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THE EIGHT-TRACK BASCULE BRIDGE AT CAMPBELL AVENUE, CHICAGO.

Messrs. C. R. Dart and S. T. Smetters, Members W. S. E.

Presented December 8, 1909.

The Main Drainage Channel of The Sanitary District of Chicago is crossed by the Pittsburg, Cincinnati, Chicago and St. Louis Railway, the Chicago Terminal Transfer Railroad, and the Chicago Junction Railway at Campbell Avenue, near 31st Street, Chicago. The first named, and most westerly road, has four tracks at this point, and the second, lying next easterly, and the third or most easterly, have two tracks each, making a total of eight tracks crossing the channel. From this is derived the name of the structure,

THE EIGHT-TRACK BRIDGE.

The Illinois state laws affecting the Sanitary District provide that bridges over the Main Channel may be fixed spans for a certain length of time, but after the expiration of this period of time, all shall be made movable to permit navigation in the channel. When the channel was opened there were thirteen highway and railroad bridges crossing it, twelve of which were of the swinging type, except that the operating machinery had not been installed. An eight-track *swing span* was also originally designed for the eight-track bridge but was unsatisfactory to the railroad companies interested. After advertising for competitive plans, the design submitted by the Scherzer Rolling Lift Bridge Co. was adopted and the construction of the bridge was completed in the year 1900.

The eight-track bridge is really not *one* but actually consists of *four* double-track bridges lying parallel and closely adjacent to each other, each double-track bridge being to all intents and purposes an independent structure excepting that the piers and abutments are continuous under all the bridges. The P. C. C. & St. L. Ry. Co. operates over the two westerly bridges (Spans Nos. 3 and No. 4), the C. T. T. R. R. Co. uses the next easterly bridge (Span No. 2), and the east bridge (Span No. 1) is used by the Chicago Junction Ry. Co. Each company uses *only* its own bridge or bridges and has nothing whatever to do, up to the present time, with the remainder of the structure.

Each double-track bridge, as completed in 1900, consisted of three spans,—a channel-span resting at each end upon a broad pier, and an approach-span, extending from each pier to an abutment,—each connected with the channel-span over the piers by two panels of stringers supported by a steel bent on the pier masonry. This is shown in Fig. 1 from a photograph and before any work for the new bridge was begun.

The approach-spans are each double-track riveted deck-spans

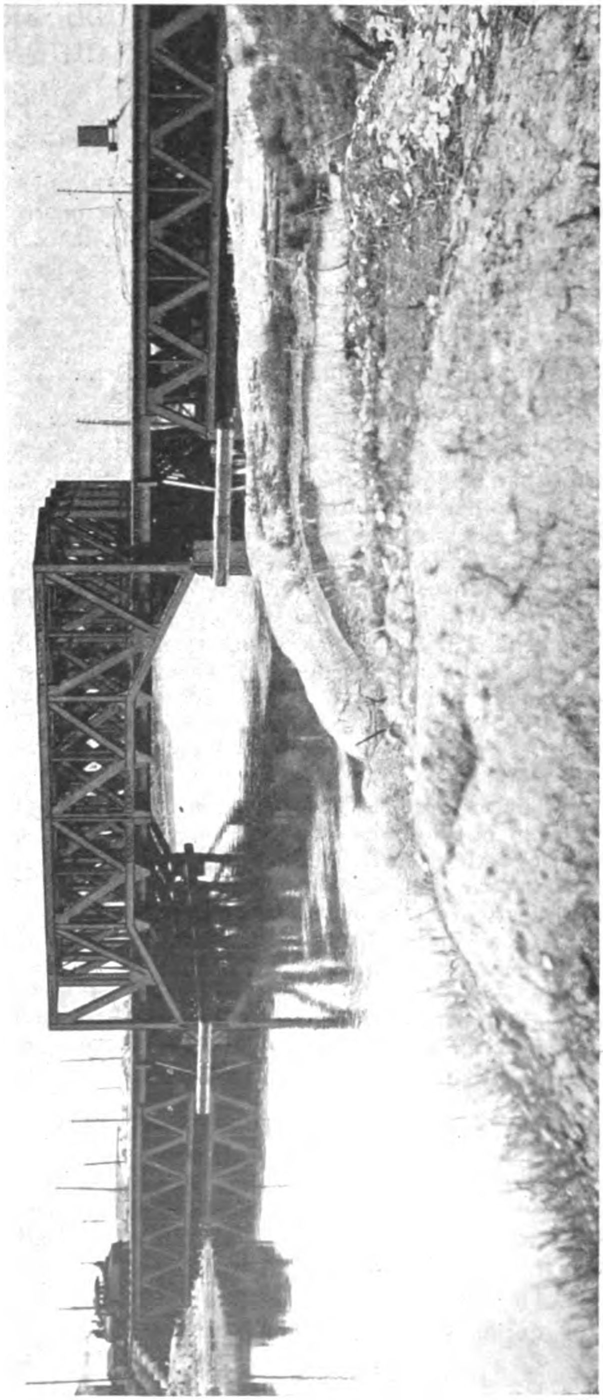


Fig. 1. Old Eight-Track Bridge Across Main Channel.

about 100 ft. in length, centers of end bearings, with the expansion ends on the abutments. The lower chords of these spans are close to the water line.

The channel-span of each bridge was designed to be a double leaf Scherzer Rolling Lift Bridge, but since, under the Sanitary District law, the operation of the bridge was not required for several years, the segmental, or rocker girders, the counterweight, and the track-girders upon which the leaves were to roll, were omitted, as was also all operating machinery. That is, there was constructed only that part of each channel-span *between* the end bearings and *over* the channel, the heel of each leaf or that part over the piers back of the main bearings being omitted. Each channel-span then was a three-hinged arch having one pin at the intersection of the lower chord and end post over each pier, and a pin at the center of the span in the center line of the upper chord. The distance between centers of end pins was 150 ft., each leaf being 75 ft. long.

Connecting the end floor-beam of each leaf with the end floor-beam of each approach-span were two panels of steel stringers supported by a steel bent resting on the center of the pier, as heretofore mentioned. These stringers and bent were intended to be temporary only and to be removed when the leaves were completed by the addition of track-girders, segmental-girders, counterweight, machinery, etc.

In Fig. 2 is shown the original bridges with the track, segmental girders, and operating struts in position as they would have been had they been equipped as movable spans. The illustration shows the general dimensions of channel and approach spans, waterway, clearances, masonry, etc., with the general arrangement of the spans and the railroads operating over each.

The bridge crosses the channel at an angle of 68° 20′ between center-lines. Since bascule, or rolling lift, double-leaf bridges cannot readily be built on a skew, it was necessary to offset them to conform with the angle of crossing. Each span is therefore set 12½ ft. south of the preceding span, going westerly, which 12½ ft. is the departure from a right angle in 31½ ft.—the distance between centers of spans. Because of the skew of the crossing the right angle width of channel in clear between the piers is but 120 ft., although the leaves are 150 ft. long, centers of end pins.

The original bridge was designed in accordance with the Standard Specifications of the Pennsylvania Lines West of Pittsburg for 1897, with unit-stresses increased for use of steel. The assumed live load was a uniform moving load of 5,000 lbs. per lineal foot of track with a single load of 50,000 lbs. concentrated at any point on each track. This concentrated load was increased 50% for floor and web member connections. The unit-stresses allowed were 9,000 lbs. in tension and 9,000 lbs., reduced by straight line formula, in compression, both modified by the usual maximum and minimum formula. Shearing and bearing for shop rivets 5,500 lbs., and 11,000 lbs., field rivets 4,500 lbs., and 9,000 lbs., all modified by the maximum and minimum formula. The cost of the substructure of the bridge was about $330,000, and of the entire superstructure approximately $250,000—a total of $580,000 for construction only, including care of traffic and other miscellaneous expense.

Pursuant to the law requiring the structure to be made movable, the Sanitary District in 1907 prepared plans and specifications for completing the movable leaves, including track-girders and anchorage and equipping the leaves with operating machinery. The anchorage was not necessary for live load on the leaves, as they would still act as three-hinged arches under train loads, but was required to prevent any leaf being pushed forward into the channel when the opposing leaf was not in closed position. The shock from the leaf being stopped by the anchorage was to be taken up by an oil-buffer attached to each anchor. There was to be one anchor near the heel of each truss.

The operating machinery in this design was to be placed on a framework located over the tracks on the approach-span at the rear of each leaf, with a long operating strut-rack connecting with the leaf. The power was to be direct-current electricity. One operator on each side of the channel at diagonally opposite corners of the structure was to operate either the four leaves on his side of the channel or two entire bridges nearest to his house, as might be considered most advisable. The specifications for the electrical equipment were not prepared and this work was to be included in another contract.

When the plans were fully completed an estimate was made of the approximate cost, and it was found that in all probability it would be so great that entirely new single-leaf channel-spans could be built for a comparatively small increase in cost and which would be up-to-date bascule or rolling lift bridges, much simpler in operation, and which would act as simple spans when closed. The double-leaf spans required two sets of machinery, four segmental-girders, four track-girders, four anchorages for each span, and an expensive center-lock in each truss to insure that the leaves would engage properly when closing. With single leaves, the number of segmental-girders, track-girders and sets of machinery could be reduced one-half, and all anchorage and center-locks dispensed with, since the single leaf comes down to a bearing on the far abutment, and, after latching, is ready for train service.

There is no doubt that single leaves are preferable to double leaves for railroad bridges and would be most satisfactory to all parties concerned. The old bridge was already ten years old, would still be ten years old when equipped to operate, and was designed for a loading somewhat less than the modern standard and with higher assumed unit-stresses.

In view of these facts, and that, due to the probable longer life of new single leaves, their ultimate cost would be less than the equipment of the old bridge, it was recommended that a new design be made for single-leaf spans.

This was done, bids were received on both the double-leaf and the single-leaf designs, and the contract was let on the latter plan in September, 1908. The new single-leaf spans of the present structure are illustrated in Fig. 3.

The loading used in the new design was in accordance with the Standard Specifications for the Pennsylvania Lines West of Pittsburgh for 1906, namely, 5,000 lbs. per lineal foot of track and a single concentrated load of 60,000 lbs. on each track, the concentrated load increased 50% for floor-beam and web-member connection. The unit-stresses were 7,000 lbs. for tension, 7,000 lbs. (reduced by the straight line formula) for compression, both modified by the usual maximum and minimum formula. Rivet shear, 75% of the allowable unit-stress in the member, and reduced 20% for field rivets.

The two main piers, upon which the leaves of the old bridge were to roll, were not of sufficient width from front to back to take the longer track-girders of the single leaves, and it became necessary to provide a rear support for one track-girder of each new leaf. Four 9 ft. cylinders were provided for this purpose, two behind each main pier, one for each leaf, to be sunk to solid rock.

In Fig. 7 is shown the method of sinking the cylinders and placing the concrete. The Moran lock and the pig iron for weighting down the cylinders are in position. The pig iron was on the site to be used later in the counterweight for the adjustment of the

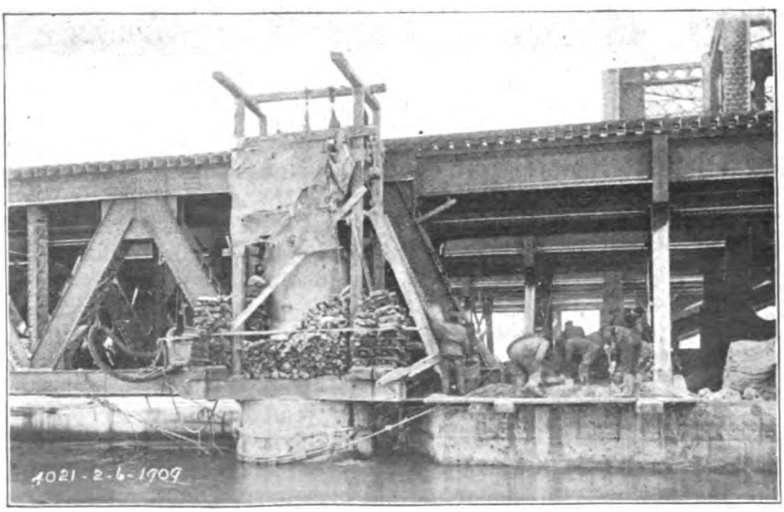


Fig. 7. Sinking Cylindrical Pier—At Rear of Masonry Pier, Bridge No. 4.

balance of the bridge. The cylinder shown is at the rear of the old masonry pier of Bridge No. 4. On the left is the front end of an approach span truss. In the right foreground is the main post of the old arch span resting upon its skewback. The segmental and track girders of the old span were not provided and the floor is continuous between approach and channel spans.

The piers themselves, having been built upon solid rock or hard pan, were considered of sufficient strength, since the live load would not be increased by the change and but two new leaves would be placed upon each pier in place of the four leaves of the old bridge. The old spans had been built so close together that it was necessary to place the leaves alternately on the north and on

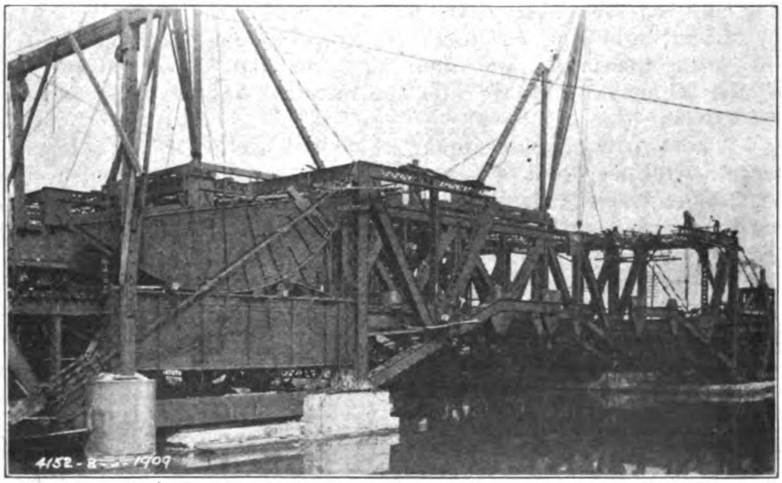


Fig. 8. Taking Down the Old Bridge, No. 1.

the south piers, as there was not room for the operating machinery racks with two adjacent leaves on the same pier.

The forward supports for the new track-girders were located behind the skewback pins of the old arch leaves, which enabled them to be placed without disturbing the old spans or the traffic thereon.

In Fig. No. 8 is shown a view taken during the removal of Bridge No. 1. The old arch span is being taken down as a cantilever. Eyebars and old floor beams anchor the channel span back to the approach spans, as is clearly shown, the eyebars running diagonally across the segmental and track girders for the new bridge which are in place. The rear end of the track girder is carried by the new cylinder pier and the front end is carried just back of the old skewback by a block of concrete which surrounds the old skewback on top of the old masonry. These supports consisted of a plate-girder placed on each side of the old skewback, supported on I-beam bolsters to provide the necessary bearing areas. Over the pair of plate-girders was placed a large cast steel pedestal upon which the forward end of the track-girder rests. The rear ends of the track-girders rest upon pedestals placed one on the pier and the other on the 9-ft. cylinder. The cylinders were so located that they also could be constructed without interference with any part of the old structure. All pedestals and supports were surrounded with reinforced concrete at the forward bearings, this concrete including the old skewbacks which had been originally thoroughly anchored to the piers by long, heavy rods.

Work in the field was commenced in the late fall of 1908, by sinking the cylinders and placing the track-girder supports on the piers. Each cylinder, which was to be placed in 24 feet of water, consisted of a cylindrical shell of ½-in. steel, 9 ft. in diameter, which it was proposed to sink into the mud on the bottom; and, when a seal was obtained, the cylinder was to be pumped out, the excavation continued to rock and the cylinder filled with concrete. The lower part of the channel, however, had been excavated in hard pan and the seal could not be obtained. Compressed air was finally resorted to, using a Moran lock, and the cylinders were sunk to rock and filled to about the water's surface with concrete, without difficulty and without mishaps. The entire substructure work was completed during the winter of 1908 and 1909, considerably before it was needed for erection of the superstructure. Rock was reached at about elevation minus 45 ft. at the cylinders on the south side of the channel, and at about elevation minus 35 ft. on the north side, referred to Chicago city datum.

Up to this time all work had been carried on without interrupting traffic on any of the bridges. In order to erect the superstructure, however, it was necessary to divert traffic from each bridge to be reconstructed to the adjacent span. The necessary track changes were made and traffic diverted from the east bridge (Bridge No. 1) on July 12, 1909. The track-girders might possibly have been placed before traffic was diverted, but this course would have caused interruption of train service, would have resulted in little gain in time and would have necessitated considerable extra cost in handling the girders. After traffic was diverted, therefore, a gallows-frame was erected over the tracks at the forward bearings of the girders, secured to the end-posts of the old leaves, and another frame was placed over the tracks at the rear bearings of the girders. This is shown in Fig. 9. Each girder is a box 42½ ft. long and nearly 11 ft. deep, weighing 71 tons. With these appliances the girders were both lifted from the cars and placed on the pedestals without any trouble on the day received at the site. The old tracks, old stringers and bent, between the girders, were then removed, and the new floor-beams, stringers, and bracing between them were assembled and riveted up during the following week. The tracks were then relaid and the cars loaded with the segmented-girders were placed thereon July 23, and these girders unloaded with the gallows-frames used in placing the track-girders. The weight of each segmental-girder was 56 tons.

During the erection of the track-girders and parts between the same, rivets were being cut out in the old channel span; that is, the heads were cut off, leaving most of them in place ready to be backed out and with sufficient bolts inserted for safety. As the channel beneath the bridge must be kept open for navigation, false-work could not be used and it was necessary to remove the old leaves as cantilevers. The floor system was taken out and the top of each end-post of each leaf was anchored back to an old floor-

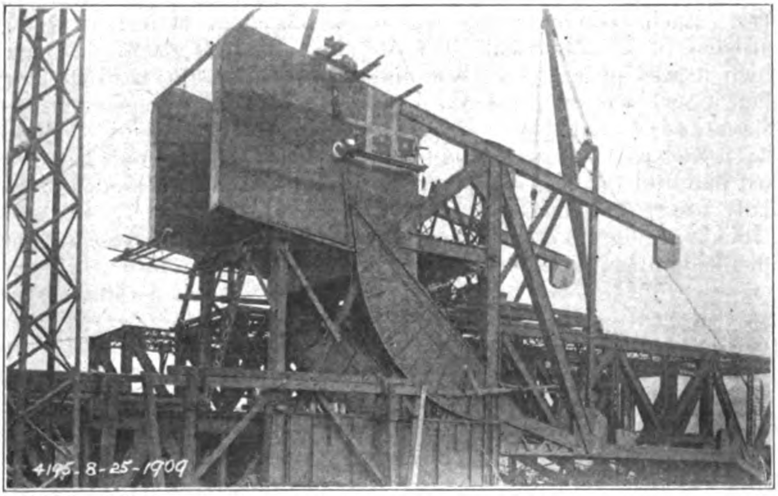


Fig. 9. Placing of Track Girders, Etc.

beam placed in the trusses of the approach-span.at the rear of the leaf.

The anchor-chains, made of old eyebars, ended in take-ups in the form of bolts at the anchor floor beam, by means of which bolts the chains were tightened to relieve the load on the center pins of the trusses. This done the removal of the old channel-span trusses was accomplished piece by piece, beginning on each leaf at the center of the span. The removal was performed by derricks located on the adjacent spans, one on each side of the channel. No difficulty was experienced in this work, the removal of the first old span being completed on August 5th. The old leaves being out of the way the segmental-girders were tilted to the position they would have in the leaf in its closed position; or, more precisely, with the forward end of the leaf about 4 in. from the full closed position. (See Fig. 9.) The girders were securely braced, each with a steel inclined post, the upper end of which engaged a toothhole in the perimeter of the segmental-girder and the lower end held by a tooth on the track-girder. Adjustment was provided by a steel wedge between the tooth and base of the post.

The segmental-girders shown in Fig. 4 have two webs, each ¾ in. in thickness. Each web is reinforced around its perimeter with four ⅝-in. and one ¾-in. side plates, and with a 7 by 3½ by 13-16 in. curved connection angle, making a total thickness of 4 13-16 in, at the perimeter of each web, or 9⅝ in. for both webs. The total load transferred from each girder, 1,738,000 lb.. makes a unit load of 180,000 lb. per lineal inch of bearing, or about 540 r, the radius being 27 ft. 9½ in. This 9⅝ in. of surface mentioned, however, bears on a curved sole plate attached rigidly in place by rivets, and which provides the surface that is in contact with and rolls upon the track-girder.

The curved sole plate is 2½ in. in thickness and acts to distribute the load over a somewhat larger area where it bears on the track girder. The track-plates on the track-girders are planed off to permit a total bearing of but 11 linear inches, giving a unit load of 158,009 lb. per linear inch, or 470 r, the radius of the outside of the curved sole plate being 23 ft. The actual bearing area is several inches in width over the restricted length of 11 inches.

The assembling of the counterweight box was then commenced at the rear upper end of the girder. The counterweight box consists of steel plates stiffened with angles and with interior bracing, and is filled with concrete reinforced with rods for tension. The main portion of the box, extending across the leaf from truss .to truss, is as deep as possible longitudinally with the leaf, the depth being such that it will not strike the track on the approach-span when the leaf is raised. To obtain additional weight, blades 3½ ft. thick are projected back of the main box and pass down each side of the approach-span to near the water level when the leaf is up.

As the box was assembled a strong timber-bent was placed beneath it as an additional precaution during erection of the leaf. At the same time a portion of the trusses over the channel and immediately forward of the segmental-girders were placed as rapidly and as far as was possible without overbalancing that part behind the bearing points of the whole on the track-girders. (See Fig. 9).

The counterweight box having been assembled and riveted (or nearly riveted), erection of the trusses was continued. In Fig. 10 is shown the span when partially erected, with derrick in position on adjacent old span. This derrick did not interfere with the traffic on the old span. Concrete was placed in the counterweight box in sufficient amounts and at such times as was necessary to keep the leaf slightly over-counterweighted at all times, so that there was always a load on the rear supporting-bent under the counterweight box; but for safety the rear end of the leaf was

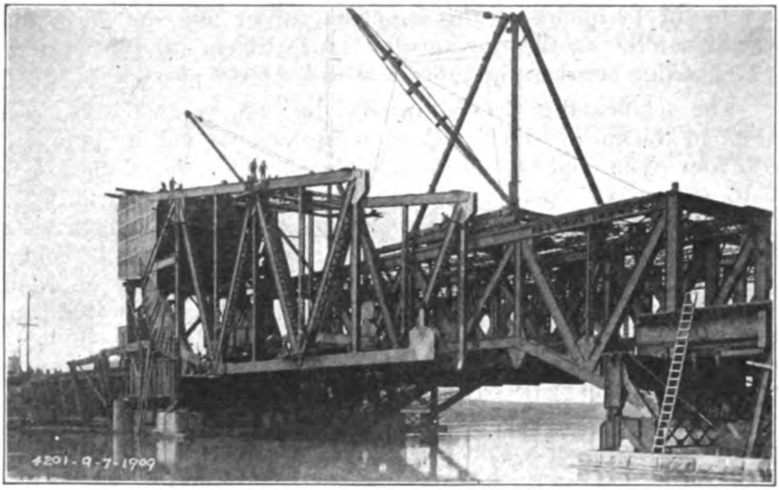


Fig. 10. Span of New Bridge Partly Erected.

anchored down with cables passed over the tops of the counterweight blades and fastened to the track-girders.

Work was continued in this manner until the forward end of the leaf was in place over the supporting-bent on the opposite pier. This is shown in Fig. 11; this point was reached on September 9, 1909. The leaf was found to be practically as expected as to alignment and elevation, the variation from the calculated alignment and proper relative elevation of ends of trusses being but a fraction

Fig. 11. Erection of Bridge No. 1, Almost Completed.

of an inch, which was easily corrected. This variation was avoided entirely in the erection of subsequent spans by giving lines and levels as the work was assembled. These were not given in erection of the first leaf.

When the erection and riveting of the leaf was completed the timber-floor and tracks were placed and the leaf was drawn down

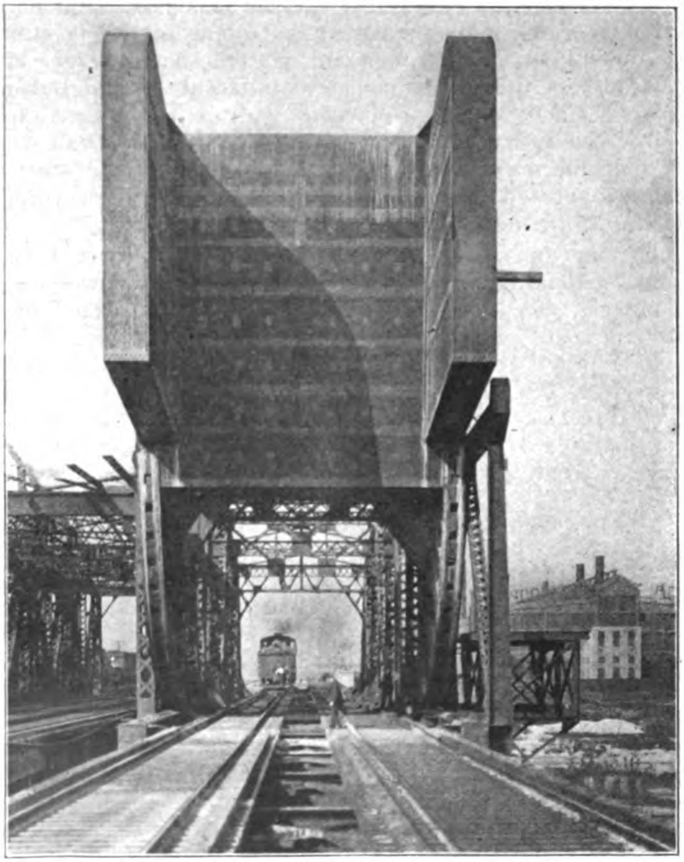


Fig. 12. End View, Bridge No. 1.

on its forward end support and tied there with cables, the final balance to be made later with pig iron placed in pockets in the counterweight box. These pockets are located at top and bottom of the box, so as to provide for adjustment of the balance of the leaf in all positions.

Traffic was returned to Bridge No. 1, after reconstruction as hereinbefore described, on October 2, 1909. The entire length of time the span was out of service was therefore 82 days.

August, 1910

The operating machinery for raising and lowering a leaf is placed upon the leaf itself, supported upon a framework over the tracks just forward of the counterweight box and back of the main post over the forward end of the segmental-girder. A shaft passes through this post in each truss at the center of the circle of which the perimeter of the segmental-girder is an arc. The center line of the shaft, therefore, moves in a horizontal plane as the leaf is operated and remains in that plane for all positions of the leaf. A pinion at the outer end of each shaft engages a horizontal fixed rack placed immediately adjacent to and outside of each truss. Each rack is connected with and supported by the track-girder beneath the same, the length of the rack being slightly greater than the maximum horizontal movement of the shaft when the leaf is operated. The racks between the bridges could not be placed until the adjoining old spans were removed.

Each main operating-shaft just described is geared back to a long shaft extending across the bridge, connecting the two sets of machinery. No equalizer is provided, as it has been found unnecessary in spans of this character, the flexibility of the leaf being sufficient to practically divide the load between the two racks. To the long cross-connecting shaft just mentioned will be geared two 50 H. P. direct-current electrical crane motors each provided with a brake operated by a solenoid. This brake releases automatically when the current is cut into the motors and sets again when the current is cut out. The brakes can be released for coasting by means of a foot switch at the controllers in the operator's house.

An auxiliary brake, released by a small motor, is also placed on the long cross-connecting shaft as an additional safety guard in case the solenoid brakes should fail to act or should be insufficient. This brake must be released by means of a switch in the operator's house before the leaf can be moved, and is set again by opening the switch after the operation.

The cross shaft is also geared to a smaller shaft upon which are two chain wheels provided with chains reaching down to the floor of the bridge. With these chains the leaf can be moved by hand-power in case of failure of the power or of the motors.

At the forward end of the leaf is provided a heavy latch-bar which, when the leaf is closed, can be pushed forward into a casting on the supporting-bent. This latch is operated by a small motor and is also provided with a means for hand-operation. All electric motor circuits are provided with automatic cutouts at limits of the movements of the leaf or of the latch and also with indicators to show position. The latch machinery and operating machinery are interlocked with each other and with the railway interlocking signals. A cutout in the operator's house places the control of all current to the motors in the hands of the signalman in the interlocking tower at the railroad crossing south of the bridge.

The erection of the second span to be reconstructed (the west span or No. 4), was commenced by diverting traffic therefrom on September 15, 1909. The work was carried on in the same manner as on Span No. 1, excepting that by reason of previous experience the work was laid out and executed to much better advantage and traffic was restored to the span on November 22. The time required for reconstruction of this leaf was therefore 68 days, whereas it required 82 days on the first span rebuilt.

The approximate weight of each new moving leaf is as follows:

	Tons.
Structural steel	702
Machinery and electrical equipment	38
Concrete counterweight, 490 yards or	940
Timber floor	38
Track, etc.	10
Pig iron for counterweight	10
Total weight	1,738

This is distributed between two segmental-girders making 869

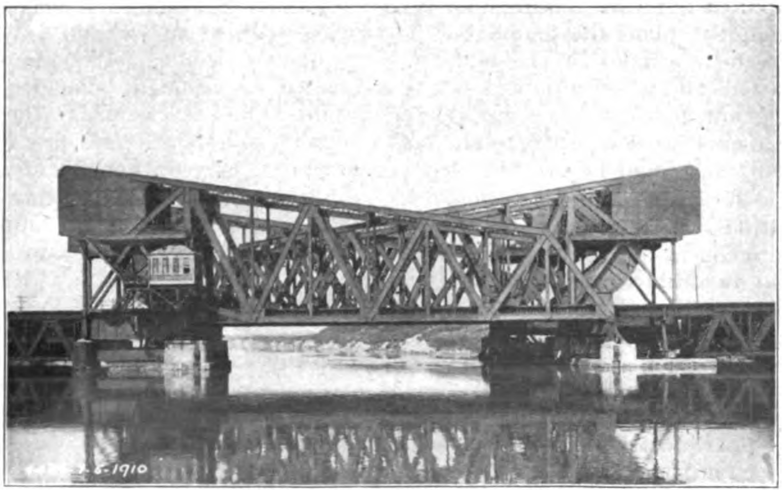


Fig. 13. Eight-Track Bridge Completed.

tons on the perimeter of each girder. The concrete for counterweight was a 1, 3, 6½ mixture of Portland cement, sand, and 1½ in. maximum size crushed stone.

The general contract for the entire work of reconstructing the bridges was let to the Chicago Bridge & Iron Works. The erection was sublet to the Ketler-Elliott Erection Co., the electrical equipment to George P. Nichols & Brother, and the machinery to the Featherstone Foundry & Machine Co., all of the above being located in Chicago. The planing of the track-girders and perimeters of the segmental-girders required special appliances designed for this express purpose, and necessitated very careful and accurate workmanship. We believe that on this part of the work we have secured results not inferior to similar work on any other bridge of this type that has ever been built.

Note.—(May 1, 1910). All four spans have been erected and are now in service for traffic, although not yet operated for navigation.

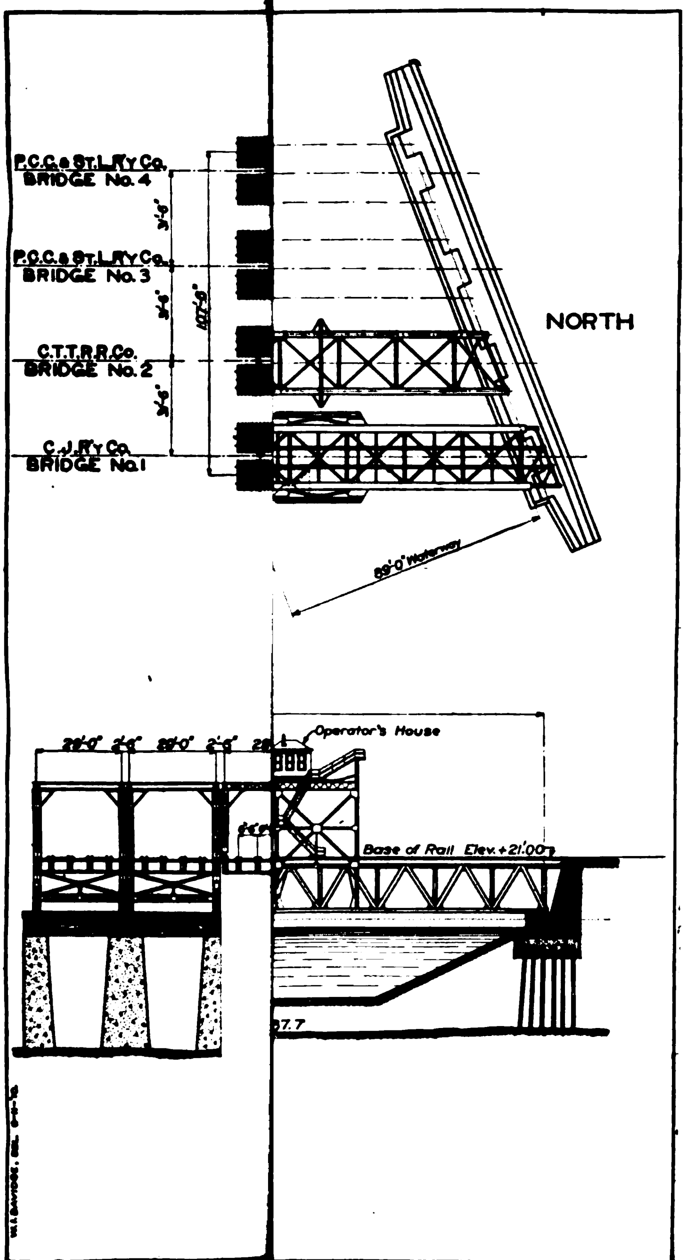
Discussion.

Mr. Geo. T. Horton, M. W. S. E.—The fabrication of this bridge was quite a pleasure and also quite a lot of work. Outside of the magnitude of the thing, the principal features that we had to contend with were the heavy track-girders and the segmental-girders. The track-girders we had to plane on the top and bottom. That we did with a rotary planer on a fifty-foot bed, which traveled the full length of the girder and I think gave very satisfactory results. For the segmental-girders we built a special machine, which consisted of a rotary milling tool twenty-eight inches wide, and large enough to plane the segments. That was mounted on a radial arm driven by a motor. The segment was put in, leveled up, the thing started, and after running over it a week or so we finally managed to grind it down. We did get fine results. The tracks inside the segmental-girders are ground down to almost a perfect fit and I think there will be no movement or creeping between the girders.

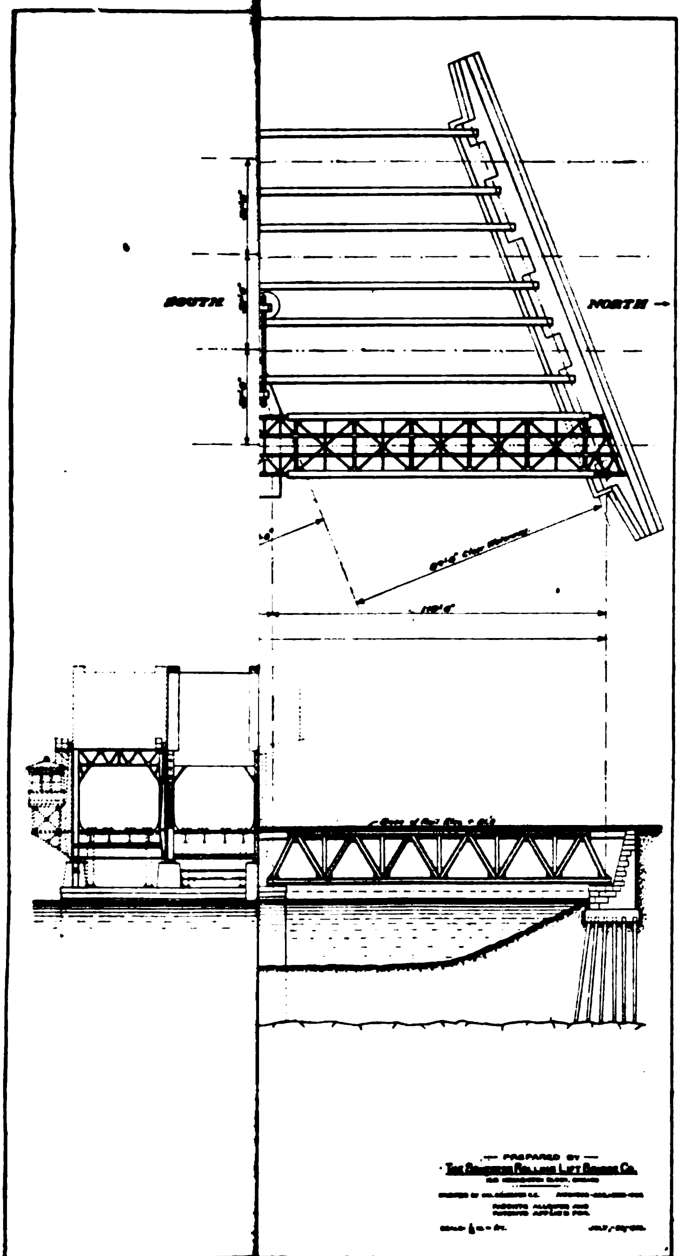
Mr. T. L. Condron, chairman:—I was impressed by the illustrations of this work with what must have been the unusual difficulties in handling the parts of the structure in the shop; and I was also favorably impressed by the repeated statement made by the speakers that here, there and elsewhere they had no trouble doing so-and-so. It is not unusual to have very considerable trouble in the field with a structure that has so many unusual and difficult features; and if the work came out of the shop in such shape that the engineers, representing the Sanitary District, repeatedly say that they had no trouble in the field, I think it is a high compliment to the manufacturers.

Mr. Andrews Allen, M. W. S. E.:—I was impressed with Mr. Horton's method of planing the segmental-girders and the track-girders. That is one feature that has not been adequately handled in previous bridges of this type. There has always been more or less difficulty in the creeping of the track and breaking down of the angles connecting the track with the segmental-girders. It looks to me as though those things are going to stand in this case, and I am sure that credit is due both to the Sanitary District and the manufacturers in this respect.

Mr. T. L. Condron:—I wish to ask Mr. Kandeler if the Terminal Transfer R. R. bridge at Taylor Street is not the longest Scherzer bascule bridge that has been built.



P.C.C.& St.L.R'y Co.
BRIDGE No. 4
P.C.C.& St.L.R'y Co.
BRIDGE No. 3
C.T.T.R.R.Co.
BRIDGE No. 2
C.J.R'y Co.
BRIDGE No.1
NORTH
Operator's House
Base of Rail Elev.+21.00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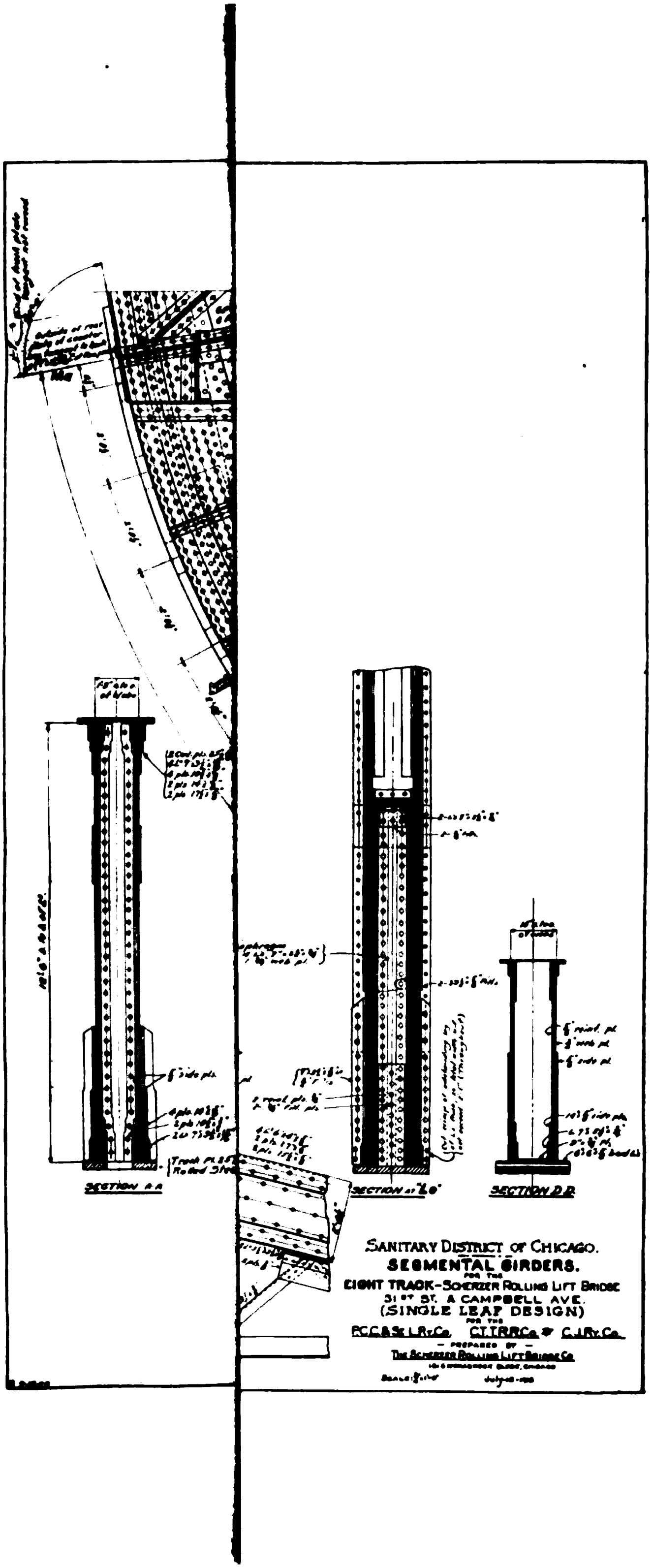
SECTION A-A
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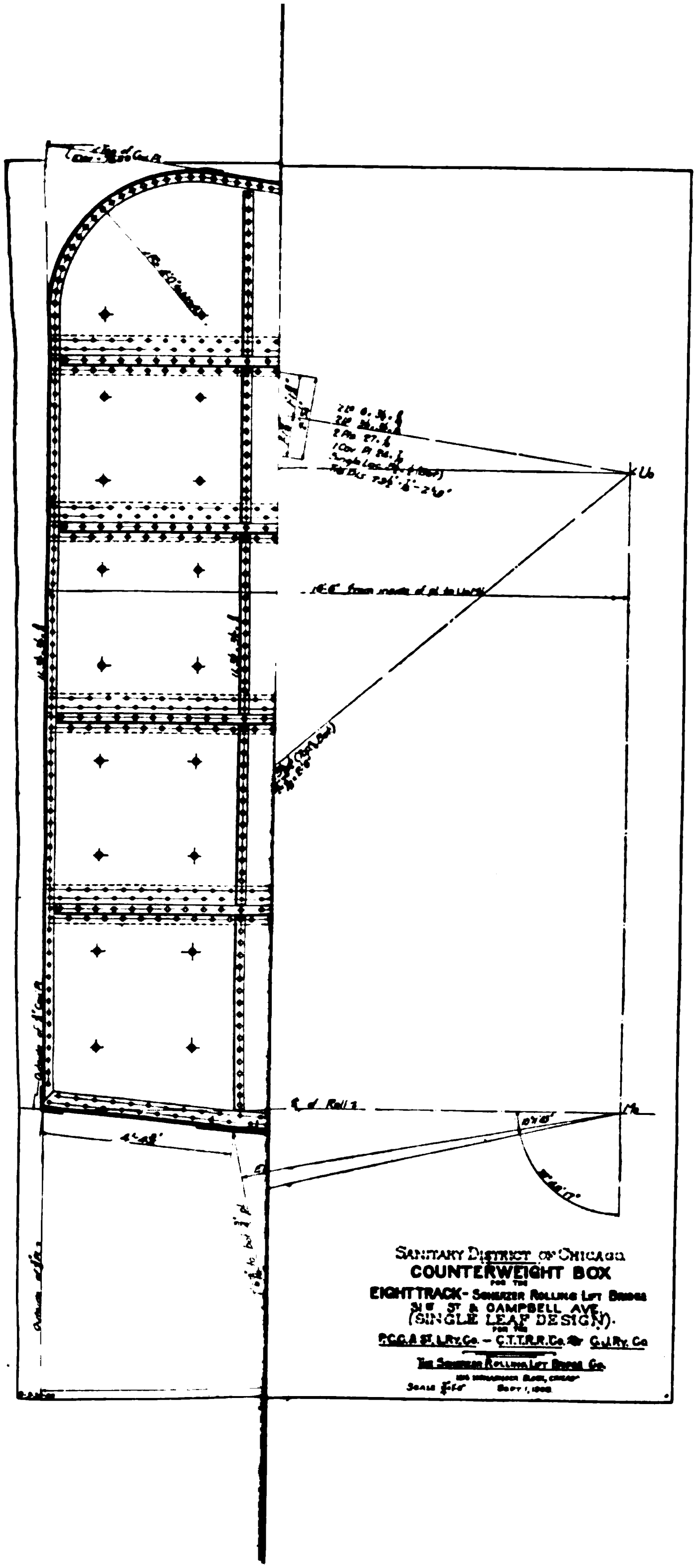
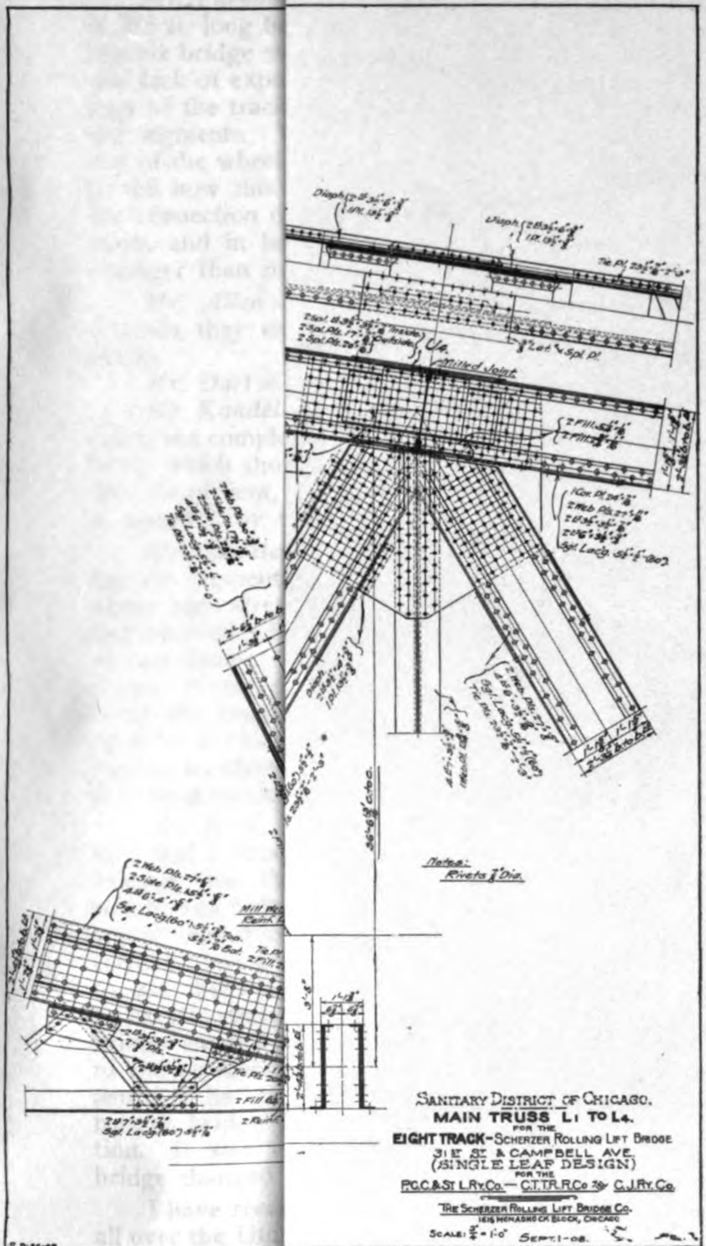
SANITARY DISTRICT OF CHICAGO.
SEGMENTAL GIRDERS.
FOR THE
EIGHT TRACK-SCHERZER ROLLING LIFT BRIDGE
31ST ST. & CAMPBELL AVE.
(SINGLE LEAF DESIGN)
FOR THE
P.C.C.&St.L.Ry.Co. C.T.T.R.R.Co. & C.J.Ry.Co.
— PREPARED BY —
THE SCHERZER ROLLING LIFT BRIDGE CO.


Sanitary District of Chicago
COUNTERWEIGHT BOX
EIGHT TRACK - Scherzer Rolling Lift Bridge
(SINGLE LEAF DESIGN).
C.T.T.R.R.Co.


Milled Joint
Notes:
Rivets 7/8" Dia.
SANITARY DISTRICT OF CHICAGO.
MAIN TRUSS L1 TO L4.
FOR THE
EIGHT TRACK-SCHERZER ROLLING LIFT BRIDGE
31ST ST. & CAMPBELL AVE.
(SINGLE LEAF DESIGN)
FOR THE
P.C.C.&St L.Ry.Co.— C.T.T.R.R.Co. & C.J.Ry.Co.
THE SCHERZER ROLLING LIFT BRIDGE CO.
1616 MONADNOCK BLOCK, CHICAGO
SCALE: 3/4" = 1'-0"
SEPT. 1-08.

Mr. Theodore Kandeler:—The Terminal Transfer R. R. bridge is 275 ft. long between centers of bearings, and is the longest span bascule bridge ever built. This was built some years ago and there was lack of experience then; the special uncertainty was the fastenings of the track-plates placed on the track-girders, under the rolling segments. When a wheel rolls on a rail both the rail and the rim of the wheel will be bent to a certain extent, and it is very hard to tell how this bending will affect the connection of the rail and the connection of the rim. Assumptions had to be made to figure these, and in later years these fastenings have been made much stronger than in the earlier bridges.

Mr. Allen:—I wish to ask Mr. Dart or Mr. Smetters what formula they use for calculating the distribution of load on the tracks.

Mr. Dart:—We use an empirical formula for the bearing.

Mr. Kandeler:—The theory of the bearing of the wheel on the rail is not completely developed. Some experiments have been made lately which show that the bearing in the older bridges of this type was insufficient, but I do not think there is a perfect theory that is accepted by the profession.

Mr. Smetters:—Present ideas differ materially, but in designing the segmental and track-girders we assumed that the material, under high stress, is restrained from deformation by the surrounding material which is under little or no stress. That is the basis of our theory. This condition is indicated in straightening metal plates. A steel plate can be straightened if worked from the side, toward the center, but it is practically impossible to straighten a plate by working outward from the center. I give this as an illustration to show that when material is restrained in this manner it is hard to change its shape.

Mr. E. N. Layfield, M. W. S. E.:—I wish to call attention to a fact that I think has not been sufficiently emphasized in this discussion, that this bridge takes the place of a double-leaf bridge which was built about eight years ago and was completed to the extent that it could be used as a fixed bridge, the segmental and track-girders and machinery being omitted and the intention being to add them later and make it a movable bridge. It was shown by careful study that it was more economical to tear out the original bridge entirely and put in a new bridge. This appealed forcibly to the representatives of the railroad companies, of which I happened to be one, for the reason that the center lock in a two-leaf bascule bridge is very objectionable from the standpoint of operation. It was very satisfactory to the railroad men to have this bridge changed from a two-leaf span to a single-leaf span.

I have received quite a number of letters from bridge engineers all over the United States and outside of the United States, concerning the center lock on our big bridge near Taylor Street. That lock, I believe, is a very good design, as good as any that I have seen for such a purpose; but it is impossible, I think, to make a center lock in a two-leaf bascule bridge that is thoroughly satisfactory for railroad service. Necessarily the load on one leaf has to be carried over to the other leaf, and a movable lock is hardly a practicable thing for railroad service. It would have to be, of course, a very heavy and expensive device in order to carry the weights that go over such a bridge. I received a letter from the bridge engineer of one of our large railroad systems, in which he asked my opinion as to the practicability of putting a tension lock in the bottom chord of such a bridge. I understand that several such designs have been gotten up, but it seems to me that this is something that it would be practically impossible to accomplish; and our experience with the big bridge referred to at Taylor Street is sufficient to make me say that anybody building a bascule bridge should not only strain a point, but strain it to the utmost, to make the span a single-leaf, even if it is carried to the extreme limit of the span that can be built. This lock that I speak of has not given us any serious trouble; but it is something that has to be watched very carefully and it is subject to possible accident at any time in a way that an ordinary movable bridge is not subject to.

Regarding the breaking down of the track-girder or the segmental-girder, there has been a great deal said about the breaking down of the rolling-girders, particularly with respect to this bridge; but the trouble that we have had with the breaking of the bolts has been largely overcome by simply putting in larger bolts and more of them. We have within the past year doubled the number of bolts and made them somewhat larger. When these bolts were put in, I used Swedish iron and steel for the purpose of ascertaining if the Swedish iron bolts would be better. They cost us very much more than the steel bolts, and I am having figures made now as to just what the cost was. Since they were put in I have not been able to observe any difference between the Swedish iron bolts and the steel bolts, because none of them have broken.