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Proceedings of The Second Pan American Scientific Congress

WASHINGTON, U. S. A.

Monday, December 27, 1915
to Saturday, January 8, 1916

Compiled and edited under the direction of
Glen Levin Swiggett, Assistant Secretary General

SECTION V

ENGINEERING

W. H. BIXBY, BRIGADIER GENERAL U. S. A. (RETIRED), CHAIRMAN

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JOINT SESSION OF SUBSECTIONS 1 AND 5 OF SECTION V.

RALEIGH HOTEL,
Wednesday afternoon, December 29, 1915.

Chairman, E. L. CORTHELL.

The session was called to order at 9.30 o'clock by the chairman.

BASCULE BRIDGES.

By J. B. STRAUSS.

The bascule bridge has in recent years become an important factor industrially, and an outline of its possibilities in connection with waterway development and the work of the scientific congress will, it is hoped, be of interest. Other types of movable bridges have also undergone recent development, as will be referred to hereinafter, but the modern bascule bridge has become and seems destined to remain the most generally adaptable and widely used of the modern types of structures for the bridging of navigable channels.

The term "bascule" as applied to movable bridges has two possible derivations, the most technical being from the French verb "basculer," meaning to rock. All bascule bridges have motion in a vertical plane, revolving or rocking about a center at one end. In operating they do not occupy more space laterally than the width of the bridge. These bridges are characterized further by having a long arm spanning the navigable channel and a short arm with counterbalance on the opposite side of the center of rotation or support. They are designed both as machines and as structures carrying land traffic. In their modern form neither function is sacrificed for the other, as was generally the case in the earlier stages of development.

EARLY FORMS.

It will be desirable to glance at the early history of the bascule, not only in order to adequately appreciate the great strides that have been made in recent years, but also because in this field as in most others the modern engineer owes a considerable debt to his predecessors, as the analogies herein drawn will evidence.

The origin of the principle of lifting bridges dates back to feudal times when drawbridges were used to give access to baronial castles or, as was more often the case, to prevent access. These bridges were opened by manual power applied through ropes or chains. Apparently the first people to go the next step farther and counterbalance the lifting part were the Hollanders, and they also seem to have been the first to use these bridges over navigable streams. The topography of Holland is such that high level bridges were not suitable, since the land is flat and lies close to the water level. Furthermore, since the country is traversed by numerous canals which furnish one of the principal means of transportation, the question of operating bridges demanded early attention.

One of the first examples of Holland's bascule bridges is shown in Figure 1, although no accurate knowledge of the date when such bridges were introduced is readily obtainable.

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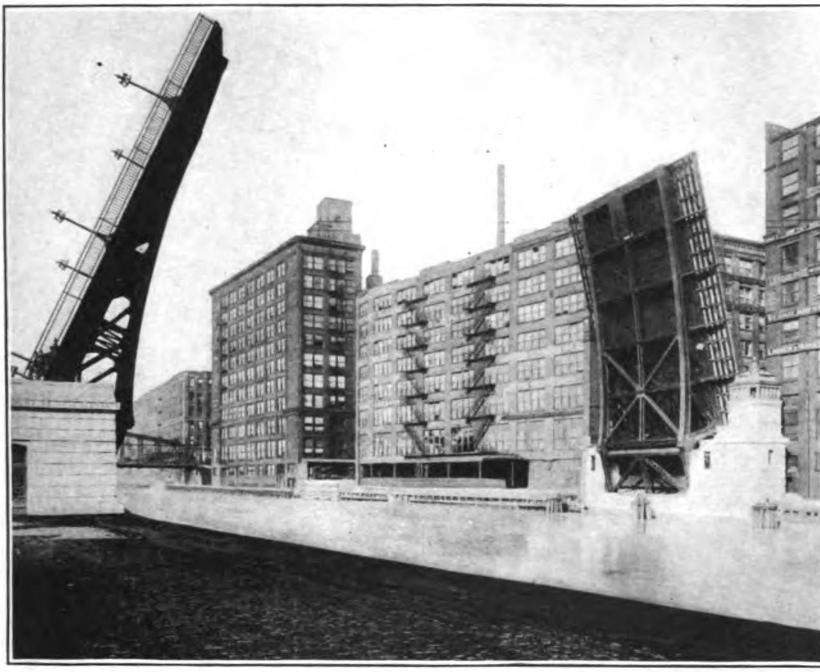

Strauss trunnion bascule, built 1916.[1] Jackson Street Sanitary District, Chicago. Bridge designed to accord with the "Chicago Plan"—will constitute main avenue of entrance to new Union Depot, now under construction. Length of span between trunnions, 202 feet; roadway, 37 feet; two 13-foot sidewalks.

[1] Bridge completed after paper was read but before publication.

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Figure 2 is a view of such a bridge photographed at Amsterdam in 1894. Many hand-operated bridges of this type are still in use in that city, in Rotterdam and other cities of the Netherlands. Bridges of like character were also built in Denmark. This type of bridge is sometimes referred to as a prototype of the design developed by the writer, known as the "heel trunnion" type, though there is a salient difference which will be referred to hereinafter.

In France more ingenious means were developed for counterbalancing in the various compensating counterweight bridges built there. Belidor used the first method as early as 1816 (see figure 3). His leaf was counterbalanced by a weight traveling on a track forming a sinusoidal curve so that the "pull" of the counterweight decreased in correct relation to the decreased leverage of the leaf as it opened. This type has been also occasionally used for larger and more recent bridges, such as that shown in figure 4 built in 1898 at Harway Avenue, Brooklyn, under designs by Joseph Mayer, and that built at Michigan Avenue in Buffalo in 1897.

The spiral pulley bridge introduced by Capt. Derché early in the nineteenth century, is shown in figure 5. The radius of the spiral (which is the moment arm of the counterweight) decreases as the span is operated, thus compensating for the descreasing moment arm of the leaf. A variation of this design was built over the Ozama River in Santo Domingo about a quarter of a century ago. the leaves being balanced by a counterweight connected thereto by means of a chain passing around a conical shaped drum at the base of the tower. The writer was commissioned to design a new bridge over the Ozama River at this point a year ago by the Obras Publicas of the Santo Dominican Republic. The new bridge, consisting of a modern bascule span 83 feet long and four fixed spans, one 100 feet and three 140 feet long, is now nearing completion.[1]

Other forms of the compensating bridge were built at Manitowoc, Wis., and other points in the United States, compensation in these designs being effected by automatic dropping-off sections of the counterweight as it moved up and down in the interior of a tall tower, at the top of which the pulley for the cable was mounted.

A bridge somewhat similar to the sinusoidal type was built in recent times (1908) by Augustus Smith between Portsmouth and Tiverton, R. I., stiff members being used for cables and a special curve being provided for the traveling counterweight, but in general the compensating methods of counterbalancing have not been found suitable for modern conditions and may be considered obsolete.

It will be noted that in the above structures, the counterweight or the leaf or both, travel about a fixed axis of rotation. A totally different principle is embodied in the wheel bridge of Col. Bergére, introduced about the year 1825 and illustrated in figure 6. A similar design, built at Havre by Lomblardie shortly before the year 1825 is illustrated in figure 7. In these structures the counterweight acts about a "movable" axis of rotation. This system of counterbalancing happened to be the medium through which the bascule was first applied extensively to modern conditions, taking the name of the Scherzer bridge in the United States and of the Hansa bridge in Germany. Various other forms of this same general type have also been developed, all now being included under the general head of "rolling contact" bridges forming one of the two modern groups of bascules with which this paper deals.

Figure 8 illustrates still another early idea in bridges moving in a vertical plane introduced by Ardagh. Strictly speaking this bridge is not a bascule but a "folding bridge." It does not employ a counterweight. An endeavor was made by Schinke to apply this principle to modern traffic bridges in the Sixteenth and Huron Street bridges in Milwaukee, built about 1896, along these lines and later efforts were made by others, but these efforts were not successful and this type, like the compensating bridges, have also become obsolete.

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[1] This bridge has now been completed.

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A type of early bascule bridge found in England, Germany, the Netherlands, Denmark, and Sweden is known as the "fixed trunnion" type. This forms the basis of the second group of modern bascule bridges, in which the leaf is mounted on trunnions (axles or short shafts) turning in bearings rigidly fixed or secured to the masonry. The trunnion (or fulcrum) divides the leaf into a long arm, spanning the channel, and a relatively short arm extending landward, which is counterweighted sufficiently to make the turning moments of the two portions equal and opposite. In other words, the fixed trunnion bridge is essentially a simple lever balanced about a fixed fulcrum.

One of the first of these bridges built is illustrated in Fig. 9 being a double leaf bridge on the line of the North Eastern Railway at Selby, England, completed in 1839. It has a rack wheel, hand-power gearing, and when closed acts as an arch. It is still in service. Another early trunnion bridge is the old Knipplesbro, built in 1867, at Copenhagen, Denmark, which was replaced in 1908 by a bridge designed by the writer. Further reference will be made to the latter design subsequently.

Other examples are to be found in the Fijenoord trunnion bridge at Rotterdam built in 1878 and the Honig trunnion bridge built at Koenigsberg in 1880, and in many first-class structures built in Holland prior to 1894. One of the latter is illustrated in Fig. 10.

A notable example of the trunnion bridge is found in the well-known tower bridge over the Thames at London, built in 1894 under designs by Sir John Wolfe Barry.

The fixed trunnion type while much slower than the rolling-contact types in being brought up to present-day requirements, has nevertheless found the widest and most satisfactory application in the present industrial era. It has proven most responsive to the increasing demands of the times and has made possible an increase during the last 20 years of single-leaf spans from approximately 100 feet to 260 feet and of double-leaf spans from 200 feet to 336 feet actual and 400 feet possible.

COMPARISON OF THE BASCULE WITH SWING BRIDGES.

The year 1894 may be taken as marking the new era in bascule bridge usage, especially in the United States. Prior to that time the center-pivot bridge had been used almost exclusively. In the early beginning of the commercial and industrial development of this country, engineers generally resorted to the use of the horizontal swing bridge to serve the requirements of a movable span, since space and time were not valued so highly as now. The bascule was adopted only for special locations and this led to the impression, in force many years, and even felt to a slight extent still, that this type could only be used or was only economically applicable to congested locations and small spans. An important consideration in altering this impression was the development of electric power, which made it as easy to operate and control the bascule as to operate the swing. Modern types of bascules have also reduced the difficulties of fabrication and erection so that at the present time the bascule is finding an ever-increasing field of usefulness.

There are and always will be conditions where the swing bridge can be advantageously used, but it is no longer safe to assume that the bascule is not the cheapest and best solution even where in past years the reverse has been the case. For instance, in a broad river, where approach spans are required on either side of the channel, it is still maintained by some that there could be no economy in anything other than the swing. However, if the water is deep and the foundations difficult, the saving in substructure and draw protection possible in the bascule may so far outweigh any economy of the swing in the superstructure as to leave the advantage with the former. The writer has found this to be the case in several instances, notably at Green Bay, Wis., where the river is about 1,000 feet wide, 36 feet deep, and where firm material in the river bottom is overlaid by a strata of mud 70 feet deep. The writer designed two complete crossings for that city, using in each case a single-leaf bascule of 100 feet span, which gave a lesser total cost than the swing.

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In general the advantages of the bascule over the swing may be summed up as follows:

1. The center pier and draw span protection of the swing bridge are eliminated, These are especially objectionable in narrow channels, obstructing the flow, while the draw protection, if not maintained, causes damage to passing boats. In Chicago many damage suits are brought in behalf of shipowners on account of such accidents.

2. Future addition of immediately adjoining bridges or additional tracks on either or both sides of existing bascule bridges is obtainable, which is impossible in case swing bridges are used.

3. For small vessels the bascule need only open far enough to give sufficient vertical clearance, whereas the swing bridge must be opened fully in any event. The reason for this is that the entire width of navigable channel must be clear to permit passage, which is obviously impossible if the swing bridge be only partly opened.

4. As a corollary it follows that a quicker passage of vessels and resumption of traffic results than with the swing bridge.

5. In a double-leaf bridge the bascule offers an effective barrier against highway traffic going off the roadway into the river, a class of accidents common with the swing bridge.

6. The bascule can be erected without interruption to land or water traffic.

7. The bascule does not encroach on adjacent property or docks and does not isolate the operator from shore when open.

8. In railroad bridges mitered rail joints can be used without the necessity of rail-lifting devices.

9. All stresses are statically determinate; ordinarily in the swing bridge continuous beam action takes place.

The swing bridge, on the other hand, has the advantage over the bascule, viz, where two independent channels are required, or where the foundations may be as economical as in a bascule or where quick operation is not essential and navigation infrequent. This type of bridge, in fact, appears to be capable of greater development than it has so far undergone, and the writer has recently undertaken the presentation of a new design of the horizontal drawbridge which it is believed will overcome some of the objections above noted, while at the same time effecting a saving in cost. The limits of this paper do not permit a description of this design, but it may be of interest to point out one feature, namely, the use of direct-driven trucks instead of center or rim-bearing turntables, these trucks being similar to those used on the "Aeroscope," an amusement device designed by the writer and built at the Panama Pacific Exposition in San Francisco in 1915.

THE MODERN ROLLING CONTACT TYPE OF BASCULE.

The first modern bridge of the rolling contact type was designed by William Scherzer in 1893 for the Metropolitan West Side Elevated crossing of the Chicago River (see Fig. 11) and completed in 1895. This was followed by two similar bridges for the city of Chicago, one at Van Buren Street and the other at North Halsted Street. William Scherzer died before the completion of the Metropolitan Railway bridge and a considerable interval elapsed before the design was developed further. With the construction of the Sanitary Canal of Chicago the question of water flow and consequent removal of center pier bridges from the Chicago River portion of the Sanitary Canal became a vital one. Meantime the design of William Scherzer had been made the basis of the Scherzer Rolling Lift Bridge Co., and the first success of the company was recorded in the construction of a large series of these bridges for the Sanitary District of Chicago, after which the company entered into the business of furnishing these bridges over navigable streams in general with a large measure of success for many years.

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The Scherzer Bridge is a pure rolling contact type as distinguished from those forms which use the rolling contact principle in combination with other methods. The vital feature of the Scherzer bridge is the segmental girder, which is the quadrant of a circle and rests on a horizontal track girder supported on piers at its ends. The center of gravity of the leaf is coincident with the center of the arc of the quadrant and in the later forms of the bridge this point has also been selected for the location of the operating pinion. The operating racks with which the pinions engage are usually supported on separate frames built outside of the planes of the trusses or girders of the leaf.

In operation, the segments roll back upon the track girders with the result that the center of gravity moves in a horizontal line, eliminating the lifting of the weight as a factor in the power consumption. In some of the earlier bridges, however, the leaf is in equilibrium only at the 45° position, so that the motors are required to do work against the weight both in forcing the bridge down and up from this position. The movement of translation in this type involves the additional work of moving the entire load horizontally back and forth upon the track girder, which is not the case in a trunnion bridge. To prevent slipping on the tracks, teeth are provided engaging recesses in the segmental girders, the action being similar to that of the toothed segment in the Lomblardie bridge, previously noted.

In the deck type of Scherzer bridge the point where the fixed and movable floors join (termed the break in floor) is behind the center of rotation, requiring so-called "live load" locks. Furthermore, as the bridge opens the portion of the floor behind the center moves down, usually into a pit formed in the substructure. There is thus formed an opening between the fixed floor and the floor of the bascule, which has occasionally resulted in accidents. As a result of this the city of Chicago insists upon the fixed floor being carried over the pit in its trunnion bridges. The deck type of Scherzer bridge is shown in figure 11, already referred to. This is a double-leaf bridge, each leaf acting as a cantilever under live load, anchorage being provided at the tail end to take the uplift. The through truss type of bridge with the counterweight overhead is indicated in figure 12, being a single-leaf bridge over the River Rouge at Detroit, Mich., built in 1914 for the Delray Connecting Railroad, a plant railway owned by the Solvay Process Co. In this type the opening in the floor above noted does not occur, and likewise the live load anchorage is omitted, this being required only in double-leaf spans.

The River Rouge Bridge differs from the earlier Scherzer bridges in respect to the track detail. As constructed for 15 years, the tracks of the segmental girders were made of a circular tread plate, bolted or riveted to the flange angles of the segmental girder. In practice it was found that the concentration of the load on this tread induced failure of the connecting rivets, and rapid deterioration of the flange plate and the angles. An account of this development can be found in the bridge engineers' report in the 1907 message of the mayor of Chicago, and reference is also made thereto in a paper by Mr. B. R. Leffler, engineer of bridges, New York Central Lines west in the March, 1914, bulletin of the American Railway Engineering Association, as well as in various other publications, American and foreign.

In the River Rouge bridge at Detroit relief from these troubles is sought in a sectional cast-steel tread having one straight face and one curved face and a deep flange. This construction, which insures a lessening of the overstress in these parts, was developed and patented by the writer in 1908 after a study of the principle of the rolling contact, which led to the conviction that a better distribution of the stresses was necessary. The writer, however, is not prepared to say that this detail will completely eliminate the difficulties which have so far manifested themselves, but it at least will have the effect of deferring their development to some extent.

Several Scherzer bridges were built in Cleveland for various railroads, among them being the 230-foot, single-track, single-leaf span over the Cuyahoga River for the

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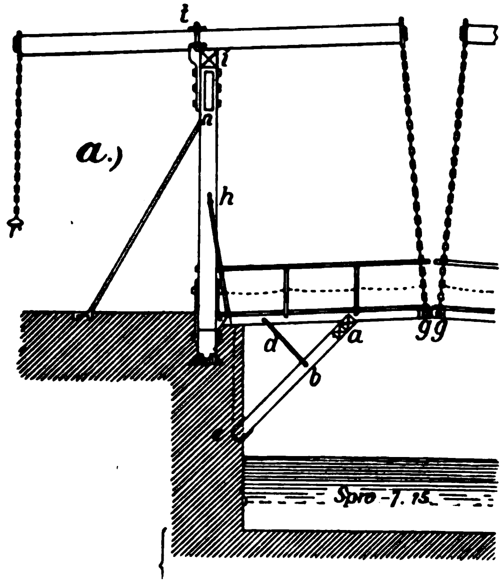

Fig. 1.

Early design without counterweight.

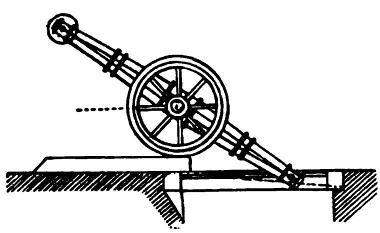

Fig. 6.

"Wheel" bridge—1825.

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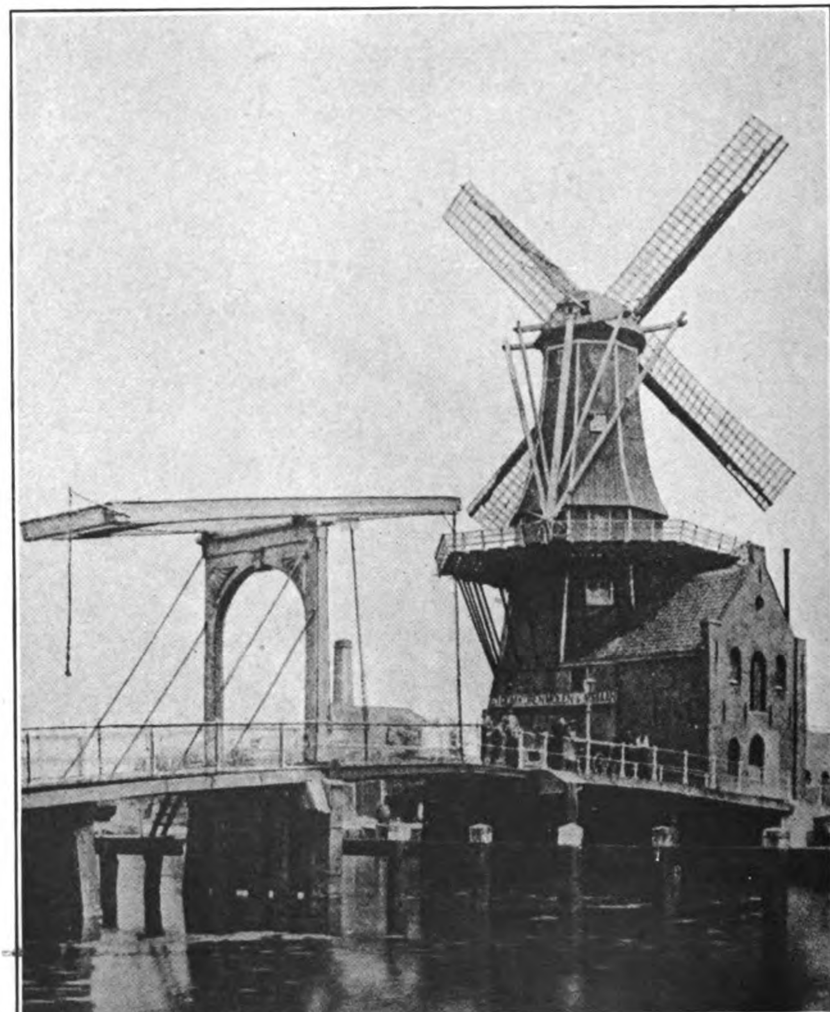

Fig. 2.

Early bascule type, photographed in Amsterdam, 1894

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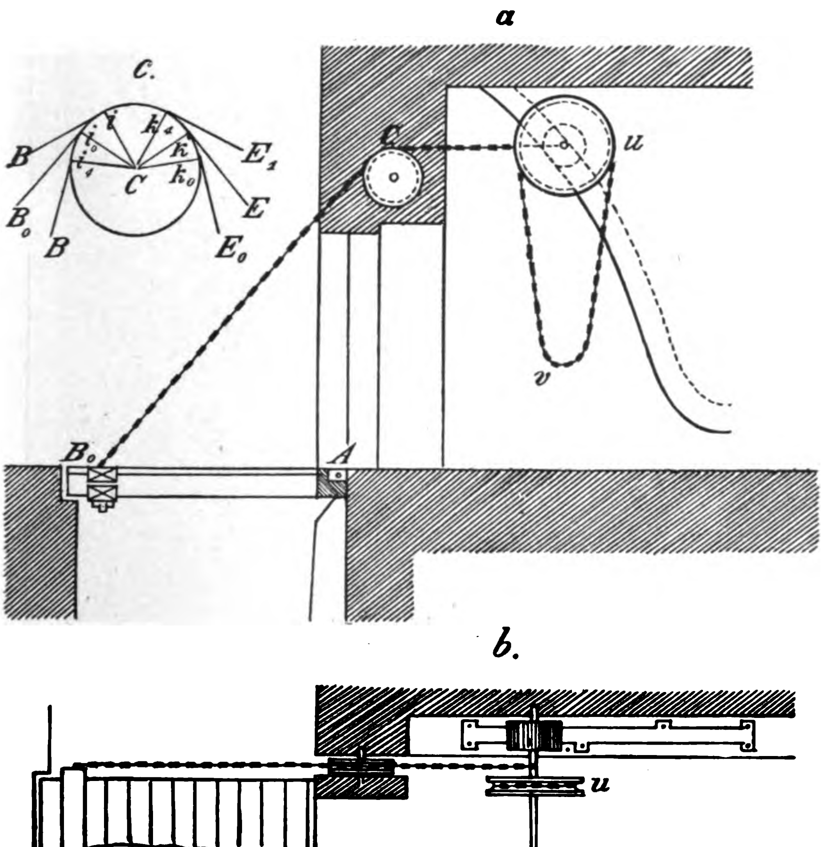

Fig. 3.

Sinusoidal design, 1816.

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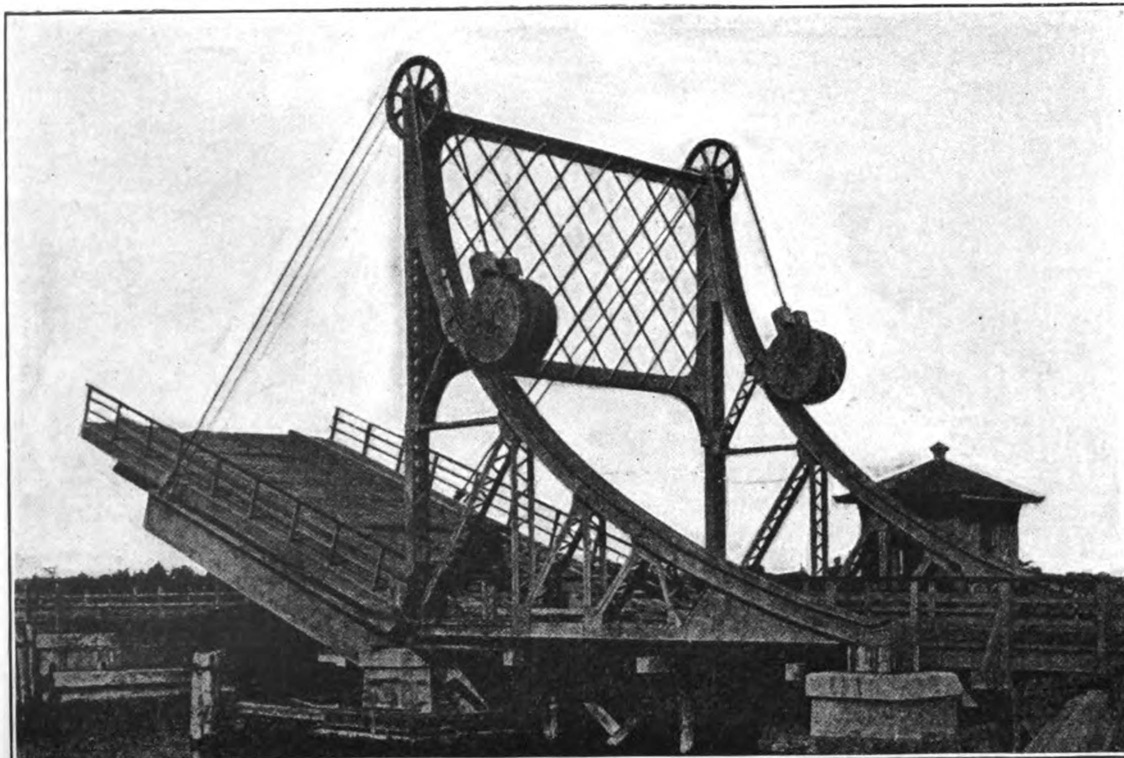

Fig. 4.

Harway Avenue bascule, Brooklyn, N. Y., built 1898.

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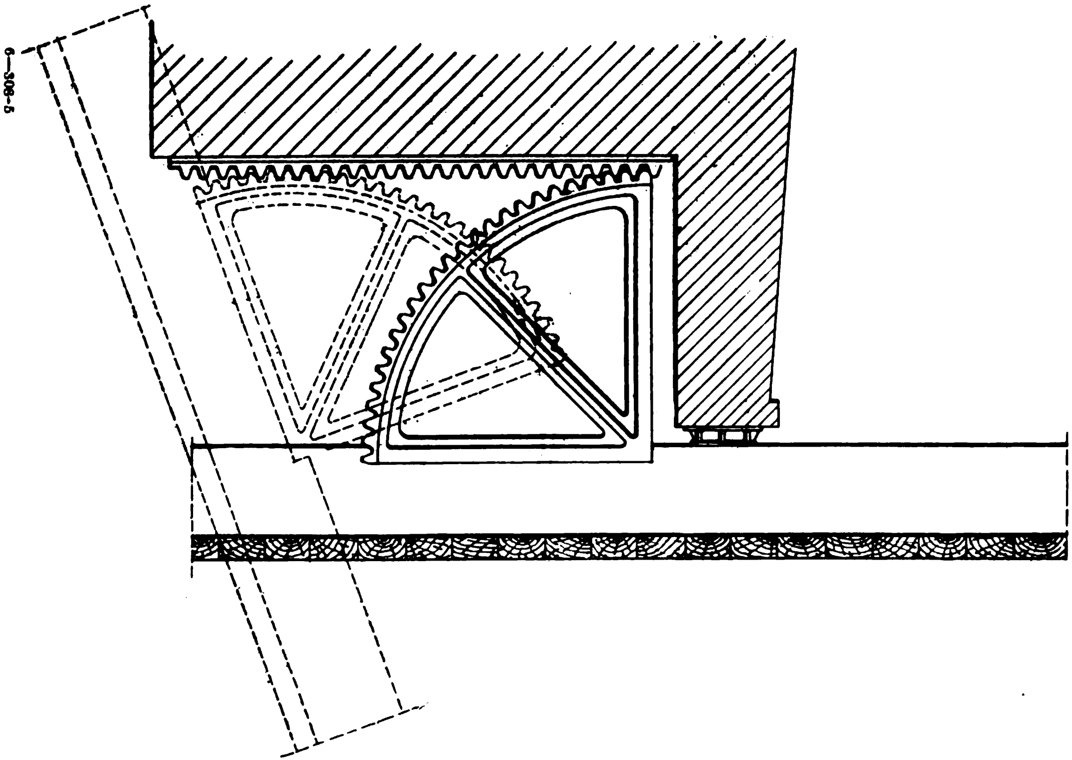

Fig. 7.

"Rolling lift" type—Havre, about 1825.

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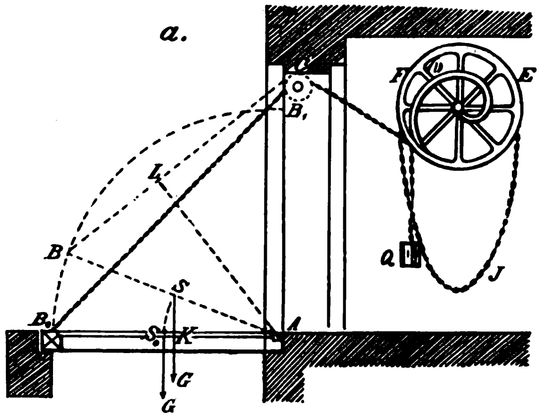

Fig. 5.

Spiral pulley design—early nineteenth century.

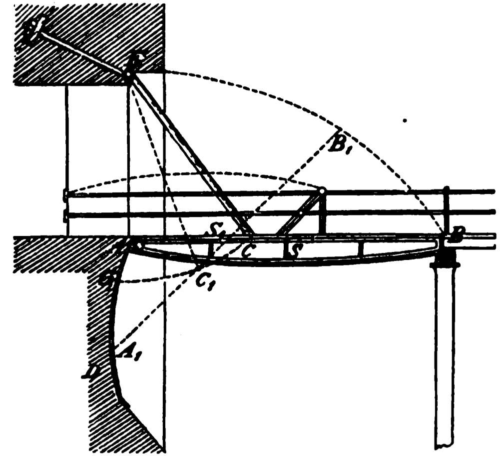

Fig. 8.

Folding or "jack-knife" bridge.

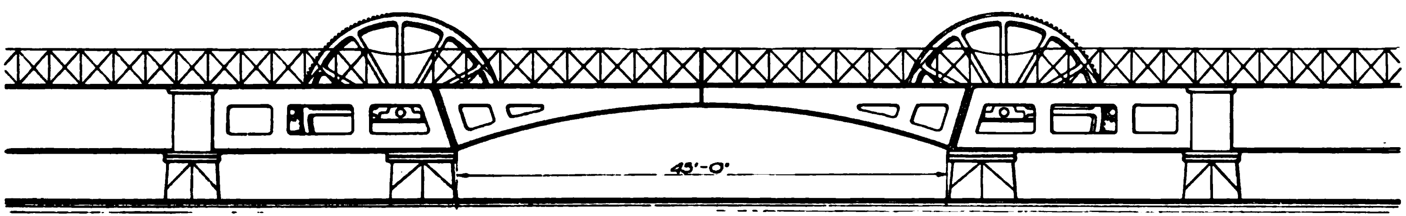

Fig. 9.

Early trunnion bridge, built 1839. North Eastern Railway, Selby, England.

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Fig. 10.

Trunnion bridge, Holland. Comparatively modern.

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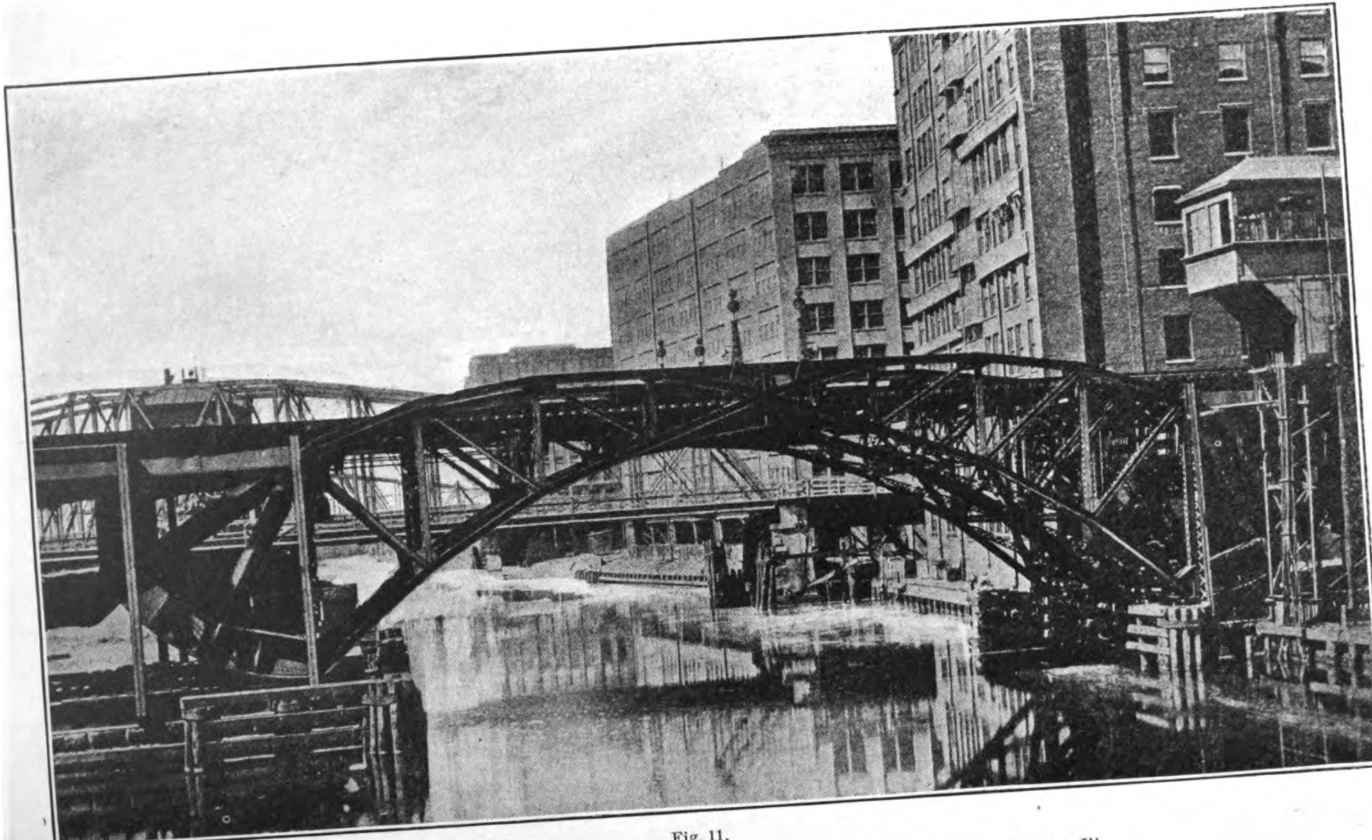

Fig. 11.

First Scherzer rolling-lift bridge; built 1895. Metropolitan West Side Elevated Railway, Chicago, Ill.

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Fig. 12.

Scherzer rolling-lift bridge; built 1914. Delray Connecting Railway, Riv. Rouge, Detroit, Mich.

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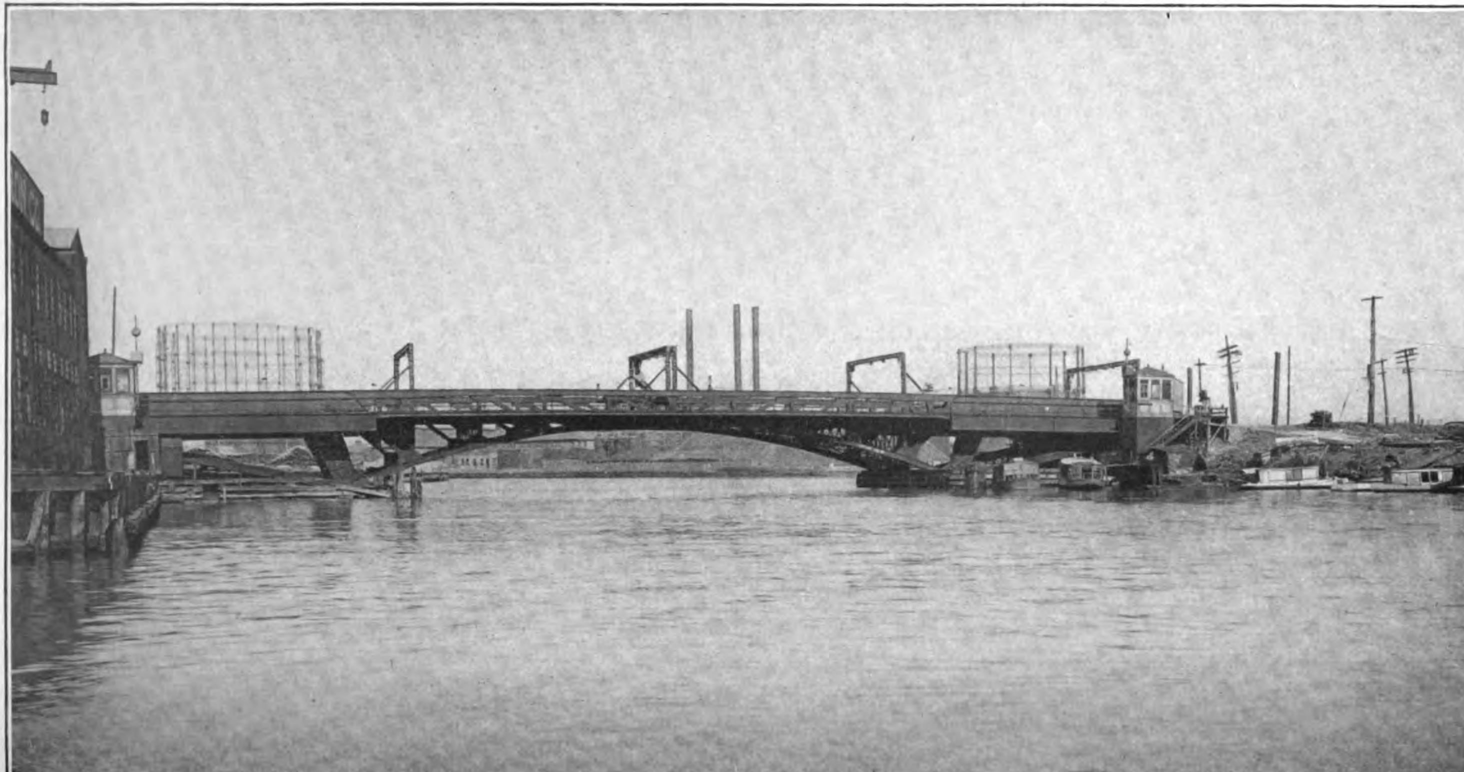

Fig. 13 (a).

Page bascule bridge—built 1902. Ashland Ave. Sanitary Dist., Chicago.

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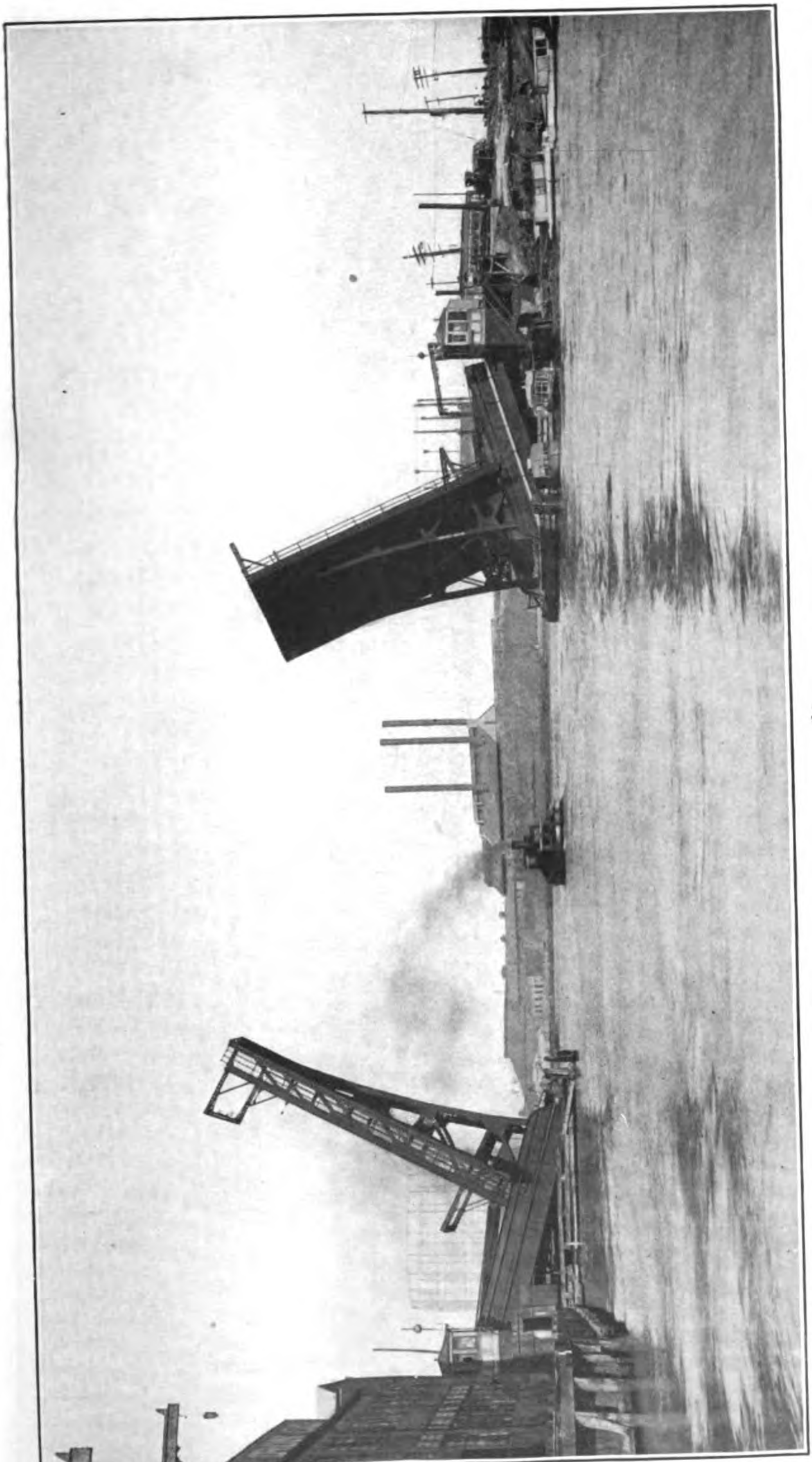

Fig. 13 (b).

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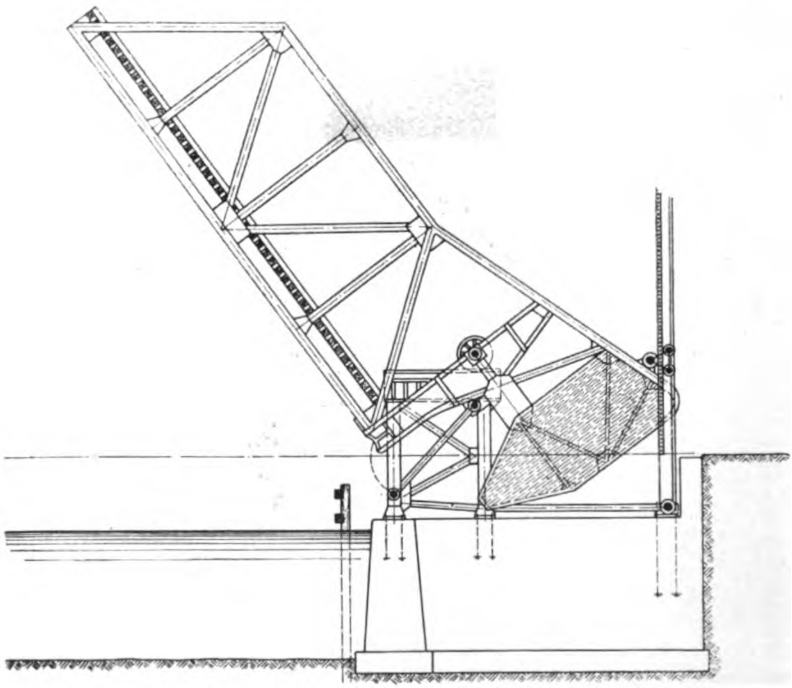

Fig. 14.

Roll bascule bridge—built 1909. L. S. & M. S., B. & O. and Penn. Rys., Indiana Harbor.

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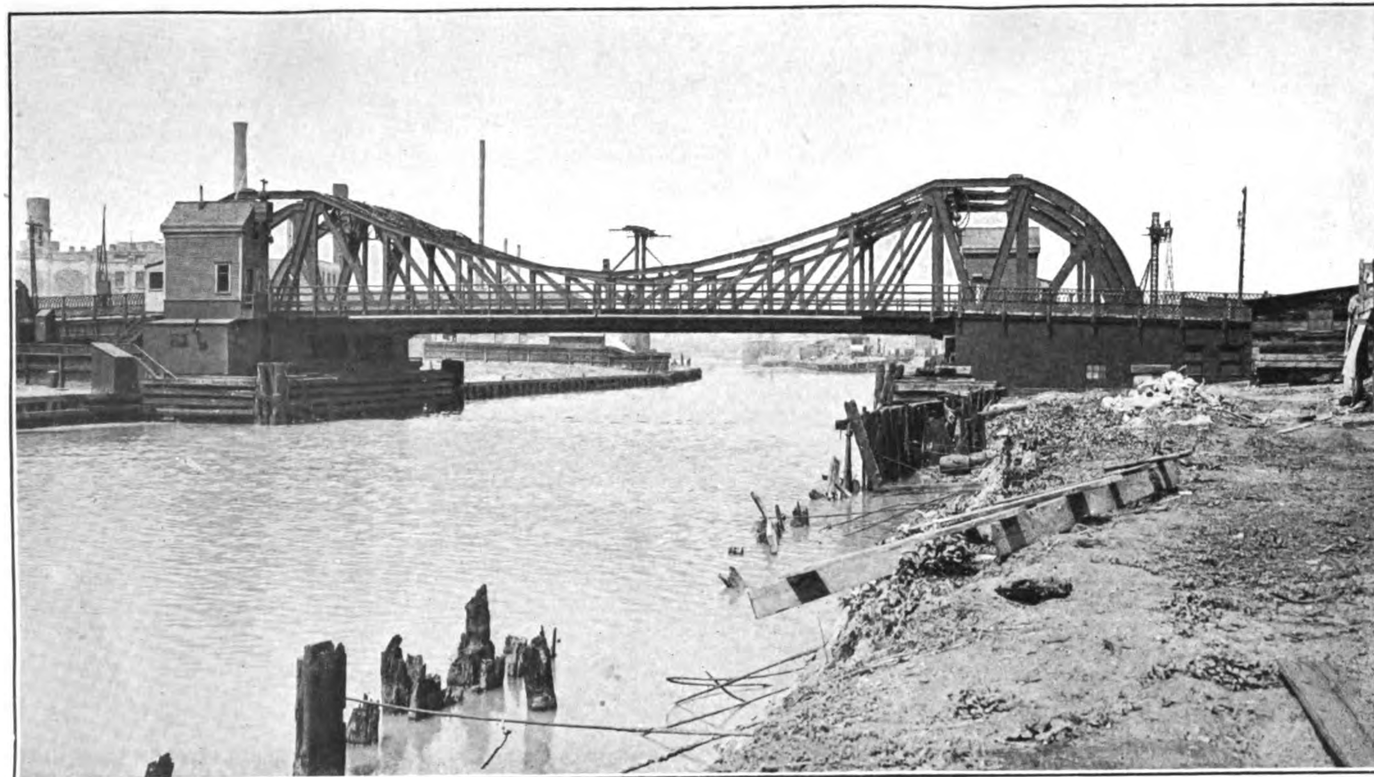

Fig. 15.

First Chicago city trunnion bascule—built 1902. Clybourn Place, Chicago.

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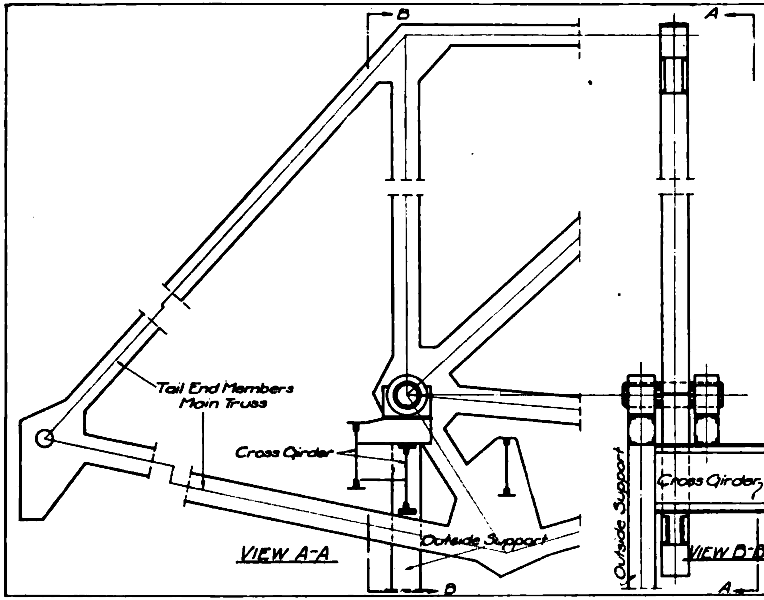

Fig. 16 (a).

Strauss trunnion bascule—built 1905. W. and L. E. R. R., Cleveland, Ohio.

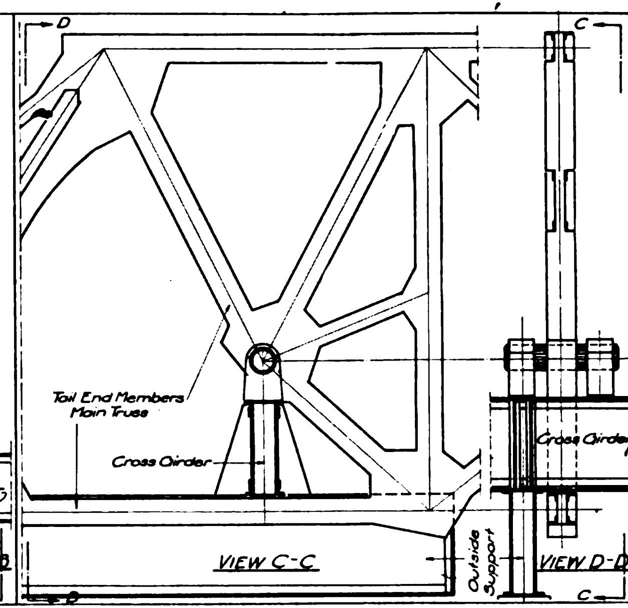

Fig. 16 (b).

Chicago city bascule—built 1914. Washington Street, Chicago.

Sketches showing arrangement of truss members around trunnion and trunnion support as employed by the writer, 1905, and similar arrangement employed by City of Chicago—1914.

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Fig. 17.

First Strauss trunnion bascule—built 1905. W. and L. E. R. R. Cuyahoga Riv., Cleveland, O.

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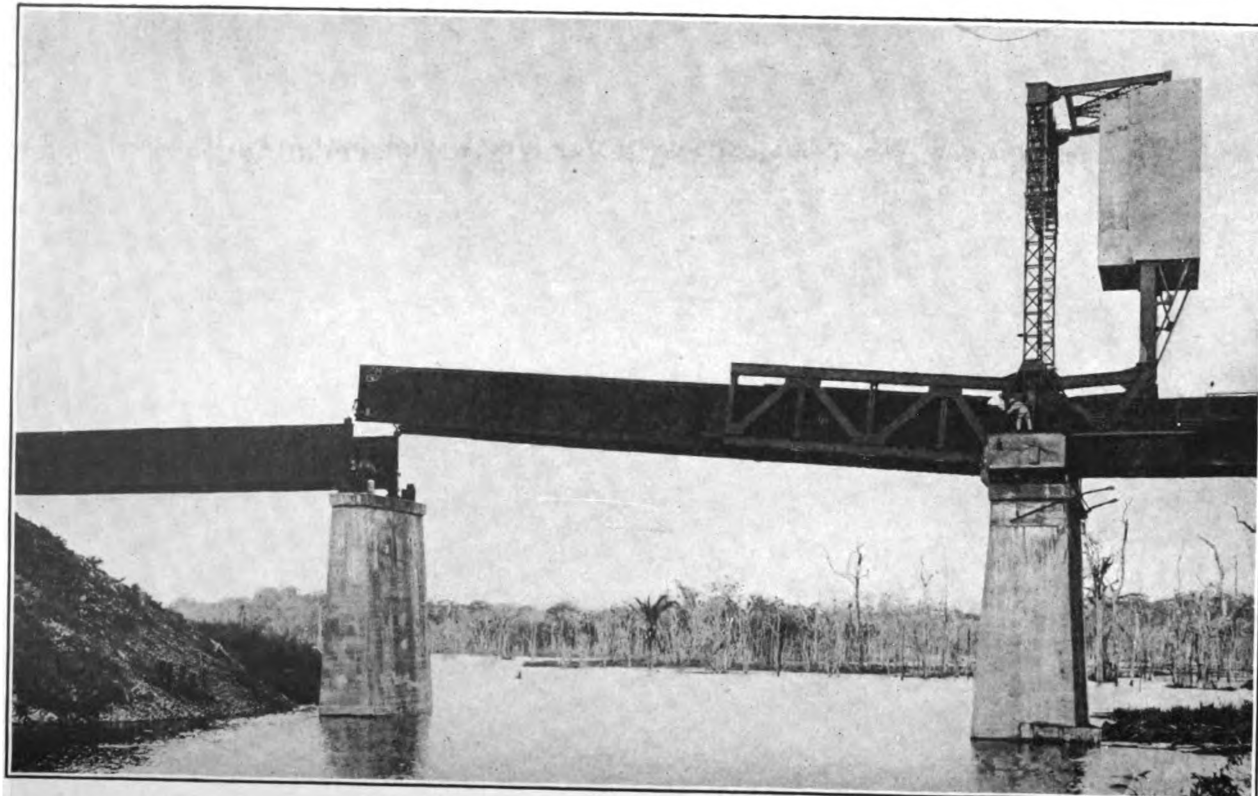

Fig. 18.

Strauss trunnion bascule (converted from fixed span) built 1913. Panama R. R. Gatun Riv. Canal Zone.

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Baltimore & Ohio Railroad, completed in 1907, which has the record length for a single-leaf Scherzer bridge. The New York, New Haven & Hartford Railroad built a number of Scherzer bridges prior to 1910. The longest double-leaf, double-track Scherzer bridge was built in 1901 jointly for the Sanitary District of Chicago and the Chicago Terminal Transfer Railroad across the South Branch of the Chicago River. The leaves act as cantilevers under live load. Renewal of this bridge is now being considered. The city of New York also has several Scherzer bridges in service, the most important of which is the Vernon Avenue Bridge across Newtown Creek, completed in 1905. In England and her colonies several Scherzer bridges have been built among these being the 225-foot, double-leaf, single-track railway bridge over the Pamban Channel, completed in 1913.

The next rolling contact type of bridge to be developed was the Page bridge, which was also brought out in connection with the work of the Sanitary District of Chicago, the first bridge of this type being built across the Chicago River at Ashland Avenue for the Sanitary District in 1902. This structure is a combined rolling contact and trunnion bridge and is illustrated in figure 13. The main trusses turn on trunnions in bearings secured to the pier. The leaf is counterweighted by a weighted approach span, one end being pivoted on the abutment, the other end having rollers bearing on a track girder forming the tail end of the main trusses. These track girders are of special curvature, the contour being determined by the requirement that the moment arm of the counterweight must decrease relatively the same as the moment arm of the leaf. This bridge has five floor breaks instead of three; these floor breaks themselves have not been found objectionable but the opening in the floor has, and is not in accordance with the present practice of the city of Chicago, as already pointed out.

An interesting feature of this structure is its operation by means of large screws supported on the approach girders, which act both as driving means and as brakes. Subsequently to the Ashland Avenue Bridge three additional Page bridges have been built—one, a highway bridge, at San Francisco; one, a double-track structure, for the Chicago & Alton Railroad, at Chicago; and one, a single-track railroad span, for the Monon Railway, near Chicago. In these latter bridges the operating screw is replaced by less unusual and more economical mechanism. It is worthy to note that the same trouble with the track girder has occurred in the Ashland Avenue Bridge as well as in the type just described. Since 1907 no further Page bridges have been built.

The next step in the rolling contact bridge is represented by the Rall bridge. In this structure rollers are connected to the girders or trusses at approximately the center of gravity, these rollers being mounted on tracks similar to the Scherzer bridge. The rollers, however, in this case are complete circular rollers, and their connection to the girders is through the medium of a trunnion, so that as the roller moves back and forth on the track the bridge itself is free to turn angularly. The movement is limited and controlled by a strut, the office of which is to turn the leaf vertically as the roller moves it back horizontally. The center of gravity in this structure moves horizontally as in the Scherzer bridge, and the work to be done in moving the bridge back and forth is the same as in the Scherzer except that the travel is not so great. Operation is effected through an operating strut.

The first one of these bridges was a deck span built over the Miami & Erie Canal in 1901 for the Pittsburgh, Fort Wayne & Chicago Railway, the length of span being only 26½ feet. The next installation was a single-track deck bridge of larger span but carrying interurban traffic, built at Peoria in 1907. After this the Rall bridge was built jointly by the Lake Shore & Michigan Southern Railway, the Baltimore & Ohio Railroad, and the Pennsylvania Railroad, at Indiana Harbor, in 1909, this structure comprising four double-track bridges of the through truss overhead counterweight type, having a span of 86 feet, illustrated in figure 14. The largest Rall bridge is that over the Willamette River at Portland, Oreg., built in 1913. Full description, with an instructive comparison of estimated and final cost, will be found in Engineering News of October 9, 1913.

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The Rall bridge possesses the same feature as the two other rolling contact bridges described, namely, that of carrying heavy concentrated loads on line-bearing devices. The effect is somewhat heightened, as compared with the other bridges, for the reason that the diameter of the roller is necessarily limited. The original Rall rollers had cast centers and separate steel tires. These were found unequal to the work at Indiana Harbor and were replaced by solid vanadium steel rollers. The Rall deck bridge is analogous to Scherzer in respect to the opening in the floor, and there is also the same effect on the foundations, resulting from the moving back and forth of the great loads of the superstructure.

The Rall and Scherzer bridges have one characteristic in common, i. e., the secural of the minimum length of span for a given opening, except in those cases where Rall must use through trusses and place the roller near the upper chord, in which event the Scherzer bridge has a slight advantage over Rall in respect to length of span. This gain in leaf length gave the rolling contact types of bascule some advantage over the plain trunnion bridge in respect to first cost for long spans, an advantage which was not overcome until the "heel trunnion" design (hereinafter described) was introduced.

THE MODERN FIXED TRUNNION TYPE OF BASCULE.

The beginning of the modern fixed-trunnion bridge really dates from the design developed and built by the city of Chicago. Before this time, however—i. e., in 1893—the trunnion bascule of the Tower Bridge of London, previously referred to, had pointed the way to the successful adaptation of the bascule principle to large-span bridges. The Tower Bridge was a bold venture, a jump from the toylike bridges of early days to one which even now is rarely exceeded in size. It is notable not only for this but also for its monumental character and remarkable performance record. Naturally enough, however, it is not designed along the lines of the present standard trunnion bridge. Its engineers were properly conservative, and fortunately also they were not limited in respect to cost. Consequently we find the Tower Bridge equipped with lead counterweights, hydraulic-operating machinery, roller bearings for the trunnions, and other exceedingly expensive refinements. It required some time to dissipate the notion which prevailed after the construction of this bridge that these were necessary and that the trunnion bridge was too expensive for general commercial use.

In 1901, however, the city of Chicago, as a result of extended investigations under the direction of the bureau of engineering, developed an efficient design of trunnion type of reasonable cost, which, with some variations and exceptions, it has built ever since. The first bridge of this type, placed in service at Clybourn Place and completed in 1902, is illustrated in figure 15. While patterned after the early trunnion bridge of Europe, as was also the Tower Bridge, it is simpler and more direct in character. The method of trunnion support comprises trunnions keyed to the bottom chords of the trusses and symmetrically supported in cast-steel bearings bolted to twin longitudinal girders of uniform depth supported on the front and rear walls of the counterweight pit and between which girders the tail ends of the bascule trusses swing. The counterweight is made up of cast-iron blocks secured to the chords of the tail ends of the trusses. In the later city designs (referred to hereinafter) these girders are of greater depth under the trunnion bearings where the load is applied and taper toward the rear to permit a counterweight box to pass below them and connect rigidly to the tail ends of the trusses. These girders also take the live load uplift from the bascule trusses. The counterweight in the later designs is pig iron with cement grout, carried in the steel box, moving within the water-tight inclosure in the structure, above referred to as the counterweight pit. The trunnion bearings are provided with simple phosphor bronze bushings. The operating power is electric, the installation comprising street-car motors and cast-steel gear trains driving pinions

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meshing with a pin rack in the circular top chord of the tail end of the trusses. Motors and gears are located in readily accessible inclosures beneath the roadway of the street leading to the bridge.

All bridges built by the city subsequent to the completion of the Clybourn Place Bridge were practically of identical character, with minor changes as noted above, until the Washington Street Bridge, completed in 1914, was projected. This differed radically in the method of trunnion support as a result of the city's efforts to overcome the limitation of the available space for counterweight imposed by the twin supporting girders above described. By dispensing with the inside girder, the entire space between the bascule trusses was made available as counterweight space, with the result that sufficient volume was obtained to permit the use of less iron and more concrete, consequently greatly lessening the cost. This was finally accomplished by supporting the inside trunnion bearings on a cross girder passing through the bascule trusses and supported outside of these trusses. This is made possible by carrying the chords of the trusses above and below the cross girder and arranging those web members whose center lines intersect at the center of the trunnion so that they will not foul the cross girder when the bridge operates. In other words, the form of the rear part of the truss was changed from triangular elements to quadrilateral elements. There were also numerous other changes from the original design, the principal one being the use of a small radius internal rack instead of a long radius external rack.

The trunnion supporting cross girder passing through the bascule trusses was first employed by the writer in the first of his bridges, hereinafter described, built for the W. & L. E. R. R. in 1905, nine years before the Washington Street Bridge was undertaken. Figure 16a illustrates and shows the arrangement of the main truss members and support for the trunnion bearings for the W. & L. E. bridge as designed and patented by the writer, while figure 16b illustrates the arrangement of the corresponding parts in the Washington Street Bridge of the city of Chicago. In the writer's design this construction is not so essential for economy as it is in the Washington Street Bridge, since considerable economy is due alone to the pivotal connection of the counterweight to the tail end, which will be referred to hereinafter.

The city of Chicago has in service and under construction 7 trunnion bridges of the Washington Street, or later, type[1] and 12 bridges of the earlier type, or 19 in all. In addition, the city has built 1 Strauss bascule, and jointly with the sanitary district is building another. The city program for the next three years contemplates the replacement of all the remaining center-pier bridges with fixed trunnion bascule bridges, which will not only give Chicago the distinction of having the largest number of trunnion bascule bridges of any one municipality but also the largest aggregate of both trunnion and rolling lift types.

Almost simultaneously with the city of Chicago, the city of Milwaukee likewise undertook the development of the trunnion bridge and really completed the first of its series before the completion of the Clybourn Place Bridge, in 1902, at Chicago. These early trunnion types in Milwaukee are not nearly as large or costly as the Chicago bridges. They are all deck-plate girder spans, with tail ends swinging between twin approach girders on which the trunnion bearings are mounted and which also take the uplift. The counterweights are of cast iron rigidly attached to the tail ends of the trusses, the supporting approach girders being spread enough to permit this. The piers run parallel with the girders instead of crosswise, as in the Chicago bridges, and there is thus a separate pit for each counterweight instead of a single pit for the two counterweights of each leaf combined as in the Chicago bridges. Nine trunnion bridges in all have been built by the city of Milwaukee and are in active service.

Preceding either Chicago or Milwaukee, the independent efforts of Augustus Smith should be recorded. The little structure designed by him and built over the Mott

[1] The validity of the writer's patents covering this construction has just been sustained by the United States courts, which renders all these later bridges built by the city of Chicago infringements.

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Haven Canal at One hundred and thirty-fifth Street, New York, in 1901 is a single leaf deck bascule of 30 feet span, with the characteristic gooseneck trunnion supporting girders of the early European bridges. The operating mechanism is unusual for a trunnion bridge in that the racks are fixed to the inner walls of the counterweight pit, while the driving mechanism is on the moving leaf.

Following in the footsteps of Chicago, the city of Philadelphia built a large double-leaf trunnion bascule at Passyunk Avenue in that city in 1911, and the city of Seattle is now building two double-leaf trunnion bascules across the Lake Washington Canal, the two latter being an exact copy of the Washington Street design of the city of Chicago and the former being a close copy of the earlier Chicago city design.

As machines, the trunnion bridges of Chicago and Milwaukee have proven efficient. The dead and live loads are fixed and concentrated at the trunnion. The location of the break in floor in front of the trunnion prevents the bridge from opening under live load independently of the tail locks and keeps dirt and surface water out of the pits. The placing of the machinery on the fixed supports instead of the moving leaf is important from the standpoint of efficient operation. In all of these respects the trunnion type, in the form developed by the cities of Chicago and Milwaukee, represents a distinct step toward the present standard of safety and efficiency.

Aside from the Chicago and Milwaukee designs, and one or two isolated efforts, no attention was given to the development of the trunnion type during all those years when the rolling contact type was being so actively exploited, and this accounts for the early preponderance in numbers of operative structures enjoyed by that type. Another disadvantage under which the trunnion type labored was the rather high first cost of the first Chicago and Milwaukee bridges.

High cost was, in fact, characteristic of all types of bascule bridges, due principally to the use of iron as counterweight material, and also in the underneath design to the necessity of deep pits. Elimination of these pits or frequently merely making them shallow, to reduce their cost, meant curtailment of the counterweight arm and consequent increase of counterweight to a prohibitive degree. As a result, in 1901 the limit of length and weight of bascule spans and consequently the field of usefulness, though greater than in 1893, when the Metropolitan Elevated Scherzer Bridge was built, was still greatly restricted.

In that year the writer, who had been associated with the work on practically all types of bascules in use, undertook the task of removing the limitations above referred to by selecting of the available types that which promised greatest efficiency and by modifying the counterweighting mechanism in such manner as to reduce the cost. without sacrificing efficiency. Determining upon the "fixed trunnion" type as the most dependable, he substituted concrete for the cast-iron counterweights, effecting at once a saving in cost proportional to the relative cost of the two materials. The cast-iron blocks employed up to that time cost from five to seven times as much as concrete, weight for weight. It still remained, however, to so arrange the construction as to obtain either a longer leverage for the counterweight or to so dispose the counterweight as to obtain room for the greatly increased volume required by the concrete.

Figure 17, which shows the W. & L. E. bridge already referred to, illustrates the method employed to obtain these results. The counterweight, instead of being rigidly attached to the moving leaf, is connected thereto by means of trunnions located at the extremity of the tail end of the bascule trusses. These counterweight trunnions are located at a point which would correspond to the center of gravity of the fixed counterweight, i. e., in line with the main trunnion and center of gravity of the front end of the moving leaf. The counterweight proper is located above the roadway and supported on structural steel legs or columns whose bases terminate in bearings carried on a cross girder riveted to the ends of the tail ends of the bascule trusses.

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The counterweight is further supported by means of a rigid member termed a "counterweight link," one end being pivoted to the counterweight and the other to the fixed tower, forming the trunnion support. This link is parallel and equal in length to a line joining the main and counterweight trunnions forming the so-called "parallel link" counterweight system, which obtains through all the various forms of the writer's types of bascule. As the bridge is operated the counterweight is thus constrained to move parallel with its original position, and so maintains the leaf in equilibrium at all times. Operation is effected by means of operating struts actuated by pinions driven by alternating current motors. (It is interesting to record the fact that this bridge is the first bascule on which the use of alternating current equipment was attempted, involving the working out of many new problems.)

It will be evident that if the counterweight trunnions are correctly located it is immaterial where the actual center of gravity of the counterweight mass is located. It can either be located above the roadway, as just described, or below the roadway, as shown in figure 19, without raising the center of gravity (i. e., the trunnions) of the structure as a whole. Where the counterweight is rigidly connected, as in all the previous designs described, this important latitude is not possible.

The result in the case of the W. & L. E. bridge was a saving of approximately $20,000 in first cost and the ultimate adoption of concrete counterweight by all designers of both bascule and lift bridges. Although thus first applied in the overhead type of bridge in 1904, the pin-connected concrete counterweight was originally proposed by the writer for the underneath counterweight type of bascule in 1901 in a series of plans which became the subject of much discussion and which later were embodied in patent application No. 738,954, applied for in December, 1902, and issued September, 1903.

In that year, i. e., 1903, adaptation of the pin-connected concrete counterweight was made in a 30-foot Scherzer bridge of the underneath counterweight type built at Marseilles, Ill., and completed almost simultaneously with the W. & L. E. bridge, but not until two years after the completion and thorough demonstration of the W. & L. E. bridge was the great economic advantage of the all-concrete counterweight recognized by the engineering profession in general and universally adopted for all types of lift bridges.

The W. & L. E. design, while having rendered excellent service at Cleveland, has been superseded by later and more economical forms which the parallel link counterweight system has taken. One of these is illustrated in figure 18, which shows the Gatun River Bridge on the line of the Panama Railroad in the Canal Zone, built in 1913, under plans furnished by the writer. This type of structure, termed the "vertical counterweight type" is unique, having no near parallel in either early or late designs. It has found a large field of usefulness in connection with deck or through girder and pony truss bridges because of its compactness and economy. A specially interesting characteristic of this design is the separation of the main girders and the lifting girders. The latter form the bascule proper, the main girders in this instance being the original girders used when the bridge was a fixed structure and which were simply connected to the lifting girders to convert the span into a bascule.

As already indicated, the parallel link counterweight is not less advantageous where the counterweight is below the roadway than where it is above. This is demonstrated in the Polk Street Bridge, Chicago—figure 19—a typical Strauss bascule of the underneath counterweight type, which was found more economical than the early Chicago city design and was consequently built by the city in 1908. It has a span length of 193 feet center to center of trunnions and gives a clear channel of 140 feet at right angles to the channel. When closed the leaf is supported on the piers in front of the main trunnions at points in the lower chords, which would correspond

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to the springing line of an arch span. A bearing is effected at these points by means of cast shoes—one secured to the truss and the other anchored to the pier—which come into contract when the leaves close. This point is located 10 feet 6 inches in front of the main trunnions, so that the live load on the leaf tends to lift the bridge slightly from the main trunnions and the front support thus becomes the fulcrum for the leaf and counterweight. The leverage from the front support to the main trunnion or center of gravity of the leaf obtained in this manner is sufficient to balance the maximum live load on the leaf, and the tail end anchorages are unnecessary except as safeguards for maximum loads.

Each leaf of this bridge is operated by two 35-horsepower electric motors actuating operating pinions which engage curved racks on the bottom chords of the tail ends of the trusses, the machinery itseelf being located on an immovable platform. The break in floor is ahead of the trunnions, thus securing the advantage of the closed pit and eliminating live-load locks. The pit itself is but 10 feet deep as against 20 feet or more customary in Chicago, this being due to the character of the counterweight movement already described. The link in this design not only guides the counterweight in its movement but prevents its oscillation or swaying and also permits the counterweight to be nonhomogeneous or even eccentric with respect to its point of support, which makes it cheaper and easier to construct. This type of pin-connected counterweight requires a special design of the fixed supports of the bridge to provide clearance and suitable locations for the machinery, etc.

A fourth form of the parallel link counterweight system is found in the heel trunnion type of bascule already referred to, and which was developed by the writer to meet the demand for increased size and capacity of bascule bridges, particularly for railroad service. This design is best adapted for through truss bridges, such as illustrated in figure 20, showing the Northern Pacific Railway bridge over Lake Washington Canal at Seattle, Wash.

A similarity will be noticed between this design and one of the early bridges of Holland, illustrated in figure 1. It will be noted, however, that in the heel trunnion design, the tower supporting the counterweight is in the shape of a right-angled triangle, and further the member connecting the leaf and counterweight is rigid, so that it may take compression as well as tension and is connected at the hip of the leaf truss. It will also be noted that the trusses of the leaf and tower are in the same vertical plane, which is essential to economy.

One result of this arrangement is the separation of the counterweight load from the leaf—that is, the pier under the vertical leg of the triangular tower supports the counterweight and the pier at the heel of the truss supports the moving leaf. This decreases the concentration of the dead-load reactions on the trunnions and on the foundations, which reactions in the large modern bridges reach enormous proportions. Moreover, these dead-load pier reactions are vertical and constant for any position of the bridge, an all-important advantage. Other results are the securing of a large angle of opening, the secure holding of the bridge against wind, and the provision of a large volume (and consequently economical) counterweight.

It will be evident from the foregoing that the early designs in Europe referred to did not and could not accomplish these results, and further that these results were not contemplated by the early designers. In addition to the above features, the design also accomplishes what the rolling contact type accomplishes, viz, maximum channel for navigation, with the minimum length of span, obtained by locating the axis of rotation in the bottom chord, while at the same time securing the additional advantage of keeping the heel of the leaf always on the pier top and making the leverage of the wind forces, when the span is opened, a minimum.

In the earlier heel trunnion bridges the machinery was located at the hip of the trusses, on the moving leaf, the operating pinion engaging racks secured to a built-up operating strut, one end of which was pivoted to the inclined leg of the counterweight

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tower. In all the later designs the operating strut is pivoted to the trusses at the hips and the operating machinery is located in the portal of the counterweight tower. The latter arrangement is considered better since the machinery is secured to fixed supports and is usually under the same roof with the operator where it is at all times accessible. This also permits a simple and direct connection for the secondary or reserve power operation.

In the bridge illustrated, as well as in all these later designs, an air brake works directly against the flanges of the operating strut. Heretofore all bascule and lift bridges had brakes located on one of the intermediate shafts of the operating machinery, thus requiring machinery heavy enough to withstand the impact of the braking force. In the operating strut brake the machinery is relieved of this impact and an increased factor of safety is attained, since the bridge is held independently of gears and shafting. This design has been patented by the writer and applied to both his bascule and lift bridges.

In the heel trunnion type the greatest advances in bascule construction so far made have been recorded. The longest single leaf bascule bridge built is a heel trunnion double-track span across the Calumet River at South Chicago for the Baltimore & Ohio Railroad, this structure being 235 feet in length. A similar railroad bridge of 260 feet length is now being built in Chicago for the Illinois Central, the Michigan Central, the Chicago and North Western, and the Burlington Railways jointly. Another special application of the heel trunnion type is the 186-foot double-deck highway and railway bridge on the line of the Canadian Pacific Railway over the Kaministiquia River at Fort William, Ontario. A more unusual structure still, illustrating the use of the heel trunnion type for a double leaf simple span bascule, is shown in figure 21, this being a single track railway bridge on the line of the Canadian Pacific Railway over the New United States Ship Canal at Sault Ste. Marie, Mich., completed September, 1913.

For railway bridges the double-leaf cantilever design with live load anchors, as previously described, is objectionable on account of the extremely heavy anchorages. The deflection and play at the center of such a span is also a serious factor in railway service and spans of 300 feet and over are beyond the economical and practical limit of a single-leaf span. By building two heel trunnion leaves adapted to interlock automatically at the center a single simple span bridge is obtained of a length, in this Sault Ste. Marie design, of 336 feet center to center of piers. The interlocking is effected by a compression lock in the upper chord and a tension lock in the lower chord, which are engaged and disengaged by the movement of the leaves in the process of opening and closing the bridge. This movement and the expansion and contraction under temperature are made possible by mounting one entire tower on expansion rollers, which is practicable in this type only because of the divided dead load reactions and the vertical and constant character of these reactions. The tower is locked as soon as the operation of the leaves is under way. Secondary locks for the main locks are also provided.

This bridge, the first of its kind and the longest double-leaf bascule and longer than any vertical lift in the world, has been in service over two years, during which time it has had a great number of openings and withstood higher winds than probably any other, yet no deficiencies in the locking devices or other troubles have developed. An editorial comment on the advance which this structure represents will be found in the Engineering Record of June 20, 1914.

The writer also used the parallel link system in a new type of direct-lift bridge illustrated in figure 22, this being a 210 foot span over the Louisville and Portland Canal built by the United States Government in 1915.

Reference to this structure is somewhat aside from the subject of bascule bridges, but since the method of counterbalancing is so similar to that employed in the bascule the writer takes the liberty of alluding to it in a general way. The design dispenses

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with cables or chains, and is economical where low vertical clearance for navigation is required (in the design illustrated the travel in one direction of the span is 40 feet) and where the span is long. The counterbalancing mechanism can also be located entirely below the roadway and inclosed in the piers when the height of span to be lifted is very limited, for instance over inland canals. The writer has designed such a bridge for the city of Ottawa, Canada, over the Rideau Canal in which the vertical travel of the span is 20 feet. The bridge consists of a center lift span 95 feet long and an approach at either end 52 feet 6 inches long and when closed presents the appearance of a fixed structure. The largest and longest lift bridge so far proposed and now being built, is the Twelfth Street Bridge for the City of Chicago, this structure having a lift span of 240 feet and a vertical travel (in one direction) of 100 feet.

MISCELLANEOUS TYPES.

In addition to the principal types above described, there have been a number of designs developed from time to time which have found local favor. One of those is the Cowing bascule at Cleveland, Ohio, which comprises a circular cradle on the pier, a series of rollers in the cradle, and a circular engaging girder on the bascule. The bridge is a double leaf structure with underneath counterweight, through trusses, and has a clear span of 122 feet. It was built in 1907 and is still in service, but has not commended itself for further adoption.

The Brown bridge is a unique structure, two of which have been built, one at Ohio Street and the other over the Buffalo River Ship Canal at Buffalo, N. Y. The design embodies a bascule leaf mounted on trunnions at the base of a tall tower. A compensating girder of special curvature is built out from the top chord of the leaf trusses, near the trunnion end. Over this girder run a series of cables connecting to the lead trusses at the bottom chord and passing over sheaves at the top of the tower. A counterweight is attached to these cables. The function of the compensating girder is to vary the pull of the counterweight on the leaf. The operating machinery at Ohio Street was hydraulic; in the second design this was abandoned and an electrically driven gear train and operating strut substituted. The action of this bridge is similar to the compensating counterweight bridge described at the outset of this paper and the design is not therefore in accord with the modern tendency in bascule design which is away from the use of cables or flexible devices and high towers.

At Vancouver, British Columbia, there is a trunnion bridge designed by J. A. L. Waddell, and erected over False Creek in 1909. This bridge is a single leaf through span of 128 feet, with overhead counterweight. The trunnions are above the clearance line for traffic. Their bearing surfaces are spherical in shape and are integral with a cross girder supported in castings located at the top of vertical posts outside the trusses, thus forming a single trunnion whose length is slightly greater than the distance between trusses. The trusses are pivoted on the spherical surfaces of this trunnion. Operation is effected by cables passing over the bottom chord of the tail end of the trusses (which are curved in the form of circular arcs) and driven from a drum located behind the span. The bridge is rarely opened and the waterway it crosses is shortly to be abandoned and the bridge removed. No other bridges of this type have been built.

Many other designs of bascule bridges have been proposed and some few have reached the point of actual construction. The field has been an inviting one to engineers as will be evident from the fact that over 100 United States patents on various types of bascule bridges have been taken out. At the present time the activity in developing new types has greatly diminished, with the tendency more and more to the fixed trunnion type as the universal standard.

AESTHETICS IN DESIGN.

The Tower Bridge in London furnishes the first striking example of elaborate aesthetic treatment in bascule bridge design. The bridge at Rotterdam illustrated in figure 10 is another example of artistic treatment without recourse to the use of

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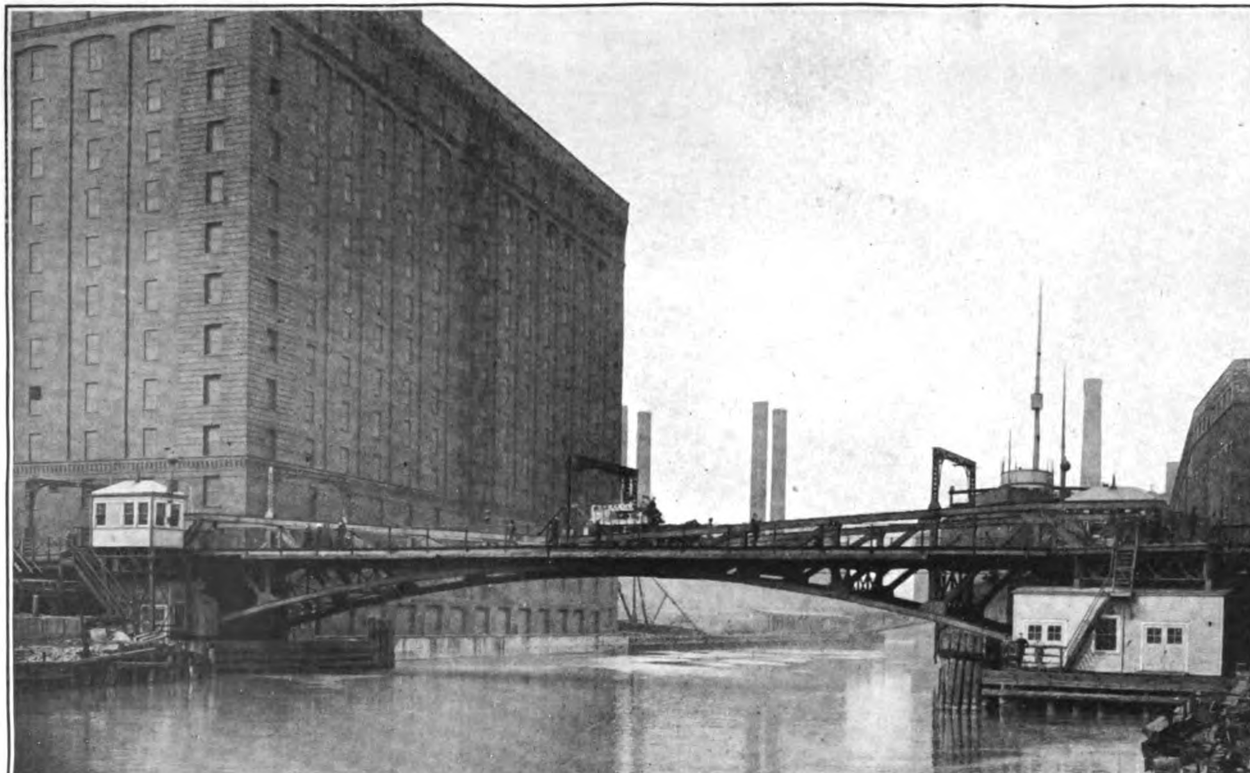

Fig. 19.

Strauss trunnion bascule—counterwts. concealed—built 1908. Polk Street, City of Chicago.

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Fig. 20 (a).

Strauss "heel trunnion" bascule- built 1914. Nor. Pac. Ry.- -Lake Wash. Canal (under construc.) ,Seattle, Wash.

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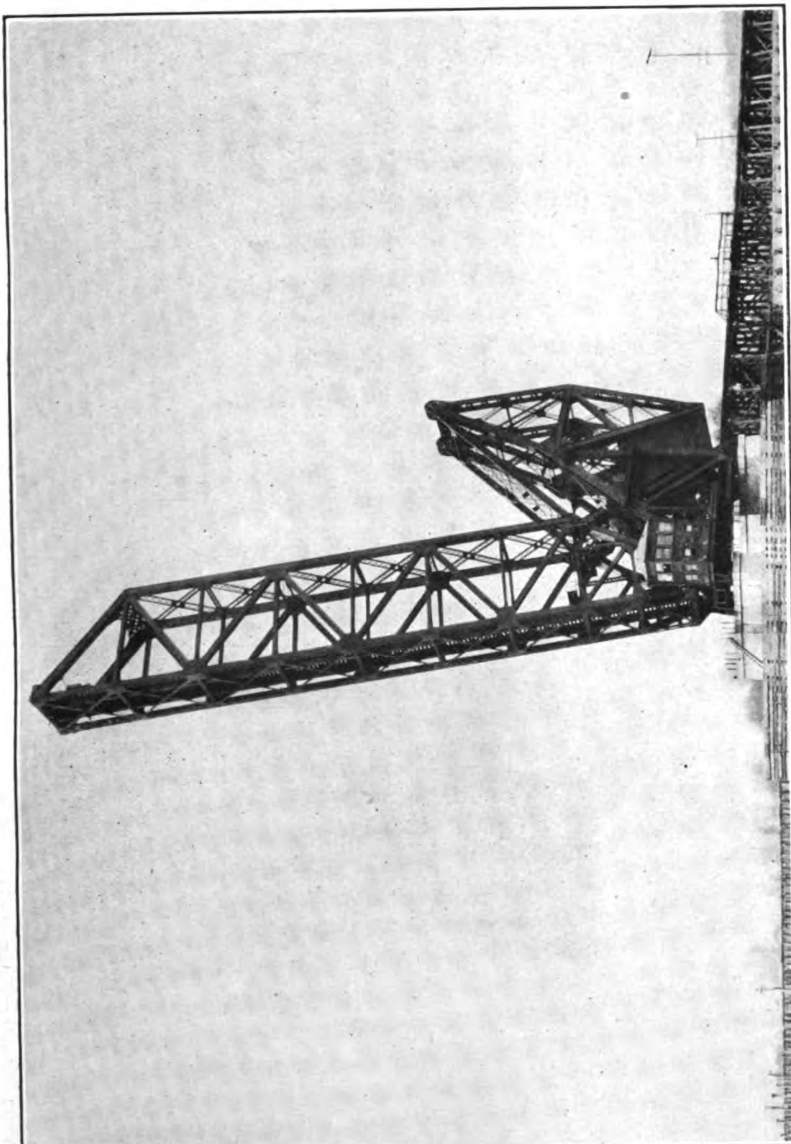

Fig. 20 (b).

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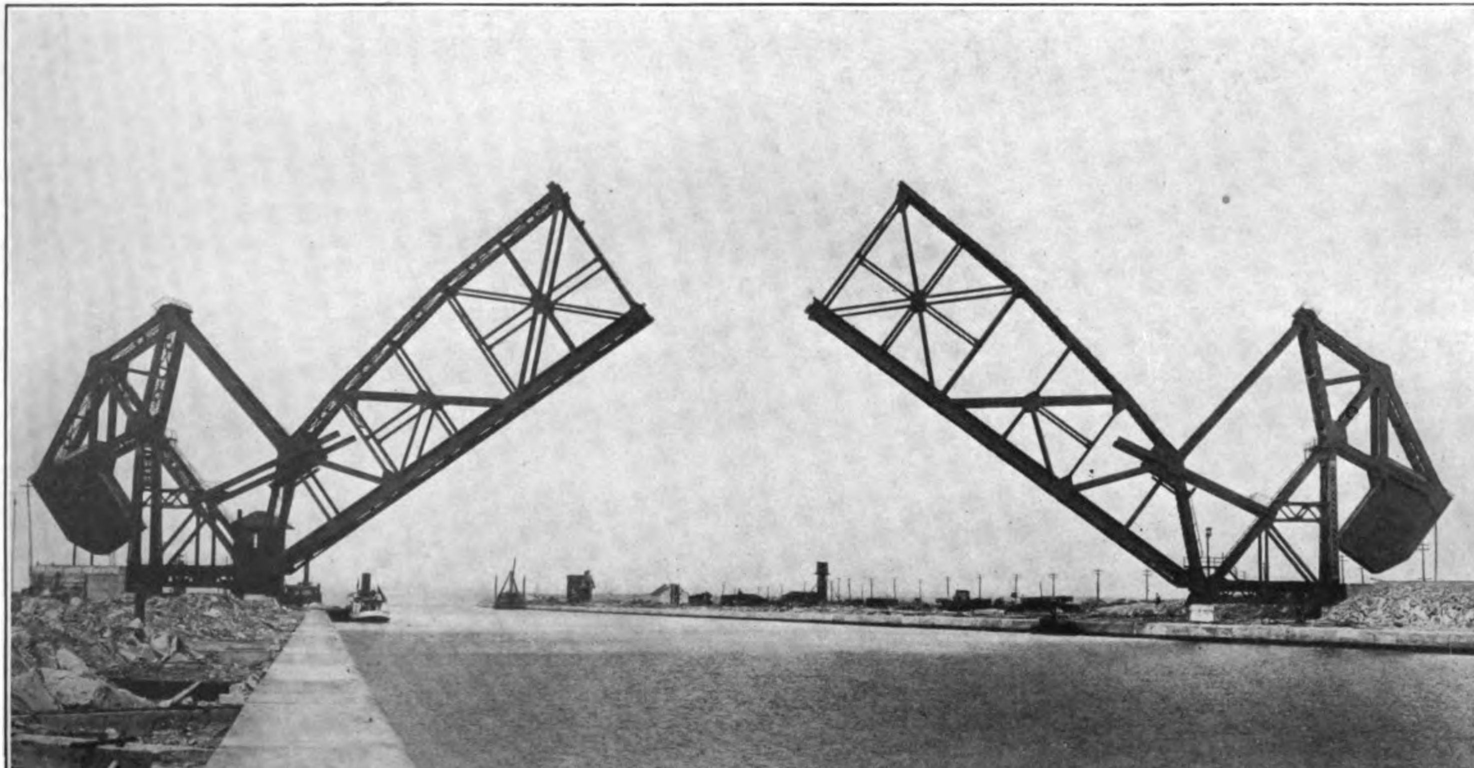

Fig. 21.

Strauss double leaf simple span bascule—built 1913. Can. Pac. Ry., U. S. Ship Canal, Sault Ste. Marie, Mich. Span length bet. trun's. 336 ft. (longest in world).

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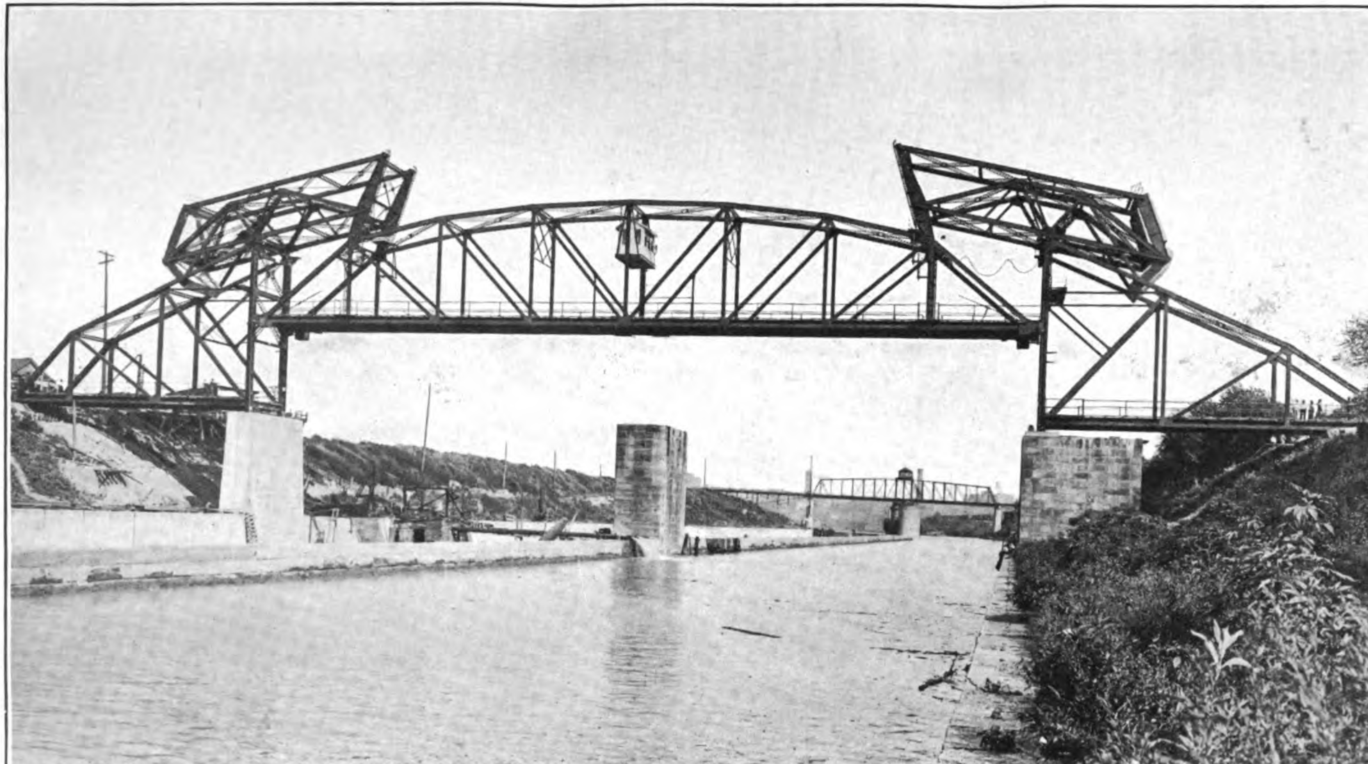

Fig. 22.

Strauss "direct lift" bridge—built 1915. U. S. Gov't. Louisville and Port. Canal, Louisv., Ky.

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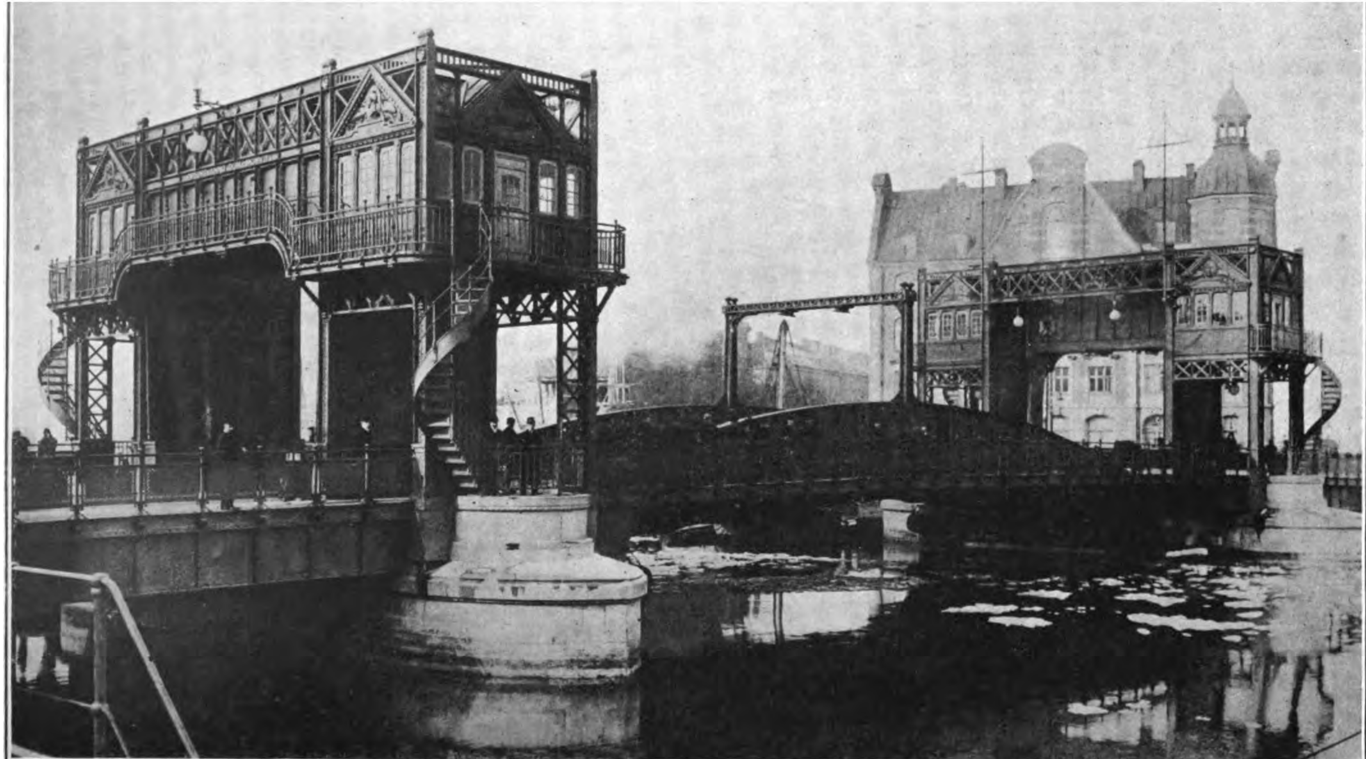

Fig. 23.

Strauss three hinged arch bascule—built 1908. Harbor Board, Copenhagen, Denmark.

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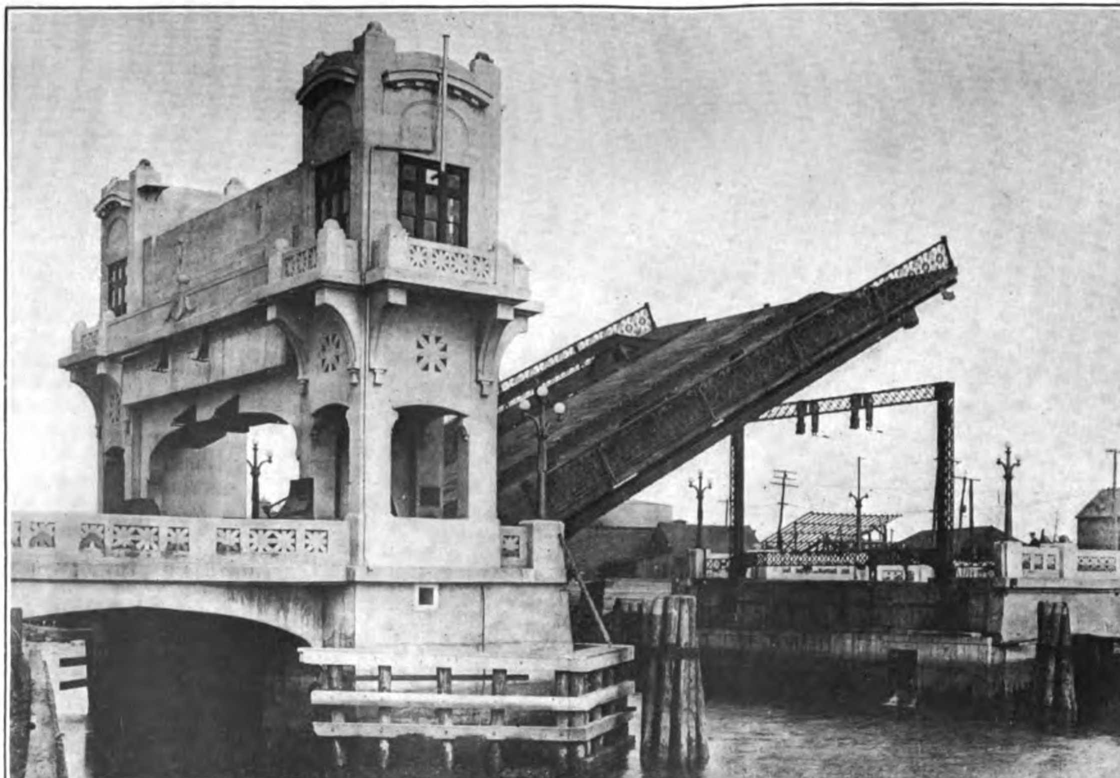

Fig. 24.

Strauss ornamental portal bascule—built 1908. Federal Street, Camden, N. J.

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specially erected towers. In most of the bridges in Europe, notably municipal or government structures, much attention is paid to this feature. Quoting from a "Report on Movable Bridges as used in Europe" of January 1895, by George W. Rafter, State engineer of New York, the following observation is made:

> Nothing impresses the visitor to the European cities more than the elegant appearance of the various classes of bridges. In many places where bridges are required over canals, large open spaces have been left, and the bridge, by effective architectural treatment, made the central point of attraction of the open space. In other cases, embankments and quays of the most expensive character have been constructed along streams passing through the towns, in order, largely, to give the full architectural value of the river bridges as a part of the effective adornment of the town.
>
> It is the use of engineering skill of this high order which has made the European cities so far superior in mere finish to our own; and it is the belief that an enlightened public opinion will demand the use of a similar class of skill in the future public works of this State, that leads to this brief discussion of the artistic side of the question, as opposed to the mere utilitarian, at this time.

As a more recent example of the attention given to this subject in Europe figure 23 illustrates a bridge designed by the writer for the harbor board over the entrance to the inner harbor at Copenhagen, Denmark, built in 1908. The architectural treatment was worked out in detail by the local authorities, but in selecting a design in international competition the writer's design was selected partly because the arrangement of the counterweight and operators' houses furnished a natural means of architectural treatment.

In this country the first step in this direction will be noted in a Strauss bascule at Camden, N. J., completed in 1908. Figure 24 illustrates the effect obtained by using reinforced concrete around the towers and building the counterweight itself in the form of an ornamental portal.

There is a tendency on the part of some engineers and others to carry aesthetic treatment to extremes. The fitness of things should be taken into account; for instance, railroad bridges are very frequently built in manufacturing districts or near freight yards where absolutely no attention has been given, or ever would be, toward beautifying the environment, and it would be obviously improper to expend effort and money in erecting an ornamental structure at such locations. In other cases the utility and safety of so-called inartistic designs so far outweigh any argument for better outward appearances obtained, as generally is the case, by sacrificing the former requirements that the demand for mere architectural treatment becomes insignificant. In the United States there is also a disposition on the part of some to lay down the law that all highway bridges must be deck structures, whereas in Europe the best results have been obtained with portal towers.

CONCLUSION.

In this paper the purely technical phases of the subject have not been covered, the writer confining himself to an outline presentation of the various bascule types with particular reference to the modern forms, and especially those developed in his practice in this field of engineering. The writer's own opinions concerning the subject, as a result of his experiences, are also set forth.

The basis of design of bascule bridges has been largely left to the designers themselves. Many engineers have considered that the various general specifications in use were sufficient to insure the placing of various bascule types on an equality. This impression has now disappeared, it being recognized that no standard specification covers those parts special to bascule or lift bridges. namely, impact for the bridge moving, machinery design, safe loads on the elements of movement, etc. Since it is in these very items that the variation between the various types occur, and since these are the items which determine the relative cost of the different types, the need for bascule specifications as supplementary to ordinary standard specifications, is evident.

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This need is now partly supplied by the specifications of B. R. Leffler, bridge engineer of the New York Central lines west and those of J. E. Greiner, consulting engineer, the former for railway work, the latter covering also highway work. There are still some things to be desired in this respect, and the writer hopes to be able to submit a specification shortly which will cover the work more fully. It is believed that the practice of inviting simultaneous designs and bids still adhered to by some is not in accord with good practice as obtaining in other branches of engineering work.

Selection of the type of bascule or the bascule design is an engineering proposition pure and simple, and must be entirely separated from the contract for construction. Designs and types should be selected on their relative merits and after this selection is made and full plans are prepared by the successful contestant, bids from contractors should be received. In no other way can the client be fair to the designers and insure the best result to himself. The invitation sent out by the Chicago & North Western Railway in asking designs for their bridge at Deering, Chicago, and by the Illinois Central Railway for their bridge at Sixteenth Street, Chicago, is here submitted as an example of the best modern practice in this respect, as follows:

In making a comparison and in deciding upon a type of bridge to be used the following are some of the points which will be considered: (*a*) Efficiency and dependability, (*b*) facility and economy of erection, (*c*) liabilty to wear, (*d*) first cost, (*e*) cost of maintenance and operation, (*f*) probability of accident by failure of working parts, (*g*) liability to injury in case of accident or train wrecks or if struck by vessels.

As to design, while the proper allowable stress on rollers and rolling girders has not yet been determined, the allowable unit stress on trunnions has been definitely established. The average bearing load on trunnions for bridge moving is 1,100 pounds per square inch running up to 2,000 pounds for peak loads. This has been found to give satisfactory results over a long period of years in the heaviest service. In some of the first of the modern heavy trunnion bridges, difficulty in lubrication was experienced under these pressures, but this has been entirely overcome in the oiling systems now in use and which are in accord with the requirements of Leffler's specifications, above referred to. As regards the machinery, the present tendency is to relieve it from shock by using a brake acting independently, as referred to previously. Cut gears are also coming into more general use. The location of the operating machinery on the movable section of the bridge is not sanctioned in Leffler's specifications, and is rapidly passing out.

As regards the general design, more consideration is now being given and properly so, to safety and low cost of upkeep. It is no difficult task to produce a movable bridge which will operate, but that is no longer enough. It is now recognized that the bascule bridge is really a machine and like any machine the criterion is safety and minimum upkeep. In line with this tendency the use of flexible and fallible elements is now discouraged and such features as tail and front end live load locks, openings in the floor through to the pit, etc., and other means of reducing first cost are gradually disappearing.

There is every indication that the bascule bridge is now reaching the best stage of its development and that it will attain ever increasing importance in our expanding industrial life.

ADDENDUM.[1]

Reference is made on page 315 to the writer's design of direct-lift bridge. As this type was developed with the object of eliminating the unsatisfactory features which in the opinion of various engineers are believed to exist in the cable type of vertical-lift bridge, the following comparison concerning the two types of vertically lifting bridges is appended herewith. The cable design will be referred to as the "vertical lift," and the writer's design as the "direct lift."

[1] Furnished by the writer after the delivery of the paper.

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(1) The direct lift, as the name implies, has its component parts directly connected by nonflexible members. The vertical lift has its component parts flexibly connected.

(2) The direct lift is economically and exactly balanced. The operating motors therefore are not required to do work against the dead weight of any part of the structure. The vertical lift must employ the use of expensive auxiliary balancing devices, such as chains, to balance the weight of the cables, which hang alternately on the span side and counterweight side of the sheaves, or else the operating motors are overtaxed.

(3) In the direct lift the main elements of movement, the trunnions, are completely enclosed and protected from the weather, dirt, grit, etc. In the vertical lift the main elements of wear, the cables, are exposed throughout their entire length, (in a span of any size and importance they aggregate a length of 2 miles or more), and are difficult and expensive to inspect and maintain.

(4) In the direct lift all parts of the structure are of equal longevity, while in the vertical lift the life of the cables is limited. In bridges infrequently used the cables may assume a semipermanent set around the sheaves and when not lubricated will rust into solid rods.

(5) The moving load in the direct lift is supported at each end of the span in all cases on single tower posts and at a lower point on the post than in the vertical lift, where the moving load is always concentrated at the extreme top of the post, and where in some cases twin tower posts at each end are required.

(6) In the verticla lift, where roadways are cantilevered on brackets outside of the trusses, special provision must be made to prevent the span from overturning under eccentric loading. The transverse bracing between lifting members of the direct lift provide for eccentric loading.

(7) In the vertical lift the operating machinery and house should be placed in the middle of the span on account of unequal stretch of the cables. In the direct lift the machinery and house can be placed close to one end of the span on account of the rigid connections and rack and pinion drive. This decreases the dead-load moment on the span.

(8) The use of the counterweighted levers permits support of the span at intermediate points, reducing the dead-load stresses, which is not possible with the vertical lift, since the span must be supported at its ends.

(9) The method of support referred to in (8) permits the erection of the direct lift in the open position by the cantilever method with minimum false work. In the vertical lift expensive false work is required for such erection.

(10) By reason of the counterweight lever device system the direct lift can be built for low lifts with the counterbalancing and operating mechanism entirely below the floor. The same result can not be accomplished as directly with a vertical lift.

(11) The vertical lift requires more power to operate, even when the unbalanced weight of the cables is compensated, than the direct lift because it has in addition to the friction of the sheave journal bearings and cable equalizing devices (which equal the friction of the trunions in the direct lift), the friction of the cables on the sheaves or drums), the bending of the cables around same, the sliding friction of the counterweights, and the greater friction of the guides for the span itself. This latter friction is greater in the vertical lift because the cables which suspend the span have little or no longitudinal or transverse resistance to the wind whereas the stiff connecting members and bracing in the direct lift furnish proper stability and greatly relieve the friction on the guides for the span, while no guides are required for the counterweight.

(12) Capitalizing cable maintenance and renewal and power consumption of the vertical lift together with its greater height of towers and disadvantages of the dead load support of the main span, necessity of auxiliary counterweight chains, and greater

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cost of erection, it will be found, in most cases, where a vertically lifting bridge is desirable, that the direct lift is more economical to build and use than the vertical lift.

Having hereinbefore given a comparative statement relating to the center pivot swing bridge and the bascule bridge, it will be appropriate to incorporate here a statement concerning the comparative use and advantages of the bascule and the vertically lifting bridges.

(1) There are approximately in use or under construction in this country and Canada 400 important bascule bridges, while the vertically lifting bridges of consequence number about 50. Both types were introduced simultaneously.

(2) The bascule is positively connected to the piers and moves upon supports directly on the masonry. The vertically lifting bridge is supported high above the piers, has no positive connection to them at any time and in operation moves bodily away from them.

(3) The mass of the bascule is concentrated near the pier tops. In the vertically lifting bridge the combined mass of span and counterweight is concentrated at a considerable height above the pier tops.

(4) The center of side wind pressure in the bascule is half as high as in the vertically lifting bridge, important, when it is remembered that the wind seldom blows in a horizontal direction, but usually obliquely, thereby exerting a proportionate pressure on the horizontal surface of the floor.

(5) The vertically lifting bridge usually has the operating machinery located on the lift span. The bascule in modern bridges usually has the operating machinery located on a fixed part of the structure.

(6) The bascule movement being rotative, requires no guides. The vertically lifting bridge requires guides in some designs for both counterweight and span.

(7) In the bascule, snow, ice, and other accumulations are discharged automatically as the bridge opens; in the vertically lifting bridge they add to the power waste, unless removed by manual labor.

(8) The time required to pass a vessel through the draw and resume traffic is less with the bascule than with the vertically lifting bridge.

(9) The vertically lifting bridge is at a disadvantage in the matter of repairs. The span must be fully raised and all work done high in the air and above water, which is slow, dangerous and costly.

(10) The vertically lifting bridge naturally permits of the use of wood block pavement. In the bascule special provision, such as holding angles laid transversely at intervals and secured to the subplanking, has been used successfully for the past two years on all bridges where block paving is required.

(11) The vertically lifting bridge fixes the vertical clearance for the navigation requirements obtaining when built. If built for river traffic, for instance, masted vessels and ocean-going steamers are barred or their advent on such streams discouraged if not restricted, and as a compliment to this condition high towers may become wholly unnecessary should ocean-going traffic change to low craft. Such considerations do not enter at all for the bascule, since it provides unlimited vertical clearance without in any way increasing or decreasing first cost.

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OBSERVACIONES GENERALES SOBRE EL RÉGIMEN DE LOS CURSOS DE AGUA DE LA REPÚBLICA ORIENTAL DEL URUGUAY, DESDE EL PUNTO DE VISTA DE LA CONSTRUCCIÓN DE PUENTES—SOLUCIONES ADOPTADAS.

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La República Oriental del Uruguay que por su clima y condiciones generales del suelo brinda una explotación fácil y próspera de sus tierras, posee en cambio el sistema hidrográfico menos aparente para favorecer el desarrollo la navegación interior y el aprovechamiento de las aguas con fines industriales, constituyendo además una seria dificultad a las soluciones francas de las comunicaciones terrestres.

Con frecuencia se emiten juicios favorables respecto a la multiplicidad de nuestros cursos de aguas, considerando esta circunstancia altamente beneficiosa para el desarrollo de la industria ganadera. Es posible que así sea. Pero esa condición natural que tanto parece apreciarse, no es sino la más evidente manifestación de la impermeabilidad del suelo, uno de los dos principales factores que determinan el régimen torrencial de la casi totalidad de los cursos de agua del territorio uruguayo.

La impermeabilidad del terreno es variable. La zona del Sudeste, de constitución topográfica montañosa, lo es en alto grado; la del Norte y Central cuyo suelo es, con algunas excepciones, suavemente ondulado, se presenta con características más favorables, siendo la zona Sudoeste, de suelo igualmente ondulado, la extensión menos impermeable del país. En cuanto a la última no es difícil hallar la explicación. Los departamentos situados al Sudoeste comprenden terrenos en los cuales la tierra vegetal adquiere una profundidad considerable, condición que apreciada por su influencia en la producción, ha dado lugar a que los campos de los departamentos de Colonia y Soriano sean los más codiciados. Sin embargo, toda persona observadora no dejará de notar la cantidad de molinos de viento instalados en aquellos campos, con el objeto de extraer el agua para surtir los abrevaderos. Los arroyos y cañadas escasean, en los potreros faltan aguadas, es necesario excavar pozos para elevar las aguas que los ganados no encuentran en la superficie.

A pesar de todo, esas tierras son las que han adquirido mayor valorización. La realidad de los hechos está pues en contraposición con la idea muy generalizada respecto a las ventajas que ofrecen la multiplicidad de los cursos de agua. Las consecuencias de una red tan cerrada, por lo que ella significa dentro de las diversas circunstancias que dan origen al régimen de un río, permiten llegar también a conclusiones poco favorables respecto a nuestro sistema hidrográfico.

La intensidad de las lluvias constituye el otro factor primordial. Los observatorios metereológicos han llegado a registrar, recientemente, precipitaciones diurnas de 135 y 150 milímetros de altura.

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