did not have two spans adjoining the draw, 250 feet long. The latter provision was, however, impracticable on account of the location of the canal.

In 1883 the eastern long span, or No. 3 from the Iowa end, was rebuilt, it having been knocked down by the Steamer "War Eagle" in the year 1881. The old material was used as far as possible, and the same form of truss was used. The circumstances of the accident to the "War Eagle" are given by Mr. M. Meigs as follows:

"The 'War Eagle,' a side-wheel boat and one of the largest "class employed on the upper Mississippi River, came down over "the rapids at a very high stage of water, being loaded down to "about a 6-foot draft. The current was so rapid that the pilot "was afraid of the east draw opening and attempted to pass "through the opening next the Iowa shore by stopping the boat "and floating her through. Unfortunately the bow of the boat "was caught in the eddy above the bridgealong the Iowa shore, "while the stern projected into the strong current outside the lock. "The result of these two forces was to turn the boat broadside to "the bridge with her stern pointing towards the Illinois shore. "The pilot backed the wheel on the lower side and attempted to "straighten her up, but before he could do so the bow struck one "of the piers and she passed through the raft span broadside-to,

"pushing the span off its bearings and allowing it to drop into the "river. The falling bridge razed the guards and wheel from the "lower side of the boat and she floated over the submerged span "and passed on through in a sinking condition. The pilot had the "nerve to stay in the pilot house, and, assisted by the engineers, "managed with one wheel to work the boat to shore some distance "below the bridge on the Iowa shore, where she sank across the "submerged railroad tracks. She was afterward raised and re-"paired, running for many years on the Upper Mississippi."

The original trusses are still in use and it is the only one of the early iron bridges built under the act of 1866, except the St. Louis bridge, that has not been rebuilt. It has not yet, however, quite reached the age of the Dubuque bridge, the last spans of which are being rebuilt this year. One of the piers is about 6 inches out of line, having been slid on the smooth rock foundation during an ice gorge.

41 QUINCY, ILL.

C. B. & Q. R. R.—Built 1868.

The river in this vicinity crosses the valley to the bluffs on the Illinois side at the town of Quincy, and follows them for about a mile and then flows through the valley with low ground on either side for several miles. The slope at the time the bridge was built was about 0.4 foot per mile, the current gentle and the location of the channel fairly permanent. The low water width was about 3,000 feet and the high water width was several miles, extending from bluff to bluff. The range between high and low water was about 20 feet.

The bridge is about a mile above the old steamboat landing at Quincy, and was built by the Quincy Railroad Bridge Co., under the authority of the act of Congress of 1866, and was opened to travel in November, 1868.

The approach to the bridge from the Illinois side was across Quincy bay, thence across the lower end of an island. Beginning on the Illinois side the original structure consisted first of the bridge of six spans over the bay, then a span of 82 feet, then 85 feet, then a draw span 190 feet long with 80 feet clear openings, then a span of 85 feet and one of 82.5 feet to an embankment 285 feet long, then 400 feet of trestling and an embankment of 670 feet to the main bridge. The main structure consisted of 17 spans as follows:—Beginning on the Illinois side, first a span of 200 feet, then eleven spans of 157 feet each, then two spans of 200 feet, then one of 250 feet to the draw, which was 362 feet long with clear openings of 160 feet, and last a span of 250 feet, which

was partly over land. The length of the bridge over the main river was 3,185 feet and over the bay 525 feet, while the total length over the trestles and embankment was 5,068 feet from abutment to abutment. The bridges were on a straight line, while the portion across the island was on a 4 degree curve.

The bridge throughout rested on masonry piers built of stone from Keokuk and Grafton. All the piers in the main bridge except the pivot pier, and all in the slough rest on piles. The pivot pier in the main channel rests on four iron cylinders each 14 feet in diameter 30 feet long. These cylinders were sunk nearly to bedrock by weighting them and dredging the sand from their interiors. They were afterwards filled with concrete lowered in a box and leveled by a diver. The masonry of this pier was built in a water-tight caisson, the bottom of which was composed of three course of timber 12 x 14 inches laid 4 inches apart, and covered with 2-inch plank. The caisson was placed in position over the cylinders and sunk by the weight of the masonry as it was laid up inside of it. The sides of the caisson were removed after the masonry was completed.

The pier west of the draw and the first two east of the same rest on piles, those under the piers adjacent to the draw being driven to rock, while under the other one they were driven about 25 feet. A crib was sunk around the piles which were cut off about 5.5 feet below low water; the top of the crib was about even with the top of the piles, and the space around them and inside of the cribs was filled with rip rap and concrete. A grillage consisting of three courses of timber was floated into position over the piles and suspended by 10 screws 2¾ inches in diameter. The masonry was then laid on this grillage, which was lowered as rapidly as the masonry could be kept above the water. Some of these grillage platforms were lowered in as much as 15 feet of water. From the 6th pier to the east shore, the cribs were sunk before the piles were driven, and the sand dredged from their interior; piles were driven from leads resting on the cribs, sawed off and concrete placed about them.

All of the piers were built of rough ashlar stone facing and backed with concrete. The guard pier is a rock-filled crib connected to the pivot pier by floats. The foundations for the abutments were of concrete, the top being about low water; excavation was made inside a coffer dam.

The superstructure was built by the Detroit Bridge & Iron Works. The fixed spans of the main bridge were triangular trusses, double intersection, with cast top chords and posts of phoenix section and bottom chords of open links. The maximum rolling load

was assumed at 2,500 lbs. per foot, allowable tensile strain 10,000 lbs. per sq. inch, and a "compressive strain on upper chords or posts of which the factor of safety shall be not less than five." All the main chord links, main and counter ties, suspension bolts and lateral tie rods were tested in a hydraulic press, connection to the machine being made by pins through their eyes, and with nuts on the screw ends of the bolts, thus putting the strain on the members in the same way it would occur in the bridge. They were strained to 23,000 lbs. per square inch and struck with a hammer while under strain.

The testing of the material for this bridge and that for the one at Burlington, which was being erected at the same time, involved the handling of over 10,000 pieces of finished iron.

In the draw, over the main channel, both chords were rolled channels riveted together and it was of wrought iron throughout. The bridge over the bay was a Bollman truss with cast-iron upper chords and posts; the draw was the same with riveted upper chords and supported by hog chains over a central tower. The trusses were 10 feet high and 10 feet wide, with the track on the top chord.

The main draw span was operated by steam, and that over the bay by hand.*

The trestle on the island has long since been filled. The bridge over the bay was renewed in 1886 by a plate girder structure with the same length of spans. In 1898 seven spans at the eastern end of the main bridge were filled up with an embankment, and in 1898-99 the remaining spans of the main bridge, except the draw span, were rebuilt. The fixed spans are single intersection with trusses 16 feet apart, center to center. The original draw span is still in use, the floor beams and hangers having been renewed. I am informed by a prominent bridge engineer, who recently made an official examination of the bridge, that this span is in better condition than some draw spans built 15 to 20 years later.†

The new bridge is a combined railroad and highway bridge, the highway being provided for on the fixed spans by brackets outside the trusses, giving a roadway 11 feet 6 inches wide from

*The chief engineer was Mr. Thomas C. Clark, who wrote and published a very complete description of the bridge with full drawings in a volume entitled, "Iron Railway Bridge Across the Mississippi River at Quincy, Ill." D. Van Nostrand, 1869.

† This draw span was rebuilt and completed in April, 1902. The draw span piers and rest piers were remodeled and capped with granite. The new draw span is 358 feet 4 inches long over all. Height at center 55 feet, and at ends 36 feet, with 8 panels in each arm 21 feet 4¾ inches, center to center pins, but the center panel over the turntable is 16 feet. The highway is now carried on brackets on outside of trusses of draw span, similar to the fixed spans.

the center of the truss, on each side. Over the draw span the highway runs through on the same floor as the railway. In order to make the turn from the roadway outside the trusses to the one between the trusses, the suspension rod supporting the first floor beam from the end of the truss adjacent to the draw is omitted, and the stringers are made of double the ordinary panel length. The highway is carried across the bay on the old bridge

In 1899 an additional bridge was built across the bay some 4,000 feet below the old one, and consisting of a draw span about 360 feet long over all, and with clear openings of 160 feet; two

An embankment on the island connects this bridge with the plate girders of about 60 feet length connect it with the embankment on the island, while two plate girders of about the same length of span connect it with an elevated structure on the main or Quincy side.

The draw of this structure is a semi-through truss with inclined top chords, and the track about 1½ feet below the top chords at the ends. The truss is 24 feet deep at the ends, and 42 feet at the center. It rests on a masonry pier resting on piles.

main channel spans and it is connected by a track, partly elevated, with the main shore end of the old bay bridge. The passenger station is situated on this connecting track and by means of the loop thus formed trains are enabled to cross the bridge from the tracks of the St. L., K. & N. W. R. R. running up the west side of the river to the station in Quincy, and return without reversing their direction of movement.

42 HANNIBAL.

Railway and Highway.

The river, some three or four miles above the bridge, bends to the right from near the center of the valley and strikes the bluffs on the Missouri shore. It is then sharply deflected through an angle of over 90 degrees, and flows along the base of the bluffs to below the town of Hannibal. The river is very narrow and deep, being confined to one channel. The low water width was about 1,500 feet, while the high water width was, before the construction of the bridge, about 6½ miles, being the entire width between the bluffs. By the construction of the bridge and the Sny Levee the high water width was reduced to 1,580 feet. The slope of the river at low water was about 0.4 foot per mile, while the range between high and low water was about 22 feet.

The bridge was authorized by the act of Congress on 1866, and was opened to traffic in 1871. It is located only a short distance below the sharp bend above referred to. It is approached, on the

Missouri side, through a short tunnel on a 9½ degree curve tangent to the axis of the bridge, the latter being at right angles to the stream. The original structure consisted, commencing on the Missouri shore, of first a 250-foot span, then a draw span 360 feet over all, with two clear openings of 160 feet each, then a 250-foot span and four spans 180 feet long to an embankment.

SUBSTRUCTURE.—The first pier or shore abutment was of masonry resting on rock and about 25 feet back of the low water line. The draw pier was of masonry resting on piles, the up and down stream faces being straight and about 21½ feet across in the direction of the bridge, while the sides next the channels were arcs of circles. The width of the pier at right angles to the bridge was 36 feet. The other piers are of masonry resting on a grillage on piles, the piles under the two eastern piers being cut off above low water. The guard pier was a detached crib filled with rock, the space between it and the draw pier being filled with floats which rose and fell with the water. The stone for the piers came partly from Joliet, Ill., and part was quarried in the neighborhood.

SUPERSTRUCTURE.—The draw span was of wrought iron thoughout and the other spans were of wrought iron, except the top chords, which were of cast iron. The 180-foot spans were 22 feet high; the 250-foot spans and the draw at the ends were 25 feet high, the draw being 35 feet at the center; all were 21 feet wide. The draw was operated by steam power.

It is a combined highway and railroad bridge, the floors of both being on the same level. It was built by the Detroit Bridge & Iron Works. It will be noted that the bridge was built in strict conformity with the provisions of the authorizing act, but it presents one of the most striking examples of the effect of obstructing the high water flow of the river. Connections with the high water marks existing at Quincy and Hannibal for 1859 and 1882 by the precise levels of the Mississippi River Commission, show that the contraction of the high water channel, by the construction of the bridge and the Sny Levee, has resulted in raising the high water level above the bridge from 2½ feet to 3 feet. This has again resulted in a very high velocity of current at high water. While the current at low water is only about 3 miles per hour, at high water it is so strong as to be almost impassable by boats except of the most powerful type. In April, 1876, the Steamer "Dictator" with an ice barge in tow was bound up stream, the gauge reading 19.6. She had succeeded in passing the draw when the current caught the bow of the barge, carrying it and the boat around against the west rest pier and the 250-foot span, carrying

the latter away. The boat and barge were sunk and nine men were drowned. (Warren.)

The superstructure was rebuilt in 1886 (Robert Moore). The short spans are single intersection, but the draw and the 250-foot spans are double intersection; all have horizontal top chords, except the draw. The old piers were used.

43 LOUISIANA.

C. & A. R. R.—Built 1873.

Authorized by act of Congress in 1871, the act requiring for the first time, on this river, that draw openings should have a clear width of 200 feet. The act was further modified in 1872 and required that the proposed location should be submitted to the Secretary of War for approval before commencing construction.

C. & A. R. R., Louisiana, Mo.

The river in this locality flows along the bluffs on the Missouri shore, and had a width of about 3,700 feet at low water, with a high water width of several miles at the time the bridge was built.

The bridge was constructed by the Mississippi River Bridge Co., and opened to travel in December, 1873.

On the Missouri side the bridge is approached on an embankment on an 8-degree curve, some 450 feet of which was in the low water channel. The first span was 162 feet, then a draw 444 feet long over all, with clear openings of 200 feet each, then a span of 256 feet, and one of 226½, then 6 spans of 161 feet each, to an embankment.

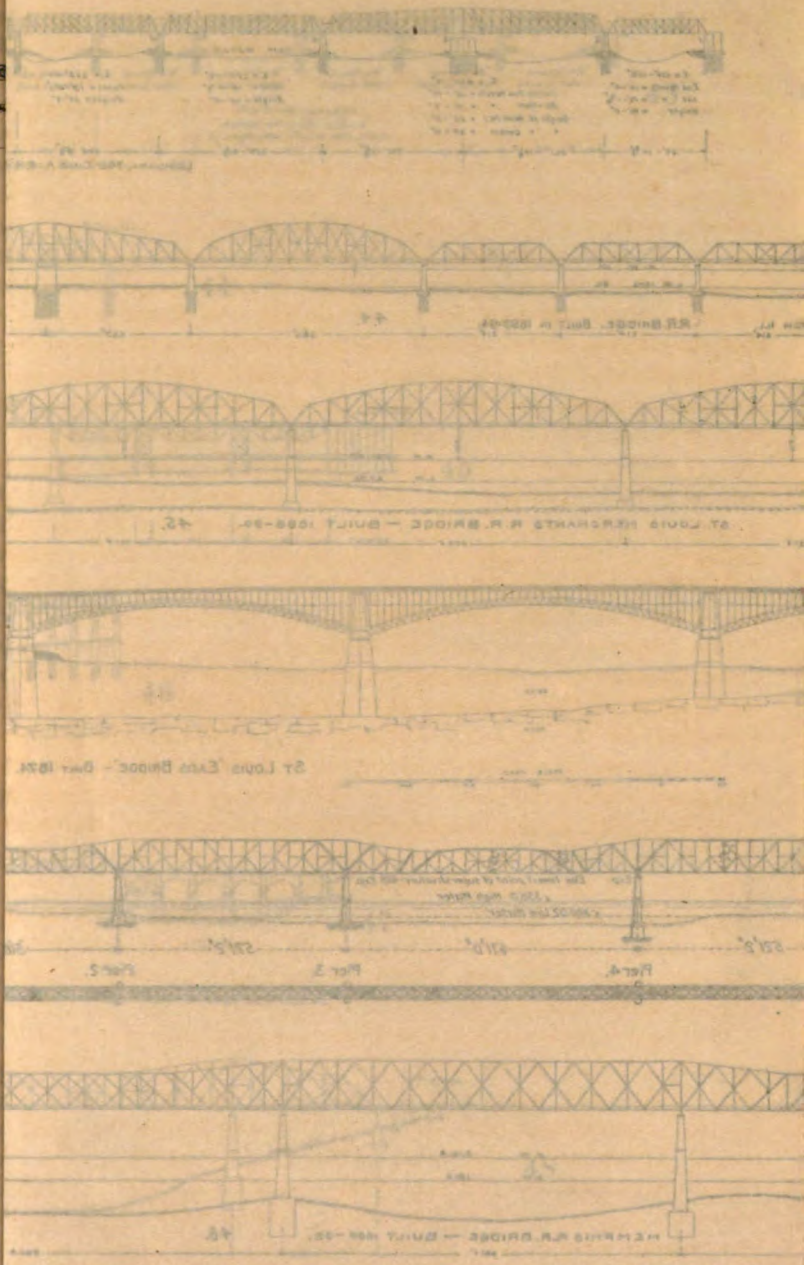
The piers are all masonry, of stone quarried in the vicinity. The west shore abutment rested on piles driven to the rock and was 21 by 4½ feet on top; no grillage was used under this pier,

concrete being placed around and over the heads of the piles. Piers No. 2 and 3, for the draw, rest on piles driven to rock. They were sawed off at the bottom of the river and rip rap placed around them. The masonry was built in water-tight caissons and lowered to a bearing on the piles; the bottom of the caissons was a grillage of two courses of 12 x 12 timber. The draw pier was 39½ feet in diameter on top, with a batter of ½ inch. Piers Nos. 2 and 4 were 9 x 25 feet on top with a batter of ½ inch per foot; the upper and lower ends are triangular. These starlings commence at high water, and in plan have a right angle at the nose; the slope of the nose of the upper starling was about 6 inches per foot, beginning about 10 feet below high water and extending to the foundation. These starlings were finished and surmounted by sections of cones and were, as were also the band courses, hammer dressed. The other piers were of the same description except that they were 7 feet wide. The piers beyond the draw pier rest on piles driven about 20 feet into the sand and cut off at the bottom of the river at that time. The masonry rested on a grillage 2 to 3 feet below water. The guard piers were detached cribs filled with rock; the space between them and the draw pier was filled with floats which rose and fell with the water.

The superstructure was of wrought iron throughout except some minor parts. The draw span at the time of its erection was the longest in this country, and it and the two long fixed spans were built by the Kellogg Bridge Co., of Buffalo. The trusses of the draw were 21 feet high at the ends and 40 feet at the center. The posts were two channels connected by an I-beam; these were 12 inches deep at the center, decreasing to 6 inches at the ends. At the center there were two additional inclined posts serving to carry part of the weight to the turntable. The upper chord for two panels each side of the center was composed of open links; in the next seven panels it was of links, channels and plates. The ties were rectangular bars with turnbuckles for adjustment and extending across two panels.

The floor beams were in pairs, one on each side of a post. The 250 and 225-foot spans were 31 feet high and 14 feet wide inside the trusses. The posts were of channels connected by an I-beam; the ties were rectangular bars with eyes and no means of adjustment. These spans were also of double intersection. The short spans were built by the Keystone Bridge Co., and were single intersection, and were 20 feet high. These were the first single intersection trusses built on the river.

As was before mentioned, the piles under the piers were cut off at or near what was the bottom of the river at that time. At the



first high water after the erection of the bridge, the increased velocity, due to the contraction of the high water area by the construction of the bridge and its approaches, scoured out the bottom, particularly under the short spans near the Illinois shore, and in spite of the fact that a large amount of rip rap was placed along the axis of the bridge and about the piers, it scoured out the bottom till at a short distance below the axis of the bridge it was from 23 to 27 feet below the bottom of the piles. On the 6th of November, 1876, the second pier from the Illinois side disappeared, carrying two spans with it, thus illustrating in a forcible manner the risk run in radically reducing the area of the high water flow. (Warren.)

The two spans were replaced by a single span of twice the length, while the material in the short spans was taken out of the river and rebuilt over a slough some three miles east.

The original bridge was rebuilt in 1897-98 by the Lassig Bridge & Iron Works of Chicago, and of the same length of spans; the old masonry was used, no changes being made, except that necessary to accommodate the new bridge shoes. The west span, the draw, the 256 and 226-foot spans were rebuilt, the 320-foot span, which had replaced the two spans washed out, was strengthened but not rebuilt. The last two 156-foot spans were strengthened by "doubling up" the old trusses with the two others rebuilt.

44 ALTON.

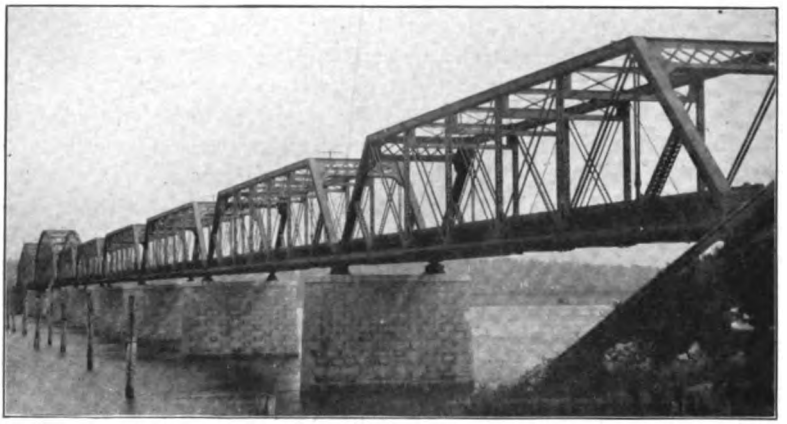
C. B. & Q. R. R.—Built in 1894.

This is the last bridge on what is known as the "upper river." It is situated near the lower limits of Alton, Ill., and about 6 miles above the mouth of the Missouri River. The city of Alton is on the bluffs and the channel of the river flows at their foot at the upper and business part of the city. The river leaves the bluff about ½ mile above the bridge and at the bridge there is low ground about ¼ of a mile in width between the low water bank and the foot of the bluffs. The bottom on the Missouri side extends across the Missouri River and has a width of a little more than 4 miles. The range between high and low water is about 26 feet. The low water channel at the time the bridge was built was near the Missouri shore, but the rectification works proposed and being built by the Government contemplated the creation of the channel down the left or Illinois bank, and the draw was located on that side. This explains why on the profile of the bridge the draw is apparently dry at extreme low water.

The bridge is a double track structure consisting, commencing on the Illinois side, of two pile and timber trestle approaches

forming a Wye connection with the railroad tracks at the foot of the bluffs, then a draw span 450 feet long over all, with 200-foot clear openings, then one span of 360 feet center to center of pins, and six spans of 210 feet to the abutment on Ellis Island.

The piers throughout are of limestone and rest on pile foundations. The piles were driven by a steam hammer, and were cut off 10 feet below low water with a circular saw, and are surmounted by a timber grillage 4 feet thick. This grillage formed



Alton, Ill., Railway.

the bottom of open caissons which were floated into position and in which the masonry was built and sunk to a bearing on the piles. The sides of the caissons were removed after the masonry had been brought above the water surface and were used on successive piers.

SUPERSTRUCTURE.—The trusses are single intersection throughout. The short spans have horizontal top chords, while the 360-foot fixed span and the draw span have inclined top chords. The draw is operated by steam. Total weight of eight spans, 7,856,900 lbs.*

41 ST. LOUIS: MERCHANTS' BRIDGE.

Railway.

Authorized by Congress in 1887 and opened to traffic May 3, 1890. The bridge is located about 2½ miles above the Eads Bridge. The river at this point flows between banks which, without levees,

*Geo. S. Morison was Chief Engineer. Lewis M. Loss was contractor for the substructure, while the Union Bridge Co. were contractors for the superstructure.

are subjected to overflow on both sides, thus necessitating long approaches on either side.

The structure is a double track railroad bridge only, and consisted, at the time it was built, beginning at the Illinois side, of first a timber trestle 1,984 feet long, then a span of 175 feet over the C. & A., Big Four and Wabash R. R. tracks; then 2,580 feet of timber trestle, then two 125-foot spans, then a 123-foot span, then three spans of 521.5 feet, 523.5 feet, and 521.5 feet respectively; then three spans of 128 feet each; 9 plate girders 40.3 feet long; then 547 feet of timber trestle to a 126-foot span over Ferry Street, and a 547-foot timber trestle to an embankment. The main spans have clear openings of nearly 500 feet and are about 50 feet above high water.

The piers supporting the main channel spans rest on caissons sunk to the rock by the pneumatic process; the rock is nearly level across the river and lies at an average depth of 46 feet below low water. The caissons for piers Nos. 1 and 4, numbering from the east, were 26 x 70 feet, and piers Nos. 2 and 3 were 28 x 70 feet, all 17 feet high. On caissons Nos. 1 and 2, cribs of yellow pine 20 to 27 feet high were placed; they were planked with 3-inch oak plank. The space above the working chamber, within the outer walls of the caisson and crib work, was filled with concrete. The first two feet above the roof was of Portland cement, the remainder of Louisville cement. The working chamber was filled with concrete after rock had been reached.

The masonry is first-class "rock face" laid in regular courses. The stone is limestone from Bedford, Indiana, with granite facing from 3 feet below low water to high water level.

The river was reduced to a width of 1,600 feet by building a solid embankment from the east side, above high water and directly under the approach spans. The west end of this embankment is at the east main pier.

The superstructure is of steel throughout and is double track. The trusses were, I believe, the first of long span built on the river with curved top chords, those at Cairo being of approximately the same length, and built only a year or two earlier, having horizontal top chords. The trusses are placed 30 feet apart center to center and are 75 feet high in the center. The double panel length is 57 feet 5 9-16 inches. The trusses are single intersection with intermediate supports to chords and floor system.*

*The superstructure was built by the Union Bridge Company, E. L. Corthell, chief engineer; George S. Morison, consulting engineer, and H. W. Parkhurst, resident engineer.

46 ST. LOUIS: EADS BRIDGE.

Railway and Highway.

Authorized by act of Congress in 1866 and opened to travel in 1874. The river in the vicinity of the bridge flows at the foot of the bluffs on the Missouri shore. It has been subjected to a great artificial contraction beginning as far back as 1838, and in 1876 the high water channel was only about 1,900 feet wide, with a low water width of about 1,200 feet.

So much has been written concerning this bridge that only a very brief description will be given of the bridge itself. The main bridge consists of three spans with the abutments at about the low water line on each side and with two piers in the river. The spans are circular segment arches, the center one being 515 and the two end ones 497 feet each in length in the clear. At each end of the main bridge spans there are five masonry arches, each of 26 feet span, which cross the wharves. The lower roadway is carried over these arches within an arcade composed of 20 arches supporting the upper roadway.

The foundations of the main piers and abutments all rest on solid rock. The St. Louis abutment was placed by means of an ordinary open cofferdam; the rock being about 13 feet below low water. The others were sunk to rock by pneumatic caissons; the depths below low water being for the west pier 58 feet, the east pier 86 feet, and the east abutment 94 feet. The foundations of the approach spans on the west side are on piles. Most of the masonry is Grafton limestone faced with granite from 4 feet below low water to above high water.

The Chief Engineer was James B. Eads, and his principal assistant was Col. Henry Flad. The foundations and masonry were erected by hired labor directly by the Bridge Co.

Each span is composed of four arch ribs spaced respectively 16, 12 and 16½ feet apart, center to center. Each rib is composed of two members spaced 12 feet apart and in a vertical plane; each member is composed of straight circular tubes, each 12 feet long, 18 inches in diameter, the ends of the tubes butting together and joined by steel couplings. The upper and lower members are braced together by a single system of triangular bracing. A steel pin passes through the couplings at each point and finishes the connections for the bracing and for attaching the support for the floor. The structure is a combined railway and highway bridge, with the highway on the upper deck. The roadways are carried from the upper member of each rib. The upper roadway rests on the top of lattice posts, which rest on the above mentioned piers. The lower roadway is supported by posts or hangers, as the road is above or below the upper member of the

arch. The railroad tracks are between the outer pairs of ribs, and are on a 1.5 per cent grade to the center of each side span, and between the latter points is a parabolic arc.

The position of the track floor is such that at the center of each span the track floor is on a level with the lower member of each rib. Between the points in each span where the upper members begin to rise above the track, direct lateral bracing between the ribs is necessarily omitted. The lower roadway at and just above the ribs was supported by a peculiar construction known as knee braces formed of tee irons; the remaining floor beams were of iron plate girders riveted to posts or suspended by hangers. The track stringers were formed of a pair of 12-inch channels back to back and about 7 inches apart, under each rail; blocks of wood about 17 inches long were supported on small bracket angles riveted to the channels near their lower edge; the whole formed a sort of trough in which the rails were carried without the use of cross ties. The original live load was estimated at 6,400 lbs. for the whole bridge, including highway.

The superstructure was built by the Keystone Bridge Co., under the superintendence of Mr. Walter Katte. It was erected without false work by suspending the tubes from temporary towers by cables and employing temporary anchorages on the banks of the river.

The railway floor was rebuilt in 1888 and is of the usual type of plate girder floor beams and stringers, with stringers riveted to floor beams, and also supported on bracket angles riveted to floor beams. At expansion points, of which there are seven in each span, the bracket forms the whole support for the stringers, which at this end is fastened to the bracket with turned bolts in slotted holes.

Yellow pine ties were used and are spaced 13 inches apart, center to center.*

47 THEBES, ILL.

Railway—under construction—1903.

The Southern Illinois and Missouri Bridge Company, a corporation under the laws of the State of Illinois, was granted authority by Act of Congress, approved Jan. 26, 1901, to construct, maintain and operate a bridge, with approaches, across the Mississippi river, at or near Grays Point, Scott County, Missouri.

This bridge is now under construction, and is situated near the extreme southwest point of Illinois, about 140 miles south of St. Louis, Mo.

*The new floor was designed by Mr. Robert Moore. The Transactions of the Am. Soc. C. E., Vol. 3, contains a voluminous discussion of this type of bridge. For a full and complete description of the bridge, see "History of the St. Louis Bridge," by C. M. Woodward.

The purpose of the bridge is to form a connection between the Illinois Central and the Chicago & Eastern Illinois Railroads on one side, and the Missouri Pacific and the St. Louis Southwestern on the other, all of which are interested in the bridge company.

The superstructure is composed of two fixed spans, four cantilever arms and three suspended spans, as follows: the central or channel span is 671 feet long and is made up of a suspended span 366 feet center to center of end pins, and two cantilever arms 152 feet 6 inches center to center of end pins. On each side of the channel span is a fixed span 521 feet 2 inches long and lastly are the short shore spans consisting each of a cantilever arm and a suspended span of the length given above.

The structure is a double track one with 28 feet clearance between trusses. The height of the fixed spans is 75 feet, and of the suspended spans 55 feet in the center, and 50 feet at the ends. The height of the bottom chord is 65 feet above high water and 103 feet above low water which is zero on the United States Gauge at Gray's Point, Mo. Only two lengths of panels have been used, namely, 32 feet 6⅞ inches in the two fixed spans, and 30 feet 6 inches in the center spans and the two shore spans. The total length of superstructure is 2,750 feet 4 inches. The superstructure is supported on four masonry piers founded on bed rock.

On each end of the superstructure are concrete arch approaches. The Illinois approach consists of five 65 feet arches, and the Missouri approach of six 65 and 100 feet arches. The piers supporting the concrete arches are founded either on solid rock or on shale.*

48 MEMPHIS.

Railway.

Authorized by act of Congress, approved May 24, 1888. Completed May 12, 1892. This is the first and only bridge built over the lower Mississippi, or below the junction of the Ohio and the Mississippi.

The river below Cairo possesses characteristics different from that of any part over which any previous bridge had been built. The two main tributaries of the lower river, the Ohio and the upper Mississippi, though of approximately the same magnitude, possess entirely different characteristics. The former, though possessing comparatively stable banks and carrying comparatively little sediment, is subject to a wide range between high and low water, while the latter, though subject to less violent fluctuations in stage, possesses all the uncertain elements of a silt-bearing stream. The river, then, below the confluence of these two

*See R. R. Gazette, Vol. XXXV., page 20, Jan. 9, 1903, for further details, including some data of design of superstructure and of concrete approaches. The above description of this latest bridge over the Mississippi river was contributed by Mr. Ralph Modjeski, chief engineer, and President W. S. E.

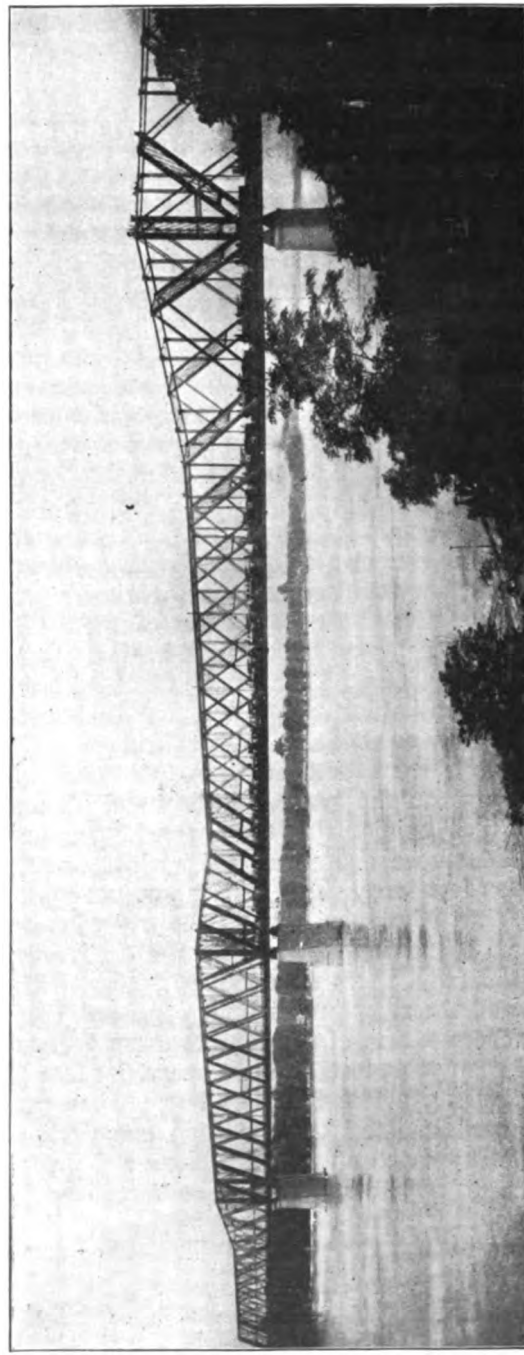
main tributaries retains the undesirable elements of both: i. e., extreme fluctuations of stage combined with a silt-bearing stream flowing in an alluvial bottom. At Memphis, 232 miles below Cairo, the extreme fluctuations in stage, owing to the greater width of the high water plane, do not exceed the fluctuations at St. Louis, ranging from —2.65 on the Memphis gauge in 1895 to 37.66 in 1897, or a total extreme, as far as observed, of 40.21 feet.

The location of the bridge is near the lower limits of Memphis, which is on the bluffs and has a river front of about three miles. The river above the city flows in a bend along the upper side of Hopefield point, nearly opposite the city, and on leaving the point impinges against the Memphis shore at nearly a right angle. After making this sharp bend, the channel follows down the bluff at some distance below the bridge. The bend on the upper side of Hopefield point has caved very rapidly and thus brought the point where the current strikes the Tennessee shore proportionally farther down stream. Large sums of money have been spent in attempts to check this caving, which between 1876 and 1893 amounted to a recession of Hopefield point of over 3,000 feet. The amount of caving since 1892 has, however, been very small, owing to the efficiency of the protection works.

The act authorizing the construction of the bridge specified that the main channel span should not be less than 700 feet in length, and the others not less than 600 feet, and that it should be 75 feet high above high water, and that it should provide for its use as a highway as well as a railway bridge.

A board of engineers, detailed from the Corps of Engineers, U. S. A., to pass on the plans, location and dimensions, were unanimous in their opinion that the channel span should be adjacent to the Tennessee shore and the majority reported that it should be 1,000 feet long. This report was not approved by the Secretary of War, who ruled that, if the east pier was placed in clear, with two spans 600 feet long in the clear, might be built. (Report Chief Engrs. U. S. A., 1888, p. 2516.) This suggestion was adopted and the structure as built consisted, commencing on spans, the anchorage arm of the cantilever 225 feet 10 inches, the main channel span 790.5 feet, and two spans 621 feet ½ inch long; then a deck truss 339 feet 8 inches long; then 20 deck plate girders supported on steel towers; then two deck girders over railroad tracks supported on masonry piers, and four deck girders on steel towers to a timber trestle. The latter has since been replaced by an embankment.

SUBSTRUCTURE.—The three main bridge spans rest on 4 piers, two of which are in water 25 to 35 feet deep at low water. The



Memphis Bridge Under Test. A Train of 18 Locomotives.

Memphis—Railway and Highway Bridge. Total length, including viaduct, 4,988 ft. 9 in. Total weight, 19,541,706 lbs. of Iron and Steel.

other two piers are near the low water line on either side. The bed of the river is of sand overlaying clay at a depth of 75 to 80 feet below low water at the channel piers, and coming to the surface and forming the bluffs on the east side. The foundations were carried into this clay and were sunk by means of pneumatic caissons, which under piers Nos. 2 and 3 were 92 feet long by 47 feet wide, and were sunk to a depth of about 94 feet below low water. These piers have a total height of something like 175 feet above the cutting edge. A detailed description of the caissons, the methods of sinking them, and the masonry, is found in a paper by Mr. Geo. S. Morison in the Minutes of Proceedings of the Institute of Civil Engineers, Vol. CXIV., p. 289.

The superstructure of the main bridge is exhaustively treated by Mr. Morison in Trans. Am. Soc. C. E., Vol. CXIV, p. 573, and only a very general description will be repeated here. The length of spans between centers of piers is given above. Considering the trusses as a whole and made up of independent spans, the main structure consists of a central fixed span 621 feet in length with cantilevers of 169 feet 4½ inches projecting beyond each end and each supporting one end of a suspended span of 425 feet 8 inches. The opposite end of the west span is supported by the west pier, the opposite end of the east suspended span is supported by a cantilever projecting 169 feet 4½ inches from pier No. 1, and is in turn supported by the anchorage span of 225 feet 10 inches.

The truss panel length throughout is 56 feet 5½ inches, divided into two panels in the floor system. The width is 30 feet between trusses center to center. The depth of truss in the central span and cantilevers is 77 feet 8 inches, and of the suspended spans 56 feet 5 inches. The trusses are pin connected throughout. Expansion is provided for by sliding joints at the ends of the cantilevers and the east end of the fixed span is on roller bearings. The wagon way on the main structure is on the same level as the rails and to provide for it a floor is planked over for a width of 20 feet. At the west end of the 238-foot deck span the wagon way leaves the main bridge and is provided with an independent trestle approach. Owing to the excessive grade on which this approach is built and the very high tolls charged, the wagon way is practically unused.*

*The chief engineer was George S. Morrison; resident engineer, Alfred Noble. The superstructure was furnished by the Union Bridge Company. It was erected by Baird Bros. on false work, except the suspended span over the main channel, which was projected from the cantilevers to the center. For a complete history and description, see "The Memphis Bridge," by George S. Morison, John Wiley & Son.