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VOLUME III. BRIDGES AND CULVERTS

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CHAPTER XXXII

CONSTRUCTION OF THE TUNKHANNOCK CREEK VIADUCT

The Tunkhannock Creek viaduct at Nicholson, Pa., on the Delaware, Lackawanna and Western Railroad's re-location between Scranton, Pa. and Binghamton, N. Y., the largest structure of its kind in the world and but recently completed, is representative of the most advanced methods of design and construction of concrete arch bridges. On account of the magnitude of the work and the difficulties attendant therewith, the methods of construction used in various parts of the work are especially interesting and valuable, representing as they do the best modern practice in high-class bridge construction. The quantities of material involved in its construction—namely, 165,000 cu. yd. of concrete and 1200 tons of reinforcing steel—give some idea of the unprecedented size of the bridge.

Construction plant and methods which are suitable and economical for work of this character would of course be entirely too costly for small work, but a glance at the historical record of concrete-bridge building will show that within the past two decades there has been a very steady increase in the span and general dimensions of concrete bridges. It is not at all illogical, therefore, to assume that methods which now seem uncommon and unusual, will in a few years become commonplace and be treated as accepted practice.

139. General Design.—The Tunkhannock Creek viaduct is a double-track structure 2375 ft. long, 34 ft. wide over all, and has a maximum height above ground of 240 ft. with a maximum total height of 304 ft. from bottom of deepest pier to top of highest masonry of the parapet. The bridge is composed of ten full-centered or semicircular ribbed arches of transverse-arch spandrel construction with 180-ft. clear span and two 100-ft. arches of the same type at the ends acting as "abutment arches" and completely buried in the approach fill. (See Figs. 428, 440, 441, 442, 444, and 446.) These arches spring from solid concrete piers founded on bed rock.

Piers.—The deeper piers have a section 40 ft. × 46 ft. below the surface of the ground and all piers are 36 ft. 6 in. × 43 ft. 6 in. in section to a point 17 ft. 6 in. below the springing line of arches. At this point a ledge 4 ft. 3 in. wide is formed in the piers to act as a seat for arch centering. This ledge was later filled out with a receding corbel to conform to that used on the ends of piers. (See Fig. 427.) The deepest pier extends about 98 ft. below the surface of the ground. The faces of all piers are vertical and the portions above ground have horizontal coursing marks 4 ft. apart.

Main Arch Spans.—The main or 180-ft. arch spans, the details of which are shown in Fig. 427, are composed of two ribs 14 ft. wide (8 ft. thick at the crown and 17 ft. thick measured radially at the skewback), spaced 20 ft. on centers, with a 6-ft. opening between ribs. The reinforcement of these arch ribs consists of fourteen 1-in. square bars, following both intradosal and extradosal lines, to provide for contraction

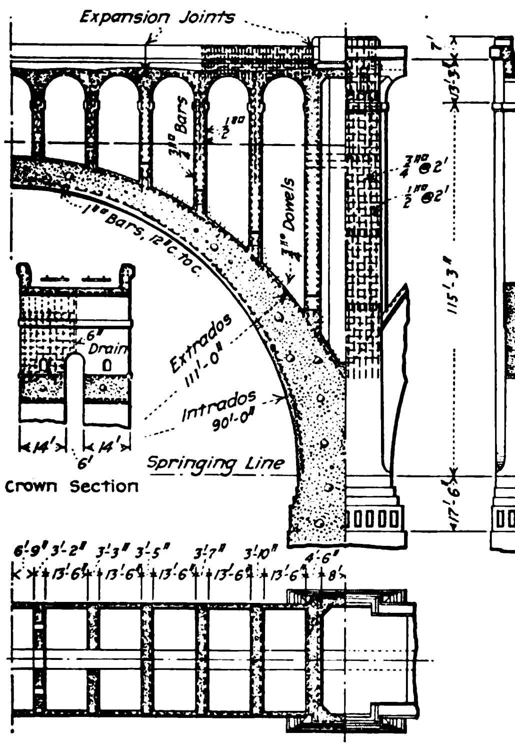


Fig. 427.—Tunkhannock viaduct. Details of 180-ft. arch spans.

and temperature stresses only. The arch ribs were proportioned so as to have the resistance line approximate very closely the arch axis and it does not, for any condition of loading, approach the outer line of the "middle third" of the ribs, thus insuring purely compressive stresses. The bridge was designed for the maximum stresses resulting either from two Mikado-type engines, each weighing 233 tons, followed by a train load of 6000 lb. per foot of track, or from two Mallet compound locomotives, each weighing 300.5 tons, followed by a train load of

6000 lb. per foot of track, both tracks carrying maximum load at the same time.

Spandrel and Deck Details.—On the arch ribs are placed transverse spandrel walls of reinforced concrete varying in thickness from 3 ft. 2 in. to 4 ft. 6 in., as indicated in Fig. 427. These spandrel walls are arched over the open space between ribs (Fig. 444) and are connected at the top by 13 ft. 6 in. semicircular spandrel arches 1 ft. 9 in. thick at the crown. In order to form a seat for the spandrel-arch centering, a 6-in. projecting belt course was placed on the spandrel walls 1 ft. 6 in. below the springing line of the arches. The floor formed by spandrel

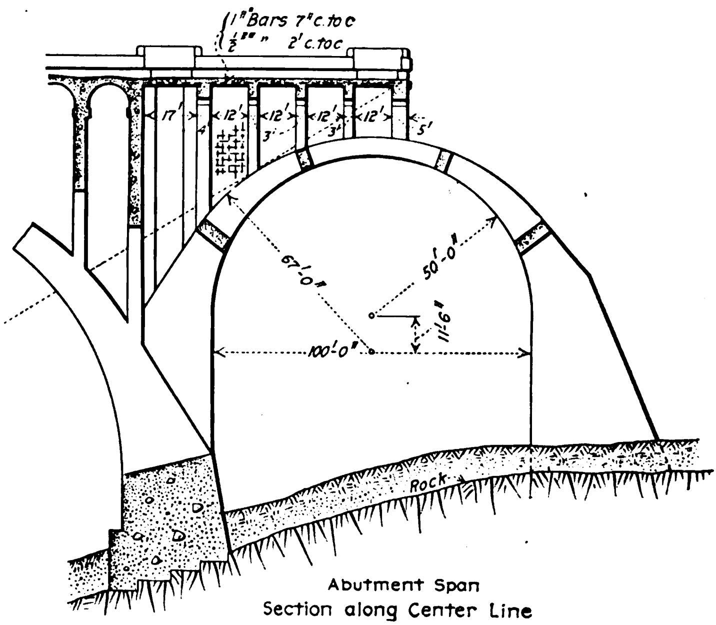


FIG. 428.—Tunkhannock viaduct. Details of 100-ft. arch span.

arches is given a 6-in. slope from crown of each spandrel arch to the center of adjacent spandrel wall for drainage, the water being carried down through a 6-in. hole in the middle of spandrel wall, discharging into the open space between ribs.

The two transverse spandrel walls over the piers are connected at each side of the bridge by a reinforced-concrete pilaster, 3 ft. thick and about 22 ft. wide, to give longitudinal stiffness to the spandrel system and to give the appearance of a solid pier.

The parapet walls of solid reinforced concrete extend the full length of the viaduct, and are 7 ft. 3 in. high above crown of spandrel arches, except at piers where the pilasters are 3 ft. higher.

Four expansion joints are provided in each span, as shown in Fig. 427. These joints consist of a ½-in. open space covered by a copper plate bent to project a short distance into the joint and having its edges turned down into grooves parallel with the joint, where it is held in place by a mastic filling. The waterproofing consisted of a 3-ply cloth and asphalt membrane protected by a 1½-in. layer of torpedo gravel mixed in an asphaltic binder. The waterproofing membrane is separated from the protecting coat by one thickness of asbestos felt.

Abutment Spans.—The abutment spans (see Fig. 428) are composed of two reinforced-concrete ribs 5 ft. 6 in. thick at the crown and 12 ft. wide, spaced 22 ft. centers, thus leaving a space 10 ft. wide between ribs. These ribs are tied together at four points by reinforced-concrete struts. A reinforced-concrete floor slab supported on five transverse walls extends over a little more than half of the span next to the first large arch, the tracks being carried on fill over the arch beyond this point. This floor varies in thickness from 1 ft. 9 in. to 2 ft. 6 in. The space between the floor slab and the arch ribs is closed by a longitudinal spandrel or curtain wall 18 in. thick along each outside face, thus giving the appearance of a U-abutment when the approach fill is completed, as shown in Fig. 446.

Materials.—"Class A" concrete, a 1 : 2 : 4 mixture, was used only in the reinforced-concrete floor slab over abutment spans. "Class B" concrete, a 1 : 3 : 5 mixture, was used for all other work above the springing line. "Cyclopean" concrete was used for all piers below springing and was of the same mixture as "Class B" concrete with derrick stone embedded in it.

140. Construction Methods.—*Methods of Locating Lines and Piers.*—A glance at Fig. 437 shows the nature of the bridge site which at once conveys the idea that the establishment of lines and the location of piers was no easy matter. The center line of the viaduct was established by the railroad engineers, by punch-marks on pieces of steel rail set vertically in the ground between piers. The pier centers were then located by careful measurements from these points at each side of each pier. A reference line of stakes was run parallel to the bridge center-line and 25 ft. to one side of it to provide a basis for checking measurements on the main base line or to re-establish such points as might become misplaced during construction.

Points were also established 3 ft. beyond either face of pier by the measurement of longitudinal distances, and transverse reference lines were then run through these points and marked at both ends by rail monuments. These lines provided means of locating piers and also for plumbing them by offsets from the face of masonry to the vertical planes determined by the transverse reference lines as located by transit set on the line.

Contractor's Plant.—The contractor began work on the structure

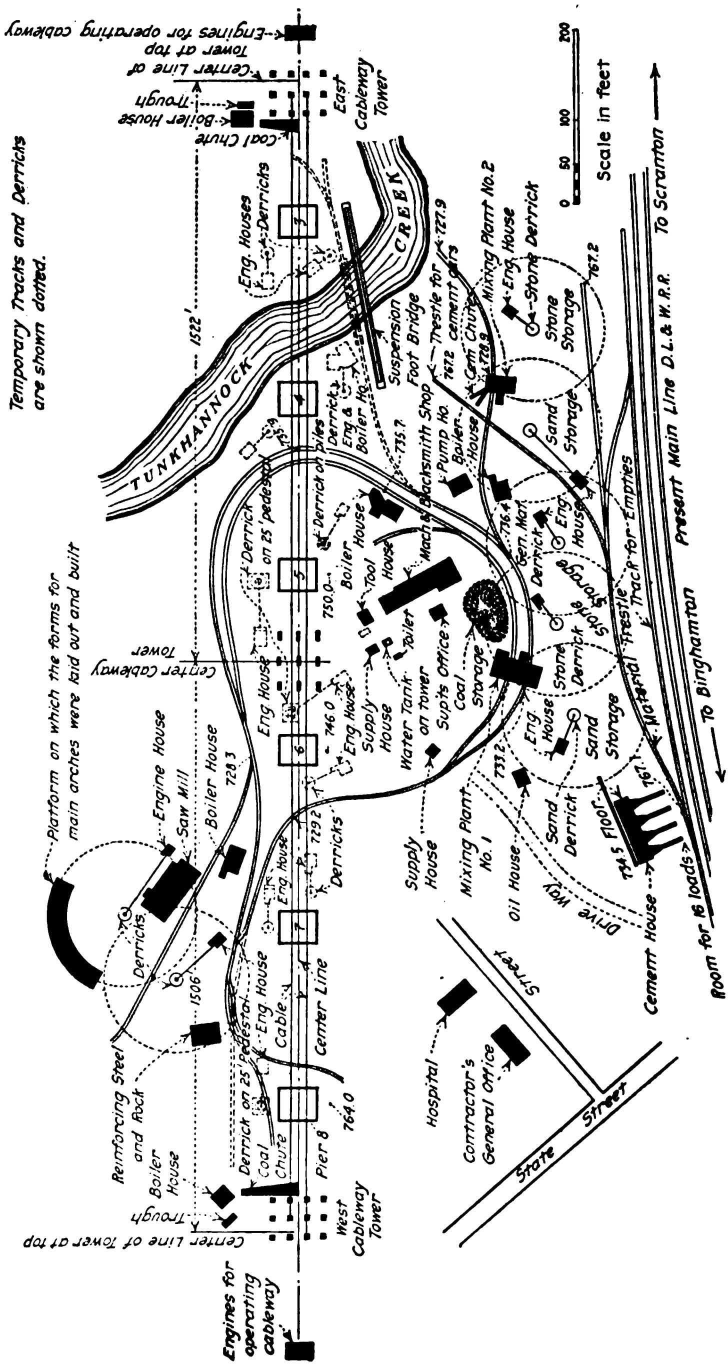


Fig. 429.—Tunkhannock viaduct. Layout of contractor's plant.

May 24, 1912. The first operations were the widening of the railroad company's embankment on the present main line nearly parallel to and about 460 ft. away from the new bridge, and the laying of the material tracks, marked "track for empties" and "room for 16 loads" in Fig. 429. After these tracks were laid, the pile trestles for material tracks were constructed. The material trestle was 30 ft. high and provided storage space for 15,000 cu. yd. of sand and crushed stone dumped directly from cars.

The general layout of the contractor's plant is shown in Fig. 429. The loop formed by the narrow-gauge track enclosed a knoll about 30 ft. higher than the general level of the valley. The general material derrick was erected on a narrow ridge connecting the knoll just mentioned with the ridge on which the present main line is located. A similar ridge extends from pier No. 6 to the high ground at the hospital. Piers Nos. 5 and 6, being located on the east slope of the knoll, necessitated about 30 ft. more of excavation on the west side of the piers than on the east. Pier No. 8 lies on a similar slope which necessitated about 40 ft. more of excavation on the north side than on the south. Piers Nos. 3, 4, and 7 are located on low ground.

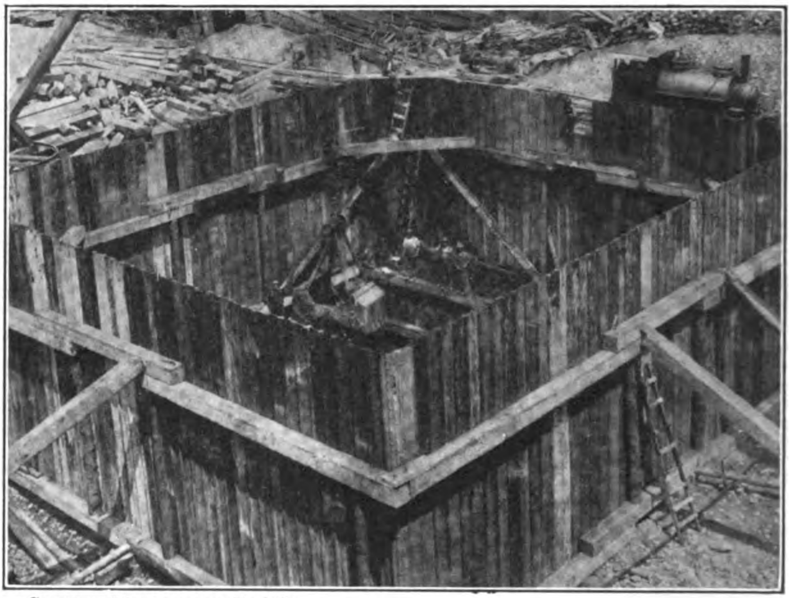
Construction of Substructure

141. General Excavation.—Early in July, 1912, after the narrow-gauge tracks had been laid from mixing plant No. 1 to pier No. 4, derricks were erected, steel sheet piling was brought in, and the excavation and building of cofferdam for pier No. 4 were started.

About the middle of July a 40-ton Marion steam shovel, with a 1-cu. yd. dipper was run from the siding down into the valley on a temporary track. Work was started at pier No. 6 where the excavation was carried down 20 ft. below the ground level on the high side, the material being hauled away in 4-yd. narrow-gauge dump cars and used for grading up construction tracks and leveling up the mixer plant sites. The shovel was then moved to pier No. 5 and, after the excavation was carried down 35 ft. below ground level on the high side or down to ground water level, the shovel moved back to pier No. 6 and carried the excavation down to the same level. The next operation was to excavate pier No. 8 to the same depth. The excavated material was used to raise the grade east of piers Nos. 7 and 8 about 12 ft., or to the level of the grade east of piers Nos. 7 and 8 about 12 ft., or to the level of the grade at mixing plant. On this fill, a saw mill, storage piles of reinforcing bars, lumber, and other materials were conveniently located.

After completing its work at pier No. 8 the shovel excavated the material down to bedrock at piers Nos. 10, 9, and 2 successively, the rock in these excavations being found above the level of ground water and only a few feet below ground line at the lower sides of pier. In these excavations the material, a clay and sand mixture, was allowed to take its natural slope, the excavation being extended back far enough to provide for natural raveling of the banks before completion of excavation of the construction of the piers. The steam shovel work was completed in December, 1912, about 50,000 cu. yd. of material having been moved.

For the end abutments and the piers adjacent to them—Nos. 1 and 2—open excavations were made down to rock (which on the hillsides was only a few feet below the surface) without the use of sheeting or



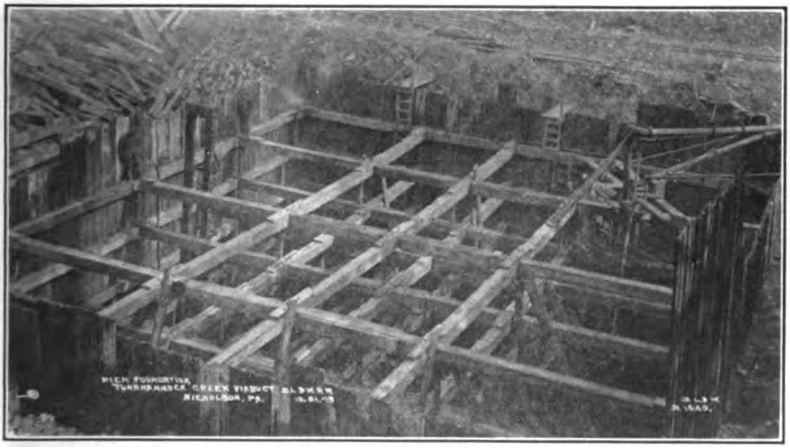
Courtesy of Lackawanna Steel Co.

FIG. 430.—Tunkhannock viaduct. Steel sheet piling (partly driven) for inner cofferdam of piers, showing timber guide forms.

derricks, the excavated material being spread out around the edge of the excavation.

142. Cofferdam Excavation.—The entire excavation for piers Nos. 3, 4, and 7 was done in open cofferdams of steel sheet pilings, as was the remaining excavation of piers Nos. 5, 6, and 8. Lackawanna steel sheet piling 12 in. wide weighing 45 lb. per linear foot was used in lengths of 30 ft., with some additional piling of shorter length driven on top of the upper 30-ft. lengths where the excavated depth was about 70 ft.

When starting the cofferdams, a 46 × 52-ft. rectangle made of 12 × 12-in. horizontal timbers spliced together was assembled. A second rectangle was then assembled on posts 16 ft. long which rested on the first rectangle. These rectangles formed the inner waling for the piling. A similar set of waling was then built 6 in. outside of the first set to act as the outer walings and as forms for sheet piling. (See Fig. 430.) By means of two guyed derricks at each pier, the steel sheet piling was assembled between the walings and driven with a 3-ton Warrington steam hammer operating in 30-ft. leads suspended from the derrick boom, as shown in Fig. 431. The piling was driven in stages of 2 or 3 ft. penetration, the hammer working around the cofferdam until a total penetration of about 10 or 15 ft. had been reached. Excavation was then begun with $1\frac{1}{2}$-cu. yd. Williams' clam-shell buckets and sets of horizontal-timber bracing were placed in the cofferdam at vertical intervals as the excavation proceeded (see Fig. 431), the bracing being



Courtesy of Mr. C. W. Simpson, Res. Eng'r.

FIG. 431.—Tunkhannock viaduct. Cofferdam for pier No. 5, steam hammer driving inner sheeting.

so arranged as to allow the operation of the bucket in the bays between braces. When the excavation had proceeded to about the bottom of piling, the latter were again driven down and the operations repeated until the top of sheeting reached the surface of the ground.

The bracing consisted of 12 × 12-in. yellow-pine timbers arranged in horizontal panels approximately 7 × 10 ft. and spaced from $3\frac{1}{2}$ ft. to 5 ft. apart vertically, being supported at intersections by 12 × 12-in. vertical posts. The braces, which were of necessity in short sections, were cut to approximate length on the ground, lowered into place by derrick with splice planks nailed to them, fitted, drilled, and bolted in position with $\frac{3}{4}$-in. bolts. The outer bays of horizontal braces were further stiffened by diagonal bracing, as shown in Fig. 432.

After the first set of sheeting had been driven down complete, a second rectangular cofferdam was erected about 6 ft. 6 in. outside the first and driven down part way. The material between the two sets of sheeting was then excavated with the clam-shell bucket, the space between the two sets braced, the first set of sheeting driven down, and then excavation resumed in the main pit—the upper set of sheeting being braced in the manner just described. (See Figs. 432 and 433.) As the inner cofferdam was driven down, the top bracing was removed and placed at the bottom. These operations were repeated until the inner cofferdam reached rock.

Practically all the steel sheet piling was used four or five times so that only a little more than enough for two complete foundations was required.

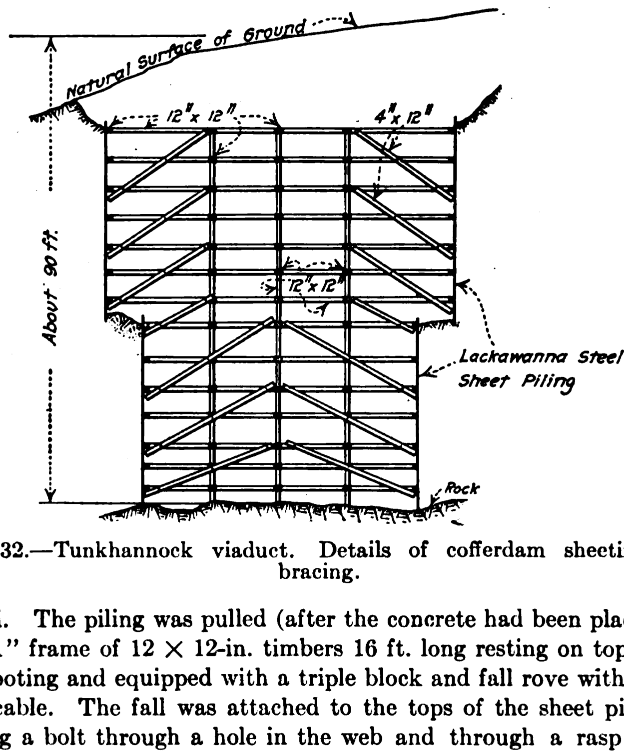


Fig. 432.—Tunkhannock viaduct. Details of cofferdam sheeting and bracing.

The piling was pulled (after the concrete had been placed) by an "A" frame of 12 × 12-in. timbers 16 ft. long resting on top of the pier footing and equipped with a triple block and fall rove with a ¾-in. steel cable. The fall was attached to the tops of the sheet piling by passing a bolt through a hole in the web and through a rasp clamp. By fastening the cable to the double block on the derrick, a pull of about 60 tons could be exerted on the pile, which was sufficient in practically all cases to pull the piling.

The deep piers, with the exception of piers Nos. 4 and 5 which gave some added difficulties on account of quicksand, were excavated mainly with clam-shell buckets operated by derricks. In corners the excavation was done by hand, and boulders which were encountered under or near the sheeting were dislodged by hand or with the aid of dynamite, and were rolled down into the deeper excavation made by the buckets. Water entered the cofferdams mainly from the bottom, but in some cases it came through the piling joints until such time as they were puddled or filled with sand. This water was at first removed by means of two 8-in. centrifugal pumps and two 10-in. Emerson plunger pumps, but after once a cofferdam was fairly free of water two of the pumps could in general keep the water down so as to allow hand excavation in the corners which were kept higher than the central portion of the pit. The material excavated was usually placed in spoil banks near piers or

Courtesy of Mr C. W. Simpson, Res. Eng'r.

FIG. 433.—Tunkhannock viaduct. View of cofferdam at junction of outer and inner sheetings, lower ends of outer sheeting visible.

used to build construction-track embankments, and to bring certain parts of the bridge site to a more or less uniform grade.

The use of open cofferdams of such unprecedented size (the largest ever used) is a remarkable engineering feat and one which proves beyond doubt the value of steel sheet piling. Steel sheet piling has been used very extensively in all kinds of bridge work and for the most part has entirely replaced timber sheet piling, the driving of the latter being difficult in hard ground or where boulders are present. The present example shows that the limit of applicability of steel sheet piling has not yet been reached.

143. Special Methods of Pier Excavation.—After carrying the excavation in pier No. 4 down to a point about 40 ft. below the surface a large pocket of fine flowing sand was struck along the west side and around the southeast corner of the pier. This sand exerted such heavy pressure on the sheeting as to distort the timber bracing and break through the bottom of the pit, causing the ground outside the sheeting to settle as much as 10 ft. At one time the cofferdam was moved bodily about 15 in. transversely by the pressure of the wet sand. The cofferdam was brought back into line by additional excavation both inside and out and by the use of jacks and additional bracing, but when the work had been carried down about 10 ft. into the sand—or to a point 12 ft. above rock—the bracing was in danger of failure and a new scheme had to be adopted in order to facilitate the work which was progressing very slowly. The cofferdams were accordingly divided by driving a line of 3-in. plank sheeting parallel to the west side of the pier and about 16 ft. therefrom. Excavation was then made to rock to the east of this row of sheeting and concrete placed to a height of 30 ft., braces being left in place in order to prevent any further distortion of the material on the west side of the sheet piling. This west portion was then divided by a transverse wall of 3-in. plank sheeting, and the northwest corner excavated and concreted to a height of 10 ft. After this was done the remainder of the excavation was made and the concrete placed.

To take care of the water entering the pit, a 4-ft. 8-in. pumpwell was left in the large portion that was first concreted and the water conducted to it by wooden drains laid close to the steel sheeting. This well after fulfilling its purpose was filled with concrete. Four pumps with a combined capacity of 200,000 gallons per hour were required to keep the excavation dry.

In excavating for pier No. 5 the usual methods were pursued until a point was reached about 75 ft. below the surface and about 17 ft. above rock, where a stratum of quicksand extending over the entire excavation was encountered. An attempt was first made to go through this quicksand by dividing the cofferdam into twenty-four compartments each of which was to be finished separately. Four compartments were started, but the sheeting was so badly bent and displaced in driving by boulders overlying the rock that the scheme had to be abandoned. It was then decided to use a pneumatic caisson on which to sink the pier to rock. The caisson (constructed in the usual manner with 12 × 12-in. timber) was divided into two working chambers each provided with one "material-lock," and was constructed with a heavy metal cutting edge 27 ft. above rock. A one "man-lock" served for both chambers since a "manway" was provided in the bulkhead. Upon this caisson the pier concrete was placed, the weight sinking the caisson as the material was excavated from under the cutting edge. The maximum air pressure required in the working chambers to keep the water from entering was only 24 lb. per square inch as the head of water was kept as low as possible by pumping above the caisson. The material was excavated by hand and removed in buckets operating through one of the air locks in each chamber. After rock was reached and the surface cleaned off, the working chambers were filled with concrete, the air locks removed, the shafts leading to them concreted, and the procedure from that point on the same as for other piers.

The air was turned on in the caisson December 13, 1914, and on the 21st a depth of 10 ft. had been reached. The excavation was completed on Feb. 4, 1915, 7 months after all other piers had been completed up to the skewbacks of the umbrella sections.

144. Concrete Plant.—While the excavation for the piers was in progress the concrete mixing plants were completed at the locations shown in Fig. 429. The cement storehouse near mixing plant No. 1 had a capacity of 3000 bbls., the cement being unloaded from cars into four inclined chutes with forked ends which delivered it to any part of the building by means of switches in the chutes. Cement was taken from this storehouse only when shipments were delayed and when no cars of cement were at hand. Ordinarily the cement at mixing plant No. 1 was loaded directly from cars into a derrick bucket, and swung to the hopper floor of the mixer, each mixing plant being served by two derricks operating 40-cu. ft. Mead Morrison clam-shell buckets. At plant No. 2 the cement was conveyed by gravity in chutes from the cars to the hopper floor of the mixer. (In Fig. 437 the stock piles and mixing plant No. 2 appear in the middle ground.)

The sand and stone were lifted from the stock piles into small bins over the mixers, from whence they passed by gravity into a measuring hopper, at which point the cement was added and the materials dropped into a 2-yd. cube mixer. After mixing each batch for at least 2 minutes, the concrete was dumped into 2-cu. yd. bottom-dump buckets on flat cars of 3-ft. gauge and hauled by 12-ton locomotives in three-car trains to the derrick or cableway which placed the concrete in the forms. One car of the train was empty to receive the empty bucket from the derrick or cableway, the train starting back as soon as the last bucket of concrete was raised. (See Fig. 436.) Two concrete trains were used and for the mass work in piers an output of 35 cu. yd. per hour per plant was attained. The first concrete was poured on Jan. 6, 1913, and concrete work was carried on almost continuously for over a year, the mass work in piers being little affected by the comparatively mild winter weather.

145. Derricks and Cableway.—The derricks were equipped with masts from 85 to 90 ft. long and had booms from 80 to 85 ft. long. Three-drum hoisting engines with swinging gear attachment were used to operate the derricks. In order to give a greater height to some of the derricks, they were placed on timber pedestals, but in general they were erected at ground level and all work which could not be reached with them was done by the cableway.

The construction of the cableway was started shortly after the excavation was commenced and in about 6 months the cableway was put in operation. The cableway consisted of two lines of $2\frac{1}{4}$-in. main cables spaced 20 ft. apart, concentric with the center line of arch ribs. These cables were supported by end towers 3028 ft. apart and 150 and 165 ft. high, also by a halfway tower 260 ft. high. The center tower divided the cableway into four independent units each about 1510 ft. long and each operated by an independent engine. The cables and carriages had a normal capacity of 7 tons. An occasional load of 10 tons, however, was allowable—such loads being imposed while erecting the steel centers, as described later.

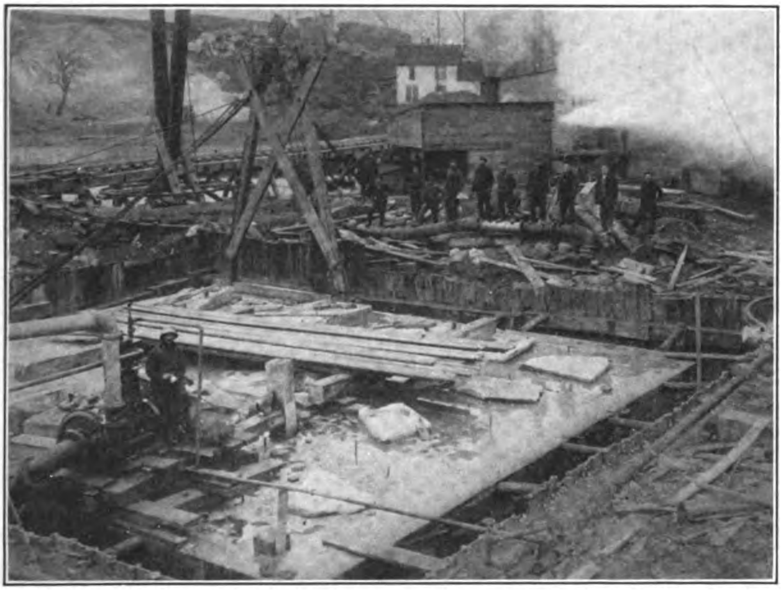
The towers were built entirely of timber resting on concrete piers and guyed with heavy cast-steel guy ropes. The end towers, located at some distance beyond the abutment arches, were wedge shaped, consisting of eight lines of battered posts with the two inner pairs intersecting, as shown in Fig. 440. The central tower consisted of nine 12 × 12-in. main batter posts in three longitudinal bents, as shown in Fig. 436. The posts of this tower were so arranged as to clear the arch ribs and by the removal of a few secondary braces the arch ribs were constructed without obstruction through the tower. This tower was later raised to a height of 300 ft. by adding a 40-ft. extension at the top and raising one line of cable at a time, meanwhile keeping the other in operation.

146. Pier Construction.—In the deep piers, concrete was placed to a height of 30 ft. (or to the neatwork line) without forms. The cofferdam was entirely filled with concrete, the bracing being removed as the concreting progressed. To prevent the concrete from sticking to and entering the joints of the steel sheet piling which would prevent the pulling of the piling, tar paper nailed to vertical wooden strips was used. The concrete work up to the neatwork line was frequently carried on continuously day and night. In one case, for a period of 7 days, 2400 cu. yd. of concrete were placed during freezing weather without protracted interruption; frequent delays of 4 to 5 hours, however, being necessitated while the bracing timber was being removed.

Above the tops of the lower cofferdams, the concrete below the surface of the ground was usually placed in forms made of rough plank braced back to the steel sheeting. (See Fig. 434.) For the remainder of the pier shaft, sectional self-supporting forms were used.

One distinct and important feature of this structure is that the design is such as to permit the extensive use of sectional forms on all parts of the work. Wherever possible the designers duplicated parts so as to allow the use of the same formwork many times, sometimes even on entirely different parts of the work. This indicates very forcibly how the designing engineer who is alert to methods and costs of construction can materially lessen the cost of a structure without decreasing its strength or esthetic beauty in the least.

The sectional forms used for the construction of pier shafts above ground are good examples of the utility and construction of the general type of formwork used wherever possible. These forms were made in two sizes, one 15 ft. 8 in. long by 17 ft. 9 in. high, and the other 18 ft. 3 in. long and of the same height as the shorter one. Two of the long sections formed the shorter sides, or ends of piers, and three of the shorter



Courtesy of Lackawanna Steel Co.

FIG. 434.—Tunkhannock viaduct. Pier concreted up to ground level inside of cofferdam. Note large stone embedded in the concrete.

sections made up the form for the long side of pier. A total of ten sections therefore composed a form, providing for the concreting of a net height of 16 ft. of pier—the lower $10\frac{1}{2}$ in. of the forms extending down over the concrete previously poured and no concrete being poured against the upper $10\frac{1}{2}$ in. (See Fig. 435.) These precautions were taken to prevent, as far as possible, the formation of lips or fins at the junction of sections and to insure the plumbness of the finished work. A total of four complete sets of these sectional forms sufficed for the construction of piers and, after completion of same, the forms were used with little or no alteration on other parts of the work.

The sections were built up of two layers of 1 × 8-in. tongue-andgrooved boards nailed at right angles to each other and diagonally to 8 × 10-in. horizontal timbers, or studs, spaced 2 ft. 5 in. on centers. Vertical timbers 10 × 10 in. in section and 20 ft. long were bolted to these studs at the ends and middle of the sections—the end verticals being half on one section and half on the adjacent one, as shown in Fig. 435. The inside face of the forms was covered with sheets of No. 24

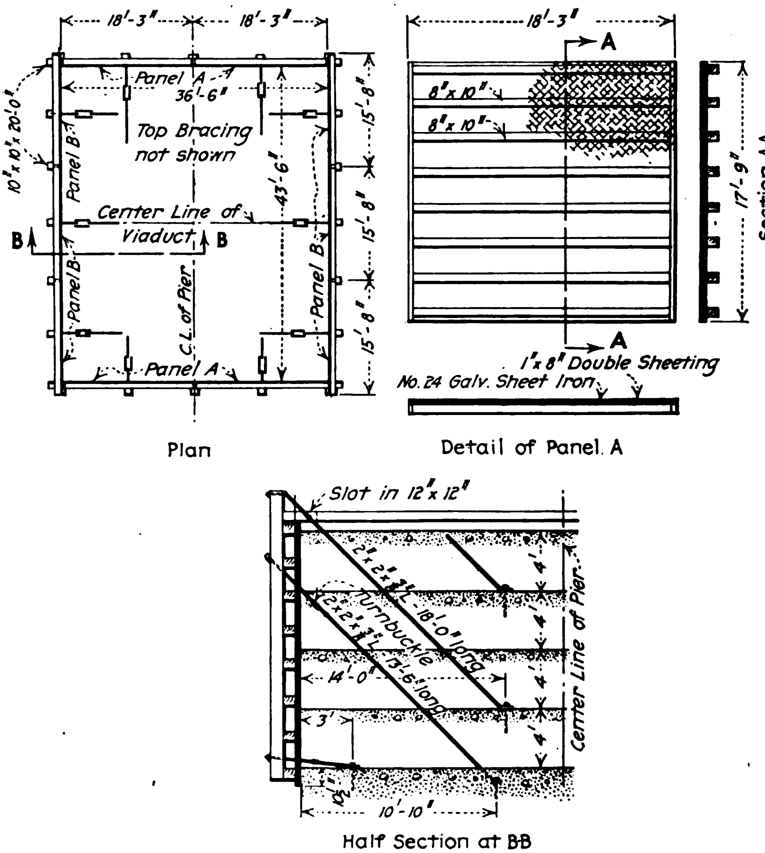
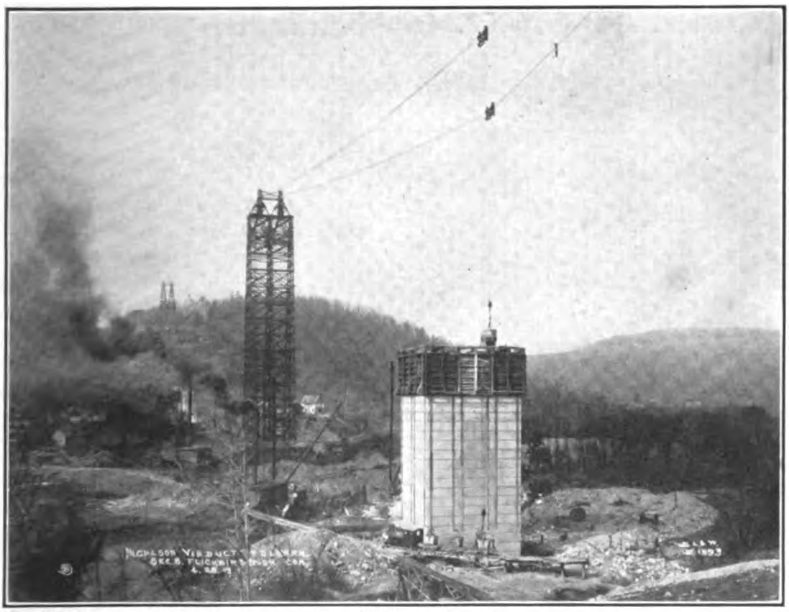


FIG. 435.—Tunkhannock viaduct. Details of sectional forms for main piers, showing methods of holding forms in line and place.

galvanized iron so as to give a smooth surface against which to spade the concrete. The weight of the larger sections was about 7000 lb.

The forms were held in line and position by diagonal ties consisting of steel angles and 12 × 12-in. horizontal struts wedged against the opposite verticals. The former held the forms from moving out and the latter from pushing in at the top as the concrete was placed in the bottom portion. Diagonal bolts with nut bearings on exterior beveled washers were connected by means of turnbuckles with the long diagonals which remained in the concrete. (See Fig. 435.) These diagonals had their lower ends bent and punched to engage permanent vertical anchor bolts built into each course of concrete. The turnbuckle permitted the tightening and plumbing of the forms and, after the section was concreted, the upper portion of the stay (which was set in a pipe sleeve) was removed by unscrewing the bolt from the turnbuckle. The hole was then grouted up.



Courtesy of Mr. C. W. Simpson, Res. Eng'r.

FIG. 436.—Tunkhannock viaduct. Concreting pier shafts in sectional forms. View also shows general plant layout and two of the cableway towers.

At first concrete was placed in these forms in four courses, each 4 ft. thick and containing about 235 cu. yd., poured continuously in about 6 hours. Later two of the 4-ft. courses were placed in one continuous run of 11 hours' duration. In the lower portions the concrete was placed with the derricks, while the upper portion was placed by means of the cableway, the buckets being lifted from the concrete train and dumped (while suspended over the forms) by a special attachment devised by the contractor for dumping with the cableway. (In Fig. 436 the pier forms are in place and the concrete is being dumped into same by the cableway.) At the joints between the sections, V-shaped strips were nailed to the forms and the concrete stopped at the inner edge of the same; the construction joints are thus inconspicuous and the scorings relieve the monotony of the plain surface. After the top course was from 3 to 7 days old, depending on the weather, the upper ends of the diagonal rods were removed and the panels lifted by derricks or cableway to a new position and re-erected. A force of six carpenters was able to do this in 2 days, which is exceedingly rapid work when one considers the height above ground at which some of this work was done, and it shows how well the type of forms used were adapted to the conditions. That the method of holding the forms in line was a good one is witnessed by the fact that none of the pier shafts were even ½ in. out of plumb.

The piers were carried up in these forms until a point 17 ft. 6 in. below

Courtesy of Mr. C. W. Simpson, Res. Eng'r.

FIG. 437.—Tunkhannock viaduct. General construction view, some of the piers completed.

the springing line of arches was reached. Here a temporary ledge 4 ft. 3 in. wide was formed on both sides to act as a seat for the arch centers. The portion above this seat to the skewback of arches (a total height of 54 ft. 6 in.) was carried up monolithic with the rest of the pier. These umbrella sections, though in reality a portion of the arch ribs, were concreted in special wooden forms of similar construction to those just described. These sections projected about 7 ft. beyond the springing line of the arches, as it was more economical to construct them as part of the piers due to the fact that the departure from the vertical is very slight.

The arch-rib reinforcement in this portion was placed in short sections for each lift of forms and the upper surface of the concrete at the skewbacks of arches was finished off in a radial plane with rectangular recesses or key slots to key the umbrella sections to the arch rib voussoirs placed on them later. Two inclined anchor bars 1½ in. in diameter were concreted in the umbrella sections of each rib to aid in erecting and securing the centering trusses against wind pressure, as described later. In Fig. 437, which gives a general view of the bridge, the pier shafts are shown in various stages, while in Fig. 440 pier shafts are shown completed up to the skewbacks of the arches.

As previously stated, the concrete used in each pier shaft up to the springing lines was of a 1:3:5 mixture with a maximum of about 11 per cent of Cyclopean stones of a size which could be conveniently handled by derricks. These stones were carefully embedded in the concrete and some were set so as to project into the course, thus binding the different courses together. (See Fig. 434.)

In very cold weather adequate precautions were taken to prevent the freezing of concrete before setting took place. The aggregates and water were accordingly heated with live steam so as to have the concrete go into the forms at a temperature of 50 or 60° F. The concrete, after being placed in the forms, was protected by packing hay between the vertical sides of the forms with strips nailed over the hay to keep it in place, and at night tarpaulins were placed over the top surface of the concrete.

Construction of Superstructure

147. Details of Arch Rib Centers.—The centers for 100-ft. arch spans were composed of timber trusses, one set under each rib resting on a timber tower at the center. At the ends, ledges were left on the umbrella sections to receive short wood struts braced top and bottom to the central tower by inclined struts upon which the ends of the trusses rested. Upon these centers 4-in. lagging was laid for the arch-rib forms with sectional timber side forms.

The centers for the main or 180-ft. arch ribs consisted of four pin-connected arch trusses for each rib, spaced 3 ft. 10 in. centers and braced with top- and bottom-chord laterals and radial sway-bracing frames. After completing one arch rib of the span, the entire centering was moved transversely on rollers for a distance of 20 ft. and the second rib poured. Five complete sets of centering were used, so that each set was erected twice and moved transversely the same number of times.

In Fig. 438 the sizes of the various members of the centering trusses as well as the loads coming upon them are indicated. It will be noted that the top chords were composed of two channels and a cover plate, while two latticed channels made up the bottom chords. The former were designed for local bending between panel points, due to the weight of fresh concrete. The web members consisted of latticed channels or angles. The trusses were shipped in four sections, the connections near crown and at the lower ends being made by pins while the others were bolted.

The top and bottom chords converged at the crown pin, and a rigid triangular frame at either side of crown resting on the top chords, supported the lagging over the crown panels. The space between these frames was filled with an oak block about 2 ft. long resting on bracket angles.

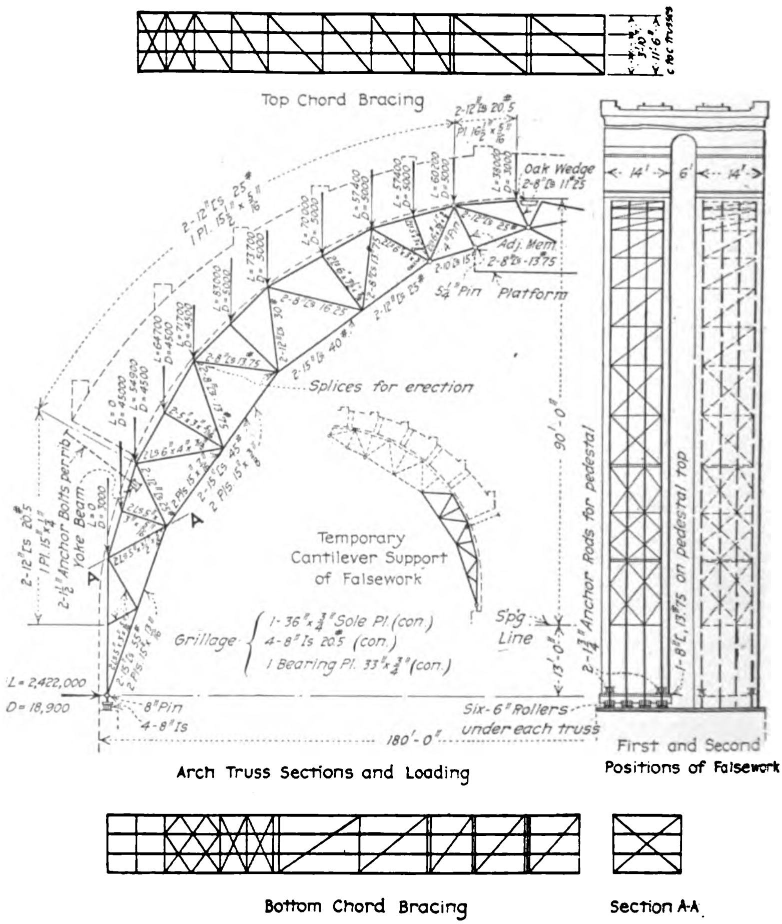


FIG. 438.—Tunkhannock viaduct. Make-up of members and loads on centering trusses, 180-ft. arch span.

The horizontal thrust due to dead load on each truss was 18,900 lb. When the trusses were being shifted to position concentric with the second rib, this thrust was taken up by two horizontal rods 1 in. in diameter connecting the base pins at each end. The horizontal wind pressure acting on the half trusses was resisted by two $1\frac{3}{4}$-in. vertical anchor bolts through the pedestal at each end, and the inclined anchor bolts $1\frac{1}{2}$ in. in diameter anchored into the umbrella sections. As a further safeguard against excessive wind pressures, the trusses were guyed laterally in both directions at the crown and quarter points by wire cables attached to anchors buried in the ground.

The lower ends of the trusses rested on, and were spaced by, built-up

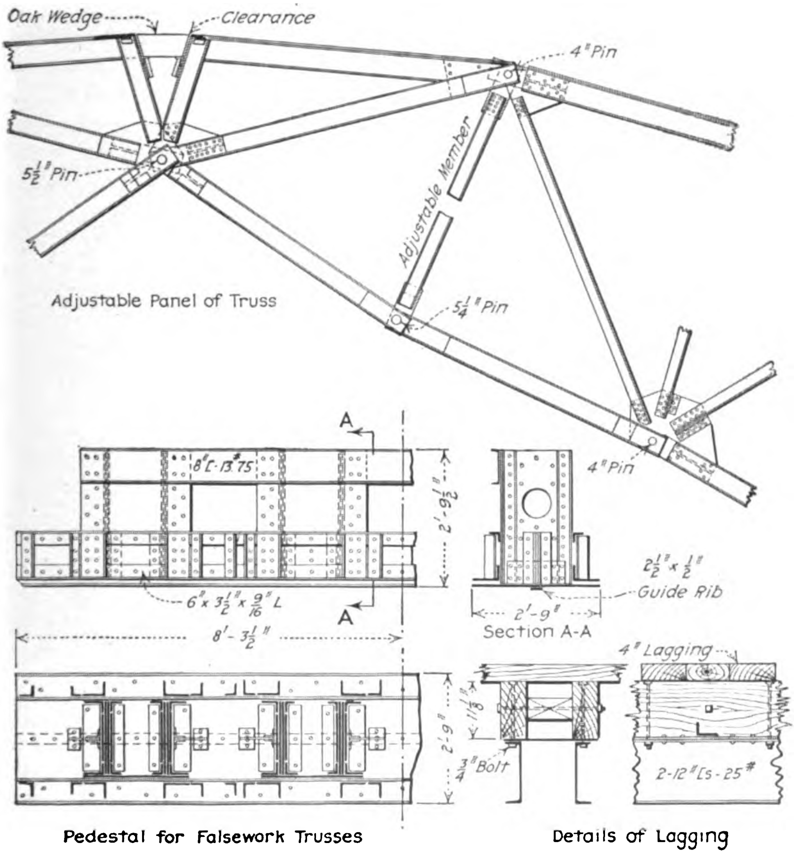
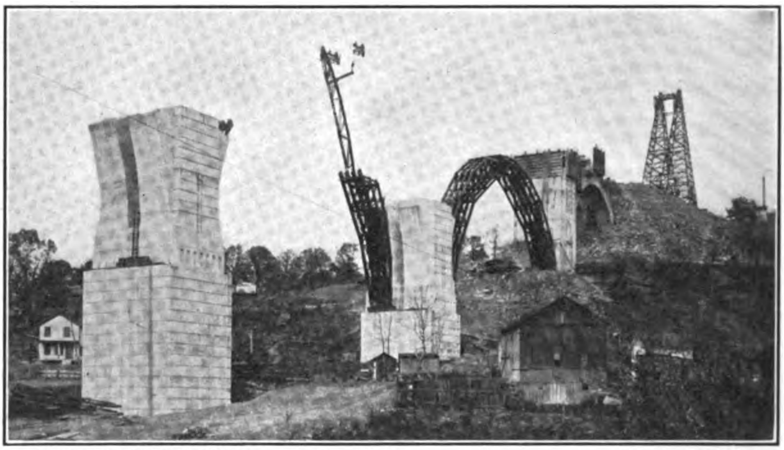


FIG. 439.—Tunkhannock viaduct. Details of adjustable panels of centers Pedestal and lagging details.

pedestals, the details of which are shown in Fig. 439. The base plate of the pedestal had a $2\frac{1}{2} \times \frac{1}{2}$-in. guide rib riveted to it, which engaged the shoulders of a set of six 6-in. rollers under each truss, to facilitate shifting of the centers. These rollers operated on an I-beam grillage consisting of four 8-in. beams 35 ft. 6 in. long resting on the pier ledge.

In order to adjust the height of the centers at the crown, the first web member beyond the crown normal to the top chord was built in two pieces, connected by a right- and left-thread screw operated by a ratchet and lever to allow of easy adjustment. Since the three panel points on each side of the crown were pin connected, this adjustable member acted as a toggle to increase or diminish the chord length of the arched trusses and thereby lower or raise the crown. (See Fig. 439.) A platform was hung from U-bolts over lower-chord pins near the crown to give a working space for the adjustment of the centers.

148. Erection of Centering.—The erection of the arch-truss centering was accomplished entirely with the use of the cableway. The trusses were assembled on the ground nearby in four sections each. The pedestals were first set in place and then the lower sections were hoisted into position by the cableway and connected by anchor pins to the pedestal. After the lower sections of the four independent trusses were



Courtesy of Mr. C. W. Simpson, Res. Eng'r.

FIG. 440.—Tunkhannock viaduct. Erecting segment of arch centering by means of double cableway. Centers for one rib in adjacent span erected.

erected and temporarily held in place with the aid of the cableway, the bracing was bolted up and yoke beams were attached to the inclined anchor bolts passing through the umbrella sections to engage the top chords of the sections of the semi-trusses at a point about 52 ft. above the base pins. (See Fig. 438.) This yoke beam held the sections securely and made the segments act as cantilever trusses. When the lower or cantilever sections of each group of semi-trusses on opposite piers had been erected, the upper halves were hoisted into position and bolted up to the first segments, as shown in Fig. 440. Until all the upper sections were erected and the crown pins driven, each half of the center acted as a cantilever truss, fulcrumed about the base pin and held by the yoke beams anchored to the umbrella sections, without any other external support.

By the operation of the inclined bolts through the umbrella sections, the semi-trusses were raised or lowered slightly until the pin holes registered and the pins could be driven. The yoke beams holding the lower portions to the umbrella sections were then released from bearing on the top chords of the trusses, and the entire centering made to act as a three-hinged braced arch; the yoke beams, however, were not drawn so far from the top chords as not to be able to act as anchorage against wind pressures. A completed arch center ready to receive lagging is shown in Fig. 441.

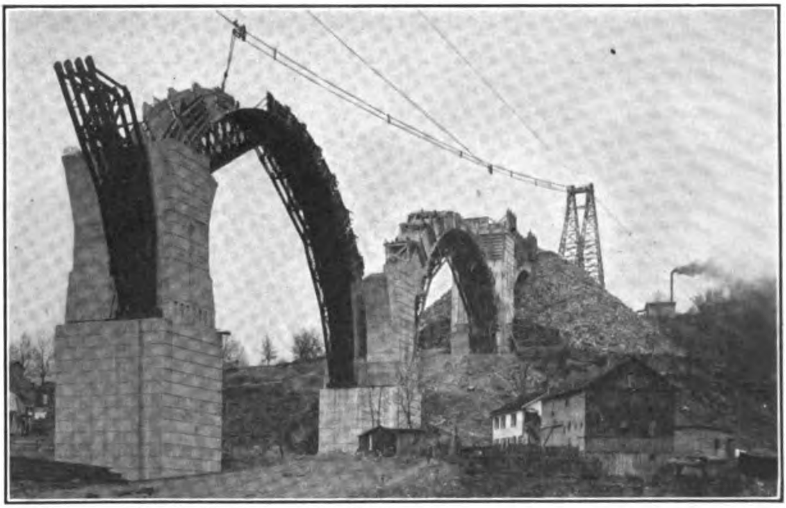
The 4-in. lagging of the arch ribs was laid on plank ribs cut to fit the

Courtesy of Engineering and Contracting.

FIG. 441.—Tunkhannock viaduct. Near view of completed arch truss center for one arch rib of 180-ft. span. Completed arch ribs for 100-ft. abutment span are also shown.

curve of the arch intrados and placed in pairs directly over the channels making up the top-chord members of the centering trusses. These ribs were anchored to the channels by ¾-in. bolts (about 18 in. on centers) with wood spreaders and transverse bolts to hold them securely in pairs. (See Fig. 439.)

The centers were erected for arch ribs on alternate sides in adjacent spans, as shown in Fig. 442, to allow the use of both cableways simultaneously for the delivery of materials. When one rib of each span was completed, the arch centers were lowered by lengthening the adjustable members at the crown, and the entire centering was jacked over on the rollers under the pedestals for a distance of 20 ft. to a position under the second rib. After completing the second rib and allowing the proper time for hardening, the centers were again slacked down and rolled back to a position directly under the opening between arch ribs where the lagging was removed and the trusses dismantled in sections, then lifted up through the opening and transported to the next arch to be connected by means of the cableway. After the removal of centers, the ledge on piers serving as a seat for centers was filled in with concrete in receding steps, as shown in Fig. 427, to conform to the architectural treatment of the remainder of the pier.



Courtesy of Mr. C. W. Simpson, Res. Eng'r.

FIG. 442.—Tunkhannock viaduct. Concreting keyways of arch rib in one span, erecting side forms for voussoirs in the next, lower segment of centering in the third span.

149. Constructing Arch Ribs.—The steel arch centering having been erected and the lagging for arch-rib soffit placed, the side forms for the large voussoir blocks were erected with the aid of the cableway, as shown in Fig. 442. Each arch rib was divided for construction purposes into eleven voussoirs or blocks separated from each other by comparatively narrow keyways, as indicated in Fig. 443. The forms for the voussoir sides were built in units of similar construction to those used on the piers, hoisted into place, and held in position with diagonal braces, rod ties and timber separators connecting the forms on either side. End forms for the voussoirs were next built, forming an entirely independent form for each block so that any voussoir could be concreted entirely independent of any other. On the lower end of each voussoir form, a triangular extension was built as a side form for pedestals or seats for transverse spandrel walls so as to provide a horizontal bearing for the latter.

The arch-rib reinforcement, in lengths of about 30 ft., was placed in position before the transverse voussoir forms were built. All reinforcing bars were lapped 40 diameters. The bottom bars were held in the proper position above the lagging by the transverse rods, while the upper bars were secured by and rested on transverse rods or wires fastened to the side forms.

The concreting of voussoirs was done with the aid of the cableway, the order of concreting being as indicated numerically in Fig. 443. It will be noted that the first pair of voussoirs placed were those at the skewbacks, then the pair midway between crown and skewback, and next those adjacent to the crown voussoir. This order of placement was used so that the loading of the centers would be as balanced as possible, and would thereby prevent any undue deformation of the centers caused by unequal or improperly distributed loads. The section

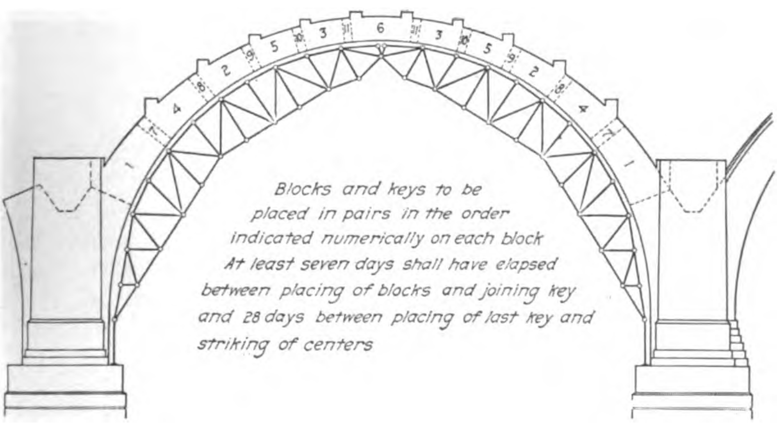


FIG. 443.—Tunkhannock viaduct. Diagram showing schedule of pouring voussoirs and keyways of arches.

at the crown was the last one to be poured. The concreting of the keyways was then begun, starting with the lower ones and working up to the crown. In every case, however, a period of at least 7 days was allowed to elapse between the concreting of the voussoirs and the adjoining keyways.

The forms for the keyways were in no way dependent upon the voussoir forms for support and the latter were therefore removed as soon as allowable and put into use on another arch. With this arrangement it was possible to construct the twenty 180-ft. arch ribs with two complete sets of arch forms. (The keyway forms are shown in position on the main-arch rib to the right in Fig. 442.) The arch centers were not struck until at least 4 weeks after the last keyway had been concreted.

150. Special Methods Used in Constructing Arch No. 6.—As previously stated the central cableway tower was located at the center of the arch span between piers Nos. 5 and 6, and was so placed as to locate the central bent between the arch ribs and the outside bents entirely clear of these ribs. This necessitated some changes from those cited above in the operations of concreting and erecting centers. On account of the difficulties encountered in the construction of pier No. 5, the arches 5 and 6 were the last to be constructed. Instead of building one rib at a time, as with the other spans, the centers for these arches were erected so that both ribs of each span were concreted at the same time—all other arch ribs being completed and enough centers being made available to so carry out the work.

The lower sections of centers for arch No. 6 did not interfere with the cableway tower and were erected complete for both ribs in the usual manner. For the erection of the middle sections of centering trusses, one panel of cross-bracing on each face of tower was removed temporarily and then replaced after the centers were completed and properly adjusted. The formwork for arch-rib voussoirs and keyways was then placed in the usual manner, the cross-bracing in the panel above that through which the centering trusses passed being removed to allow the arch-rib concrete to be poured.

After the arch centers for this span were set no hoistways remained through which the concrete could be hoisted by the cableways. This necessitated the use of four derricks (two derricks on the top of pier No. 4 and two on the top of pier No. 6) to hoist the concrete buckets from the ground below to the bridge deck where they were transferred to the cableways and placed where desired. The portion of arch No. 6, enclosed by the cableway tower, was concreted by spouting from hoppers at the faces of the tower into which the buckets were dumped from the cableway. The economy of the cableway in handling concrete is illustrated very forcibly by the fact that the hoisting of the buckets of concrete to the bridge deck with the derricks required 90 seconds, or three times as long as with the cableway.

The central cableway tower also interfered with two of the transverse spandrel walls and, in order to erect forms for and to concrete these walls, the cross-bracing was removed in one panel on each side of the three center posts of the center bent transverse to the viaduct between the arch ribs. The tower did not interfere with the pouring of the viaduct floor except where the three posts above mentioned passed through it. Here small square holes were bulkheaded off around the posts and filled in with concrete after the tower was removed.

151. Spandrel Construction.—The construction of the deck over the arch ribs was not commenced until the main arch centers had been struck. The transverse spandrel walls supporting the spandrel arches were concreted in sections of varying height in self-supporting sectional forms (see Fig. 444) lined with galvanized iron. The concrete was delivered to a dumping platform by the cableway and was then shoveled into the forms, the width of the same not being great enough to allow dumping directly. Just below the springing line of the spandrel arches a heavy projecting coping was placed on the walls to support the ends of the arch centers.

The spandrel arch centers were built in sections 10 ft. 4 in. long, four sections for each arch, consisting of 2-in. lagging nailed to 3 × 12-in. bow-ribs spaced 2 ft. 4 in. centers, as shown in detail in Fig. 445. These sections were made adjustable to facilitate erection and removal. The bottom chords of the ribs had a 4-in. opening at the middle, covered by 2-in. fish-plates bolted on each side to allow the striking of centers. Above the second bottom chord from each end a rod and turnbuckle

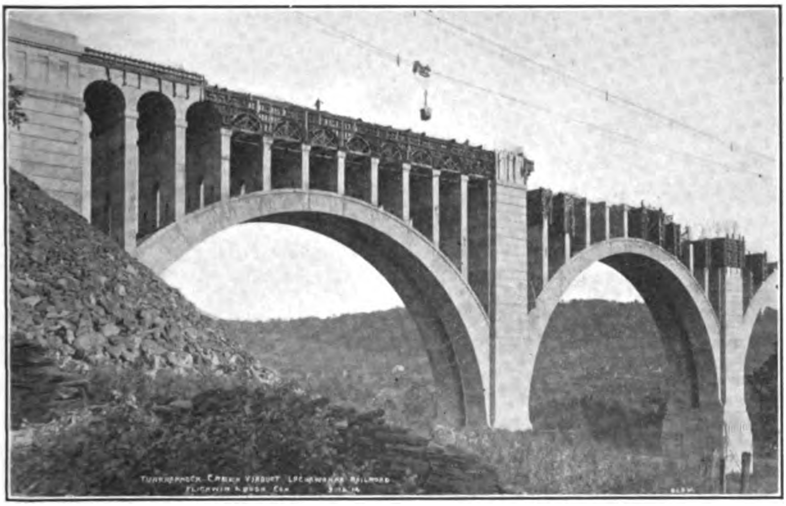


Fig. 444.—Tunkhannock viaduct. Completed arch ribs for two 180-ft. spans. Transverse spandrel walls, pier pilasters, and spandrel arches being concreted.

were placed which, when all the fish-plates were removed, were tightened up to slack the centers away from the concrete and allow their removal after the wedges were drawn. A total number of 80 sections sufficed for the construction of the spandrel arches for the entire bridge.

At the time the spandrel arches were poured, the parapet wall, up to the first offset of the coping, was also concreted in order to avoid an unsightly construction joint at the floor level. The forms for this portion of the parapet were built in sections extending from the crown of one arch to the crown of the one adjacent, as shown in Fig. 444. The reinforcement for spandrel arches and parapet was placed complete before any concreting was done. As soon as the forms for spandrel arches were removed, the wooden forms for the parapet copings were erected, reinforcement placed, and the concreting done in the same manner as for transverse spandrel walls.

The cableway could not be readily used for removing the spandrel arch centers on account of the eccentric loading which would of necessity come upon it during such a procedure, and a stiff-leg derrick was there-

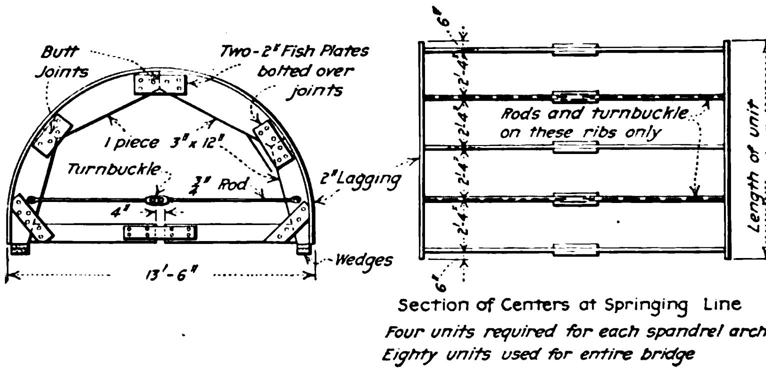


FIG. 445.—Tunkhannock viaduct. Details of spandrel arch centers.

fore erected on the finished floor to handle these centers, and moved along as the work progressed.

During cold weather the freshly poured sections of floor were covered with tarpaulins and a steam pipe run under same to keep the concrete warm until it had set. In hot weather newly constructed sections of the

FIG. 446.—Tunkhannock viaduct. Progress photograph, June 26, 1915.

floor were dammed up at the ends and flooded with water until the concrete had set. After completing the floor the waterproofing was laid, the track ballast placed, and the track laid. Fig. 446, a progress photograph of the viaduct, shows the status of the work on June 26, 1915. The entire bridge has since been completed (Nov. 7, 1915).

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CONSTRUCTION METHODS ON THE TUNHANNOCK AND MARTIN'S CREEK VIADUCTS, LACKAWANNA RAILROAD.

By C. W. Simpson.*

Two large concrete structures, known as the Tunkhannock and Martin's Creek Viaducts, have recently been completed by the Delaware, Lackawanna and Western Railroad Company, in connection with a grade improvement between Clark's Summit and Hallstead, Pa. As the design and structural features of these viaducts have been extensively described in the technical press, this paper will be limited to a brief outline of the structures and to pointing out a few of the more essential features of the planning and carrying out of the work of construction.

Martin's Creek Viaduct.—The Martin's Creek Viaduct is a three-track bridge having a maximum height above stream-bed of 150 ft., and a length of 1600 ft. It has two 50-ft. and two 100-ft. semi-circular arches, and seven 150 x 59-ft. three-centered arches. The larger arches are 6 ft. thick at the crown and are divided into two ribs, 17 ft. 6 in. wide, spaced 29 ft. 6 in. center to center, which carry transverse spandrel walls supporting an arched floor system. This structure required about 26,000 cu. yd. of foundation excavation, 77,000 cu. yd. of concrete and 1,600,000 lb. of reinforcing steel. The completed bridge is shown in Fig. 1.

Tunkhannock Viaduct.—The Tunkhannock Viaduct is a two-track bridge composed of ten 180-ft. and two 100-ft. semi-circular arches springing from solid piers and supporting transverse spandrel walls, upon which rests a floor system composed of 13-ft. 6-in. semi-circular spandrel arches. The deeper piers have a section 40 x 46 ft. below the ground surface and all piers are 36 ft. 6 in. by 43 ft. 6 in. to a point 17 ft. below the springing line of the main arches. At this elevation a 4-ft. 3-in. offset provides a seat for the temporary steel centering. The deepest pier extends 103 ft. below the original ground surface, and at this pier it is 309 ft. from the bottom of the foundation to the highest point of the masonry. Each main arch is composed of two ribs, 8 ft. thick at the crown and 14 ft. wide. About 163,000 cu. yd. of concrete, 2,500,000 lb. of reinforcing bars, and 48,000 cu. yd. of foundation excavation were required. All piers were carried to solid rock, the depth of which had been determined by borings. The completed bridge is shown in Fig. 2.

The natural conditions at the site of each of these structures and the method of carrying out the construction work (with one exception) were so nearly identical that a description of the Tunkhannock Viaduct will apply equally as well to the Martin's Creek. The exception noted is that the

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Martin's Creek bridge was constructed entirely with derricks, while at the Tunkhannock Bridge both derricks and a cableway were used. The reason for the use of a cableway at the latter structure was its height and the length of the spans.

GENERAL PLAN OF PROCEDURE.

The contract for this work was let in June, 1913, and the time set for completion was July 1, 1916.

In planning the work no detailed schedule was laid out, but the following general plan of procedure was determined upon.

Of the thirteen foundations, six were more than 40 ft. deep, and steel sheeting was adopted for these six excavations. At three of these and at three of the other foundations, the configuration of the ground was such that a portion of the excavation could be accomplished with a steam shovel. Of the other three deep foundations, two were partly in the bed of the stream and were considered to be the most difficult. It was decided to provide sufficient sheeting for these two piers; to start them at the earliest possible date; and to re-use this sheeting at the other four deep excavations. In the meantime the steam shovel excavation was to be carried out and the other shallow piers excavated.

In planning the concrete schedule it was necessary to consider that the mixing plants would be on low ground while five of the shallow excavations were in much higher ground and could be reached economically only by the use of the cableway. For this reason no large amount of concrete could be placed until either the cableway or some of the deep foundations were completed. It was estimated that of the excavations accessible without the cableway, four (two shallow and two deep) could be completed on or before January 1, 1913, and the concrete schedule was made out from that date, as the cableway could not be ready for use before February.

These conditions made it necessary to contemplate the placing of 163,000 cu. yd. of concrete in 30 months. It was, of course, recognized that concreting could be carried on much more rapidly and continuously while working on the foundations and on the main pier shafts than would be the case when working on the arch rings and spandrel system. About half the concrete, or 80,000 cu. yd., is below the springing line of the main arches, and it was decided that this quantity must be placed during the first ten months, or at the rate of 8,000 cu. yd. per month. This made the rate for the remaining twenty months 4,200 cu. yd. per month.

It must not be understood from this that it was the intention to complete all the work below the springing line before proceeding with the superstructure. On the contrary, it was desired to combine work on the superstructure with the part below the springing line as much as possible; but it was realized that the pier work must predominate during the first third of the allowed time. Also, it was not expected to maintain a uniform monthly rate. The schedule was simply a general guide as to the sufficiency of the plant and forces engaged.

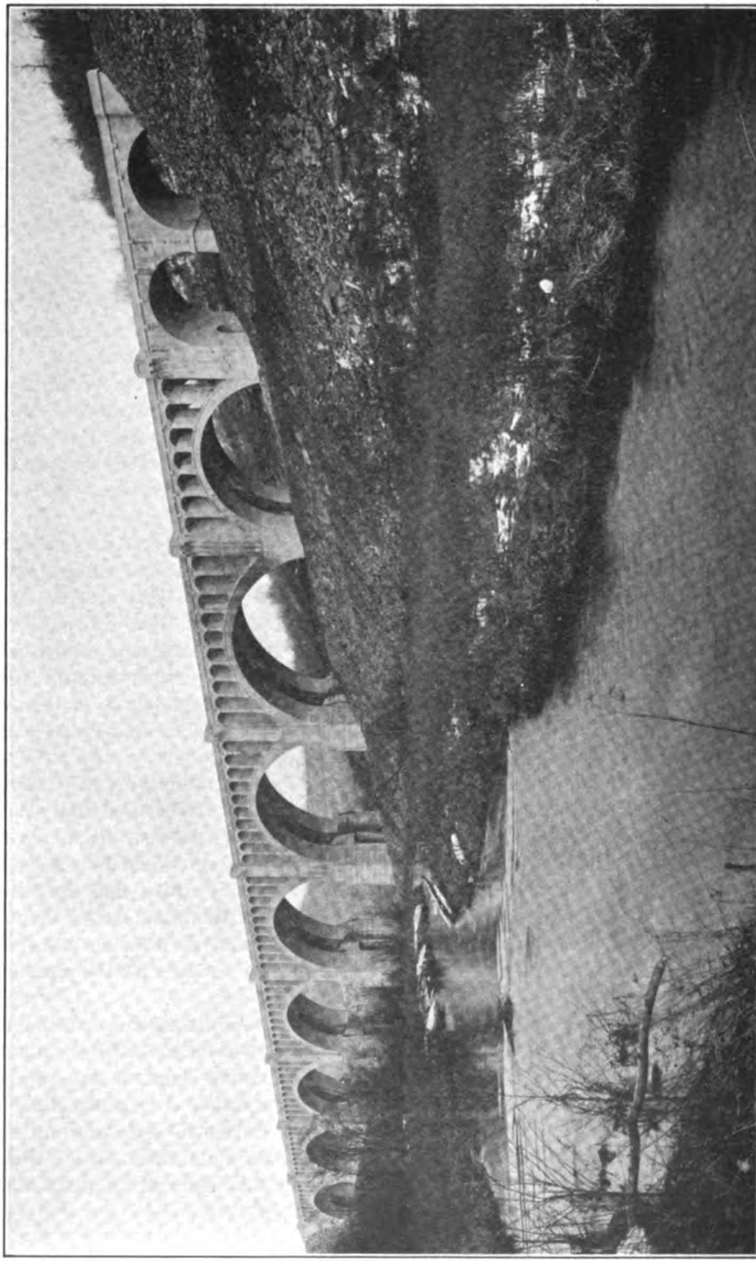


FIG. 1.—MARTINS CREEK VIADUCT, LACKAWANNA RAILROAD.

The organization of forces was as follows:

A general manager was in complete control. To him reported a superintendent and an office manager. A timekeeper and a material clerk reported to the office manager regarding office matters and to the superintendent regarding field matters. The superintendent's assistants were as follows: master mechanic, general carpenter foreman, foreman rigger, foremen of concrete gangs, foremen of excavation gangs, mixer foremen, foreman of material gang and foreman of steel gang. The master mechanic was in charge of all machinists, enginemen, hoist runners, cableway runners, steam shovel men, pumpmen, drill runners, blacksmiths, signal men and electricians. The carpenter foreman had under his direction sub-foremen, mill-men, carpenters and helpers. The rigger foreman was responsible for the condition of the cableway and derricks. The duties of the other foremen are evident from their designation. Laborers and sometimes foremen were shifted from one class of work to another as occasion demanded, but all men were kept at the same work so far as possible.

GENERAL LAYOUT.

Before the completion of the improvement the main tracks of the Delaware, Lackawanna and Western Railroad were approximately parallel with and about 450 ft. distant from the viaduct. This is shown in Fig. 3 (Plate I), which shows the general plant layout. (It will be noted that this plant is to scale between piers 3 and 8 only, the abutments and piers 1, 2, 9, 10 and 11 being omitted, as no plant was located between the piers shown and the end cableway towers.) The railroad company's tracks were on an embankment, so that they were about 60 ft. higher than the creek bed and about 35 ft. higher than the ground level at the mixing plants. The loop formed by the narrow gage track encloses a knoll about 30 ft. higher than the general level of the valley. On this knoll are located the machine and blacksmith shops, superintendent's office and water tower. The general office and hospital are located on ground at about the same elevation as the knoll above mentioned. The general material derrick is located on a narrow ridge which connects the railroad embankment with the knoll at the blacksmith shop. A similar ridge extends from pier 6 to the high ground at the hospital. Cuts were made through these ridges to permit the laying of the 3-ft. gage tracks.

The first operation was the widening of the railroad company's embankments and the laying of the track marked "Track for Empties" and "Room for 16 Loads." This track was completed on June 12; a track pile-driver immediately started to construct the material trestles; the general material derrick was erected; work was commenced on the shops, storehouses and office building; and a narrow gage track was laid from the material derrick to pier 4. During July a steam shovel started foundation excavation, and sheet piling was being driven at pier 4. During August the erection of the cableway was started; a trestle carrying a narrow gage track was built across the creek to give access to pier 3, and a large amount of plant and supplies were delivered on the ground.

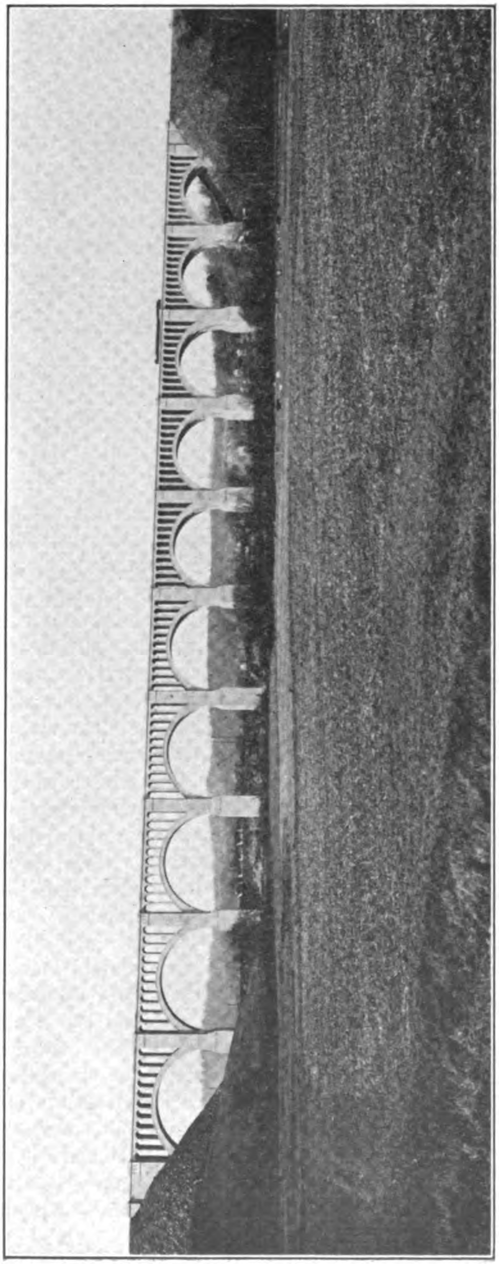
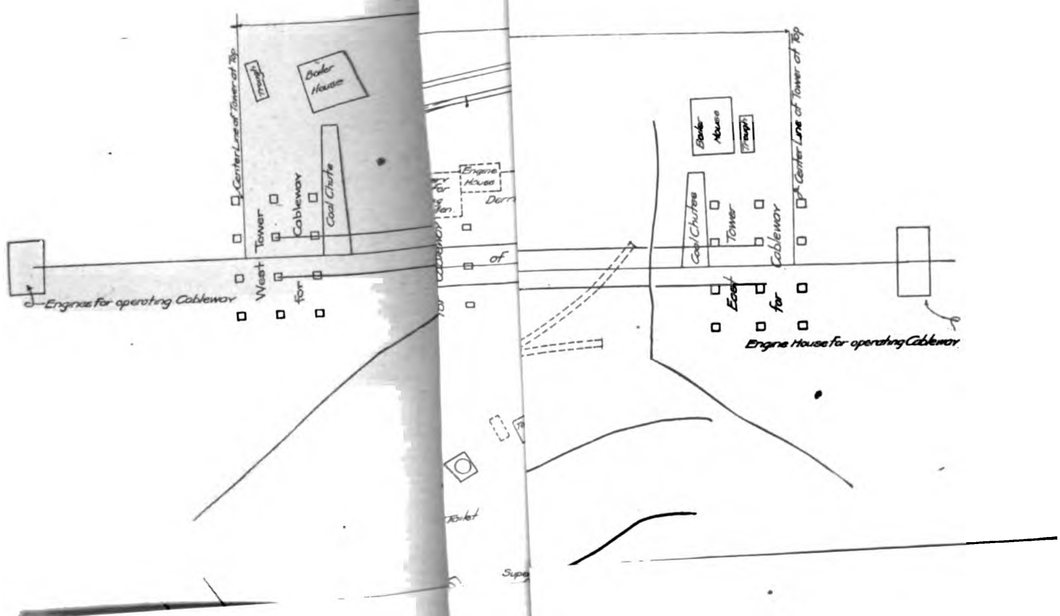


FIG. 2.—TUNKHANNOCK VIADUCT, LACKAWANNA RAILROAD.

PLATE I.
PROC. AMER. CONC. INST.
VOL. XII, 1916
SIMPSON ON CONSTRUCTION OF
TUNKHANNOCK VIADUCT.



FOUNDATION EXCAVATION.

A steam shovel having a 1-cu. yd. dipper excavated piers 5, 6 and 8 down to ground-water level and piers 2, 9 and 10 down to rock. The material was allowed to take its natural slope, and the excavations were made sufficiently large to take care of the raveling of the banks prior to the completion of the piers. The shovel loaded the material into 4-cu. yd. cars, and it was utilized in grading for the narrow gage tracks and in bringing all low ground between the creek and the railroad up to a level with the mixing plants. All the ground around the sawmill, laying-out platform, steel rack, boiler house, and mixer 2 was "made" in this way. This "leveling up," amounting to as much as 12 ft. in some places, was done at practically no extra cost and proved a very great benefit in handling the work. The shovel completed its portion of the excavation in December, 1912, having excavated about 50,000 cu. yd., 15,000 cu. yd. of which was pay material.

In excavating below water level, interlocking steel sheet piling in lengths of 30 ft. were used. The sheeting was driven with a 3-ton steam hammer and was braced with 12 x 12-in. timber. Sheeting was required for depths of from 50 to 75 ft., necessitating the use of two and three lengths of sheeting.

The method of procedure with the excavation was to erect one set of sheeting on lines about 3 ft. outside of the required foundation area, and to drive the sheeting as far as convenient. The excavation was then carried down to the bottom of the sheeting by means of 1½-cu. yd. clam-shell buckets, operated in the bays between the timber braces, which were so spaced as to admit the operation of the bucket. The bracing was put in on about 5-ft. centers, vertically, as the excavation proceeded.

After the excavation had been carried down to the temporary bottom of the sheeting, the latter was driven farther, and the operation was repeated until the top of the sheeting was down to the ground surface. Another set of sheeting was then erected about 6 ft. 6 in. outside the first set, and was driven as deep as was thought advisable. The material between the two sets of sheeting was excavated with the clam-shell bucket; the first sheeting was then driven farther; and the excavation was resumed. As the inside set of sheeting was driven down, the upper set of timber bracing was removed and placed at the bottom. The process was continued until bedrock was reached. Almost all of the sheeting was recovered, some of it being used four times.

Two of the piers gave serious trouble on account of quicksand. The difficulty was overcome in one of these by dividing the last 12 ft. of the excavation (the total depth was 62 ft.) into three pockets and taking each pocket down separately. A somewhat similar plan was tried in the other excavation but was not successful, and it was necessary to resort to compressed air. A caisson was built inside the sheeting with its cutting edge 45 ft. below the top of the excavation and 32 ft. above bedrock. The two lower sets of bracing timbers were built into the caisson and were carried down with it. Concrete was placed on top of the caisson as it sank in the usual manner. Had it not been for the difficulties that had to be overcome in excavating for this pier, the work would have been completed well within the contract time. This excavation was not completed until February, 1915, and yet the entire bridge was completed in September, less than three months later than the contract time.

CONCRETE PLANT.

Sand and stone were delivered on the material trestles in bottom-dump hopper cars and dumped into the storage piles. Each mixing plant was served by two derricks which operated clam-shell buckets of 40-cu. ft. capacity. These derricks conveyed the sand and stone from the storage piles to small bins over the mixers. From these bins the material passed by gravity into a measuring hopper where the cement was added. From the measuring hopper the material passed by gravity into a 2-cu. yd. mixer which dumped directly into double-line bottom-dump buckets on flat cars. Twelve-ton locomotives hauled trains of three flat cars, one car being empty to receive the empty bucket from derrick or cableway. At mixer 1 the cement was conveyed from the original cars on the material trestle to the hopper floor of the mixer by the sand derrick. At mixer 2 the cement was unloaded from the cars into chutes, which conveyed it to the hopper floor. All cement was shipped in cloth. A cement house (see Fig. 3) of 3000 bbl. capacity was built and filled, but no cement was used from this source except when shipments were delayed and no cement was available in cars.

The mixing requirements made it necessary to turn each batch from 2 to 2½ minutes and limited the mixer output to an average of 17 batches per hour. Each mixer gang consisted of one foreman, two derrick operators, one mixer runner, one fireman and eleven laborers. Two trains, each requiring one engineman and one laborer, served each mixer. One foreman with from eight to sixteen laborers spread the concrete in the forms. The above organization, with the addition of cableway runners and signal men, averaged about 30 cu. yd. of concrete per hour.

The following table gives the cubic yards of concrete placed during each month. It is interesting to compare this with the original schedule.

	1913	1914	1915
January	8410	3400	2000
February	5740	2260	5130
March	4520	1460	5620
April	6630	5090	4010
May	7190	3270	3200
June	13890	4010	3400
July	12150	4770	4000
August	8810	4450	1800
September	3820	4910	
November	3270	4310	
December	2160	4000	

About 8900 car loads of sand, stone and cement were handled on the material trestles and 1200 car loads of other material were handled by the general material derrick.

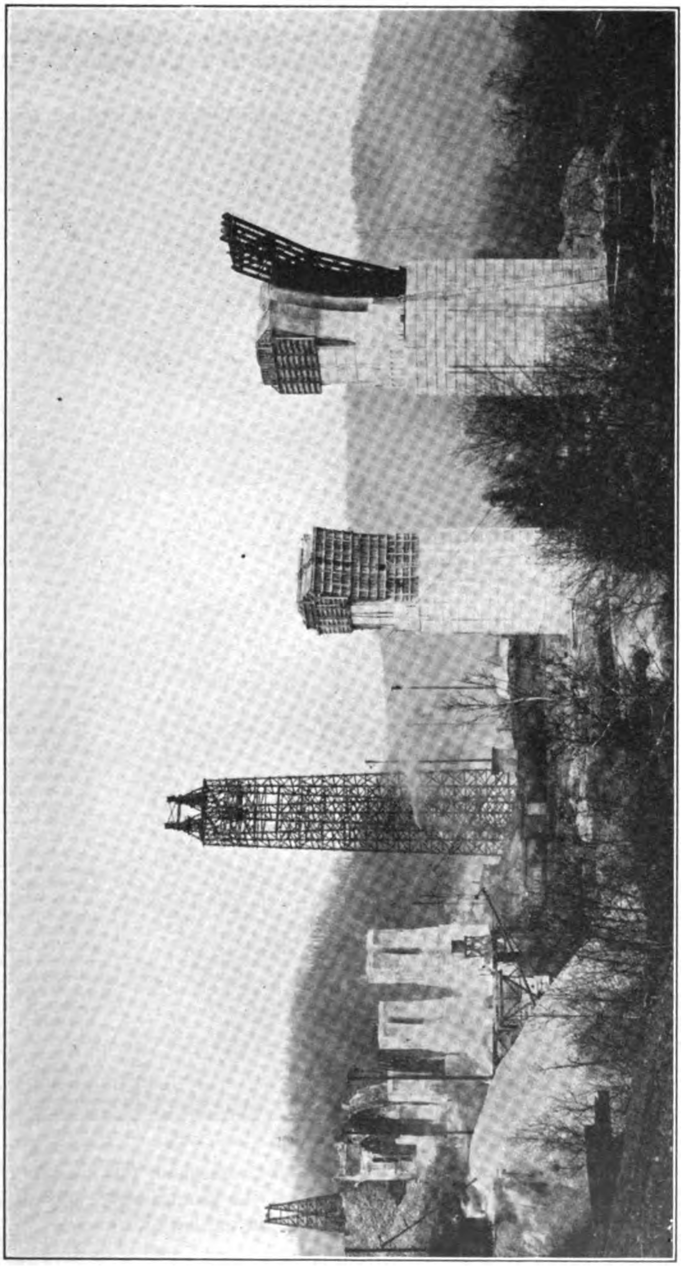


FIG. 4.—CABLEWAY TOWERS, ETC.

The cableway consisted of two lines of 2¼-in. main cables, spaced 20 ft. apart and supported by end towers about 160 ft. high and an intermediate tower 300 ft. high. The end towers were 3028 ft. apart and the intermediate tower divided this distance into two spans of about equal length. Four engines and carriages operated as four independent units. The towers were of timber and the intermediate tower was so located and designed that the arch rings and all the floor system except a narrow slot could be constructed through it and thus utilize the cableway to the fullest extent. The type of tower construction is shown in Figs. 4 and 5.

The last centers to be erected were those passing through the center tower. The adjacent piers were carried up to the top of the floor before

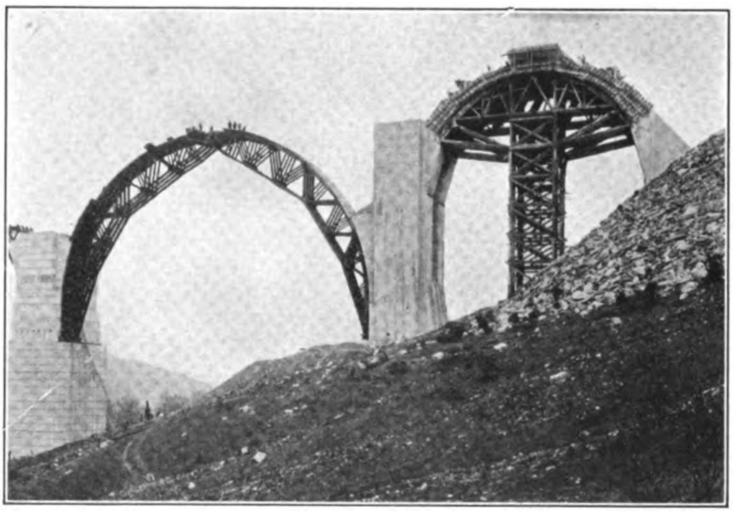


FIG. 7.—CENTERING WITH TIMBER TOWER.

these centers were erected and two stiff-leg derricks were located on each pier. After these last centers were erected, all material was raised above them by the derricks and then transferred to the cableway for transportation to its destination.

ARCH CENTERS.

Five sets of three-hinged steel arch centers were used in constructing the 180-ft. spans. Each set was composed of four ribs weighing 47 tons per rib, spaced 3 ft. 10 in. center to center, and provided support for one of the two concrete ribs composing each span. A 4-ft. 3-in. ledge or offset, 17 ft. 6 in. below the springing line of main arches, was provided to support the centers. On this offset rested an I-beam grillage extending the full width of the pier and carrying 6-in. rollers on which the pedestals of the centers rested. For erection purposes each steel rib was built in four sections.

Before the centers were erected the adjacent piers were constructed to an elevation about 37 ft. above the springing line, forming what is termed the "umbrella." The procedure of erection was as follows: After the I-beam grillage, rollers and pedestals were in place, the lower quarters of the ribs were raised to position, the bottom pins driven and the top of the sections anchored to the "umbrella" tops by bolts passing through the concrete. One of the upper quarters was next raised to position and bolted to the quarter already in place. The other upper quarter was then put in position, bolted to its lower section and the crown pin driven. The ribs were so designed that the half rib would support itself as a cantilever. Fig. 6 shows two sets of centers in place and the lower quarters of another set erected. Fig. 5 shows the upper quarters being erected through the center tower.

To provide for striking the centers or adjusting the crown elevation, the first panel on each side of the crown pin was constructed with pin connections, and the web member at right angles to the chords consisted of two parts connected by a right-and-left thread screw operated by a lever and ratchet. By lengthening or shortening this member the distance between the crown and end pins was decreased or increased, thus lowering or raising the crown.

After serving their purpose under one rib of a span, the centers were slacked off and jacked over to their position under the twin rib. When the span was completed, the centers were rolled back under the opening between the concrete ribs and transported to their next point of service. In constructing the last two spans, centers were erected under both ribs simultaneously in order to hasten the completion. Timber centers resting on a timber tower were used for the 100-ft. spans. The type of construction of these centers is shown in Fig. 7, which also shows the placing of lagging on a set of steel centers.

FORMS.

With very few exceptions the forms were built on the ground in sections and hoisted to position by cableway or derrick. These sections were re-used a great many times, some of the first ones built being still in service at the end of the work. To illustrate the construction and utility of this type of form, a description of the forms used for the main pier shafts will be given in some detail. These sections were of two sizes, one being 18 ft. 3 in. and the other 15 ft. 8 in. long, and both were 17 ft. 9 in. high. The larger section weighed about 7000 lb. Four of the larger and six of the smaller sections were required to surround one pier and were termed a set. Four sets sufficed to construct all the piers up to the centering ledge without in any way retarding the progress of the work and, with slight alterations, these same sections were used up to the tops of the piers and also as spandrel wall forms. These forms are shown in Figs. 4 and 5.

Each section is made by nailing two layers of 1 x 8-in. tongue-and-groove boards to 8 x 10-in. horizontal studs spaced 2 ft. 5 in. on centers, one layer being at right angles to the other and both layers at 45 deg. with the studs.

The studs were bolted to 10 x 10-in. verticals which extended about 2 ft. above the planking. All forms were faced with No. 26 galvanized sheet iron and, in some cases, paper was laid between the layers of boards as an aid in protecting the concrete during freezing weather. The forms were kept in position by rods running down at an angle of 45 deg. from the vertical posts to anchors in the concrete and by 12 x 12-in. timbers resting on the top edge of the planking and wedged against the verticals. The rods were provided with a threaded sleeve joint so that the projecting end could be removed from the concrete.

Six carpenters with two cables or one derrick would remove and re-erect one set of forms in somewhat less than two days. On two occasions when the plant was available and it was desired to move the forms with as much speed as possible, 16 carpenters, with the aid of two derricks and two cables, removed and re-erected a set of these forms in seven hours.

The forms for the arch rings were very similar in construction to the pier forms, and two sets, that is, forms sufficient to cover two complete ribs, sufficed for the entire work.

The main arches were constructed with large blocks or vouissoirs separated by small keys. The block forms were made entirely separate from the key forms. Fig. 6 shows the key forms in place on one span and the block forms being erected on the adjacent span.

These structures were designed and built under the direction of Mr. G. J. Ray, Chief Engineer, and Mr. F. L. Wheaton, Engineer of Construction. Mr. A. B. Cohen was in charge of the design and the writer was Resident Engineer in charge of the construction of the Tunkhannock Viaduct.

The contractors were Flickwir & Bush, Inc., for whom Mr. F. M. Talbot was General Manager and Mr. W. C. Ritner, Superintendent.

FIFTY-EIGHTH QUARTO VOLUME

From January 1, 1915 to June 30, 1915

Railway Age Gazette

(Established in April, 1856)

SIXTIETH YEAR

NEW YORK CHICAGO CLEVELAND LONDON

1915

FIRST HALF

Progress on Summit Cut-Off of the Lackawanna

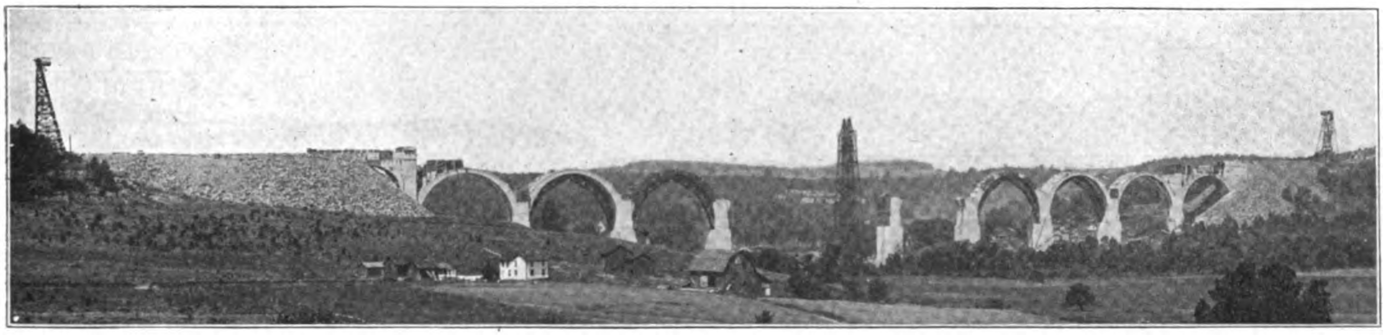
A Description of the Present Stage of Construction of World's Largest Concrete Bridge and a 3,630-ft. Tunnel

It is expected that the new three-track line of the Delaware, Lackawanna & Western between Clark's Summit, Pa., and Hallstead, on which some unusually heavy work has been under way for the last three seasons, will be ready for operation by December 1 of this year. This cut-off of 39.6 miles is being built at a cost of about $12,000,000 to reduce the distance 3.6 miles, the maximum grade eastbound from 1.23 per cent uncompensated to 0.68 per cent compensated and westbound from 0.52 per cent uncompensated to 0.237 per cent compensated; and the maximum degree of curvature from 6 deg. 22 min. to 3 deg., to eliminate 327 ft. of rise and fall and 2,440 deg. of central angle, to add a third track and to abolish all grade crossings. As the maximum train loading is fixed by the grades on the remainder of the engine district, no increased tonnage will be made possible by the improvement, but an important saving in mileage of helper engines and in running time over this portion of the line will be effected. The reasons for this work were fully covered in the *Railway Age Gazette* of April 25, 1913, and November 14, 1913.

A General View of Martin's Creek Viaduct Which Is Now Completed

GENERAL

The construction of this line required the excavation of 13,318,000 cu. yd. of material. The interesting methods of handling this heavy grading work were described in the second article referred to above. The grading is now about 85 per cent completed and about 25 per cent of the track has been laid.



A General View of the Tunkhannock Creek Viaduct Under Construction

The small bridge work is practically completed, and the last concrete in the Martin's creek viaduct, one of the two large structures, was poured on November 14. The 12-span concrete arch bridge over Tunkhannock creek, which is the largest structure on the line, will probably be the last work completed. This double track viaduct consists of ten 180-ft. and two 100-ft. arches with a total length of 2,375 ft., and a height of 242 ft. from stream bed to top of coping. These dimensions with the concrete yardage of 167,000 make it the largest structure of its type in the world.

The method of sinking the piers to rock at a depth of 10 ft. to 95 ft. below the ground line and the construction of these piers above the ground to the top of the umbrella section 37 ft. above the springing line were described in the *Railway Age Gazette* of December 5, 1913. At present all of the substructure has been finished except pier 5, which has been delayed by serious difficulty with quicksand. A comparatively slight delay was caused by a pocket of quicksand at one corner of pier 4, but as the material at the other end was solid, it was possible to divide the area, finish one end and then brace against the concrete to hold back the pressure of the soft material.

In pier 5, a stratum of quicksand extending over the whole area of the cofferdam was encountered about 75 ft. below the surface and 20 ft. above the rock. An attempt was made to drive sheeting inside the caisson to divide the area into 24 parts, each of which could be finished separately, but this sheeting was bent and displaced by boulders overlying the rock, making this method impracticable. It then became necessary to use a pneumatic caisson which was built in two chambers with two locks in each. The caisson was constructed with the cutting edge 27 ft. above rock; air was turned on December 13, and the caisson had been sunk 10 ft. on December 21.

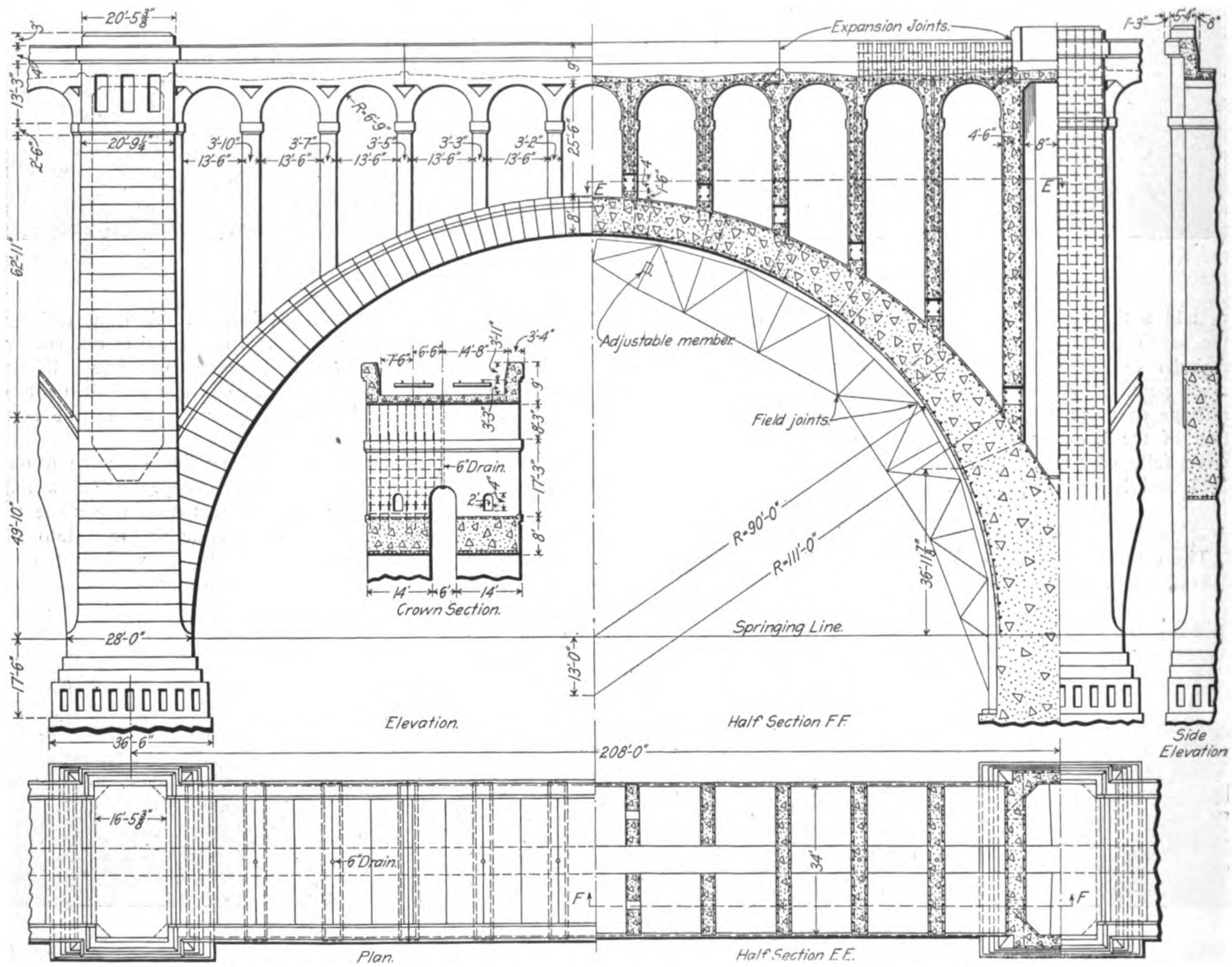
DESIGN OF CONCRETE ARCH VIADUCTS

As stated in the previous article, the substructure in reality includes the piers and the umbrella tops forming the skewbacks for the arch rings. The superstructure differs somewhat in the 100-ft. and the 180-ft. arches. The former are located at the ends of the structure and are termed abutment spans, as they are completely buried by the approach fill. In these spans the two arch ribs are 5 ft. 6 in. thick at the crown and 12 ft. wide. They are spaced 22 ft. center to center leaving a 10-ft. opening between the ribs and are tied together by four reinforced concrete struts. The ribs support reinforced transverse walls on which is carried a floor slab from 1 ft. 9 in. to 2 ft. 6 in. thick. An 18-in. curtain wall along each outside face closes the opening between the arch ring and the floor slab.

In the 180-ft. spans the arch ribs are 8 ft. thick at the crown and 14 ft. wide, the intrados being semi-circular; the extrados is segmental with a radius of 111 ft. The arch ribs are spaced 20 ft. center to center, leaving a 6 ft. opening between them. They support transverse walls varying in thickness from 3 ft. 2 in. to 4 ft. 6 in., which span the center opening. These walls are connected at the top by spandrel arches of 6 ft. 9 in. radius with a crown thickness of 1 ft. 9 in. Belt courses on the walls 1 ft. 6 in. below the springing line of the spandrel arches provide seats for the centers used in building these arches. The two walls over each pier are connected at the ends by pilasters 3 ft. thick, which stiffen the spandrel system and give the appearance of a solid pier.

Outline Elevation of Tunkhannock Creek Viaduct Showing Progress up to January 1, 1915

The floor is pitched 6 in. to the center of the transverse walls, the drainage being carried down through 6-in. pipes in these walls and discharged in the space between the arch ribs. The minimum depth of ballast is 12 in. over the expansion joints of which there are four on each span, two at the piers and one over the third transverse wall from each pier. These joints consist of a ¼-in. open space covered by a copper plate bent to project down into the joint slightly and with its edges turned down into grooves parallel with the joint, where it is held in



The General Elevation and Cross Section of the Tunkhannock Creek Viaduct

place by a mastic filling. The waterproofing is carried continuously over this plate. A parapet wall with an overall width of 3 ft. 4 in. extends 7 ft. 3 in. above the floor at the crown of the spandrel arches and the pilasters extend 3 ft. above the top of the parapet.

The general design of the Martin's creek viaduct is similar to the Tunkhannock creek bridge, except that it will carry three tracks and that seven of the eleven are 150 ft., three-centered arches, consisting of two ribs 17 ft. 6 in. wide with an open space of 12 ft. between ribs. The spandrel arches are flattened to conform with the appearance of the main arches. The total length of this structure is 1,600 ft., the base of rail is 150 ft. above the stream and 78,000 cu. yd. of concrete were required in its construction.

CONSTRUCTION OF CONCRETE ARCH VIADUCTS

The contractor's methods adopted in building the superstructures of the two large viaducts were practically the same, so that a description of the work on the Tunkhannock bridge will apply in general to the Martin's creek structure as well. As mentioned in the article on the substructures referred to above, all form material and concrete at Martin's creek were handled by derricks, while at Tunkhannock a combination of derricks and a double cableway is being used. The center tower of this cableway was 260 ft. high for the early stages of the work and was later raised by a 40-ft. addition in accordance with its design. Two duplicate concrete mixing plants at Tunkhannock and one at Martin's creek, each with a capacity of about 40 cu. yd. per hour, were provided.

With the exception of the abutment spans in both structures, for which wooden centers supported on wooden towers were used, the arch rings were built on self-supporting steel arch centers. These were seated on benches on the sides of the piers, which in the Tunkhannock bridge are 4 ft. 3 in. wide and 17 ft. 6 in. below the springing line. The spandrel arch centers and all forms are of wood. Five sets of arch centers are used, each of which supports a single main arch rib. After the construction of one rib in a span the centers are moved over under the other rib in the same span and used again without dismantling. In order to utilize both material cables at the same time, the centers are erected on alternate sides in adjacent spans.

Each set of steel centers consists of four three-hinged arches spaced 3 ft. 10 in. center to center and thoroughly braced. The assumed loading on these centers, including the weight of the trusses, lagging and forms, is 1,370,000 lb., which produces a maximum horizontal reaction at the lower skew back pins of 261,100 lb. During the lateral movement of the centers the thrust resulting from the weight of the trusses and lagging is taken by two 1 in. rods connecting these pins. The wind load on the forms is taken by four 1¾-in. anchor bolts extending into the concrete bench on each side of the pedestals. As an added precaution, the contractor used two ¾-in. steel cable guy lines from the crown of the centers.

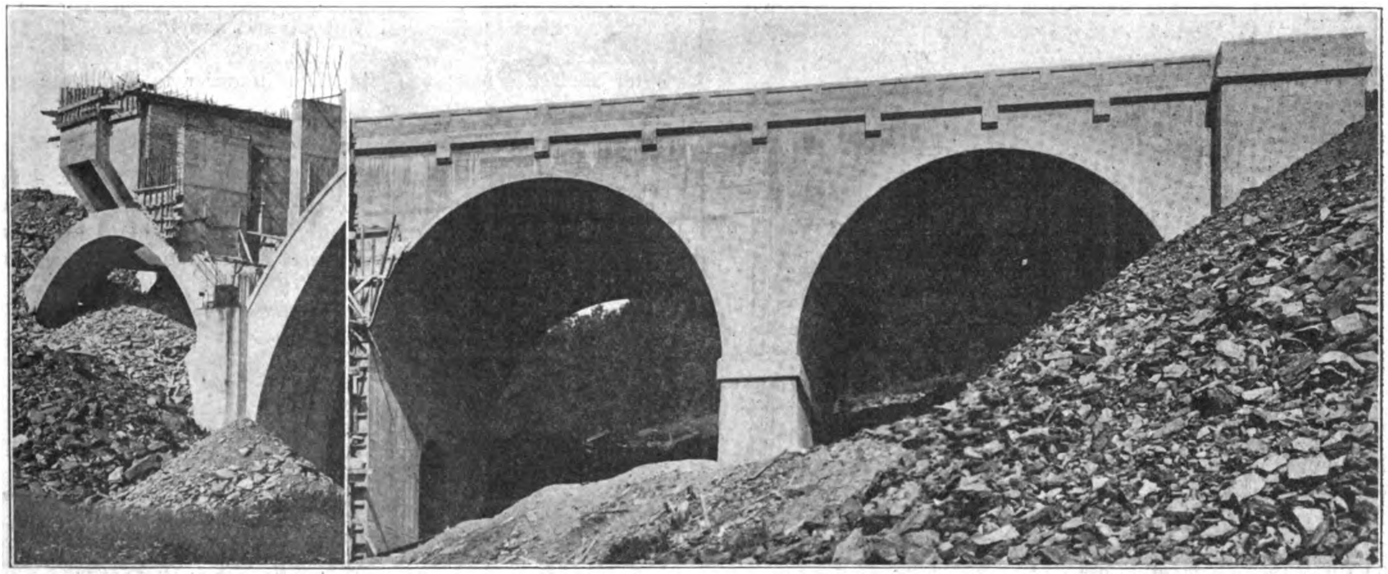
The four arch trusses in each set are supported by a pedestal 16 ft. 7 in. long. In order to provide for the side movement from one arch rib to the other, the base plate under this pedestal is provided with a guide rib ½ in. by 2½ in. which engages the shoulders of 6-in. rollers running on a bottom grillage. This grillage is 35 ft. 6 in. long, consisting of four 8-in. I-beams with top and bottom cover plates, the former having a guide plate to engage the rollers similar to the one on the pedestal.

The 3½-in. lagging is carried on planks set on edge over each rib with their outer edges curved to conform to the intradosal line. As the top pin is 6 ft. below the crowd of the arch, the lagging for one panel length on each side of the crown is carried on a rigid triangular frame above the top chord sections. The adjacent members of these frames over the pin are about 2 ft. apart at the crown, an oak block being supported in this space by bracket angles to carry the lagging over the joint.

The adjustment of the height of the centers necessary to strike them before removal is accomplished by changing the length of the diagonal members of the two panels adjacent to the crown. Pin connections are used in these panels to make this possible and the diagonals are each made in two pieces connected by bolts with left and right handed threads.

The centers, which have a total weight of about 200 tons, are erected by the cableway, each rib being handled in four pieces. The lower half of each semi-truss is erected first and held in position on the skewback pins by two temporary bolts through gas pipe sleeves in the concrete of the umbrella tops which bear on washer plates at the upper ends of the pipes and support a short I-beam yoke under the upper chords of the trusses. The upper halves are then erected and bolted to the lower sections, the entire semi-trusses being supported as cantilevers from the piers until the crown connections are made, converting them into three-hinged arches.

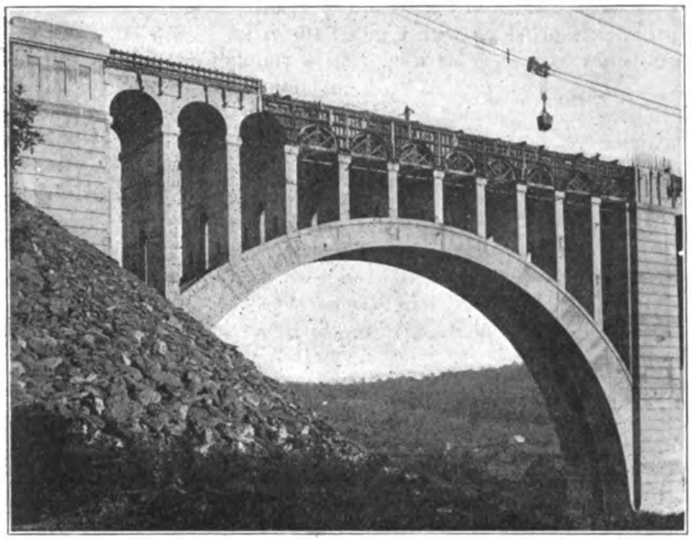
After the completion of the first rib, the centers are struck and are then jacked over on the grillage, a distance of 20 ft., to bring them under the second rib. After this rib is concreted and set, the centers are again struck and rolled into the space



The Abutment Span Before Completion and the Two Short End Spans of the Martin's Creek Bridge

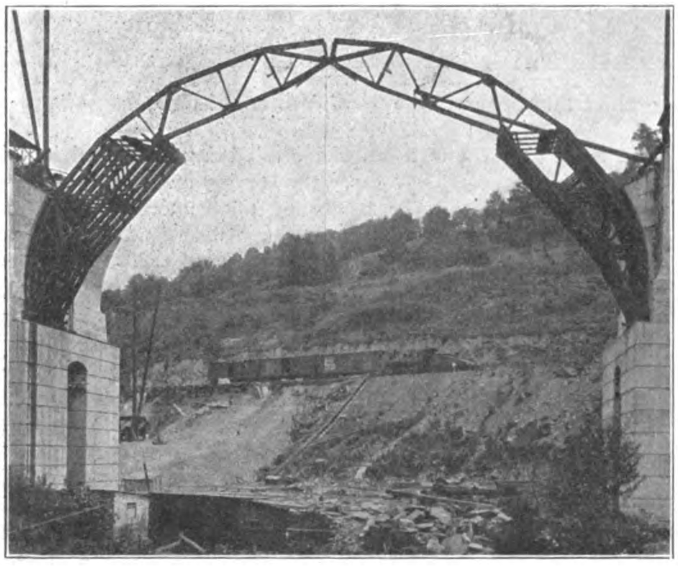
between ribs where the segments can be removed one at a time by the cableway for erection in another span.

Each arch rib consists of 11 vouissoirs and the necessary connecting key sections. The corresponding vouissoirs on opposite sides of the arch are concreted simultaneously, and after the last one is placed a set of seven days is allowed before the keys are put in. Separate forms are provided for the vouissoir blocks and the key sections allowing the former to be removed for use on another span while the keys are being placed.



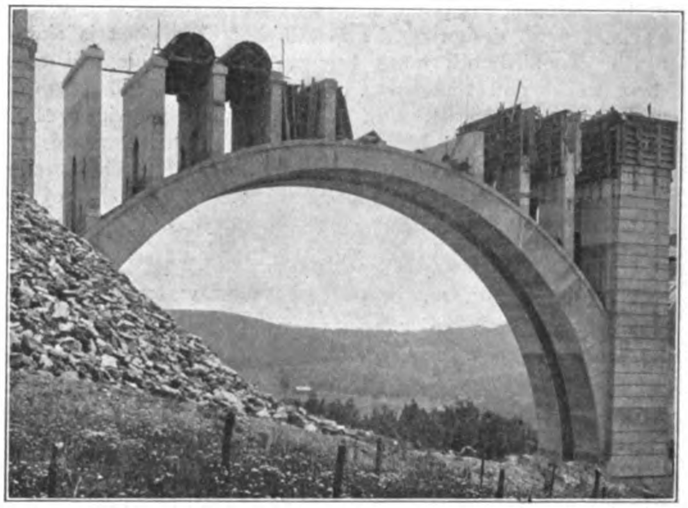
The End Span of the Tunkhannock Viaduct Showing the Pilasters at the Piers and the Spandrel Arches Partially Completed

All the concrete is handled in bottom dump buckets by the cableway from cars pulled by dinkey engines from the mixing plant. In most cases these buckets are dumped directly into the forms, but in the case of the spandrel walls for example, where the width of forms is not great enough to permit this, dumping platforms are used. A stiff-leg derrick was erected on the finished floor as soon as one section was completed and is moved out as the work progresses to handle the spandrel



Erection of the Steel Centers for One Span at Martin's Creek in Progress Showing Details of Crown Connection and Adjustable Members in the Top Panel of Each Semi-Truss

arch forms from under the completed floor at the sides of the bridge, thus obviating the necessity for using the cableway for eccentric loads. In hot weather each floor section is kept flooded until it has set, and in cold weather a tarpaulin cover is provided and a steam pipe run in to heat the surface. The lower section of the parapet walls up to the first offset on the



A Construction View at Tunkhannock Creek Showing Forms in Place for Spandrel Walls, Arches and Pilaster

outer surface is cast with the floor in order to avoid the appearance of a construction joint.

THE NICHOLSON TUNNEL

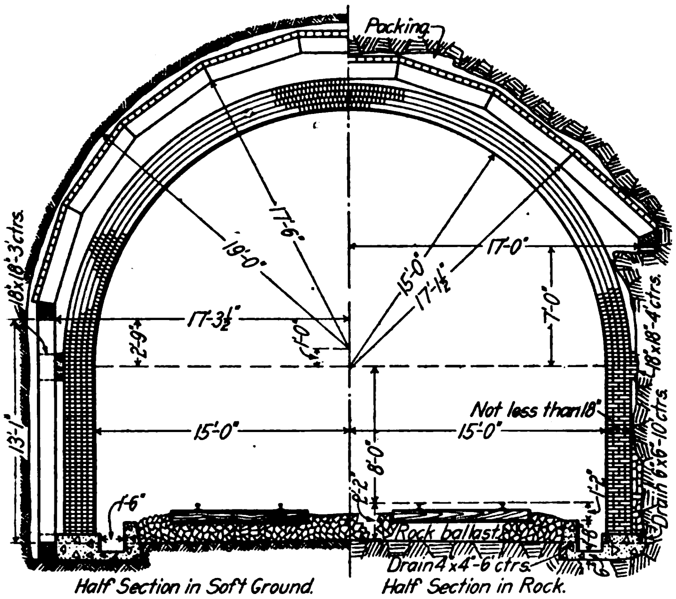
The excavation in the double track tunnel 3,630 ft. long near Nicholson, amounting to 146,000 cu. yd. was completed about the first of November, and work is now in progress on the lining of this bore, 1,600 lineal ft. of lining having been

Two Spans of the Tunkhannock Viaduct in Each of Which One Rib Has Been Finished and the Centers Are Now in Place Under the Second Rib

completed. As mentioned in one of the previous articles, two shafts were driven at the third points in order to advance the work before the completion of the portal cuts, which are about 100 ft. deep, and one of which contains over 1,000,000 cu. yd. of material.

Center top headings 9 ft. by 12 ft. were driven in both directions from each shaft and also in from the west portal as soon as the cut at that end had progressed far enough to make this possible. These headings were later widened to allow the placing of the wall plates and the 12 in. by 12 in. roof timbers, which were spaced 4 ft. center to center. The remainder of the section was excavated by a single pass of a 40-ton Marion shovel operated by compressed air. The material was shot down ahead of the shovel in two benches, the upper having a face of about 6 ft. and the lower about 12 ft. The shovel loaded the material into 6-yd. cars operated in trains of 10 by dinkey engines burning hard coal.

Two tracks were provided in the tunnel for this narrow gage equipment with a switch about 200 to 300 ft. from the working face. A train of empty cars would be pushed up to this switch on one of the tracks and the loaded cars collected by another engine on the other track. The first engine would push in two empty cars to the shovel, run back of the switch, the second engine would come up and pull out the two cars as soon as loaded, and the first engine would then set in two more. By the time the loaded train was ready to leave, another train of empty cars would arrive and the process be continued, always having two engines at the shovel to switch the cars. The haul varied from ½ mile to one mile from the portal. The shovel completed the excavation in 350 days elapsed time,



Typical Cross Section in Earth and Rock of the Nicholson Double Track Tunnel

making a progress of about 12 ft. per day of actual working time.

Three compressors located in a plant at the west end supplied air for the shovel and drills, the 10-in. air main being carried for a maximum distance of about one mile. A generator located in the compressor plant furnished electricity for lighting the tunnel during the placing of the lining, although large carbide torches and individual gasolene lights were used until the completion of the excavation.

The tunnel is being lined with vitrified brick which has been shown in extensive tests to have a high compressive strength and resistance to corrosion. The estimates showed that a concrete lining could be placed for about 60 per cent less per cubic yard than the brick, but the yardage is decreased by using the brick so that the comparison of the total costs does not show as great a difference. The proximity of unusually good supplies of brick was a factor considered in this case. The side bricks are obtained in Corning, N. Y., and the arch bricks in Scranton, Pa. The bricks are of two sizes, those in the side walls being 2¼ in. by 4 in. by 8¾ in., and those in the arch 2¾ in. by 4 in. by 8 in. The lining is four courses thick, except in the short section of earth near the east end, where a fifth course is added.

The brick lining is carried on a concrete footing which is extended toward the tracks to form an open drain 18 in. wide and 12 in. deep. The thrust of the arch is taken by 18 in. square thrust blocks of brick at the springing line, spaced 4 ft. center to center. The space above the ring and behind the side walls is back-filled with selected rock, and 6 in. by 6 in. drains through the concrete footings at intervals of 10 ft. afford an outlet for any water collecting behind the lining. In the east approach cut where the grade is descending toward the tunnel, a vitrified pipe line for drainage will be laid with a grade sloping away from the tunnel. So far no difficulty has been encountered with water, and none is anticipated.

The concrete footings are built in 15-ft. form sections, the concrete being mixed at the top of one of the shafts and lowered by a derrick. A crusher was installed here to supply crushed stone for this concrete, using the rock removed from the tunnel. The output of the crusher was also used for the concrete in a small culvert near by.

The brick arch is being built on four 32-ft. sections of centering which are moved forward on wheels. Bricks are laid in 1:2 cement mortar mixed by an electrically operated Ransome mixer in the tunnel. A motor-driven conveyor is also used to elevate the bricks and the mortar to the working platform of the centering. The mason gang employed at present on this work can average 1,500 to 2,000 bricks per man in an eight-hour day.

The plans for this cut-off line and the construction work have been handled under the supervision of G. J. Ray, chief engineer. The designs for the large concrete arch viaducts were made by A. B. Cohen, concrete engineer. All field construction work is directed by F. L. Wheaton, engineer of construction, the residency including the Tunkhannock viaduct, the Nicholson tunnel being in charge of C. W. Simpson, resident engineer.

LAFAYETTE YOUNG ON GOVERNMENT OWNERSHIP

[From the Des Moines Capital]

The railroads are out of politics. In a political sense they are boycotted. Prove that a man is subservient to railroad influence and his defeat is certain. The conditions are much better because these achievements have been had.

Therefore, we cannot agree with Dr. Frank Crane in his desire to put all the corporations into politics. He wants the railroads, tramways, telephone and telegraph lines, and all other systems of transportation; all water-ways, all electricity, gas and the like put under the ownership of the government.

The editor of The Capital has been in nearly every country in the world, and we can say truthfully that the telegraph and telephone lines, also the railway lines, are better managed in the United States, and give better service than in any country in the world where government ownership prevails. The charges in the United States are not excessive.

In a republic where the majority rules, and the majority are in the government employ, what are the other people going to do? We very much fear that under universal government ownership American politics would become so corrupt that the government itself would go down under the weight.

Government ownership is justifiable only when private ownership everlastingly fails. Some arguments could be put up for government slaughter and packing houses; even for flouring mills. But when the transportation business is well managed, why put millions into it?

We venture the statement that very few businesses in America have been destroyed by transportation charges.

Dr. Crane points to higher conditions morally, and anticipates an appreciation of responsibility upon the part of everybody, which is not at present warranted by the facts.

Moody's Magazine

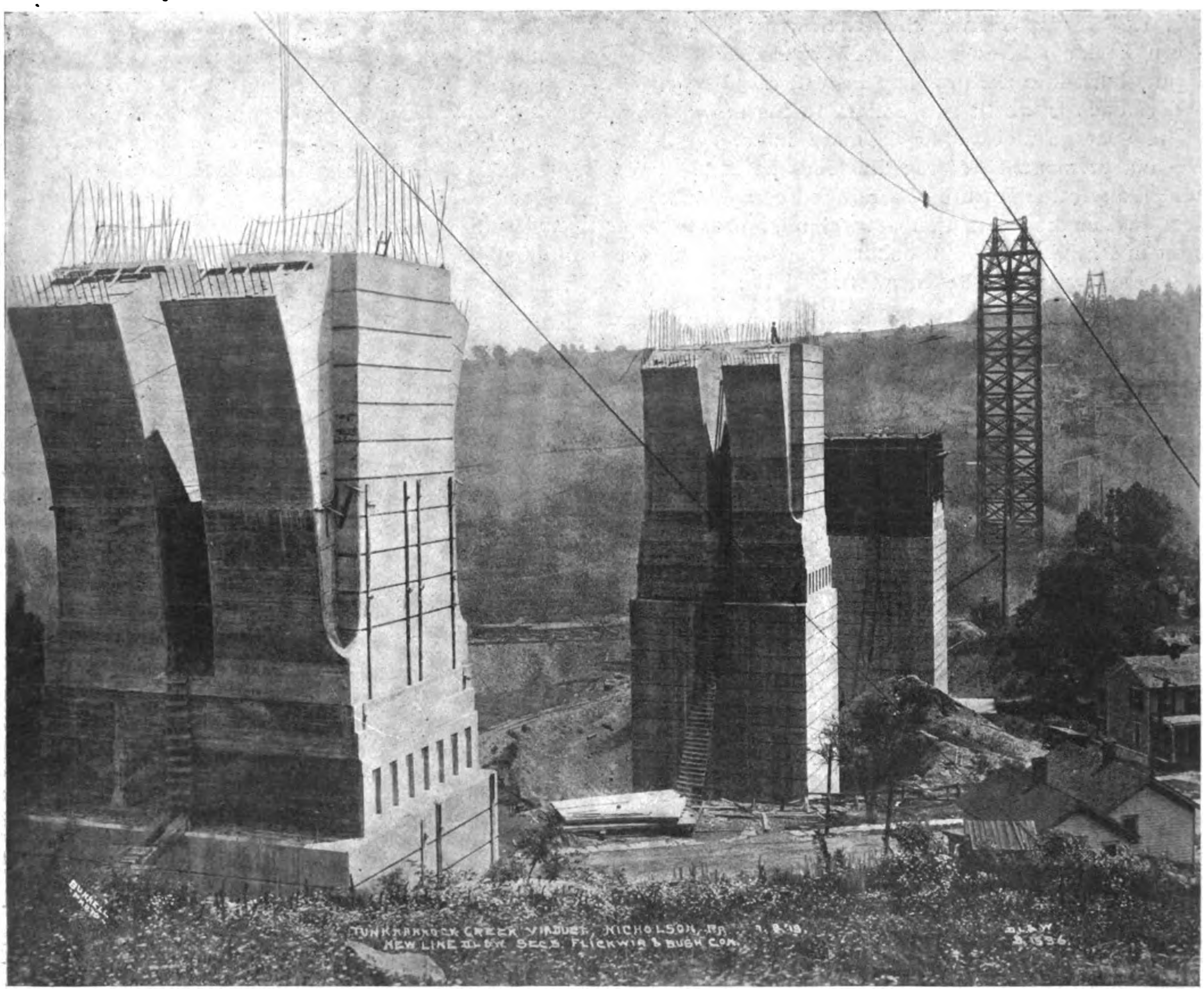
THE INVESTOR'S MONTHLY

Vol. XVI

July, 1913---December, 1913

The Moody Magazine & Book Company, Inc.
35 Nassau Street, New York
1913

The big saving will come not so much from the shortening of track as from the reduction of curvature and grades. Sharp curves and grades reduce speed and the former add immensely to the cost of maintenance of rolling stock. The illustration showing a stretch of the present tracks and the excavation for the new line of track which will replace it graphically indicates what the change will mean. The present tracks curve gracefully and repeatedly to a point in the distance which the new tracks will reach in an absolutely straight line.



THE FORMIDABLE PIERS OF THE TUNKHANNOCK CREEK VIADUCT.
The lines showing at the top, resembling wires, are substantial steel rods which bind the cement.

To determine the amount of saving the new work will bring about the engineering department has studied every possible phase, getting down to so fine a point as to consider the waste employed in engine maintenance. The items considered were:

(1) The total cost of operation and maintenance for the year 1910.

(2) Total train miles for 1910, exclusive of work train mileage.

(3) Cost of operation and maintenance per train mile; that is, Item 1, divided by Item 2—$1.67.

(4) Average yearly increased cost of operation and maintenance per train mile from 1900 to 1910, 4.4%.

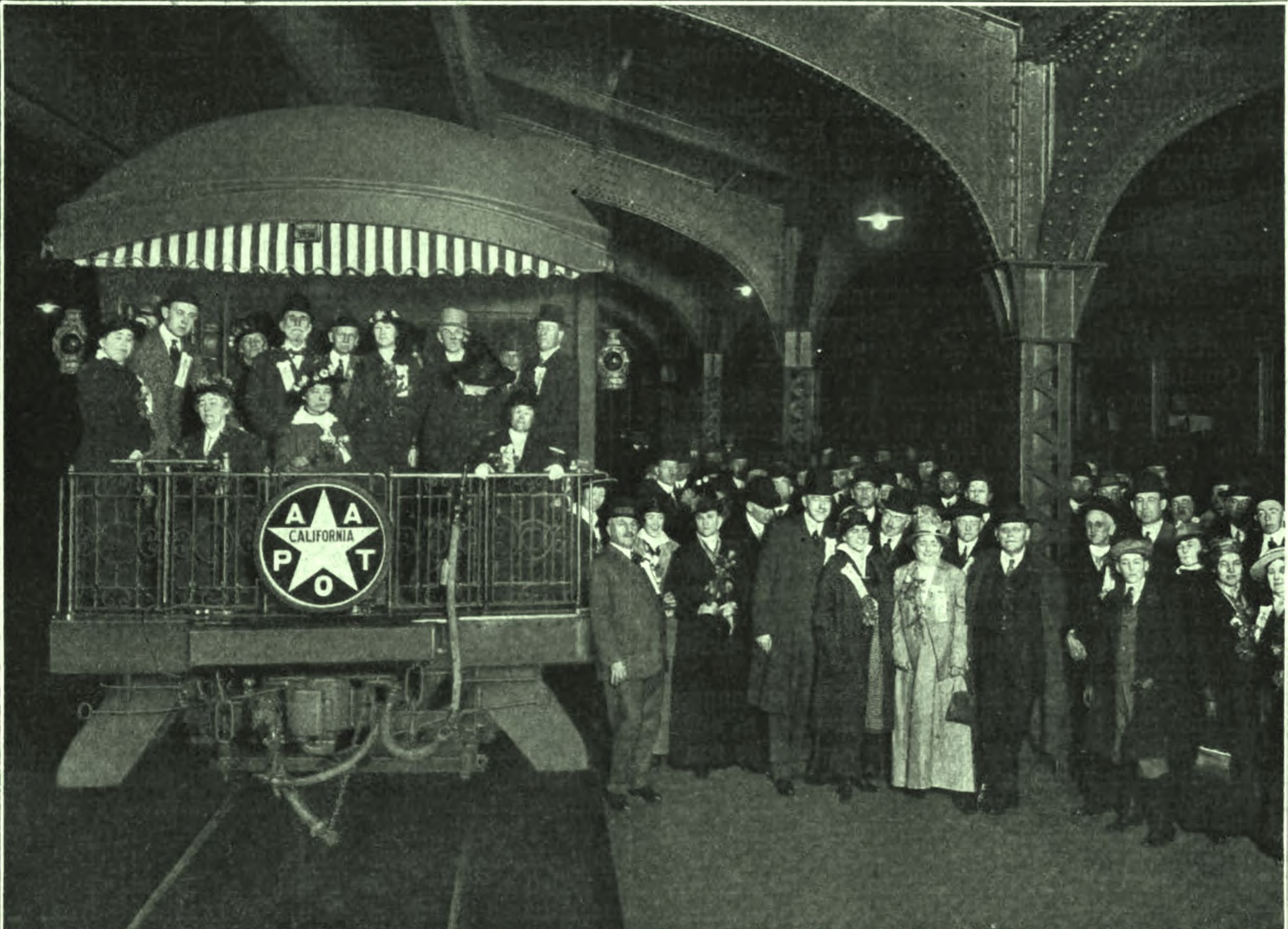
(5) Average yearly increase in net tons of freight handled, 1900 to 1910—7.425%.

(6) Average yearly increase in passengers carried, 1900 to 1910—8.2%.

(7) Total net tons manifest freight, moved over the territory in question, 1910. East, 1,324,907; West, 592,-713.

(8) Total net tons of all classes of freight moved over the territory in question, 1910: East, 3,134,688; West, 6,967,267.

(9) Total number of freight cars moved over the territory in question, 1910: East, 188,237 loads; West, 143,279 loads; East, 122,919 empties; West, 123,146 empties; total tons East, 8,306,003; total tons West, 12,066,973. (Continued on page 192.)



Railway journal

National Association of Railway Agents

LACKAWANNA'S BIG VIADUCT.

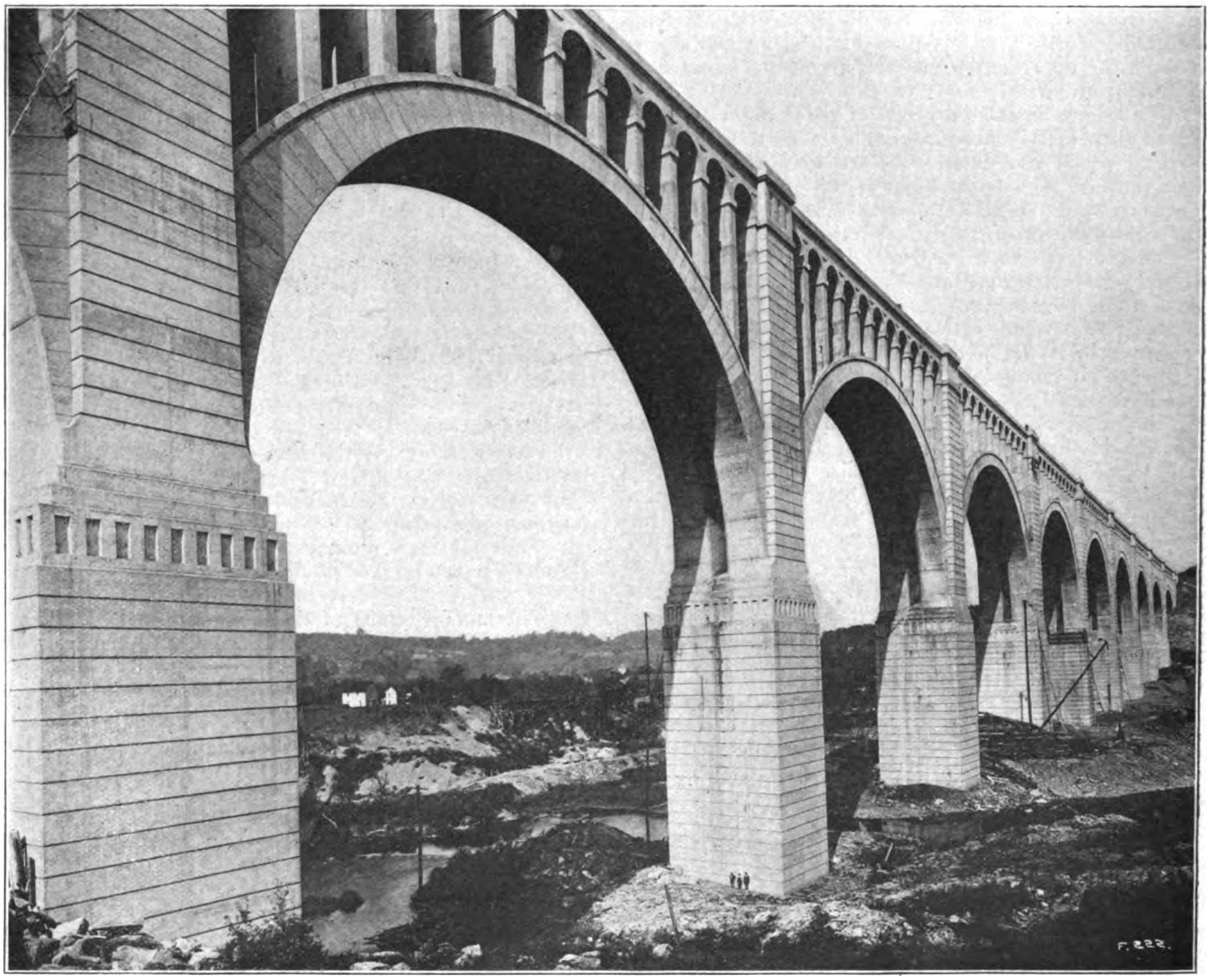
On November 7 the Delaware, Lackawanna & Western opened for traffic its cut-off between Clark's Summit and Hallstead, Pa., 39.6 miles, reducing the distance between New York and Buffalo only 3.6 miles.

The engineering features of this cut-off are interesting and were costly to the company; the cost is approximately $12,000,000. Some very heavy fills were required, a number of big cuts, a tunnel (double track) 3,630 feet long and a concrete viaduct over the Tunkhannock valley are among the heavy pieces of work necessary. The tunnel with its approach cuts aggregated 27,000,000 cubic feet of excavation.

The accompanying illustrations show the Tunkhannock concrete viaduct, which is 240 feet high at lowest part of the valley, is half a mile long, and is claimed to be the largest concrete railroad viaduct in the world. The viaduct proper consists of ten spans of 180 feet each and two spans of 100 feet each. It contains approximately 4,509,000 cubic feet of concrete, and 2,280,000 pounds of re-enforcing steel. The railroad tracks are enclosed between massive parapet walls 3 feet thick and rising above the track to a heighth of 4 feet, thus insuring safety without interfering with the extraordinary view from train windows. All of the foundations were carried to solid rock. Two of the piers required an excavation of 95 feet in depth, while the excavation for the piers in the bottom of the valley was carried through sand, gravel and boulders to a depth of 60 feet below the water level.

By this cut-off the maximum grade is reduced from 1.23% to .68%; formerly the total curvature was 3970 degrees; it is now reduced to 1570 degrees.

At Martin's Creek another viaduct was built which is 150 feet high and 1600 feet long, containing 11 spans, 7 of which are each 150 feet long, 2 are 100 feet and 2 are 50 feet each. In this viaduct 2,092,500 cubic feet of concrete were used and 1,600,000 pounds of reinforcing steel. The entire work of building this cut-off was planned and executed by George J. Ray. F. L. Wheaton was chief engineer of construction in immediate charge of the work. The Tunkhannock viaduct was built under the personal supervision of F. M. Talbot.



TUNKHANNOCK VIADUCT, DELAWARE, LACKAWANNA & WESTERN RAILWAY.

The I. C. Commission has ruled that railroads are justified in charging two train fares for drawing rooms and one and a half train fares for compartments on sleeping cars, exclusive of Pullman charges.

TRAFFIC AND FINANCE.

The Baltimore & Ohio has secret agents taking snap shots of its employes if caught drinking intoxicating liquors.

Plans are being formulated for the reorganization of the Frisco System along an assessment plan about $50 per share.

Though there has been no serious shortage of freight cars on western and southern roads, they are all showing big gains in freight earnings.

J. W. Kendrick, special examiner of the Rock Island property, estimates that $35,000,000 should be expended on that system in the next five years.

Banker Jacob H. Schiff, of New York, says: "Prosperity has come and prosperity is going to stay. It is not going to cease with the end of the war."

According to Garrett Fort, general passenger agent of the Union Pacific, the railroads of the United States expend about $10,000,000 per year on advertising.

The Great Northern Pacific S. S. Co. announces that, effective November 26, it inaugurated service between San Francisco and Honolulu, touching at San Pedro and Hilo.

The U. S. Supreme Court holds that a railroad company has a right to confiscate a ticket or mileage book if presented for transportation by anyone other than the original purchaser.

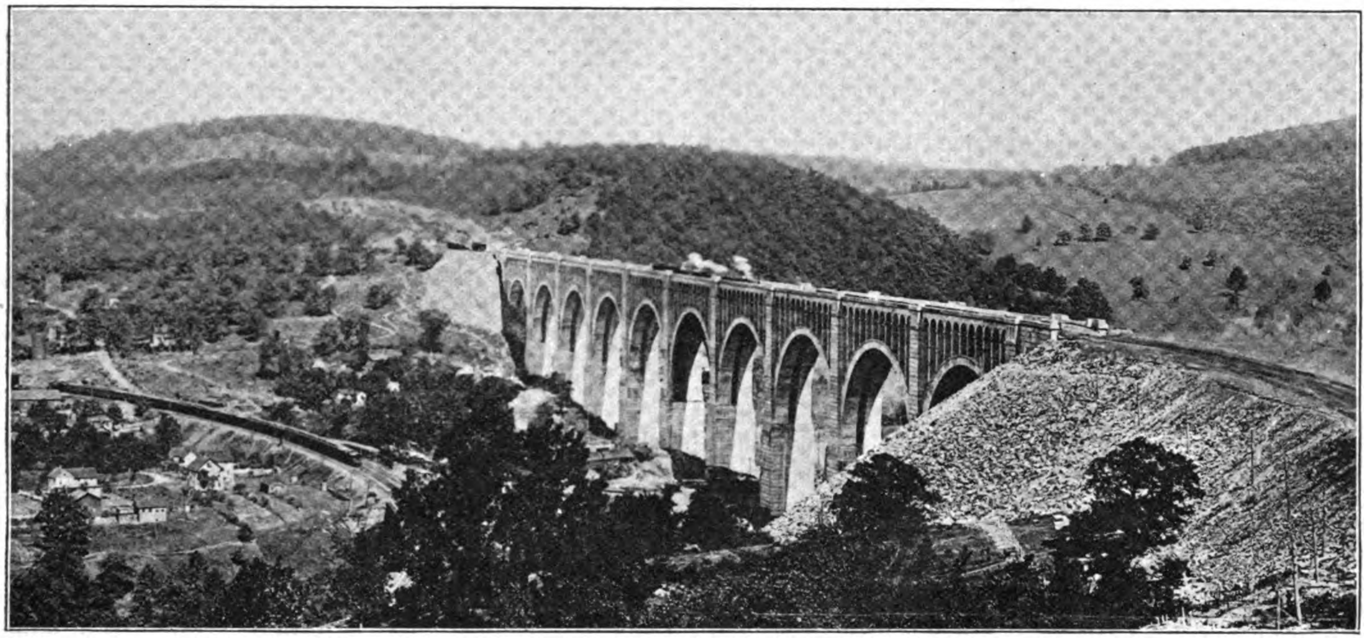
J. J. Hill states that the Great Northern should carry about 185,000,000 bushels of grain this year as against 112,000,000 last year. He estimates the November earnings this year to exceed those of November in 1914 by $2,000,000 or more.

Transporting hunting and pet canines was a source of $10,000 revenue to the Baltimore & Ohio Railroad last year, according to reports of the baggage department; at a charge of twenty-five cents each, 40,000 dogs were handled without a claim for loss or injury.

The Pacific Mail S. S. Co. has discontinued its agency at Acapulco, Mexico, after fifty years' service at that point. This has been the chief port of call between San Francisco and Panama for steamers of this company. Several new companies are getting into that field as the result of the Pacific Mail Co.'s action.

The Wall Street Journal says that a "federal statute conferring upon some federal body, say the Interstate Commerce Commission, the power to pass upon any proposed railway reorganization, is greatly needed and should be enacted by Congress at the coming session."

The Luckenbach Steamship Company has announced that it will be compelled to abandon its San Francisco-New York service and sell its ships or transfer them to foreign registry unless the Panama Railroad freight rates set forth in the latest schedule are modified. On account of the frequent slides in the Panama Canal, steamship lines operating through it have to also figure on cost of transfer across the isthmus in the event the waterway is not open, which seems to be most of the time.



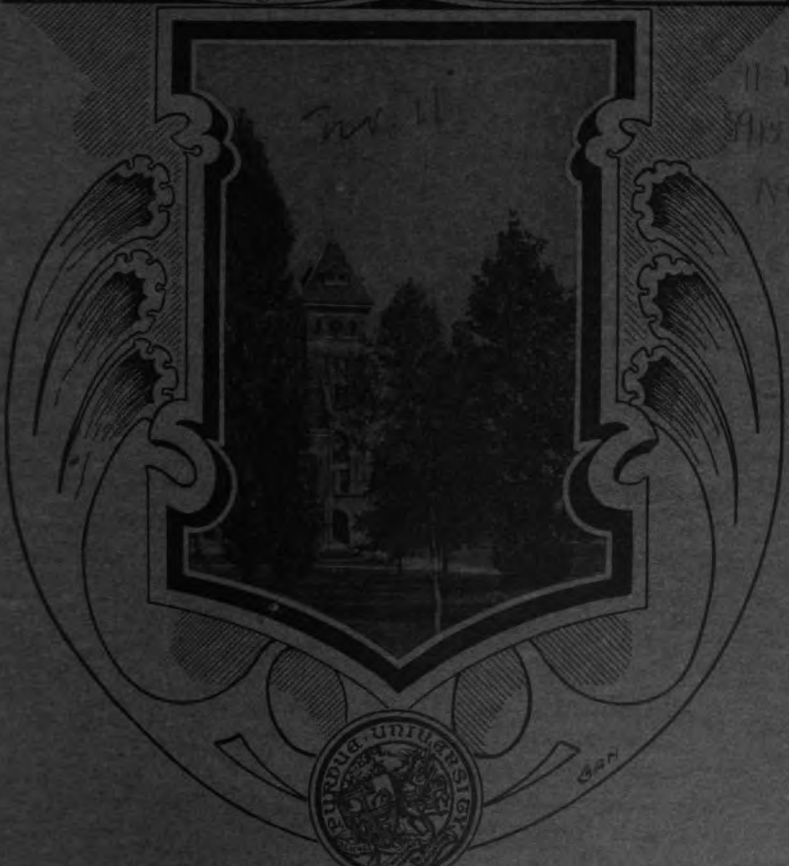
TUNKHANNOCK VALLEY, SHOWING VIADUCT.

Vice President Thompson of the Baltimore & Ohio says that that road is handling the biggest business in the history of the road. "The increase in business has necessitated our taking several locomotives out of storage, but the Baltimore & Ohio has a sufficient number in reserve to move business during cold weather. When cold weather prevails the hauling capacity of locomotives is lessened; in fact, as soon as the temperature falls below 45 degrees the loading must either be decreased or extra engines put in service. It is calculated that with a drop of every 10 degrees below 35 degrees from 70 to 90 extra locomotives are required to move our same business. With the engines in good repair and a number of them held in reserve for cold weather, the Baltimore & Ohio will enter upon its winter business better than in previous years."

Dr. Joseph F. Tearney, chief medical examiner of the Baltimore & Ohio, has placed a ban on alcoholic liquors as a medicine or stimulant.

The United States government has begun actual construction work on the Alaskan railway, with a force of 1,400 men. An appropriation of $35,000,000 has been made for this road, a sum about five times as great as the purchase price of Alaska less than 50 years ago.

The Purdue ENGINEERING REVIEW



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1915

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EXPANSION AND CONSTRUCTION JOINTS IN REINFORCED CONCRETE VIADUCTS

By A. B. Cohen, '05*

Synopsis: Are expansion joints necessary and on what types of concrete construction?
What has been the experience of the D. L. & W. Ry. with expansion joints on the several large viaducts recently constructed on their system?
These questions and others pertaining to the details of expansion and construction joints, Mr. Cohen answers in this article.

Second only in importance to the determination of the most economical sections in reinforced concrete design of any magnitude, is the detail of expansion joints and following this consideration closely, is the location of the construction joints. These details are so important that it sometimes becomes necessary to waive economic considerations in order to properly provide for stresses due to temperature changes; to proportion sections for construction consistent with the daily capacity of the plant thus precluding the possibility of stopping work at a critical point that would impair the strength of an important member.

Expansion joints are unnecessary in bridges of about one hundred feet in length. The slight movement due to temperature changes is taken up by the elasticity of the structure. For greater lengths, the movement due to these changes becomes appreciable and owing to the low tensile strength of concrete, expansion joints dividing the structure into smaller units are necessary to prevent dangerous and unsightly cracks.

There is, however, a type of reinforced concrete construction known as the flat slab system which has been used for viaducts of great length without resorting to expansion joints. Eighteen and one-half acres of ground were covered by this type of design in the construction of the "Soo Line" Terminal at Chicago. The Delaware, Lackawanna & Western Railroad has just completed a combination viaduct and station of similar design, in eliminating the grade crossings by track elevation through South Orange, New Jersey. This system has also been adopted for an elevated structure supporting seven tracks in the Lackawanna Terminal improvements now under way at Buffalo, New York. The structure will be 150 feet in width and 1,000 feet in length.

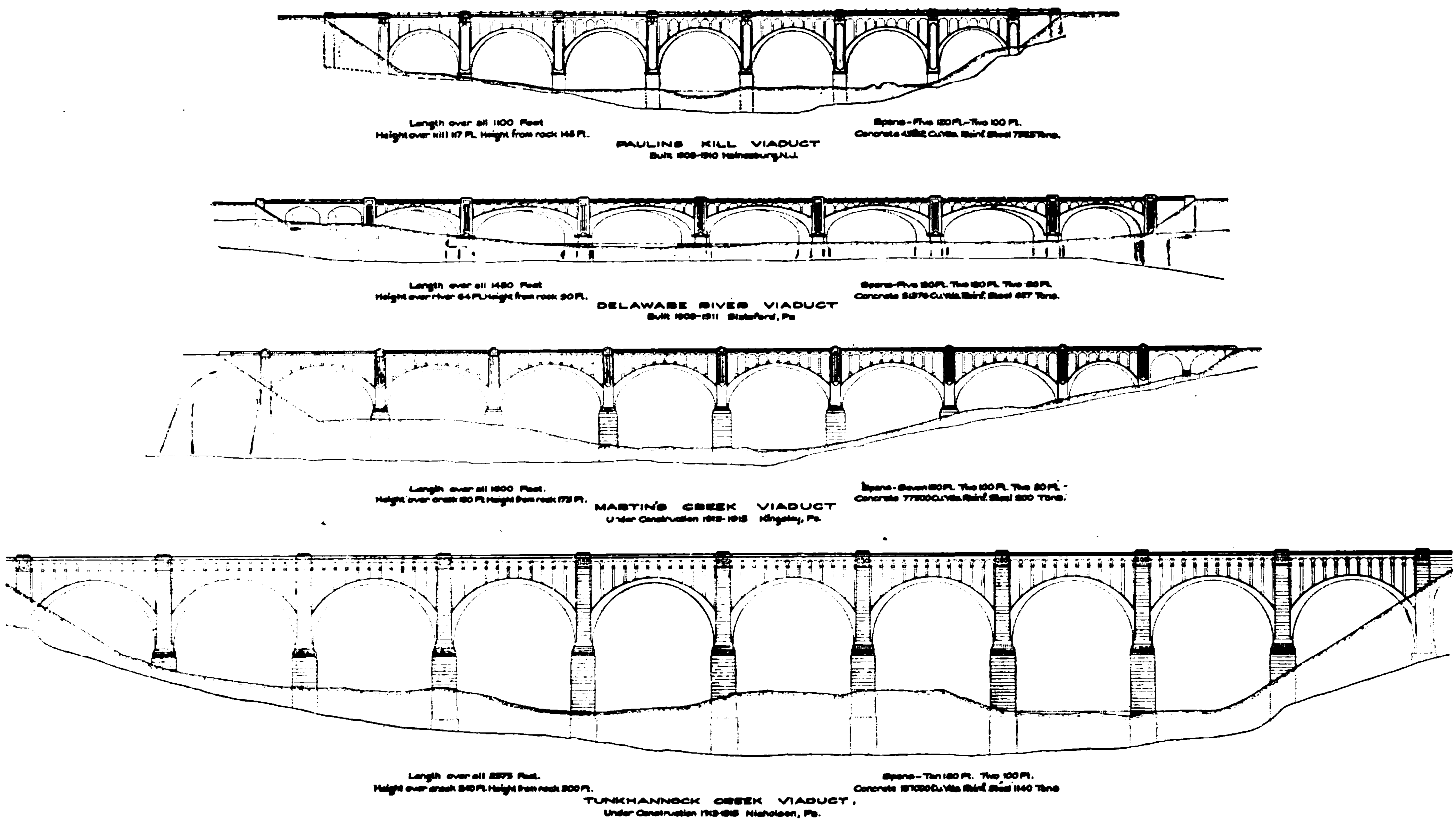
The flat slab system consists of a slab of uniform cross-

*Engineer of Concrete Design, Delaware, Lackawanna and Western Ry., Hoboken, N. J.

section, supported on columns forming panels 20 to 30 feet square. There are no beams or girders and the loads are carried from the slab directly to the columns. Because of the uniform cross-section, the slab can be effectively reinforced for changes in length due to temperature variations, by inserting steel bars to maintain a constant tensile strength throughout and particularly across the construction joints. Since steel and concrete have approximately equal rates of expansion, no amount of steel would prevent cracks resulting from the temperature changes. The steel, however, prevents cumulative action of the stress at any particular section and distributes the strain uniformly, resulting in an infinite number of minute cracks. Our experience with this type of construction does not extend over a sufficient length of time to ascertain definitely what effect the repeated action due to temperature changes will eventually have on the strength of the structure. Very close observations of existing structures of flat slab construction without expansion joints have disclosed no deleterious effect due to these causes.

In concrete viaducts consisting of a series of arches, surmounted by transverse spandrel walls supporting a floor system, or in viaducts of the column, beam and slab design, the temperature changes are of more vital consequence. In the case of the beam and slab design, the constituent members have different sections and therefore offer varying degrees of tensile resistance. There arises the difficulty of transferring the movement due to temperature from the larger through the smaller members, as from the deep beams through the thin slabs. In the arch type, the very appreciable vertical movement of the heavy arch ring, for a rise and fall of temperature, is transferred to the comparatively light floor system, which must also resist its own movement in a horizontal plane. These movements cannot be resisted by the addition of any amount of steel, and expansion joints must therefore be provided.

In 1911, the Delaware, Lackawanna & Western Railroad completed two large concrete structures known as the Delaware River and Paulins Kill viaducts (see plate 1) on a 28-mile revision of the main line across the western part of New Jersey. In connection with the design of these structures, after an extended investigation had been made of existing structures of similar type, it was decided to construct the viaducts without expansion joints in the floor system. No precise data could be obtained at that time



D.L.&W.R.R.
CONCRETE VIADUCTS
SCALE

Fig. 1.

concerning the extent of the seemingly small rise and fall of the existing arches. It was thought that most of the cracks, attributed to temperature changes, were due to shrinkage of the concrete in the first few months of construction and that if the viaducts with foundations carried to rock were built in such a manner as to minimize this action, the expansion joints could be eliminated.

The plan and sequence of construction were outlined in the following manner: the main arch rings were built in voussoir blocks about ten feet in length measured along the axis of the arch ring and spaced two feet apart. The blocks were allowed to set seven days before the two foot openings or keys were poured and twenty-eight days after the last key was poured the arch center was removed. This eliminated an undue settlement of the arch ring due to shrinkage and the theoretical crown elevation for which the arch was designed was further insured by cambering the arch center for its deflection under the ring load. No part of the floor system was built until the arch centers had been removed. The floor was built in alternate sections, but the reinforcing steel in the slab was continuous for the full length of the viaduct, which, in conjunction with the elasticity of the superstructure, was deemed adequate to resist the rise and fall of the arch ring without the formation of large cracks. It was expected that a number of small cracks would result from this movement, but these were not considered so objectionable as the leaky expansion joints that were in evidence on most of the structures inspected.

An examination of the Delaware River and Paulins Kill viaducts, after they had been in service for some time, disclosed the fact that large transverse cracks had formed at the crown of each of the two spandrel arches adjacent to every pier of the viaduct. This indicated that there had been a drop of the main arch rings due to fall in temperature. (See Plate II). Over the crown, the spandrel arches were in compression and no cracks developed while those adjacent to the pier were in tension. It may be here noted that the floor system was built during the summer months and therefore the movement in the main arch ring due to rise in temperature, would bring the floor system back to its normal position, or, if there were a movement beyond this it would be so slight as to make its effect on the floor system directly over the crown negligible, as compared with the effect of a fall in temperature on the floor adjacent to the piers.

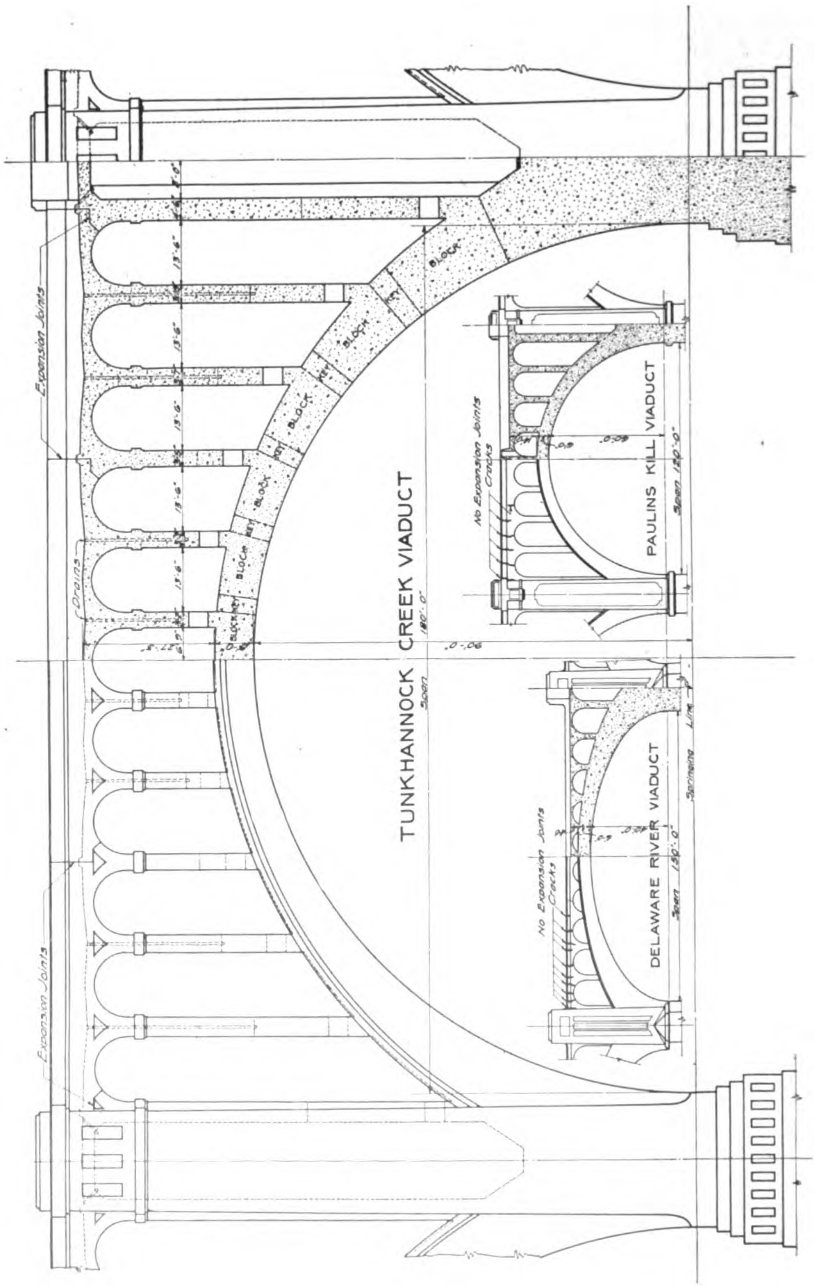

TUNKHANNOCK CREEK VIADUCT
Span 180'-0"
PAULINS KILL VIADUCT
Span 120'-0"
DELAWARE RIVER VIADUCT
Span 150'-0"
Expansion Joints
Drains
No Expansion Joints
Cracks
Springing Line
BLOCK
KEY

Fig. 2.

In view of the above observations, it was decided in designing the Tunkhannock and Martins Creek viaducts, recently completed on another revision of the main line west of Scranton, Pa., that expansion joints were necessary in the floor system at the piers and quarter points of every span. The quarter points of the span are approximately the points of contraflexure in the arch ring. For a fall in temperature the extrados of the arch ring between the points of contraflexure is in compression, beyond these points in tension and vice versa for a rise in temperature. The expansion joints divide the superstructure into three parts, separated at the points of contraflexure, each section acting in compression or tension as the case may be. This arrangement has proved successful for both viaducts, which have been exposed to the entire range of temperature.

In the detail of the expansion joints, it is imperative that a minimum amount of sliding surface be provided, otherwise the frictional resistance becomes greater than the tensile strength of the floor, which would cause cracks to develop adjacent to the so-called expansion joints. The sliding surfaces of the expansion joints of the big viaducts were lubricated by an asphaltic membrane. The drainage is prevented from percolating through the joints by dykes built across the floor.

As previously stated, the construction joints should be given careful consideration. It is a necessary precaution, in concrete design, to indicate the construction joints on the plans, in order to guide the foreman or superintendent who is frequently unfamiliar with the theory of design. Otherwise, a joint might be placed, for example, at a point of maximum shear, or at the junction of the stem and flange of a T beam. The massive solid piers of the Tunkhannock Creek viaduct were scored horizontally by nailing strips of moulding to the inside of the forms. These strips mark the construction joints four feet apart. Each of these sections contains 234 cubic yards, which is approximately the eight-hour capacity of a two-yard mixer. For the reinforced sections of the viaduct, the length of the reinforcing rods was so fixed that only the required lap projected beyond the construction joints, obviating the necessity of supporting dangling rods above the forms.

The precautions that were taken, to minimize the settlement due to shrinkage in the construction of the arch ring of the Delaware River and Paulins Kill viaducts, were repeated in the construction of the Tunkhannock and Martins Creek viaducts. Each main arch of these structures was built in two separate ribs. It is an interesting fact, that after the arch centers were struck, there was the slight settlement of one-quarter of an inch in one, one-eighth of an inch in three and no settlement in the other sixteen ribs.

Civil Engineering Building, Purdue University

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1915

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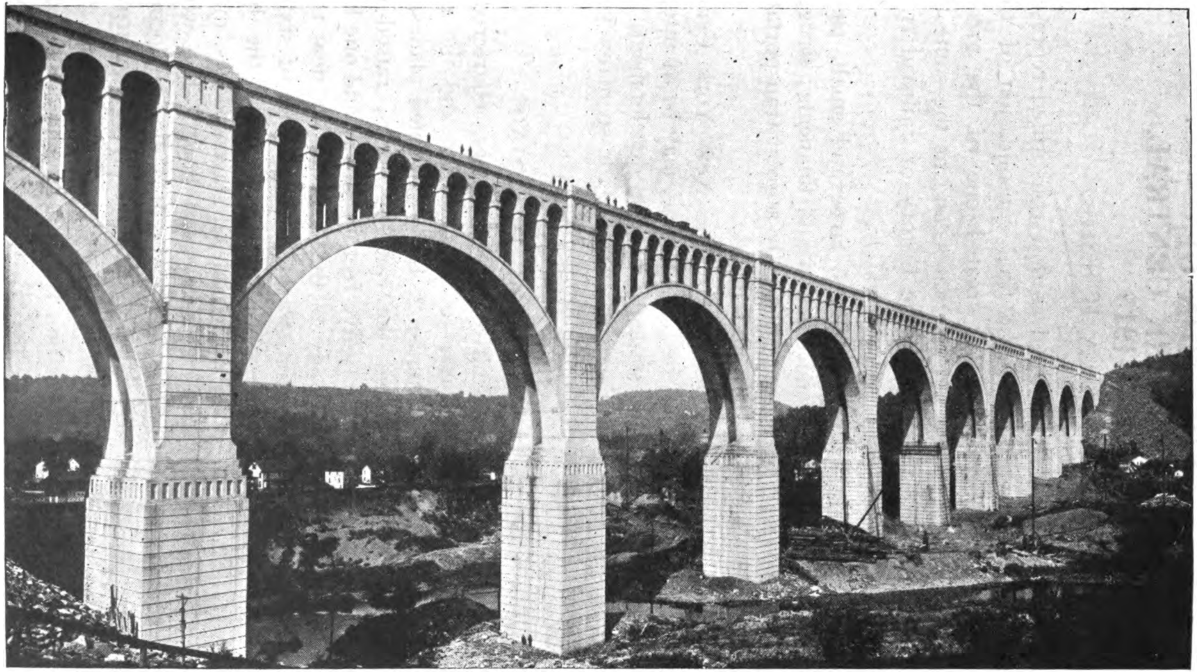
THE GREAT TUNKHANNOCK VIADUCT



This viaduct, which is the largest in the world, was built in connection with the Lackawanna Railroad's new 39-mile Scranton-Binghamton cut-off. It is half a mile long and 240 feet high and consists of ten spans of 180 feet each and two spans of 100 feet each. Some of the foundations were carried down to a depth of 95 feet before reaching solid rock.

The Technical world magazine

THREE MILLIONS *a* MILE

By Charles Frederick Carter

AT the close of a recent convention of the American Society of Civil Engineers, the society adjourned to look at a half-completed job on the Lackawanna Railroad in order to see why that company had made up its mind to spend twelve million dollars on a piece of engineering work that was to cut off but three and six-tenths miles between two little towns on its route. They advanced, a force of four hundred, on a naked viaduct stretching out over a valley at a tremendous height, and soon they saw.

The Lackawanna was not attempting to shorten the time between two big cities when it undertook this monster work; the three and six-tenths miles of cut-off were a minor consideration. The grades through this particular district of the Alleghany Mountains, one hundred and fifty-two miles west of New York, are steep and long; the curves are sharp and frequent, and the saving in power which is to accrue by reason of the removal of these two handicaps will be tremendous. Figures show that the expenditure of the twelve million dollars is thoroughly justified.

The Lackawanna Railroad was originally a one-horse affair, intended solely as a means of getting hard coal to market. The engineers who built it did the best they could with the meager means at their disposal; and their best must have been wondrous good, when it is remembered that this railroad joke of sixty years ago has developed into a great trunk line whose average earnings per mile are exceeded by only one other American railroad.

At last the time came when the traffic could no longer be handled satisfactorily, although the two tracks were crowded all the time with trains hauled by two, three, four, and sometimes even five locomotives. A third track through the mountains west of Scranton, the principal collecting point for coal traffic, had to be provided. Also, there were some twenty-seven highway crossings at grade to be abolished. Extra tracks and the abolition of grade crossings cost money. The first proposition then, was for the engineers to see if they could not make the investment in these improvements earn more by adding to it.

In other words, would it not pay to relocate the line through the mountains?

Part of it could not be changed because Scranton, an important point, lies down in a valley, and the railroad simply had to climb down into that valley and out again. But west of the Summit, where the country is rough and broken like a choppy sea, with no natural, easy grades, was the place where improvement might be made. From the Summit to Hallstead, half the line was on curves, many of which were from four degrees to more than six degrees—rather sharp for heavy traffic; while the grades ranged from thirty to sixty-five feet per mile, calling for a good deal of pusher service.

The problem was to eliminate all pusher grades west bound from Clark's Summit and reduce the grades east bound, so that a locomotive of any size could handle, with the aid of one pusher, as big a train as it could haul into Hallstead from the west. This had to be done at a cost which would be less than the saving in expense of operation and maintenance, capitalized at five per cent.

To ascertain what this saving would be, required some elaborate computations covering a period of ten years, and it was found that to insure a profit would require some clever work. The engineers laid aside their pencils and took up their surveying instruments to see what they could find in the way of a route. No Geological Survey maps being available, they had to go out to the hills and do real locating work.

Three years were required for the task, for the country was so rough that any line following a fair grade with a minimum of cutting would be impossible on account of the curves, while a decently straight line demanded mammoth earthwork, with very long tunnels. Ultimately the choice simmered down to four possibilities. One of these would have saved twenty-one miles in distance, but the cost of construction would have been heavy and the new line would have missed Binghamton and Owego, with the Syracuse, Utica, and Ithaca connections. The latter consideration eliminated this possibility. Another route gave much more satisfactory grades and alignment, but would require a tunnel seven thousand feet long through bed rock.

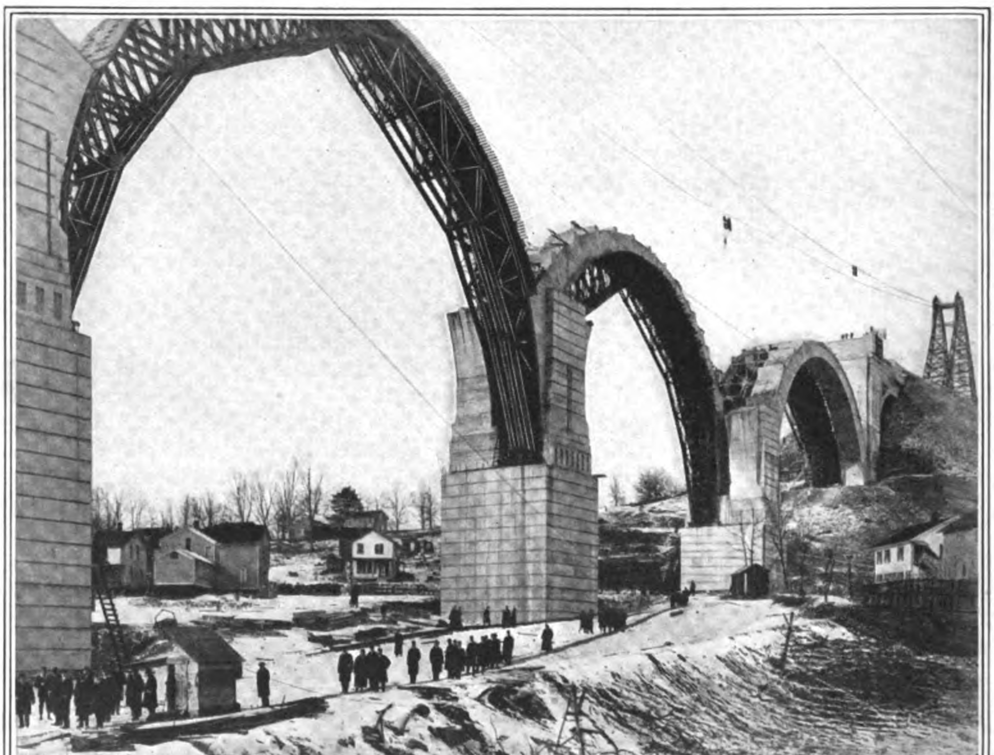
The route finally selected runs parallel to the old line for a mile west of Clark's Summit; then it strikes across country through a succession of heavy cuts and fills for ten miles, returns to the old route and follows it, within a few hundred feet, all the way to Hallstead, but at a higher level. All the saving in distance and all the spectacular engineering is done in the first ten miles.

With field notes complete, the engineers returned to the office for another session with lead pencils. The new line reduced the maximum curve from six degrees twenty-two minutes to three degrees, reduced the total rise and fall by three hundred and twenty-seven feet, and the total curvature by twenty-four hundred degrees. The net result was the doubling of the hauling capacity of all locomotives. This achievement, it was found, would justify the expenditure of twelve million dollars.

After all the computations had been verified by outside engineers, working independently, the work was authorized. The whole line was placed under contract in August, 1912, and by February, 1914, the work was half finished.

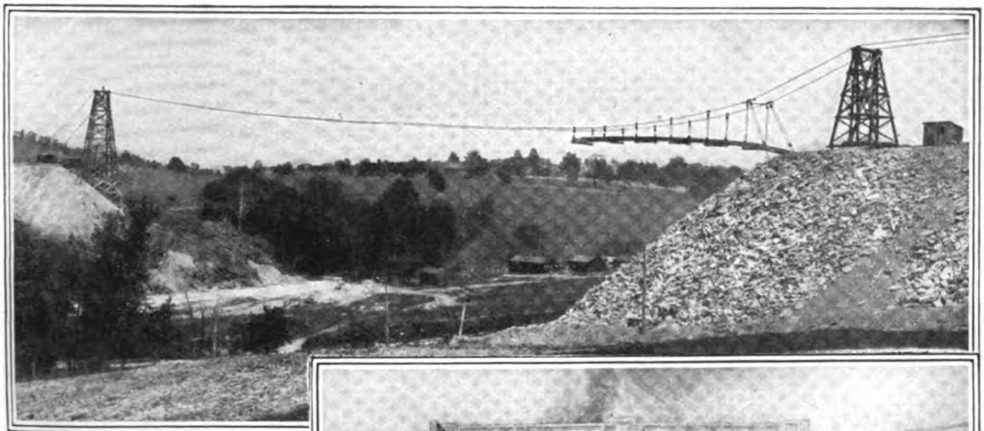
The feature which won the especial admiration of the party from the American Society of Civil Engineers was the Tunkhannock viaduct at Nicholson, twenty-two miles west of Scranton. The viaduct, which is in plain sight of passing trains on the old tracks, is two thousand three hundred and seventy-five feet long, two hundred and forty feet high, and consists of ten arches. It is of reinforced concrete, and is the largest concrete structure in the world. When the concrete is set, this great viaduct will be as solid as if carved out of a single piece of rock. It will be stronger than a steel bridge and less expensive to maintain.

Methods of construction are on a scale commensurate with the magnitude of the work. Big clamshell buckets operated by a steam engine dig the holes down to bedrock, sixty feet below the surface, for the pier foundations. Cement and sand are delivered in carload lots on a special side track to a warehouse, and hoisted by steam to huge mixers operated by steam. After mixing, the concrete runs by gravity into buckets holding six tons each, set on narrow gage cars. A small locomotive runs a train of these cars out under a double cable way the whole length of the viaduct and twenty feet above its top and from these cars the buckets are hoisted and conveyed to the place where their contents are needed. The great arches are molded in forms of heavy steel framework with



THE CIVIL ENGINEERS LOOK

The biggest concrete bridge in the world was to them one of the greatest pieces of work of this concrete age. There are ten arches like these three. The railroad steps across the valley as a giant would over a ditch, as the trains thunder on over their new short cut.



FILLING FROM A SWAYING SUSPENSION
The gigantic fills were made with the aid of temporary bridges in some places instead of with the customary wooden trestle.

FIXING A GRADE CROSSING
Railroads are accustomed to eliminating them in the big cities but out in the country it is usually a different story.

sides of plank faced with galvanized iron, built in sections so that they can be taken down and used over again.

The weight of the little mountain which makes the biggest fill will be so enormous that the foundations for the double-barreled culvert, each barrel of which is twenty-four feet in diameter, will have to be carried down to bed rock. And as bed rock in the bottom of the valley lies deep, the engineers have moved the creek to a new location up on the side hill where the rock lies near the surface.

Practically everything is done by machinery, all of which is of gigantic proportions. In boring holes for blasting, large well drills are chiefly used instead of ordinary steam drills. From thirty to forty steam shovels are busy the year round loading rock as well as earth into cars which are drawn by locomotives to places where they are needed. Several of the big fills are made from movable suspension bridges; the smaller fills are made in the ordinary way from trestles.

If all goes well trains will be running over the new line by June, 1915. But this depends more on the courts than on the engineers, and courts were never known to hurry. As soon as the new line was located, the land at once became immensely valuable. The real estate department of the railroad, being experienced in such matters, had counted on this swift rise in values, and had consequently estimated that an average of two hundred and twenty-five dollars an acre, or two hundred and eighty thousand dollars for the one thousand two hundred and fifty acres needed, would suffice to swing the deal. This merely shows how much mistaken even a seasoned railroad real estate man can sometimes be, for the estimate was far off.

Whenever such a settlement is thrown into the courts, the owner of the land usually receives a higher price. For instance, where an enterprising citizen, seeing a chance for a speculation, bought a plot of four acres of this land for four thousand dollars, as soon as the line had been located through it. Then he took a spade and devoted half a day to opening a "gravel pit". Although the gravel was forty miles from the nearest market for such stuff and therefore valueless, since an abundance of such material was obtainable much nearer, he demanded, and was awarded, eight thousand dollars for the sand and gravel of which the railroad deprived him. When the contractors wanted to use this gravel for making concrete, the experts who tested it found it worthless for the purpose and forbade its use.

This exploit is only equaled by that of a native who in an earlier day scooped out a hole, lined it with clay, let it fill with rain water and then sold it for two thousand five hundred dollars cash to the Erie Railroad as a "spring". The Erie spent another two thousand five hundred dollars piping the "spring" to a water tank. By the time the hole ran dry the railroad discovered that the land was mortgaged.

Other enterprising citizens did fairly well by laying out "town lots" on the right of way, after the line had been located, although there has never been anything more than the usual dismal way station every few miles and no reason exists why there ever should be anything else.

Still others have resorted to the primitive methods of the New York gun man to get their share of the railroad's money. One particularly obstreperous farmer, threw the steam drills and other movable apparatus over a cliff at night; then on a later occasion filled up the drill holes and finally assaulted a superintendent and an engineer with a shovel. However, in spite of all these obstacles the great project is going through successfully and the Lackawanna will have its cut-off.

SNAP-SHOTS AT NIGHT

By

A. J. MANSON

EVEN in the daytime it is very difficult to obtain a clean-cut photograph of a golf ball just after it has left the driver of a professional golfer, and it is almost impossible to get such a photograph by flash light at night.

Yet this feat was recently accomplished with a high-speed flash-light outfit. The photograph, showing the golf ball just over the "hazard", was taken at nine o'clock in the evening, with an exposure of only one-two-thousandths of a second. Three flash lights, located at different points so as to give the proper light diffusion and intensity, were fired simultaneously.

In photographing moving objects by daylight, it is only necessary to have the shutter speed of the camera such that a clear-cut image will be obtained, for the daylight is of constant intensity during the period of exposure. It is, however, an entirely different problem, when photographing at night with flash-light powder. It is not only necessary to adjust the shutter, but it is also necessary to time the shutter with the flash light; otherwise sufficient illumination will not be obtained for the photograph. The flash-light powder is a variable quantity. The length of duration of the flash varies between one-tenth and one-fifteenth of a second, and, moreover, varies greatly in intensity, so that some reliable means must be obtained to operate the shutter of the camera at the maximum intensity of the flash.

We are all familiar with the everyday method of flash-light photography where the object is at rest, and the plate or film is exposed during the whole period of the flash; but this method is limited in rapidity to one-fifteenth of a second and can not be used for moving objects.

To catch moving objects it is necessary to have the shutter of the camera set for high speed, open at or just prior

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PROGRESS AND DEVELOPMENT OF CONCRETE WORK ON THE DELAWARE, LACKAWANNA AND WESTERN RAILROAD.

By A. B. Cohen.*

A brief review of a few historical facts concerning the road itself is essential to a better understanding of the progress and development of concrete work on the Delaware, Lackawanna and Western Railroad.

The Lackawanna Railroad at its inception was built to transport coal from the anthracite region around Scranton, Pa., to the seaboard. A line was projected eastward as early as 1850. Like the few other roads of that day, it lacked financial strength, and since the country through which it necessarily extended was at best exceedingly rugged and mountainous, the management was compelled to follow the line of least resistance rather than the direct route toward the coast. The road was built in a southeasterly direction from Scranton over the Pocono Mountains and through the Delaware Water Gap to Portland, Pa., a point on the river a few miles below the Gap, by the parent company and from this point to Hampton, N. J., by a leasing line, the Warren Railroad Company. These lines were 61 and 21 miles in length respectively.

At Hampton the greater part of the coal was delivered to the Central Railroad of New Jersey for transportation to tidewater, and at Washington, N. J., a portion was transferred to the Morris Canal, then in the height of its activity, for transportation to Paterson, Newark and other towns along its route.

At Washington, the Warren Railroad crossed the line of the old Morris and Essex Railroad extending from Hoboken to Phillipsburg on the Delaware River. In 1860 this road was leased by the Delaware, Lackawanna and Western Railroad, and in this way the latter company obtained a through line from the coal fields of Pennsylvania to tide-water at New York.

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Previous to this, however, about 1852, the line was extended westward from Scranton to a point near Binghamton, N. Y., where connection with the Erie Railroad made possible western shipments. In 1869, by the purchase of the controlling interest of stock of the Syracuse, Binghamton and New York Railroad, operating between Binghamton and Oswego on Lake Erie, the Delaware, Lackawanna and Western Railroad obtained an opening to the Great Lakes. This line, in 1881, gave way to the Buffalo extension from Binghamton as the main line.

The combination of these various lines, built independently of each other in the early days of railroad construction, necessarily resulted in some very heavy grades and many detours.

With the advent of an entire new management in 1889 under the direction of President Truesdale, it was soon determined that extensive improvements at a number of points were necessary for a more economic operation. Traffic had increased far beyond the expectations of the original builders, which might be said of all the earlier railroads. While the motive power and equipment followed in a measure the advancement of the day, nevertheless the heavy grades and roundabout routes made operating very expensive. Gradually improvements were made which resulted in a highly developed system embodying the best practice of railroad construction and equipment. Concrete has played a very important part in this development by reason of the facility and the rapidity with which it can be placed; these have so expedited the construction of structures necessary in improvements of the magnitude of those made by the Lackawanna Railroad, that it can be safely asserted that the use of concrete has made possible these economic changes. This can readily be understood by description of these various improvements and the uses that have been made of concrete showing its progress and development.

NEWARK TRACK ELEVATION AND DEPRESSION.

The first improvement of importance made by the new management was the elimination of grade crossings and reduction of grades through Newark, N. J., in 1903 to 1905. This line through Newark had long since given way to the Boonton Branch through Paterson as the main line, but it tapped the highly developed New Jersey suburban district. A maximum grade of 138 ft. per mile made operation of even suburban trains very difficult. By restoring to part track elevation and part depression, this grade was reduced to 60 ft. per mile. All the bridges were built of structural steel, but concrete was used extensively for the first time by the Delaware, Lackawanna and Western Railroad in the construction of the retaining walls (see Fig. 6).

About the time of completion of this work, the Hoboken Terminal and several docks burned down. In the reconstruction, concrete was used to great advantage in the docks carrying engine loading. This work consisted of a grillage of piles driven over the entire area carrying a solid floor of 12 by 12 in. at mean low water. A cinder fill over this floor, suppporting track laid in the usual manner, was retained by massive concrete bulkhead walls. Practically the first reinforced concrete was used in roof and floor construction of the railroad shop built at Kingsland in 1903, but the most extensive use of reinforced concrete in building construction was made in 1906–1908 when the Scranton shops were built. Brick was used for the walls of all the buildings, but the frame work of a number of them was constructed of concrete and it was used in subway construction of great length, in storage bins and large foundry casting platforms.

NEW JERSEY CUT-OFF.

Starting from the eastern terminal, the main line crossed the State of New Jersey by a very circuitous route. It was 85 miles by rail, while the air line distance is but 58 miles. A ruling gradient of 1.14 per cent uncompensated over the western half of the state necessitated the use of pusher engines for heavy traffic. The heavy grade, together with the roundabout route, made operation very expensive. To improve this condition, a cut-off line was located, in 1905, between Hopatcong and the Water Gap. By resorting to very heavy construction, crossing the drainage of the country at right angles, it was possible to establish a ruling compensated grade of 0.55 per cent, or 29 ft. per mile. The following table, showing the physical characteristics of the old and new lines, will give an idea of the character of the work:

	OLD LINE.	NEW LINE.	SAVING.
Distance, miles	39.57	28.45	11.12
Maximum grade, ft. per mile	68	29	39
Number of curves	57	15	42
Maximum grade	6 deg. 54 min.	3 deg. 36 min.	3 deg. 18 min.
Total degrees	2,000	440	560
Rise and fall, ft	248	11	237

The saving of this new line, based on the actual cost of operation, maintenance of roadway, structure, repairs, etc., war-

FIG. 1.—SIGNAL TOWER AT HOPATCONG, N. J.

ranted the expenditure of $11,000,000, the cost of the improvement. The cost per mile is $387,000. This work gave the real impetus to concrete construction on the Delaware, Lackawanna and Western Railroad. With one exception, all of the 70 bridges were built of concrete, which required 260,000 cu. yd. The largest structures are the Paulins Kill and the Delaware River Viaducts.

SIGNAL TOWER.

The first structure on the cut-off line is the concrete signal tower (Fig. 1) at Hopatcong, the junction of new and old lines.

The walls are paneled and bush-hammered to relieve the otherwise plain surfaces. The roof is glazed tile. This tower was built by company forces and is of the type adopted as a standard.

RAILROAD BRIDGES.

All the highways crossing the cut-off line have been carried either under or over the tracks by arches or reinforced flat-top bridges. The Hopatcong Road arch, shown in Fig. 2, represents the best type of this construction. Some attention was given its appearance, since it spans a much-traveled county turnpike. The semi-circular arch, however, of 20, 24 and 30 ft. spans, was

FIG. 2.—HOPATCONG ROADWAY ARCH, MUSCONETCONG FILL.

the general type used on the new line. These arches were built under varying conditions—on piles, earth and rock foundations, under fills to depth of 110 ft.; on steep highway grades, and there were many skew arches, some of which were built on an angle of 45 deg. with the center line of track. Similar conditions prevailed for culverts carrying water courses.

COMBINATION HIGHWAY ARCH AND CULVERT.

The greater height of fills made it economical to divert streams for comparatively long distances to highway arches so that one structure would carry both highway and stream. The road is carried over the stream on a reinforced concrete slab, the abutments of the arch serving as side walls for the culvert. The culvert has a reinforced-concrete invert built simultaneously with the arch abutments, thus preventing the undermining of the abutments by the scouring action of the stream. The box formed between the abutments furnishes a brace should settlement occur which might tend to collapse the arch.

FLAT-SLAB BRIDGES.

Where the vertical clearances were limited, flat-slab bridges were built in spans of 20 and 24 ft. The problem in designing

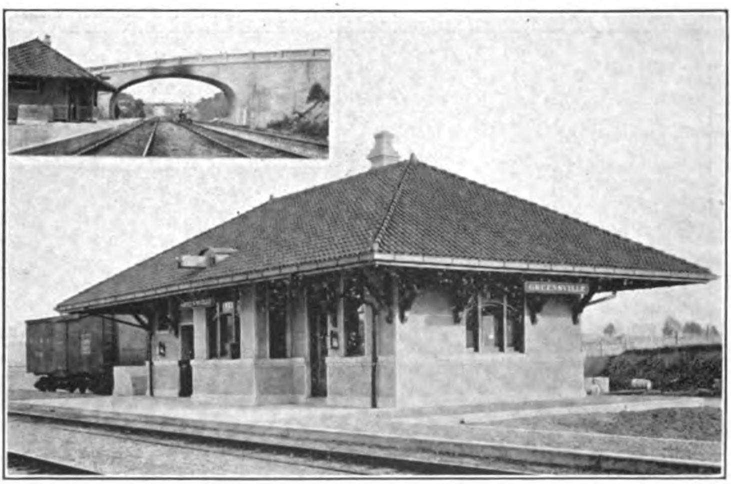


FIG. 3.—GREENSVILLE STATION.

these bridges on a skew was solved by reinforcing the slab on the right span and the parapet wall to act as a girder carrying the triangular or skew portion of the floor. The slab and parapet girders were built in continuous operation.

OVERHEAD HIGHWAY ARCHES.

The highways are carried overhead on reinforced-concrete arches of the elliptical type. The span for arches normal to the track was made 56 ft., giving clearance for four tracks; rise 12 ft.

6 in.; crown thickness 1 ft. 6 in. The Greensville arch shown in Fig. 3 has a skew angle of 45 deg. It was designed for a skew span and constructed in laminæ parallel with the center line of the highway. To eliminate any tendency of the ring to slide, the abutment skewback was formed in offsetted inclined planes normal to the pressure line of the arch.

STATIONS.

Previous to the cut-off work a number of stations were successfully built of concrete; it was therefore decided to construct the three stations on the new line in similar manner, adopting the pleasing effect obtained with signal tower design resulting from the combination of bush-hammered concrete and glazed tile roof. The Greensville Station is shown in Fig. 3.

PEQUEST RIVER DOUBLE-BARREL ARCH BUILT ON GRAVEL FOUNDATION UNDER 110-FT. FILL.

The line crosses Pequest Valley on a fill 3 miles long, averaging 75 ft. in height and containing 6,625,000 cu. yd. of earth. The maximum height of the fill is 110 ft. Next in importance to the Delaware River and Paulins Kill viaducts, is the Pequest River arch through which the river flows under the deepest part of this embankment.

Soundings at the site showed a 30 ft. stratum of gravel with varying amounts of clay and fine sand. At intervals large boulders were encountered, making the driving of piles impossible. A 40-ft. arch was proposed, but under the heavy fill the maximum pressure on the foundation was found to be far in excess of the safe carrying capacity of the soil. This being impracticable, the alternative was a 20-ft. twin arch. Even with this construction, very large abutments would be necessary to keep the maximum toe pressure under 6 tons per sq. ft. Further investigation showed a heavily reinforced invert or mat foundation to be not only more stable but less expensive. By reason of this design the base of the foundation could be placed just below the surface of the gravel, with no possibility of it being undermined by the water, as might be expected if the abutments were independent of each other. The length of the arch is 309 ft. In determining the dead load on the arch, no allowance was made for any arching action of the fill. The weight of the total fill above the top of the arch was taken at 100 lb. per cu. ft.

To keep the same working stresses for the steel and concrete and to obtain as nearly as possible a uniform pressure on the foundation, the ring, abutments and inverts were decreased in four sections from the middle to the face of the barrel. The middle section was designed for the maximum fill of 90 ft. over the crown, and the remaining sections were designed for the ver-

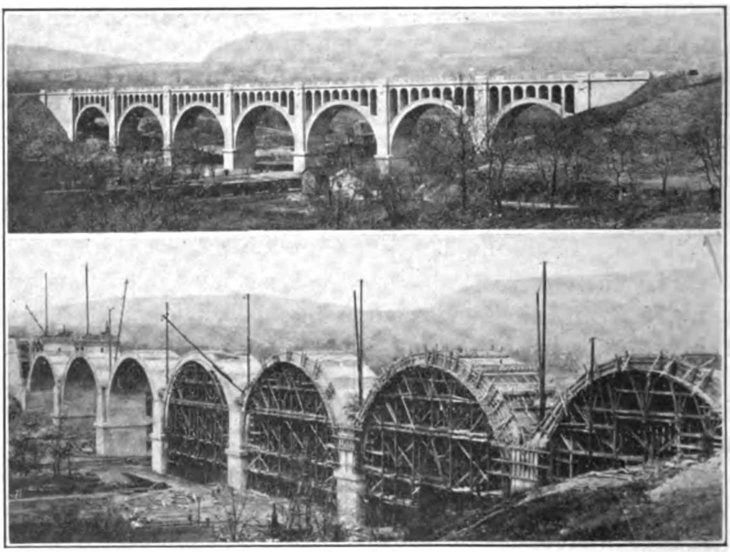


FIG. 4.—PAULINS KILL VIADUCT, HAINESBURG, N. J.

tical fill over each as determined by a slope of 1¾ to 1. The total load transferred to the pier and each abutment was approximately equal, making the pressure on the base about uniform. On the middle section this amounted to 5.6 tons per sq. ft. and the slab for the invert was designed to resist this pressure. The structure contains 10,950 cu. yd. of concrete and 520,000 lb. of reinforcing steel.

PAULINS KILL VIADUCT.

The second largest structure on the cut-off line is the Paulins Kill viaduct at Hainesburg, N. J. It is a double-track bridge

100 ft. long, 34 ft. wide and 117 ft. above the water, consisting of five 120- and two 100-ft. full centered arches with crown thicknesses of 6 ft. and 5 ft. respectively. All the piers are carried to rock, the depth of which varies from a few feet below the surface at the abutments to a maximum of 30 ft. at the center pier.

For construction a mixing plant was located close to the viaduct site, from which concrete was hauled in one-yard buckets on narrow-gage trains to the various derricks for distribution. The first position of the derricks was on the ground near each pier, where they remained until the piers were completed to the springing line. Next they were raised to their second position upon steel I-beam towers erected upon each pier. From this position all the concrete in the ring was poured. The ring was cast in blocks and keys placed in position to uniformly load the timber centering. At least 7 days were required to elapse between the pouring of any block and the adjacent key, and 28 days after the last key was completed the centering was lowered. This method was used so that the shrinkage might have little effect upon the finished ring. The derricks were finally placed upon the top of the two center spandrel arches which were poured from the second position. From this final position the remainder of the floor system was completed. Fig. 4 shows the various stages of construction together with a view of the completed structure.

The abutments are of the "U" type with three longitudinal reinforced-concrete walls supporting a reinforced slab to carry the roadway. The embankment was allowed to take its natural slope between the walls, tied together with reinforced-concrete struts, as was the case on the outside of them.

Surmounted on the main arches, the superstructure consists of a series of transverse spandrel walls and arches. The true arch action was here destroyed by pouring the top of the arches to a level surface to form the floor on which the track was laid over 3 ft. of rock ballast. The floor is waterproofed by a membrane composed of four layers of felt and five layers of asphaltic compound. This is protected by a layer of brick, grouted and covered with the compound.

In the construction of the viaduct there was used 43,200 cu. yd. of concrete and 735 tons of reinforcing steel.

DELAWARE RIVER VIADUCT.

The largest structure on the cut-off line is the Delaware River viaduct at Slateford, Pa. (Fig. 5). It is a double-track bridge 1,450 ft. long and 64 ft. above the river. It consists of five 150-ft. and two 120-ft. elliptical arches, rise 40 ft. with crown thicknesses of 6 ft. 0 in. and 5 ft. 4 in. respectively; also two 33-ft. full centered arches. The two smaller arches and one 120-ft. arch on the west end are on a 3 deg. 36 min. curve and this, together with a skew angle of 25 deg. for the remainder of

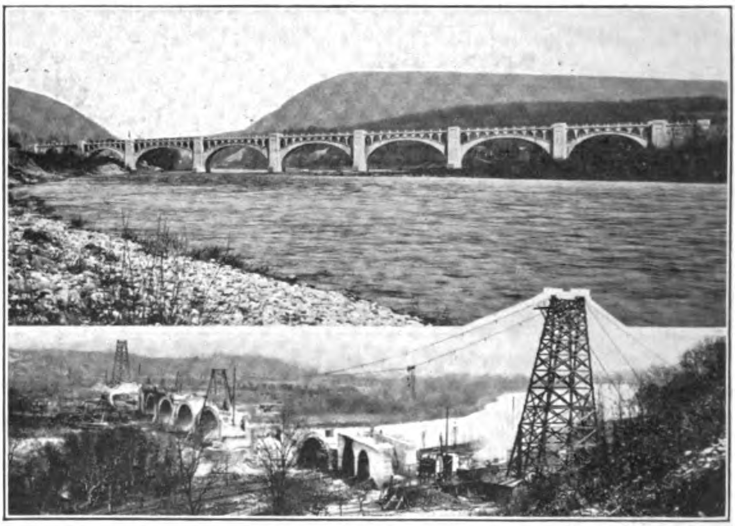


FIG. 5.—DELAWARE RIVER VIADUCT, SLATEFORD, PA.

the structure, made the construction more difficult than that of the Paulins Kill viaduct.

The rock stratum is comparatively level, but because of the unevenness of the ground the depth ranged from 25 to 53 ft. The construction was carried on by means of a traveling cableway suspended over the center line of the viaduct, and supported from timber towers on either bank, approximately 2,400 ft. apart. Midway between these towers an A-frame mounted upon two large temporary piers furnished the intermediate support and divided the cableway into two working units. (See Fig. 5.)

A mixing plant was established on each side of the river directly beneath the cableway. With the longest haul each plant had a capacity of 250 cu. yd. per 10-hour day. Little difficulty was experienced in driving ordinary timber sheet piling. The material excavated for piers was gravel and boulders. Contrary to expectations, the gravel formed an almost impervious obstruction to the water. One pump was able to take care of the leakage into the pier excavation.

Steel centering was used in the construction of the 150-ft. arches. This centering was composed of ten separate 3-hinged arches spaced 4 ft. centers and braced laterally to form a rigid unit. The ribs were supported by short structural steel columns placed upon an I-beam grillage which rested upon an offset of the pier foundation. The centering was lowered by means of a double toggle joint at the crown panel, by which the two vertical members were lengthened or shortened for lowering or adjusting the centering. Similar to the construction of other skew arches, the skew backs of the piers were formed in six offsetted inclined planes normal to the pressure line of the arch ring.

The U-shaped retaining walls of the east abutment are a feature of the design. They consist of two heavily reinforced walls 3 ft. thick at the top and increasing on a uniform batter to 1 ft. 5 in. at an elevation which is approximately one-third of the height of the walls. At this point of resultant earth pressure, reinforced struts 1 ft. 10 in. x 3 ft. 0 in. spaced 5-ft. centers connect the two walls with sufficient steel to resist the horizontal thrust. Above the struts the walls were reinforced for cantilever action. The footing course is continuous under both walls. Total height of wall is 57 ft. The combined weight of the U walls (on earth foundation) and fill resists the horizontal thrust from the adjacent 120-ft. arch. The vertical load of the arch is carried to rock on two 9 x 40-ft. caissons.

The floor of the viaduct was waterproofed with two layers of an asphaltic compound applied hot and bound by two layers of very light cloth fabric. This coating, about $\frac{3}{16}$-in., was protected by 2 in. of concrete. There are no expansion joints in the floors of the Paulins Kill and Delaware River viaducts, the longitudinal reinforcing steel being continuous.

The Delaware River viaduct contains 51,400 cu. yd. of concrete and 627 tons of reinforcing steel. The work was begun August, 1908, and was completed three years later.

MONTCLAIR IMPROVEMENT.

Another improvement is the complete revision of the Montclair Branch, 4 miles in length, extending from Newark to Montclair. The line, which for the most part was a single track, has been double tracked, and all the grade crossings have been eliminated. New stations have been built at Watsessing and Bloomfield, sundry improvements at Glen Ridge and the Montclair Terminal has been reconstructed.

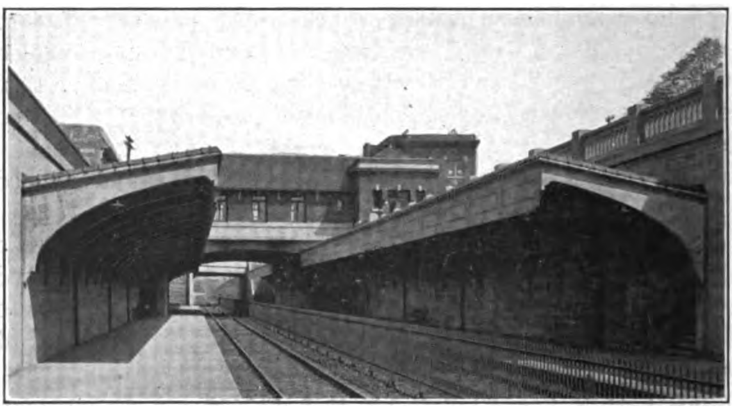


FIG. 6.—WATSESSING AVENUE STATION, BLOOMFIELD, N. J.

This line takes care of a very large suburban traffic to and from New York City, which is 15 miles from Montclair. In addition the branch also handles a very large milk and ice business and serves a large number of industries.

Because of limited right of way through Watsessing, the reconstruction followed along the old line. In making the depression a trench was excavated in which the retaining walls on one side were constructed without removing the tracks or delaying the traffic. After its completion, the tracks were shifted over beyond the walls, the depression was then made and the other wall built. These retaining walls are of gravity type built on rock in alternate sections of 20 ft. in length without any horizontal joints. The drainage beyond the walls is taken care of by blind drains of loosely piled stone, placed at each construction joint and extending from the base to the full height of the wall. Weep holes were placed at the lower ground line for each drain.

Watsessing Avenue Station, shown in Fig. 6, was built directly over the tracks. The building faces the avenue which is carried over the railroad on an elliptical arch. The station is supported on four reinforced-concrete arch girders with intradosal curves similar to the arch carrying the roadway. A 4-in. concrete ceiling was built between the girders to give the appearance of a con-

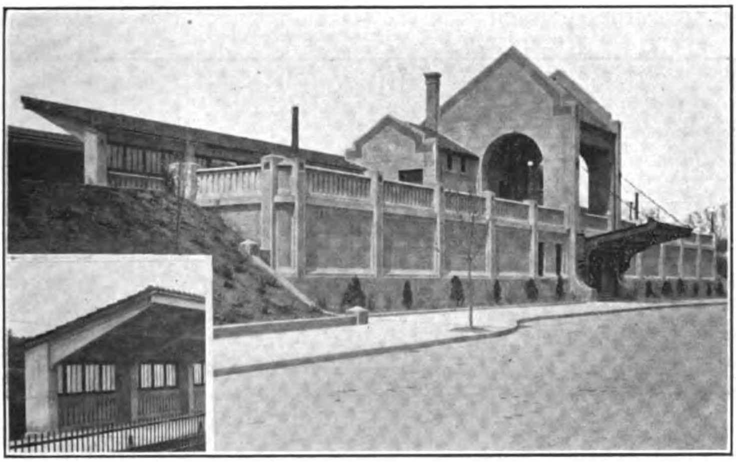


FIG. 7.—STATION, BLOOMFIELD, N. J.

tinuous arch. The canopy is also reinforced concrete. The brackets are cantilevered from the retaining wall, the base of which is widened to take the increased overturning moment.

The new Bloomfield Station (Fig. 7) was built of concrete bush-hammered and decorated with green tile. Here also the canopies are of reinforced concrete, but instead of being supported from retaining walls they are carried on columns of an elevated platform. The fill was made to the top of the platform beams, after which the concrete slab was built without forms. Clearance requirements necessitated the use of structural steel through girder bridges for two crossings. Glenwood Avenue and Washington

Street adjacent to the Bloomfield station. These were entirely encased in concrete to conform with the architectural features of the station; Glenwood Avenue bridge is shown in Fig. 8.

Montclair with a population of about 25,000 is the terminus of this branch. It is situated on the slopes of the Orange Mountains and this location, together with its close proximity to New York City, makes it a very attractive residential section. Many influential people are numbered among the inhabitants. The old station was served by one track and a turn-table. To accommodate the heavy daily morning traffic to New York City it was necessary to store the passenger cars over night at the terminal, and this storage room was crowded on three stub tracks over

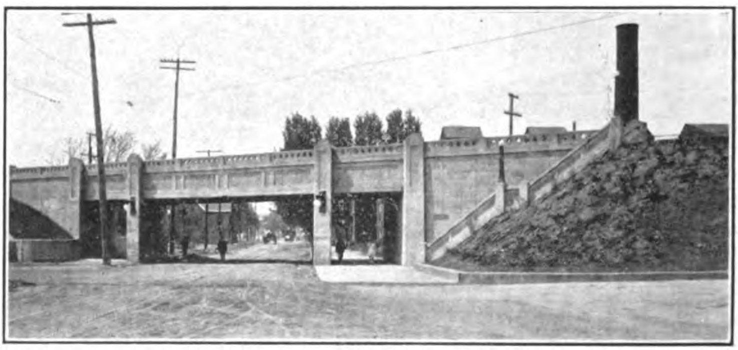


FIG. 8.—GLENWOOD AVENUE BRIDGE, BLOOMFIELD, N. J.

which the freight and milk business was also handled. The new layout provided for six tracks, and the area formerly occupied by both freight and passenger facilities is now entirely devoted to the passenger terminal shown in Fig. 9. The new station is built of tapestry brick trimmed with artificial stone made of concrete which is faced with terazza chips exposed by a wash finish. The structural steel umbrella shed has a concrete roof slab covered with flat tile laid in asphalt. In the background can be seen Grove Street viaduct (reproduced in insert), which is of the T-beam design with spans of 36 and 38 ft. Reinforced-concrete stairways lead from the bridge to the platform and station grounds. The kiosks, pilons and balustrade are all of concrete.

Several retail coal trestles were displaced by this layout. The coal business was centralized in one large pocket shown in Fig. 10. This is of cantilever type built of reinforced concrete. The partition walls, the lower portion of which form the cantilevers, divide the coal pocket into twelve bins.

The cross-section of the bin floor is similar to the letter W. Coal can be drawn simultaneously from three gates of each bin, from two under the cantilever portion and from one over the driveway between the columns. The capacity of the pocket is

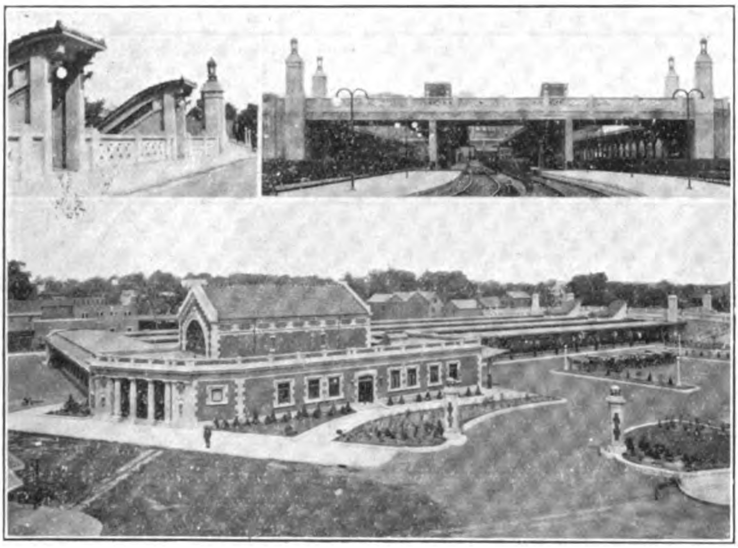


FIG. 9.—STATION, MONTCLAIR, N. J.

3,000 tons. It is fed from the two tracks and is sheltered by a timber and corrugated metal shed. The approach to the pocket is on a concrete trestle.

CLARK'S SUMMIT-HALLSTEAD CUT-OFF.

Going back to the main line, it is found that there is but one point where a railroad east of Scranton can pass the barrier imposed by the rugged range of the Kittatinny Mountains, and that is at the Delaware Water Gap where, in ages past, the Delaware River cut its way through the range. It is impossible to shorten the line between Scranton and the Water Gap. Scranton is located in a deep valley with rising grades on all sides, and the reduction of the grade on this section would require excessive length and curvature.

The improvement known as the Clark's Summit-Hallstead Cut-Off, which involves some of the heaviest railroad grading and concrete bridge work ever undertaken, extends from Clark's Summit, 7 miles west of Scranton, to Hallstead, Pa., about 14 miles east of Binghamton, N. Y. In the 39.6 miles of the new

FIG. 10.—COAL POCKETS, MONTCLAIR, N. J.

line the excavation quantities are 5,525,000 cu. yd. of earth, 7,647,000 cu. yd. of rock and 146,000 cu. yd. tunnel excavation.

PHYSICAL CHARACTERISTICS OF THE OLD AND NEW LINE.

	OLD LINE.	NEW LINE.	SAVING.
Distance, miles	43.2	39.6	3.6
Maximum grade EB, per cent	1.23*	0.68	0.55
Maximum grade WB, per cent	0.52*	0.23	0.28
Maximum curve	6 deg. 22 min.	3 deg. 00 min.	3 deg. 22 min.
Total degrees	3,970	1,570	2,400
Degrees per mile	91.2	37.9	53.3
Rise and fall, feet	553.0	226.0	327.0

* Uncompensated.

Approximately 300,000 cu. yd. of concrete will be used in the construction of the two large viaducts and in eighty minor structures. Some of the minor structures are being built under extraordinary conditions: an arch is being erected over a highway on a 15-per-cent grade; an overhead highway arch springs about midway down the sides of an 80-ft. rock cut; the south branch of the Tunkhannock Creek will be carried through an embankment 145 ft. high, 480 ft. wide at the base. This is the largest fill on the line and will contain 1,600,000 cu. yd. At the original location of the creek the rock was 50 ft. below the surface. To obtain suitable foundations for the culvert the creek was diverted by a considerable amount of excavation farther up the hillside, where the rock at the elevation of the flow line of the creek was close to the surface. The structure has two 24-ft. openings and will be 470 ft. long.

TUNKHANNOCK CREEK VIADUCT.

The two largest structures on this work are the Tunkhannock and Martin's Creek viaducts, which, when completed, will be the largest concrete structures of their kind.

The Tunkhannock viaduct, the larger of the two, is being built at Nicholson, Pa., 22 miles west of Scranton. It is a double-track bridge 2,375 ft. long and 240 ft. high above the creek, consisting of ten 180-ft. and two 100-ft. full-centered arches. All piers are carried down to rock, which is reached at a depth of from 10 to 95 ft. below the ground surface, making a difference of 300 ft. in elevation between bed rock and top of parapet at the deepest pier.

The piers are 36.5 x 43.5 ft. above and 40 x 46 ft. below the ground. The foundation for six piers was excavated, three to the ground-water line and three to rock, by a one-yard steam shovel. The shovel dug its way through the sand and gravel from pier to pier and the material excavated was used for the bed of a narrow-gage construction track. The other piers were built in open excavation sheeted with interlocking steel piling driven by a steam hammer.

The deepest foundation required two lengths of 30 ft. sheeting. First, an enclosure was driven for the full length of the piling about the outside of the lower diameters of the pier and

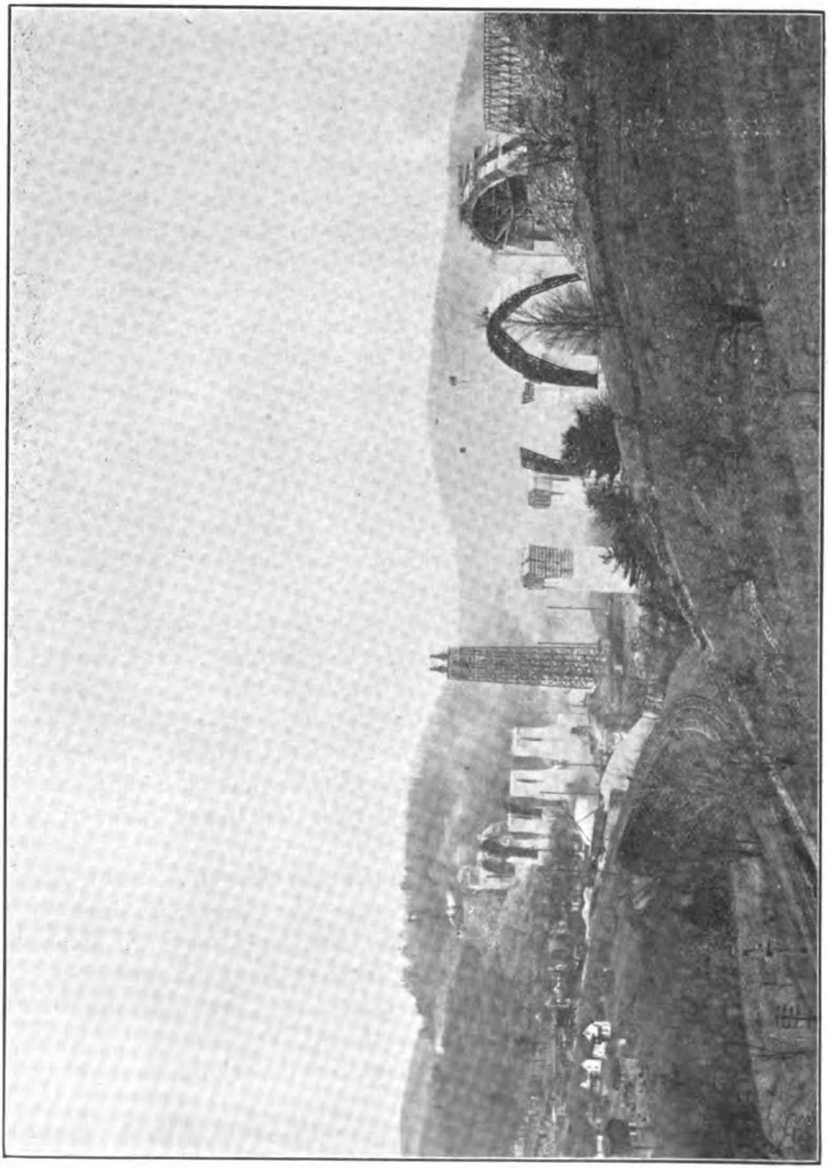


FIG. 11.—BIRD'S-EYE VIEW TUNKHANNOCK CREEK VIADUCT, NICHOLSON, PA.

the excavation was carried down with the driving. Next, another enclosure was started about 5 ft. outside of the first, after which both were carried down together as the driving progressed. The bracing for the upper or outer enclosure was entirely above the lower, so there would be no interference between the two sets of bracing. During the placing of concrete in the pier the water was collected and carried by drains to a sump in which pumps were located. In this manner, no concrete was placed under water. The pipe line from the pumps can be seen in the far right-hand corner. The footings carried to the bottom of the neat work were placed without forms. Tar paper was placed against the steel sheeting and the entire cofferdam, excepting the sump, was then filled with concrete. The sump was next concreted. The piling was drawn with an eight-part tackle hung from an A frame. The force applied was 40 tons.

Figure 11 shows bird's-eye view of viaduct in construction. The contractors' material siding off the present main line can be seen in the left-hand corner. The material is being handled by derricks from storage piles to the mixing plant located alongside and from the mixing plant to points beneath the cableway over the center line of the viaduct on the narrow-gage construction tracks previously mentioned. The end towers supporting the cableway are 150 and 165 ft. high and 3,028 ft. apart. The intermediate tower is 260 ft. high and 40 x 60 ft. at the base. On account of the long distance between the engine houses (located at the end towers) and the points of loading and unloading along the cableway, a complete telephone system was installed. The operators, provided with head sets, received directly all the signals from the men at the dumping points.

The pier forms are built in sections 17 ft. 9 in. high and four lifts of concrete are laid before raising them. The framing of the forms is of 8 x 10-in. and 6 x 8-in. timbers with two opposite diagonal layers of 1-in. sheeting faced with galvanized sheet iron. On the inner faces of the forms, strips of molding are placed at 4-ft. intervals to form the construction joints and the horizontal scorings around the pier. A 4-ft. lift contains 235 cu. yd. of concrete which must be run in one operation. The forms are braced by a system of 3.5 x 3.5-in. angles set in the concrete after every 4-ft. lift. The connection with the forms is made by turnbuckles.

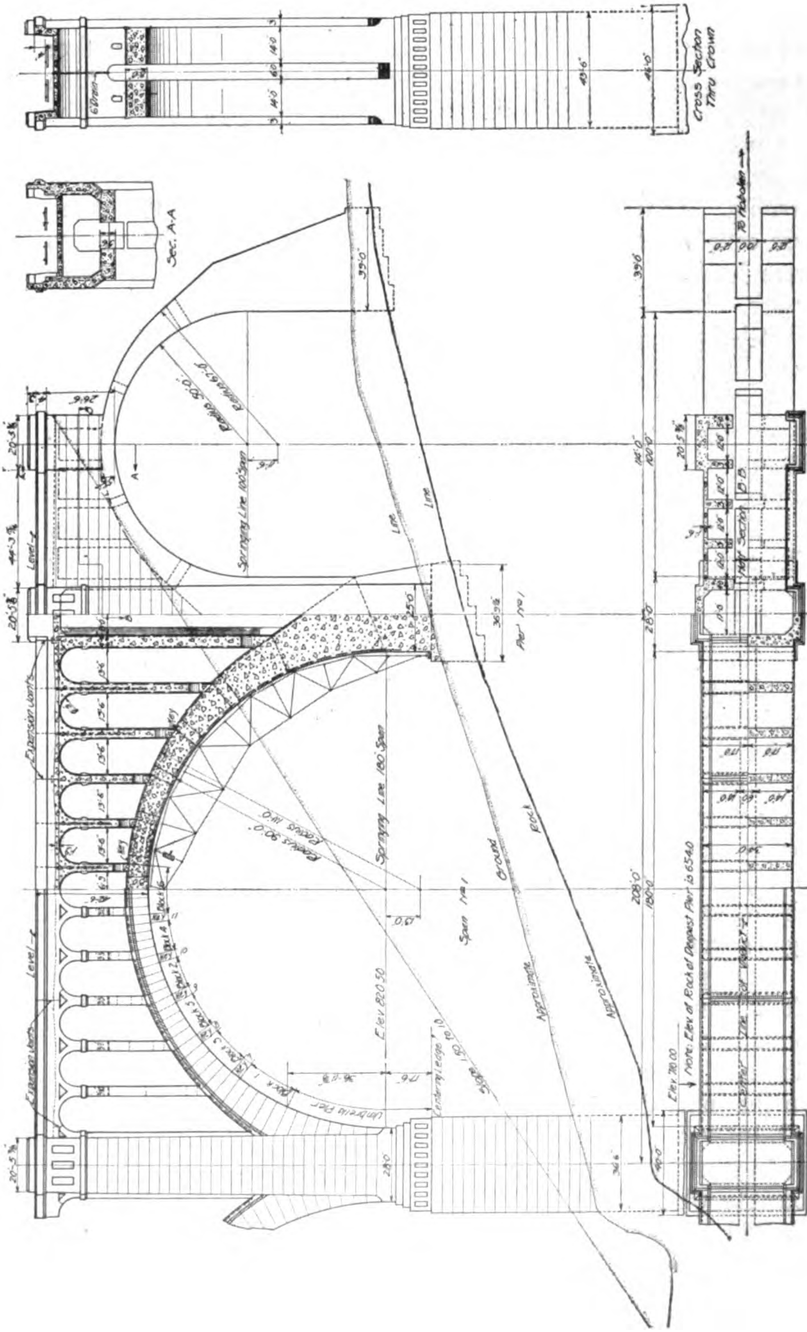


FIG. 12.—DETAIL DRAWING OF 180-FT. ARCH AND 100-FT. ABUTMENT SPAN, TUNKHANNOCK CREEK VIADUCT.

A detail drawing of 180-ft. arch and 100-ft. abutment span is shown in Fig. 12. The section at the right is through the crown of the main arch. This arch is divided into two ribs 14 ft. wide and 6 ft. apart. The crown thickness is 8 ft. The centering is steel similar to that used in construction of the Delaware River viaduct. The width of the pier at the springing line is 28 ft.; 17.5 ft. below the springing line the width of the pier is increased 4 ft. 3 in. on each side. The centering is supported on this ledge. The panels and steps shown on pier to the left covering the centering ledge will be built on sides of the pier after the centering has been removed. The 6-ft. openings between the ribs facilitate the moving of the centering by cableway to the next span. The superstructure on the main arch is composed of eleven 13 ft. 6-in. transverse spandrel arches. The floor is ramped from the crown of each arch to the center of the spandrel walls through which the drainage will be carried in 6-in. cast iron pipes to the opening between ribs.

An examination of the Delaware River and Paulins Kill viaducts, after they had been in service for some time, disclosed the fact that transverse cracks had formed at the crown of each of the two spandrel arches adjacent to each pier of the viaduct. This indicated that there had been a drop of the main arch rings due to fall in temperature. Over the crown the spandrel arches were in compression and no cracks developed while those adjacent to the pier were in tension. It may be here noted that the floor system was built during the summer months and therefore the movement in the main arch ring due to rise in temperature would bring the floor system back to its normal position, or, if there were a movement beyond this it would be so slight as to make its effect on the floor system directly over the crown negligible compared with the effect of a fall in temperature on the floor adjacent to the piers.

In view of the above observation it was decided in designing the Tunkhannock and Martin's Creek viaducts to place expansion joints at the pilaster and quarter points of each span. A floor system similar to that of the main arches will be continued to the center of the abutment span. The fill covers the other half and slopes through the hollow superstructure, completely concealing the abutment arch. The heavy approach fill will not come upon the back of the last main arch.

In construction the rings are carried up 43 ft. above the springing line with sectional timber forms before the erection of the steel centering. The centering is erected by bolting the upper and lower sections together, and until the placing of the opposite half are held in cantilever by bolts through the top of the umbrella pier assisted by cable guys anchored to the adjacent pier. The heaviest section weighs about 14 tons; capacity of each cable is 10 tons. The precautions that were taken by building the arch rings of the Paulins Kill viaduct in block and keys to load the centering uniformly and minimize settlement due to shrinkage will be repeated in the construction of the Tunkhannock and Martin's Creek viaducts.

During the process of preliminary design, when study was

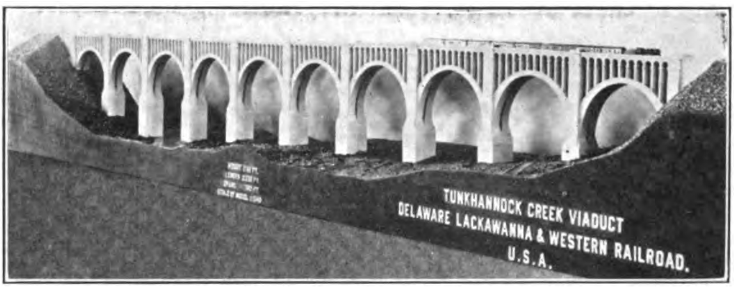


FIG. 13.—MODEL OF THE TUNKHANNOCK CREEK VIADUCT.

being made of the relative merits of structural steel versus concrete construction for this viaduct, the writer with his assistants undertook the making of a wooden model of the concrete design on a scale of 1 to 240, to better study the proportions of the structure. A photograph of the model is shown in Fig. 13. The result of this work was to dispel all doubt concerning unbalanced proportions and reduce the study to structural and economic considerations.

When completed the Tunkhannock viaduct will contain 167,000 cu. yd. of concrete, which is classified in three grades known as "A," "B" and "Cyclopean." Class "A" is a 1 : 2 : 4 mixture used in the reinforced superstructure of abutment spans. Class "B" is a 1 : 3 : 5 mixture and used in rings and superstructure of main spans. "Cyclopean" is the same mixture as "B"

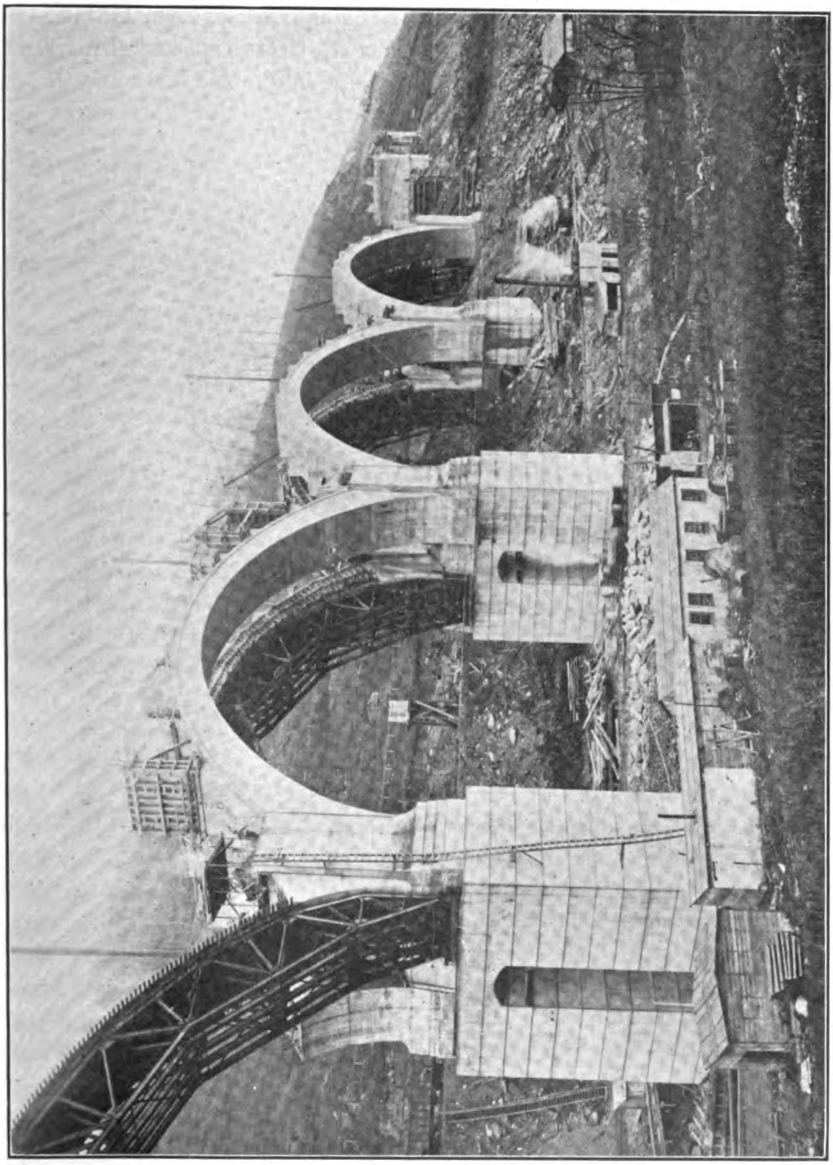


FIG. 14.—MARTIN'S CREEK VIADUCT, KINGSLEY, PA.

with large size derrick stone bedded in the concrete and is used in all the work; below the springing line of main arches 2,300,000 lb. of reinforcing steel will be used. The earth (to the sheeting lines) and the rock excavation will amount to 40,000 and 3,500 cu. yd. respectively. The contract calls for the completion of the viaduct in 3 years. It was begun August, 1911.

MARTIN'S CREEK VIADUCT.

The bridge over Martin's Creek is 1,500 ft. long and is being built for three tracks. The top of parapet of the new structure is 150 ft. above the bed of the stream and 88 ft. above the present main tracks which are bridged by the viaduct. It is composed of two 50-ft. and two 100-ft. semi-circular arches, and seven 150 x 59 ft. three-center arches. The structure is similar in general design to the Tunkhannock viaduct and the method of construction by derricks (shown in part view Fig. 14) is similar to that used for Paulins Kill viaduct. The main piers are solid for 17 ft. below the springing line and below that elevation they are divided into two legs 23 x 28 ft. separated by a 12-ft. opening. All piers are built on solid rock, which is reached at an elevation varying from 10 to 60 ft. below the ground surface, requiring 27,000 cu. yd. of excavation. The viaduct will contain 78,000 cu. yd. of concrete and 500 tons of reinforcing steel.

This viaduct is second in size to the Tunkhannock Creek viaduct, but, like the Delaware River and Paulins Kill viaducts, it is somewhat dwarfed by comparison. This comparison is shown in Fig. 15 where the four viaducts are drawn to same scale.

With the completion of the cut-off line, the Delaware, Lackawanna and Western Railroad will have placed 2,000,000 cu. yd. of concrete since 1900, having placed only 26,000 cu. yd. that year and 50,000 cu. yd. the following year. The average yearly placement is 130,000 cu. yd. and the maximum 226,000 cu. yd. in 1913. About two-fifths has been placed by company forces and the remainder under contract. The company has been very fortunate in its selection of contractors who have taken an unusual pride in obtaining the very best results. This, together with the selection and placing of material under rigid specifications and inspection, has given a quality to the work that impresses even the casual observer with its apparent permanence.

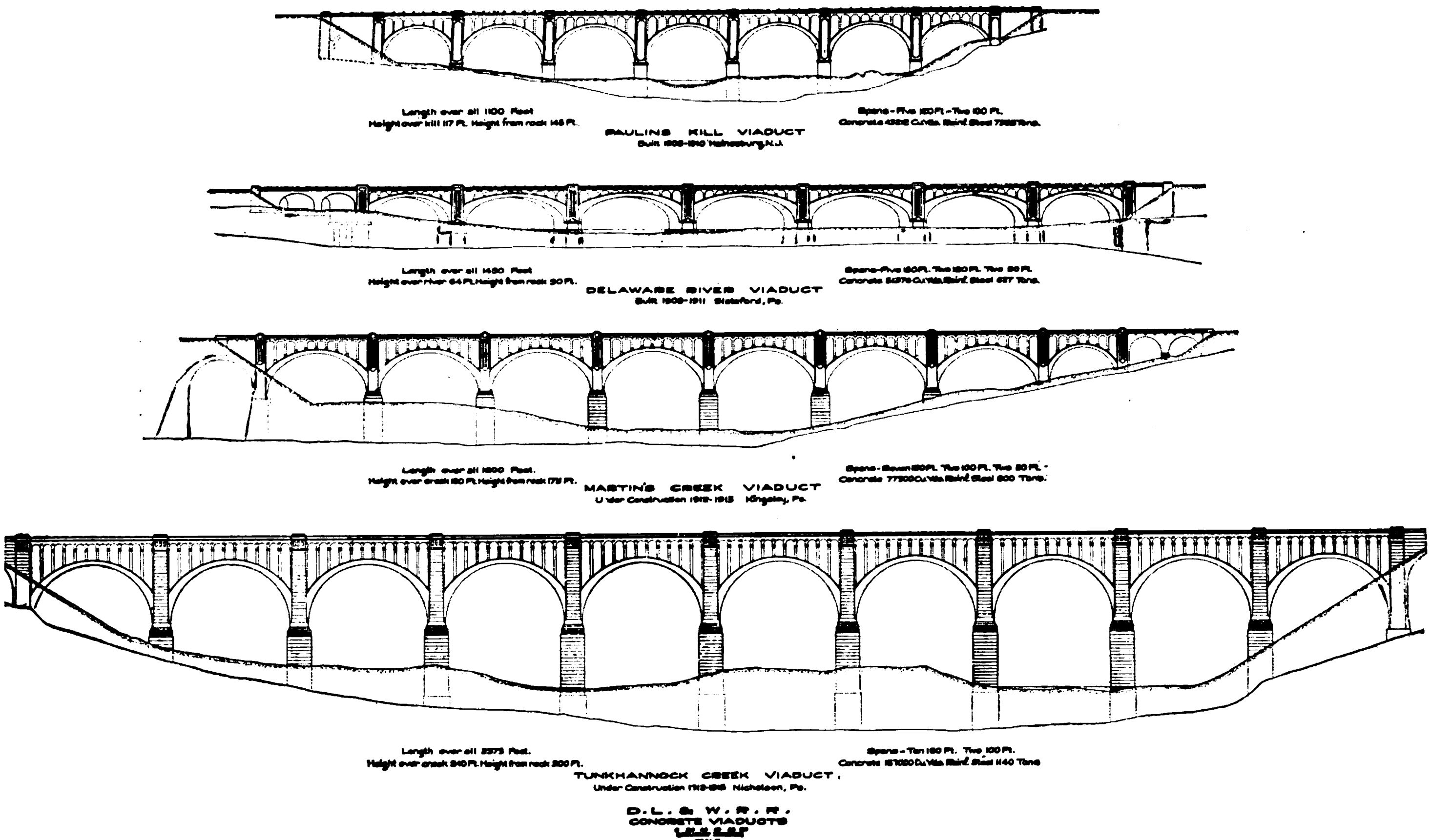


FIG. 15.—COMPARISON OF PAULINS KILL, DELAWARE RIVER, MARTIN'S CREEK AND TUNKHANNOCK CREEK VIADUCTS; DRAWN TO SAME SCALE.

The New Jersey Cut-Off was started under the direction of Mr. Lincoln Bush, chief engineer (resigned), and completed by his successor, Mr. G. J. Ray, under whose direction the design and supervision of construction of all the subsequent improvements was performed by company engineers. The stations were designed under the direction of Mr. F. J. Nies, company architect. Mr. B. H. Davis, assistant engineer, whom the writer succeeded, was in charge of the design of the Paulins Kill and Delaware River viaducts. Mr. F. L. Wheaton was engineer of construction on both cut-off lines and was assisted by Messrs. C. W. Simpson and W. L. Lozier, resident engineers during the construction of the Tunkhannock and Martin's Creek viaducts respectively. The construction of the Montclair improvements, also design of coal-handling plants, was supervised by Mr. G. T. Hand, division engineer, assisted in the former by Mr. W. H. Spiers, resident engineer, and in the latter by Mr. C. Healy, assistant engineer.

The Bureau of Engineering

OF

THE PUBLIC SERVICE COMMISSION

OF THE

COMMONWEALTH OF PENNSYLVANIA

FIRST ANNUAL REPORT

For the Year Ending June 30th, 1914.

F. HERBERT SNOW, C. E., Chief.

HARRISBURG, PA.:
WM. STANLEY RAY, STATE PRINTER
1915.

"SEVENTH. That the borough of Miners Mills pay 1% of the total cost, including the damages awarded to the owners of adjacent property;

"EIGHTH. That each of the parties interested, assessed with a portion of the cost of said improvement, shall pay its proportion of the amounts ascertained and determined by the Commission, or by the proper authorities on appeal, as damages for property taken, injured or destroyed, to the parties entitled thereto, and the balance of the total cost to the Wilkes-Barre Connecting Railroad Company, in conformity with any contracts of the said railroad company providing for said construction and upon monthly estimates furnished by the engineer of the Wilkes-Barre Connecting Railroad Company and approved by the Chief of the Bureau of Engineering of the Public Service Commission.

"NINTH. That the existing grade crossings of the Wilkes-Barre Railway Company and of Mill Street over the tracks and facilities of the Central Railway Company of New Jersey and the Wilkes-Barre Connecting Railroad Company shall be abolished at such time during the construction of the above mentioned improvement as shall seem best for the safety of the public, in the opinion of the Public Service Commission.

"BY THE COMMISSION:

"(Signed) Sam'l W. Pennypacker,
"Chairman."

Attest:
A. B. Millar,
Secretary.
(Seal)

DELAWARE, LACKAWANNA AND WESTERN RAILROAD.

Clarks Summit to Hallstead.

Clarks Summit borough until recently was a village in South Abington ownship, Lackawanna County, on the main line of the Delaware, Lacka-anna and Western Railroad, about 12 miles west from the city of Scranton. he city of Scranton is located in the valley of the Lackawanna River. Clarks ummit is so called because it is located at the summit of the range of hills orming the western boundary of the Lackawanna Valley and hence it is the ummit in the grade of the railroad. The population of South Abington Township including the then village of Clarks Summit was 1,987 only. Since then he village has experienced a rapid growth due partly to the construction of a rolley line connecting with Scranton.

Hallstead borough, population 1,538 in 1910, is in Susquehanna County on he Susquehanna River 2.5 miles south of the State line between New York nd Pennsylvania. It is also on the main line of the Delaware, Lackawanna nd Western Railroad.

The distance by railroad between Clarks Summit and Hallstead by the line hat existed before the changes described in this report were undertaken, was 2.6 miles.

The old line extended northwesterly from Clarks Summit down the valley of Ackerly Creek to the south branch of Tunkhannock Creek at LaPlume and thence across country to Tunkhannock Creek at Nicholson and thence up a tributary known as Martins Creek to near New Milford and thence down the valley of Salt Lick Creek to Hallstead. In this distance there were maintained 11 passenger stations and the line passed through 9 boroughs, 8 townships and also served one adjoining borough and four adjoining townships, having all told a total population in 1910, of 16,361. The location of the stations and the said boroughs and townships and the population of each is shown in the following table:

From Hallstead west the maximum grade is 12 feet per mile into Binghamton, N. Y.

Passenger Station.	Location of Railroad.				Population in adjoining townships.	
	Borough	Population.	Township.	Population.		
Lackawanna County.			So. Abington, ..	1,987		
1—Clarks Summit, ...	Clarks Summit,.					
2—Glenburn, ...	Glenburn, ...	319			Waverly B., ...	[illegible]
3—Dalton, ...	Dalton, ...	767			W. Abington, ..	[illegible]
					N. Abington, ..	[illegible]
4—LaPlume, ...	LaPlume, ...	258				
5—Factoryville, ...	Factoryville, ...	759			Benton, ...	[illegible]
Wyoming County.						
			Clinton, ...	464		
6—Nicholson	Nicholson, ...	852	{ Nicholson, ... }	720		
			{ Nicholson, ... }			
Susquehanna County.						
7—Foster, ...	Hopbottom	364	{ Lathrop, ... }	614		
			{ Lathrop, ... }			
			Lenox, ...	1,109		
8—Kingsley, ...			{ Harford, ... }	1,230	Brooklyn, ...	[illegible]
9—Alford, ...			{ Harford, ... }			
10—New Milford, ...	New Milford, ..	654	{ New Milford,. }	1,110		
			{ New Milford,. }			
			Great Bend, ...	815		
11—Hallstead, ...	Hallstead, ...	1,538				
		5,511		8,039		2,811

Borough population, ...		5,511
Township population, ...	8,039	
	2,811	
		10,850
Total population, in 1910, ...		16,361

It may be well to note the elevations along the line of this old railroad location. At the city of Scranton over the Lackawanna River the elevation of the railroad was 736.1 feet above sea level. At Clarks Summit 1,242 feet or an ascent of 506 feet. The elevation of the tracks over the south branch of Tunkhannock Creek at LaPlume was 885.5 feet, or a descent of 353 feet, equivalent to 74 feet per mile. The ascending grade to Clarks Summit from Scranton was equivalent to 75 feet per mile. In crossing the country to Nicholson, the elevation of the summit reached was equivalent to an ascent of 30 feet per mile and the descending grade into Nicholson to 74 feet per mile. The elevation of the tracks at Tunkhannock Creek in Nicholson was 754.5 feet.

Passing up Martins Creek Valley to the summit near New Milford, an elevation was obtained of 1,166.8 feet or an ascent of 412. feet equivalent to 36 feet per mile. From this summit near New Milford down Salt Lick Creek valley to Hallstead, a descent of 295 feet was made to elevation 872 at Hallstead, equivalent to a grade of 60 feet per mile.

When the railroad was originally built, the line was selected and built along a route cheapest to construct and hence little attention was paid to grades and curves. The traffic at that time was light and did not warrant the larger expenditure required to build a perfect railroad. This was between the years 1850 and 1853. It was known then as the Leggits Gap Railroad because the route from Scranton westerly was up Leggits Run Valley and through Leggits Gap between Scranton and Clarks Summit.

In the year 1911, when the through passenger and freight traffic on this main line between Buffalo and New York City, and particularly between Binghampton, N. Y. and Scranton, Pa., had become so enormous as to make necessary, from a standpoint of economy, a reduction in the grades and in the curves between Binghampton and Scranton, there were on this part of the railroad, 14 grade crossings in Lackawanna County, 6 in Wyoming County and 17 in Susquehanna County, from Clark's Summit to Hallstead inclusive. Their location is shown in the following tabular statement:

Grade Crossing on Old Line.—1911.

County.	Municipality.	No. of Grade Crossings.	
LACKAWANNA.	S. Abington Township.	4	(Now in Clarks Summit Boro.)
	Glenburn Borough, ...	5	
	Dalton Borough, ...	3	
	LaPlume Borough, ...	2	
			14
WYOMING.	Factoryville Borough, ...	2	
	Clinton Township, ...	2	
	Nicholson Township, ...	1	
	Nicholson Borough, ...	1	
			6
SUSQUEHANNA.	Lathrop Township, ...	2	
	Hopbottom Borough.	3	
	Lenox Township, ...	0	
	Harford Township	3	
	New Milford Township, ...	3	
	New Milford Borough, ...	2	
	Great Bend Township, ...	2	
	Hallstead Borough, ...	2	
			17
	Total grade crossings, ...	......	37

Besides these crossings at grade of public highways of which 20 were within borough limits in 1911, there was a highway crossing beneath the railroad in LaPlume borough, in Factoryville borough, in Nicholson borough and in Harford Township and a highway over the railroad tracks in Clinton Township at the tunnel, making in all 42 highway crossings.

Early in the year 1911, the railroad company undertook the solution of one of the most expensive engineering projects consummated in the eastern section of the country, involved in the obviating of heavy grade, the elimination of sharp and reverse curves and the avoidance of grade crossings. Most of the distance between Clarks Summit and Hallstead where the contemplated changes were to be made is a mountainous district presenting natural difficulties to the construction of a railroad, the surmounting of which meant excessive expenditures of money, warranted only by the heavy through traffic and for this reason only. It can be readily seen that a total population of 16,000 people in 1910, tributary to the railroad from Clarks Summit to Hallstead, would not afford a revenue from its patronage sufficient to warrant any change in the old railroad. In fact, the traffic there supported two local trains daily between these two stations; but the through passenger traffic and express and freight traffic between New York City and Buffalo and between Scranton and Buffalo and other important intermediate points did warrant the undertaking. It is also apparent that to straighten the line and to obviate heavy grades, the new route through a mountainous district must involve a departure from the valleys of the creek and the construction of numerous bridges and high viaducts and possibly the construction of tunnels, and consequently the new route would be expected to alter and materially change some of the existing facilities which have since 1850 affected the growth and development of the villages and towns along the old line, such for example as existing freight depots and passenger stations and siding facilities, more particularly if the project involved the abandonment of the old line of railroad and the old depots and stations after the new line was completed and put in operation. Hence this phase of the project is peculiarly interesting, and it may be stated, that where the 42.6 miles of railroad under discussion, a highway of traffic through a populous district that the attempt to abandon the old line might entirely fail of having been successful.

The said railroad company, by due and proper corporate action, under and by virtue of the laws of the Commonwealth of Pennsylvania, declared the necessity for a widening, straightening, enlarging and otherwise improving of the line extending between a point in the township of South Abington, Lackawanna County, near Clark's Summit, to a point in the township of Great Bend, Susquehanna County, near Hallstead. This action, as to that portion between Clarks Summit and New Milford, was taken in the year 1912, and between New Milford and Hallstead in the year 1913. The said company had acquired by purchase or condemnation most of the right of way necessary for the said improvement and had engaged in the construction work to a considerable extent, prior to the creation of the Public Service Commission. At that time, July 26th, 1913, the work of constructing the road bed for the said improvements had so far progressed that some of the tracks were being laid and it was necessary for the railroad company to ascertain and decide upon the location of its signals, sidings, depot and terminal facilities. There were, however, a number of crossings that required the approval of the Public Service Commission.

The Improvements.

Beginning at Clarks Summit borough where the tracks are straightened and the grade is lowered some 30 feet, the new route lies to the east of the old route and passes into Glenburn borough where at the new Glenburn station the tracks are about 2,000 feet east of the old tracks and about 100 feet higher; thence through a portion of Dalton borough, where at the new station the tracks are about 2,500 feet east of the old tracks and about 100 feet higher; thence through a portion of North Abington Township into the extreme edge of LaPlume borough, where at the new station the tracks are about 4,000 feet east of the old track and about 115 feet higher; thence through the western edge of Benton Township into Clinton Township at the extreme eastern edge, where at the new station the tracks are 8,300 feet distant from the old track and about 150 feet higher; thence into Nicholson Township, through the tunnel and over the Tunkhannock viaduct into Nicholson borough, where at the new station the tracks are 1,000 feet east of the old track and 193 feet higher; thence through a narrow strip of Nicholson Township and a small stretch of Lenox Township into Lathrop Township to Foster Station in Hopbottom borough, where at the new station the tracks are 1,200 feet distant from the old track and about 125 feet higher; thence through a small portion of Lathrop and Lenox townships and Harford township into Brooklyn Township to the new Kingsley station, where the new tracks are about 2,300 feet west of the old tracks and about 75 feet higher, the crossing over the valley of Martins Creek from the east to the west sides being by means of the Martins Creek viaduct; thence continuing through Brooklyn Township to the new Alford station where the tracks are 800 feet west of the old tracks and about 50 feet higher; thence through Brooklyn Township and New Milford Township to New Milford borough, where at the old station, which is to remain, the new and the old routes come together, but the new tracks are two feet higher; thence through the New Milford and Great Bend townships, where the new tracks lie west of the old ones, and where the old tracks will be used for west bound traffic, to Hallstead borough at the new station, whose location is about the same as the old, but the new tracks are 20 feet higher.

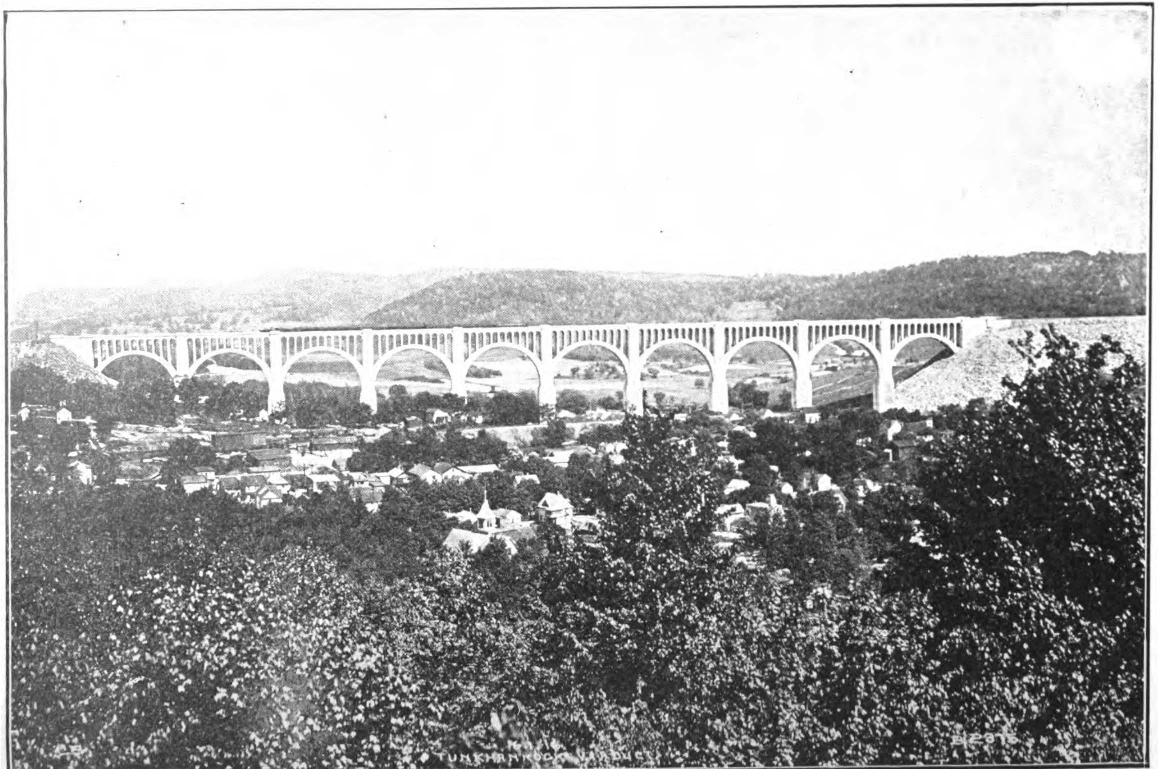
This new route between Clarks Summit and Hallstead is 3.6 miles shorter than the old line, and the running time of trains will be cut between 20 and 30 minutes between each point.

The summit of the depressed tracks through Clarks Summit borough have an elevation of 1,212.5 feet above sea level; thence the grade will descend at the rate of 36.27 feet per mile to the tunnel near Nicholson and at the Tunkhannock viaduct in Nicholson borough the elevation is 947 feet or 240 feet above the creek beneath; thence the grade ascends at the rate of 12.5 feet per mile to the New Milford summit at elevation 1,140.3; and thence the grade descends into Hallstead borough at the rate of 32.15 feet per mile. The maximum grade on the old line was 1.23%, whereas on the new line it is but 0.68%. The total curvature on the old line was 3,970 degrees, whereas on the new line it is 1,570 degrees only. The maximum degree of curvature on the old line was 7 degrees, whereas on the new line it is 3 degrees and compensated. The grade from Clarks Summit to New Milford summit has been reduced from 71 feet in a mile to 36 and 12.5 feet in a mile, and from New Milford summit to Hallstead it has been reduced from 60 feet in a mile to 32 feet in a mile.

The location of the new stations, the distance between the new and the old tracks and the difference in location is shown in the following tabular statement:

Passenger Stations.

Passenger Stations.		New Location of Railroad, etc.		
Name.	New or Old.	Distance between old and new station.	Difference in elevation of new tracks.	Location.
Lackawanna County.		Feet.	Feet.	
1 Clarks Summit,	Old station.	0	301 lower,...	Clarks Summit Borough.
2—Glenburn,	New station,	2,000	100 higher,..	Glenburn Borough.
3—Dalton,	New station,	2,500	100 higher,..	Dalton Borough. North Abington Township.
4—LaPlume,	New station,	4,000	115 higher,..	LaPlume Borough. Benton Township.
Wyoming County.				
5—Factoryville,	New station,	8,300	150 higher,..	Clinton Township. Nicholson Township.
6—Nicholson,	New station,	1,000	193 higher,..	Nicholson Borough. Nicholson Township.
Susquehanna County.				
7—Foster,	New station.	1,200	125 higher,..	Lenox Township. Lathrop Township. Hopbottom Borough. Lathrop Township. Lenox Township. Harford Township.
8—Kingsley,	New station,	2,300	75 higher,..	Brooklyn Township.
9—Alford,	New station,	800	50 higher,..	Brooklyn Township. New Milford Township.
10—New Milford	Old station,	0	2 higher,..	New Milford Borough. New Milford Township. Great Bend Township.
11—Hallstead,	New station,	0	20 higher,..	Hallstead Borough.



Tunkhannock Viaduct at Nicholson Borough, Looking East.

Along the new route 42 public highways are crossed, at 19 of which the highway is bridged over the railroad, and at 22 of which the highway is carried under the railroad, and at one place an old grade crossing is maintained on the old line as a grade crossing because it is impracticable to avoid it. This is in New Milford township about a mile north of New Milford borough where the two new tracks are laid a few hundred feet west of and paralleling the two old tracks. The new tracks are elevated sufficiently so that the township road which crosses the old tracks at grade is carried underneath the new tracks. To separate the grades of the old tracks and the township road, on account of drainage, would make it necessary to build a viaduct of great length over Salt Lick Creek and the old track and estimated to cost at current prices about $50,000. The township road is travelled on an average by 6 or 8 teams per day. The 41 crossings where the grades are separated are about equally divided, 20 of them being in the townships and 21 of them being in the borough. In the following table the location of these crossings is shown:

County.	Highway.		Location.	
	over.	under.	Borough.	Township.
Lackawanna County.	4	....	Clarks Summit.	
	1	2	Glenburn.	
	1	3	Dalton.	
		1	....	North Abington.
	1	1	LaPlume.	
	2	....	....	Benton.
Wyoming County.		1	....	Clinton.
	2	(at tunnel)	....	Nicholson.
	1	1	Nicholson.	
Susquehanna County.	1	1	....	Lathrup.
	1	1	Hopbottom.	
		1	....	Harford.
	1	4	....	Brooklyn.
	2	2	....	New Milford.
	1	1	New Milford	
	1	1	....	Great Bend.
		2	Hallstead.	
	19	22		

The improvement has eliminated 36 grade crossings and in their place substituted 41 overhead and underneath crossings. The cost for the masonry work at these new crossings including the steel work amounted to $681,000 and the cost for constructing the approaches including incidental damages amounted to about $419,000, making a total cost of approximately $900,000. Two of the crossing are carried over a tunnel, and two of them are spanned by a viaduct, so that the average cost for the remaining 37 separated crossings is $24,300.

Types of Bridges.

Tunkhannock Viaduct—The Tunkhannock viaduct, so called because it is built across the valley and over Tunkhannock Creek in the borough of Nicholson, Wyoming County, is the largest re-inforced concrete bridge in the world. It is a two track structure, 2,375 feet long and stands 240 feet above the creek bed and 300 feet above bed-rock foundations. The accompanying photograph, shows the massive proportions, particularly when one discerns the railroad train shown on the viaduct. The bridge consists of 10 spans of 180 feet each and two spans of 100 feet each. The large arches are surmounted by small superimposed lateral arches upon which the solid concrete surface of the viaduct is carried. In its construction, 167,000 cubic yards of concrete and 1,140 tons of re-inforcing steel were used. The cost of the structure was approximately $1,500,000. The work was begun in the spring of 1911, and completed early in the year 1916.

Martins Creek Viaduct—Martins Creek viaduct is located partly in Harford Township and partly in Brooklyn Township, Susquehanna County, about one mile south of Kingsley Station. The bridge is a three track structure, 1,600 feet long and 150 feet above the bed of the creek. It consists of 11 re-inforced concrete spans, 7 of which are 150 feet in length, 2 of 100 feet in length, and 2 of 50 feet length. In its construction, 77,500 cubic yards of concrete were used, and 1,600,000 lbs. of re-inforcing steel. The cost was about $800,000. Its pleasing architecture may be noted by reference to the accompanying photograph.

Railroad Bridges—The accompanying photograph of the Waverly Road arch at Dalton is typical of the under highway arched crossings, the spans of which range from 24 to 34 feet. This Dalton arch is a 34 foot semi-circular span.

The accompanying photograph of the Creamery Road bridge New Milford, shows a railroad bridge over a highway similar to numerous other flat top under crossings, some of which are of slab and others of beam construction. The span of the structure shown in the photograph is 20 feet and has a vertical clearance of 12 feet only. The borough council consented to these dimensions. The Public Service Commission did not then have jurisdiction. The span of all other structures of this kind along the line is 24 feet with a vertical clearance of 14 feet. Within one half a mile of this New Milford underpass, and also within said borough, there is a highway over crossing. The reason that a vertical clearance of 12 feet was agreed to was on account of drainage. 300 feet distant and at a slightly lower level is Salt Lick Creek.

The accompanying photograph of the Church Street bridge in Hallstead Borough shows another form of slab construction for a railroad bridge over a highway. Church Street is a borough highway. The total width of the bridge or street between the abutments is 50 feet. The sidewalks are 8.5 feet in the clear and the two roadways on both sides of the centre piers are 14 feet in the clear and the vertical clearance is 14 feet.

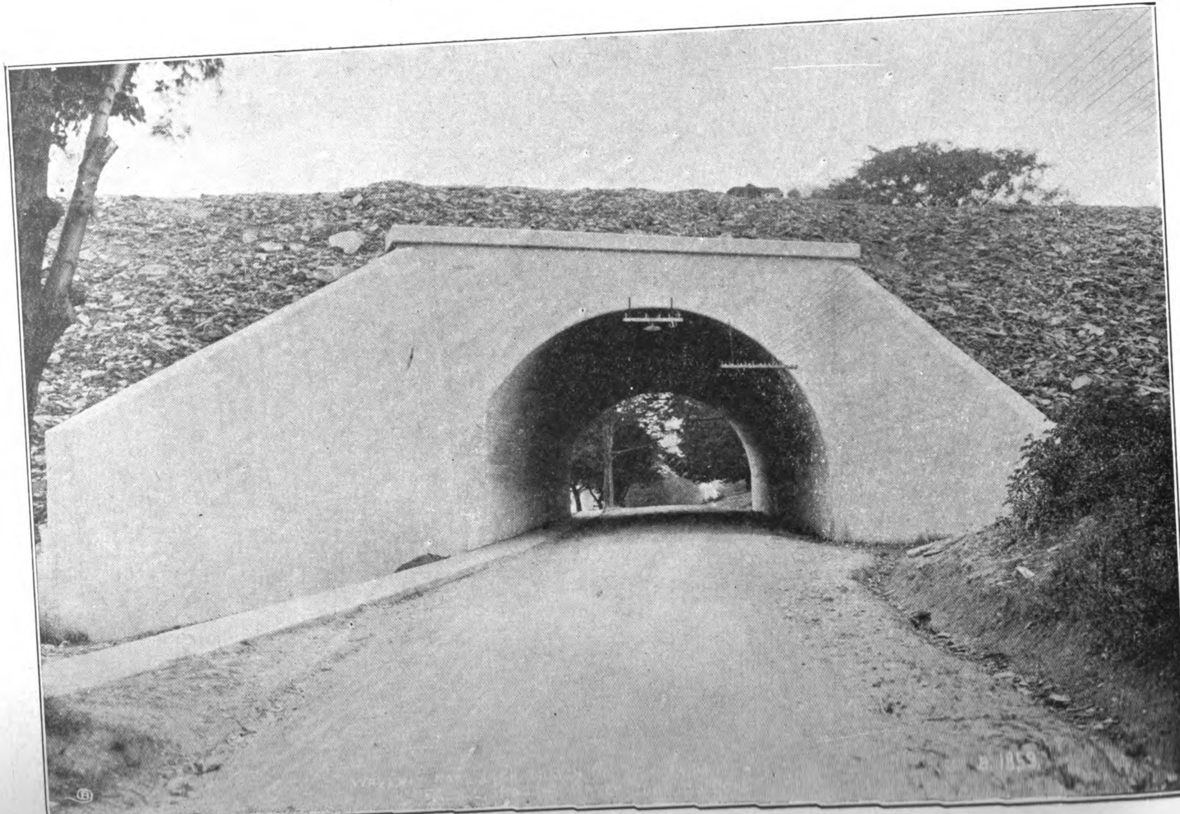
Highway Bridges—The accompanying photograph of the Gilmore Road bridge in Benton Township, showing the Crissman Road arch in the back ground is typical of some of the overhead highway arches along the new line. The 60 foot span provides for a 4 track roadway and the width of the bridge for highway traffic is 24 feet in the clear as are all of the highway bridges along the route. The floor is of slab construction and the wearing surface is macadamized.

The accompanying photograph of the Alford Road bridge in Brooklyn Township is typical of some other overhead highway arches along the new line. The span of 60 feet provides for a 4 track roadway. The arch is elliptical and has 10 foot 9 inch rise and 1 foot 6 inch crown thickness.

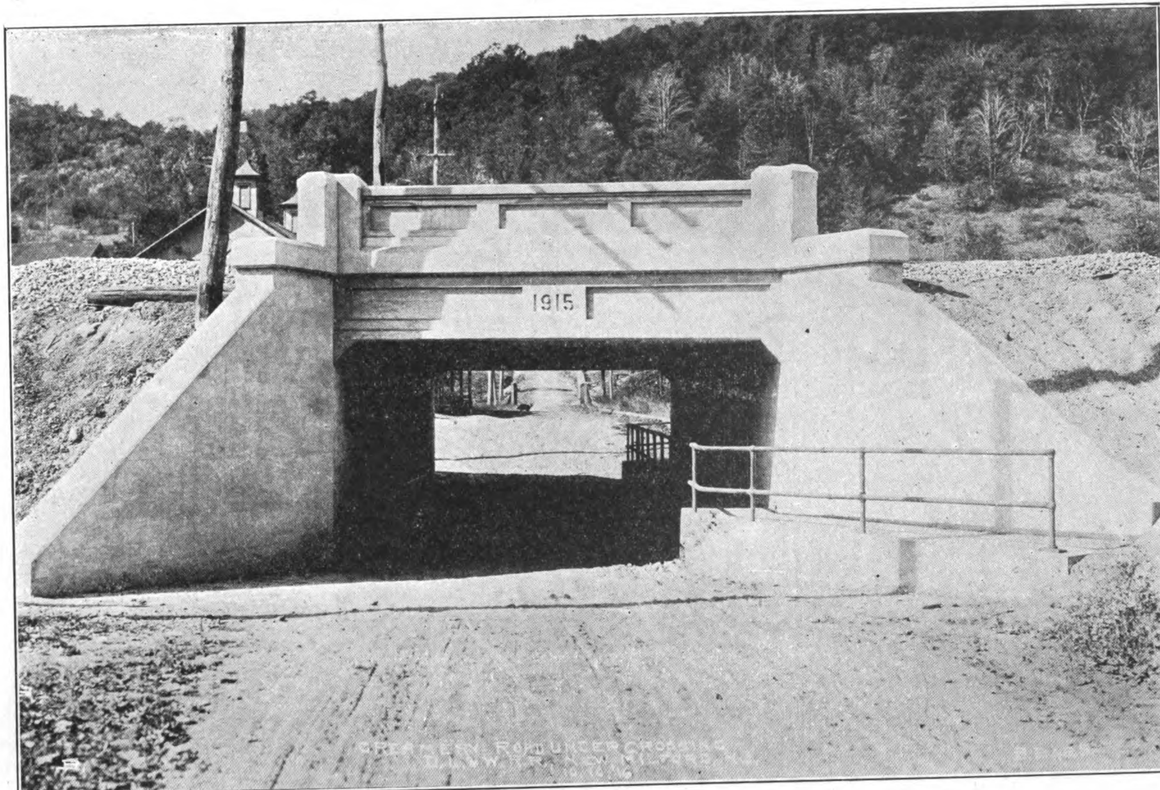
The Tunnel.

The tunnel is located in Nicholson Township, Wyoming County about one mile south of the Tunkhannock viaduct. It is a two track structure built in rock, faced with concrete and lined with brick, 3,200 feet long with two air

Martins Creek Viaduct, Looking North up Stream.



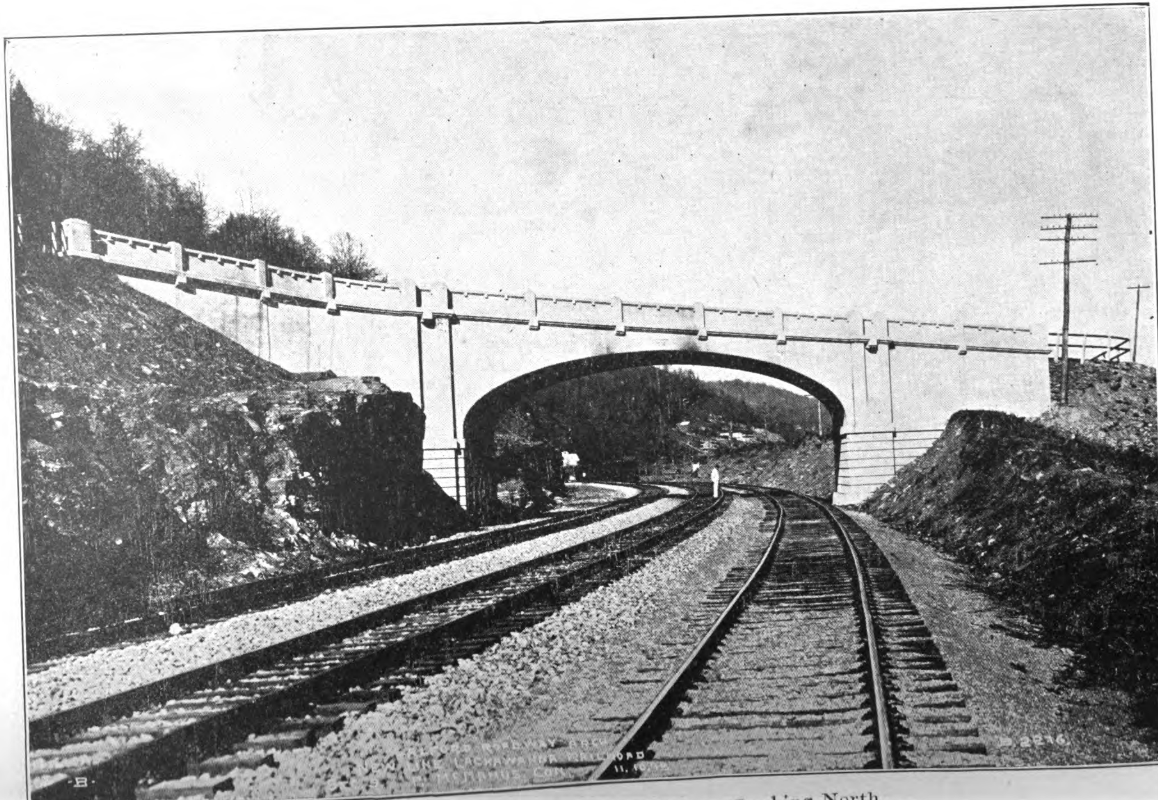
Dalton, Waverly Road Arch, Looking East.



New Milford, Creamery Road Bridge, Looking West.

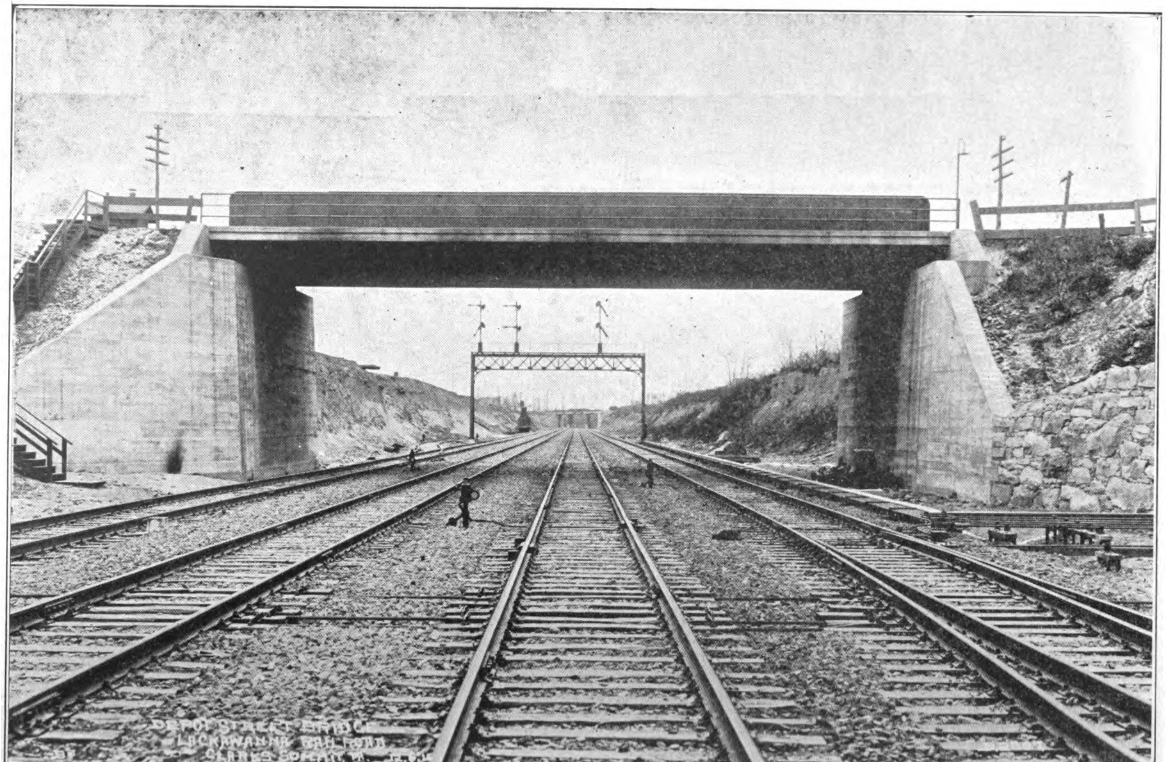
Hallstead, Church Street Bridge, Looking West.

Benton Township, Gilmore Road Bridge, Looking North. Crissman Road Arch in the Background.

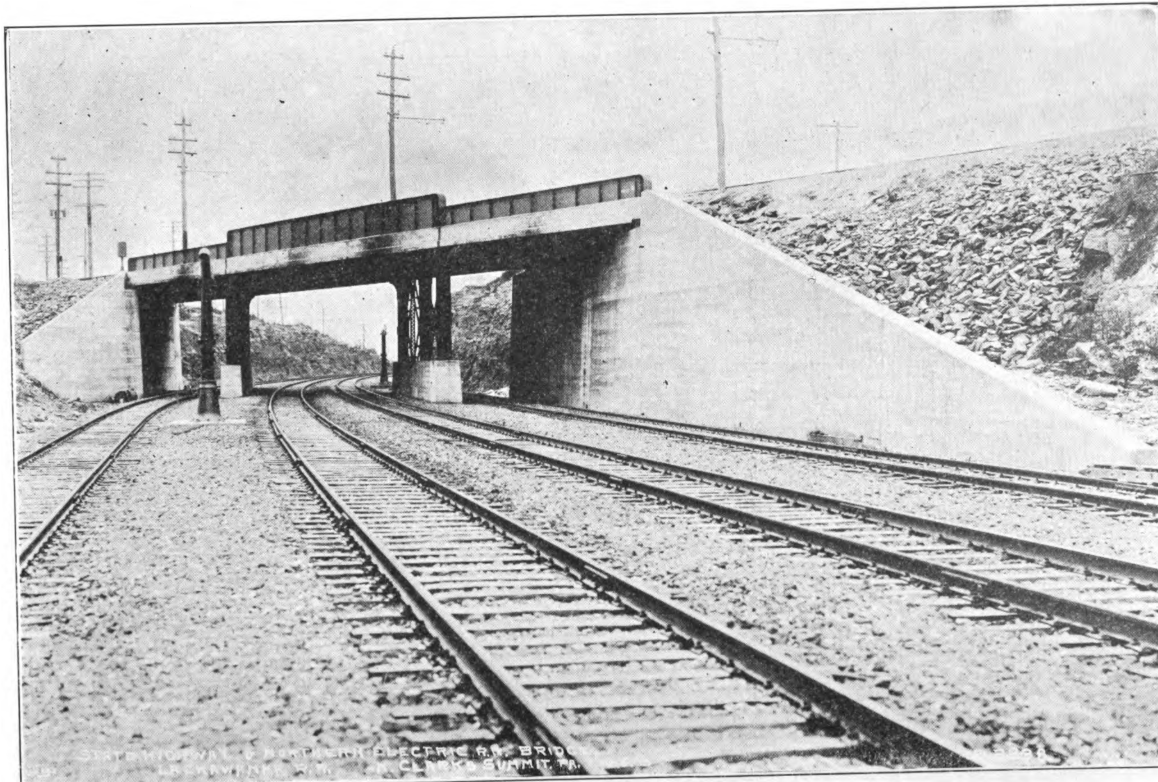


Brooklyn Township, Alford Road Bridge, Looking North.

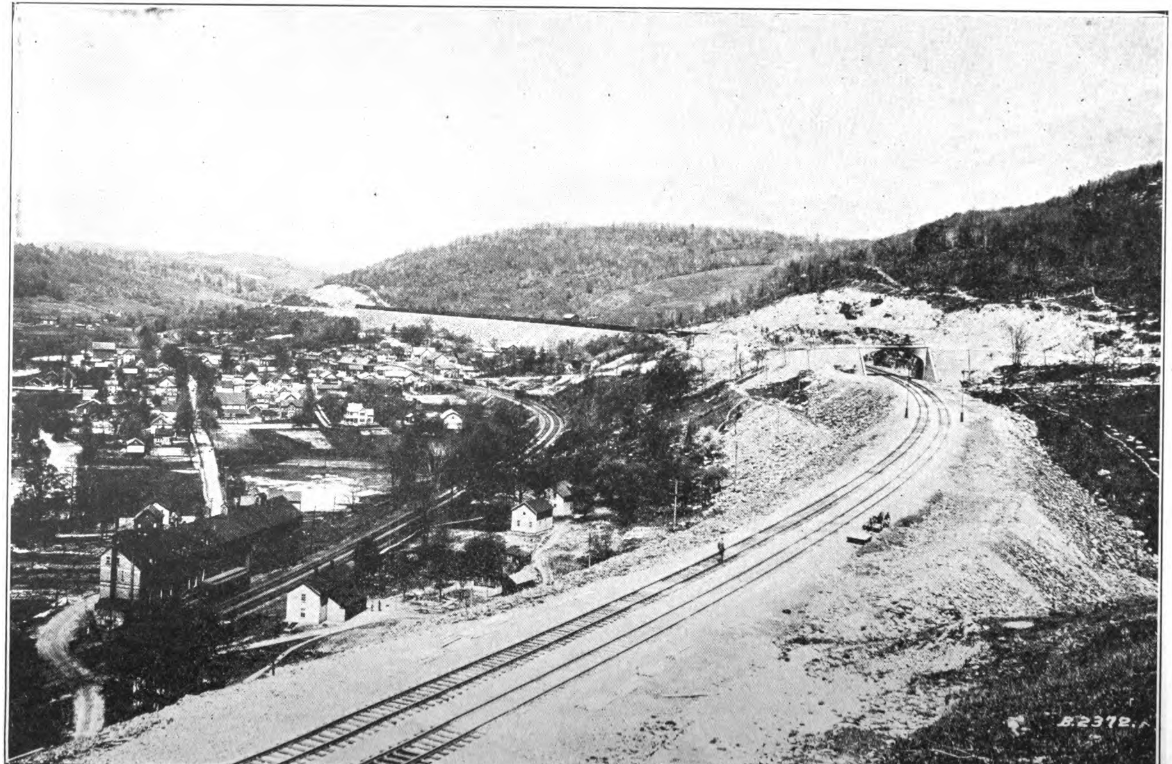
Clarks Summit, Main Street Bridge, Looking North.



Clarks Summit, Depot Street Bridge, Looking North.



Clarks Summit, State Highway Bridge, Looking North.



Hop Bottom, Looking North, Showing Old and New Tracks.

Hop Bottom, Glenwood Road Bridge and Foster Station, Looking North.

shafts. It is 30 feet wide at the track level, the arch is semi-circular, 15 feet radius, the springing line being 8 feet 8 inches above the level of the base of the rails. The tracks are laid on 13 foot centres, the centre line of each track being 8 feet 6 inches distant from the nearest side wall. This provides a vertical clearance of 20 feet above the top of the outside rail of each track.

Total Cost of Improvements:

The amount of earth removed in making the improvements reached a total of 5,525,000 cubic yards, the rock excavation reached a total of 7,647,000 cubic yards, and 300,000 cubic yards of concrete were used in the bridges, viaducts and culverts, also 4,720,000 pounds of re-inforcing steel. The total cost of the project, including stations and equipment, damages and legal expenses, was approximately $12,500,000, for 39 miles of new railroad, equivalent to a cost of $320,513 per mile.

Crossings Considered by the Commission.

In Clarks Summit—This borough although a small community now has great expectations of growth. The railroad company by agreement with the town council erected three highway bridges over its new right of way and tracks. They are shown in the accompanying photographs. The first photograph is a view looking north of the Main Street bridge and the old passenger station roof may be seen in the background at the left at the elevation where it is to remain. A platform on the level of the tracks 30 feet below is now constructed and steps lead up to the station. The baggage is taken up on an incline plane operated electrically. It will be noted that the bridge is a steel girder, deck type, supported on steel columns with its ends resting on concrete abutments. In the back ground, the Depot Street bridge may be seen.

The second photograph sows the Depot Street bridge, a thru steel girder structure of the type used where spans and clearances prohibit the use of concrete. The I-beam floor is encased in concrete. The vertical clearance of all bridges over the railroads is nowhere near less than 22 feet above the top of the rail. In the back ground may be seen the city highway bridge.

The third photograph shows the state highway bridge over the railroad. Because of the length of the span due to the oblique crossing, the thru steel girder, with I-beams encased in concrete were supported by steel columns as shown in the photograph.

In spite of the fact that these three bridges are not far apart, the borough petitioned the Public Service Commission for the construction of a fourth highway bridge. The population now is about 1,700. Owing to proximity to Scranton, a very much larger population is anticipated within a few years and hence the local authorities have deemed it inexpedient to sanction the closing up of any highway laid out and used across the right of way and track of the railroad company. Knapp Road distant a few hundred feet south from Main street is alleged by the petitioners to be such a highway. At the close of the year, covered by this report, a conclusion had not been reached by the Commission.

In Hopbottom—Nearly all of the borough of Hopbottom is shown in the first of the two accompanying photographs. The first photograph looking north shows the new tracks high above the town and the old tracks, and it also shows the Glenwood Road arch highway bridge over the new tracks. This bridge and the approach to it was made the subject of a petition to the Public Service Commission. The borough of Hopbottom complained that it would be irretrievably damaged for all time by reason of the abandonment of the old road station and freight depot which were on a level and in the heart of the village and about which the community had settled and the substitution therefor of the new tracks and station high above the town and that as part compensation for such damages the railroad company should widen, straighten and otherwise improve the public highway by relocating the same so as to provide a minimum grade on the approach to the new station and bridge over the tracks and pay all of the costs and expenses incident thereto. This the railroad company declined to do, but it has constructed a switch-back connection, starting from the new tracks between Nicholson and Foster and descending along the slope of the hill-side to connect with the old tracks at the lower level into Hopbottom. By means of this connection the company purposes to maintain and use the existing freight depot at its old level in Hopbottom and thence via the old tracks or track at the old level transport freight in and out of Nicholson as well as Hopbottom. The distance between these towns is about 5.4 miles, and along this length of the old road including the boroughs there are 6 grade crossings.

The second photograph shows the Glenwood Road bridge and in the back ground the new Foster station at Hopbottom constructed in conformity with the plans approved by the Public Service Commission.

Clinton:

In Benton Township—The Gilmore Road crossing in Benton Township illustrated by an accompanying photograph was considered by the Public Service Commission and approved.

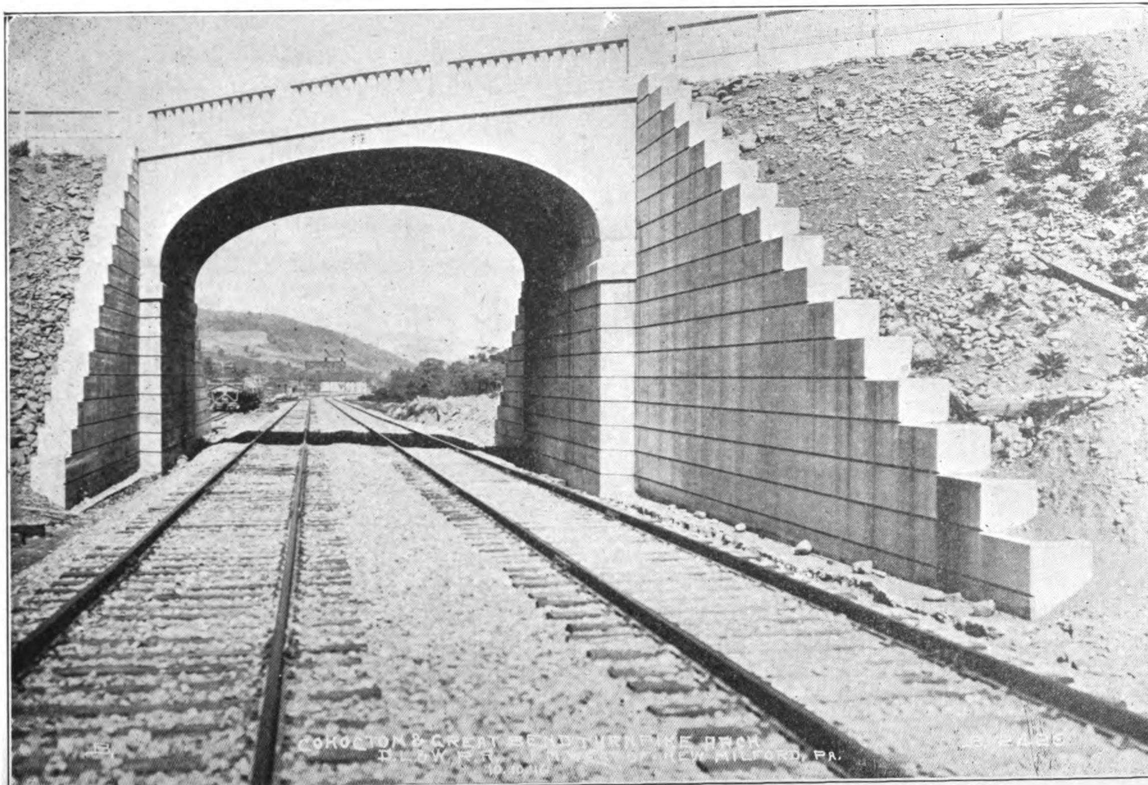
In Clinton Township—The vacation of one highway and the construction of a highway beneath the railroad at the new Factoryville station in Clinton Township, and particularly the matter of the location of the new station a mile and a half distant from the old station and the borough of Factoryville was made the subject of a complaint to the Commission. The underpass was constructed, also the new station, and the company at the end of the year covered by this report was considering the feasibility of building a siding for freight to connect with the borough and the old station.

In Nicholson Township—The matter of vacating one highway and of substituting therefore a re-located highway over the tunnel in Nicholson township came before the Public Service Commission. The matter was adjusted and at the expense of the railroad company.

In Lathrup Township—The construction of a township highway over the new tracks in Lathrop Township came before the Commission and received favorable action.

In New Milford Township—A very material relocation of the state highway and the construction of the new highway over the west bound tracks, being the old line, came before the Public Service Commission for approval. The accompanying photograph shows the new bridge as constructed in conformity with the plans approved.

In Great Bend Township—The abandonment of the so-called McKinney and Florence highway crossings in this township and the substitution therefor of a re-located state highway and bridge over the railroad came before the Public Service Commission and was the subject of protracted hearings and an order dated April 9, 1915.



New Milford Township. State Highway Bridge, Looking North.

Engineering and Contracting

Devoted to the Economics of Civil Engineering Design and to Methods and Costs of Construction

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lingsworth as general superintendent and W. Naugle, R. E. Mosier and W. B. Converse as assistants on the various operations.

Inspecting, Coating and Testing Steel Pipe for 112 Mile High-Pressure Gas Line from Taft to Los Angeles, Calif.

The construction of a 112 mile high-pressure steel pipe natural gas line from Taft to Los Angeles, Calif., was completed in the fall of 1912. The following notes on the mill inspection of the pipe and the field coating and testing of the pipe line are taken from an article by W. E. Barrett in a recent issue of the American Gas Light Journal.

The pipe line was designed to work at an initial pressure of 450 lbs., and a terminal pressure of 50 lbs., which would give a delivery capacity of 26,000 million cubic feet per day. The pipe ordered was plain-end steel tubing, 12¾ ins. outside diameter, weighing nominally 33 lbs. per lineal foot. About 75 miles of this pipe was of double length, ranging from 34 ft. to 40 ft. in length; the balance was standard, 18 ft. to 20 ft. lengths. By using the double lengths of pipe, in the valleys on the north and south ends of the line, a saving of approximately $31,000 in the cost of couplings alone was effected for the benefit of the client, as the work was carried on under the J. G. White Engineering Corporation standard method of "Cost plus a fee."

Inspection.—As this pipe line was to work under heavy pressure, it was deemed advisable to exercise very reasonable precaution in its manufacture and preparation for shipment as well as in the construction of the line. The J. G. White Engineering Corporation furnished its own retained inspectors at the mills of the contractor tube company. The certificates of chemical composition of the ingots from which the skelp was made were at the inspectors' disposal, upon request. The inspectors' principal duties were to observe the size by the ring test, the alignment of the tube, the length, weight and hydrostatic pressure test; this latter was required at 700 lbs. While the pipe was at a temperature of practically 100° F., brushed free from all mill scale, it was given a shipping coat of specially prepared protective material, allowed to dry, then shipped.

Coating.—On account of the large percentage of ground salts (strongly alkaline in composition) present along the proposed route, the protection of the pipe from the destructive effects of these salts was a very necessary precaution. For this purpose, a carefully prepared, neutralized coating was used, which had for its base a clean coal tar not a tar produced at a low temperature of say 1,600° F., to 1,800° F., but one produced at a temperature of about 2,400° to 2,600° F. There is a considerable difference even in coal tar, outside of the fact that it is black. After the pipe was received and distributed, any abrasions of the shipping coat were carefully cleaned and all dust or dirt brushed off. The spots were first coated, then the entire length given two, three or four coats, as the analysis of the soil dictated. These analyses were made in the laboratory of the University of Southern California.

Testing.—After the line was completed and the pressure tests were applied, only one length was found defective, and in this length the seam ripped at 368 lbs. The line was tested to 470 lbs., for the first 43 miles from the Taft terminal; 370 lbs., for the next 39 miles; and 250 lbs. for the balance of the distance to the Los Angeles terminal, and, after tightening some of the asbestos joints, with which the first 10 miles of the line from the Taft terminal was laid, to the small whisper-leaks, which only developed after the line had been raised in pressure to 368 lbs., then dropped to zero, when the blowout occured, and again raising the pressure to 470 lbs., careful inspection showed the small leaks. These leaks were apparently caused by the lack of sufficient resiliency in the gaskets to recover their original position after the high internal pressure had been applied. However, when these were once made tight under pressure they remained permanently so. The line when finally tested proved bottle tight. A second test was applied, about May 20, 1913, after the line had laid over the wet season. A pressure of 170 lbs. was then applied, from end-to-end, and it was still perfectly tight, holding this pressure 7½ hours without any drop in the gages. All the gages were carefully proven on two dead-weight test sets, and adjusted to perfect agreement.

Bridges

Design and Construction Features of the Tunkhannock Creek Viaduct on the D., L. & W. R. R. at Nicholson, Pa.

Contributed by C. W. Simpson, Resident Engineer D. L. & W. R. R., in Charge of Construction.

The Delaware, Lackawanna & Western Railroad Co. is constructing some grade improvement work of large magnitude between Clark's Summit and Hallstead, Pa., the improvement consisting of a new three-track line about forty miles long. The new line does not deviate widely from the present one, as can be seen by an inspection of the map shown in Fig. 1. The greatest divergence is about 1½ miles, but for the greater part of the distance the lines are only a few hundred feet apart. The new line does, however, greatly reduce the grades and eliminates the sharp sags and peaks in the grade line. The maximum grade has been reduced from 1.23 to 0.682 per cent, and a very long 0.40 per cent grade has been reduced to a 0.237 per cent grade. The principal structures along the new line are the Nicholson Tunnel, a double-track bore 3,630 ft. long; the Martins Creek Viaduct, a three-track concrete structure having a maximum height of 150 ft. and a length of 1,600 ft.; and the Tunkhannock Creek Viaduct, a double-track structure having a maximum height of 240 ft. and a length of 2,375 ft. The quantities of materials involved in the construction of the new line are 7,647,000 cu. yds. of rock, 5,525,000 cu. yds. of earth, 146,000 cu. yds. of tunnel excavation, 370,000 cu. yds. of concrete, and 2,360 tons of reinforcing steel. The total cost of the improvement will be about $12,000,000.

This article will treat only of that part of the improvement known as the Tunkhannock Creek Viaduct, the construction features of this viaduct being explained in detail.

DESIGN FEATURES.

The Tunkhannock Creek Viaduct, which is said to be the largest concrete railroad bridge in the world, is composed of ten 180-ft. and two 100-ft. semi-circular arch spans springing from solid piers founded on bedrock, supporting transverse spandrel walls, upon which rests a floor system composed of semi-circular spandrel arches. The deeper piers have a section 40x46 ft. below the ground surface, and all piers are 36 ft. 6 ins. by 43 ft. 6 ins. to a point 17 ft. 6 ins. below the springing line of the arches. At this elevation a 4-ft. 3-in. offset provides a seat for the temporary steel centering. The deepest pier extends 98 ft. below the ground surface, and at this pier it is 304 ft. from the bottom of the foundation to the highest point of the masonry.

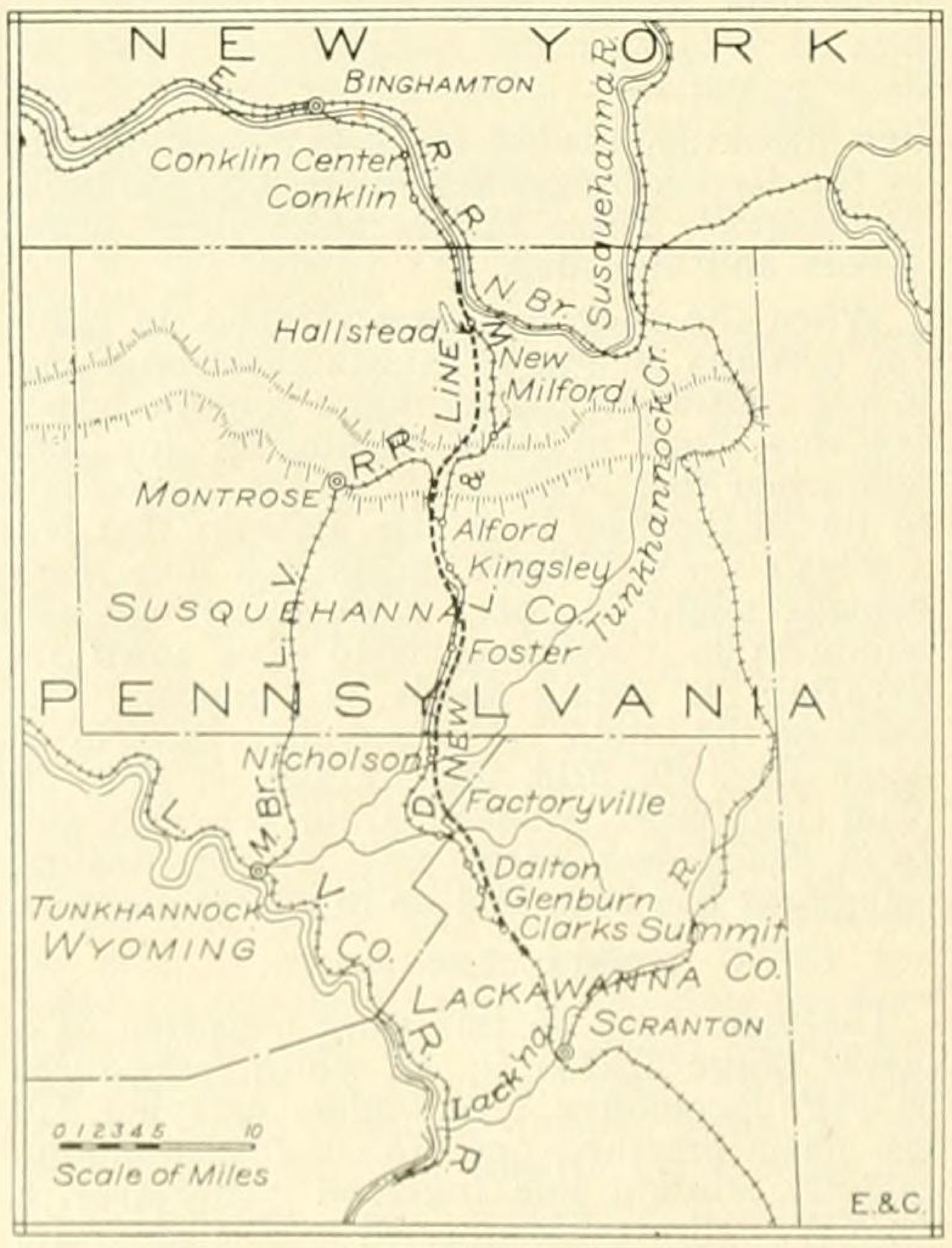


Fig. 1. Map of Region in Vicinity of New Line of D., L. & W. R. R., of Which Tunkhannock Creek Viaduct Is a Part.

A 100-ft. span is located at each end of the structure. This is termed an "abutment span," as it will be entirely buried by the approach embankment. Each of these spans is composed of two ribs 5 ft. 6 ins. thick at the crown and 12 ft. wide. These ribs are 22 ft. on centers, thus leaving a 10-ft. space between the ribs. The two ribs are tied together by four reinforced concrete struts. They support reinforced transverse walls on which rests a reinforced floor slab varying from 1 ft. 9 ins. to 2 ft. 6 ins. in thickness. The floor slab extends a few feet beyond the crown of the arch, and the space between the arch ring and the floor slab is closed with an 18-in. longitudinal curtain wall along each outside face, so that when the approach embankments are completed these "abutment spans" will have the appearance of "U" abutments.

Each 180-ft. span, a design drawing of which is shown in Fig. 2, is composed of two ribs 8 ft. thick at the crown and 14 ft. wide. These ribs are spaced 20 ft. on centers, thus leaving a 6-ft. opening between them. Each rib is reinforced with fourteen 1-in. square steel rods in both the intrados and the extrados (see Fig. 2, b and c). These ribs carry reinforced transverse spandrel walls varying from 3 ft. 2 ins. to 4 ft. 6 ins. in thickness (see Fig. 2, a and b). The spandrel walls are arched over the space between the ribs and carry a floor system composed of 13-ft. 6-in. semi-circular spandrel arches having a thickness of 1 ft. 9 ins. at the crown. The spandrel walls carry a 6-in. belt course 1 ft. 6 ins. below the springing line of spandrel arches, thus providing a seat for the temporary arch centers.

Directly over the piers the span opening which is left between the segments of the arch is closed by means of a pilaster 3 ft. thick and about 22 ft. wide, bonded to the spandrel walls to give longitudinal stiffness to the spandrel system and an appearance of solidity to the piers. The parapet wall, which extends the entire length of the viaduct, rises 7 ft. 3 ins. above the viaduct floor (see Fig. 2, b and c). The pilasters at the piers extend 3 ft. above the top of the parapet wall (see Fig. 2, b and d). To provide drainage the top of the floor is given a 6-in. slope from the crown of each spandrel arch to the center of the adjacent spandrel wall, and the water is carried down through the center of the wall through a 6-in. opening and is discharged into the space between the main arch ribs. The floor over each span is provided with four expansion joints, one over each main pier and one over

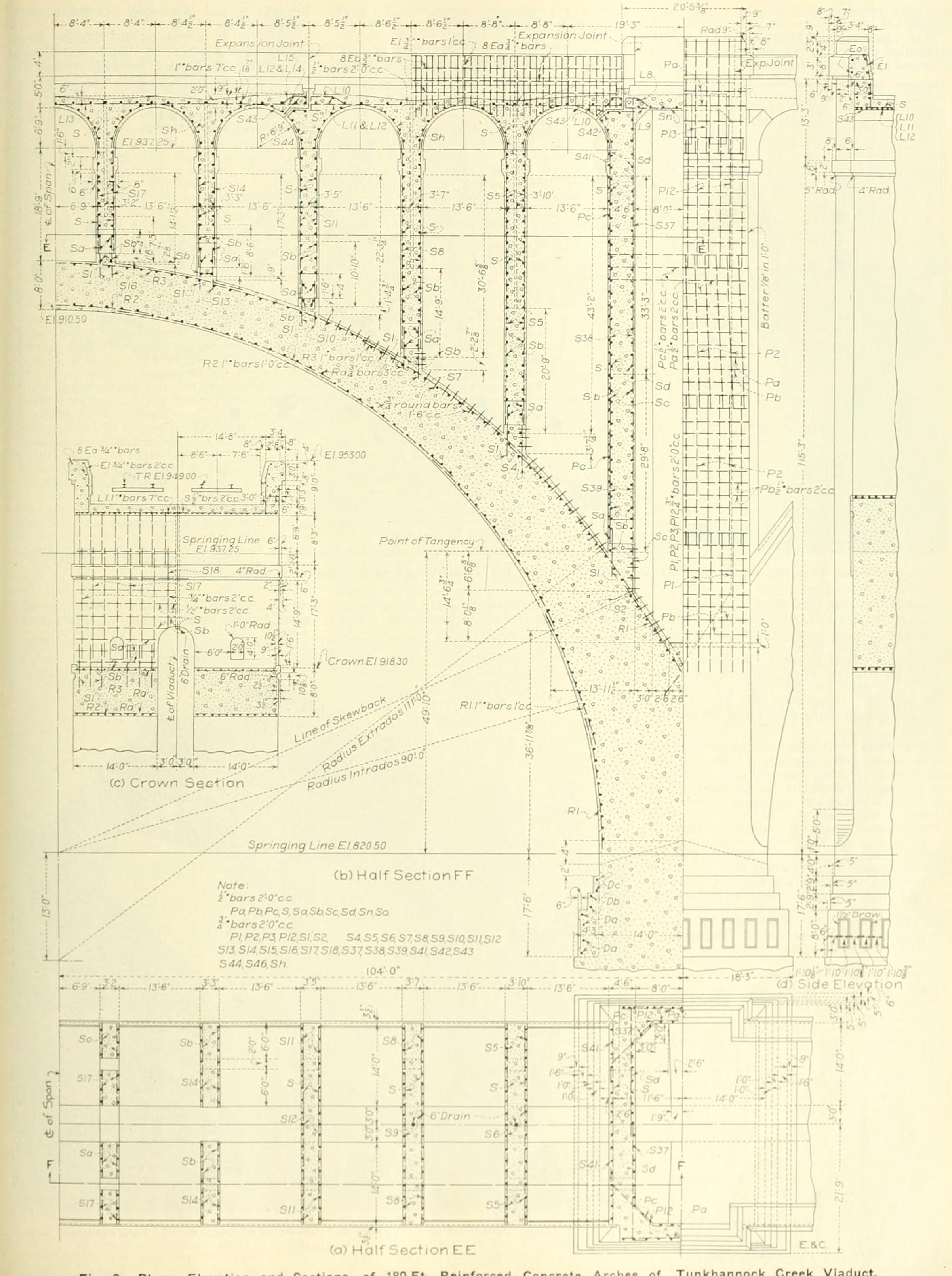


Fig. 2. Plans, Elevation and Sections of 180-Ft. Reinforced Concrete Arches of Tunkhannock Creek Viaduct.

the third spandrel wall from the pier (see Fig. 2, b).

This viaduct requires 47,000 cu. yds. of foundation excavation, 165,000 cu. yds. of concrete and 1,200 tons of reinforcing steel. Three classes of concrete were used, designated as "Class A," "Class B," and "Cyclopean." Class A concrete is a 1:2:4 mixture and is used only for the reinforced floor slab over the "abutment spans"; Class B is a 1:3:5 mixture, and is used for all other work above the springing line; "Cyclopean" is the same as Class B, with "derrick" stone embedded in the concrete, and is used in the piers below the springing line.

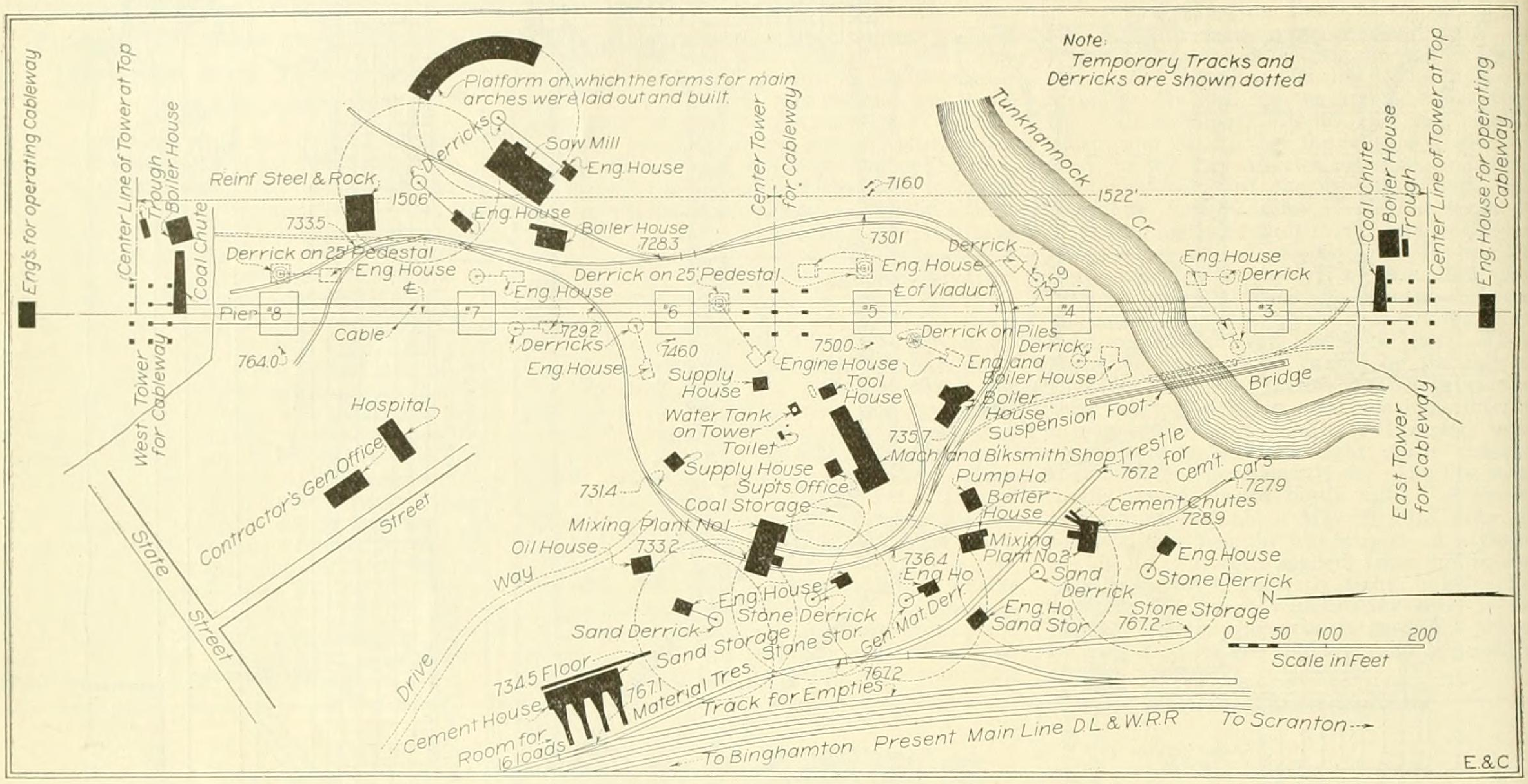


Fig. 3. Layout of Contractors' Plant for Construction of Tunkhannock Creek Viaduct.

CONTRACTOR'S PLANT AND GENERAL PROCEDURE.

The contract for the construction of the viaduct was formally executed in June, 1912, but the successful bidder was notified about the middle of May and started work on May 24, 1912.

The general layout of contractor's plant is shown in Fig. 3. The present tracks of the railroad company are on an embankment which rests on a small ridge, so that they are about 60 ft. higher than the creek bed and about 35 ft. higher than the ground level at the mixing plants. The loop formed by the narrow-gauge tracks encloses a knoll about 30 ft. higher than the general level of the valley. The general office and the hospital are located on higher ground.

A narrow ridge extending westward from the west end of the blacksmith shop connects the above mentioned knoll with the ridge on which the railroad company's tracks are located. The general material derrick is located on this ridge. A similar ridge extends from pier No. 6 to the high ground at the hospital. Piers Nos. 5 and 6 are located on the east slope of the knoll so that the ground surface at the west side of the excavations is about 30 ft. higher than on the east side. Piers Nos. 3, 4 and 7 are located on the low ground and pier No. 8 lies on a slope, so that the ground surface at the south side of the excavation is 40 ft. lower than on the north side.

The first operation of the contractors was the widening of the railroad company's embankment and the laying of the track marked "Track for Empties" and "Room for 16 Loads" (see Fig. 3). This work was started May 24, 1912, and on June 12 the track was completed and a track piledriver started to construct the material trestles. The general material derrick was erected in June, during which time work was progressing on the shops, storehouses and office buildings.

FOUNDATION EXCAVATION.

After the narrow-gauge tracks had been graded and laid from the location of mixing plant No. 1 to pier No. 4, embracing a small

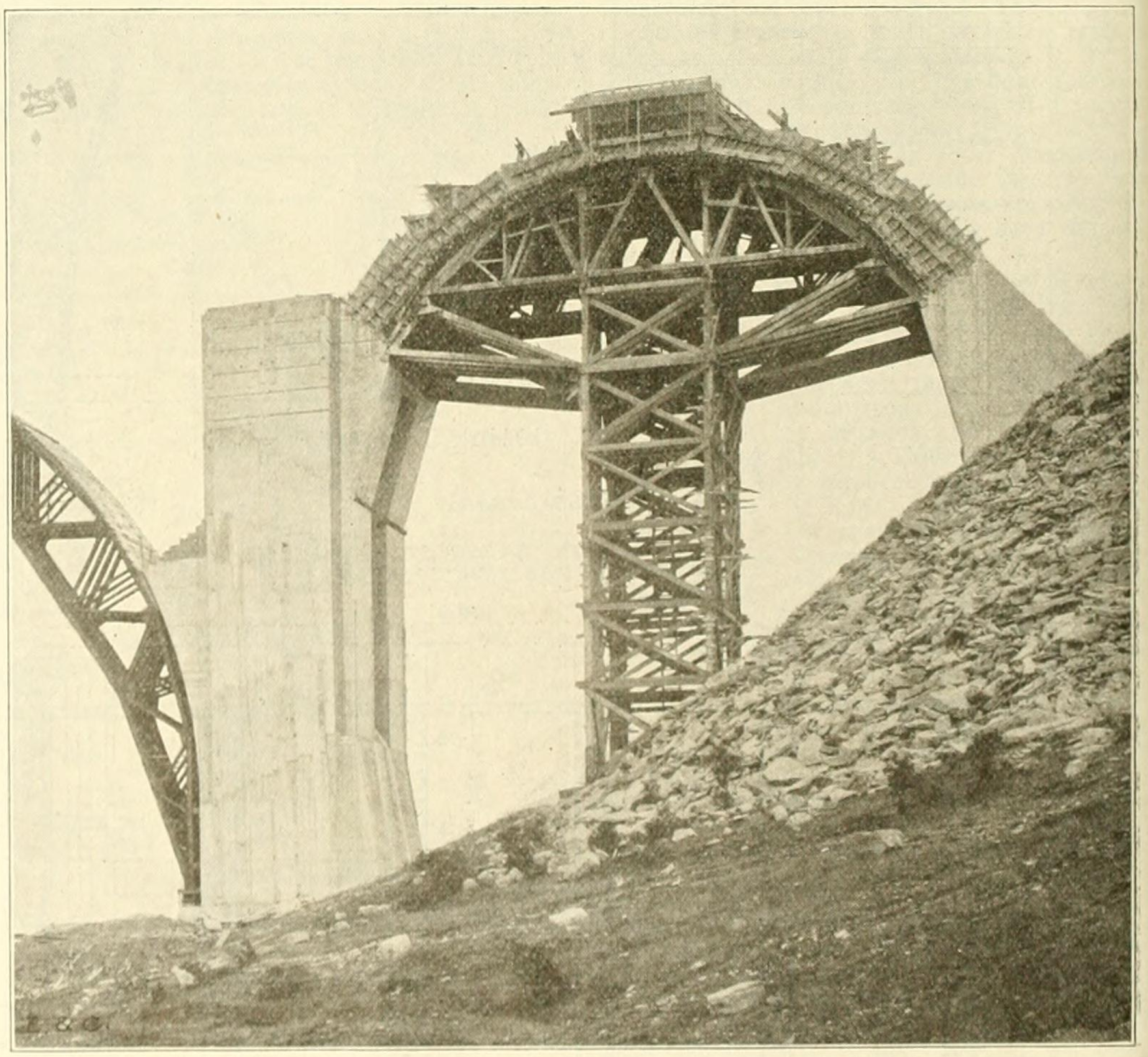


Fig. 4. Wooden Centering and Support for 100-Ft. End Arches of Tunkhannock Creek Viaduct.

cut through the above mentioned ridge, derricks were erected, steel sheet piling was brought in, and excavation was started early in July at pier No. 4.

On July 16 a "Model 40" Marion steam shovel, having a 1-cu. yd. dipper, was brought in and started digging its way through the ridge connecting pier No. 6 with the high ground at the hospital. The material excavated was loaded on 4-cu. yd., 3-ft. gauge Western dump cars, and was utilized in grading for the narrow-gauge tracks and for leveling the ground surface around the mixing plants. This shovel excavated pier No. 6 to a level 20 ft. below the ground surface on the high side, then moved to pier No. 5 and excavated this pier down to the level of ground water, which was about 35 ft. below the ground level on the high side. From pier No. 5 the shovel moved back to pier No. 6, and after excavating this pier to the same level as No. 5 moved on to pier No. 8, where the excavation was carried to the same level. The material from these excavations was utilized in raising the entire ground surface east of piers Nos. 7 and 8 a distance of about 12 ft., thus bringing it up to a level with the surface graded around the mixing plants and providing a satisfactory location for the saw mill and for the storage of reinforcing bars, lumber and other materials. From pier No. 8 the shovel was taken successively to piers Nos. 10, 9 and 2, in each case excavating the material to bedrock, which was above the level of ground water and was only a few feet below the surface at the lower sides of the piers. In making these excavations the material, which was a mixture of clay, gravel and sand, was allowed to take its natural slope, and the excavation was extended far enough beyond the sheeting lines to provide for the natural raveling of the banks prior to the completion of the excavation. The shovel completed its work in December, 1912, after having excavated about 50,000 cu. yds., 15,000 cu. yds. of which was "pay material."

In excavating piers Nos. 3, 4 and 7 and in continuing the excavation of piers Nos. 5, 6 and 8 the contractor used Lackawanna interlocking steel sheet piling in lengths of 30 ft. This piling was braced with 12x12-in. timbers, and was driven with a three-ton Warrington steam hammer. As these piers required sheeting for depths of from 50 to 70 ft, it was necessary to use two lengths of sheeting, and in two cases short lengths were driven on top of the upper 30-ft. lengths. The method of procedure with the excavation was to erect one set of sheeting on lines about 3 ft. outside of the required foundation area, and to drive the sheeting as far as convenient. The excavation was then carried down to the bottom of the sheeting by means of Williams 1½-cu. yd. clam-shell buckets, operated in the bays between timber braces which were so spaced as to admit the operation of the bucket. The bracing was then put in on about 5-ft. centers, vertically, as the excavation proceeded. After the excavation has been carried down to the temporary bottom of the sheeting, the latter was driven farther, and the operation was repeated until the top of the sheeting was down to the ground surface. Another set of sheeting was then erected about 6 ft. 6 ins. outside the first set, and was driven as deep as was thought advisable. The material between the two sets of sheeting was excavated with the clam-shell bucket, the first sheeting was then driven farther, and the excavation was resumed. As the inside set of sheeting was driven down, the upper set of timber bracing was removed and placed at the bottom. The process was continued until bedrock was reached. In two cases the two 30-ft. lengths of sheeting were not sufficient and short lengths of sheeting was driven directly on top of the second set. The contractor has been able to recover almost all of the sheeting, so that sufficient sheeting for two complete foundations has sufficed for the entire work. Some of the sheeting has been used four times. All of the 30-ft. sheeting was purchased new for this work, but the shorter lengths had been previously used on other work. The sheeting was pulled by means of an "A" frame, constructed of 12x12-in. timbers about 16 ft. long, resting on the top of the completed pier footing and carrying a triple block-and-fall rove with a ¾-in. steel cable. This fall was attached to the sheet piling by means of a bolt through the web, and a rasp clamp. The derrick fall, which is a double block, was made fast to the ¾-in. cable, and in this way a pull of about 60 tons could be exerted on the pile.

The material excavated from pier No. 4 was utilized to grade the track shown by dotted lines in Fig. 3, and a trestle was constructed across the creek, thus giving trackage facilities to pier No. 3, the excavation of which was started early in September. The excavations for the abutments and the piers near the ends of the viaduct were shallow, and the work was accomplished without the use of derricks or sheeting. The only excavation which gave any serious trouble was for pier No. 4. About 40 ft. below the surface there was encountered a large pocket of fine flowing sand along the west side and around the southwest corner of the pier. This sand exerted a very heavy pressure on the sheeting, distorting the timber bracing and several times breaking up through the bottom of the excavation and causing the ground surface outside the sheeting to settle as much as 10 ft. When the excavation had reached a depth of 50 ft. below the surface and was about 12 ft. above bedrock it was found that very little progress was being made, the bracing being so badly distorted as to be in grave danger of failure. At this point it was decided to drive a line of 3-in. plank sheeting parallel with the west side of the pier and about one-third of the width of the excavation from it. The portion of the excavation to the east of this sheeting was then carried down to rock, and was filled with concrete to a depth of 30 ft. All timber bracing was left in place, thus making any further distortion of the west one-third almost impossible. A row of 3-in. timber sheeting was then driven on an east-and-west line across the remaining one-third of the excavation. The northwest corner was then excavated, and concrete was placed to a depth of 10 ft. The southwest corner was now excavated and concreted without serious trouble. The excavation of this pier was not completed until the middle of July, 1913. All of the foundation excavation is now completed, with the exception of that required for pier No. 5, which is about 30 ft. above bedrock.

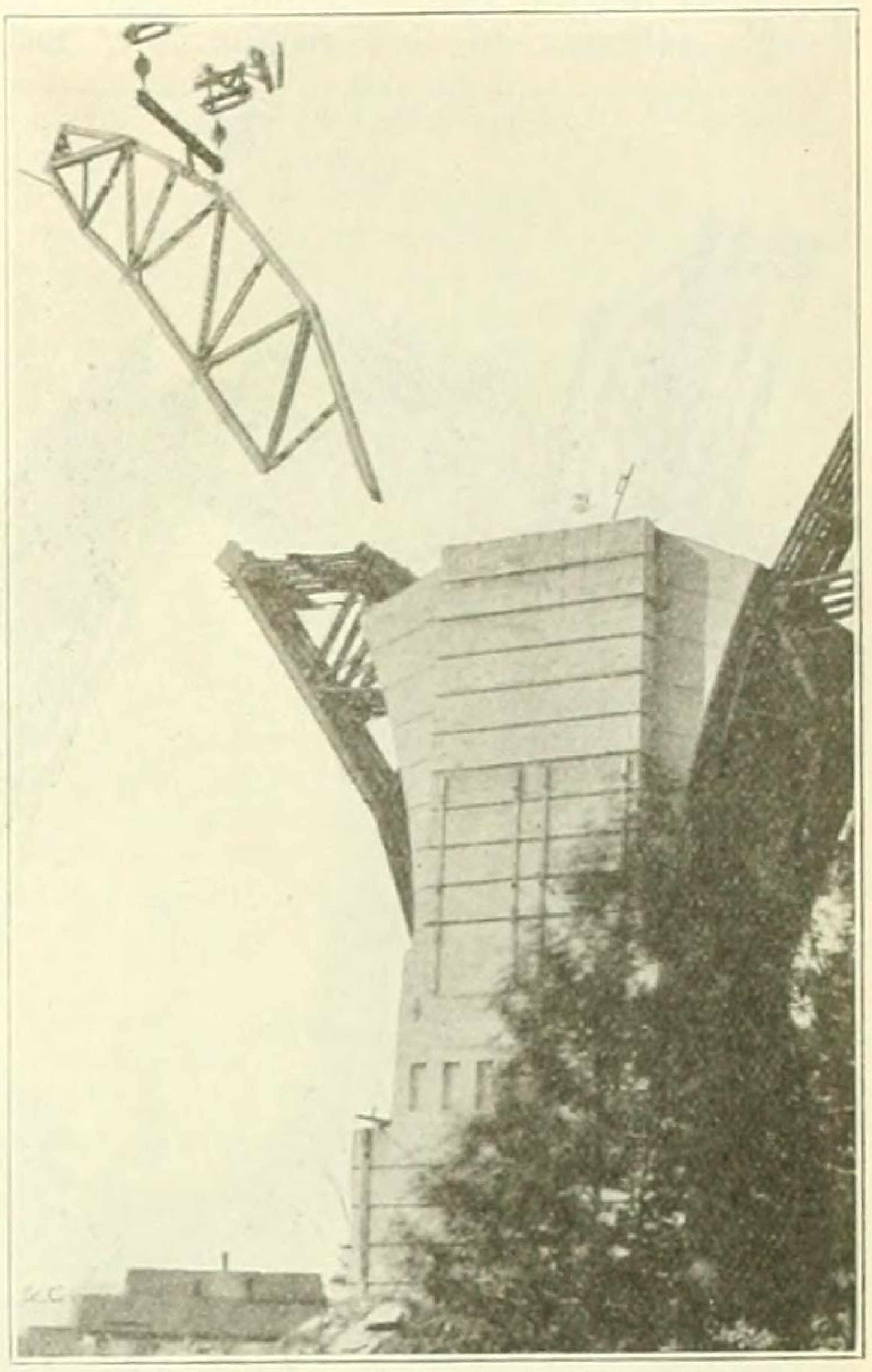


Fig. 6. Erection of 180-Ft. Steel Centers for Intermediate Spans by Means of Cableway, Tunkhannock Creek Viaduct.

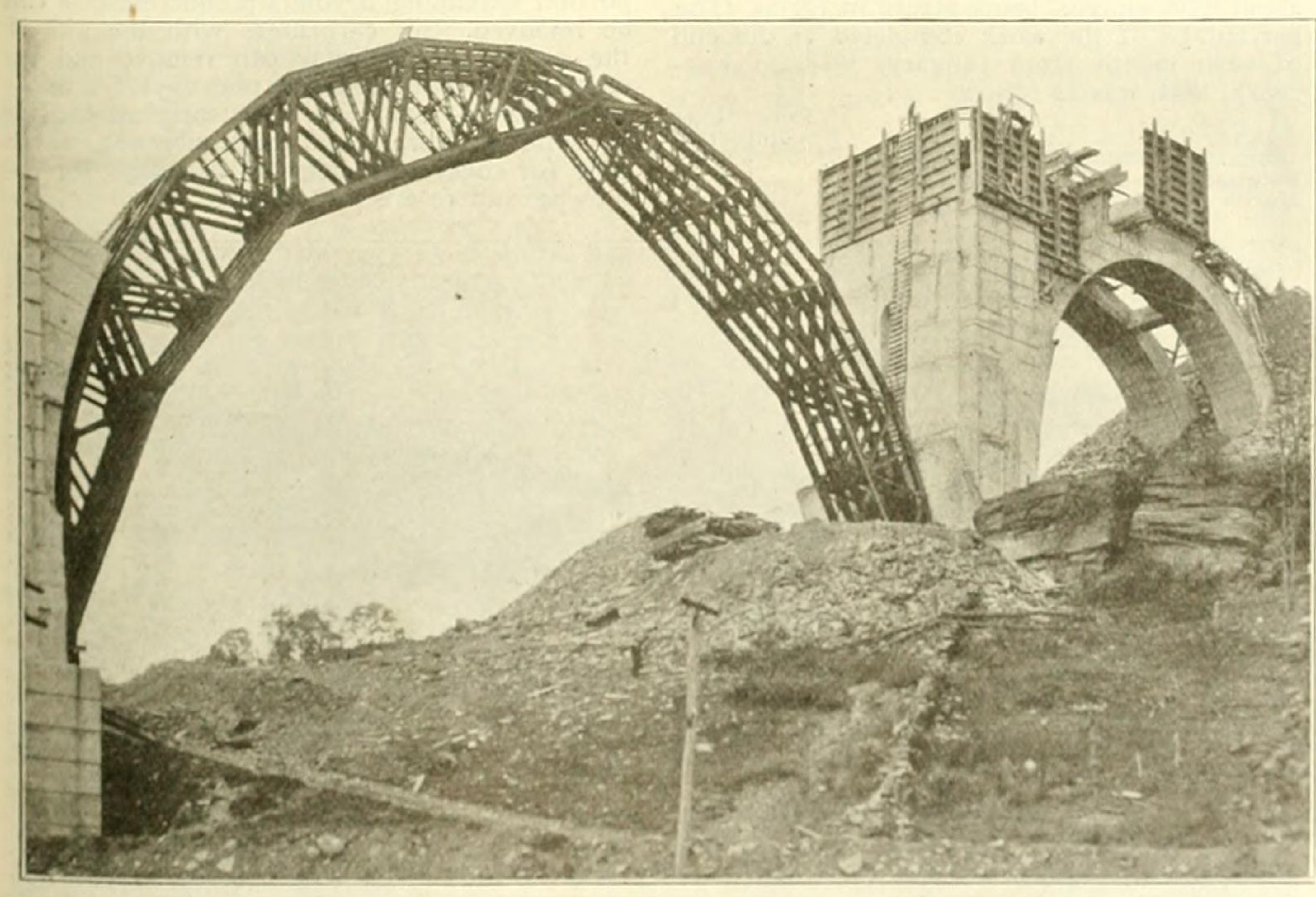


Fig. 5. Steel Centering for 180-Ft. Arches—View Also Shows West 100-Ft. Arch in Process of Construction.

CONCRETE PLANT.

Prior to January, 1913, the cement shed, which has a capacity of 3,000 bbls., had been completed and filled, mixing plant No. 1 had been completed (for location see Fig. 3), and a large amount of sand and stone had been placed in the storage piles. The sand and stone are placed on the contractors' side track in bottom-dump hopper cars by the railroad company. The cars are spotted on the material trestle, which is about 30 ft. high, by a 30-ton standard-gage locomotive and their contents dumped into the storage piles. Each mixing plant is served by two derricks which operate 40-cu. ft. Meade-Morrison clam-shell buckets. At mixing plant No. 1 the cement is ordinarily loaded directly from the cars into the derrick bucket, and is landed on the hopper floor of the mixer. At plant No. 2 the cement is unloaded from the cars into chutes which convey it by gravity to the hopper floor of the mixer. Cement is taken from the cement house only when shipments are delayed and when there is no cement available in cars. The mixer derricks convey the sand and stone from the storage piles to small bins over the mixers. From these bins the materials pass by gravity into a measuring hopper where the cement is added. From the measuring hopper the materials pass by gravity into a Carlin cube mixer of 2 cu. yds. capacity, which dumps directly into 2-cu. yd. Lockwood double-line bottom-dump buckets on 3-ft. gage flat cars. Twelve-ton locomotives are used to haul trains of three cars (one empty to receive the empty bucket from the derrick or cableway) to the point of disposition or to the point of transfer to the cableway.

The contractors are required to turn the mixer for not less than two minutes, and, although adhering to this requirement, each mixing plant has a regular working capacity of 18 batches of 2 cu. yds. per hour, about one minute being consumed in charging, starting, stopping and dumping the mixer. One foreman, 2 derrick operators, 1 mixer runner, 1 fireman, and 11 laborers are required to operate one mixing plant; while 1 foreman and 8 laborers, in addition to the engineman and helper, are employed to unload all cement, sand, and stone for both mixing plants. These gangs, with the aid of the material derricks, also unload practically all other materials and supplies used on the work. Two trains are used to transport the concrete from the mixer to the derrick or cableway. It requires 2 men to hook the buckets, 2 operators for the derrick or cableway, and 2 signal men to place the concrete in the forms where it is spread by 1 foreman with from 8 to 16 men. In the massive concrete work below the springing line of the main arches, this organization handles about 35 cu. yds. of concrete per hour.

A bag room, built as a part of the mixing plant, is provided. The floor of this room is about 8 ft. lower than the hopper floor, and as soon as the cement bags are emptied into the hopper they are thrown into this room. One man carefully shakes the cement from these bags, and ties them into bundles ready for shipment back to the mills, so that when the mixer stops at the end of a day's work the bags used that day are all ready to return. The contractors state that the loss of bags is less than 2 per cent, and that of this loss a considerable portion has been used for legitimate purposes on the work. Although more than ordinary care is taken to empty thoroughly the bags into the material hopper, test measurements of the amount of cement regained on the bag-room floor show that this saving more than pays for all the expense connected with the handling and shipping of the empty bags.

The first concrete was placed on Jan. 6, 1913, and as the winter of 1913-14 was very mild concreting has been carried on almost continuously up to the middle of February, 1914. The total amount of concrete placed during this time was about 90,000 cu. yds., the largest amount being placed during the month of June, 1914, when 14,000 cu. yds. were put in place, about 9,000 cu. yds. being placed in forms. The percentage of the work completed at the end of each month from January, 1913, to February, 1914, was as follows:

Date.	Percentage completed.
January, 1913	5.0
February	8.4
March	11.1
April	15.0
May	19.2
June	27.5
July	34.7
August	39.3
September	45.1
October	47.4
November	49.3
December	50.6
January, 1914	52.6
February	53.9

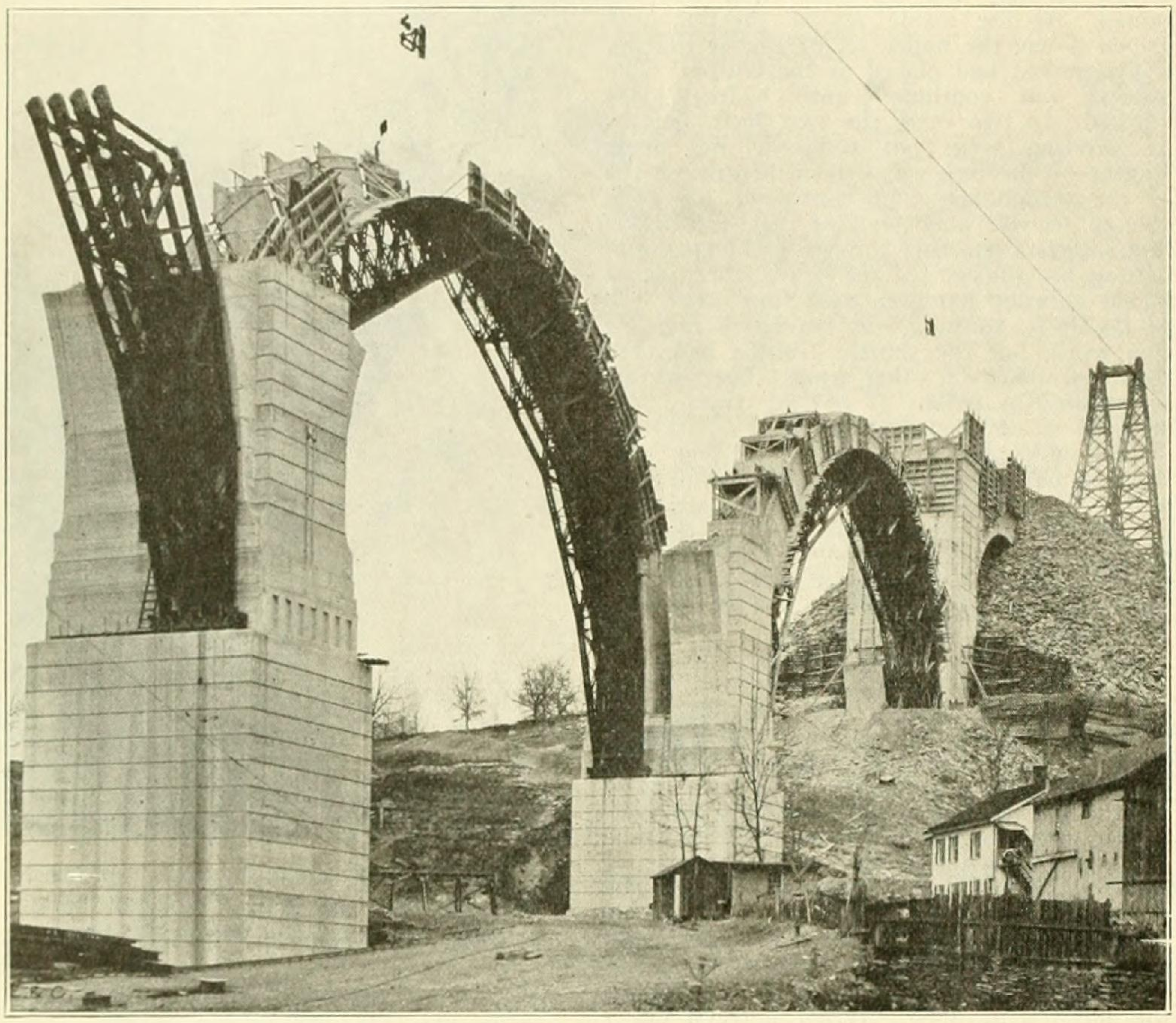


Fig. 7. West Spans of Tunkhannock Creek Viaduct, Showing Centering and Forms—One Rib Ready for Running Keys—Abutment Span Partially Buried.

FORMS FOR PIERS AND ARCHES.

The design of this bridge is such that sectional forms can be used with great economy and the contractors are taking advantage of this feature to an unusual extent. With few exceptions the forms are built on the ground, in sections, and are raised to the required position by the derrick or cableway. As an illustration of the utility and construction of these sections, the forms used for the main pier shafts will be described somewhat in detail. These forms are of two sizes, one of which is 15 ft. 8 ins. long by 17 ft. 9 ins. high, and the other, 18 ft. 3 ins. long by 17 ft. 9 ins. high. Two of the longer sections form the shorter sides of the pier, and three of the shorter ones form the long sides. Ten sections are required to surround one pier, and they provide for concreting a net height of 16 ft. These ten sections constitute one set, and four sets have sufficed for concreting all of the piers up to the centering ledge, without in any way retarding the progress of the work. One set is being retained for completing piers Nos. 5 and 6, and the other sections are now being used with little or no alteration for other parts of the work. Each section is made by nailing two layers of 1x8-in. tongue-and-groove boards to 8x10-in. horizontal studs spaced 2 ft. 5 ins. on centers, one layer being placed at right angles to the other, both layers being placed at 45° with the studs. These studs are bolted to 10x10-in. verticals, spaced so that a vertical will be halved at each joint and one in the center of each section. The verticals extend about 2 ft. above the top of the planking. The form is faced with No. 26 galvanized sheet-iron, the larger section weighing about 7,000 lbs. The forms are kept from moving outward by rods which run down at an angle of 45° from the vertical posts to anchor bolts placed in the concrete; they are prevented from moving inward by 12x12-in. horizontal struts which rest on the top edge of the form and are wedged against the opposite verticals. The rods are left in the concrete, and are provided with a sleeve attachment so that the portion extending beyond the concrete face can be removed. Six carpenters with the aid of the derrick or cableway can remove and re-erect one set of forms in two days. A minimum cycle of operation frequently attained is as follows: Two days for concreting, three days for concrete to set, and two days for removing and re-erecting forms.

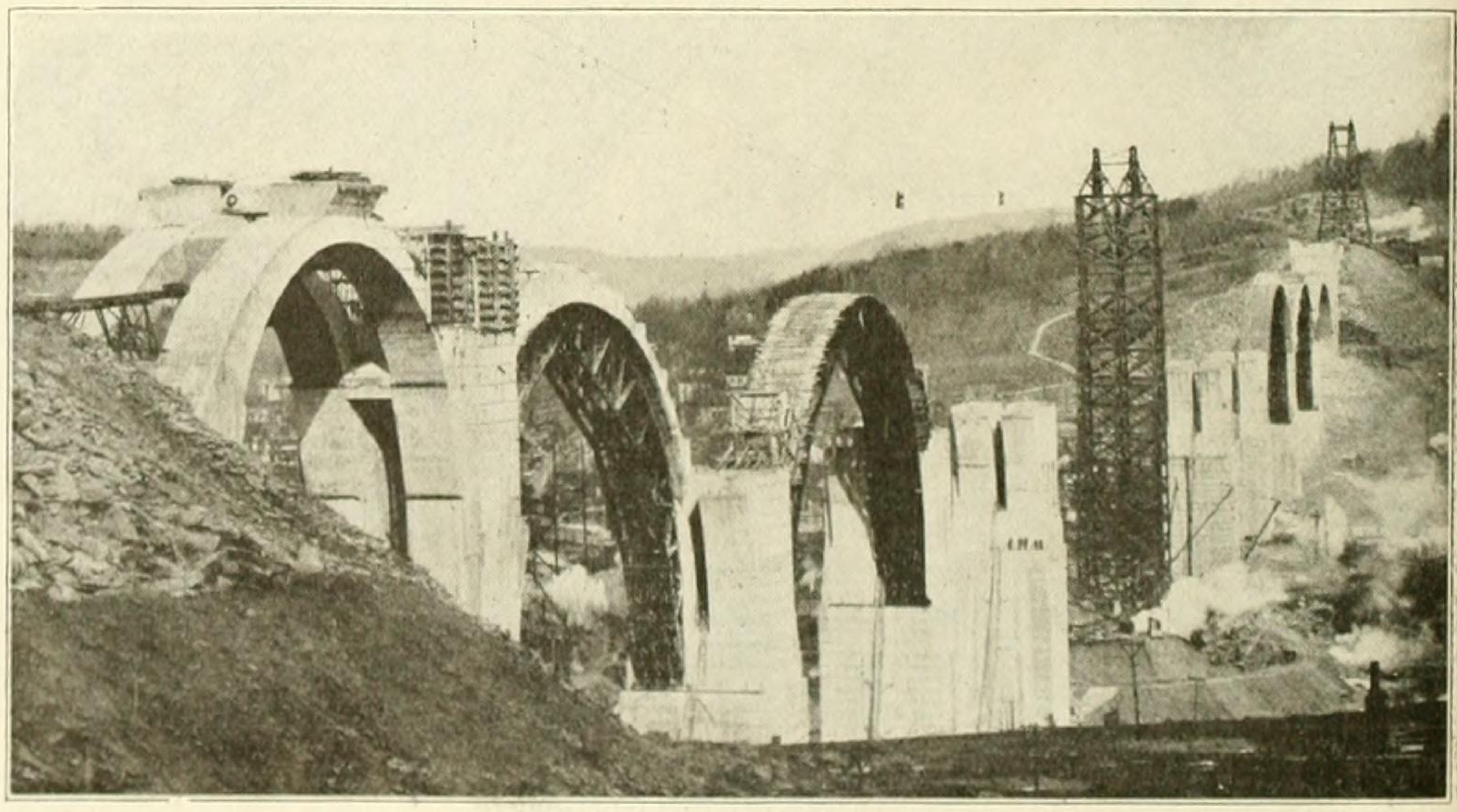


Fig. 8. Present Progress of Construction of Tunkhannock Creek Viaduct—View Shows Two of the Three Towers and Cableway for Erecting Spans.

In constructing the arch rings the concrete is being placed so as to form large voussoirs separated by small keyed openings. The voussoirs are all run and allowed to set for seven days before the keys are concreted. Fig. 7 shows some of the centers in place and a portion of the arch ring concreted. The forms for any voussoir are entirely independent of those for the adjacent blocks, so that any block can be concreted independently of any other. Separate forms are provided for closing the key openings, so that the voussoir forms can be used for concreting on one arch while the keys are being filled on another span. Two complete sets of arch forms have been constructed; they will suffice for the entire 20 main arch ribs.

The contractors' saw mill is equipped with circular and band saws, a planer, and an air compressor for the air-boring tools. The blacksmith and machine shop is equipped with forges, a planer, a lathe, a thread machine, and drill press.

ARCH CENTERS.

Wooden centers are used for the construction of the two end 100-ft. arches, the centers being supported on a wooden tower. Fig. 4 shows a view of one of the end 100-ft. spans with the centers and arch forms in place.

Five sets of three-hinged steel arch centers will be used in constructing the main arches, each set being composed of four ribs weighing 47 tons per rib, spaced 3 ft. 10 ins. center to center. Figure 5 shows a view of the steel centers for the 180-ft. arches. The view also shows the west 100-ft. span. Figure 6 shows a view of an intermediate pier with part of the steel centering for the adjacent spans in place. The view also shows the manner in which the steel centers are erected by the use of carriers supported on a cableway. Figure 7 shows some of the centers and forms at the west and of the viaduct, and indicates the order of constructing various parts of the work. These centers are supported on 4-ft. 3-in. ledges located 17 ft. 6 ins. below the springing line of the main arches. An I-beam grillage, resting on this ledge and extending the full width of the pier, supports roller nests of 6-in. rollers on which the pedestals of the centers rest. For erection purposes each rib of the centers was built in four sections. The centers are so designed that the half rib will support itself as a cantilever.

Before the centers are erected the piers are constructed up to a point about 37 ft. above the springing line, forming what is termed the "umbrella." The lower quarters are lifted into position, the bottom pin is driven, and the top of the section is anchored to the top of the umbrella by bolts which pass through the concrete. One of the remaining quarters is then raised to position and bolted to the section already in place. The last quarter is now raised into position, bolted to its adjacent lower quarter, and the crown pin driven. For striking the centers, the first panel on each side of the crown pin is constructed with pin connections, and the web member at right angles to the chords consists of two parts connected by a right and left thread screw operated by a lever and ratchet. By lengthening this member the distance between crown and end pins is shortened and the centers are thus lowered.

After one of the main arch ribs has been completed the centers are slacked down and are rolled over to their position under the twin rib. When both ribs are competed the centers are rolled back under the opening between the ribs and are taken up through this opening and transported to their next point of service.

The centers were built by the Fort Pitt Bridge Works.

CABLEWAY AND DERRICKS.

All derrick timbers were shipped to the work in a rough condition, and were dressed, framed and fitted by the contractors. Castings were made in commercial foundries from patterns owned by the contractors, and other fittings were made in the machine shop. The masts are from 85 to 90 ft. long, and the booms are from 80 to 85 ft. long.

All derricks are operated by three-drum, 8¼x12-in. Mundy hoisting engines with swinging gear attachment. In a few cases the derricks have been placed on timber pedestals about 25 ft. high, but in most cases they have been erected at the ground level, and all work above the reach of the derricks is carried on by means of a cableway.

The erection of the cableway was started in August, 1912, and it was put in operation in February, 1913. There are two lines of 2¼-in. main cables spaced 20 ft. apart on centers and supported by end towers 150 and 165 ft. high and by a center tower 260 ft. high. The head blocks of the end towers are 3,028 ft. apart, and the included distance is divided by the intermediate tower into two spans of about equal length. Four engines and carriages operate as four independent units. The towers are of timber, and the type of construction is indicated in Fig. 8. The view also shows a part of the cableway and indicates the present state of construction of the viaduct.

The cableway was designed by and all material, except timber, was furnished by the Lidgerwood Manufacturing Co. The contractors for the viaduct built the towers and erected the cableway.

PERSONNEL.

The bridge was designed and is being constructed under the direction of the Engineering Department of the Delaware, Lackawanna & Western Railroad Co., of which Mr. G. J. Ray is chief engineer, Mr. F. L. Wheaton is engineer of construction, Mr. A. B. Cohen is concrete engineer, and the writer is resident engineer in charge of the viaduct. The construction work is being carried out by Flickwir & Bush, Inc., for whom Mr. F. M. Talbot is general manager, and Mr. W. C. Ritner is general superintendent.

Roads and Streets

Methods of Making Surveys and Plans for Trunk Line Highways in Michigan.

Under the Trunk Line Highway Law, which went into effect July 1, 1913, it became the duty of the Michigan State Highway Department to make the surveys and plans for the roads designated in the law. A paper describing some of the more important and interesting features of the field and office work involved and the way in which various difficulties encountered in the work were overcome was presented at the recent annual meeting of the Michigan Engineering Society by Mr. Harry L. Brightman of the Michigan State Highway Department. The information given in the paper is practical and of value to engineers who have road surveys and plans to make. Some of the methods are also useful for railroad surveying, especially for interurban railway surveys. We reprint the major portion of the paper as follows:

Office and Mapping Methods.—A set of drawing room standards was written and blueprinted in book form, which covers pretty well the details of the drawing. The plan shows a plat of the road with topography and drainage worked out. Projected below this is the accompanying profile showing the center line and ditch lines of the present ground together with two lines of hubs, one on each side of the roadway. There are three grades laid—the center line and each ditch. Five sets of figures are given showing the distance the center line grade is above or below the hubs and the actual cut or fill at center line from the present surface to the top of the finished metal surface. All this is put on a sheet of tracing cloth 36 ins. long by 20 ins. in width with 10x10 cross sections printed on it. This allows a scale of 100 ft. to the inch, natural, for the plans and 100 ft. horizontal and 10 ft. vertical to the inch for the profile, and gives a sheet to each half mile of road. There are usually two cross sections of the road shown on each sheet with suitable title and what detail information appears necessary.

The plan shows the curves to scale and the center line of the road is put always 2 ins. below and parallel to the top of the sheet. This necessitates breaking the plan, which is done without making a disconnected profile. For laying grades we have a long table which allows five sheets to be laid end to end and gives a continuous profile 2½ miles long on which we can lay a grade much more advantageously than on a single sheet at a time.

From the notes we lay as good a grade as we can in the office, figure the center line cuts and fills and blueprint the work. The prints are taken into the field, the grades are compared with the ground and the drainage checked up. The prints are then returned to the office together with the report of the inspecting engineer. The plans are altered to meet the suggestions in the report, and finished. They are blueprinted and sent to the township or county officials.

We limit the grade to 6 per cent for those roads which lie north of the line drawn from Bay City to Grand Rapids and to 4 per cent on roads south of that line except in a few special cases where it would entail a hardship on the county or township to cut to a 4 per cent grade. The rolling grade is thought by us to be the best. We use vertical curves for all changes of grade of 2 per cent or over. This enables us to fit the ground much better and to produce a grade which, when constructed, is both pleasing to the eye and easy for traffic.

For the purpose of making curves easier riding we give them a super-elevation in the following manner: Curves with a radius of 66 ft. to 250 ft. at a rate of 1 in. per foot; curves with a radius of 250 ft. to 600 ft. at a rate of ¾ in. per foot; curves with a radius of 600 ft. to 800 ft. at a rate of ⅝ in. per foot; curves with a radius greater than 800 ft. receive no super-elevation. The radius of curvature for a 7° curve is 819.02 ft. This is somewhat like the practice followed by the highway engineers of the state of New York. We differ from them, however, in that we believe the road should receive a crown when super-elevated as well as when there is no super-elevation.

Field Work.—The field work consists of the reconnaisance, the location survey and the inspection of the road during construction and upon completion. The location survey comprises running the center line, taking the topography, drainage, soil and material notes and running the necessary levels. This work is usually done by a party made up of a man sent out from this office who has charge of the party and keeps the notes, a local engineer and local men for chainmen, rodmen, etc. By this means we keep the surveys uniform in character and obtain the notes we want.

We encountered more difficulty with the field work than with the office work. The notes lacked many of the essential things and the work in the field was not conducted as it should have been at the start. This was due, no doubt, to the lack of written instructions. It is difficult for a man to listen for an hour to a set of oral instructions and to go out in the field and carry them out in detail. To remove this difficulty a set of "Instructions to Field Men" were prepared. These instructions cover in a general way the work we want done in the field, and leave to the man's judgment the detail procedure for special cases. Some errors, and the most of these were made by local men, seem to be inexcusable, unless one can be excused for carelessness.

Many little, yet important, things were left out, such as names of small villages, streams, etc., the date of the work, the names of townships and section numbers, the description of the point of beginning, etc. Under the head-

Tunkhannock Viaduct Nearing Completion

Last Steps Include Concreting Arch Ribs and Spandrel Walls Through Upper Panels of Central Cableway Tower

THE MAIN RIBS for the center arch of the Tunkhannock viaduct, which have just been concreted, were built through two bays of the central double cableway tower without stopping operation of the cableway. This tower rises more than 320 ft. above the creek bed, and supports four cableways, two on each side. The viaduct, 2375 ft. long and 240 ft. high from the creek level to the parapet, is now nearing completion, only 6000 of its 162,000 cu. yd. of concrete masonry remaining to be placed. It consists of ten 180-ft. and two 100-ft. arch spans, and is the largest structure of its kind in existence. The viaduct is part of the 43-mile Nicholson cut-off of the Delaware, Lackawanna & Western Railroad in northeastern Pennsylvania. Its construction, including special features of the foundation work, the arch centering and the twin double-span cableways, erected for handling centering and concrete, have been described in the issues of the Engineering Record of May 3, 1913, page 484, and Nov. 29, 1913, page 594.

The central cableway tower is of timber on concrete pedestals midway between piers 5 and 6. The timber tower consists of three bents, parallel to the bridge, of three posts each. The faces of the tower perpendicular to the bridge are battered, while those parallel to the bridge are vertical. The central bent is located between the main arch ribs, which are in pairs for each span, while the outside bents are entirely clear of the concrete construction.

Centering for Last Arch Span Set

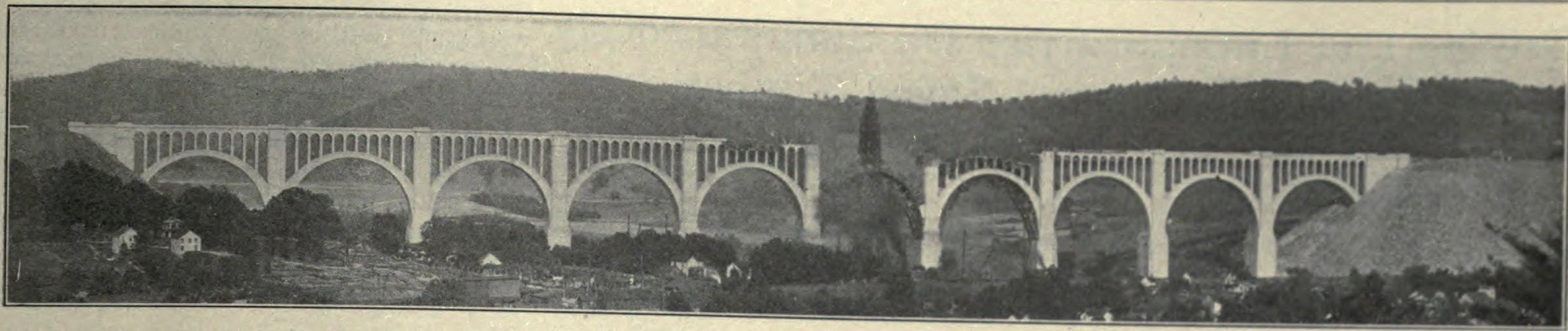
As will be remembered from the former articles, each arch center is in four sections. The four sections next to the piers for the two sets of centering are entirely clear of the tower, and were set first. The four middle sections were then erected by temporarily removing one panel of X-bracing on each face of the tower and replacing it through the framework of the centering after the latter had been set. The X-bracing in the panel above was then removed to allow the rib concrete to be poured.

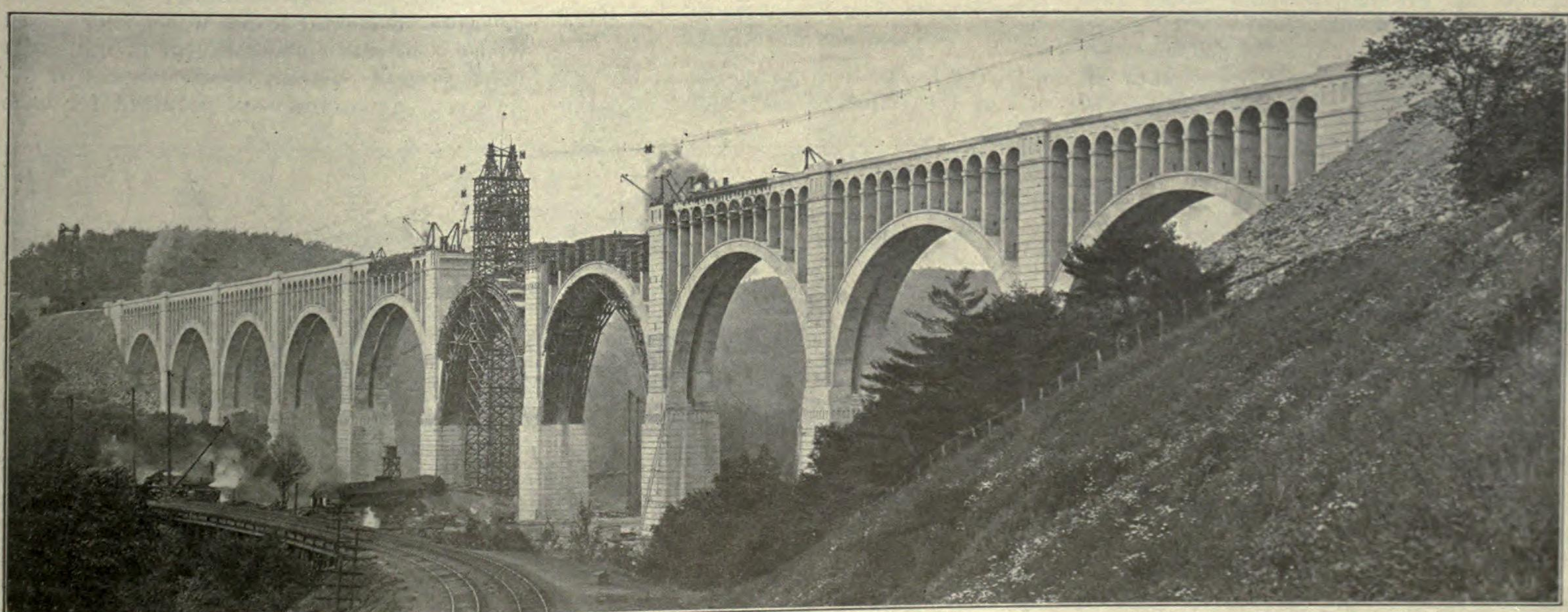
Between each of the batter faces of the tower and the three center posts on a line at right angles to the viaduct comes a spandrel wall. To concrete these two walls the X-bracing is removed in one panel between the three posts of the bent between the arch ribs. In concreting the floor of the viaduct three small square holes will be left for the three posts of the center bent. The concrete clears the cableway tower at all other points.

This construction was all planned at the time the cableway was designed. When the last arch centers had been set, the last remaining clear hoistways through which the cableways could reach the ground were blocked. Provision had to be made, therefore, for raising concrete buckets from the tracks on the floor of the valley to the bridge deck and transferring them to the cableways. This is done by four derricks, two on top of pier 6 and two on pier 4. Pier 5 was not used, as it was not quite finished at the time the last arch centers were set. Because of the smaller hoists used, it takes 90 seconds to hoist a bucket with a derrick as against 30 seconds with the cableway. Buckets can be handled right to the face of the tower, and dumped into hoppers, the concrete being spouted the short distance remaining to the center of the arch. Two yards has been the standard concrete unit handled on the job, and 30 cu. yd. per hour, or better, have been placed for each cableway span in service.

The cableway tower construction was planned by Lincoln Bush and engineers of the Lidgerwood Manufacturing Company. Flickwir & Bush are the contractors for the viaduct, and F. M. Talbot is general manager of the company. The design and construction of the viaduct has been under the direction of G. J. Ray, chief engineer of the Delaware, Lackawanna & Western Railroad. F. L. Wheaton is engineer of construction in charge of the entire cut-off work, and A. B. Cohen, concrete engineer, handled the design of the viaduct.

CLOSE VIEW SHOWS ATTRACTIVE PROPORTIONS OF STRUCTURE AND GIVES AN IDEA OF ITS MAGNITUDE





TUNKHANNOCK CREEK VIADUCT ON LACKAWANNA RAILROAD ENTERS LAST STAGE OF CONSTRUCTION

With its length of 2375 ft. and its height of 240 ft. above creek level, this structure is conceded to be the most remarkable concrete viaduct in the world.