

The New Bridge Crossing the Mississippi River at Clinton, Ia.; Chicago & Northwestern Ry.

By F. H. BAINBRIDGE.*

One of the important railway bridges crossing the Mississippi River is that of the Chicago & Northwestern Ry. between Fulton, Ill., and Clinton, Ia. The first bridge at this point was completed in 1864, and after having its spans strengthened and renewed at different times it has been superseded by an entirely new structure parallel with it. This bridge is now completed, with the exception of the draw span. The bridge is on the main line of the Chicago & Northwestern Ry. between Chicago and Omaha. It is used also by the Chicago, Rock Island & Pacific Ry. for freight transfer, and by the Chicago, Burlington & Quincy Ry. for its lines from Clinton, Ia., to Mendota, Ill., and to Savanna, Ill.

The design and construction of the new bridge have been under the direction of Mr. E. C. Carter, M. Am. Soc. C. E., Chief Engineer of the

In 1858 the management of the Chicago, Iowa & Nebraska Ry., being interested in the development of the present town of Clinton, Ia., started the construction of a bridge at Clinton from the left or east bank of the river. This was finished in 1859, as far as Little Rock island (an outcrop of rock well above high water in the river and forming the eastern boundary of the west channel at the crossing). It connected with the Chicago & Galena Union Ry. by a line along the east bank of the river to Fulton, Ill. Between Little Rock island and the Iowa shore a car-ferry was operated by the Chicago, Iowa & Nebraska Ry. This railway was leased to the Chicago & Galena Union Ry. in 1862. In 1864 the west channel was bridged, completing not only the second bridge across the Mississippi River, but also one of the most important bridges of its day.

It is of interest to note that Mr. W. D. Walden, Foreman of Carpenter Work on the first construction in the east channel in 1858-59, and on the west channel in 1864, is still in active work for the Chicago & Northwestern Ry., as superintendent having in charge the maintenance of the Clinton Bridge.

of the east channel spans, the heaviest engine in service on the Chicago & Galena Union Ry. weighed (with tender) 28 tons. The heaviest engines operated over the present bridge weigh (with tender) 140 tons. The new bridge is designed for Cooper's E-50 loading, the engines for which weigh (with tender) 177.5 tons.

All the east channel piers were of cut stone masonry on a foundation of piling capped with a wooden grillage. The west channel abutments and piers were all of cut stone masonry, and are still standing in good condition. The abutments were founded on rock. The center pier and the two rest piers of the draw were founded on wooden cribs loaded with stone and sunk to the river bed.* The remaining west channel pier was on piling capped with a wooden grillage.

The McCallum trusses were the first to require renewal. The easterly McCallum truss span was rebuilt as a 200-ft. pin-connected Pratt truss in 1869, and this in turn was replaced by heavier Pratt pin-connected spans in 1881 and 1898. The remaining McCallum spans were renewed with pin-connected Pratt spans 150 ft. in length in 1870. These latter were replaced with heavier

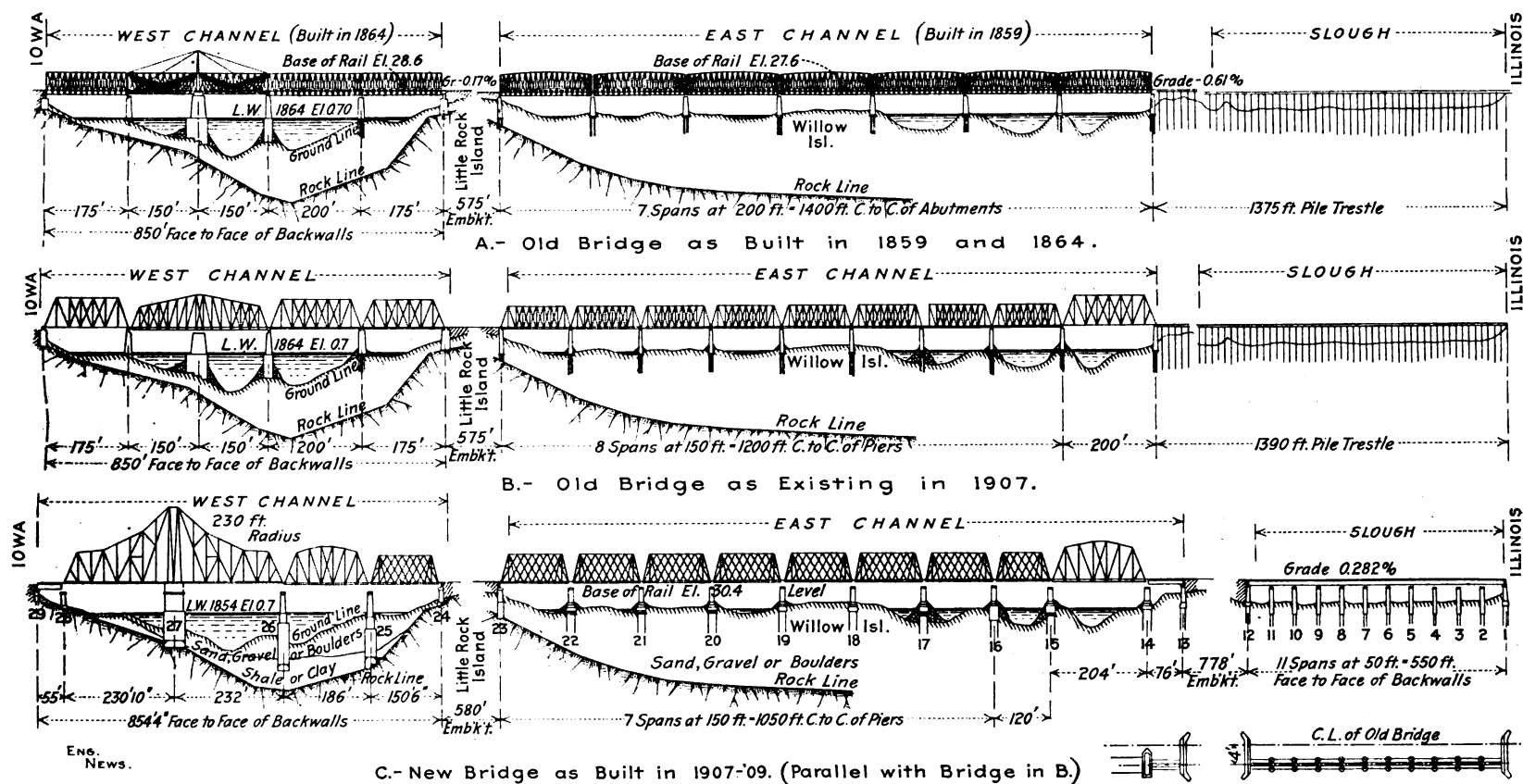


FIG. 1. ELEVATIONS OF THE OLD AND NEW BRIDGES OVER THE MISSISSIPPI RIVER BETWEEN FULTON, ILL., AND CLINTON, IA.; CHICAGO & NORTHWESTERN RY.

Chicago & Northwestern Ry.; Mr. W. H. Finley, M. Am Soc C. E., Assistant Chief Engineer, and Mr. I. F. Stern, Engineer of Bridges. Mr. H. M. Spahr is assistant engineer on the work. The writer is Resident Engineer in charge of the construction of the bridge.

HISTORICAL REVIEW.—The Chicago & Galena Union Ry., the nucleus about which the present great Chicago & Northwestern Ry. system has been built, was finished as far as Fulton, Ill. (opposite Lyons, Ia.), on the Mississippi River, in 1855. In 1858, the Chicago, Iowa & Nebraska Ry. was laid from Clinton, Ia. (about 2½ miles downstream from Lyons) westward to Lisbon, Ia., a distance of 66 miles. It was the intention of the management of the Chicago & Galena Union Ry. at that time to build a high-level bridge across the Mississippi River between Lyons, Ia., and Fulton, Ill., or about 2½ miles up-stream from the site of the present structure. Difficulties in securing right of way in the town of Lyons delayed the matter, and finally (with other causes mentioned below) caused the abandonment of this project. This was unfortunate, as the Lyons site is far better than the one chosen.

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The crossing at Lyons, at first contemplated (as noted above), was over a single channel 1,450 ft. in width. This had high bluffs on each side, and a rock foundation not far below low water, and was an ideal location for a high level bridge. This site is now occupied by a highway bridge between Fulton and Lyons, built in 1891.

The Clinton crossing has a total length of 4,200 ft., and is broken by two islands; Little Rock island (above high water), over which the track is carried on an earth embankment; and Willow island (below high water), which is spanned with trusses.

The profile and elevation (A) in Fig. 1 represents the first bridge, as built from 1858 to 1864. The east channel spans were McCallum trusses built entirely of wood, except for bolts and for diagonal rods in the third and fourth panels at each end of each truss. The fixed spans in the west channel were Howe truss spans. The draw span was of the Bollman pattern. The top chords were composed of two 12-in. channels with 12½-in. cover plates top and bottom. The bottom chords had two 6-in. channels with 12-in. cover plates top and bottom. The center posts, turntable and end posts were of cast iron.

This bridge was designed for a moving load of 2,500 lbs. per lin. ft. At the time of the building

spans of the same type from 1882 to 1886. The Pratt truss spans were in service until the opening of the new east channel spans in August 1908.

The draw span was renewed in 1887. The Howe trusses of the west channel were replaced first with pin-connected Pratt trusses in 1875, and again with heavier spans of the same type in 1898. The upper and lower treads of the turntable of the draw span, and also the end lift mechanism, were replaced in 1901. Many minor repairs for strengthening the floor system and connections became necessary, both in the east and west channel spans built prior to 1898, owing to a traffic constantly increasing in frequency and in concentration of weight.

The draw span was replaced in a novel manner. The new span was erected (in the up and downstream position) on the protection pier, the new turntable being put in and connected to the old span. The new span was coupled up to the center tower of the old span and when everything was in readiness to transfer traffic, the star-shaped combination of the new and old spans

*Pieces of old iron strap rails were used for the iron-work required in the construction of this cribbing, in 1863. Some of these pieces were recovered in 1908 and showed no signs of deterioration. This was noted in our issue of Aug. 6, 1908.—Ed. Eng. News.

The map, Fig. 3, shows the relative positions of the old and new structures and the adjoining highway bridge. The profile and elevation (C) in Fig. 1 show the outline of this bridge. In the following description the piers and spans will be designated by the numbers shown on the cut. The elevations shown on the plans are referred to the U. S. Engineers' datum plane; the extreme observed low water elevation is 0.7 ft. above this plane, and extreme high water elevation 21 ft. above this plane. For the purposes of description the crossing naturally divides itself into five parts from east to west, as fol-

Work on the temporary trestle was started July 10, 1907, and the cylinder piers were finished complete by Jan. 28, 1908. The superstructure of plate girders and cross girders was erected with a derrick car. This latter work started June 5, 1908, and riveting was finished July 20, 1908. The quantities in this section of the work are as follows: Piles, 633; cut stone, 1,109 cu. yds.; concrete, 1,335 cu. yds.; steel in

SUBSTRUCTURE.—All the piers and abutments are built of dimension stone masonry. The abutments (Nos. 13 and 23) are of red-rock sandstone from Ablemans, Wis. Piers Nos. 20, 21 and 22 are of Kettle River sandstone, and



THE RIVER EMBANKMENTS.—Between the east channel and the slough is alluvial ground averaging about 10 ft. above low water, and well covered with brush and full grown timber. The old bridge crossed this by a pile trestle. For the new bridge, abutments were built at the west end of the slough span (No. 12), and the east end of the east channel span (No. 13), and the intervening space was covered with a sand embankment made by a hydraulic dredge working in the east channel. The average height of

In constructing Pier No. 16, the adjoining pier of the old bridge settled to such an extent that extreme precautions were necessary. In consequence, piles were cut off with the rotary

saw at 11 ft. below low water and part of the concrete footing was deposited through the water before pumping out the cofferdam. This avoided the danger of an inflow of material from around the adjoining pier.

The quantities in this section of the work are as follows: Piles, 1,750; grillage, 140,700 ft. B. M.; concrete, 2,200 cu. yds.; cut stone masonry, 4,400 cu. yds.; rip-rap, 1,500 cu. yds.



FIG. 4. THE EAST CHANNEL PORTION OF THE NEW CLINTON BRIDGE; CHICAGO & NORTH-WESTERN RY.

(The view is looking east. On the left is the old single-track bridge. There are eight riveted lattice truss spans and a Pratt truss span.)

A temporary pile trestle with 16-ft. spans and carrying two tracks, was built with its center line on the center line of the permanent bridge for handling material. It had five piles to a bent, and caps 28 ft. long. A stiff-leg derrick was set up on piling at each pier, but much of the material was handled with a Brown hoist crane or a derrick car.

Work on this section of the substructure was started July 3, 1907, and finished March 14, 1908.

SUPERSTRUCTURE.—As previously intimated, the lengths of the spans were fixed by the positions of the old piers. Beginning at the east end and running west, they are as follows: 74-ft. deck plate girder; through riveted Pratt truss span, 202 ft. 3¼ ins.; through riveted lattice truss span, 115 ft. 7¼ ins.; and seven through riveted lattice truss spans of 146 ft. 5½ ins. There were no unusual features in these spans except that the Pratt truss is longer than is customary practice for a riveted span. Fig. 4 is a general view of the east channel spans, showing the riveted lattice trusses. At the left is the old single-track bridge. Fig. 5 shows the Pratt truss span (202 ft. 3¼ ins.) over the "raft channel." Fig. 6 is an end view, and gives a good idea of the massive construction of the trusses. It shows also the deck construction, which is described later. This view is looking west. On the right is the old single-track railway bridge, while on the left is the high-level highway bridge.

The method of erection was unusual. The falsework put in for constructing the substructure was used for the erection of the superstructure without change. The stringers on the falsework were at the proper level, so that the floorbeams and stringers of the iron span could be blocked on them at their proper elevation. Floorbeams and stringers were first laid complete for a span on the falsework. As this falsework was not of sufficient width to support the trusses directly, they were erected in position supported by the floorbeams. All steel was handled with a derrick car, no traveler being used. Opposite members in the two trusses were put up consecutively, so as to keep the trusses nearly balanced in weight at all times.

The work of erection started Jan. 27, 1908, and was finished and falsework removed July 14, 1908. Ice broke up in the river at this point on March 7, 1908, and the falsework was slight-

ly damaged. The movement was confined almost entirely to the west channel, so that the falsework escaped serious injury. The weight of the superstructure of this section of the bridge is 3,214 tons.

The West Channel Spans.

This channel is much the more important. Though only 600 ft. wide at low water and 850

(having foundations as previously described), it was decided to found the new piers on rock or other firm strata below the reach of scour, thus providing the best possible waterway and one least liable to bring about a serious ice gorge.

It should be noted that conditions at the present time are essentially different from those at the time when the old west channel piers were built. In 1891, dams of rip-rap and brush extending from 2 ft. to 3 ft. above low water were built by the U. S. Engineers between the heads of Little Rock and Willow islands. This was with a view to increasing the flow in the west channel and scouring away bars formed below the contracted channel at the crossing, caused by the interposition of the two islands and the consequent divided flow which obtained below the islands. At the present time, therefore, there is far greater probability of scour around the piers than previous to the construction of these dams.

SUBSTRUCTURE.—Borings made with a churn drill in 1901 located a supposed rock line as shown by the dotted line in the profile of the west channel Fig. 3. Experience with the first caisson sunk showed the ledge rock to be far below what was supposed, and a correct rock line was located by a new set of borings made in April and May, 1908. These borings were described by the writer in "Mine and Quarry" for October, 1908. [See end of article.—Ed. Eng. News.]

Piers Nos. 24, 28 and 29 are founded on a soft, porous buff limestone belonging to the Gower stage of the Niagara series of rocks. Piers Nos. 25 and 27 are founded in a hard compact, white limestone belonging to the Delaware stage of the Niagara series. Pier No. 26 is founded in a peculiar strata consisting of sand and clay well indurated. This deposit (though recent) is pre-glacial. It can be traced to a period during which the carboniferous rocks, which formerly covered this section, were degraded. At that time the Mississippi River at this point was a lake of many miles in width and of great depth, similar to the existing Lake Pepin. The high ground to the west of Clinton shows evidence of having been an island in this lake. The clay is a water deposit due to the



FIG. 5. PRATT TRUSS SPAN OVER THE RAFT CHANNEL IN THE EAST CHANNEL PORTION OF THE CLINTON BRIDGE (SPAN, 202 FT. 3 1/4 INS.).

point on the right bank about 1,000 ft. above the bridge. This boom is removed to a safe position at the close of navigation. A similar construction will be used for the new bridge.

Although no difficulty had been experienced with the west channel piers of the old bridge,

degradation of the carboniferous shales and the sand is wind blown from the neighboring carboniferous sandstones. The coloring matter in the upper strata of the clay is black (from degraded coal measures), and in the lower strata red (from degraded iron ore beds.)

Piers Nos. 24, 28 and 29 were built in open cofferdams made with single rows of the United States steel sheet piling.

Piers Nos. 25, 26 and 27 were put down by the pneumatic process. The greatest air pressure used was 34 lbs., in pier No. 26. The powerhouse was located on Little Rock Island, just south of the crossing and the air was led by pipes over the temporary trestle built as a construction trestle for the piers and as falsework for the superstructure. After a number of unsuccessful attempts to maintain an air pipe on the bottom of the river, air was carried to pier No. 27 by a pipe laid over the adjoining highway bridge, which is a high level crossing. This furnished an uninterrupted connection.

Pier No. 25 was sunk during January-April, 1908. Pier No. 27, being the one most protected from the river current at high water, was put down in May to August. Pier No. 26, being the most exposed to the current during the low water period, was put down during September-November.

The caissons were constructed on ways on the west river bank, launched in the water and

all coarse material excavated; this was used also for the ingress and egress of the men and the placing of concrete for sealing.

The abutments (Nos. 24 and 29) were built of cut stone masonry from the Ablemans (Wis.) red-rock quarry. All the other piers in this section above the crib line were of dimension stone from the Ablemans white-rock quarry. The quantities were as follows: Timber in cribs and caissons, 520,000 ft. B. M.; concrete, 5,850 cu. yds.; dimension stone masonry, 3,328 cu. yds. Material was all brought to the site over the temporary wooden pile trestle and handled with two stiff-leg derricks (supported on piling) at each pier.

SUPERSTRUCTURE.—The four spans in this section are from east to west as follows: One through riveted lattice span, 146 ft. 5½ ins.; one through riveted Pratt truss span, 182 ft. 5½ ins.; one through pin-connected swing span, 460 ft. c. to c. of end floorbeams, and one deck plate-girder span of 52 ft. 7½ ins.

By Dec. 12, 1908, the center of the draw span was all in and riveted, and the west arm erected complete. Piles were all driven in the falsework

Notes on the Design of the Steel Superstructure.

SPECIFICATIONS.—The moving load assumed throughout for each track is Cooper's E-50, consisting of two 177.5-ton consolidation engines coupled, followed by a uniform load of 5,000 lbs. per lin. ft. The assumed weight of the deck is 550 lbs. per ft. of track. Impact is added to the moving load stresses in accordance with the Prichard formulas: (A) for stresses resulting from load on one track; (B) for stresses resulting from load on two tracks. In these formulas L = live-load stress; D = dead-load stress; I = impact.

$$(A) I = L \frac{L}{L+D} \quad (B) I = \frac{1}{4} L \frac{L}{L+D}$$

The unit stresses used are substantially those proposed by Mr. C. C. Schneider, and as adopted by the American Bridge Co.

The trusses are spaced 32 ft. c. to c., which is wider than ordinary. This is in order to allow derailed cars to reach the guard timbers without striking the trusses. The minimum lateral clearance for trains is 8 ft. from the center lines of the tracks. The minimum vertical clearance is 22 ft. 6 ins. from the base of rail, with the usual allowance for brackets at the corners of the clearance rectangle. The tracks are 13 ft. c. to c., and stringers and girders are spaced 3 ft. 3 ins. from the center lines of their respective tracks.

The requirements as to quality of material and workmanship vary but little from common practice. The bronze used in the turning mechanism and end lifts of the swing span is required to be made of new metals, and to show the following analysis: copper, 86%; tin, 13%; zinc, 1%.

Reaming is covered by the following clause in the specifications:

In structural steel, wherever used in tension members, in top and bottom flanges, end connections and splices of floor beams and stringers of girders and beams, built or rolled, and in the web members of all riveted trusses, all punched holes shall be reamed with a twist drill unless otherwise marked. In reamed work, the diameter of the punched hole on the die side shall be at least 3/16-in. less than the diameter of the finished hole after reaming.

DECK OR FLOOR CONSTRUCTION.—The deck construction is of the type which is standard for important steel structures on the Chicago & Northwestern Ry. It is shown in Fig. 6. The ties are of long-leaf pine, 8 x 8 ins., surfaced to a uniform thickness of 7¾ ins. They are 12 ft. long. An outer guard timber 10 x 12 ins., laid on edge and dapped 1 in. over the ties, is placed at each end of the ties. This is fastened to each tie with ¾-in. bolts. Outside of each rail and at a distance of 4 ins. from the inside flange, is a plank 4 x 10 ins., laid flat and spiked to each tie. Inside the rail is a similar plank, with the nearest edge 9½ ins. from the inner flange of the rail.

Backed up to the latter plank (and between it and the rail) is an angle 6 x 4 x ¼ ins., with the 6-in. leg bearing on the ties. These angles are attached to the inner planks with ¼-in. screws 4 ins. long; they are fastened to every fourth tie with a track spike having the head lapping the edge of the angle. This deck system is continuous from backwall to backwall, except for ¼-in. expansion joints at the ends of each span. At each end of the bridge (and for the track approaching the bridge at that end), 60-lb. rails continuous with the angle guard rails are spiked to the embankment ties. These rails meet at a frog point 150 ft. from the backwall.

The theory of this plan of deck is that in cases of derailment the flanges of the derailed wheels on the inside of the track will be carried by the guard angle, and the treads of the derailed wheels outside the track rail will be carried by the plank, and so prevent cutting of the ties. This deck is the design of Mr. E. C. Carter, Chief Engineer of the Chicago & Northwestern Ry. In two cases in which it has been called into service it has performed its work perfectly. It has now been in use on this railway for 18 years.

Fig. 6 gives a good idea of the appearance of the deck. Particular attention is called to this deck construction on account of the statement

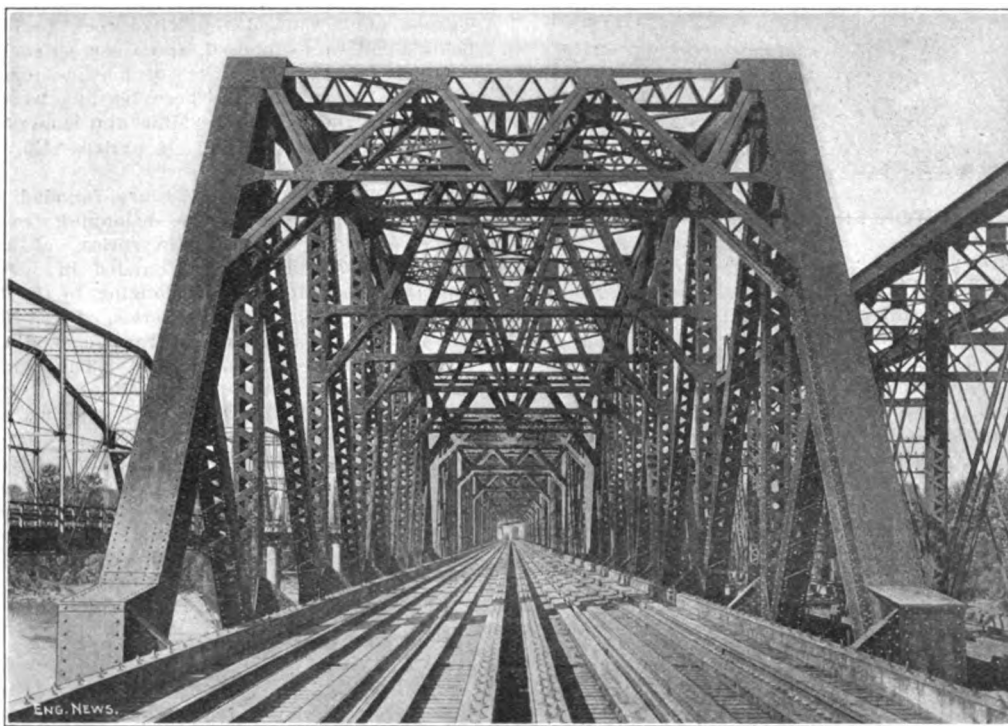


FIG. 6. END VIEW OF THE EAST CHANNEL SPANS (LOOKING WEST); SHOWING THE DECK CONSTRUCTION.

(On the right is the old single-track bridge. On the left is the high-level highway bridge.)

towed to place. At pier No. 26, as the new pier was put down on one side through the rip-rap of the old pier, considerable dredging was necessary to level the river bed. As the east side of the new pier No. 27 was sunk through the crib of the old protection pier, the west side of the new pier was supported on pillars made of bags filled with sand, to allow sufficient weight to be added to overcome the effect of the necessary air pressure and to carry on sinking.

Previous to sinking piers Nos. 25 and 26, considerable apprehension was felt as to the safety of the old piers during the sinking of the adjoining new piers. To obviate any trouble, single rows of United States interlocking steel sheet piling were driven in elliptical form around these piers to elevations believed to be 20 ft. below the bottom of the piling in pier No. 25 and 20 ft. below the crib in pier No. 26. The actual settlement experienced was slight, about 2 ins. at the south end of No. 25 and ¼-in. at the south end of No. 26.

The caissons were of the usual type of wooden deck caissons. Fig. 7 shows the details of the masonry and caisson for pier No. 26. Fig. 8 shows the same for the center pier, No. 27. Two blow pipes, one each near the upstream and downstream ends of the caisson, were used for forcing out all fine material. One Moran lock, located near the center of the caisson, handled

of the fixed spans and for a few bents of the east arm of the draw. River navigation closed for the season Nov. 15, 1908. Falsework in the east arm of the draw was started soon after, but was partly carried out on Dec. 3.

The draw span is being erected by means of a three-bent double-rail traveler, but it is the intention to put up the fixed spans with derrick cars. The estimated weight of the draw span is 2,225 tons; and of the entire west channel superstructure, 3,107 tons.

The draw will be operated by two 45-HP. electric motors operating the turning mechanism, and two 20-HP. motors (one at each end of the draw) operating the end lifts. Power will be furnished from a powerhouse located on the west bank. The prime movers will be two 50-HP. two-cylinder vertical Otto gasoline engines, working either directly through electric generators, or through the latter and a Westinghouse storage battery.

It is the intention to have the spans entirely finished, traffic turned over, and the old west channel spans removed before the opening of navigation in the spring of 1909. Traffic was turned over the new east channel and slough spans on Aug. 4, 1908, the turnout from the east channel spans of the new bridge to the west channel spans of the old bridge being on Little Rock Island.

made by the writer of an article on "Some Historic British Bridges" in Engineering News, Sept. 17, 1908. At the close of this article is the following:

Compared with it [the bridge-guard system] our American way of sending a train at 60 miles an hour across yawning chasms with nothing but the track rails to guard it from destruction is at least a contrast.

This is correct with two exceptions: (1) It is not customary on American railways to send trains across high viaducts or trestles at 60

deep bear on cast bed plates located on the caps of the cylinder piers. Fixed and expansion spans alternate. The fixed spans are riveted at both ends to the cross girders. The expansion spans are riveted at one end to the cross girder and at the other end bear on a casting carried by a suspension bracket, as shown in Fig. 9.

Fig. 9 shows also the arrangement of the section in the flange of the stringers, the idea being to provide a perfectly flat surface unobstructed

Of the east channel spans, span No. 1-15 (generally known as the "raft span"), 202 ft. 3¼ ins. long c. to c. of end pins, is the longest riveted fixed span on the Chicago & Northwestern Ry. The weight exclusive of deck is 565 tons. This span is shown in Fig. 5. It is 32 ft. wide c. to c. of trusses, 32 ft. deep c. to c. of chords at the hip suspender, and 42 ft. deep c. to c. of chords at the center. All connections are riveted, except the end connections with the

shoes. Expansion joints are provided for the track stringers at one of the panel points adjacent to the center of the span. There are seven panels of 28 ft. 10¼ ins. each.

The expansion joints are similar in construction to that shown in Fig. 9. Expansion joints in the stringers are provided to reduce lateral bending in the flanges of the floor beams, and also to reduce longitudinal stress in the stringers and their riveted connections due to the elongation of the span under moving load. It can be shown theoretically and has been proved by Prof. Turneure with extensometer experiments* that these stresses at times reach alarming proportions in spans of moderate length, when not provided against.

Fig. 10 shows the end floor beam and connection of the expansion shoe and rollers. Attention is called to the teeth provided at the ends of the rollers to prevent the latter from creeping. This device is believed to have originated in the engineering department of the Chicago & Northwestern Ry. It was first used eight years ago and has given uniform satisfaction. Since that time many other companies have adapted it.

Span 24-25 in the west channel, 182 ft. 5¼ ins. c. to c. of end pins, is similar in design to the 202-ft. span above noted.

The remaining spans in the east channel (with the exception of one 74-ft. deck plate girder span) are of the riveted lattice type. This type originated on the New York Central Ry. in 1859, as the work of Mr. Howard Carroll. For a great number of years it has been the accepted type of iron or steel truss on the Chicago &

Northwestern Ry. for spans of 150 ft. and under. The bridges have given very satisfactory service, although in the older designs the floor beams were badly constructed.

This type is somewhat heavier than riveted Pratt spans proportioned for the same specifications where there is ample distance between the base of rail and the required under clearance for through spans. It does not appear to pos-

*Journal of the Western Society of Engineers, December, 1907.

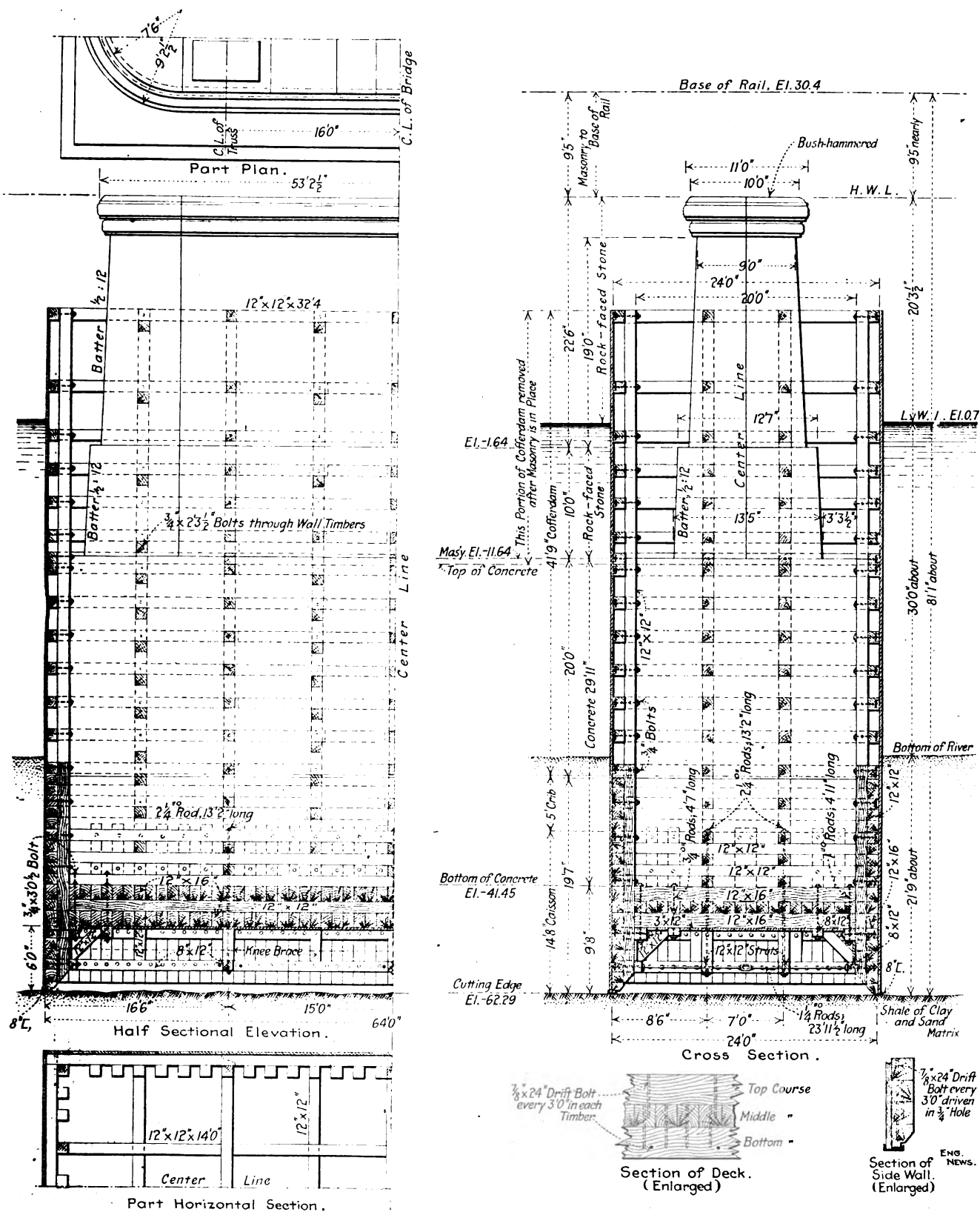


FIG. 7. CAISSON, COFFERDAM AND MASONRY FOR PIER NO. 26 (WEST CHANNEL) OF THE NEW CLINTON BRIDGE.

miles per hour; and this probably never happened except as a result of an accident, the speeds being usually limited to 20 miles per hour or less; (2) it is not customary to depend entirely on the track rail for protection, most railways providing inner and outer guards of more or less efficiency.

DETAILS OF THE STEEL SUPERSTRUCTURE.—In the girder spans across the slough, the cylinders are in pairs, those in each pair being 19 ft. 6 ins. c. to c. Cross girders 66 ins.

by rivets or cover plates for the bearing of the track ties. As the ties are not dapped over the flanges of the girders this arrangement allows any defective tie to be removed without disturbing the track rail. This design is due to Mr. W. H. Finley, Assistant Chief Engineer, and was used first by him when Engineer of Bridges of this railway about 15 years ago. It has since been used in all deck girders requiring greater sections than two angles can furnish, and it is rapidly growing in general favor.

sess any advantages over the latter system under such conditions. But where the clearance is limited, necessitating short panels and shallow stringers and floor beams, the riveted lattice spans are both economical and satisfactory. This is a fact which most designers have overlooked. The end connections with the shoes of these spans are pin bearings and the design of the roller bearings is similar to that shown in Fig. 10.

Fig. 4 shows the riveted lattice spans over the east channel. Span 24-25, in the west channel, is identical in design and construction with the east channel spans of the same length. The last span of the west channel is a plate-girder span of 52 ft. 10 ins., and is similar in construction to the plate girders of the slough spans, described above.

girders of the drum are arranged in the form of a square, with additional girders in the inner corners of the square so as to form an octagon. A circular tread is bolted to these outer girders. To the longitudinal outer girders of the drum are riveted a pair of cross girders bearing on a center which turns upon a lenticular bronze disk. Upon the completion of the span, half of the entire dead weight will be transferred to this center by means of hydraulic jacks, the weight transferred being measured by gages on the jacks. The remaining load will be carried by a live ring of wheels.

Test Borings for Foundations.

For the test borings at this bridge, a Sullivan diamond drill with 2-in. core bits was used. This

more serviceable. The tripod consisted of three pieces of Douglas fir 5 x 8 ins. and 32 ft. long. An 8-in. wrought-iron pipe, near the center of the scow, and bolted with a pipe flange to the bottom of the scow, made a well for passing the 4½-in. standpipe and the 3-in. casing.

The materials encountered were in order as follows: Recent alluvial sands; glacial drift of gravel, sand and boulders; a shale consisting of sand with a clay matrix, and finally limestone bed rock. The upper stratum of bed rock was identified by fossils and general appearance as belonging to the Gower stage of the Niagara series of silurian rocks. This overlaid rock conformably of the Delaware stage of the same series. In the middle of the river the Gower rock and nearly 50 ft. of the Delaware rock had been entirely eroded.

Great care was taken to ascertain the possible existence of subterranean pockets or overhanging cliffs in the rock. Only two of these pockets were found (both

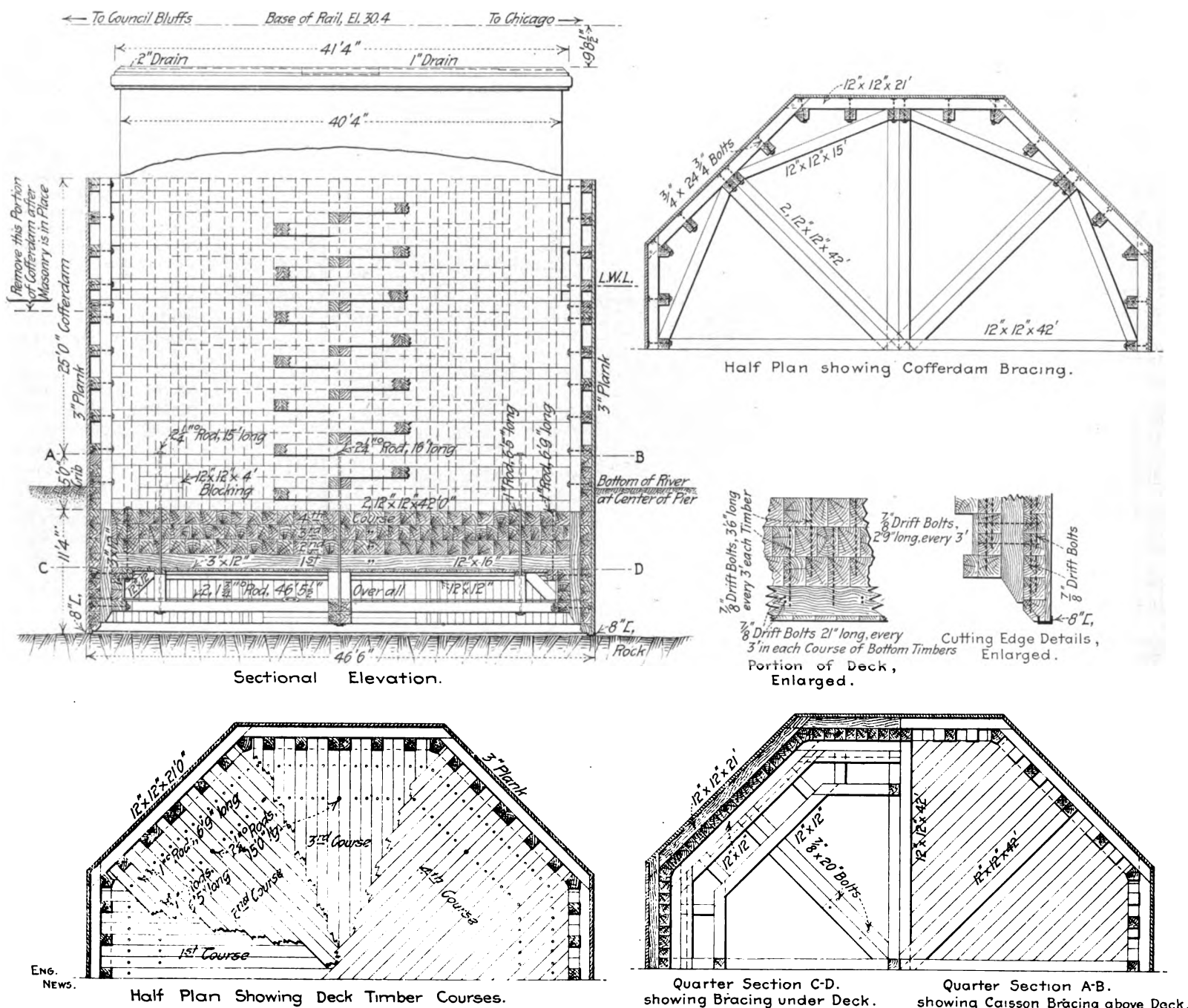


FIG. 8. CAISSON, COFFERDAM AND MASONRY FOR THE CENTER PIER OF THE DRAW SPAN (WEST CHANNEL) OF THE NEW CLINTON BRIDGE; CHICAGO & NORTHWESTERN RY.

DRAW SPAN.—The design of the swing span (460 ft. c. to c. of end floor beams) is governed by the limited clearance between the elevation of the high water line and that of the base of rail. This clearance is 9.4 ft., and it is limited by three conditions: (1) a grade crossing with the Chicago, Milwaukee & St. Paul Ry., about 400 ft. west of the bridge; (2) connections with the Chicago, Burlington & Quincy Ry., in Clinton, adjacent to the west end of the bridge, and (3) a grade crossing of 2d St. in Clinton.

To avoid the questionable expedients of double drums, or an entire center bearing, the weight of each truss is carried to the drum by four posts arranged in pairs, as shown in Fig. 3. The

worked in a 4½-in. standpipe and 3-in. casing, both of which had flush joints. This equipment had been used previously at the Missouri River bridge of the Chicago & Northwestern Ry. at Pierre, So. Dak. From the article by Mr. Bainbridge, and mentioned above, in his reference to this part of the work we take the following particulars.

The same apparatus, tools, piping, etc., were used as at Pierre, but the manner of working and the materials encountered were essentially different. These borings were started in April, 1908, and it became necessary to mount the drill on a scow. The scow was 15 ft. wide, 32 ft. long on the bottom and 37 ft. long on top. Experience in rough water showed that a scow 10 ft. longer on top with somewhat more rake to the ends would have been

in the same boring), and these were only 1 in. and 6 ins. in depth. Both were filled with sand consisting of about equal parts of quartz and dolomite sand. Some of the borings were carried down 30 to 40 ft. into the bed rock to determine the possible existence of these subterranean pockets.

All the boulders encountered were such as could easily be broken with the chopping bit and no dynamite was found necessary. To determine the consistency of the shale, cores were taken out with saw tooth bits working dry, showing perfectly the consistency of the material. The saw tooth bit or the chopping bit working with the pump gave no idea of what this material was, and without the expedient of the dry core an excellent foundation would have been overlooked and a foundation sought 30 ft. lower.

Borings in the limestone were made with a bortz

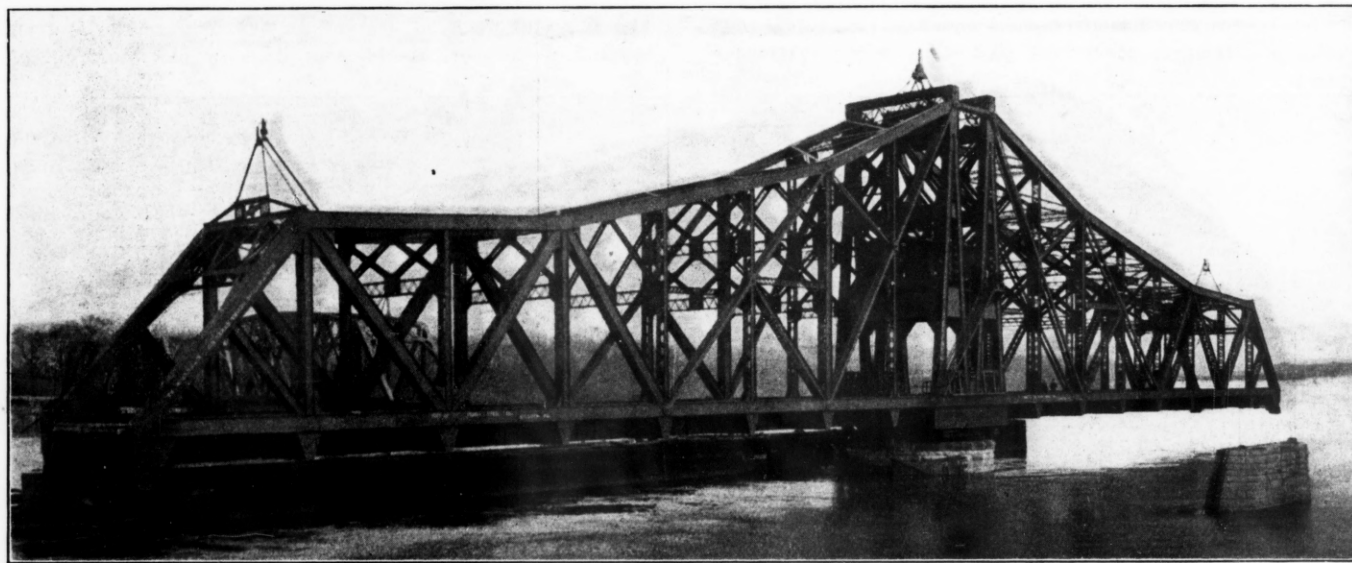
THE CLINTON BRIDGE OF THE CHICAGO & NORTH WESTERN.

The new double-track bridge of the Chicago & North Western over the Mississippi river at Clinton, Iowa, has a total length of 4,200 ft., was two years in building, the authority for expenditure having been issued March 21, 1907, and the contracts let the following May.

The Clinton crossing, which was the second bridge to be built across the Mississippi, has an interesting history. The first Clinton bridge was built in 1859 and 1864. As shown by the map and the elevation of the bridge herewith, the river has two channels at this point, the east and the west, separated by Little Rock and Willow islands. The original cross-

center posts, turntable and end posts of the swing span were cast iron, the top chord two 12-in. channels with 12½-in. cover plates top and bottom, and the bottom chord two 6-in. channels with 12-in. cover plates top and bottom. The abutments and piers in the west channel were cut stone and are still in good condition. All of the spans over both channels were renewed from one to three times, the easterly McCallum truss span, for example, being replaced by a 200-ft. pin-connected Pratt truss span in 1869, and heavier spans of similar pattern being substituted again in 1881 and 1898 respectively, making three renewals. The draw span was renewed in 1887, and important repairs made to it in 1901.

As shown by the map herewith, the new bridge was built 40 ft. south of and parallel to the old bridge. This map also



Clinton Bridge; 460-ft. Swing Span.

ing of the east channel was built in 1858-9 by the Chicago, Iowa & Nebraska Ry., which connected with the Chicago & Galena Union Ry., the parent line of the North Western system, by a line of 2½ miles up the east bank of the river to Fulton, Ill. Service over the west channel, which, although the narrower, is much the deeper and more important of the two, was maintained by a car ferry. The Chicago, Iowa & Nebraska was leased by the Chicago & Galena Union in 1862, and the west channel was bridged two years later. This first crossing had all wooden spans, except the draw span. The east channel portion was made up of McCallum trusses resting on cut stone piers on a foundation of piling capped with a wooden grillage. The west channel fixed spans were Howe trusses and the swing span was of the Bollman pattern. The

shows the location of the high-level highway bridge, seen in some of the photographic views, which crosses over the level of the railway bridge on Little Rock island. All elevations shown on the drawings are from the U. S. Engineers' datum plane, the extreme observed low water elevation being 0.7 ft., and extreme high water 21 ft. above this plane.

The new crossing has three separate steel structures, separated by embankments. The easterly structure is over a slough and is 550 ft. long. In the old bridge this slough was crossed by a pile trestle 1,390 ft. long, which formed the approach to the east channel section. The bed of the slough at the surface is muck a few feet down, below which is sand. There is little or no flow of water below a stage of 10, and standing timber at the head of the slough prevents drift or



West Channel Spans.

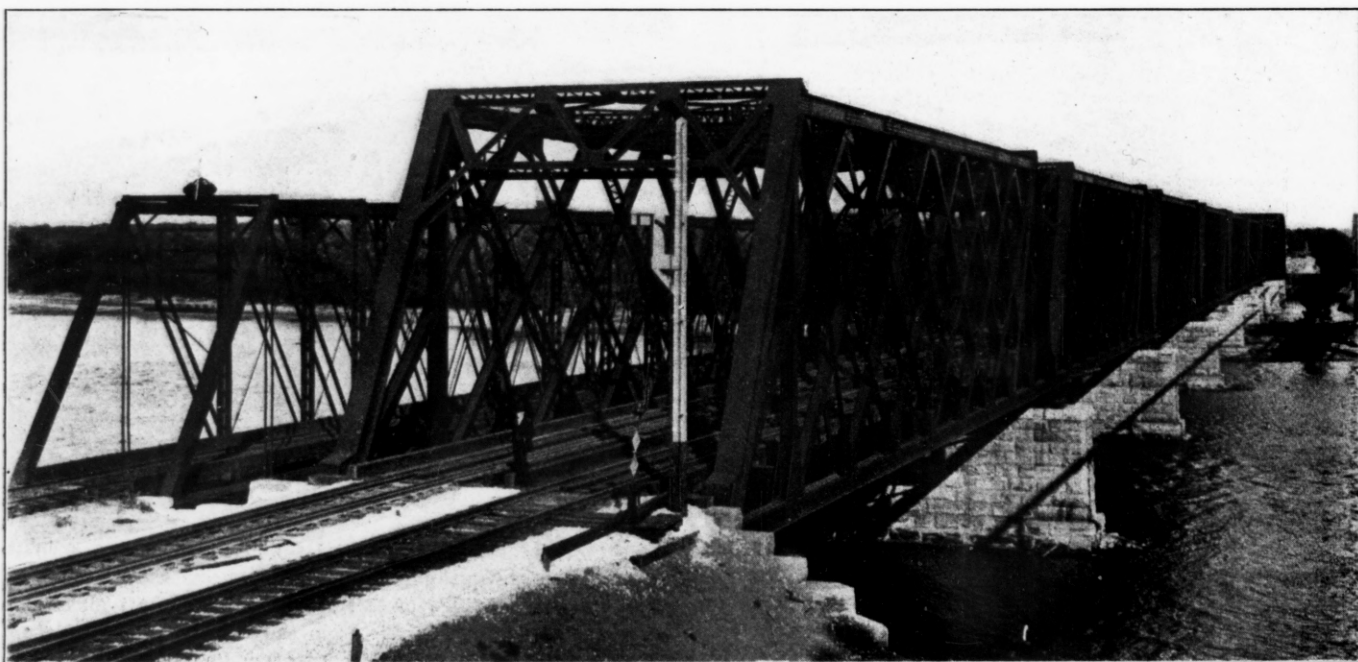
ice from being carried through. The bridge consists of 11 double-track plate girder deck spans carried by Cushing cylinder piers on piling. There are 15 to 18 piles to each cylinder, averaging 28 ft. long. The cylinders are 8 ft. in diameter, made of $\frac{3}{8}$ -in. plates, and capped with white sandstone. The abutments are red rock sandstone on concrete footings supported on piling. The superstructure of plate girders and cross girders was completed in July, 1908.

Between the slough spans and the east channel spans is a sand embankment 778 ft. long, made by a hydraulic dredge from the east channel. It has an average height of 18 ft. and contains 40,700 cu. yds. The embankment between the east and west channel spans, across Little Rock island, was made in the same way and contains about 10,100 cu. yds.

All piers and abutments of the east channel spans are built of dimension stone masonry, and all rest on piling except the westerly abutment, which was carried to rock. The seven

to adopt methods in building the former which would disturb the old piers as little as possible. The old bridge was carrying a traffic amounting at times to 150 train movements in 24 hours and it was absolutely necessary, of course, that there should be no interruption to this traffic. All of the piers but one were founded in open cofferdams, the exception being due to the presence in the river bed of the wreckage of a span of the adjacent steel highway bridge, blown there by a heavy wind some years ago. As it would have been necessary to remove this span before steel sheet piling could be driven, piles were cut off under water with a rotary saw and an open caisson landed on them.

While some settlement of the old piers occurred, in only one instance did the vibration from driving steel sheet piling cause settlement serious enough to require extreme precautions. This was pier 16. To prevent an inflow of material from around the old pier, the piles of the new pier were cut off



East Channel Spans, Looking East. Old Bridge on the Left.

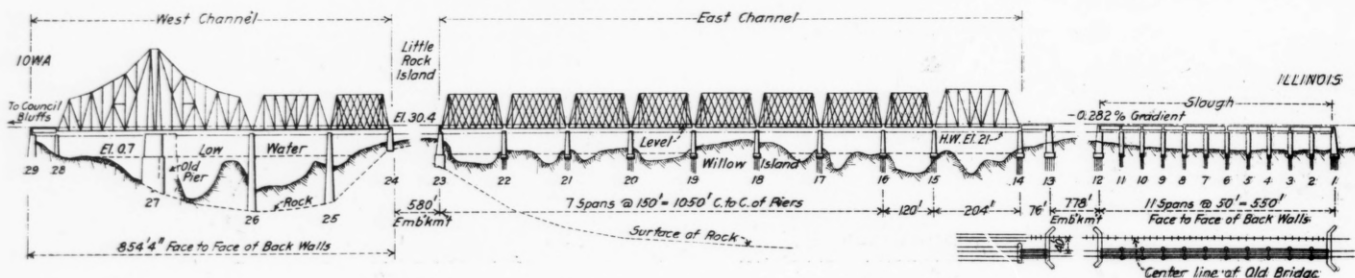
westerly spans of the new bridge are the same length as the old, bringing the piers of the two opposite to each other. The riprap around the old piers, which gave a ground line for the new varying from above low water at the upstream end to a depth of 20 ft. or more at the downstream end in some instances, caused a variation in the method of founding the piers. Where the ground surface over the area of the footing averaged only a few feet below the water level, the concrete footing was deposited directly on the piling. Where the water was deep on the downstream side the piles were completely surrounded with riprap to obtain a level bottom, upon which a timber crib was lowered. The first plan was used on piers 13, 14, 16, 18 and 19, and the second on the remainder.

The proximity of the new piers to the old made it necessary

at 11 ft. below low water and a part of the concrete footing deposited through a tremie pipe before pumping out the cofferdam.

For handling material for the substructure a temporary double-track pile trestle was built. It has 16-ft. spans, five piles to the bent and caps 28 ft. long. A stiff-leg derrick was set up on piling at each pier, but as far as possible the material was handled by a Brown hoist crane or a derrick car. The east channel structure was begun July 3, 1907, and finished March 14, 1908.

The substructure is composed of ten spans as follows, beginning with the east end: 74-ft. deck plate girder; through riveted Pratt truss span, 202 ft. $3\frac{1}{4}$ in.; through riveted lattice truss span, 115 ft. $7\frac{3}{4}$ in.; and seven through riveted



Elevation of Clinton Bridge; Chicago & North Western.

lattice truss spans of 146 ft. 5½ in. A general view of this portion of the crossing is given in the illustrations. The Pratt truss span which is of unusual length for a riveted span, is the longest riveted fixed span on the North Western. The steel work was erected from the falsework described in the previous paragraph without change. The stringers on the falsework were at the proper elevation to have the steel floor beams and stringers blocked up on them at their final level. These members would be laid complete for a span and the trusses then erected in position, supported by the floor beams, the falsework not being wide enough to support them directly. Balance in weight was maintained as nearly as possible by putting up opposite members of the two trusses consecutively. The work was done with a derrick car. It was begun January 27, 1908 and the last of the falsework was removed July 14, 1908.

The west channel, which, as already mentioned, is the



Detail View of Draw Span at Center Pier.

the pneumatic process. Prior to putting down the first two, to minimize disturbance to the adjacent piers of the old bridge a single row of steel sheet piling was driven around each pier to what was thought to be safe depths. Only slight settlement occurred, the maximum being 2 in. at the south end of No. 25. In sinking the caisson for the center pier (No. 27), the east side had to pass through the crib of the old protection pier, while the opposite side was over deep water. This side was supported by a pyramid of sand bags on the river bottom and the air pressure kept carefully adjusted by a gage so as to preserve the proper balance as the caisson went down. Failure thus to maintain the equilibrium before the bed of the river was reached would have resulted disastrously, causing a serious displacement of the caisson. Details of the center pier caisson are shown in the illustrations. The west channel piers and abutments are cut stone masonry.

The superstructure contains four spans: one through riveted lattice span, 146 ft. 5½ in.; one through riveted Pratt span, 182 ft. 5½ in.; one through pin-connected swing span, 460 ft. c. to c. of end floor beams; one deck plate girder span,



West Portal of Draw Span.

deeper and therefore the main channel of the stream, is 600 ft. wide at low water and 850 ft. at high water. As shown on the map, there are two government dams in the river between the east and west channels, built in 1891—one between Little Rock and Willow islands (the latter island is below high water) and the other extending westwardly from the upper end of Willow island. They are built of riprap and brush, extending 2 to 3 ft. above low water, and were designed to increase the flow in the west channel to scour away bars which had formed below the bridge. The map also shows a floating sheer-boom in this channel extending from the draw span protection pier to a point on the west bank about 1,000 ft. above the bridge. There is a strong set of the current from the east towards the west bank in this channel. For this reason timber and log rafts passing down the river use the east channel, except at low stages of water.

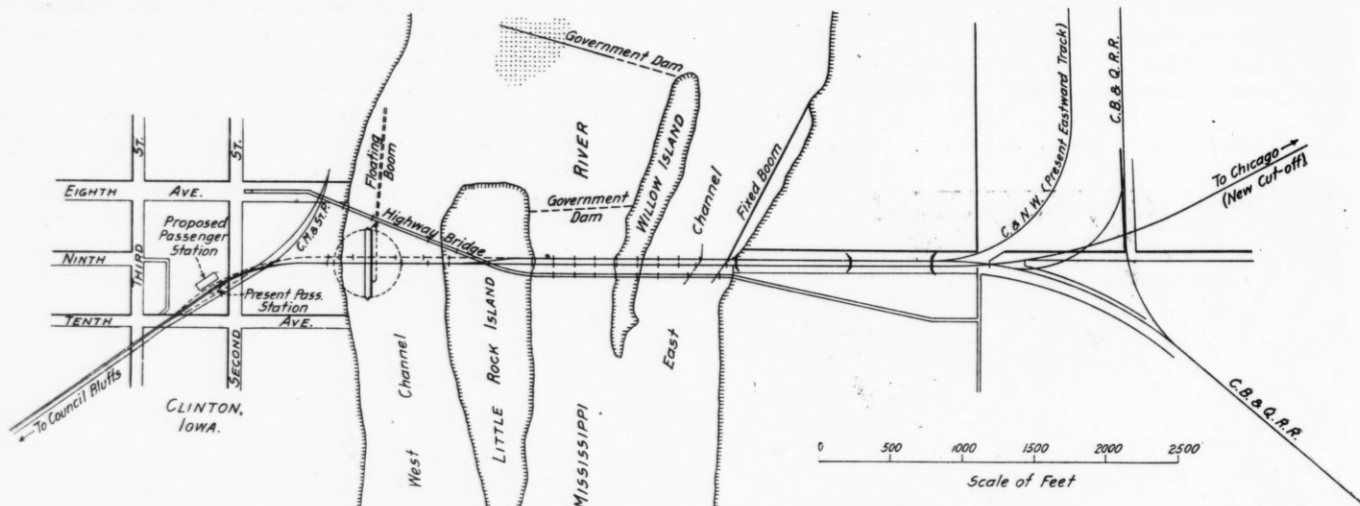
The new piers in the west channel are carried down to rock or other firm strata to avoid all danger from scour. Nos. 25 and 27 are on rock and 26 rests on hardened strata of sand and clay. The two abutments and pier 28 were built in open cofferdams, and piers Nos. 25, 26 and 27 were put down by

52 ft. 7½ in. A temporary wooden pile trestle had been put in for handling the substructure materials, as for the east channel spans, and the fixed spans were erected on this with a derrick car as with the previous spans. The draw span was erected by means of a three-bent double-rail traveler. The work of raising this traveler was begun October 28, 1908. By December 12 the center of the draw span was all in and riveted up and the west arm erected complete. Navigation closed November 15 and the contractors were then free to proceed with the east arm of the draw.

The design of this draw span is worthy of special note, due to the fact that it was governed by a clearance of only 9.4 ft. between highwater line and base of rail. This condition was imposed by, (1) a grade crossing with the Chicago, Milwaukee & St. Paul Ry., about 400 ft. west of the bridge; (2) connections with the Chicago, Burlington & Quincy Ry., adjacent to the west end of the bridge, and (3) a grade crossing of Second street, Clinton. The resident engineer in charge of the construction of the bridge describes the design as follows: "To avoid the questionable expedients of double drums, or an entire center bearing, the weight of each truss

is carried to the drum by four posts arranged in pairs. The girders of the drum are arranged in the form of a square, with additional girders in the inner corners of the square so as to form an octagon. A circular tread is bolted to these outer girders. To the longitudinal outer girders of the drum are riveted a pair of cross girders bearing upon a center which turns upon a lenticular bronze disk. Upon the completion of the span, half of the entire dead weight was transferred to this center by means of hydraulic jacks, the weight transferred being measured by gages on the jacks, and the remaining load is carried by the live ring of wheels."

are located in the operator's house, have change gears for reducing the speed one-half. With the slow speed gearing and one motor, the bridge can be swung with only one engine. For centering and locking the span, air-operated plungers are used at each end, controlled by a four-way valve interlocked with the motor controllers. Air at 90 lbs. is furnished by a 10-h.p. motor-driven air compressor for centering, braking motors when coasting to final position and blowing whistle signals. The end-lift motors are controlled by automatic switches at the ends of the span, which stop the motors independently of the operator at either end of travel by open-



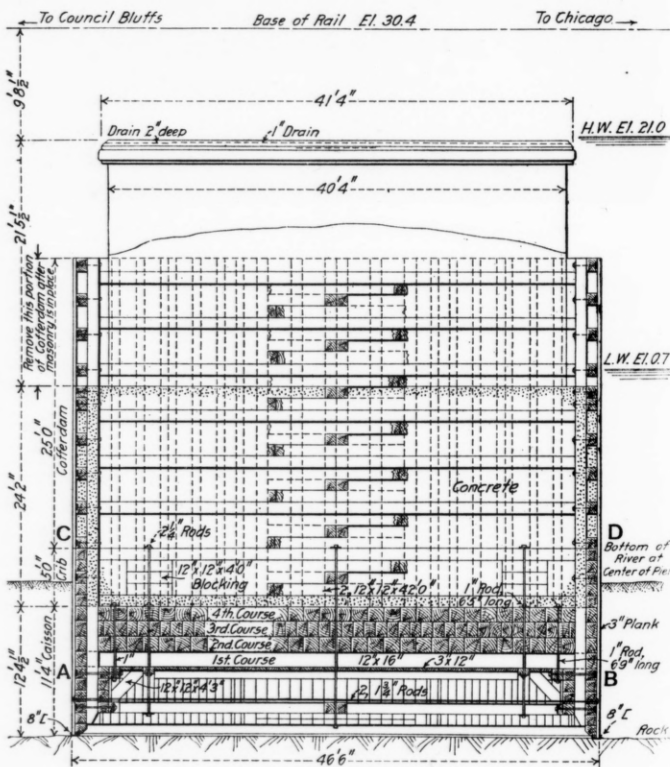
Map Showing Bridge Site and Vicinity.

A departure from previous practice has been adopted in the power installation for moving the swing span, in that the prime mover is located on the adjacent west shore instead of on the bridge. The reason is twofold: First, the size of the engines and their accessories, and, second, to free the span of the vibration which high speed gas engines cause when mounted on the structure. Another feature which determined the land location was the installation in the power plant of a large storage battery. The power house is brick and is 400 ft. from the center pier. As the bridge is swung from the batteries, and only in case of emergency from the engines, the latter are smaller than would otherwise be installed, since they are used ordinarily for charging the batteries only. They are twin cylinder, vertical 50 h.p. Otto gasoline engines, running at 360 r.p.m., direct-connected to Western Electric 300-volt 30-k.w. d.c. generators. The liability of shut-down is minimized through the following electrical combinations on the switchboard: From storage battery; from both engines working in parallel; from either engine separately; from either engine and battery in parallel. As the power may be used for other purposes than swinging the draw, meters are provided on each feeder leaving the switchboard, enabling accurate records to be obtained at all times. The storage battery contains 120 cells, having a total capacity of 640 ampere hours. The cycle of operations from the releasing of the motor controller levers to a full open draw is $1\frac{1}{2}$ minutes, or 15 seconds for lowering the ends and $1\frac{1}{4}$ minutes for the swing. The battery has capacity for 16 swings at this speed and 8 additional swings at somewhat reduced speed, or 24 swings in all. The signals and derrails and the different lights are operated from the battery.

Connection from the power house to the switchboard in the operator's house on the bridge is by means of a submarine cable sunk in the bed of the river. With the draw swinging 90 deg. either way and back, no pivot switch is used, the connection being through a flexible cable. The bridge is swung by two 50-h.p. street railway motors in parallel, and a 20-h.p. motor works each end lift. The swing motors, which

ing the circuit on the distributing board. Indicating lights on the switchboard show the operator when the plungers are in or out, when the ends of the span are raised or lowered, and when the bridge is full opened or nearly closed.

The end lift mechanism is the eccentric rocker type, first used on the Sabula bridge of the Chicago, Milwaukee & St. Paul by C. Shaler Smith nearly 30 years ago. It is the



Sectional Elevation.

Details of Center Pier for Draw Span.

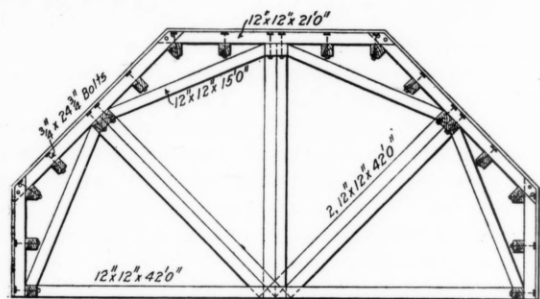
standard arrangement on the C. M. & St. P., but this is the first time it has been used on the North Western. It is thought that for a draw of this length and weight some advantage in time, and a multiplication of power in lifting the ends, might be obtained by substituting eccentric gears for the circular gears on the rocker shaft. It is estimated that a multiplication in power of about $2\frac{1}{2}$ times could be obtained, and it is possible that this change in the present arrangement may be made later.

The steel superstructure of the bridge throughout is designed for Cooper's E-50 loading for each track. The weight of the deck is assumed at 550 lbs. per foot of track. Impact for moving load stresses is added according to the Pritchard formulas, (1) for stresses resulting from load on one track; (2) for stresses resulting from load on two tracks. The trusses are spaced 32 ft. c. to c., which is wider than ordinary, the purpose being to allow derailed cars to reach the guard timbers without striking the trusses. The minimum lateral

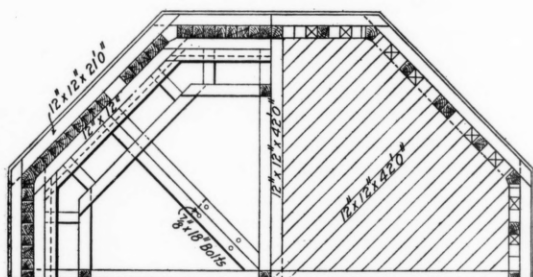
to every fourth tie with a track spike. Outside the rail, 4 in. from the inside flange, is another 4-in. x 10-in. plank, similarly spiked to the ties. In cases of derailment the wheels inside the track are carried by the guard angle and the treads of those outside ride the plank, saving the ties. To prevent rail creeping, "L. & S." anti-creepers are used freely, there being two with the traffic and one against it for each 16-ft. panel.

The weights of steel in the superstructure of the different sections of the crossing are as follows: Slough spans, 5,694 tons; east channel spans, 3,214 tons; west channel spans, 3,107 tons; the swing span weighing 2,200 tons. The design and construction of the bridge were done under the direction of E. C. Carter, chief engineer; W. H. Finley, assistant chief engineer, and I. F. Stern, engineer of bridges of the Chicago & North Western. F. H. Bainbridge was resident engineer in charge of the work, and H. M. Spahr, assistant engineer. The contract for the substructure was let to the Foundation Company, New York; for furnishing and erecting the east channel and slough spans, to the Wisconsin Bridge & Iron Co., Milwaukee, Wis.; for furnishing and erecting the west channel spans, to the Pennsylvania Steel Co., Steelton, Pa. The last named sub-let the work of erection to the Missouri Valley Bridge & Iron Co., Leavenworth, Kan.

Besides the main line traffic of the North Western on its

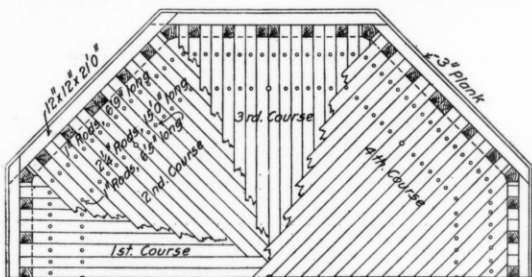


Half Plan Showing Cofferdam Bracing.



Section A-B Showing Bracing Under Deck.

Section C-D Showing Caisson Bracing above Deck.

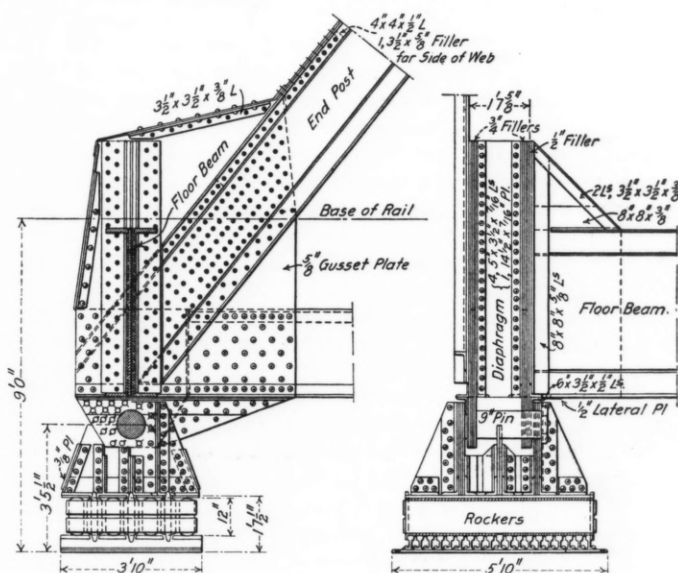


Half Plan Showing Deck Timber Courses.

Caisson and Cofferdam.

clearance for trains is 8 ft. from center line of track, and the vertical clearance is 22 ft. 6 in. from base of rail. The tracks are 13 ft. c. to c.

The deck construction, which may be seen in the portal view, follows the standard type of the North Western. The ties are long leaf pine, 8 in. x 8 in., surfaced to uniform thickness of $7\frac{3}{4}$ in., and 12 ft. long. There is a 10-in. x 12-in. outer guard timber at each end of the ties, laid on edge, dapped 1 in. over the ties, and fastened to each with a $\frac{3}{4}$ -in. bolt. Inside each rail, with the outside of the vertical leg $9\frac{1}{2}$ in. from the inner flange of the rail is a 6-in. x 4-in. x $\frac{1}{2}$ -in. angle, with the 6-in. leg on the ties. Backing up this angle is a 4-in. x 10-in. plank laid flat and spiked to each tie. The end is attached to this plank by $\frac{1}{2}$ -in. screws, 4 in. long, and



Detail of Expansion Bearing for 202-ft. Span.

Chicago-Omaha line, the bridge is used by the Chicago, Rock Island & Pacific for freight transfer, and by the Chicago, Burlington & Quincy for its lines from Clinton, Iowa, to Mendota, Ill., and to Savanna, Ill. This traffic is included in the total train movements mentioned earlier in the article.

The west channel spans of the old bridge have been removed. It was the intention at first to retain the east channel portion as a third track, but it was decided later that this would not be desirable and these spans also will be removed.

In connection with the bridge work and other improvements to be made at and in the vicinity of Clinton, a cut-off for through trains is being built on the Illinois side of the river. The location at this point was mentioned in the beginning of the article in referring to the connection between the Chicago, Iowa & Nebraska and the Chicago & Galena Union, a line $2\frac{1}{2}$ miles long up the east bank of the river to Fulton. This right-angled location has been maintained up to the present. The new cut-off forms the hypotenuse of the triangle of which the old line is the other two sides. It is 4.95 miles long and shortens the distance 1.2 miles. All through trains will use it, leaving five trains a day each way over the old line through Fulton.