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JEFFERSON STREET BRIDGE, SOUTH BEND, INDIANA

A. J. HAMMOND, CONSULTING ENGINEER.

Presented June 13, 1906.

The city of South Bend is located in the extreme northern portion of Indiana, on the St. Joseph river at the point where the river abruptly changes its westerly course and flows north to Lake Michigan, and this freak of nature gave the city its name. Our local geologists tell us that the original course of the river was westward through the Kankakee Valley to the Mississippi, but this plan was changed by subsequent glacial action.

The city of South Bend, now some three-quarters of a century old, was built on both sides of the river, which was early spanned by pile trestle bridges. Some twenty years ago Whipple truss iron bridges replaced the old trestles, and these in turn are now being replaced by plate girder and concrete-steel arch bridges. The old steel bridges are being removed to other sites where their light capacities will not be exceeded.

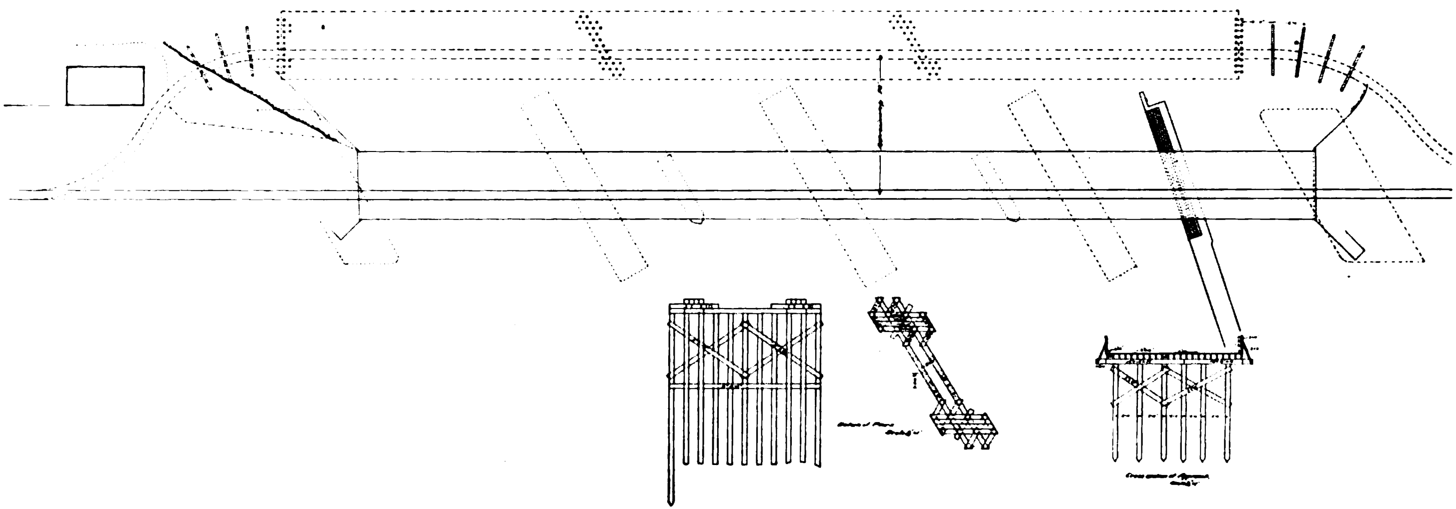
On Jefferson street, at a point some three hundred ft. above the dam in the St. Joseph river, a three span Whipple truss bridge spanned the river, the two piers being on a skew with the axis of the bridge, and the spans being respectively 163 ft., 158 ft., 163 ft., long on pin centers. It was decided to replace this bridge with a 4-span concrete arch, and in order to utilize the river frontage as well as to preserve the water-way, it was decided to keep the length of the new bridge practically the same as the old one.

In order to provide for the traffic during the construction of the new bridge, I submitted plans for the removal of the entire superstructure 72 ft. down stream, in a direction parallel to the current and on a skew with the street axis. The trusses were to be set on nests of piles, and trestles built at each end to connect with the street. These trestles were on reverse curves of about 70 ft. radius, but the rails were bent in place with jim crows, and the track men got quite a smoothly riding curve for so short a radius.

The bridge spans were floated down to the new site on scows, which were afterwards used during the construction of the new bridge, as described in the following pages by Mr. Strehlow. The work of removal was very successfully and quickly accomplished.

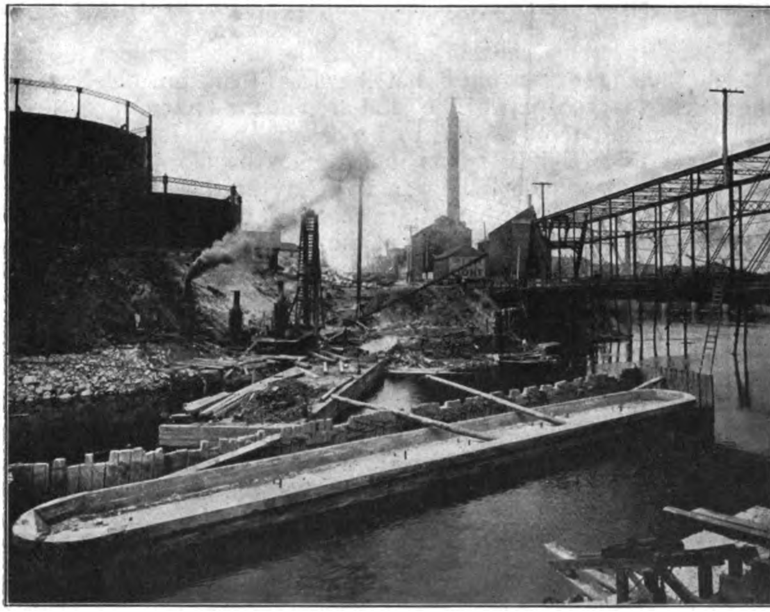
At the east end of the bridge site the old bridge extended some 60 ft. beyond the shore line, and a stone wall with steps leading down to the water was one of the features of Howard Park, a beautiful little city park which lies adjacent to the river on the south side of Jefferson street. This river wall is about four feet above the crest of the dam, and during extreme high water the back

Plan
Showing Temporary Location
of
Jefferson Street Bridge.



water spreads over the wall to a maximum depth of about a foot. The maximum rise in the river is, therefore, about five feet.

No local soundings were taken to determine the nature of the bottom of the river, because numerous soundings had recently been taken near the dam site, which disclosed a bed of blue clay some 35 ft. thick, lying immediately below a few feet of gravel, which constituted the bed of the river. Occasional pockets of quick sand or fine river silt had also been found, so that a pile foundation was determined upon. Some boulders, as a result of the glacial drift, are found in the river, and these interfered, to some extent, with



PIER FOUNDATIONS—COFFERDAM PARTLY REMOVED

the coffer-dams, but, nevertheless, very good coffer-dams were obtained for all foundations.

The new bridge consists of four elliptical arches having a span of 110 ft. each. The distance between the abutment faces is 482 ft., and the total length is 554 ft. The bridge is 72 ft. in width between the spandrel walls, only 10 ft. less than the full width of the street. The sidewalks are also widened at the ends of the bridge, so as to spread within 4 ft. of the width of the street. The roadway proper is 52 ft. wide, with two street car tracks.

A bridge of the Melan type was decided upon, and the specifications were practically standard for this type of structure, the calculations being based on the following conditions:

Dead load, concrete..............Weight of 150 lbs. per cu. ft.
Fill ....Weight of 120 lbs. per cu. ft.
Pavement ....Weight of 150 lbs. per cu. ft.
Live load for roadway and walks..Weight of 150 lbs. per cu. ft.
Concentrated moving load for double tracks....40 ton electric car
Modulus of elasticity of concrete..................1,500,000 lbs.
Modulus of elasticity of steel.....................30,000,000 lbs.
Maximum stress on concrete
For compression, exclusive of temperate stresses 500 lbs. per sq. in.
For tension, exclusive of temperature stresses.. 50 lbs. per sq. in.
For shear .... 75 lbs. per sq. in.
Maximum stress on steel.................18,000 lbs per sq. in.

The steel must be capable of taking the entire bending moment, and the flange areas must not be less than on one-hundred-and-fiftieth (1-150) part of the total arch at the crown.

The foundation piles were to be driven so as to penetrate not more than three-eighths of an inch under the blow of a hammer weighing 2,240 pounds falling 25 ft. Any hard wood piles which would stand the hammer blow were accepted, provided they were not less than nine inches in diameter at the small end, and twelve inches in diameter at the large end. The piles were spaced 3 ft. apart c. to c., and were allowed to project 2 ft. into the concrete.

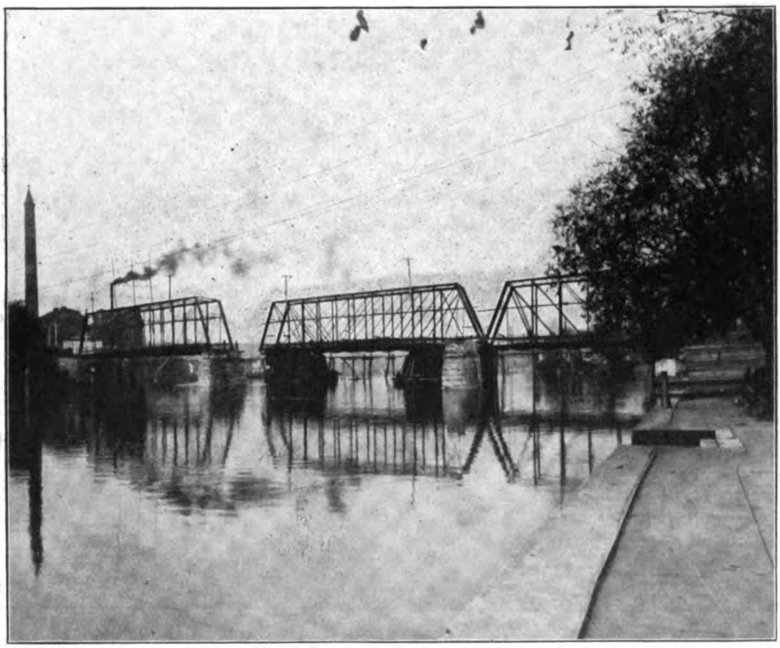
The contractor was paid per foot for only the actual number of feet of piles driven, cut off, measured in place, so that it was to his interest to drive the piling to grade for the cut off, so as to lose the minimum of timber.

As the site of the bridge is only about 300 ft. above the dam, and the bed of the river tends to rise from silting, the foundations of the piers were carried only some six feet into the clay, or to a depth of 19 ft. 7 ins. below the springing line, the depth being uniform at the piers, and the abutments being carried into the clay.

In order to have the piers parallel with the current of the river, and to preserve harmonious relations with the streets at the ends, it was necessary to construct the bridge on a skew of 60 degrees, and to use a uniform grade of 1.3 per cent ascending towards the west. The springing line was given a uniform elevation of about mean high water, or two feet below extreme high water, so that the rise in the arches was respectively 15.85 ft., 14.25 ft., 12.5 ft. and 11.0 ft., and because of the grade and the skew, the north spandrel wall shows about 0.54 ft. more face above the crown of the arch than the south side, but as one cannot see both faces of the bridge at the same time, this is not of consequence.

The various lines of the bridge, as shown in the illustration, are pleasing. The ellipse was used for the intrados of the arches, as I believe it very little more difficult to build than a three centered arch, and the curve is more pleasing to the eye, avoiding the abrupt changes in curvature to be seen in some three centered arches. Of course this abruptness is often due to carelessness in making the change in curvature, or point of tangency, and might be avoided, to some extent, by the use of easement curves. The actual rise of the flat elliptical arch is much less than the apparent rise, and flat elliptical arches have been objected to because the sharp curvature at the ends and the light curvature at the center do not lend themselves to harmonious treatment, presenting too much of a beam effect. This, however, is a matter of taste; some people like the beam effect, although it does not appeal very strongly to me.

The central pier of the three was made larger than the other two, not for the purpose of using it as an abutment pier, although it has



MOVING OLD IRON TRUSS SPANS

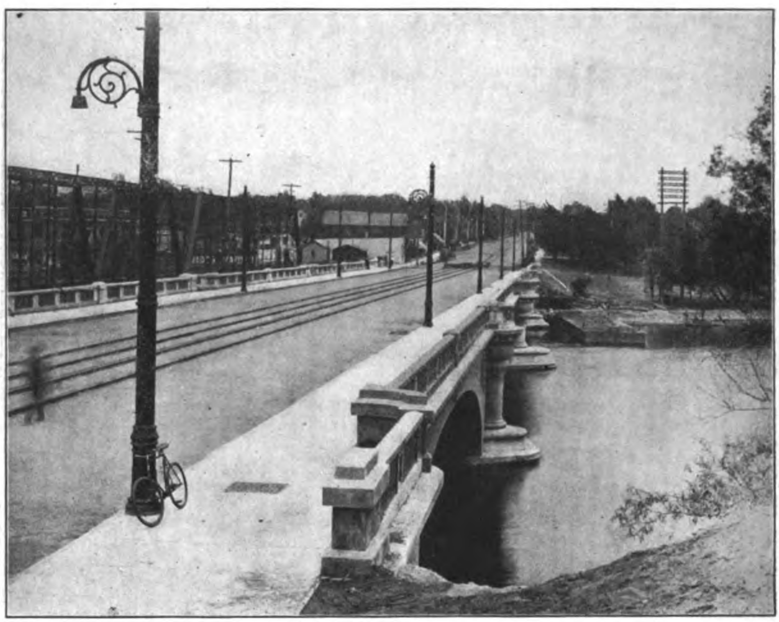
had a useful effect in that way, but for its effect in the architectural treatment of the bridge. This pier at the springing line was four feet thicker than the other two, and five-and-a-half feet longer. The noses of the piers at each end were semi-circular.

The abutments projected three feet beyond the face of the spandrel walls of the arches, and the corners were round in harmony with the piers.

A longitudinal view along the facade of the bridge shows a projection beyond the general line of the bridge face of three feet over the abutments, at little more at the smaller piers and still more at the central pier, so as to break the view from end to end outside the balustrade.

In order to have rest spots on the bridge, or view points outside the traveled way, heavy corbels resting on what were slightly more than half columns, projected over the piers. The variation in grade was taken up entirely in these columns, so as to produce, to some extent, the illusion of no grade on the bridge.

The bridge, as noted, is constructed on the Melan system, properly speaking, according to the patents for reinforcement obtained by Prof. von Emperger, in 1897, which provide for steel ribs fol-



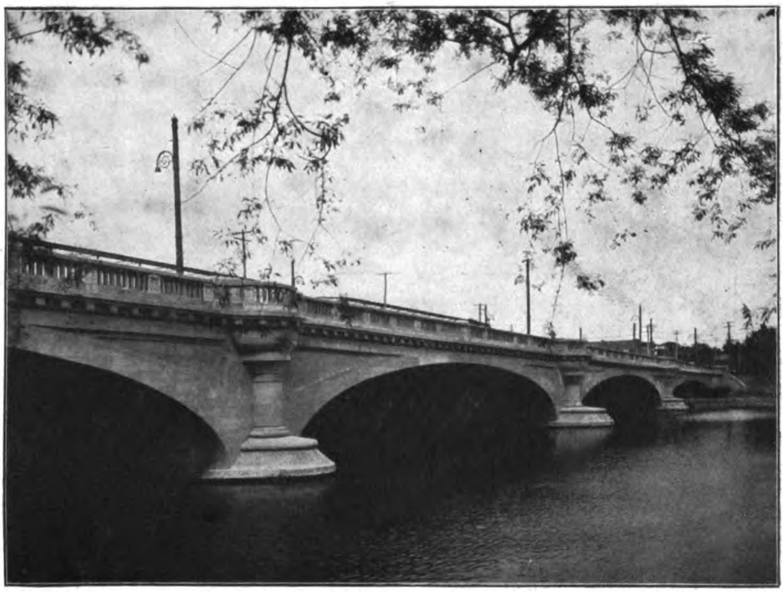
REINFORCED CONCRETE BRIDGE—JEFFERSON ST. SOUTH BEND, IND.

lowing the lines of intrados and extrados, with a lattice connection.

The steel ribs or arches were built up of four 3 in. x 3 in. x 5-16 in. angles, two for each flange with lattice of 1¾ in. x ¼ in. flat bars. The upper and lower chords were carried well into the abutment and pier concrete and anchored transversely by 3 in. x 3 in. x 5-16 in. angles riveted to the ends of the ribs. The steel ribs were spaced 35 in. on centers, and tied together at every third rib by flat bars at top and bottom flanges spaced ten feet apart. The concrete, as afterwards described, was laid in longitudinal sections three ribs wide. These bars were on the line of separation and tied the sections together. The steel ribs were built in three sections and the splices were field riveted. All steel arches were connected by their top flanges continuously over the piers.

The thickness of concrete arch rings at the crown were 27, 28, 29 and 30 inches respectively, beginning with the arch of greatest rise. The flanges of the steel arch ribs were three inches inside the arch ring.

The maximum loading used in the strain sheet was obtained by placing the 40 ton electric car with a 25 ft. wheel base on the quarter point of the arch ring, and the stresses were obtained graphically by methods developed by Mr. Edwin Thacher for the

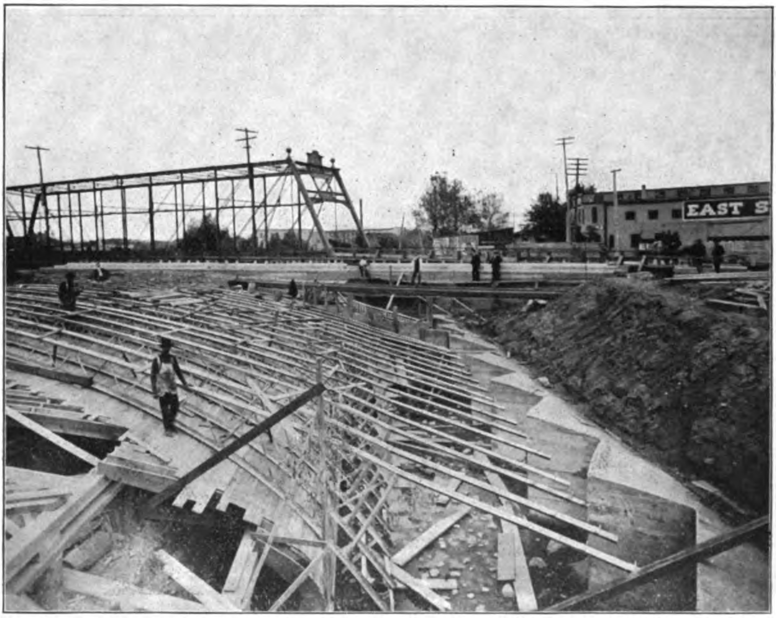


JEFFERSON ST. CONCRETE ARCH BRIDGE—SOUTH BEND, IND.

reinforced arch ring. The lines of pressure in the piers and abutments were also determined graphically, the resultant being required to come within the middle third of the bases.

The corbels over the piers were tied into the spandrel walls by built Z bars, two to each pier, spread so the lower leg was anchored into the pier concrete, and corrugated bars were used for tying in and sustaining the corbel. The base column and corbel are also tied together by vertical corrugated bars spaced radially. Vertical bars and reinforcement was also used in the spandrel walls to tie them into the arch concrete.

The concrete used in the work was, as a rule, laid wet, using unwashed pit gravel and Portland cement. The gravel was remarkably clean, and approximated very closely the correct proportions for sand and crushed stone. The concrete was mixed in the proportion of one part Portland cement to eight and one-half parts of gravel, for the piers and abutments, and one part cement to seven and one-half parts gravel, for the spandrel walls, cornice and balustrade and parapet walls. For the arches, the proportions were one to five. All exposed faces were given a mortar face one inch thick deposited with the concrete, the proportions being one part cement to two and one-half parts sand. All the cement was tested, the results of numerous tests averaging as follows, for the cement used: viz. Universal Portland.



REINFORCEMENT OF CONCRETE BRIDGE—MELAN TYPE, SOUTH BEND IND.

Fineness, passing a No. 100 sieve, 98.39%; passing a No. 200 sieve, 78.63%. Tensile tests on neat briquettes, seven days old, developed 550 lbs. and in twenty-eight days 711 lbs. For a mixture of one part cement to three of standard sand the seven days test showed 216 lbs. and at twenty-eight days 359 lbs. tensile strength. The contractor as a rule kept about a thousand barrels on hand, so that ample opportunity was afforded to test the cement.

The concrete in the piers was carried up to the springing line, but a depression was left in the center for the location of the steel ribs and for tying in the next layer of concrete. The piers were then carried up into the forms on a serrated design, making a break at each third rib, so that a longitudinal arch ring three ribs wide, which could be deposited easily as a day's work from one mixer, was given a right angle bearing over the piers and abutments. In reality, therefore, the arches are made up of a series of arch ribs normal to the face of the pier masonry as laid, and with the line of thrust parallel with the axis of the bridge. These longitudinal ribs were in all cases built complete at one time, requiring, at times, the work to extend well into the night.

The corbels developed quite a warped surface, and required very careful treatment in the design and construction of the forms, and which I think the contractor very successfully executed. I may say, in this connection, that the effective treatment of this moulded work was due largely to the interest the contractor and his engineer in charge took in the work.

As the arch ring was given no projection, the plain face had to be given an effective treatment by some other method, which was effected by a very deep and heavy panel over the haunches, the panel being six inches in depth, and also by a moulded projection at the crown of the arch; the moulds for the laurel and other scrolls were carved out of a single heavy pine board and used for all arches.

The cornice projected fifteen inches with a heavy dentil course below. The cornice, pier corbels and columns and base, base of hand rail and balustrade posts were cast in place in timber forms; the balusters and hand-rail were moulded in cast iron forms; the concrete or mortar for the latter being mixed quite dry, in the proportions of one to two and a half. A groove was left in the top and bottom of the hand rail, so that the mortar dowels on the ends of the balusters tied them in place; similar dowels were used on the hand rail.

The forms for arches and spandrel faces were made of 2 in. dressed lumber, with one inch dressed lumber for the lagging. The centers were required to be framed for a rise of arch greater than the rise shown on the drawings by an amount equal to one eight-hundedth (1-800) part of the span, or about one and three-quarters of an inch. This allowance was for the compression of the centering and deflection of the arch rings. The compression resulting from the dead load of the arch ring and back fill ranged from one-half inch to one and one-quarter inches, and a further deflection of a tenth to fifteen-hundredths of an inch took place on removal of the arch centering..

The tops of all arches were treated to a coat of cement grout and a layer of hot coal tar, as was also the back of the spandrel walls. The drainage over the piers was through two-inch gas pipes, and weep holes were left through the retaining walls at the abutments.

The fill on the bridge was mostly sand and gravel furnished from an excavation in the park near by. The fill was thoroughly soaked and permitted to stand over winter, to be more thoroughly settled, and then rolled with a 13-ton roller, so we anticipate the back fill to be quite compact, and will be free from serious settlement.

The pavement is of asphalt on a Portland cement concrete foundation, six inches in thickness.

The sidewalks are of cement, having a base four inches thick of one to six concrete, and a top surface of one inch of one and a half to one cement mortar. A nine inch steel channel forms the curb face and curved openings are cut through the web to discharge the street water into the river at the arch crowns.

The space under the walks on the north side of the bridge was used for water and gas mains. An expansion joint was put in the gas main, but no provision was made in the water main. Electric conduits were placed under the south walks.

The electric poles used for lights and also for span wire of the street railway are very heavy, and were furnished by the two companies; as these poles are only about 124 ft. apart and on both sides of the roadway, with a 2,000 c. p. arc light for each pole, it may be readily understood that this will be one of the best lighted bridges in the country.

The exposed face of all concrete below the cornice has been gone over by hand, and the pores filled with grout and rubber with a pine float, so that no body of cement is to be left on the face of the work, and a uniform appearance is thus given to the walls.

The contracts were awarded August, 1904, to Scribner & Heyworth, Mr. J. O. Heyworth, of Chicago, afterwards taking over the work, with O. E. Strehlow in charge. The steel work was furnished by the Wisconsin Bridge & Iron Co.

The contract price of the bridge, exclusive of piling, was $119,000; the piles were driven at an expense of 33c per ft., and this amounts to a total of $9,376.95, making the total cost of the bridge $128,-376.95.

The contract price paid for the removal of the old steel bridge was $7,000.00 of which the Street Railway Company paid a proportion. The total cost of the bridge was, therefore, $135,376.95.

CONSTRUCTION OF JEFFERSON STREET BRIDGE, SOUTH BEND, INDIANA.

O. E. Strehlow, C. E.

A brief description of the methods employed and of the details of construction of bridge work, which Mr. Hammond has fully described as regards the location, design, etc., together with some additional views, showing temporary and permanent work and plant, are presented herewith by the writer, who was in local charge of this work for the contractor, James O. Heyworth, Chicago.

The first work was to move the three 170 ft. Whipple spans of the old steel bridge down stream to temporary pile piers driven far enough from the old piers to clear the new bridge. The plan decided on and adopted was to float the three spans, one at a time, on two scows, to the temporary piers. The shore end of the east span, which overlapped the bank about 70 feet, was slid over to its new location on four 60-pound rails, the river end floating on the scow. These spans weigh about 125 tons each, and the scows are 20 ft. wide, 70 ft. long and 4 ft. 6 ins. deep. Three longitudinal bulkheads, the two gunwales, and six transverse bulkheads, divided the scow into 28 compartments to reduce the effect of a rush of water in the scows, due to slight unequal loading or other causes, and also to lessen the chance of sinking a scow. The east span was moved over in about three hours, the middle span in about half the time, and the west span was moved in about fifteen minutes. The two barges were used on the work of building the new bridge and on other work later.

A dam about 300 feet below the bridge site, with about 2 feet of flash boards on the crest, backs up the river for three or four miles, and high water raises this pool only four or five feet more. This condition permitted dispensing with a cableway for constructing the new bridge and the unusual width of the bridge made a fixed cableway undesirable. Light trestle work across the river, carrying light tracks, derricks on land and water, and the two scows and a smaller one, proved to be sufficient for carrying on the work that otherwise would have been done by a cableway had one been installed.

The dry excavation of east abutment was done with teams and drag scrapers, about one-half of the material being wasted on the low river bank down stream from the bridge; the remainder was placed in Howard Park at end of the bridge and was graded to conform with the elevation of Jefferson street. This filled area and a portion of the street constituted the storage yard for 4,000 cu. yds. of sand and gravel being stored at one time. A guy derrick with 65 ft. mast and 60 ft. boom was erected on the center line of bridge at the top of the west slope of the east abutment excavation. This derrick which hoisted the remaining excavation and the old masonry of east abutment, also placed the concrete and a large quantity of the stone of the old masonry, in the new abutment. The concrete mixer was a "No. 5 Smith," and discharged directly into the derrick skips. The location of the mixer proved to be the most economical, not only for the work at the east abutment but for the work as a whole. The gravel was conveyed from the storage yard to the mixer in 1½ cu. yd. dump cars, the track having a slight down grade, to the mixer. The tracks leading from mixer to the three piers and west abutment were level and two feet above the springing line.

A part of the west abutment excavation was removed with teams, then by hand (which was wheeled into a coffer-dam for other parties), and the remainder was handled by the derrick which was moved over from the east abutment. This derrick also handled the stone from the west abutment and placed it in the concrete in much the same way as the east abutment. The concrete was conveyed in cars from the mixer on the east bank in 1½ cu. yd. bottom dump cars which were hoisted bodily with the derrick and swung to any point in the abutment. While waiting for concrete cars, the derrick, which operated quickly, was working to its full capacity placing stone in the concrete. This derrick also removed the levee around the abutment coffer-dam and placed it in the back-fill of the west abutment, using a ¾ yd. "orange peel" bucket.

The coffer-dams, which were single rows of 6-inch, 7-inch, or 8-inch Wakefield sheet-piling, driven through sand and gravel into moderately stiff clay (with isolated pockets of sand) were surrounded with the wet excavated material, which was to a large extent removed with the orange-peel excavator before pumping out the coffer-dam. One illustration shows the coffer-dam pumped out, and another shows one side of the coffer-dam removed. The bucket would not dig the clay, so about five feet of clay was dug by hand and hoisted in skips and dumped outside of the coffer-dam. Two 6-inch Morris centrifugal sand pumps run by two 30 H. P. motors were used to pump out the coffer-dams. The round piles for the foundation were driven by a "swivel" pile driver provided with extension leaders.

A large proportion of the concrete in the arches was conveyed in dump cars or ¾ yd. two wheeled bottom dump steel carts on flat cars, which were hoisted up an inclined track. As there was no hoisting engine available at this time, one of the centrifugal pumps and its motor were set up to take the place of the hoisting engine. The shell, etc., of the pump was removed and a "niggerhead" put on the shaft. A 1-inch Manila rope attached to the concrete car and wrapped on the "niggerhead" gave the man absolute control, to vary the speed of the car up to ten miles per hour.

The centering rested on pile bents parallel to the piers 12 ft. apart on centers. The piles were capped with 4x12 in. 16 ft. timbers, on which the 8x12 in. 16 ft. stringers were blocked with wedges. These stringers supported 2x12 in. 12 ft. joist 12 ins. apart on centers and bridged. The lagging was of inch lumber, 4, 6 and 8 ins. wide dressed on one side and edges beveled. The joists were sawed to the true curve of the arch at the planing mill. The pile bents were well braced with 2x12 in. and 3x12 in. plank. The steel ribs were built by the Wisconsin Bridge & Iron Works, in sections, about 40 ft. long, and were given a coat of milk grout before shipment from the Milwaukee shops. Owing to the ribs being built in long sections, the erection work was reduced to a minimum.

The balustrade, except the piers and base, was molded in cast iron forms, the top rail being generally in sections 8 ft. 4 ins. long.

The brand of cement used was "Universal," furnished by the Illinois Steel Company.

DISCUSSION

Albert Scheible—M. W. S. E.—Having been at South Bend while this bridge was being built, I am glad to state that the people there seemed to generally appreciate the combination of the practical with the unusually artistic which they are getting in this bridge.

As long as I am not personally acquainted with Mr. Hammond, I think I might say it seems characteristic of the engineering work which he is securing for that city.

As a layman in bridge building I would like to ask two questions: One is as to whether the Melan type of construction was called for, or specified, in asking for bids, or whether the specifications merely mentioned the general conditions to be met in a reinforced concrete construction, so that this method was selected as the most economical?

Mr. Hammond—The Melan system was called for.

Mr. Scheible—The other question is as to whether any observations were made to determine the seriousness of the cracking in the east arch? The reports, which were considerably magnified in the papers (probably for political reasons), stated that some surface cracking was due to a too hasty removing of the under-pinning from the centers of the arches. I do not know whether the deflection of 3½ inches refers to that arch as well as to the other, or whether the cracking was serious enough to warrant any determinations, but it would seem interesting, from an engineering standpoint, to have a case where there really was a difficulty resulting from removing the substructure too early.

Mr. Hammond—The forming was removed after two of the arches had been built, and the thrust of the east arch, (which is the flattest arch) was obtained against one abutment and against the other arch and pier, so that the force against the next pier was such as to cause a greater deflection than there should have been. In other words, the resistance of the pier and the second arch was insufficient to hold the load, and it settled much more than it should have done, the deflection being about five inches. That deflection caused some fine cracks in the ring, but those are very fine, and levels were taken continuously on that arch after the forming had been removed, until about a week ago when levels were taken to determine the conditions then. After the forming had been taken out for a short time, they put part of it back up, until the other two arches were completed and the force of the thrust of the entire bridge was brought to bear against the east span. From that time levels have been taken frequently and the entire deflection has been about five inches, and practically all that deflection developed during the period the arch forming was out, or a little afterwards. As soon as the thrust of the other arches came against this, it raised a little. The cracks were of such small nature of to be of no consequence. In fact, it is now very difficult to see any cracks in the bridge. The fact is, the construction was carried on in a way that is a little unusual, the cornice being put on at the same time the arch ring was constructed and the forming used for the spandrel walls, deflected along with the arch ring, and in consequence of that there was a strong deflection in the cornice. The cornice was afterwards removed, and I think you would not notice any trouble from that score now, so, as far as the strength of the bridge is concerned and permanence, there is no question about that at all.

L. K. Sherman—M. W. S. E.—I would like to ask how long the arch centering was left in after the concrete was placed? In other words, how long a setting did the concrete have?

Mr. Hammond—The specifications called for the centering to be left in 28 days. Also all the arches were to be in before any arch forms were removed; after the four arches were completed, they were left 28 days and the entire filling was placed on the arches before any centering was removed.

W. S. Cowles—M. W. S. E.—I would like to ask what provision, if any, was made for expansion.

Mr. Hammond—The bridge has expansion joints over the spring lines and also about one-third of the way across the bridge, and in the spandrel walls and cornice more frequent joints were left.

One thing I may say in regard to the construction of the bridge. The specifications originally called for crushed stone in the arch ring, and the contractor, desiring to avoid shipping any stone, took the matter up with the Board and myself in regard to using gravel. A compromise was effected by a reduction in the contract and gravel was used in place of crushed stone all through the bridge, for the arch rings as well as the foundations.

Jas. B. Marsh—M. W. S. E.—I have just come from South Bend and the bridge looks fully as well as the cuts thrown on the screen. It is a very handsome piece of work.

In regard to the gravel concrete, my idea is that gravel is just as good when used as they used it there in the concrete as the crushed stone.

I think they had a great many difficult problems in that bridge, owing to the skew of the bridge and the extreme flatness of the arch. The centering being lowered when only two spans were in would tend to make the pier act as an abutment, taking the horizontal force. As I recall those spans, the pier on the east or north side is something like 42 feet thick, that thickness being required to take the thrust on a span 110 feet long with only 11 feet rise, or one-tenth rise. And the question is, how would a metal bridge have acted under similar circumstances? I think it was the stiff ribs in the Melan type of bridge that saved the spans from any permanent injury. Withal it is a very nice piece of work and a credit to the engineer and contractor.

Ernest McCullough—M. W. S. E.—I would like to ask if any royalty was paid for the use of the system. I believe it has been asserted that the patents were knocked out a little while ago.

Mr. Hammond—The county paid a royalty to the Concrete-Steel Engineering Company of New York.

Mr. McCullough—What was the percentage of reinforced concrete, compared with the area of the steel, in sections?

Mr. Hammond—1/150 part.

Mr. Sherman—Did you have any trouble, Mr. Hammond, with distortion of the ribs for the skew-arch centers? Some of the ribs of course do not run clear across the span; that is, they break off, as shown in the cut, in front of the bridge. We naturally suppose that in placing concrete at the haunches there has been a horizontal thrust on the ribs, and that it would tend to throw them out.

Did you make any provision to carry that force, or was there no distortion?

Mr. Hammond—There was no distortion of that kind.

Andrews Allen—M. W. S. E.—In regard to the steel ribs used in this arch, there are certain questions with which I happen to be familiar that may be of interest. The arches were continuous over the piers; that is, the 3x3 angle chords were spliced over the piers for their full value. It was not thought possible to determine in advance with sufficient accuracy the exact location of the rivet holes for these connections, and the splice plates were therefore left blank and drilled in the field to fit the holes in the angles. In the first arches furnished, both the plates and the angles were left blank.

The specifications required the use of Portland cement grout on these arches and we experimented a long time before finding a grout that would stick. We finally used a milk grout, skimmed milk and Portland cement, which served the purpose extremely well. The same grout has been since used by us for the preservation of steel work used in permanent contact with moisture. While we do not advocate it as a paint for general use, it has its value under certain conditions.

J. H. Warder—M. W. S. E.—Was that mixture composed of milk and cement only?

Mr. Allen—Yes. We seem to have found some engineering use for milk.

Mr. Warder—Where did that idea originate, of using milk instead of water?

Mr. Allen—Our superintendent, Mr. Coddington, had heard of it and tried it.

Mr. McCullough—I would like to ask whether that grout coating is of any permanent value, or whether better results would be obtained by leaving that off, providing the metal was kept reasonably free from rust?

Mr. Allen—The difficulty is in keeping the metal free from rust. It is shipped and sometimes stored for weeks and months, and it was not thought best to expose it to the elements without any covering at all. The use of paint would not have answered the purpose because it would not have formed sufficient bond with the concrete.

It may also be of interest to know that while the arch was an ellipse, the curve was figured as a many centered circular arch, ordinates being figured every two feet for both the inside and outside arch.

Mr. McCullough—In regard to this question of rust, I made some experiments along that line, and when we coated the rods we left some of them exposed for a while until there was quite a lot of rust on them. These we embedded in mortar and left for eighteen months. On breaking them open we could find no signs of rust at all. Some rods had been polished, and in others, where slight rust had accumulated, we found the adhesion was much better than on the smooth rods.

I understand some extensive experiments were made in Europe to test the matter in the same way, and they found there that a slight amount of rust seemed to be beneficial rather than otherwise. I would like to know whether the grouting does any good or not. Mr. Marsh has probably had as extensive experience in building bridges as any man in this country, and it seems to be his opinion, perhaps as a contractor, that the coating with the grout is not of enough benefit to warrant one going to the expense, and in some cases it is a question whether it is any benefit at all.

Wm. Seafert—ASSOC. M. W. S. E.—The influence of rust on steel which is to be covered with Portland cement mortar, was thoroughly discussed by the German Association of Cement Manufacturers at several of their meetings, a committee having been appointed to investigate and report on the matter. The substance of this report and of the discussions following was, that a slight coat of rust without scale increased the adhesion between the cement mortar and the steel, at least 10 per cent. The practice of permitting a slight coat of rust to form on steel to be used in reinforcing concrete is now quite general in Europe.

A clear distinction between concrete and cement mortar must be drawn. The surface of the rusted steel must be covered with a rich cement mortar; ordinary concrete will not answer as a covering. It goes without saying that the steel must be free from scale.

The Krupp Co., of Essen, Germany, are placing a new iron cement on the market similar to Portland cement except in color and strength. It is made of lime and silica and 10 per cent. iron ore mixed in the raw cement material. This is burned the same as Portland cement, the 10 per cent. iron ore displacing 7 per cent. of alumina. The resulting product is of a chocolate color and possesses high compressive and tensile strength.

Mr. Allen—I might add in this regard that the form of these arches being composed of angles with a space between, with rivet heads at frequent intervals, and with lacing bars between, is such as to give a very good mechanical bond with the concrete.

Mr. Cowles—Is not the adhesion of the concrete to the steel one of the main points in the use of reinforced concrete, the action of the adhesion itself being the main point to be considered?

In regard to rust, I would like to know how must rust is desirable to produce this 10 per cent. increased adhesion. Certainly if the rust were great enough, it would have a bad effect, although I understand that a small amount might not be detrimental.

Mr. Seafert—There must be no scale. The cementing property between the metal and the concrete is increased. The cementing property in some sandstones is in proportion to the iron present.

J. N. Darling—M. W. S. E.—I would like to ask whether there is any iron added to the Universal Portland cement.

Mr. Seafert—There is no iron added, simply the slag. In the furnaces they use an iron ore of known constituents, especially selected, which gives a slag that is used instead of clay. This slag is ground up and a little more limestone added to it before being burned to a clinker.

Mr. Darling—I have found iron in all samples I have tested of Universal Portland cement.

Mr. Allen—Do you find that in other cements?

Mr. Darling—I have not recently tested other cements for iron, and I *thought* that the iron in the Universal cement came simply in the slag used in its manufacture.

Oscar E. Strehlow—M. W. S. E. (by letter)—It may be of interest to state that a part of the apparent deflection of the east arch is due to the settlement of the east pier, both having been determined with a level, and referred to a bench mark near the bridge. The pier settled about 0.1 foot and the centering was built about 0.06 foot too low, which, with the compression of the forms, is quite appreciable.

In regard to the comparative widths of pier and abutment, I wish to say that the former is 18½ feet, and the latter 42 feet, as stated by Mr. Marsh. Considering the abutment effect of the first two rows of 26 heavy arch piles (driven to refusal) near the east pier under the adjacent arch, also the excess excavated material washed in against the pier by the high water, and finally the tension developed in the continuous steel ribs, the resultant thrust was resisted by the combined action or resistances mentioned, I doubt that the weight of the adjacent arch or the abutment effect of the center pier was brought to bear very much.

The wedges which Mr. Hammond stated as being replaced, were 12 in. by 18 in. and, owing to their size and positions, it was not possible to drive them sufficiently to secure a bearing of the heavy stringers against the soffit. The wedges remained loose until finally removed, but the precaution taken was not out of order.