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What the D. L. & W. Is Doing in Concrete Design

Long Precast Slab Spans are Used Successfully by Engineers of This Road

Part I

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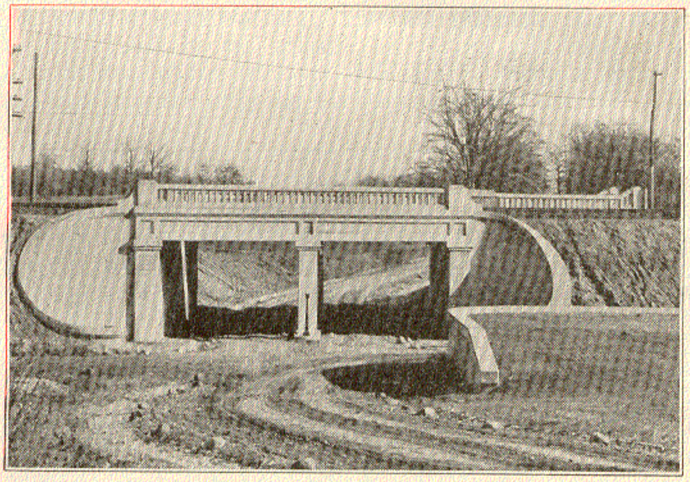


Punch Bowl Crossing, Convent, N. J.

THE problem presented by the necessity of replacing bridges on a railroad is one whose solution requires a design or plan contemplating a minimum disturbance of railroad traffic. Until recent years, this consideration made it imperative that steel bridges be replaced by new structures of similar material, because of the rapidity and facility of erection as compared with concrete bridges cast in place.

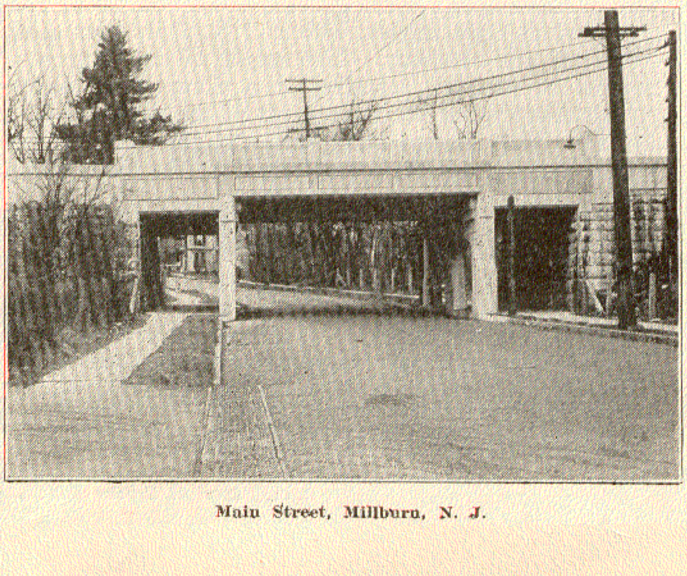
The alternative, adopted with caution by the railroads, was the use of reinforced concrete members, precast away from the site of the bridge, allowed to cure and, when cured, placed in position on the piers or abutments. The few early examples of precast concrete construction occurred where the spans were short and the conditions of skew, grade and alignment of track were favorable to the use of precast concrete members.

Frequently the problem of grade crossing elimination involves the same conditions as does that of replacement, in so far as it precludes any disturbance of railroad traffic. The solution, in the event of concrete design in such situations, is precast members similar to the design for bridge replacement.

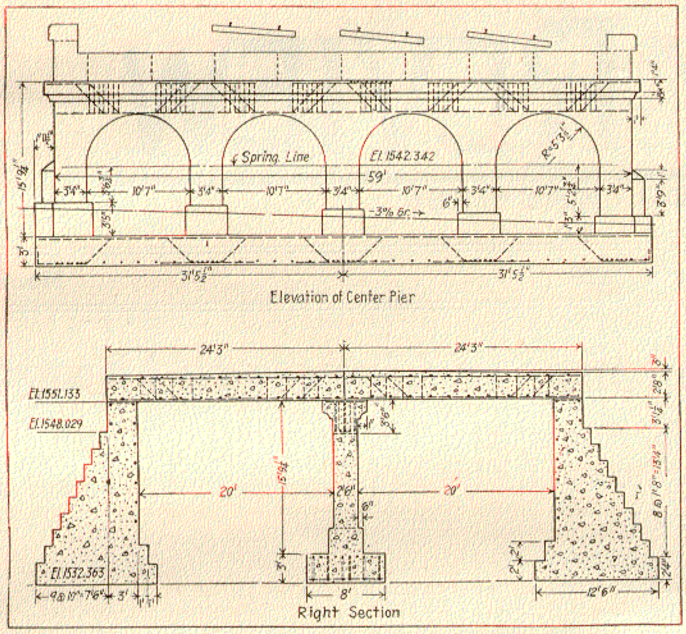
Other factors which, heretofore, have limited the use of precast reinforced concrete slabs and beams, as well as those cast in place, were those of span and available floor depth resulting from restricted headroom. Recently the Delaware Lackawanna & Western R. R., by the use of slabs reinforced for compressive stresses, and by means of establishing continuity over two spans, has so removed these limitations as to make them almost negligible. The examples which will be cited vary in their conditions of loading between the extremes of railroad bridge construction, from the heavy locomotive type of loading for the undercrossing to the light pedestrian loads of the footbridge.

Development of Concrete Design

It would not be amiss to review briefly the history of the progress of the precast type of reinforced concrete bridge design on the Lackawanna lines. The first design on this railroad, which contemplated the use of precast concrete slabs for rather large spans, was made in 1909 for a grade crossing elimination on the Scranton division at Moscow, Pa. This is an undercrossing consisting of two twenty-foot clear spans with an arched pier 2 ft. 6 in. thick at the center of the roadway, widened at the top to four feet to provide greater bearing surface for the slabs resting upon it. Two sets of slabs were designed and placed symmetrically about the center line of the center pier. For an E-50 engine loading, which at that time was the standard, a thirty-five inch thickness of slab was required at the center of span with a three inch pitch toward either abutment to provide for drainage. At that time, precasting and setting track slabs of this magnitude was looked upon as a considerable feat, the accomplishment of which marked a definite advance in the construction of railroad concrete bridges. The structure at Moscow was finished late in 1911, and its successful com-



Main Street, Millburn, N. J.



An Early Crossing, Moscow, Pa.

pletion encouraged the engineering department to continue this type of design, where conditions justified its use, with the result that it was employed not only on the Scranton division but on the whole of the Lackawanna system.

Following this, precast concrete construction has been used on various types of bridges, and these types may be divided as follows: (1) Railroad undercrossings designed as simple slabs—principally twin spans; (2) undercrossings with reduced depth of floor by means of compressive reinforcement—single spans; (3) undercrossing where reduction in the depth of floor was accomplished by continuity over two spans and compressive reinforcement; (4) overhead highway bridges—both T-beams and simple slabs; (5) foot-bridges completely precast.

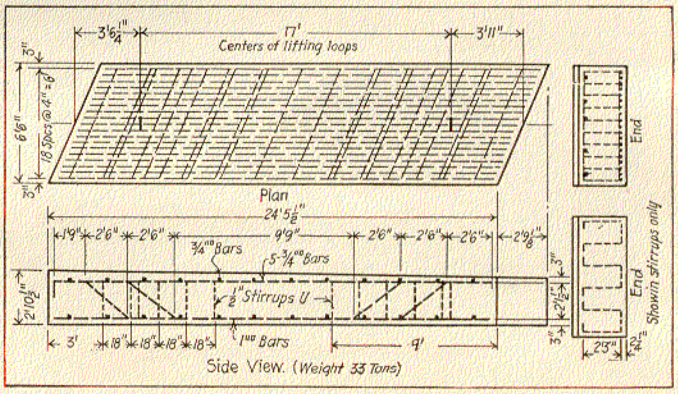
SIMPLE SLAB UNDERCROSSINGS

A number of these simple slab bridges have been constructed on the Lackawanna, but the most interesting as well as the most effective in appearance is the one known as "Punch Bowl Crossing" at Convent, N. J.—interesting both from the architectural standpoint and the complexity of design.

This bridge consists of two parts, one to accommodate two tracks of the Lackawanna, the other a single track of an interurban trolley railway line known as the Morris County Traction Co. The street has a forty foot roadway, permitting two openings, each 18 ft. 9 in. in the clear, measured at right angles, with a 2 ft. 6 in. pier at the center of the roadway. The angle of crossing is 67 degrees 00 minutes, resulting in a skew of 23 degrees 00 minutes, so that the clear spans of the slabs are 20 ft. 4½ in. The railroad slabs were designed for an E-60 engine loading, which was standard at the time (1916) this structure was designed. This increased loading was met by increased allowable compressive stresses in the concrete—650 lbs. a sq. in. for 2,000 lb. concrete. With a live load distribution over two slabs 6 ft. 6 in. wide, there resulted a slab thickness of 2 ft. 10½ in. at the pier, pitched to 2 ft. 7½ in. at the abutments. In all cases the impact was figured by the formula $1=\frac{LL}{LL+DL}$. The reinforcement consisted of nineteen one inch square bars, of which ten were bent up to resist shearing stresses. The transverse reinforcement consisted of ¾ in square bars on two feet centers top and bottom. In addition, ten ½ in. square bar stirrups (five near each support) were bent around the main steel to aid in resisting the shearing stresses. The slabs weighed thirty-three tons apiece.

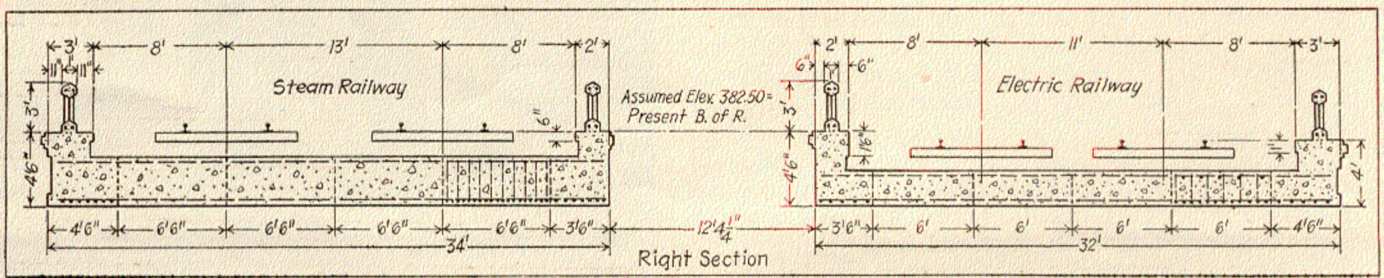
That part of the bridge supporting the street railway was designed for a live load consisting of a thirty ton ballast car with 30,000 lb. concentrations on each axle. This loading required a slab 2 ft. 1½ in. thick at the pier, pitched to 1 ft. 10½ in. at each abutment, with a width of six feet. The tensile reinforcement consists of twelve one inch square bars, of which six were bent up to take shearing stresses. The shearing stresses were resisted also by 8½ in. square bar stirrups, four near each support. This slab weighed twenty-two tons.

Because it was decided the parapets with the small sections of slab adjacent to them should be cast in place, the precast slabs next to them were provided with transverse bars protruding four feet out of the precast sections to bond them with the cast in place parapet sections.

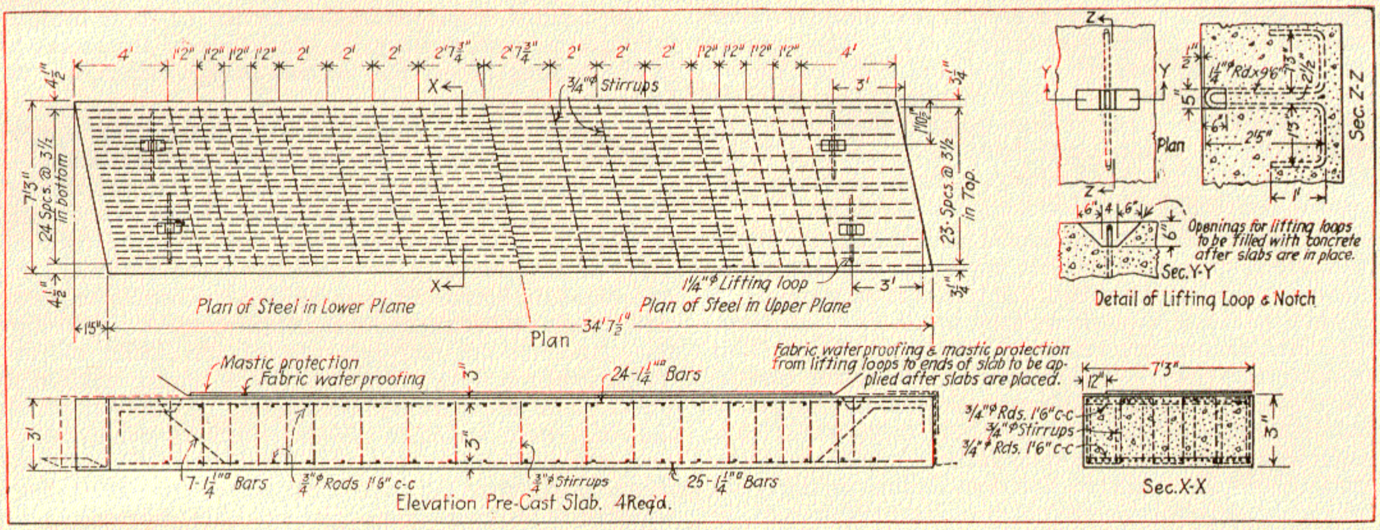


Details Slabs B—Convent.

The center pier, which was of the arched type with 11 ft. openings, was cast in place, the girder portion being reinforced with ten one inch square bars both top and bottom. An additional feature of this structure is the curved retaining wing walls all of which were the cantilever type of reinforced wall. The illustration gives an idea of the effectiveness of the design of this structure and yields no indication other than of a completely cast in place bridge. This example serves as an excellent illustration of this type of bridge.



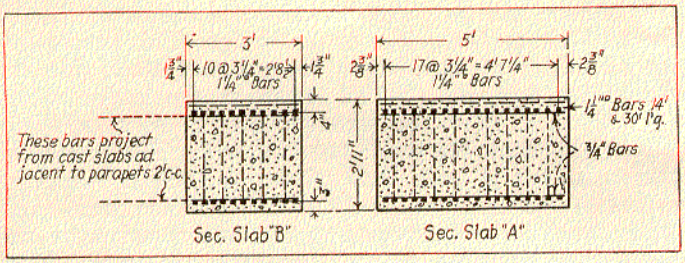
Arrangement of Tracks and Slabs at Punch Bowl Crossing, Convent, N. J.



Details of Precast Slabs, Main St., Millburn, N. J.

SLABS REINFORCED FOR COMPRESSION

Up to a few years ago, twenty feet was considered the limiting length of span for which precast slabs could be designed to carry railroad loadings. But, as necessity is the mother of invention, the exigencies of a particular case brought about the extension of the use of the precast slab for greater spans. This occurred in a situation where the available depth between base of rail and underclearance necessitated the reduction of slab depth from that of a simple slab designed for tensile and shear reinforcement only. The case in point was that of a crossing known as Riverside drive in Johnson City, N. Y., a suburb of Binghamton. The street consists of a twenty-four foot clear roadway and two sidewalks. The angle of crossing is 72 degrees 40 minutes. It was decided to build, under traffic, a box abutment around the sidewalk; in the meanwhile casting the slab so that, when cured, the abutments would be ready to receive the load from the slabs. The available floor depth was 2 ft. 11 in., which was insufficient for the span if a simple slab was used. For this reason it was decided to make up the deficiency by the use of steel reinforcement to take up the excess compressive stresses.

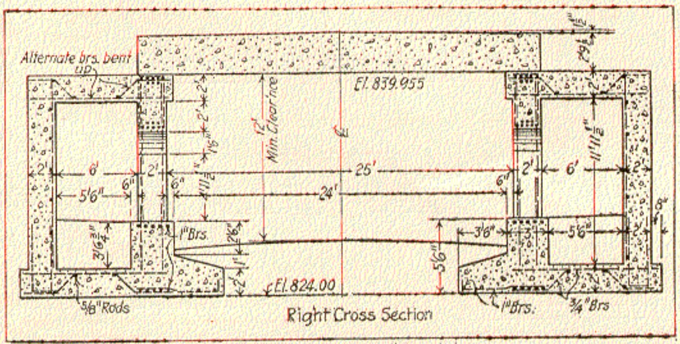


Sections of Slabs, Riverside Drive

The slabs were so designed that two 5 ft. widths take the loading of each track, with a 3 ft. slab between and on either side of the five foot sections to make up the 13 ft. track centers. The parapet sections were cast in place around transverse bars protruding from the adjacent precast sections. The reinforcement in the five foot sections consists of eighteen 1¼ in. square bars in the lower plane for tension, and the same number in the upper plane for compression. Eight bars of the bottom row are bent up to take shearing stresses. The corresponding bars in the upper plane were cut short. The transverse reinforcement consists of ¾ in. square bars three feet on centers in both planes. For handling, there are included two lifting loops made of 1½ in. round rods imbedded in every slab. For drainage the slabs are pitched 1½ inches in both directions from the center. The falsework consisted of pile bents driven on either side of the box abutments and in the center of the roadway to give spans of about twelve feet so that 8 in. by 16 in. stringers, four of which were required under each rail, could be used. The abutments were cast in place after the excavation had been made, while the slabs were constructed on a platform on the ground. After both masses of concrete had been cured the piles were cut off and the slabs set between trains. After this the parapet sections were placed and the construction completed. This bridge was designed and construction started in the spring of 1920.

AN INTERESTING EXAMPLE

The next example of this type of design marks a still greater advance in its use as regards length of span. It is interesting also because of the development which resulted in the selection of the precast slab type for the bridge. The undercrossing in question is that at Millburn, N. J. The problem was the replacement of a structural steel bridge over Main street, on the main line of the Morris & Essex division, which has a heavy suburban traffic between Morristown and Hoboken, N. J. The old bridge was the through girder type with girders 14 ft. 6 in. center to center, supported on steel columns along the curb. The ties were placed on shallow stringers to form an open floor thus giving no protection over the roadway. This bridge was built in 1894 and, as the loadings increased, became overstressed so that, in 1921, it had to be renewed. The type first considered was similar to the existing structure, except the sidewalk spans were to be of concrete and main spans to have a solid floor. The girders were to be supported on concrete arched piers which would encase the existing columns. The piers

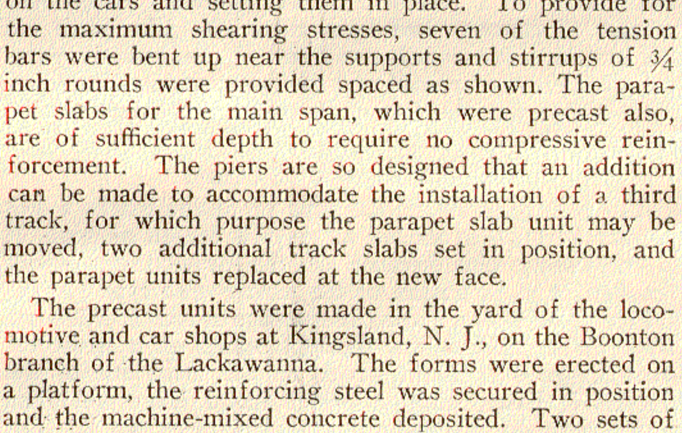


Box Abutments, Riverside Drive.

were to carry the sidewalk spans also; the through girder spans were to be over the roadway only. This scheme was discarded for one which dispensed with the use of the through girders, and which consisted of a floor of 30-in. Bethlehem girder beams spaced about two foot centers, and filled solid with concrete to form a 36-in. solid floor spanning the roadway. The final design substituted reinforcing steel for the structural beams.

The clear roadway, maintained in the new design, is thirty feet, measured at right angles to the center line of Main street, which crosses the tracks at an angle of 79 degrees, resulting in a skew span of 30 ft. 7 in. clear. The track centers are maintained at 14 ft. 6 in. This required two slabs 7 ft. 3 in. wide to carry the load of one track. For an E-65 loading a slab, simply supported and reinforced for tension and shear only, would have required a depth of forty-nine inches for this roadway span. Since the depth of slab was limited to thirty-six inches, the deficiency in the compressive resistance of the concrete was compensated for by the use of compressive reinforcement in the upper plane of the slab, with the necessary additional tensile reinforcement in the lower plane. Twenty-four 1¼ in. square bars were required for compression and twenty-five for tension, to resist the maximum moment at the center of span. After the quarter point of the span was passed the steel was reduced to take the maximum moment at that point. Two lifting loops of 1¼ inch round rods were imbedded at both ends of the slabs for the purpose of loading them on the cars and setting them in place. To provide for the maximum shearing stresses, seven of the tension bars were bent up near the supports and stirrups of ¾ inch rounds were provided spaced as shown. The parapet slabs for the main span, which were precast also, are of sufficient depth to require no compressive reinforcement. The piers are so designed that an addition can be made to accommodate the installation of a third track, for which purpose the parapet slab unit may be moved, two additional track slabs set in position, and the parapet units replaced at the new face.

The precast units were made in the yard of the locomotive and car shops at Kingsland, N. J., on the Boonton branch of the Lackawanna. The forms were erected on a platform, the reinforcing steel was secured in position and the machine-mixed concrete deposited. Two sets of forms were used, and one track slab and one main parapet slab were completed in one operation. The concrete was cured in the open air, but flushed twice a day for two weeks, and allowed to cure for thirty days before the units were loaded on the cars for shipment to their destination. The weight of the individual track slab is fifty-seven tons.



Long Span Slab at Erie Crossing.

The method employed in the erection of these bridges is illustrated best, perhaps, by an outline of the sequence in the process of erection of this bridge, which was as follows:

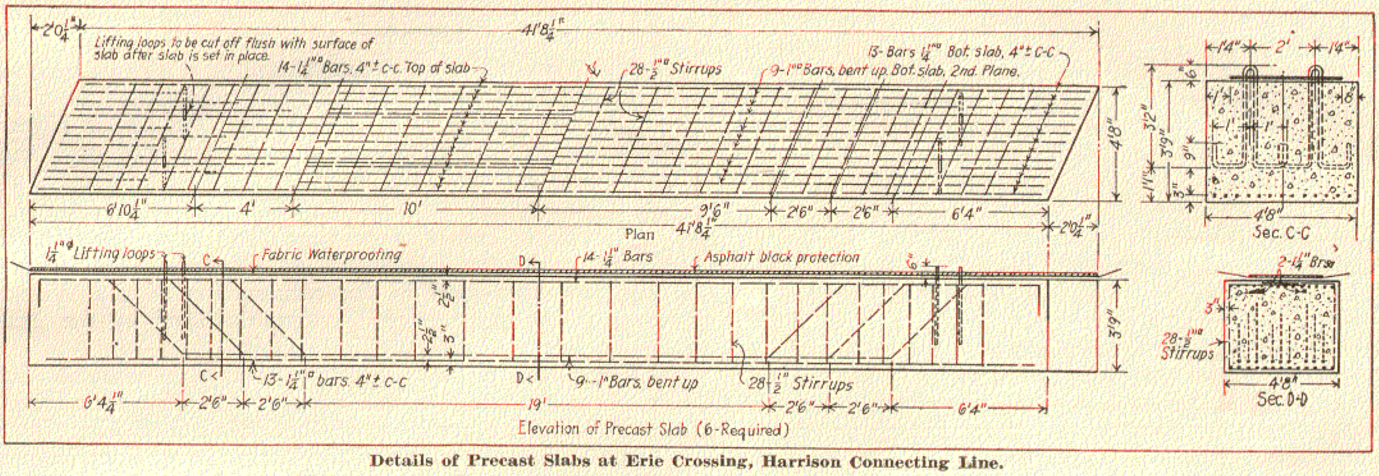
The precast units were loaded on flat cars at Kingsland and transported to the site of the work at Millburn. It was planned to complete the erection and the raising of the track between the passage of a westward train at 11:33 p. m. Sunday, and that of an eastward train at 4:11 Monday morning, or within a little more than four and one-half hours. It was decided to install the westward track first because of the superelevation; therefore this track was cut east and west of the limits of the bridge while a work train was placed on the eastbound track. The work train consisted of the cars on which the slabs were loaded, a 150-ton wrecking crane, empty cars, and a 35-ton crane. The floorbeams of the westbound track were cut free from the center girder, and, together with their fascia girders, each sidewalk span was lifted by the respective cranes into the empty cars which were then moved out of the way. These cars were replaced by two other empty cars, with the cranes situated on either side so that together they could lift the main span (fascia girder and floor beams) and load it onto the cars. The smaller crane then moved into the siding while the remainder of the train was manipulated so the wrecking derrick was placed east of the cars containing the track slabs. The smaller crane then was shifted into position west of the cars. This enabled both cranes to handle the units, which were placed in position clear of the center girder and the tracks blocked up to new level 2 ft. 6 in. above the old elevation.

It became necessary then to raise and ballast the track for 1,800 ft. on both sides of the bridge. This precluded the possibility of completing the eastward track side of the bridge that night. The tracks at the bridge were blocked up to allow the waterproofing to be completed. Two nights later the work was resumed. The eastward track was cut at both ends of the bridge, the wrecker placed at the east end, and the crane at the west end, while the train was stopped so the empty cars were on the recently installed span of the westward track. The cranes then lifted the old steel sidewalk spans into the empty cars which were drilled out and replaced as before. The main steel span was loaded and moved out of the way. The cars containing the slabs were switched into position, and the slabs, handled by the two cranes, were placed and aligned. The track was graded and ballasted on both sides of the bridge over which it was blocked up; traffic was resumed on both tracks, and the waterproofing completed between trains. Afterwards the ballast was placed on the slabs. The bush hammering then was completed, and a concrete balustrade cast in place. The result is a structure as pleasing as one built in place.

SPAN LENGTHS INCREASED

The most recent extension of the span length for which precast sections were used is that of a crossing on the new connecting line completed recently by the Lackawanna between Kingsland, N. J., on the Boonton branch and Harrison, N. J. on the Morristown line. The bridge in question is a crossing under the Greenwood Lake branch of the Erie Railroad about midway of the connecting line.

The connecting line crosses two tracks of the Erie on a skew of 23 degrees 27 minutes 40 seconds. In addition, the alignment of both railroads at this crossing is on curves, a two-degree curve for the Lackawanna, and a 2 degree 30 minute curve for the Erie. The superelevation of tracks requires increased clearances, greater span,



Details of Precast Slabs at Erie Crossing, Harrison Connecting Line.

and width of bridge. The clear span, measured at right angles to the Lackawanna tracks, was made 33 feet 3 inches for 13-foot track centers and 3 inch additional clearance on the concave side of the curve over the standard of ten feet required from the center line of track. By applying the skew, however, the clear span becomes 36 feet 3 inches measured along the tangent to the center line of the two Erie tracks.

The Erie tracks on both sides of this crossing are on 14 foot centers. This allows a width of three 4-foot 8 inch precast sections (three being selected rather than two because of the excessive weight of the latter) for each track. A depth of 3 feet 9 inches was available for thickness of slab, after allowing for track, ballast, and waterproofing. A depth of 4 feet 10 inches would have been required to design a simple slab over the 36 foot 3 inch span, if reinforced for tension and shear only. It was necessary, therefore, to use steel reinforcement in compression to compensate for the deficiency in the concrete section available for compression.

In lieu of the thirteen inches of concrete, fourteen 1¼ inch square bars are placed near the top surface of the 4 foot 8 inch sections. This made it possible to install this type of structure under the given conditions, and at the same time reduce the weight of these heavy units to about 55 tons, thereby facilitating their erection. The reinforcement for tensile stresses consists of a plane of thirteen 1¼-inch square bars, which are carried straight for the full length of the slab; three inches above these, nine one-inch square bars, bent up near the supports to take diagonal tension, for which purpose one-half inch square bar stirrups are added, are spaced as shown on details. Two lifting loops of 1¼-inch round rods are embedded near each end to permit the use of a spreader in erection.

The parapet slabs are designed without consideration of the engine loading and, therefore, require no compressive reinforcement. The bars in the upper plane are inserted merely to take stresses due to temperature changes. On the parapet units there is erected a concrete balustrade, the panels of which were precast while the posts between them were cast in place. For this purpose vertical stubs protruding from the parapet at the positions of the posts were provided.

Waterproofing was installed also in the casting yard, leaving only the work at the edges of the slabs to be completed in the field. The waterproofing consists of two layers of asphalt-saturated open mesh cloth, with a protection of 8 inch by 4 inch by 1¼ inch thick asphalt paving blocks. The waterproofing cloth was bent back near the edge. The blocks were laid up to the point where the cloth was bent back, respectively one foot and eight inches from the edges of the slab. The slabs were allowed to cure and were loaded on flat cars for shipment to the site of the work as soon as the abutments were hardened sufficiently.

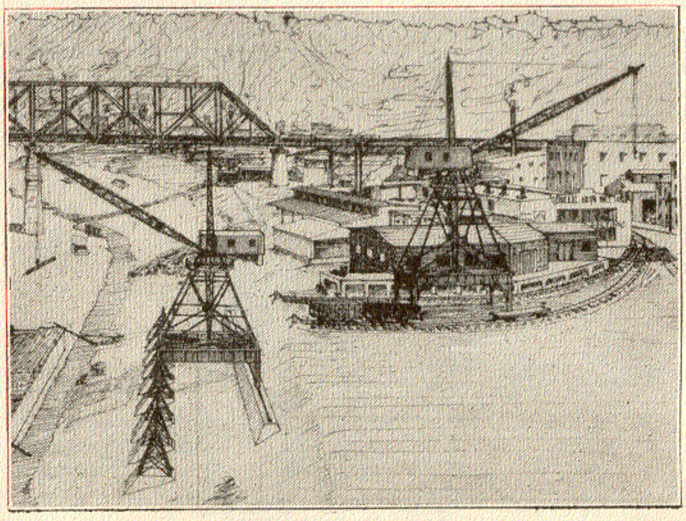
Between the passage of Erie trains two cranes, placed on either side of the opening, lifted the slabs off of the flat cars and set them in position. One-half of the slabs were set on one day, the remainder the following day. The waterproofing at the joints of the slab were completed by bending back the fabric and setting the asphalt blocks over it. The bridge then was ready for operation of trains.

(*To Be Continued October* 16)

Unique River-Rail Terminal

Cincinnati will be the first city on the Ohio River to be equipped with a modern river-rail terminal. A project, which is designed to transfer bulk and heavy commodities from river barges to railroad cars and motor trucks, is now under construction in that city and it was completed and put in operation October 1.

The Constitution of this terminal marks the culmination of a movement inaugurated by the Cincinnati chamber of commerce in 1922. At that time a committee of business men was appointed to investigate ways and means for providing Cincinnati with facilities to enable its shippers and receivers of freight to utilize the Ohio River as a means of transportation. The committee reported in 1923 recommending that the chamber of commerce foster and promote a corporation to undertake the construction of a river-rail terminal. The Cincinnati River-Rail Transfer Co. was an outgrowth of this recommendation. The members of the committee acted as



The Cincinnati River-Rail Transfer.