11 well-filled coaches, from Buffalo Creek to East Salamanca, a distance of 60 miles, in two hours, the grade rising 1,200 ft. in the first 40 miles of the run.

This system was developed by H. C. Woodbridge, general manager's special representative of the Buffalo, Rochester and Pittsburgh.

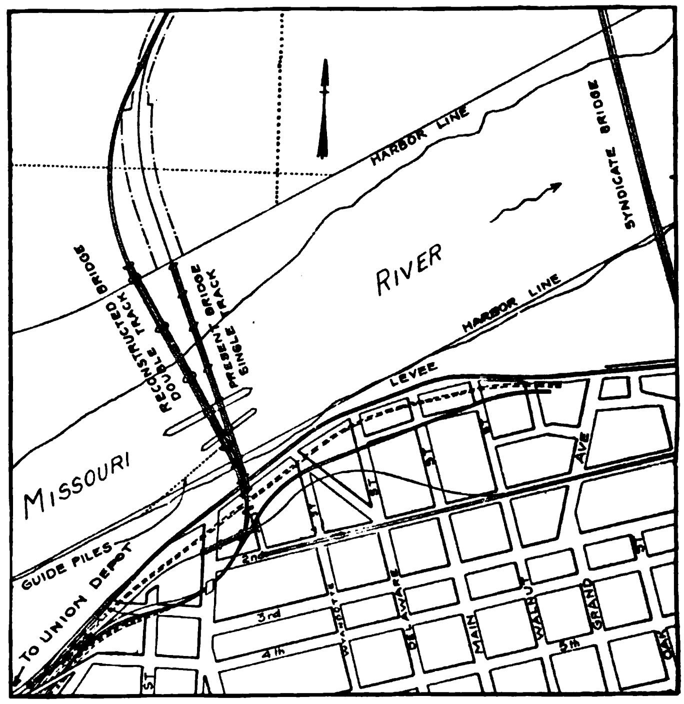
A NEW BRIDGE OVER THE MISSOURI RIVER AT KANSAS CITY

The Chicago, Burlington & Quincy has recently let contracts for a bridge across the Missouri river at Kansas City to replace the old Hannibal bridge, so-called because it was built by the Hannibal & St. Joseph Railway in 1869. This was the first bridge across the Missouri river. It was used for many years by the Burlington, Wabash and Rock Island as an entrance to the old Kansas City Union station, located three-quarters of a mile to the west, and is still used by these roads to reach the new Union station by way of the new Burlington connection around the bluff, south of the old station site. The old structure consisted of single track combination wood and steel through trusses on masonry piers. The superstructure was replaced by Pratt trusses in 1888, which are still in use on the original substructure, although it has been necessary to reinforce the piers extensively with iron rail bands. It is also used as a highway bridge, a plank floor being provided on the track deck and teams being allowed to cross the bridge between trains.

The new structure, which will cost about $1,500,000, will be located adjacent to the old bridge. In fact, the south ends will coincide, the only difference in position being brought about by the fact that the new bridge will be a square crossing, while the old one makes an angle of about 15 deg., with a perpendicular to the river channel. In consequence the north end of the new bridge will be about 250 ft. up stream from the end of the old structure. There will be a 450-ft. draw span near the south side of the river with two 330-ft. fixed spans to the north, and one 120-ft. span on the south, making five waterway openings between harbor lines as against six in the old bridge. With the exception of the 120-ft. span the superstructure will consist of sub-panel through Pratt pin-connected trusses. There will be two decks, a lower one for two railroad tracks 13 ft. center to center, and an upper deck for a highway 25 ft. above the base of rail of tracks. Low iron is 26.25 ft. above standard high water and 40.53 ft. above standard low water. The clear width of the channel opening on either side of the center pier of the draw span is 200 ft. at standard low water.

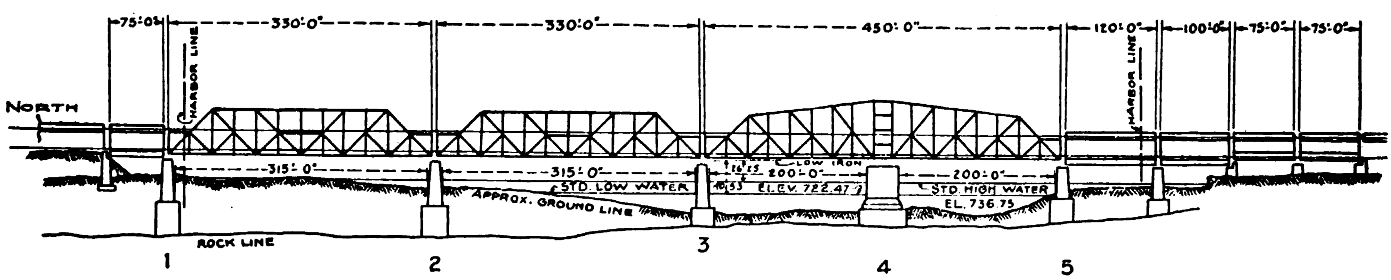
The 120-ft. span south of the draw consists of a deck girder span for the lower deck and a through girder span for the highway deck. South of this span there will be an approach, consisting of a 100-ft. span of the same type and two 75-ft. through girder spans for the railroad deck, as well as for the highway deck. Access to the latter will be had by means of a viaduct incline downward to a connection with Broadway. North of the bridge there is a 75-ft. approach span, consisting of deck girders for the tracks and through girders for the highway, the latter being continued on a viaduct incline downward on the east side of the railway embankment. The north railroad approach connects with the present alinement 1,300 ft. to the northeast by means of a 4 deg. 30 min. curve on an embankment. The viaduct approaches are on 6½ per cent grades.

The design involves the use of high loading and high unit stresses, following the same idea as that used on the Metropolis bridge over the Ohio river. The live load on the trusses consists of two Cooper's E-90 engines followed by 7,500 lb. per ft. of track for the near track, and a uniform load of 7,500 lb. per ft. of track for the far track, except on floor, hangers and subdiagonals, where the load is two E-90 engines on each track. The designing stresses under full dead load, live load and impact are 35,000 lb. per sq. in. for nickel steel eye-bars, 25,000 lb. per sq. in. for tension and 30,000 lb. per sq. in. for compression for silicon steel to be used in all main members of the truss spans other than eye-bars, and 18,000 lb. per sq. in. for medium steel to be used in all other parts of the bridge. The steel work amounts to 5,500 tons, and will be furnished by the American Bridge Company.



Map Showing Location of Bridge

The piers for all of the main spans will be carried to rock, which is located from 70 to 130 ft. below the base of rail, the surface of the rock dipping downward from south to north. Pneumatic foundations will be necessary. The substructure for the south approach will be on rock foundation, as the elevation of the rock rises rapidly south from the river bank. The north approach is located on flat river bottom and will require pile or spread foundations. The Union Bridge & Construction Company, of Kansas City, have the contract for the substructure and will commence work as soon as the present high water subsides. The design and construction of the bridge is under the direction of C. H. Cartlidge, bridge engineer of the Burlington, who furnished the information given above.



Elevation of the Kansas City Bridge

Engineering News

VOLUME 71 FEBRUARY 26, 1914 NUMBER 9

Interchanging Two Bridge Spans, Wabash R.R. Bridge at Hannibal, Mo.

By F. W. Curtis*

The Missouri Valley Bridge & Iron Co. has just completed some alterations of the Wabash bridge across the Mississippi River at Hannibal, Mo. A very interesting portion of this work was the successful changing of location of a 360-ft., 532-ton draw-span, raising it off its bearing on the old pivot pier, and shifting it westward half its length to a new pivot pier which had been put in place. At the same time a fixed span weighing 270 tons, which had been in place to the west of the draw, was taken out and put in its new location at the east end. Both operations were accomplished by floating the spans from old to new position by means of barges.

The bridge is a combination railroad and wagon bridge, originally built in 1871, the superstructure being rebuilt in 1887 by the Detroit Bridge & Iron Co. It is owned by the Hannibal Bridge Co. and leased by the Wabash R.R. It is of double-intersection Whipple-truss construction and is 1580 ft. long. Calling low-water level of the river zero, the floor of the bridge is at El. 35.7 ft., and high water is 22.5 ft. The greatest depth of the river is 25 ft.

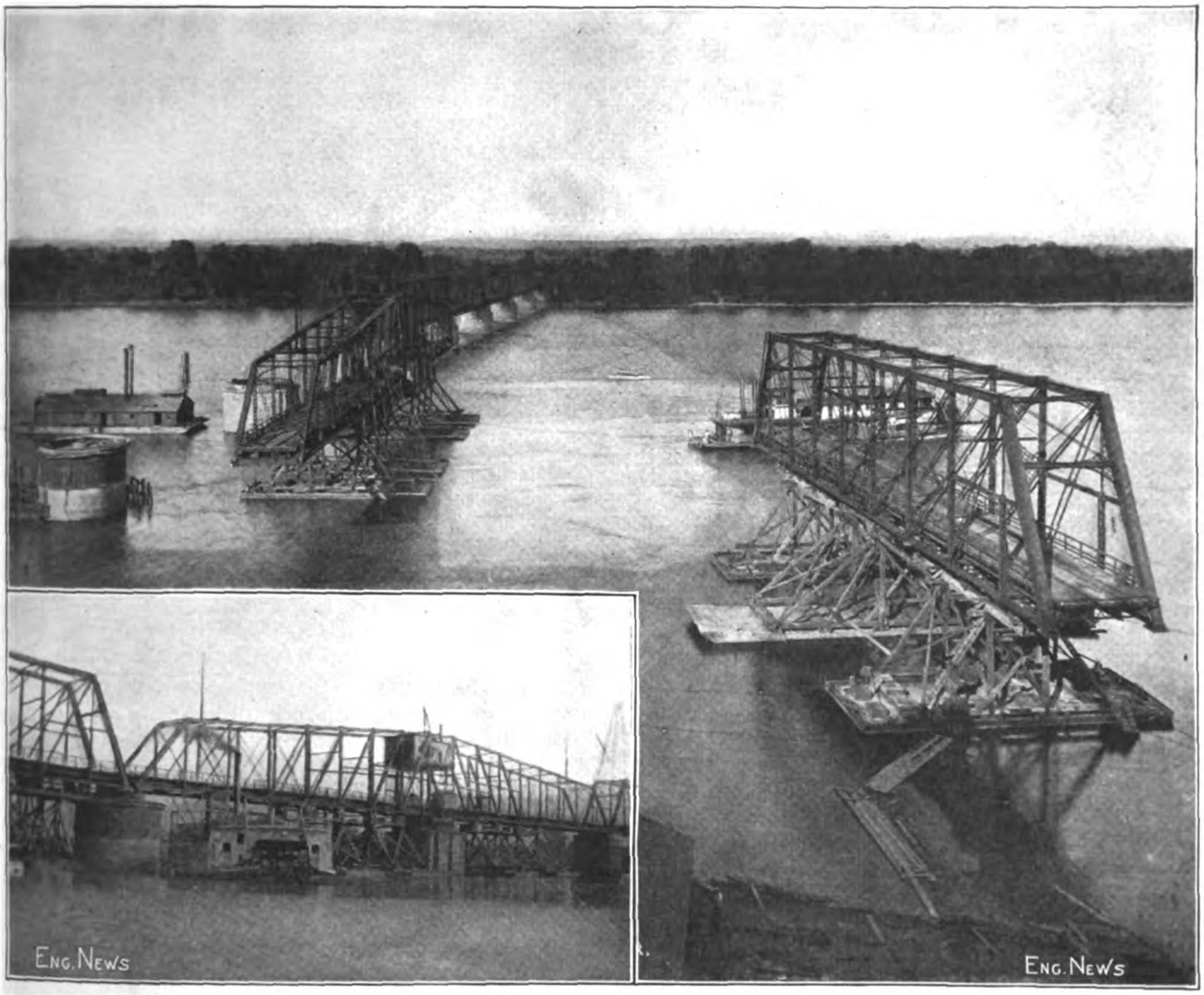


Fig. 1. Moving the 360-Ft. Draw-Span of the Wabash R.R. Mississippi River Bridge at Hannibal, Mo.

(Small picture shows span before moving, but with barges, blocking, etc., in place. Note the old and new pivot-piers.)

*Assistant Engineer, Wabash R.R. Co., St. Louis, Mo.

Starting at the Missouri or west shore, the bridge consisted of one span 250 ft., a draw 360 ft., another fixed span 250 ft., and four 180-ft. spans. All the piers were of limestone, resting on 8 courses of 12x12-in. timber grillage, this in turn being supported by foundation piles. These piers are in an excellent condition, not having settled at all; the stones on the outer surface had been bonded together with long driftpins, and the cement mortar was so hard that picks were used to break it up.

Rivermen Complain of Old Bridge

The alterations and changes in the bridge were caused by the complaint of captains of boats and others interested in river navigation, who claimed that the bridge had become an unreasonable obstruction to free navigation by reason of the location of the draw openings, the entire absence of guide fences or sheer booms, and the presence of artificial deposits of stone about the piers of the bridge, which they believed had increased the current through the draw openings to a dangerous extent. Several boats, barges and rafts of logs had in times past struck the piers and either been sunk or badly damaged, though testimony showed the fault in most cases to have been that of the pilot or men in charge of the rafts. A serious accident which brought the matter to a head occurred in June, 1903, when the Mississippi reached the highest stage ever known, 22.5 ft. above low water or only 13.2 below the decking of the bridge. At this time the captain of the "Flying Eagle" endeavored to take a Methodist sunday-school picnic up the river for a boat ride and incidentally show them the Mississippi River at its highest stage. The children were on a barge being pushed by the steamboat. While passing through the draw, the pilot attempted to change the course of his boat, with the result that he lost control and both barge and steamboat were thrown sidewise against the pivot pier and open draw span, both of them sinking. Luckily a large force of Wabash employees were on the draw at the time and aided the passengers on the boat in climbing onto the bridge, so that only four lives were lost.

Formal complaint as to conditions was first filed with the War Department by the rivermen, on Jan. 2, 1905. The Engineer Corps, to whom the complaint was referred for investigation, reported the bridge to be an unreasonable obstruction to navigation and recommended that the draw-span be shifted half its length to the shore: that the 250-ft. span at the west end be cut down to 180 ft. in length and put at the east end of the draw-span to fill up the gap left on account of moving the draw and a new 70-ft. girder-span be placed to connect the draw with the shore; that a new rest pier be built for the east end of the girder and west end of the draw, the old west rest pier torn out and a new pivot pier substituted, the old pivot pier taken down and a new rest pier for the east end of the draw put in, these piers to be in the exact location of the old ones; and that a guide fence be built up the river from the west rest pier, and protection work both upstream and downstream from the pivot pier. A hearing for all concerned was given by the Government Engineers at Rock Island, Ill., on June 6, 1905, and a second at the same place, by request of the Wabash R.R., on Mar. 10, 1906. At the latter, the Wabash R.R. and the bridge company were given until Mar. 15, 1907, to make the changes before mentioned. An appeal was made to the War Department, Wm. H. Taft at that time being Secretary of War, but on July 20, 1906, the Rock Island decision was upheld.

Neither the Wabash R.R. nor the bridge company having made the changes in the time given them, suit was filed by the Government on June 4, 1907, to compel the changes being made. An interesting feature of this suit was that the Government was represented by Henry W. Blodgett as its chief counsel, while his father, Wells H. Blodgett, represented the railroad company; the son came out the victor. The case was then appealed to the Supreme Court, and a decision was rendered May 15, 1911, upholding the previous decision.

Contract for Reconstruction; Work Begins

A contract was let by the Wabash R.R., through A. O. Cunningham, Chief Engineer, to the Missouri Valley Bridge & Iron Co.* (E. H. Connor, Chief Engineer; C. L. Greever, Superintendent of Construction) for making the changes ordered by the government. Plans were drawn by the bridge company, and after having been approved by the Wabash, work was started in the spring of 1912, with T. W. Cartledge in charge of the superstructure work, M. C. Taylor looking after the substructure, and the writer serving as engineer for the Wabash.

Falsework was placed under all panel-points of the 250-ft. west span, and under the west half of the draw-span, and ten 24-in. I-beams were placed over the west rest-pier, supported on the falsework, to carry the ends of both spans. The blocking under the draw-span was so arranged that it could be removed at any time so as to allow the opening of the draw. This kept one channel of the river open for navigation as well as keeping railroad traffic going; no attempt was made to keep the bridge open for vehicles and foot passengers, and in fact the wooden decking was torn out soon after work was started.

Dredging of riprap from around the old rest-pier was started at once, also construction of the new rest-pier near the bank.

West Rest-Pier and Span

Constructing the new west rest-pier was simple: The bottom was dredged out to a solid rock foundation where the pier was to go—only 7 ft. below the water level at the time. A box form for the footing course was well calked and weighted down with rock till it sank in place, and the form then sealed by lowering concrete into it by means of a derrick and a bottom-drop bucket, the bottom of bucket not being opened until on the bottom of river. After this concrete had set the water was pumped from the form and the pier completed. The pier footing is 12x38 ft. and 6 ft. high, the bottom of main body 9 ft. 4 in.x26 ft. with nose on both ends protected against ice with angle-irons, and the top, 7x26 ft. The pier is 29½ ft. high, and contains 411 cu.yd. of concrete. The concrete was a 1 : 2½ : 5 mixture, made with sand and gravel dredged from the river and screened to take out some of the sand so as to leave the proper mixture.

While this work was being done, the superstructure of the west span was being taken down, leaving the floor system only in place. The batter posts, some of the bottom chords, and such other parts as were to be redrilled, shortened and changed, were sent to the Leavenworth shop. In the meantime, three 20-ft. panels were cut out

*Leavenworth, Kan.

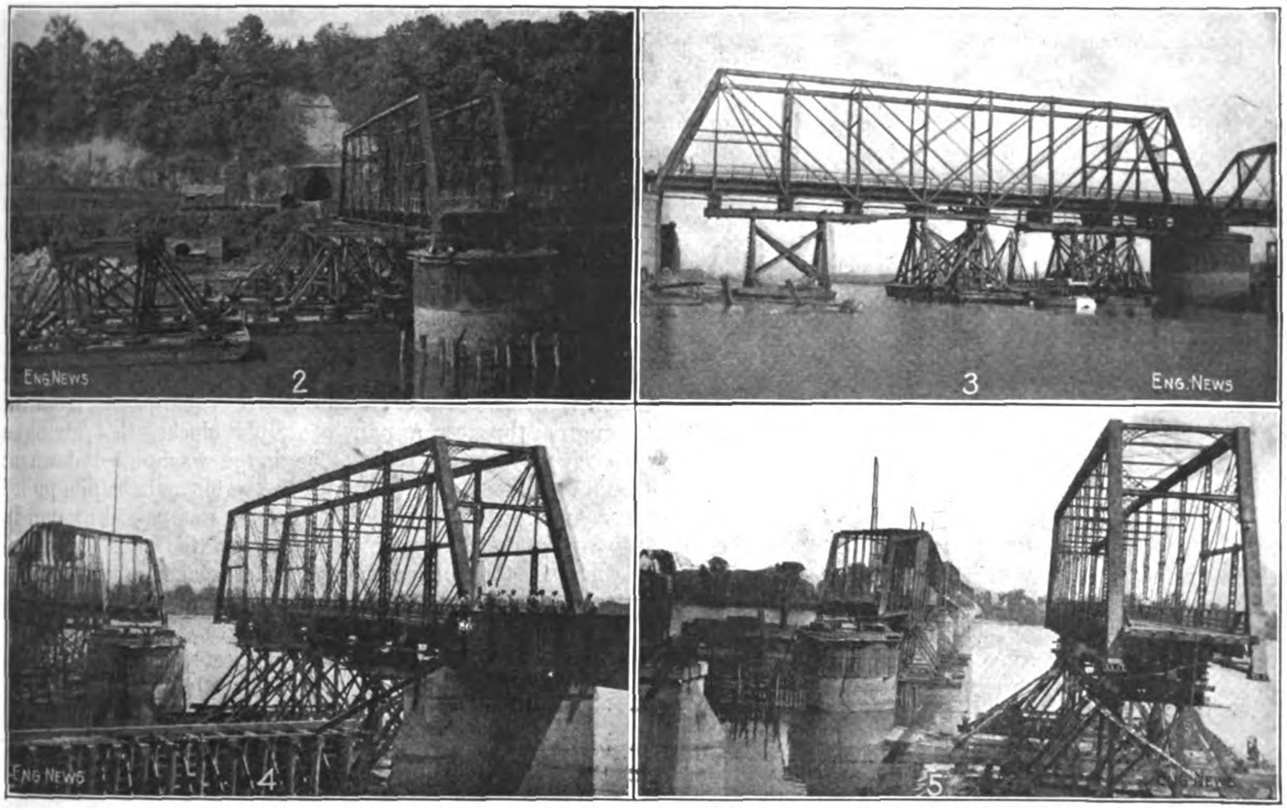
of the floor system and 5 ft. cut off the stringers at each end of the span, cutting its length from 250 ft. to 180 ft. The floor system was then jacked up so as to allow of placing steel rails under it, parallel with the span, these rails were oiled, and the floor system was pulled together by means of steamboat ratchets. The 70-ft. girders were then swung into place from the shore abutment to the new pier, and the old west span (now 180 ft. long) was reërected.

Before this was completed, however, the tearing down of the old rest-pier was commenced. Though the pier was a well built structure, no trouble was encountered in getting it out down to the water level. Various plans were considered for tearing out that portion below water, but it was finally decided to drill and shoot it, then dredge the fragments. Hand drilling was done at first to drill and 7 days to dredge the 146 cu.yd. of masonry, and the diver worked 17 days.

Pivot Pier Caisson Foundation

The caisson for the new pivot pier was immediately built and lowered into place, being weighted down with concrete. Sandhogs started work on Dec. 7, 1912, and sank the caisson through 17 ft. of sand, gravel and boulders, reaching shale foundation on Dec. 27. Three shifts a day were used, averaging 11 men to the shift, taking out 654 cu.yd. of material. Bottom was struck at 27.75 ft. below datum, or 35 ft. below water surface (stage of water about 7 ft.). Only light pressure, 17 lb. per sq.in., was used in this caisson. D. W. Hendrick was in charge of the sinking.

Concreting was kept up as the caisson was being sunk,



Figs. 2-5. Moving the Westerly Fixed Span, after Shortening from 250 Ft. to 180 Ft.

Fig. 2. Looking toward west bluff and tunnel; barges with towers ready to be put under span. Fig. 3. Looking upstream; barges and blocking in place. Fig. 4. Span just leaving original location; new pivot-pier at left, new rest-pier and new girder span at right. Fig. 5. Span cleared from original location.

but was too slow, so two steam drills were put to work. A great deal of trouble was experienced in getting the holes down, as the drills tended to strike the slanting seams in the masonry and stick. In shooting the pier, only a few holes were shot at a time, and it was necessary to use great care in shooting, trying to use enough dynamite to break up the pier yet not shoot out the surrounding falsework, which was only 15 ft. away from each side of the pier. No serious trouble to the falsework resulted. The loose rock was dredged out, and, a diver being employed to fasten chains around the separate sticks of grillage and foundation piles, these were pulled out by a derrick.

The old pier contained 439 cu.yd. masonry. The 293 yd. above water was removed in 13 days with an average force of 11 men. For the bottom part it took 9 days

in spite of, or possibly, to be more accurate, on account of the very cold weather prevailing at the time: the river was practically frozen over, with only a narrow channel open and this filled with heavy floating ice; there was ground for fearing that the river might gorge above the bridge and then break loose, carrying the falsework away before the spans were landed on the pier. Concreting was rushed as much as possible, using hot water and salt in the mixing. Owing to local conditions and lack of time it was impracticable to heat the sand and gravel; the thickness of the forms, the great bulk of the pier, and salamanders inside the form and above the concrete, had to be relied upon to keep it from freezing. The forms were left on until spring, and even though the concrete was put in at a low temperature there was no sign of its having been frosted; no scaling whatever appeared, and holes drilled into it showed it to be as solid as if it had been put in in the summer.

The pier was barely completed when the ice gorged, going out two weeks later and taking most of the falsework. There was ample time for the pier to harden before the load came on it. Work was then stopped for the winter.

The base of the pier is hexagonal in shape, 36 ft. between parallel faces, and 25 ft. high; the upper part is cylindrical, 32 ft. 6 in. in diameter and 29 ft. high, containing 1722 cu.yd. of concrete.

Moving the Spans

On resumption of work in the spring, the sheer boom and protection work above the pivot pier were built, and then preparations were made for moving the spans.

First the tension bars, posts and braces in the center of the draw-span were packed with wooden blocking, bolted into place, so as to withstand the compression which would be caused by supporting the span at the ends only, while moving it.

Four barges, each 70x24 ft., were selected for carrying the draw-span. Framed timber towers were built on them to support the span. The total draft of each barge when loaded was figured as follows:

$$\text{Displacement per inch} = \frac{61 \times 24 \times 62\tfrac{1}{2}}{12} = 7600 \text{ lb.}$$

Weight of barge = 116,400 lb.		
Draft unloaded = 116,400 ÷ 7600 =		15.4 in.
Assumed load from span (1,064,000 ÷ 4) =	266,000 lb.	
Weight of tower on barge =	42,500 lb.	
Load per barge =	308,500 lb.	

$$\text{Displacement per inch} = \frac{66 \times 24 \times 62\tfrac{1}{2}}{12} = 8200 \text{ lb.}$$

Draft due to load = 308,500 ÷ 8200 =	37.7 in.
Total draft =	53.1 in.

It was originally intended to use but two 64x22-ft. barges for carrying the smaller span, which weighed 270 tons. The draft, figured out in a similar manner to that of the draw-span, would have been 57¾ in., and this was so great that a third barge was finally used, in order to make the draft uniform with that of the draw.

On Sept. 23, the barges were floated under the spans and water allowed to enter the holds through valves in the bottom, until the decks were only about 6 in. out of the water. Blocking was then placed between the towers and the floorbeams of the spans, so as to be ready to float the spans off the first thing in the morning. To lift the spans (by pumping the water out of the barges) high enough to clear the old piers required only a few inches on the short span, but 14 in. on the draw, in order that the pinion for turning the span might clear the rack. During the night the river went down 3 in., leaving the blocking loose. As it was urgently desirable to move the spans in as short a time as possible, so as not to delay traffic unnecessarily, an attempt was made to float the spans without tightening up the blocking; but the attempt was a failure, and finally water was let back into the barges and the towers reblocked.

The next morning, Sept. 25, 1913, the water was pumped out of the barges, successfully lifting the spans from off the piers. Three barges with hoisting-engines were anchored above the bridge, and cables from them were run to the barges carrying the spans so as to pull them into their new positions. Front and tail lines were used on the barges to steady them, the idea being that they would float a short distance downstream, then be swung over below their new locations, and then pulled upstream to where they belonged. The wind, however, was upstream, and it was necessary to use a steamboat to pull them downstream and hold them there.

The small span was floated out first and taken a couple of hundred feet downstream, where it was anchored to some piling. Then the draw-span was moved out and put into its new location. This took the balance of the day, so that the short span was not in place and the bridge open for traffic until noon of the next day, at which time the bridge was in as good shape as ever, the draw working perfectly on its new bearing.

During the time the bridge was out of commission, all trains were stopped on the east side of the river, passengers and baggage being transferred by ferry.

J. J. Kelly was in charge of the shifting of the spans. The operation was watched by many officials of the Wabash R.R. and of the Missouri Valley Bridge & Iron Co., besides as many people from Hannibal and the surrounding country as could get away.

Old Pivot Pier and New East Rest-Pier

Work was at once started on removing the old pivot pier, I. F. Lindsay now being in charge of all work.

Falsework was erected as for the other pier, and the pier torn down in a similar manner. It contained 1300 cu.yd. masonry, 8 courses of grillage 45 ft. long by 45 ft. wide, and 250 foundation piles, 10 to 15 ft. long.

A chain was fastened around these piles by a diver and a water jet employed while pulling them, this to loosen them up. An attempt was first made to pull these piles *without* the aid of a jet. A heavy A-frame was erected on the front of a barge and a steel cable passed from the engine through a pair of triple blocks, this giving a straight vertical pull. The barge was pulled down so that the deck was flush with the water and the pile pulled in two, just below where the chain was passed around it, without even starting the balance of the pile. On examination, the pile, although water soaked, seemed to be perfectly sound. The friction around the pile to have been greater than its tensile strength.

The caisson for the new east rest-pier was landed on the bottom of the river 19 ft. below low water, and sunk 39 ft. through the same material as found in the pivot pier, to a level shale foundation. The excavation was 1175 cu.yd. of material; the foundation is 93.27 ft. below base of rail. The shape of the pier is similar to that of the first pier built, the foundation being a rectangle 18 ft. 4 in. by 44 ft. 4 in., 20 ft. high. The main pier is 14 ft. 1 in. by 26 ft. on the bottom, the sides battering to 7 ft. 11 in. by 26 ft. on top. The ends are pointed, and the upstream end is protected by steel nosing. The pier contains 1292 cu.yd. of concrete.

Tearing out the old pier was begun on Sept. 26, and the new pier was completed on Dec. 20.

With the exception of the time used in shifting the spans and a few hours spent one morning in strengthening falsework, there was no interruption of either railroad traffic or navigation at any time.

Now that the work has been completed, it is an open question—and one which time only will solve—as to whether or not the changes made will in any way change the conditions at this bridge as claimed by those interested in river navigation. It is the opinion of the writer that, outside the building of the sheer boom and pier protection, the work was a waste of money, forced upon the Wabash Railroad.

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1872.

This, it may be observed, was the speed of the "Volta" during M. Jansenn's famous trip from Paris en route to join the "Eclipse" expedition. It will thus be seen, M. Jansenn writes, that the calculations required are of a very simple character. The necessity of performing them in the balloon may be obviated by having a small table prepared, so as to show the results on inspection.

The course and rate of speed can thus be obtained by a single observation, the only additional data required being the altitude of the balloon, which is taken by the barometer. Here, too, much time and trouble may be spared by using a pocket table with the corrections suited to the meteorological elements of the day of observation. In place of the barometer, small grenades on the concussion principle may be employed. One of these dropped from the balloon will ignite on striking the ground, and the number of seconds betwixt the flash and the arrival of the report will give a sufficiently clear approximation to the altitude.

The compass may be employed to ascertain the balloon's course in another way. The branches before referred to are furnished with small sight vanes. With the aid of the latter we may determine the azimuth of distant objects. By thus observing a distant object over which the balloon has passed, we can ascertain the magnetic bearing of the balloon's course. M. Jansenn adds that perfect repose is not essential to the employment of the instrument. Moments of exceptional disturbance must be avoided, but under ordinary circumstances it will be sufficient to have the car well balanced, the aeronauts keeping in their places and guarding against any movements calculated to disturb the "trim" of the machine. He found no difficulty in using an ordinary telescope in the "Volta" whenever required.

M. Jansenn promises further information upon the subject of instruments for the determination of the course and speed of balloons at night or in foggy weather. His observations have not, we believe, as yet appeared.

THE HANNIBAL BRIDGE.

From "The Railroad Gazette."

This combined railroad and highway bridge over the Mississippi river, at Hannibal, Mo., has just been completed, the seventh structure that spans the great river, below Dubuque. The work has been completed under the administration of the "Hannibal Bridge Company," formed by the consolidation of two companies—the "Pike County Bridge Company," incorporated in Illinois in March, 1867, and organized June 4, 1869, with Alexander Starne, President and Ozias M. Hatch, Secretary and Treasurer; and the "Hannibal Bridge Company"—incorporated in Missouri, May 24, 1869. In December, 1869, the consolidation was effected under the present title of the company; Mr. John T. K. Hayward, of Hannibal, was elected President and Ozias M. Hatch, of Springfield, Ill., Secretary. The present organization of the company is: Alexander M. White, President, Isaac M. Knox, Secretary and Treasurer; Warren Colburn, Consulting Engineer; Col. E. D. Mason, Chief Engineer, with E. L. Corthell and Eliot Clarke as assistants.

On the 27th of June, 1870, Col. Mason, with his corps, commenced the preliminary surveys, making minute examinations of the river bed and the underlying strata at various possible crossing places. By means of sounding rods, he bored to a depth at some points of 110 ft. below low-water mark. The direction and velocity of the current was carefully noted by the use of floats, and the line of the bridge was located at right angles to it. A base-line of 1.620 ft. was accurately measured, and its extremities indicated by raised monuments. From this line as a base all the positions for the piers were located by triangulation, and afterwards tested by actual measurement with a steel wire, proving their accuracy.

On the 29th of July, 1870, a contract for both substructure and superstructure of the bridge proper, between and including the abutments on each side of the river, was entered into with the Detroit Bridge and Iron Works. The plans for the substructure had been previously prepared by Col. Ed. D. Mason, the Chie

Engineer. The Bridge Company adopted the plans of superstructure as designed by Willard S. Pope, Engineer of the Detroit Bridge and Iron Works. The agreed price for the whole was $185,000. By the terms of the contract the work was to be completed ready for use within one year. The time was very short—much less than that before given for any similar work, but the contractors have met the requirement.

This bridge belongs to the general class of "low bridges," placed but a short distance above the high-water mark and furnished with a draw span over the channel to permit the passage of steamers and river craft generally. The comparative advantage of high and low bridges over navigable streams is a question of money only. The high bridge, offering practically no obstruction to river traffic at any stage of the water, and requiring no attention on the part of its keepers in distinction from the constant service required at a draw, presents, in this respect, points of superiority over the low bridge. But the increased height of the piers, and the length of approaches necessary to attain the elevation, adding very largely to the cost of the structure, led in this case to the adoption of the low bridge and draw as the most economical structure. Confirmations of this opinion are furnished by the bridges at Quincy, Burlington and Kansas City, as well as by the plan adopted for the bridge to be built at St. Joseph. At St. Charles, St. Louis and Leavenworth high bridges have been favored and adopted for reasons other than those of economy.

The bridge under consideration is nearly identical in form with those at Burlington and Quincy, differing only in some of the mechanical details. One of the more important distinctive features is the form of the struts or posts used. These are composed of two parallel channel or I beams secured a short distance apart by diagonal bracing of wrought iron straps, forming an open work strut, the interior of which is accessible to the brush of the painter, whose attention is frequently needed to prevent rust—the destroying enemy of iron structures. The free ventilation afforded prevents the condensation of moisture in the interior and consequent rust, a salient feature of the tube-like "Phœnix column." In weight for the same strength there is little difference, while the facility of construction is slightly in favor of the new form. The form of the chord link differs from that used at Quincy in being formed of bars and eyes, instead of the experimental form built there of elongated links drawn out from a flattened ring. The upper chord shows an important modification. Instead of being of continuous size throughout, the ends of each section are considerably enlarged and the abutting faces planed exactly perpendicular to the axes of the beams, thus adding much to their stiffness and allowing the omission of the short diagonal lateral braces. The increased size of the chord at the joints permits the passage of the tie road to an interior fastening, instead of being secured to a *lug* on the outside.

The foundations, upon which depends the permanency of the work, in all cases—excepting that of the west abutment, which is built up from the rock—are supported upon pile bases. The piles in piers 2 and 3 were driven to the rock, and at the other piers they were driven until a sufficient resistance was obtained. Upon the piles, cut off at a level with the bottom, was placed a grillage of heavy timber, forming the foundation for a floating caisson. This caisson was sunk to its position as the masonry part of the pier was added to its weight, the sides being kept above water until the mass was fairly settled upon the pile heads. This method, when admissible, furnishes the most economical, as well as expeditious, means of placing the masonry upon foundations under water. To prevent scour, the spaces between the piles themselves, and the space between the bottom of the grillage and river bed, are filled with riprap, and a bank is formed, around the outside, of the same useful material. The serviceable nature of riprap in resisting scour is well known, and the engineer in charge of this work has been led by his experience to place great confidence in its ability to withstand the currents of the Mississippi.

At the west abutment the rock bed of the river was found but a short distance below the surface, and the masonry was placed directly upon it. The rock, a variety of blue soapstone, was excavated in steps, to receive the wing walls. This abutment contains 372 yards of masonry.

The following table shows the time occupied in the construction of each pier, and the depth of water at the several points at the time of the sinking of the respective piers.

Pier No. 2, being situated in the current of the river, required protection piles as a guard against drift. All piles were driven to the rock bed, thus demonstrating that piles could be used for the subfoundations, by properly protecting them from scour, with riprap placed between and around them by divers. The average number of blows to the piles in the foundations was 112, from a hammer weighing 2,700 lbs., falling 25 ft. at the last blow. A floating caisson, formed of grillage of 12-in. sq. oak and elm timbers, well bolted together, and carrying planked sides to above the water line, was guided in its descent by cables, which were secured to a water deadener, and side anchors, until it was settled upon the heads of the cut piles, at a depth of 18 ft. below the water line of that date. The stonework consists of 496 cubic yards of masonry.

Piers.	Work Commenced.	Completed.	Depth of Water.
			Ft.
Pier No. 1 (West abutment)........................	Oct. 10, 1870.	May 27, 1871.	0
" No. 2	Oct. 10, 1870.	Nov. 13, 1870.	18
" No. 3 (pivot pier)........................	....	May 27, 1871.	31
" No. 4........................	Dec. 13, 1870.	March 8, 1871.	22½
" No. 5........................	Jan. 8, 1871.	Feb. 4, 1871.	14
" No. 6........................	Dec. 6, 1870.	March 5, 1871.	10
" No. 7........................	Nov. 22, 1870.	Jan. 31, 1871.	10
" No. 8........................	March 27, 1871.	April 5, 1871.	12
" No. 9 (East abutment)	Feb. 15, 1871.	April 22, 1871.	5

The piles of pier No. 3, the pivot pier, were driven to the rock, and, after dredging out the sand to a sufficient depth, were protected by riprapping. A sunken crib was used as a water deadener. Much trouble was experienced from sand banks forming over the heads of the cut piles, requiring the use of divers, dredges, and, finally, a water jet thrown from a steam fire-engine.

The dipping of the rock bed carried it beyond the reach of the piles for piers 4, 5, 6, 7, 8 and 9, and these piles were driven in the sand until a sufficient amount of resistance was obtained; the permanency of the sand being secured by that indispensable material, riprap.

At piers 8 and 9 the sand had to be dredged out to allow the wooden grillage to be placed at a sufficient depth below low-water mark—the condition of durability of the wood-work being that it must *always* be covered by water, in order to exclude the air. In this situation it is practically indestructible.

The draw rests are sunk on islands of riprap, and consist of strongly braced cribs presenting a sloping edge to the current. Their interior is filled with riprap to the top.

The bridge is approached from the west by a long curve, completing a right angle with the river and passing through a tunnel of 302 ft. in length, cut through what is called lithographic limestone. The excavation was made at the east heading with Burleigh drills and powder and nitro-glycerine blasts. At the west end, by hand-work alone, a heading of full width, and some 9 ft. in depth, was driven through the top of the heading, being on a line with the roof of the tunnel; the bottom was cut out afterwards. Its dimensions, after being lined throughout with brick, are 302 ft. long, 20 ft. high, and 18 ft. wide.

Both entrances are ornamented with handsome cut-stone faces.

The approach at the east bank of the river is over 1¾ miles of embankment, across the river bottom land, broken at proper intervals by paved culverts and roadways, and protected by revetment walls at points subject to wash.

The following analysis has been made of the two qualities of limestone from the Hannibal quarries used in the foundations.

The figures in this analysis give evidence of the comparative superiority of this limestone, as claimed by the engineer, in that it has comparatively small quantities of alumina a small capacity of absorption and consequent density, and very great specific gravity.

Constituent Parts.	Hannibal Brown Limestone, upper layer.	Hannibal White or Blue Limestone, lower layer.
Insoluble in acids	1.295	0.390
Iron	0.640	0.453
Alumina	0.550	0.852
Carbonate of Lime	80 805	93.865
" Magnesia	14.650	2.320
Alkalies	1.060	1.120
Water	1.000	0.500
Total	100.000	99.500
Specific gravity	2 563	2.585
Weight per cubic feet	159.73	161.00

As stone from the same quarry has already stood long and severe tests in some of the older buildings at Hannibal, there is no necessity for fine argument upon its chemical composition, and no reasonable doubt can be entertained of its being all that is required for the purpose.

In the foundations there were used 650,000 ft. (board measure) of square timber and plank, 709 piles, and 6,270 cubic yards of riprap. There are 4,519 cubic yards of masonry in the piers, distributed as follows, numbering the piers from the west bank: No. 1, 372; No. 2, 496 ; No. 3, 1,340 ; No. 4, 514 ; No. 5, 400 ; No. 6, 326 ; No. 7, 333 ; No. 8, 310 ; No. 9, 430.

In the superstructure are 1,000 tons of iron, and 280,000 ft., board measure, of timber and planks in flooring.

The cost of the bridge proper was $485,000, the tunnel on the west bank $36,000, the west approach $56,000, and the east approach $71,500—making the total cost of the structure $648,500.

SUPERSTRUCTURE.

The spans are arranged as follows : Beginning at the west bank of the river, one fixed span, 250 ft. long ; one pivot draw-span, 362 ft. long, leaving, when opened, a passage way for steamboats 160 ft. clear width on each side of the draw pier ; one fixed span, 250 ft. long ; and four fixed spans 180 ft. long each. The measurements of length are taken in each case, from centre to centre of masonry, and then the total length of the bridge, from centre to centre of bridge-seats of abutments is 1,582 ft.

The superstructure is of the general style known as the quadrangular truss, with horizontal and parallel chords, vertical struts—except those at the ends, which are inclined over one panel—and inclined ties. In the fixed spans the upper chords and the joint pieces, etc., are of cast iron, and all the remaining parts are of wrought iron. The draw-span is of wrought iron throughout, except joint pieces and wheels, truck, etc., of the turn-table, the flooring placed at the bottom of the bridge, and is uniformly 18 ft. wide.

The general characteristics of the different lengths of spans are as follows :

	In draw-span 362 ft. long.	In one fixed span 250 ft. long.	In one fixed span 180 ft. long.
Depth of truss between centre of chords, at pivot pier	34 ft.		
Depth of truss between centre of chords, at ends	26 "	25 ft.	23 ft.
Width between centre of chords	20 "	19.6 ft.	19.6 ft.
Number and length of panels, 2 centre panels	11.2 ft.		
Number and length of panels, 26 ordinary panels	12.11 ft.	19 pan 13 ft.	13 pan 13.7 ft.
Weight of cast iron	65 tons.	60 tons.	25 tons.
Weight of wrought iron	285 "	125 tons.	63 tons.
Oak flooring	81 M.	22 M.	16 M.
Pine flooring	81 "	22 M.	16 M.

STRENGTH OF BRIDGE.

The main parts of the structure are so proportioned that a moving or live load of 2,500 lbs. per lineal ft. of bridge, in addition to the weight of the structure itself, and the flooring thereon (or the dead load), shall bring on no part a greater strain than ⅕ of its ultimate capacity. This general rule was applied to those parts which receive their assumed load only when the whole or a considerable part of the span may be occupied by a train of the assumed maximum weight. Those parts, such as single-panel systems, which receive their full load each time an engine may cross the bridge, are utilized to the extent of

$\frac{1}{5}$ their ultimate capacity, while the bolts supporting the floor system can never receive a load exceeding $\frac{1}{6}$ their strength. The actual relation, therefore, between the calculated final strength of the structure and its assumed working duty is shown to be as follows, taking the 250-ft. span as an instance :

Dead weight of span	240 tons.
Live load of span	310 "
Total weight and load	550 "
Ultimate strength of bridge (factor of safety 5)	2750 "

The dead weight, of course, remains constant under all conditions ; therefore, of the gross strength ot the bridge 2,510 tons is applicable to the support of the live load, which is in the ratio of more than 8 to 1.

In other words, when the bridge is fully loaded with its assumed maximum of 2,500 lbs. per lineal ft., it will still be capable of sustaining before fracture the imposition of an additional load of 2,200 tons.

This large excess of strength is practically still further increased, from the fact that the assumed live load of 2,500 lbs. per lineal ft. can never be actually reached, even though the bridge were loaded from end to end with engines, and from the additional fact that the actual strength of the iron used is considerably in excess of that demanded by the specifications. This combination of circumstances and facts gives a reasonable assurance of abundant strength.

CONSTRUCTION.

The top chords of the fixed spans are of cast iron, octagonal in exterior section and circular within. In the 250 ft. spans these chord pieces are 14 in. in diameter between the opposite exterior faces. The thickness of metal varies with the varying strains.

They are cast in lengths of one panel, the joint occurring immediately over the head of the vertical posts to which each chord-piece is bolted. The ends are widened for the reception of the post-head, the main and counter tie-rods, and the upper lateral strut and ties, all of which assemble at that point. Thus while in the 250 ft. spans the chord-pieces are 14 in. wide throughout their interior length, they widen at their ends to 24 in. This increase of width at the joints increases largely the lateral stiffness of the bridge. Where the chord-pieces abut against each other, their faces are turned off in a lathe square and true to their axes, and they are connected with each other by a tenon and socket joint.

Immediately under the joint is placed the post or vertical strut, the seat for which, on the under side of the chord, is planed to a true bearing. The post-head is of cast iron, machine-finished to correspond with its seat. The posts themselves are of rolled channel or I beams, arranged in pairs, connected together by a system of wrought-iron riveted lattice-work. The two beams thus united form a hollow, open post, rectangular in section. They range from 10 in. to 24 in. wide, varying in depth with the depth of the constituent beams. The beams extend from the post-head to a point 6 in. below the centre of the main coupling-pin passing through their foot ; the pin-seat in the post being reinforced by a cast-iron plate or washer riveted to the web of the beams. The beams of which the posts are built vary in dimensions in accordance with their duty, from channel beams of 6 in. depth weighing 10 lbs. per ft., to I beams of 15 in. depth weighing 66$\frac{2}{3}$ lbs. per ft.

It will be seen from this description that the posts are continuous and without transverse joint from end to end ; and, furthermore, that all faces or sides of the iron of which they are built are at all times open to inspection and accessible to the paint-brush. It is considered that this is a material improvement over the closed cylindrical wrought-iron posts that are often used in similar places. Such a construction generally involves the necessity of an independent cast-iron foot or base, thus placing a full transverse joint across the body of the post; and, furthermore, the inside of these posts can never be reached either for inspection or protection, after they are once in place.

The main and counter ties are placed in piers connected at the lower end with the bottom chords and posts by a pin, and at the upper end passing through the top chord immediately over the post-head and secured in their position by nut and screw. They run diagonally, reaching from the pin at the foot of one post to the head of the second post beyond, their vertical rise being the depth of the truss and their horizontal reach being the length of 2 panels. They are of rolled iron, square in section, their lower part being formed into a loop, which is drilled to fit the pin; and their upper end being shaped into a cylindrical form on which the screw is cut. The end forming the screw is enlarged so that the sectional area of metal at the bottom of the screw thread is in each case larger than the sectional area of any part of the body of the bar. The nuts are faced to a true and perfect bearing on their respective seats.

The lower chords are of square iron of the length of one panel, formed with a drilled loop at each end, through which the pins pass. They vary in size and number in each panel, according to the duty demanded by their position. In their manufacture the most scrupulous care was taken to have them all of exactly uniform length between centres of pin-bearings.

The upper lateral struts are of rolled channel beams 6 in. deep, weighing 10 lbs. per ft., placed in pairs, between the top chords at their joints over the post-heads. The lateral ties above and below are of round iron bars 1¼ in. in diameter.

The floor-beams consist of rolled I beams 15 in. deep, weighing 50 lbs. per ft. suspended in pairs from the pins at foot of posts. The bolts suspending the floor-beams and the coupling-pins are forged bodily from selected scrap, under heavy hammers, and afterwards machine-finished for their respective positions.

The above description of the parts of the fixed spans applies equally to the draw-span, except that in that span the chords are necessarily different, as is demanded by the varying nature of the strains, which change from compressive to tensile, or the reverse, as the draw is open or shut.

They are built of channel beams 12 in. deep, 33¼ lbs. per ft., placed in pairs, and connected together with plate iron, thus making generally a trough or hollow box of 3 sides, 24 in. wide, and about 12 in. deep. The joints, which are carefully broken, are spliced with appropriate cover-plates, and the whole thoroughly riveted together.

The top and bottom chords are substantially similar, varying in dimensions, etc., only with the varying duty. The turn-table on which the draw-span revolves consists of a rectangular hollow girder or drum, 18 in. wide, and 4½ ft. deep, curved to a circle, with an exterior diameter of 37½ ft. The sides of this drum are of plate iron, and the top and bottom are of cast iron, and are separated by 30 cast-iron stiffners, or diaphragms, carefully fitted to which, and to the top and bottom segments, the side plates are thoroughly riveted. This circular drum revolves upon 48 heavy cast-iron wheels or rollers, placed under it, and they in their turn rest upon a cast-iron track bolted to the masonry of the pier. These wheels are connected with each other and with the centre step by bands and radial axles. The wheels and the upper and lower track bearings are chilled to great hardness to resist wear. From the bottom of the revolving drum pass truss-rods, the upper ends of which bear upon a heavy central cast washer, at the bottom of which is the pivot-pin, of wrought iron, 8 in. in diameter. This pivot-pin turns upon a gun-metal bearing in the top of a central conical block of cast iron, which is fastened to the masonry.

The adjustment of the load between the exterior wheels and the central pivot is made by means of the truss-rods above mentioned.

The ends of the draw are secured in their position on the piers by means of a system of cams, so arranged with screw and connecting rods as, when being run down, to absolutely lift the ends of the bridge. This device is essential, as otherwise, when a train might be entering upon one end of the draw, one wing being thus loaded and the other wing being empty, the unloaded end would rise from its bearings, and thus serious and complex strains be induced upon parts of the structure.

But by absolutely and sufficiently lifting the ends of the bridge upon solid bearings this difficulty is entirely avoided, and the structure can thus be treated legitimately and correctly as a beam resting upon 3 points of support, and the complexity of the problem of strains be immensely simplified.

The bridge is turned and the machinery of the end cams operated by a double engine of about 20-horse power(nominal) placed on an iron platform laid for the purpose on beams supported by the main posts over the turn-table. This platform or floor is placed at a sufficient height above the lower chords to allow the passage of trains beneath it.

QUALITY OF MATERIALS.

Samples of all the wrought-iron bars used in the bridge were tested to their ultimate capacity before acceptance.

The tensile strength ranged from 55,000 to 65,000 lbs. per sq. in. of sectional area, and the lowest limit of permanent set was about 2,500 lbs. per sq. in.

The stretch before final rupture was about 20 per cent. of the length of the original bar, and the diminution of area proportional therewith.

The cast iron was from a mixture of 75 per cent. of No. 1 Lake Superior charcoal pig, with 25 per cent of Scotch pig of the brand known as "Calder iron."

Test pieces were cast 2 in. deep, 1 in. wide, and 40 in. long. These were placed edgewise upon bearings 36 in. apart, and were called upon to sustain the transverse strain from a load of 2,800 lbs. placed at the centre.

All the test pieces showed higher capacity. The hollow chord pieces were drilled and accurately callipered for thickness.

After manufacture and before being placed in the bridge, each piece of bar iron was placed in the testing machine, and subjected to an actual tensile strain of 15,000 lbs. per sq. in. of sectional area, and while under such actual strain, received several sharp blows from a hammer. Any imperfection or weakness detected by this treatment condemned the bar. Of the many hundreds of bars thus treated, only 2 exhibited any sign of failure, and in both these instances the defect was in the original bar, and not in any part that had been worked at the shops. As soon as finished, and before leaving the works, every piece received 1 coat of paint, composed of oxide of iron and oil.

All the iron work was done at the shops of the Detroit Bridge and Iron Works, at Detroit, and having been fitted together there, each piece was marked, so that when brought to the place of final erection every part went to its place with perfect accuracy.

FLOORING.

Upon the iron floor-beams are laid pine stringers, placed longitudinally. Under each rail in the track are 2 pieces, 7x16 in., and in addition thereto are 4 parallel pieces, 6x14 in. All these are laid upon small oak bolsters, which rest upon the iron beam. On the top of the stringers are oak ties, 6x8 in., spaced about 20 in. apart, between centres, reaching entirely across the bridge. A double course of 2-in. oak flooring-plank forms the roadway, the track for engines and cars being of the pattern known as street rail, the top of which is flush with the top of the oak flooring. A substantial oak wheel-guard, and a strong neat hand-rail form the side protection.

PAINTING.

The entire superstructure received, after erection, 2 thorough coats of paint. For the main trusses the paint was of strictly pure white lead, tinted to a light drab, while the floor-beams, track-stringers, and hand-rail were covered with iron paint of a dark brown shade.

A LATE number of Poggendorff's "Annalen" contains an account of an experiment made by E. Budde, to ascertain whether a Leindenfrost's drop with water could be produced at a less temperature than 100 Cent. The experiment was made by letting a drop of water fall upon a hot plate covered by a partially exhausted receiver, and it was found that the drop assumed the spheroidal condition at a temperature of 85 Cent., confirming the doctrine that the force which supports the drop obeys the laws of the pressure of vapors. The star shape assumed by the drop, Berger has explained to be a phenomenon of vibration. If the drop is large it behaves like other vibrating bodies, and divides into aliquot parts, forming nodes or loops.

THE state of the Belgian iron trade continues favorable. Almost all descriptions of iron are in good demand, especially plates ; considerable quantities of these latter have been sent to Germany. A contract for 2,000 tons of rails for the North-West Austrian Railway has been divided between the Thy-le-Château, the Couillet, the Monceau, and the Sclessin Works.