This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

FIFTEENTH LIST

WESTERN SOCIETY OF ENGINEERS

ORGANIZED 1869
INCORPORATED SEPT. 1ST, 1880

CONSTITUTION,
BY-LAWS, LIST OF OFFICERS
AND MEMBERS

JUNE, 1900

SECRETARY'S OFFICE, READING ROOM, LIBRARY AND MEETING HALL,
1734-1741 MONADNOCK BLOCK
CHICAGO

XCI.

REBUILDING OF THE KINNICKINNIC RIVER SWING BRIDGE ON THE CHICAGO & NORTHWESTERN RAILWAY, AT MILWAUKEE, WIS.

BY FRANCIS H. BAINBRIDGE.

Read April 4, 1900.

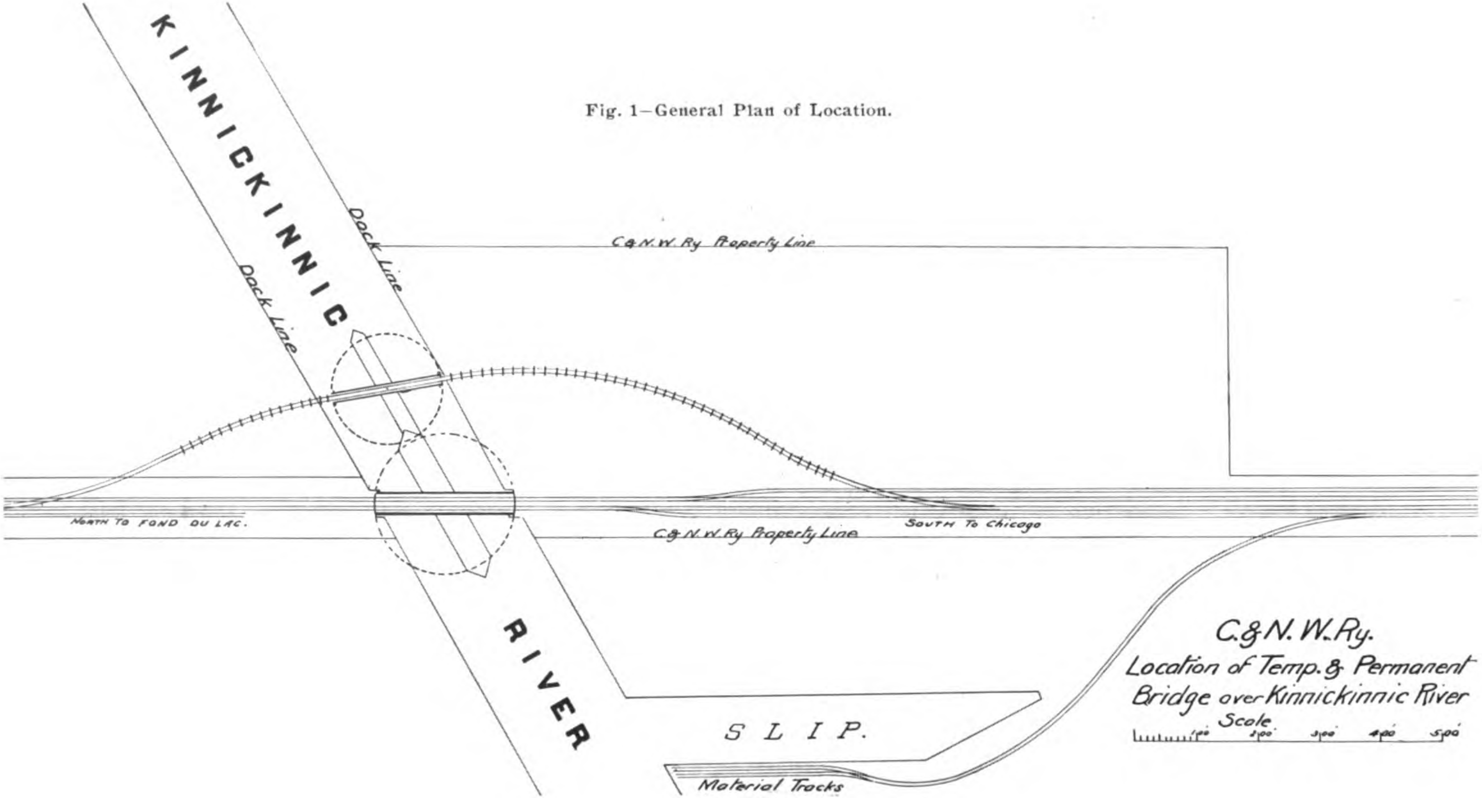
The Kinnickinnic river bridge is located on the Chicago & Northwestern Railway, Milwaukee Division, about three miles south of the Wisconsin St. station in Milwaukee, Wis. The old structure was a 177-foot single track through pin-connected swing bridge built in 1880. It was still at the time of its removal sufficiently strong to safely carry the increased weight of rolling stock, but the management of the Chicago & Northwestern Railway decided to replace the old span with a double track structure, the double track converging to a gauntlett track on the old structure.

Fig 1 shows the position of the new structure, as well as the temporary trestle and the removed position of the old structure during the rebuilding of the new. It also shows the position of the slip and material tracks from which all the material used in connection with the new structure was handled, except the filling behind the abutments, which was of course directly unloaded from cars to its final position.

The old bridge with its track, drum wheels, tread and center, weighing in all 255,800 pounds, was moved a distance of 219 feet to its temporary position to carry the traffic of the road during the building of the new span. Fig. 2 shows the position of the scows on which the bridge was lifted from its supports, and floated to its temporary position, also the arrangement of the blocking, and a stress sheet of the trusses while supported by the scows. Fig. 3 shows the arrangement of the blocking on one of the scows. The operation of removal was, briefly, to fill the scows with water ballast and wedge up under the span; to pump water out of the scows until their buoyancy carried it clear of its supports, to move the floating bridge to its proper position, and lower to place by pumping water into the scows, at the same time allowing them to fill by removing plugs from their bottom.

The pumps used in pumping out water ballast were one steam pump with 6 x 14 in. water cylinder; one steam pump with 8 x 14 in. water cylinder running 80 revolutions per min.; two fire engines

Fig. 1—General Plan of Location.



and two fire tugs, the latter using steam siphons only. The fire tugs and engines belonged to the fire department of the City of Milwaukee. The total amount of water pumped out of the scows to lift the bridge clear of the center pier was 92,600 gallons, or 1624 gals. per min. actual working time. The total amount pumped into the scows to lower the bridge was 69,400 gallons.

The time required to perform different parts of the work was as follows: The last train passed over the bridge at its permanent site at 9.05 a. m. Between 9.05 and 9.30 an ice jam was removed in the south channel in order to get the south scow under the bridge in its proper position; one fire tug and two scows, each with one fire engine, were placed in position west of the bridge, and one fire tug and two pile-driver scows east of the bridge. The boilers on the pile-driver scows furnished the steam for the steam pumps.

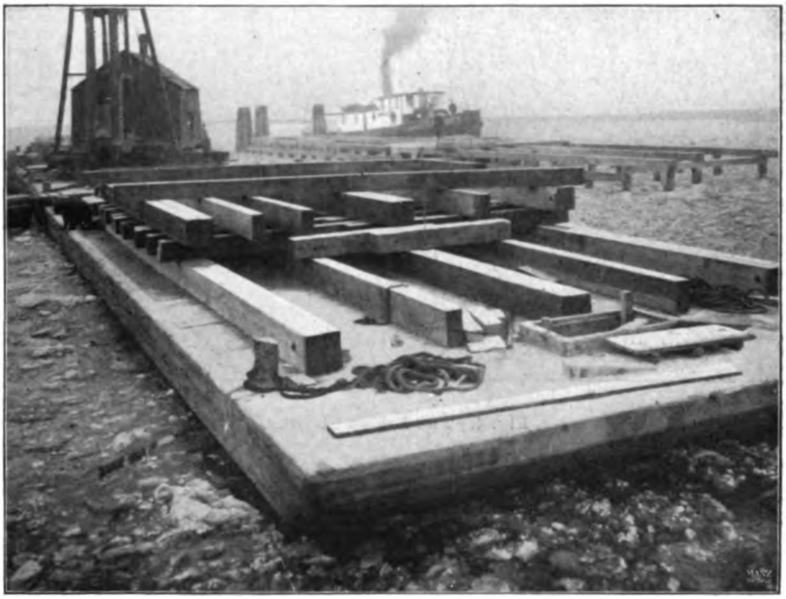


Fig. 3.—Blocking of Scow.

Up to 9.30 a. m. there was no interference with railroad traffic over the bridge. At 9.30 all pumps were started, except on one fire tug, which was started at 9.35, and at 10.35 all water was clear out of the scows, and the bridge stood 2 ft. clear of the center pier. It was believed to be essential that practically all water should be removed from the scows to prevent the sudden shifting of the water from listing the scows. At 10.45 the bridge started down the channel, being towed by the two pile-driver scows, one on each side the protection, the pile-driver scows being drawn by lines running ahead to the temporary protection, the slack of the lines being taken up on the spools of the pile-driver engine. At 11.15 a. m. the bridge was over the temporary pier and abutments ready to lower. At 11.17 four plugs, each 3 in. in diameter, from each scow, were pulled, and all pumps started to pump water into the scows to lower the bridge. At 12 m. the bridge was landed, and at 12.10 p. m. the scows that supported the bridge in moving were released. At 12.20 p. m. the bridge was swung open by its own machinery to let the scows carrying the fire engines pass down the river, and at the same time the bridge was ready for traffic.

Fig. 4.—The Bridge Starting.

Fig. 4 shows the bridge at the beginning of its transit, and Fig. 5 in the act of being lowered to its temporary position. The moving was done Dec. 18, 1898.

The substructure of the new bridge is masonry laid on two courses of grillage, and supported on piles cut off about 16 ft. below mean water level. 65 ft. piles were used for the center pier, and 60 ft. piles for the abutments. These were driven where possible to 14 ft. below water level. For the center pier the final penetration under the blows of a steam hammer weighing 4,200 lbs., with a total weight of moving parts of 8,200 lbs., and a stroke of 3 ft., varied from nothing to .85 inches—average ¼ in. The greatest moving and fixed load for each pile is 17 tons. The abutment piles were 60 ft. long, and driven to 14 ft. below water level, the final penetration varying

from 3 in. to nothing, with an average of about ⅝ in. The possible load per pile is much less than for the center pier piles.

Fig. 6 shows a plan of the center pier and abutment coffer-dams. At the center pier 2 rows of triple lap Wakefield sheet piling 34 ft. long were used; at the abutment one row of the same 34 ft. long at the front and side, and 26 ft. long at the back. At the center pier the space between the two rows of piling was filled with clay. In pumping out the coffer dams a four inch plunger pump and a ten inch centrifugal pump were used. After the water was once out no trouble was experienced in keeping the dams from flooding with the 4 in. pump alone.

Fig. 7 shows an interior view of the center pier coffer dam, and Fig. 8 the abutment coffer dam.

Fig. 5.—The Bridge Being Landed.

All masonry was laid with a steam derrick, with a 40 ft. boom mounted on a scow 81¾ ft. long, 27½ ft. wide and 7 ft. 7 in. deep. Stone was unloaded directly from cars on the tracks next the slip, marked as material tracks in Fig. 1. The scow was moved by a forward line operated from the spool of its hoisting engine. Fig. 9 shows a plan of the derrick on the scow, and Fig. 10 a photograph of the derrick laying stone at the center pier. At the center pier 600 yds. were laid in 12 days by means of the derrick scow, although the river was filled with floating ice at the time. The capacity of the scows as ordinarily used was 60 yds. of stone.

Fig. 7.—Center Pier Coffer Dam.

Fig. 8.—Abutment Coffer Dam.

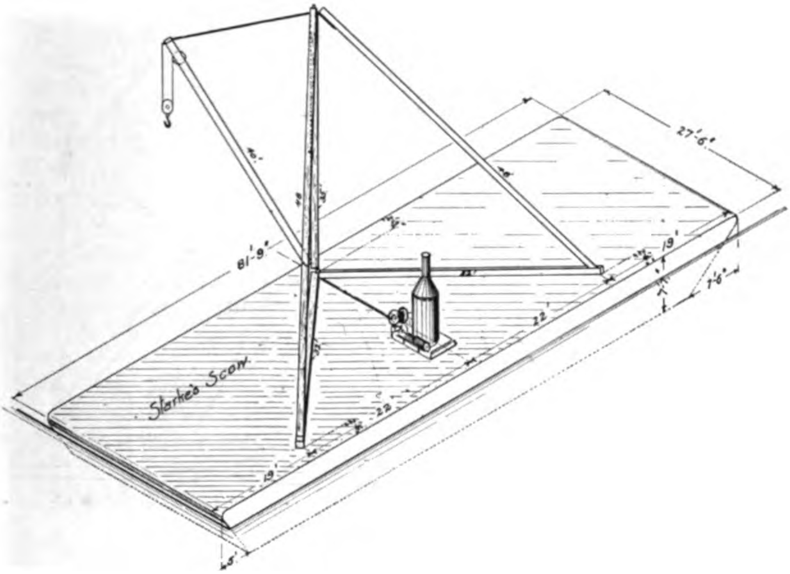


Fig. 9.—Plan of Derrick Scow.

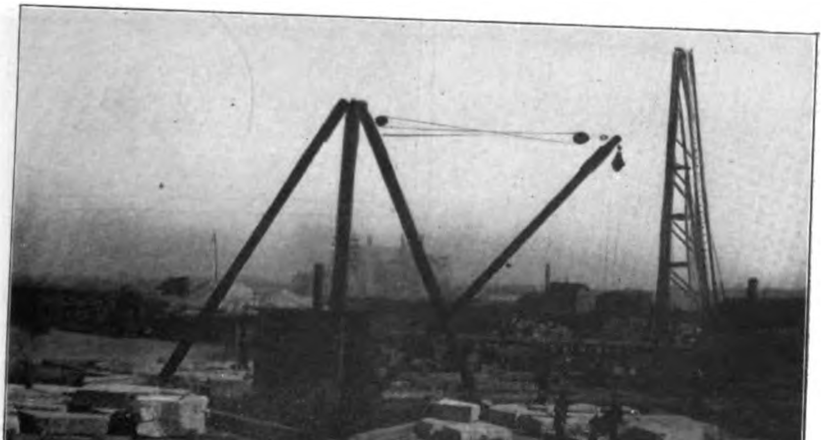


Fig. 10.—The Derrick Scow.

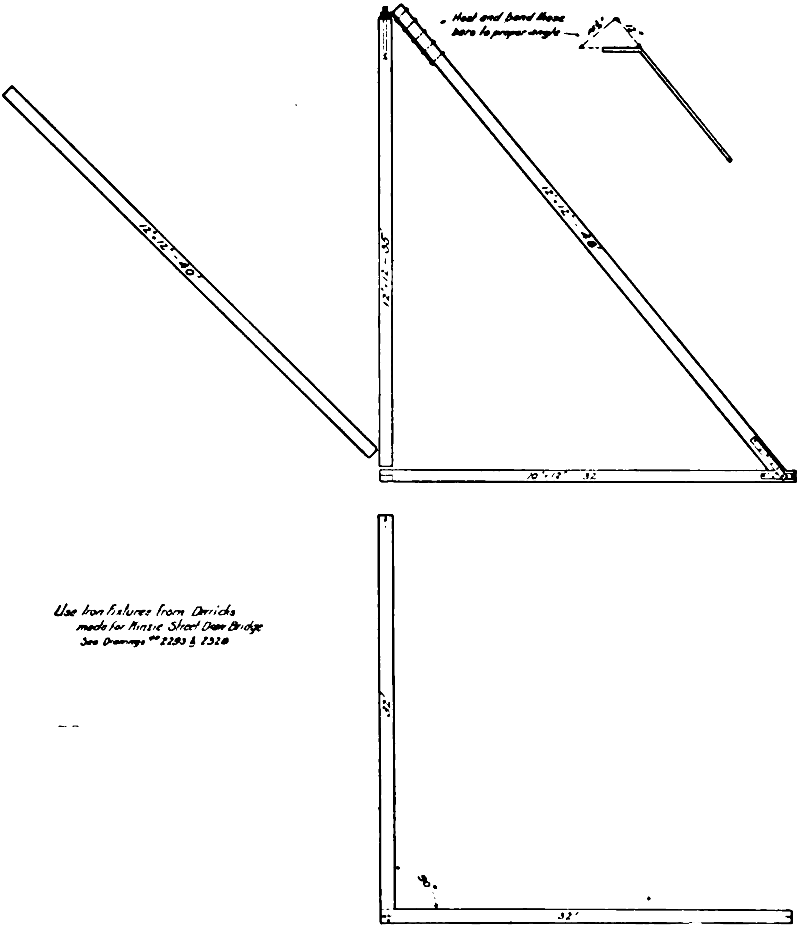


Fig. 9 a.—Detail of Derrick Scow.

THE SUPERSTRUCTURE.

The superstructure is a double track through rivetted lattice span 234 ft. over all. Fig. 11 shows a side view of the completed bridge, and Fig. 12 an end view. Rivetted lattice trusses are standard on the Chicago & Northwestern Ry. for single track fixed spans from 110 ft. to 160 ft., and for double track fixed spans from 110 ft. to 140 ft. Inasmuch as a fixed rivetted lattice span weighs from 15 to 20 per cent. more than a pin-span designed under similar conditions, some substantial reasons should exist for using the former. These are principally that rivetted lattice trusses have withstood the effects of the constantly increasing weight of rolling stock better than pin-bridges have, and that they are less liable than a pin-bridge to be

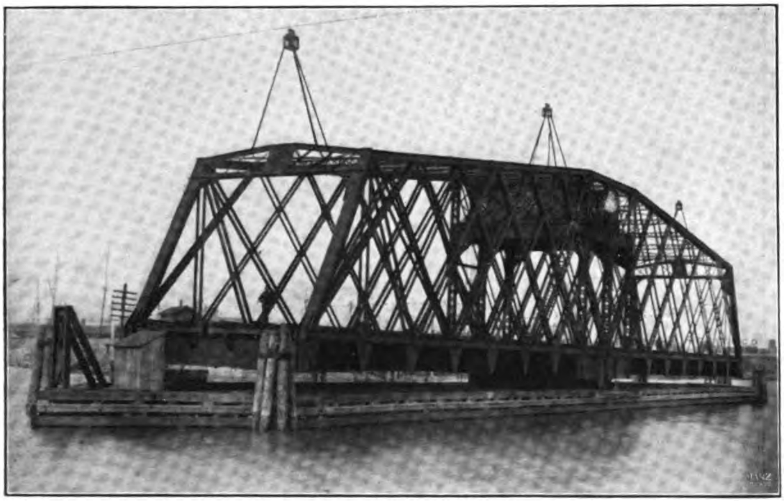


Fig. 11.—Side View of Bridge.

wrecked by a derailed train. Fig. 13 shows a rivetted lattice span at Fond du Lac, Wis., just after a collision had occurred on the bridge in April, 1898. A freight locomotive left the track and passed completely through the side of the bridge, as shown in the photograph, severing the web members at three panel points. Notwithstanding this the train which the engine had been hauling was successfully drawn off the bridge and four other trains run over it before any repairs had been made or supports supplied. Fig. 14 shows a side view of the same truss after bents had been placed under the unsupported floorbeams. It clearly shows the extent of the damage which had taken place. Some years ago Mr. Stowell, at that time bridge engineer for the state of New York, cited a number of cases in which end posts in lattice bridges had been completely broken without wrecking the structure.

Fig. 15 shows the effects of two accidents which happened to a rivetted lattice span on the Chicago & Northwestern Ry. at Daggett, Mich., both accidents being caused by logs projecting from a moving train. In both cases it would appear that a log projecting from a car struck the end post and caused the entire load of the car to shift, raking the whole side of one truss.

Fig. 16 shows a plan and elevation of the bridge center and turning machinery. The motive power is a 22 h. p. gasoline engine, with a maximum speed of 185 revolutions per minute. The multiplication from the engine pinion to the driving pinion is 27. Inasmuch as the gasoline engine can run only in one direction, two friction drums are provided for reversing the motion of the bridge, one or the other

Fig. 12.—End View of Bridge.

of the friction drums communicating power to the driving shaft, according as a hand lever operating wedge clutches on each of the two shafts is thrown forward or back.

About two-thirds of the weight is carried on the live ring of fifty cast steel wheels, the remaining one-third being carried at the center. Here the moving and fixed surfaces respectively are a 20 in. diameter phosphor-bronze disc, and a 20 in. diameter hardened steel plate. There is no adjustment for transferring weight to the

Fig. 13.—Accident to Bridge at Fond du Lac.

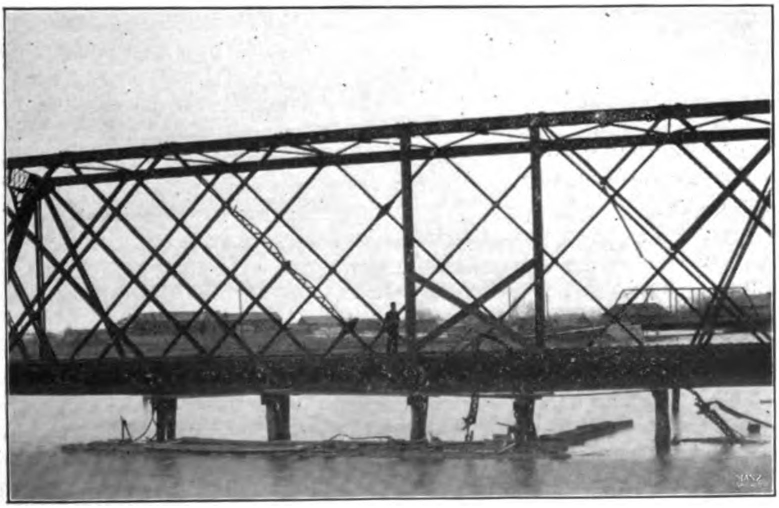
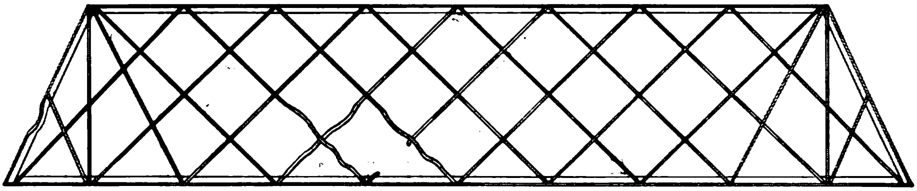
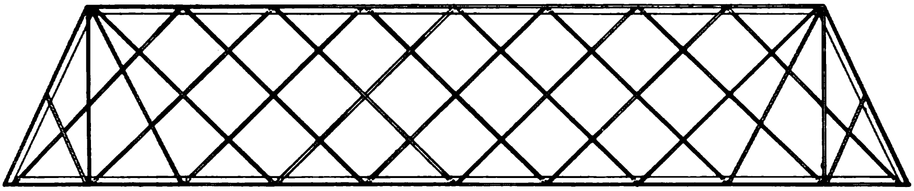


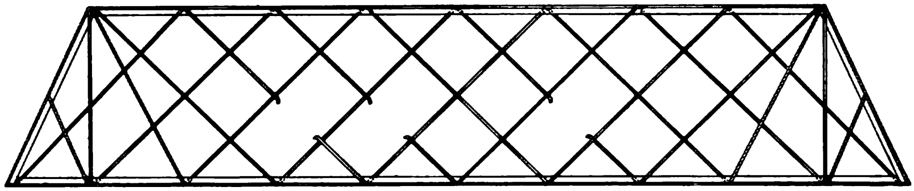
Fig. 14.—Fond du Lac Bridge Blocked Up During Repairs.



Accident of 1889



Side Elevation 117ft Thro. Riveted Truss at Daggett Mich.



Accident 1900

Fig. 15.—Accidents to Bridge at Daggett, Mich.

center, the load at that point being transferred there by jacking up the bridge after it was finished and placing an additional 3-16 in. plate over the center casting. Previously the girder rested on the center casting, which carried the weight of the girders only.

There is no drum, strictly speaking, the upper coat tread being attached directly to the distributing girders, subsidiary corner girders completing an octagonal substitute for a circular drum.

Fig. 18 is a photograph of the engine and the two friction drums. The writer has had experience with two bridges operated by gasoline engines, and in both cases the engines have proved convenient, economical and satisfactory. The engines are built commercially principally for continuous service. On swing bridges the service is intermittent and it is essential that the engine should start off at the first trial. The operation of starting is to pour a small quantity of gasoline into a receptacle below the hand air pump. This receptacle is filled with wood fibre, which absorbs the gasoline. Then with half a dozen quick strokes of the air pump air is drawn through the saturated wood fibre and forced into the engine cylinder, together with a certain quantity of gasoline vapor; next the fly-wheel is started by the operator; at the same time a match striker is struck with the hand. The flame of the match causes the first explosion, afterward an electric battery furnishes the spark. In order to make certain of an explosion of sufficient force to start the engine, the mixture of air and gasoline vapor must not vary beyond certain proportions, the proportions varying with the temperature. When the cylinder is heated an explosion is almost certain, no matter what the mixture; when cold, the mixture must be close to a fixed proportion. It required considerable experience to judge the requisite quantity to be admitted into the wood fibre, the quantity varying with the flashing point of the gasoline. When in continuous service almost any quality of gasoline, or even kerosene, may be used, but for intermittent service we have found that gasoline with a flashing point of 84 degrees gives the best result. The cost of fuel for operating is less than 2 cents a swing, so that the cost of gasoline is of little importance.

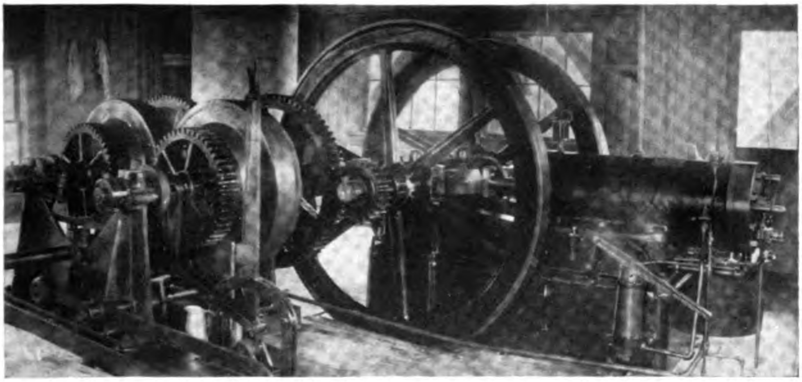


Fig. 18.—Engine and Friction Drums.

If the engine-house is attached to the bridge trusses, it must be remembered that the rapid revolution of the fly-wheel causes considerable vibration, and the engine floor and adjacent parts of the truss must be stiff enough to resist it.

The span was erected on its own protection pier, the material being transferred from cars by the derrick scow, the entire center, floor system and bottom chord being set with the derrick. The rest of the iron work was piled upon the floor system already in place, and afterward erected with a traveller in the ordinary way (see Fig. 17).

The old span was taken down with the derrick, two loads sufficing to remove the whole span. All timber in the temporary trestle, piers,

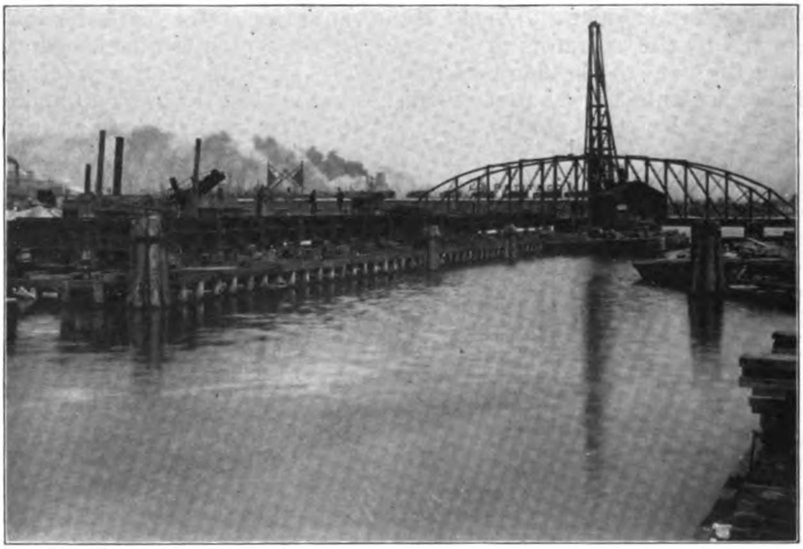


Fig. 17.—Bridge Floor During Erection.

abutments and protection pier was rafted and floated to the slip shown in Fig. 1, and loaded there directly on cars with the derrick scow. The capacity of the material tracks was such that ordinary switch service of the Milwaukee yard was sufficient to handle the material, a work train being scarcely used at all except for the filling back of the abutments.

The structure was planned and designed by the engineering department of the Chicago & Northwestern Ry., under the direction of Mr. E. C. Carter, at that time principal assistant engineer, the work in the field being carried out by the writer, under the direction of Mr. W. H. Finley, engineer of bridges.

DISCUSSION.

Mr. G. P. Nichols—I notice that Mr. Bainbridge has placed an equalizer in his cross shaft; I want to ask him if he considers that a necessity, or, in other words, if in introducing this equalizer is he not apt to give rise to more trouble than he is obviating. Would it not be just as well to figure the size of the shaft so that it will be amply strong for the service required, but at the same time have enough torsion so that in itself it would be an equalizer?

Mr. Bainbridge—I do not know whether I am enough of a mechanic to answer that question, but all large swing bridges, so far as I know, are built with an equalizer, and with this equalizer, that we had there, if one of the pinions was thrown out of gear, the other pinion was idle. Without the equalizer the load would probably be

all borne by one pinion, and you might just as well have but the one pinion, and not the two. I do not see how you could expect to have two pinions do the work without the equalizer; that is, in fact, the function of the equalizer, that the work should be distributed between the two pinions.

Mr. G. P. Nichols—My idea, based on observation and experience, is that if the rack and pinion are made and fitted with a reasonable amount of care, the pinion and whole train of gearing brought to a bearing, and then the key seat in the shaft for one of the bevel pinions or any of the gears be cut, results will be obtained which are wholly satisfactory. I have used this method on quite a number of bridges, the largest one being the Rush Street bridge, Chicago, which has now been running in this manner for about ten years and I have never heard any adverse criticism on its workings. Of course, this method should only be used where the cross shaft is of some considerable length and not where the two vertical shafts are very close together, which would eliminate the possibility of the necessary amount of torsion. The equalizer in itself is somewhat complicated on account of the introduction of additional bearings, pinions, etc., and every such complication, on a class of machinery which at the best receives very little attention, is to my mind a dangerous element and the simpler the machinery can be made the more satisfactory will be the results.

Mr. Finley—There is nothing complicated about the equalizer; it is about as simple a piece of machinery as you can put on the drawbridge.

Mr. Reichmann—While in Milwaukee the other day I spent a few spare moments in looking over the city bridges which are being operated by electricity. These bridges are small and light, and their gearing is cast and very crude and has no equalizers. I saw one of the bridges had broken a pinion shaft fully three and one-half inches in diameter, which undoubtedly was due to the fact that they were running the bridge without an equalizer, for I know we are operating bridges fully twice as heavy as that with the same size shafts, and they do not break.

Mr. Modjeski—It would seem to me that it would be rather poor policy to make that shaft light; it is one of the important parts of the machinery, and when it is made light it is subject to fatigue under reversal of stresses, and is therefore liable to give way, so that it should be made one of the strongest parts of the whole machinery.

Mr. Strobel—I would like to ask Mr. Bainbridge whether he can give us the reason for adopting a gasoline engine for that bridge, rather than the more customary electric motor. And further, whether he can give us any examples showing that the riveted lattice type of bridge will stand overload better than the pin-connected bridge, as he claims.

Mr. Bainbridge—As regards the relative advantage of gasoline engines and electricity, I think no one would use the gasoline engine where electricity was available. In this case we did not have electricity available. As regards the failure of pin-bridges from overloading, I have not in mind any specific instances just now, but the failures of pin-bridges that have occurred have been largely due to the excessive vibrations in the bridges due to the wearing of the pin. I have never seen an old pin bridge taken down but that the pins were worn from 1-16th inch to deeper, and in the case of those pin bridges from fifteen to twenty years old, when trains run over them they shake so as to frighten you; a riveted truss does not. It may be entirely in the mind, it may be the pin bridge is as safe or safer, but it does not give that impression; those old pin bridges shake and the counters break also—there are numberless instances of counters breaking. Now, with a few bad breaks on a bridge, any man who has anything to do with the bridge is frightened at it, and he immediately concludes that the bridge ought not to be there. On riveted latticed bridges there is almost no part that can break until the whole structure is ready to come down. An exception to that, however, is some badly designed floor beams. On many old riveted lattice bridges the floor beams were cut out about one-half at the ends so that they could bear on the bottom chord. These floor beams frequently break.

Mr. Strobel—I know of no pin connected bridge that failed by reason of the breakage of a pin. The vibration usually causes wear somewhere, but it is generally light members, such as counters and lateral rods, that make trouble. Where the parts connected to a pin are large, there is usually no wear. It seems to me to be an advantage if you can tell that a bridge is hard pressed. I think that these riveted bridges that are overloaded without anyone knowing that they are overloaded, are a greater danger than those bridges which indicate that they are hard used.

Mr. Finley—To carry Mr. Strobel's argument out to its logical conclusion, the safest type of bridge would be the Howe truss bridge, much more so than the pin connected or any other bridge, because it would give you more ample warning of danger ahead. I have taken down a number of pin bridges and I have found in almost all cases that the parts were well worn, and it is not so much that, as the moral effect it has. Taking a pin bridge where the pins are moving, you will always find a rust streak from the pin. I do not think there is any danger of a bridge being overloaded and a collapse taking place before those in charge find out the dangerous conditions.

Mr. Reichmann—The old lattice bridges as a rule have heavier counters than the pin bridges, because the minimum size angle that it is practicable to use give an excess of material in the center diagonals. I think if the counters are made properly they will not break. Of course we all know that an increased live load acting on the bridge will affect the counters more than any other member. In all well designed bridges this is properly considered.

Mr. Finley—The counters in a lattice bridge naturally are made larger than the counters of the pin bridge; taking up one kind of stress, that is simply a necessity in the case. Speaking of this subject of the pin and the lattice bridge, I am rather amused at the present tendency. Those who object to the lattice bridge will build a pin bridge and rivet in their posts and hip joints. They rivet those up and they have a bridge that is neither fish, flesh nor good red herring.

Mr. Bainbridge—I think the principal objections which have been urged against the lattice bridge are that it is impossible to secure good field riveting, and that in riveted joints carrying heavy strains, you can not depend upon the stress being carried by the whole number of rivets there. This objection is met by limiting the span and dividing up the systems so that the strains carried by each system are as small as possible. I think there should be a limit to the span so that the question of taking care of heavy stresses in single line should be avoided.

Mr. Strobel—What I was trying to find out from Mr. Bainbridge was what evidence there was for his statement that you can overload a lattice bridge better than you can a pin connected bridge. Of course the moral effect on those operating these bridges is quite a thing apart. Then, too, I was trying to find out whether there was any evidence of failure of the pin connected bridge by reason of the pins wearing. There have been many failures of bridges of all kinds, but almost invariably they have failed because the proportioning was bad from the start. I should prefer, if there are no disadvantages, to always have a structure that shows its weakness, if that could be.

Mr. Finley—A railroad company looks upon a bridge as a tool constructed for its use, and it wants one that will, for the least amount of money, render the best service. I am satisfied that a pin bridge would not have stood the damage and abuse that the bridge at Fond du Lac endured, or the one at Daggett, where carloads of logs passed over, ripping out web members. That is the standpoint of a railroad company in the matter of bridges; it wants a bridge that will give it a fair amount of security under the extraordinary conditions that are likely to occur.

Mr. Reichmann—I would like to ask Mr. Bainbridge whether he uses the multiple system of intersection to keep the stresses small in the individual members and thus avoid so many rivets in one connection.

Mr. Bainbridge—That is the principal reason.

Mr. Reichmann—I think theoretically there are a good many objections to the multiple system. For instance, you tie the tension and compression members, which are both acting at the same time, together. There is no question that that is not right theoretically, while practically it works all right.

Mr. Bainbridge—There is another objection to the multiple system in that the panel points are about half the distance between the car wheels. As a general thing, a bridge will be about 28 feet deep and the inclination of the laterals will be about 45 degrees; the distance of car wheels is generally about 28 feet, so that in passing over the bridge the wheels pass from one system to the other. That is an objection to the multiple system.

M. W. Trumbull—What is the relative length of time it takes to put in place a riveted bridge and a pin connected bridge, both being fixed types?

Mr. Bainbridge—Well, of course the conditions will govern a great deal in that. There is no doubt that a pin bridge can be erected in a much shorter time than a riveted bridge. In this case we were about six weeks and a half in erecting this bridge, from the time we started. A pin bridge could probably, with the same force, have been put up in three weeks and a half.

Mr. Strobel—It might be well, while speaking of this subject, to call attention to one feature. These riveted lattice bridges with short panels are exceedingly indeterminate, as we well know, in regard to the actual stresses in the members, so much so that by actual test of completed bridges it has been found that in certain cases some members have had compression that should have had tension, etc. On this account there has been a decided tendency in countries that use only riveted bridges to get away from the lattice bridge and use trusses with a single system of triangulation. Because of the large secondary stresses and because of the uncertainty of the stresses you properly ought to proportion your lattice bridge much more liberally than you do a bridge with a single system of triangulation.

Mr. Bainbridge—I believe there is no more uncertainty about the stresses in a lattice bridge than in a pin bridge. In the case of a pin bridge in which the pins are worn, the passage of a train over the bridge will in many of the web members cause the bearing surface to change from one side of the pin to the opposite side, producing shock in the member. Also it is a common occurrence in pin spans to find two tie bars side by side, one of which continues loose during the passage of a train while the other is taut at all times. If a lattice bridge is erected with ordinary care there should be no great uncertainty as to stresses. Of course, if the holes fit badly and much drifting is done there will be uncertainty. We require that where rivet holes do not match they shall be reamed in the field.

Mr. Reichmann—I think a good many fine mathematical points come in here. In figuring the moments on a pin we take the distance center to center of bearings, so the more liberally we figure our pin bearings the greater the pin moment figures. We would get results more nearly correct if we figured the moments for a uniformly distributed load over the bearings. This is one of the assumptions made in figuring pins, but there can be no objection to it since it errs on the side of safety. As far as the motion of the pins is concerned, it can only be produced by members having a reversal of stress, which, in ordinary truss bridges, would be the stiff counters.

Mr. Bainbridge—There will be two or three posts on each side of the center where there must be motion up and down; that is, providing counters are needed, there is likely to be motion in the post there.

Mr. Condron—I would like to inquire what the specifications in reference to metal and punching and reaming are.

Mr. Bainbridge—Mr. Finley is more familiar with that than I am.

Mr. Finley—They are built under the standard specifications of the C. & N. W. Railway; they all call for punching and reaming on lattice bridges. I will take the bridge that Mr. Bainbridge just described: The great point in favor of the pin bridges is the fact that they can be built without being first assembled. I believe the practice is in Europe, or at least in England, to assemble those riveted bridges in the shops before they are sent out. Here that is not necessary. This particular bridge was not even laid out on the floor; the templates were made out on the bench, and I think the bridge went together remarkably well; we had no trouble from the mismatching of holes, and did not require drifting, or anything of that sort to make them come together.

The Chair—Mr. Bainbridge, what method of riveting was used, hand riveting or pneumatic?

Mr. Bainbridge—Hand riveting entirely.

The Chair—Would not the pneumatic methods better the construction, if that could be applied to a case of that kind?

Mr. Bainbridge—Why, yes, I think as a whole that either the pneumatic hammer or pneumatic riveter is better than hand riveting.

The Chair—It approaches close to the shop practice, does it not?

Mr. Bainbridge—Yes.

Mr. Warder—I would like to make an inquiry in regard to the increased cost of the riveted lattice bridge over the pin bridge. Is it due to the greater weight, or to the shape of the bridge, or the kind of work involved?

Mr. Bainbridge—The difference is due almost entirely to the weight. But there is some increased expense in erection—I think possibly two dollars a ton increase in the cost of erection.

Mr. Finley—There is very little difference in the cost per pound erected in place.

Mr. Modjeski—The strength of pins was mentioned here. Some might be interested to hear that in the Rock Island bridge, where we took down the old bridge, some of the pins 3½ inches in diameter, if figured theoretically according to the usual method, were strained to about 180,000 pounds per square inch fiber stress.

Mr. Finley—That bears out my point of the uncertainty of pin bridges theoretically.

Mr. Bainbridge—The whole question in these pins which figure up 180,000 pounds per square inch—I have seen a number of those cases—is that the members connected to the pins in the same direction do not receive their strain uniformly; that is the whole point, and it shows, unless the pins are made very large, to allow exceedingly small deflections, that you can not depend on the stress being equally distributed over more than two members attached to the same pin.

Mr. Modjeski—I would add that among all these pins there was not a single one where one could detect any bend after it was taken out, no wear, nor any bending at all. I have figured a little closer, using different assumptions, on the actual strain per square inch that these pins would be subjected to, and I figured about 50,000 pounds.

Mr. Finley—There is a wide discrepancy between theory and actual results in pin bridges.

Mr. Strobel—The material of a bridge is never uniformly strained in any kind of bridge, riveted or pin-connected. Though we assume for purposes of calculation that there is a uniform distribution of stress over a cross section, yet we know that there never is and that we are bound to have considerable variations from that. The point I was making a little while ago was that in a single system of triangulation there was no assumption necessary to determine the stress in the truss members. For a multiple system, calculating by static methods, you assume each system will act independently of the other, which is only approximately true. After you have calculated the stresses in the different truss members, then to calculate details is another thing, and whether you get the stresses into your members better by means of riveted or pin connections is a subject that, to enter upon here, would be going too far. You can design both the pin connected bridge and the riveted bridge badly, and you can arrange so that your distribution will be very unequal. It seems to me that we ought not to lay too much stress upon these details.

Mr. Finley—The details are the most important points of the bridge; they are the points that always fail; the failure generally occurs near some attachment or connection.

Mr. Bainbridge—Some years ago I examined a bridge that was thoroughly suited for the traffic at that time, except that the pins were considered weak. The parties in charge concluded then to put false work under the spans, block them up and replace the pins. They of course had to replace them with pins of the same size, but they managed to secure for their pins a metal, I think it was gun metal, which, with all the customary requirements of elongation and reduction of area, gave an ultimate stress of about, I think, 140,000 pounds per square inch. It seems very large, but, as I remember, that was about it. I do not consider that these people had improved their bridge in the slightest; there was no danger of the pins breaking, I think that has been settled for all time, but there was just as much probability of their fancy gun metal bending and allowing a bad distribution of stress in the bars as with the old pins.

Mr. Finley—We seem to have strayed away from the drawbridge entirely.

Mr. Reichmann—I want to ask Mr. Bainbridge whether he figured on the center casting so that he would have a load on the center pin?

Mr. Bainbridge—Yes, we would like to have a load on the center, so that the drum will not vary in position on the wheels. If there is a considerable load there, it is certain that the center will be held in place, also the fact that there is a load on the center reduces the force required to turn considerably. We turned the bridge before we transferred the load to the center, and afterwards, and the difference was quite appreciable.

Mr. Modjeski—Speaking of centers and discs, I would like to ask Mr. Bainbridge whether he has ever had experience with using hardened steel discs, in place of phosphor bronze? I understand this has been used lately to good advantage, and has given very good results.

Mr. Bainbridge—You mean the use of hard steel upon hard steel?

Mr. Modjeski—Yes.

Mr. Bainbridge—No, it is something that I must confess I do not know anything about. But I will say that the people who manufacture phosphor bronze claim for it that the small frictional resistance of phosphor bronze upon hard steel is due to the granules of lead in the phosphor bronze. I do not know just how much there is in it, but it seems quite reasonable. There is a certain amount of lead in a phosphor bronze, and they claim that the plate slides on the lead granules.

The Chair—Are there any further questions, or is there any further discussion on the paper?

Mr. Bley—What is the material of it, both steel and phosphor bronze?

Mr. Bainbridge—The upper plate, the turning plate, is phosphor bronze, the lower plate is a hard steel plate.

Mr. Bley—Hardened, and with the surface ground after it is hardened?

Mr. Bainbridge—It has the polished surface.

Mr. Bley—Was that made out of tool steel, or ordinary machinery steel?

Mr. Bainbridge—I think it is tool steel; I am not quite sure about that.

Mr. Finley—We use simple hardened machinery steel.

Mr. Bley—I would like to ask what sort of friction drive was used, what sort of an arrangement did you have to transmit motion?

Mr. Bainbridge—They are simple cone frictions, with wood contact.

Mr. Bley—Each cone is perfectly solid when it is put in place?

Mr. Bainbridge—When it is forced in, yes.

Mr. Bley—Was the bearing on the side of the wood or end of the grain?

Mr. Bainbridge—The bearing is on the side of the wood. The wood is maple.

Mr. Bley—You get the drive by forcing one cone on one side into the other?

Mr. Bainbridge—Yes.

Mr. Modjeski—You made no experiments as to the percentage of friction to the weight of the bridge?

Mr. Bainbridge—No, we have not.

* * *