MARTIN

The Replacement of a Truss Bridge by a Concrete Arch

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THE REPLACEMENT OF A TRUSS BRIDGE BY A CONCRETE ARCH

BY

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THESIS

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This is to certify that the thesis of SIDNEY GRISWOLD MARTIN entitled THE REPLACEMENT OF A TRUSS BRIDGE BY A CONCRETE ARCH was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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THE REPLACEMENT OF A TRUSS BRIDGE
BY A
CONCRETE ARCH.

One of the oldest bridges over the Illinois and Michigan Canal, in the year 1910, was that of the Chicago Junction Railway Company. This ten panel Pratt truss bridge was located at Campbell Avenue which crosses the canal at Thirty-third Street on the southwest side of Chicago. Having withstood for years, the heavy traffic of stock and freight transported chiefly to and from the Union Stock Yards, the bridge showed numerous signs of failure, and was thought to be unsafe. While the trusses themselves were apparently in good condition, the bottom laterals were eaten by rust to no small extent (Figure 26). When heavy trains passed over the bridge the shaking and jarring was cause for alarm, although deflections under the heaviest loads were no more than one-eighth or one-quarter of an inch.

It was desired to replace this bridge by some structure which would be strong, durable, economical, and pleasing in appearance, as there had been talk of filling in the canal at some future date and making a boulevard of it from Chicago to Lockport. The type of bridge best suited to all of these conditions seemed to be a reinforced concrete arch. The strength of such a structure could be made sufficient to satisfy the necessary conditions,and its durability would probably be greater than that of a steel structure. Moreover, a part of the old bridge could be used as a reinforcement for the concrete by imbedding the lower chord, bottom laterals, floor beams, and stringers into the concrete. The upper portion of the steel work could then be removed, leaving a deck bridge. Where the

truss bridge had provided for only two tracks (Figures 2 & 37), the concrete arch would allow three to be used (Figures 37 & 43). Hence, the economical advantage was of no little consequence. A concrete arch would be more pleasing to the eye than a common steel bridge of the truss or girder type so frequently used by railroads over this canal (Figure 2). For these reasons, then, a reinforced concrete arch was decided upon. Drawings were made and the work was started as soon as possible. The arch, designed to fulfill all requirements, including a clearance of 16.5 feet above datum for a width of 30 feet for boats passing beneath, and a necessary span of 61 feet, was to be three centered and three ribbed, each rib supporting one of the tracks above and resting upon a suitable foundation.

In order to obtain data for the depth of the foundation, test bores were started shortly after New Year's Day, 1910. A ship augur, one and one quarter inches in diameter, was used in this work. Sections of pipe four feet long were attached to the augur as the depth became greater. Two men did the boring and when the bit would penetrate no farther, the tool was removed by means of a rope and pulley supported by the truss above. Tests were made on both sides of the stream, the greatest depth penetrated on the south side being 37.7 feet below surface or 36.3 feet below datum; and the greatest depth reached on the north being 41.2 feet below the surface or 37.8 feet below datum. In other tests made, boulders or other obstacles were encountered at smaller depths, but as the two depths given above seemed to agree with other data obtained from the Drainage Board, they were accepted, and bed rock was assumed to be 40 feet below datum. The nature of the soil encountered on the north side was as follows :

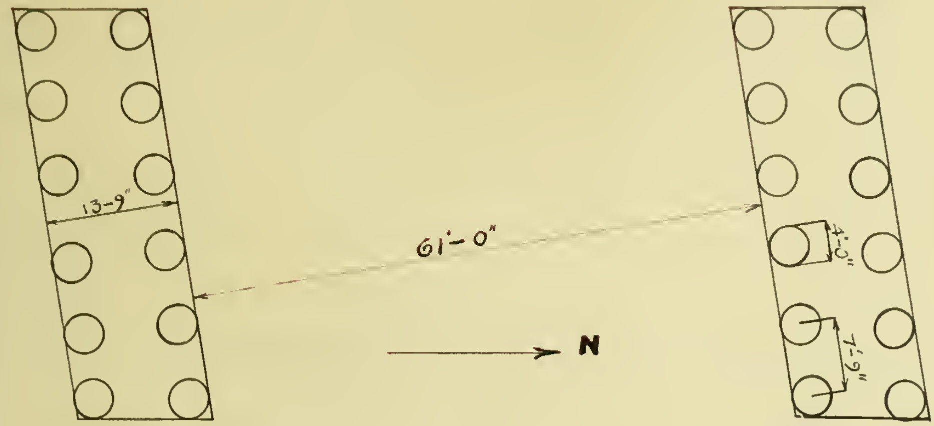
Yellow Clay	10.9	feet	thick.
Hard Pan	8.9	"	" .
Blue Clay	5.6	"	" .
Hard Pan	5.0	"	" .
Hard Pan (containing boulders)	4.3	"	" .
Gumbo Clay	4.3	"	" .
Hard Pan	2.2	"	" .

BED ROCK

The south side showed a very similar stratification except that the first layer of clay was bluish instead of yellow and the first layer of hard pan was not so thick as that on the north side.

After the test bores had been made, the next step in the engineering work was to locate the center line of the truss bridge with respect to the Western Avenue Section line (East line;Section 36;Township39 North; Range 13 E). A parallel line 500 feet west of this section line was first carefully established for reference, and from this the center line of the bridge was located. The center line of the old bridge was to be the center line of the new arch as this would allow the original width to be extended east and west just enough to fulfill the requirements for the extra track,and to give the proper clearance from the Baltimore and Ohio Chicago Terminal girder on the west. The angle between the center lines of canal and bridge was checked and found to be 67 degrees and 42'. With these data the two abutments were staked out. The concrete on the south side was to be flush against the old stone abutment (Figure 33) while on the north side a tow path about 15 feet wide intervened between the back of the new abutment and the face of the old (Figure 34). The form of these footings from

which the three ribs sprang was that of a rhomboid as shown :



Early in February the excavation was started (Figures 3 & 4). As the depth increased, sheeting consisting of white pine planks 2" x 10" x 12' long, and pointed at one end, was driven as shown in the photograph (Figure 10). This sheeting was held in place by means of ranges or wales of 6" x 6" timbers which were fastened along the sides and braced with cross timbers as shown in Figure 11. A double row of planks on the exposed or water side aided in keeping the water out of the hole. Clay was also banked up outside of the sheeting so as to keep the water from seeping through the joints (Figure 6).

When the north and south abutments had been excavated to hard pan, well-digging was started on the south side. Twelve wells, each four feet in diameter, were to be dug to bed rock in each abutment. A plank floor was built in the excavation and double doors arranged over each hole (Figure 5). Vertical posts supported, at intervals, a continuous beam of 10" x 12" timber running horizontally the length of the excavation and about 10 feet directly above the line of centers of the wells (Figure 6). Into this beam a large screw eye was fastened over

the center of each hole so that a pulley could be attached, by means of which the buckets could be lowered and raised. When a bucket was filled the laborer in the well would signal to the foreman who would see that a hook, attached to the cable over the pulley above, was lowered to be caught on the bucket handle. The bucket was then hoisted above the floor, the wooden doors dropped into place, and a wheelbarrow placed under the bucket, the bottom of which was hinged (Figure 19). By knocking out a pin the bottom of the bucket swung down, discharging the contents into the wheelbarrow, thence to be removed to the dump on the bank of the canal. The bottom of the bucket was then swung back into place and secured by the pin before lowering for a new load. The hoisting apparatus consisted of an electrically driven drum controlled by levers, upon which the cable could be wound and unwound at the will of the operator (Figure 7). As the hole was deepened, it was lagged with six foot lengths of 2" x 4" white pine to keep the earth from caving in. This lagging was supported by two iron half-rings with a projection on each end to allow them to be bolted together so as to form a circle of the required diameter. Two rings were used for each length of lagging.

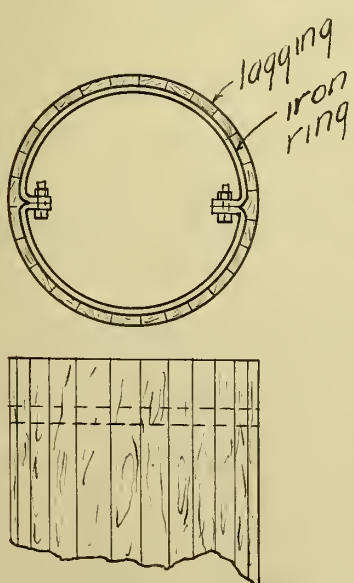


Fig. A.

Excavation had not proceeded far before it was found that trouble, due to changes in water level caused by "locking" the canal to let boats through, was to be expected. The double sheeting and puddle-wall of clay were not sufficient to keep the water out of the excavations when the level was raised (Figure 8) to within a few inches of the top of the

sheeting. An elaborate coffer dam was thought to be too expensive to construct. As a result, it was decided to fill the excavation which had been made to hard pan with concrete, building forms which would keep the concrete from filling in where the wells were to be dug (Figure 14). In this way the well excavation could be carried on after the main part of the concrete footing had been established (Figures 13 & 16). In each footing, two 24" I beams were set so as to have one end imbedded in the concrete and the other in contact with the pin at the second panel point of each truss (Figures 13, 16, 17, and 25). These beams were lined in with the transit so that their center lines would lie in a vertical plane parallel with the length of the truss. In this way, after the concrete had set, the truss was braced to some extent,and a means afforded for tying the next section of concrete to the footing. The wooden timbers for well work were also imbedded in the footing (Figures 13, 16, & 25), the top of which was at an elevation of 2.03' below city datum. Clay was puddled against the outside face of the concrete to prevent any possible seepage through the joint between the hard pan and the concrete (Figure 16). After the concrete in this footing had set, very little trouble was caused by the water. Only once or twice was the level of the water raised to such a height as to flood the holes. It did not take long to remove this water by means of a centrifugal pump operated by electricity (Figure 9).

While well work was progressing on the south side, the north excavation which had become filled with water, was pumped out and twelve cylindrical forms set to allow for well-digging after the footing had been established (Figure 14). As mentioned above, two 24" I beams, 21 feet long, were here used to

brace the trusses and were lined in before the concrete had time to set around them. The well-digging on the north side then proceeded without any serious delay until bed rock was reached in each hole. The wells were then filled with concrete.

For the purpose of mixing concrete, a turnout from the main line was built up to the masonry abutment on each side of the bridge, and to the east of the main tracks, so as not to interfere with traffic. When it was desired to mix concrete on the north side, the mixer was "spotted" on the turnout near the excavation, and other cars containing gravel, torpedo sand, and cement were coupled to the mixer car. This latter was of the Smith type driven by an electric motor (Figure 15). Plank run-ways leading to the mixer were built upon both sides of the gravel and sand cars (Figure 12). Laborers in the cars filled wheelbarrows which were placed on the run-way at one side of the cars, with sand and gravel. These barrows were then wheeled to the mixer and their contents dumped through an opening into the revolving drum, there to be mixed with cement which had been carried from the cement car in the rear of the train and was piled, ready for use, upon a platform on the mixer car. Water was supplied to the ingredients in the revolving drum by means of a hose which was attached to a fire plug several hundred feet away. The water in the canal was too muddy and stagnant to be used in the concrete. The proper amount of water was determined by the skilled laborer in charge. After each of five laborers had dumped his wheelbarrow of gravel into the drum and each of three his barrow of torpedo sand, two bags of cement and the proper amount of water were added, making the mixture practically 1 : 3 : 5. The laborers then returned with their empty barrows, crossed over to the other run-way where another set of wheelbarrows had been filled while

they were on their first trip to the mixer (Figure 12). These were then wheeled to the drum while the first set was being refilled. In this way the process was continuous and all the material that the mixer could use was dlivered at a minimum cost of labor. When thoroughly mixed, as judged by a skilled laborer, a metal apron was inserted into the drum. The concrete upon the inside of the drum fell upon this apron and slid into a wooden trough which led to the abutment or well which was to be filled (Figure 27). In case the concrete had to be turned from one chute into another, a laborer was stationed at the angle to see that the concrete was not impeded in its course (Figure 15). Laborers in the abutment below saw that the mixture was properly spread over the whole opening and that it was well tamped into the corners and around the edges especially. The mixture was not a dry one as water came to the surface without much tamping.

After the wells had been filled with concrete to within a few inches of the top, and angle irons and pieces of old rail left sticking in the concrete so as to form a bond between the ribs and piers (Figure 25), forms were started on the south side. In order to construct the arch without the use of false work which would interfere with canal traffic, and to reduce to a minimum the effect of the shaking of the bridge upon the concrete before it had properly set, it was decided to construct the arch in three sections, (1) to erect and fill the forms on one side of the canal for all three ribs so that the concrete at the highest point of the soffit at this stage would be at elevation 15.208' above datum and the elevation of the second break in the shoulder at 16.5' (Figures B and 33); (2) to start the arch on the other side of the canal bringing the elevations to the same

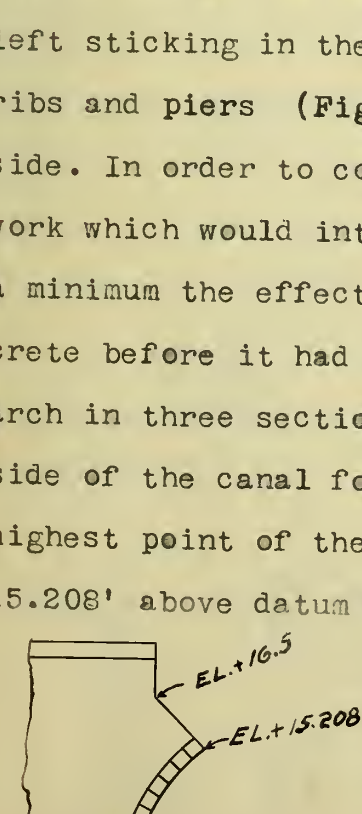


Fig B.

heights as on the first side (Figure 34); and (3) to complete the arch and bridge floor (Figures 42 & 43).

To see that the three ribs were started at points on each side of the canal so that the lines would join exactly, leaving plane faces and no warped surfaces or jogs in the arch when completed, required very careful engineering. The east face was especially important on account of the more open exposure to view than the west face. The tow path was found to be of great advantage in this work as reference stakes could be driven here and a solid footing for the transit afforded (Figure 3). The two main reference points were established by transferring them from the center line of the bridge as previously located above, to points below the bridge.

The most difficult part of the work was to fix the outside points of the arch in line and at an elevation for the stopping place in the first stage. Points had to be located in some way so that they would be not only at the correct elevation but also in the vertical plane of the face of the rib as well as in a line parallel to the short axis of the proposed arch. In order to do this it was necessary to construct some form of wooden support which would enable the point to be located. This was done by fastening a horizontal timber at right angles to the lower chord of the bridge and then nailing a vertical length of 2" x 4" to this piece. To the bottom of this, a short piece of 2" x 4" was nailed parallel to the truss (Figures C, 17, 18, 20, & 25). By

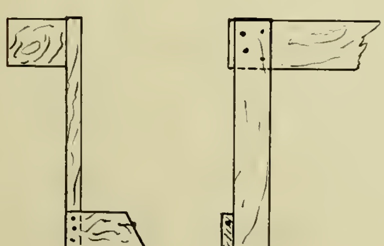


Fig. C.

shifting this frame about and, after repeated "shots" with the transit and level, the end of the bottom piece was finally set at the proper elevation and gotten in line and in the vertical

plane as required. The support was then more strongly braced and a nail driven into the end of the bottom piece in correct line and exact elevation. Four points were located in this way on each side of the bridge - two for points on the intrados of the arch and two at the break in the shoulder as shown (Figure B). Elevations were marked along the concrete footing to indicate the springing line of the arch. Points on the neat lines of each rib were also marked on the footing, both in the front and in the rear.

With these points determined, the forms were started. A small coffer dam was first constructed of clay to keep the water from the face of the footing (Figure 16) so as to allow the bottom of an 8" x 16" timber sill to be set at an elevation of-4.125 feet. After this was firmly secured, the arch centering for each rib was placed. The centers proper were cut at the mill from 3" x 14" x 9'-8" pine timbers, the radius being 86'-4" and each piece being beveled on the curve at an angle of 67 degrees and 42 minutes. Each rib of the arch, when finished, was to be seven feet wide, not including the six inch coping on the two outside ribs. Four rows of centering were used for each rib (Figure 20). Two arch centers and a length of 6" x 12" timber sufficient for the first section of the arch - 17'- 4" - were first assembled on shore before the strut thus formed was fixed in place. A 12" x 12" diagonal brace was used for the two outside struts to allow horizontal bracing to be bolted to them as shown (Figures 20, 22, and 24). The west strut of the west rib and the east strut of the center rib were first carefully lined in with the transit, use being made of the points previously suspended from the bridge to locate the soffit. These struts were held in place by timbers running horizontally to the back of the abutment, and fastened to

steel rails partly imbedded in the concrete (Figure 20). The remaining outside struts of the two ribs were then placed as accurately as possible and the 6" x 12" cap was bolted to these four struts. The east strut of the east rib was then located accurately and fastened to another length of 6" x 12" which was spliced to the first piece. The other intermediate struts were then lined in and secured to the cap, leaving a framework as shown in Figure 20 . Vertical studding, 6" x 6", was erected on both sides of each rib and spaced three feet center to center except on the east and west sides where 6" x 12" timbers were used. Four horizontal stiffeners (6" x 12") spaced about 3'-6" center to center were bolted to these studs. White pine (2" x 8") dressed on four sides was used for the concrete facing except on the soffit of the arch where 2" x 6" dressed pine was used. A bulk head was built to enclose the shoulder of each rib and when this was done the structure resembled three large, oddly shaped boxes open at the top (see Figures 21 & 22). The outside faces of the forms were then carefully aligned with the transit, and the two sides of the box were held firmly together by a series of long rods which were enclosed in old gas pipe, cut to proper lengths so as to permit the rods to be unbolted and removed from the concrete after it had set (Figure 23). Each stud was braced by wire passing around it and part of the lower chord. Four long 80# rails were set diagonally in each rib with their ends projecting out of the form. This was done for the purpose of reinforcing the rib and also to furnish a bond between the first and third sections in the concrete (see photograph, Figures 23, 24, 29 & 30). Each rib was filled with concrete to within about five and one half feet of the top of the rail.

As soon as this concrete had received its initial set, the

form work was completed up to the final height. Reinforcing rods of Ransome cold twisted square steel rods three fourths of an inch square were spaced about 6" apart both longitudinally and transversely in the flooring at an elevation of + 17.55 (Figure 26). Stirrups of the same material were also placed to take up shear in the slab.

While these preparations were being made for the final mixing of concrete for the first section of the construction, the three tracks for the new layout on the bridge were also set. The centers had been previously located and points on the guage lines of each track had been established so that the rails could be readily lined in. The form of track here used was of a type just patented by the consulting engineer. As shown in the photographs (Figures 27, 28, & 36), it consisted of two heavy rails (80#) fastened to tie plates which were secured to oak ties two feet long. Each tie was divided into two parts longitudinally by a diagonal cut so that the upper half could be removed from the con-

crete bed at any time and replaced with little trouble. A "Z" bar on the inside of the rail was also fastened to the tie and allowed a clearance of 6" between rail and bar, and which thus acted as a guard rail. The concrete was to be within 2 or 3 inches of the top of the ties on the outside and was to come up to the top of the "Z" bar on the inside of the track. The rails were to "break joints", thus giving the smoothest running track possible. It was estimated that the cost of maintaining the ordinary track would, in the long run, amount to much more than the first cost of this concrete track which would require little or no maintenance. A slight crown in the center of the track allowed the water to drain off into "weep" holes. Elasticity was furnished by the oak ties and the pressure evenly distributed by the concrete. The first

section of this track ever laid was tried on this new arch.

On account of the old track with its long ties, and also on account of the trusses themselves, which came between the two rails of the outside tracks under the new layout, it was very difficult to set the new sections of each of the three tracks and hold them rigidly in place until after the concrete had set. It was necessary to cut the old ties close to the rail of the old track so as to furnish room for the new (Figure 28). The rails and "Z" bars were fastened to the ties as far as possible before placing the new track. These were then supported and braced in correct line and elevation, repeated "shots" with both transit and level being taken before the alignment and elevation of every point on the rail were correct. Anchor bolts passing through the "Z" bars and bent diagonally downward at an angle of 45 degrees were to help anchor the track to the concrete (Figures 27 and 28).

When the three sections of this track had been set, and the reinforcing of the floor slabs completed, the final batch of concrete was mixed for the first section of the arch (Figure 27). After allowing this to set for several days, during which time trains were made to proceed very slowly over the bridge, the forms were removed. This work was facilitated by removing the bolts from the gas pipe lengths which were then left in the concrete, the end holes being later filled with grout. The various elevations and alignments were checked and it was found that the forms had moved only a very little and without any serious effect on the intrados (Figures 29, 30, & 31).

While mixing concrete and waiting for it to set on the south side, most of the carpenters were removed to track elevation work carried on by the railroad company north of the arch . The remaining carpenters were employed in framing lumber and preparing

for the form work on the north side of the canal.

The method of procedure here was practically the same as that of the south side except that the work was more complicated on account of the necessity for leaving a space for the tow path behind the ribs. The opening was to be made rectangular, the back forms being built up vertically behind the ribs, and a slab about four feet thick being formed over the tow path (Figures 31, 32, & 34). In each of the outside ribs a 24" I beam was placed so that the pin of the first panel point would bear directly on the center of the beam. One end of the I beam was supported at the bridge seat while the other was to extend into the concrete of the spandrel wall at the other side of the tow path. In this way, the weight of the floor beam over the tow path was transferred to the masonry abutment and to the footing of the arch.

With the first two sections of the arch thus completed, the work had the form shown in (Figure 38). To complete the arch and to put in the center sections of the three new tracks was all that remained to be done before the old tracks could be removed and the trusses taken down. To accomplish this, it was necessary to provide some means of supporting the forms for the arch soffits and also for the outside faces of the ribs. The plan adopted was to complete the arches on the two outside ribs with a thickness of concrete of two and one half feet, not including the six inch coping. To complete the whole rib at once would bring too much weight on the forms - but by allowing two and one half feet of concrete to set, the remaining forms and concrete could be supported in safety. As reinforcing for these segments, a box girder was placed in each. This girder was built of two small trusses latticed together at a distance of twenty-seven and one half inches back to back of angles. The lower chord was in the form of the arc

of a circle of 86' _ 9" radius, while the top chord was straight. Both chords were made up of 4" x 4" x 1/2" angles and were connected by vertical and diagonal angles 3' x 3' x 1/4". The girder was supported by the lower chord of the bridge and was fastened to the rails partly imbedded in the concrete of the first and second sections.

To provide the necessary additional support for the forms, two heavy wooden trusses for the two outside faces of the arch were constructed. These trusses were built of arch centers and timbers assembled as shown (Figures 39 & 40). The centering for the thirty feet in the center of the arch was made from 3" x 14" white pine timbers 16 feet long and cut to a radius of 86'_4". The remaining centers were the same as used in the first sections, viz. cut from 3" x 14" x 9'_8" pine to a radius of 18'_8" with a beval of 67 degrees, 42 minutes. The diagonals were chiefly 6" x 12" timbers and the posts were made of 6" x 6" pine. The top chord was composed of a double row of 3" x 12" planks set on edge. The posts of the structure to be thus formed were rigidly fastened together by means of close fitting mortise joints well bolted. Two of these trusses were made, the parts being assembled on shore and then floated out to the bridge. By means of a number of blocks and tackle, they were hoisted into place and fastened in position. The east truss was set with little trouble but the west one was very difficult to place owing to the small space between the concrete of the first two sections of the arch and the east girder of the Baltimore and Ohio Chicago Terminal bridge (Figure 2). Owing to this obstacle, considerable time was spent before the truss was finally set in its approximate position. A careful readjustment was then made so as to see that the truss would be secured in proper line and elevation. The forms were then completed and con-

crete mixed for these two segments (Figure 40).

After the concrete had set, a safer means of support for the remaining work was established (Figure 41). The wooden trusses were left standing so as to form additional support and to provide means for fastening the remaining forms. Long rods were left projecting through the concrete so that timbers could be supported horizontally from rib to rib (Figure 41). By means of such braces, the arch centers were supported, and to these the facing was nailed. The middle sections of the three tracks were also set and connected to the first two sections already imbedded in concrete. Concrete was then mixed and deposited as carefully as possible, all trains running over the bridge being flagged and made to proceed slowly to prevent unnecessary jarring and shaking. After the concrete had been allowed to set for about ten days, the forms were removed. The structure now had the appearance of a double bridge - that is, with a steel truss above and a concrete arch below. Five tracks were also on the bridge at this stage (Figure 37). The only step now necessary to complete the work was to remove the truss and old track layout from the bridge so as to connect the new layout on the bridge with the main tracks.

The truss was removed by a contracting company which employed the oxyacetylene blow-pipe to cut the steel at the top of the concrete floor. The time required to cut down an end post with this apparatus was ninety seconds - which gives an idea of the rapidity with which this part of the work was carried on. As fast as dismembered, the trusses were loaded upon cars and shipped away to be sold as scrap. The proper connections were made with the new track layout and the old track removed without delay. The irregularities left in the concrete by the steel cutters were patched by a "finisher" and the appearance was then such, that no indication of the

presence of a portion of the trusses buried within the concrete, was to be seen from the outside (Figures 41, 42, & 43).

The arch, when completed, fully satisfied the expectations of the engineer and company concerned. The method of construction adopted proved very satisfactory. Neither the traffic in the canal nor that of the railroad was stopped entirely at any time; the latter being interfered with only to a slight extent by running single track over the bridge when it was necessary to mix concrete for the flooring (Figure 27), and also by slowing the trains while the concrete was setting. These delays were practically nothing, considering the nature of the work and the time required for doing it.

In the first stage, the forms, when filled with concrete, deflected just enough to cause a slight jog in the intrados of the arch where the arcs of the first and third sections of concrete join. This did not affect the required clearance for canal traffic in any way and is barely noticeable unless attention is called to it - even then it is difficult to find. The alignments and other elevations, when checked, proved to be very nearly exact, thus compensating for the care used in construction.

Two minor accidents occurred before the work was completed, but the blame could not be placed upon the company, as all reasonable precautions were taken to protect the men. The chief danger was from trains crossing the bridge. The first accident resulted in the loss of an eye to one of the carpenters. This man was fastening an iron ring to the lagging in a well when his hammer glanced from the nail causing it to fly up into his eye. The claim department of the railroad settled with this man for a small sum of money without any legal controversy. The second accident occurred when form work was progressing for the floor system at the

south section. A train was approaching and the men warned. All of them got into places of safety but one laborer. After the warning was given, he came up from where he had been working and kneeled on the end of the railroad ties. Evidently he did not see the approaching train or hear the warning, for the cylinder of the engine hit him and knocked him down onto the concrete of the abutment several feet below. He was badly bruised but recovered after several days. The claim department also settled this case.

Upon revisiting the arch eighteen months after its completion, a careful examination showed the only difference to be that some of the fine particles of cement had been washed from the surface of the concrete, leaving it slightly rougher in places than when the forms were first removed. The joints between the various sections were also visible but not so much as to be displeasing to the eye.

The appearance of the arch as a whole, gives an impression of strength and solidity rather than of grace or architectural beauty. However, the simplicity and continuity of lines, as well as the massiveness of the structure, give a very pleasing effect.

As previously mentioned, the construction of this arch was carried on at the same time the tracks farther north were being elevated. Therefore, while waiting for the concrete to set before the forms could be removed, all carpenters and laborers not needed for other immediate work in connection with the arch were employed on the track elevation, where forms had to be built for the subway bridge abutments, excavations made, and other work was in progress at which they could be employed. In this way, the time actually spent in constructing the arch was reduced to a minimum, without the necessity of laying off the men or keeping them idle

at certain stages. The duration of the work was perhaps longer than would have been the case had the men been kept at the arch continuously.

The following itemized account was taken from the monthly labor distribution reports compiled from the daily labor reports of the foremen. The various items have been collected and arranged so as to show the cost of different divisions of the work as well as the time charged to each class of labor engaged on the work.

The material account was taken from a record of expenses kept by the railroad, and the total cost of the arch is probably correct to within one per cent of the total.

Making Test Bores for Bed Rock

115 hrs. Foremen @ 40¢ per hr.

176 " Carpenters @ 30¢ " " .

50 " Labor @ 17 & 1/2 ¢ per hr.

$ 107.55

Making Letters for Arch

83 hrs. Foremen @ 40¢ per hr.

86 " Carpenters @ 30¢ " ".

$ 59.00

Loading, Moving, and Unloading Material (Tools, lumber, caisson rings, etc.)

116 & 1/2 hrs. Foreman @ 40¢

5 " " @ $75 per mo.

1 " " @ 35¢

16 " " @ 30¢

1 " Strawboss @ 25¢

67 " Hoisting Engineer @ 30¢

284 " Carpenters @ 30¢

1216 & 1/2 hrs. Labor @ 17 & 1/2 ¢

13 " Waterboy @ 12 & 1/2 ¢

$ 373.36

Excavating for Abutments

150 hrs. Foremen @ 40¢

3417 " Labor @ 17 & 1/2 ¢

$ 657.96

Excavating Wells, Putting in Flooring, Doors, etc. (Figure 5)

249 hrs. Foremen @ 40¢

267 & 1/2 hrs. " @ 30¢

412 & 1/2 " Hoisting Engineer @ 30¢

50 " " " @ $75 per mo.

451 " Carpenters @ 30¢

9669 & 1/2 " Labor @ 17 & 1/2 ¢

142 " Waterboy @ 12 & 1/2 ¢

$ 2162.20

Lagging Wells

51 & 1/2 hrs. Foremen @ 40¢

5 " " @ 30¢

601 " Carpenters @ 30¢

310 " Labor @ 17 & 1/2 ¢

$ 256.65

Mixing Concrete for Cylindrical Piers

54 hrs. Foremen @ 40¢

2 " " @ 30¢

170 " Carpenters @ 30¢

731 " Labor @ 17 & 1/2 ¢

12 " Waterboy @ 12 & 1/2 ¢

$ 202.62

Removing Water from Wells and Other Excavations, Pulling Sheeting, Etc.

43 hrs. Foremen @ 40¢

84 " " @ 30¢

103 hrs.	Hoisting Engineer	@	30¢	
120 "	Carpenters	@	30¢	
1761 "	Labor	@	17 & 1/2 ¢	
				$ 417.47

Bracing and Sheeting Abutment Excavations

160 hrs.	Foremen	@	40¢	
802 "	Carpenters	@	30¢	
421 "	Labor	@	17 & 1/2 ¢	
				$ 378.28

Mixing Concrete for Abutments

45 hrs.	Foremen	@	40¢	
1356 "	Labor	@	17 & 1/2 ¢	
				$ 255.29

Putting in Turnouts for Mixer, Flagging Trains, Putting in New Track, etc.

114 & 1/2	hrs.	Foremen	@	40¢	
47	"	"	@	35¢	
68	"	"	@	$90 per mo.	
27	"	Strawboss	@	22 & 1/2 ¢	
37	"	"	@	25¢	
40	"	Carpenters	@	32 & 1/2 ¢	
595 & 1/2	"	"	@	30¢	
235	"	Labor	@	20¢	
4097 & 1/2	"	"	@	17 & 1/2 ¢	
113	"	Waterboy	@	12 & 1/2 ¢	
					$ 1070.63

Unloading Sand for Track

17 hrs.	Foremen	@	40¢	
2 "	"	@	30¢	
2 "	Strawboss	@	22 & 1/2 ¢	
613 "	Labor	@	17 & 1/2 ¢	
19 "	Waterboy	@	12 & 1/2 ¢.	
				$ 117.49

Erecting and Removing Arch Forms

656	hrs.	Foremen	@	40¢
28	"	Strawboss	@	35¢
420	"	Carpenters	@	32 & 1/2 ¢
5043 & 1/2	"	"	@	30¢
10	"	Hoisting Engineers	@	30¢
1606 & 1/2	"	Labor	@	20¢
793 & 1/2	"	"	@	17 & 1/2 ¢
544	"	Waterboy	@	12 & 1/2 ¢

$ 2452.91

Putting in Reinforcing, and Bracing Bridge

77	hrs.	Foremen	@	40¢
30	"	Strawboss	@	35¢
15	"	Carpenter	@	32 & 1/2 ¢
459	"	"	@	30¢
165	"	Labor	@	20¢
140	"	"	@	17 & 1/2 ¢
25	"	Waterboy	@	12 & 1/2 ¢

$ 244.50

Mixing Concrete for Arch, Putting up Chutes, etc.

231	hrs.	Foremen	@	40¢
3	"	Strawboss	@	35¢
27	"	Carpenter	@	32 & 1/2 ¢
227	"	"	@	30¢
269	"	Finisher	@	30¢
199	"	Hoisting Engineer	@	30¢
132	"	Labor	@	20¢
5301	"	"	@	17 & 1/2 ¢
204	"	Waterboy	@	12 & 1/2 ¢

$ 1290.33

Building Runways across Canal and Building Shanty

50	hrs.	Foremen	@	40¢

296	hrs.	Carpenter	@	30¢	
105	"	Labor	@	17 & 1/2 ¢	
					$ 127.18

<u>Leveling Earth</u>

15	hrs.	Foremen	@	40¢	
548	"	Labor	@	17 & 1/2 ¢	
15	"	Waterboy	@	12 & 1/2 ¢	
					$ 103.77

<u>Watching and Inspecting</u>

20	hrs.	Foremen	@	40¢	
90	"	Labor	@	20¢	
3398	"	Night Watchman	@	17 & 1/2 ¢	
2420	"	Day "	@	15¢	
					$ 983.65

TOTAL LABOR	11260.84
ENGINEER'S ROLL	1216.61
TIME KEEPER	212.35
SUB - TOTAL * * * * *	$ 12689.80

Other items of expense besides the labor as given above, are as follows :

Gravel and Sand (including freight)		1988.10
Cement " "		3398.16
Lumber		2499.98
Tools and Hardware		788.05
Reinforcing bars (Ransome)		628.38
Old Pipe for Form Work		32.63
Angles, Z bars, I beams, tie Plates, etc.		740.77
Box Girders (including freight)		288.00
Caisson Rings		245.00
Track Material Report		362.91
Taking down Truss	$ 750.00	
Credit on Scrap Steel	421.62	328.38

Roofrite for Shanty	$ 33.60
Engine Service	856.80
Electricity and Electrical Work	164.87
Telephone	119.47
Sundries	24.50
Expense Account	47.31
	$ 12536.41
Sub - total * * * * *	12689.80
<u>TOTAL COST OF ARCH</u>	$ 25226.21

Fig. 1

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

[illegible]

Fig. 11

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15

Fig. 16.

Fig. 17.

Fig. 18.

Fig 19.

Fig. 20.

Fig. 21.

Fig. 22.

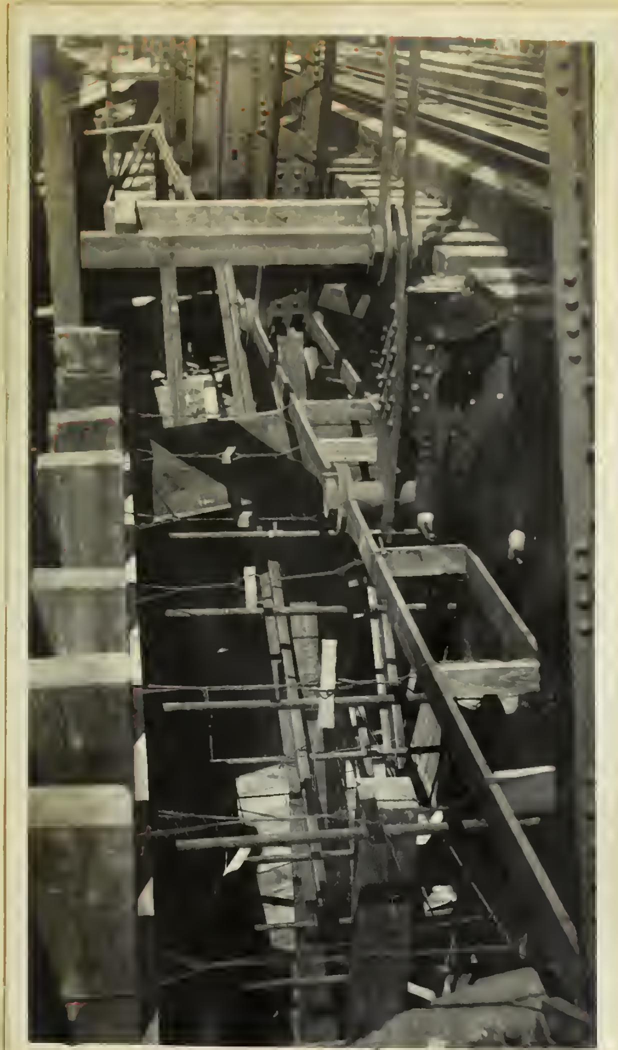


Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 30.

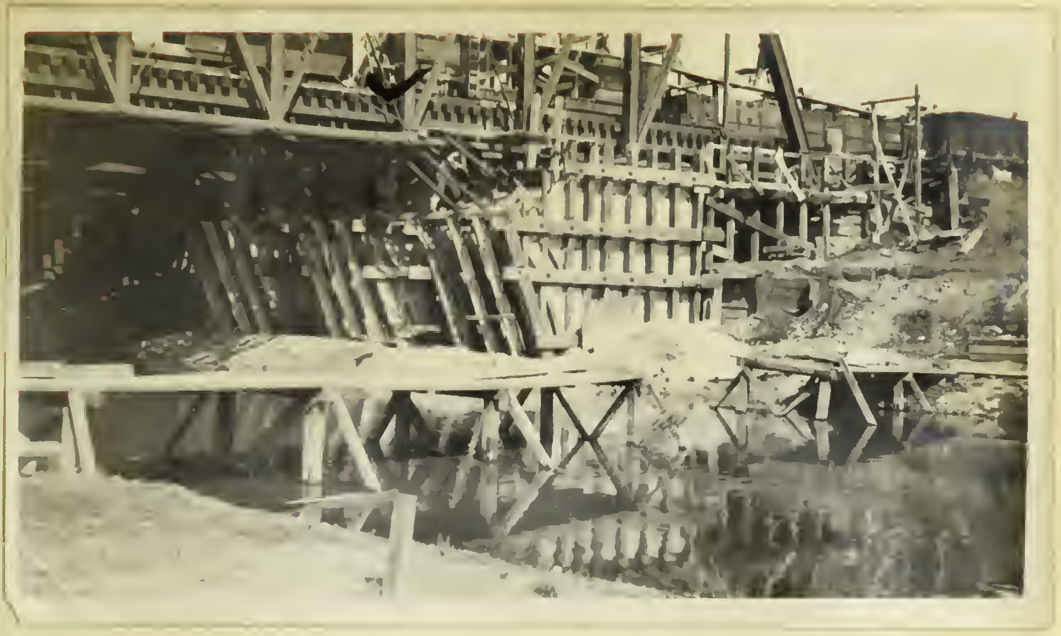


Fig. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

Fig. 39.

Fig. 40.

Fig. 41.

Fig. 42.

Fig. 43.


Monastery Hill Bindery