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Larimer Ave. and Atherton Ave. Concrete Arch Bridges, Pittsburgh

The recently completed Larimer Avenue bridge in Pittsburgh, Penn., sets a new record in size for American concrete

bridge.

Larimer Avenue Bridge

In the North Highland Ave. district of Pittsburgh, Negley Run gorge is a nararches. At the same time it is a notably row V-shaped depression 100 to 200 ft. successful work esthetically, ranking deep in the tableland, running northerly

terial employed, or for esthetic detailing. iron viaduct was built here 1891-1892, These bridges are briefly mentioned be- consisting of 60-ft. spans on wooden towlow, after a description of the larger ers. Replacement of this old and inadequate structure by a new bridge was planned at the time the Meadow St. arch was built, and the work was taken in hand after the completion of that struc-

> Alternative designs and estimates for a steel arch and a concrete arch for the

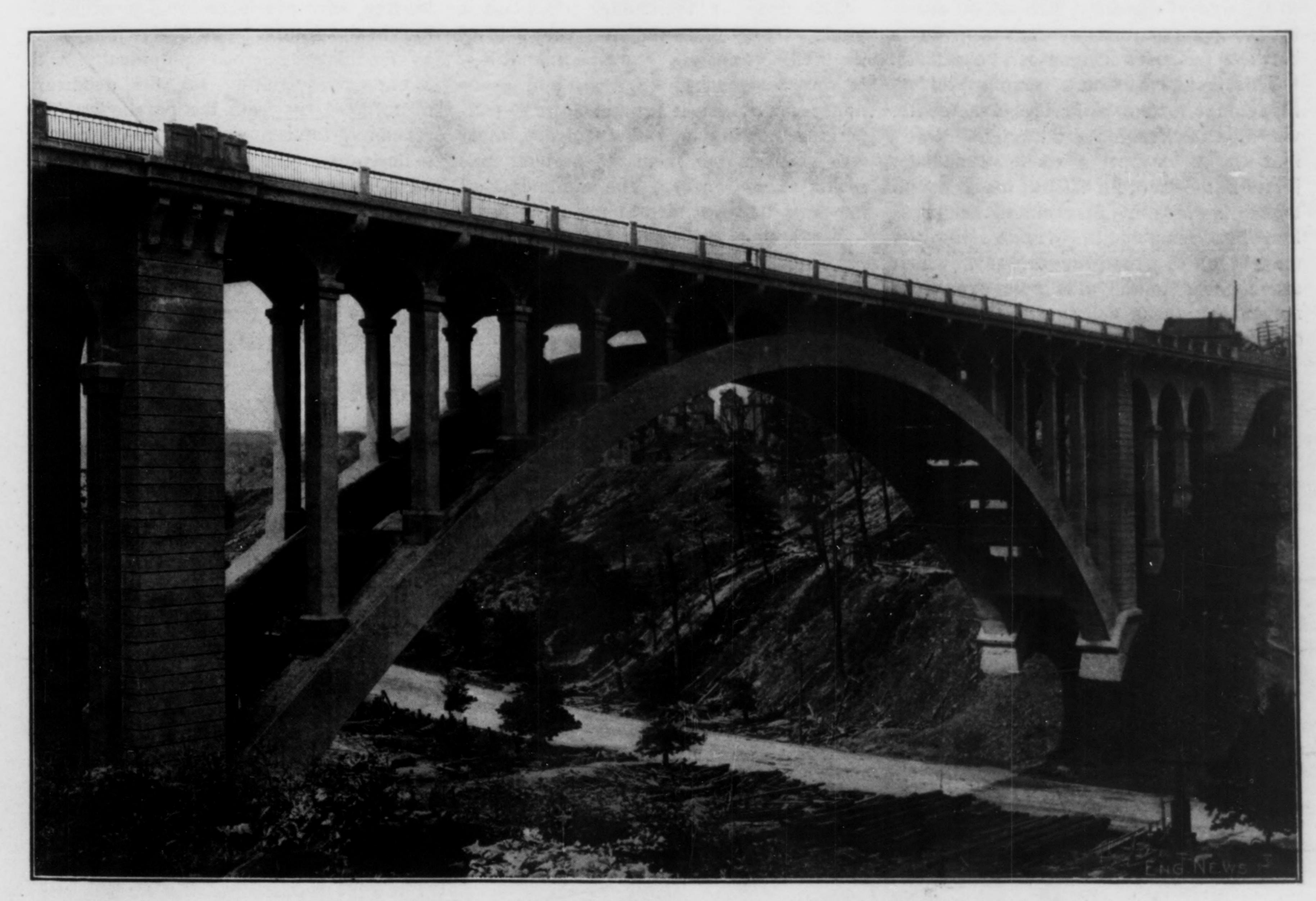


Fig. 1. Larimer Avenue Arch Bridge over Washington Boulevard, Pittsburgh, Penn. (Looking northeast.)

struction.

with the Walnut Lane arch, in Philadel- to the Allegheny River. The upper part Larimer Ave. crossing showed no very phia, in point of appearance. The view of this gorge is in two branches. The great difference in cost between the two on this page, taken about three months westerly or smaller of the two is spanned ago, brings out quite clearly the well. by a concrete arch bridge at Meadow proportioned design, as well as the satis- St., built three years ago and fully defactory surface finish attained in con-scribed in Engineering News of Dec. 1, 1910, p. 583, by N. S. Sprague. About a At this time several other concrete arch half mile east of this bridge the other bridges are under construction in the city branch of the gorge is crossed by Larimer of Pittsburgh, all of which contain nota- Ave., a main thoroughfare carrying a ble features. While not remarkable for street-car line; the car line does not size, they are worth special notice, either cross the valley at present, but may in for type of design, or for nature of ma- the future. A combination wood-and-

types. The steel arch if built with stonemasonry piers would, in fact, have cost a little more than the concrete arch. The latter was preferred, and as the available appropriation was sufficient, this type was adopted and built. The resulting structure is very similar to the Meadow St. bridge, but is considerably larger, with a main span of 300 ft. as against the 209-ft. span at Meadow St.

The Larimer Ave. arch is similar to the

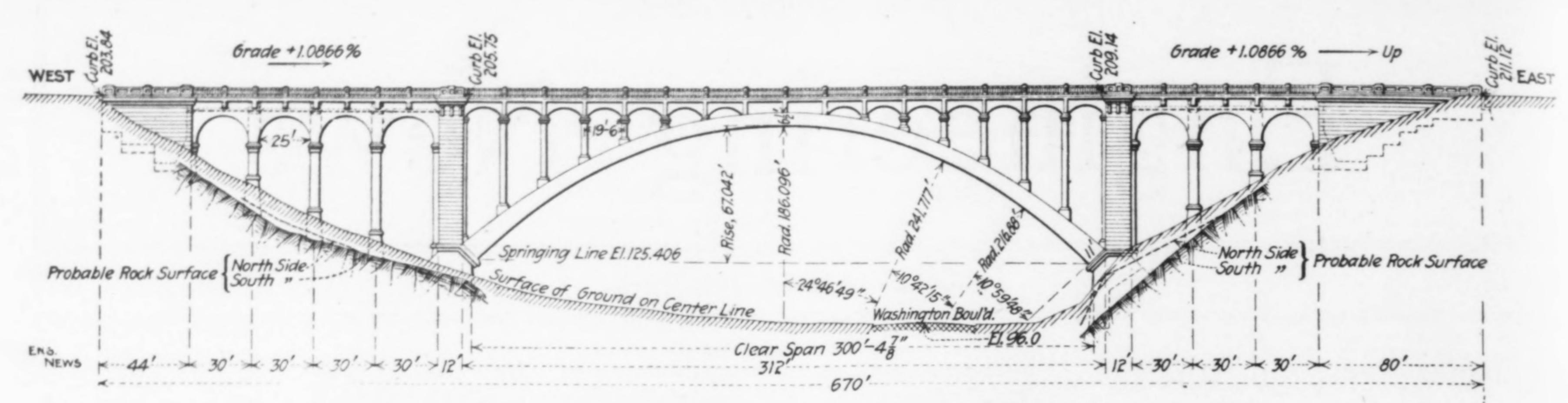


FIG. 2. GENERAL ELEVATION OF LARIMER AVE. ARCH BRIDGE, PITTSBURGH, PENN.

other in having open spandrels, separated edge of skewbacks to bottom of crown floor slab between. There is a stringer at in the vertical plane instead of normal ton Boulevard is about 110 ft.

arch ribs braced together by struts, is 67 ft. The springing line is about 30 each curb and two intermediate stringers, and a reinforced-concrete beam-and-slab ft. above the valley, so that the total besides a fascia stringer at the outer edge floor. It differs chiefly in having (1) two height from the deck of the bridge to the ribs, in place of three; (2) rib struts set lowest point of the valley on Washing-

longest of the roadway columns, which ing parabolic form. The general elevaare exposed to the maximum expansion tion drawing, Fig. 2, gives particulars. movement; these columns showed shear It has two parallel arch ribs uniformly 8

of the sidewalk; the curb stringer has arched lower edge, for appearance.

The bridge was designed for city street to the line of the arch; (3) salient skew- The deck of the bridge rises on a loading, with provision for a possible car backs; and (4) roadway expansion joints grade of 1.086% to the east (the side of line in the future. The design was made between the piers instead of at the piers. the Brilliant cut-off, Pennsylvania R.R.). by the elastic method, graphically, with This last item, whose location and ar- It was designed to be a straight grade slight approximation for the departure rangement is shown in Fig. 4 herewith, under maximum load and lowest tem- of form of rib from the parabolic. The was an afterthought, as the original draw- perature conditions, and sufficient camber reaction-intersection locus was taken as ings for the bridge called for expansion was given to the forms to produce this a horizontal straight line; the abutment joints at the main piers. But it was found result (see Fig. 7). The abutments of intersections were found graphically, for that in the Meadow St. arch this construct the arch, however, are at the same level. parabolic rib form, and the reaction tantion had resulted in overstressing the The arch is five-centered, approximat- gent lines were drawn from them. No tension will occur in the rib under any combination of conditions. The compression was limited generally to 600 lb. per cracks, evidently produced by excessive ft. wide, spaced 30 ft. center to center, sq.in., but in the arch it was allowed to

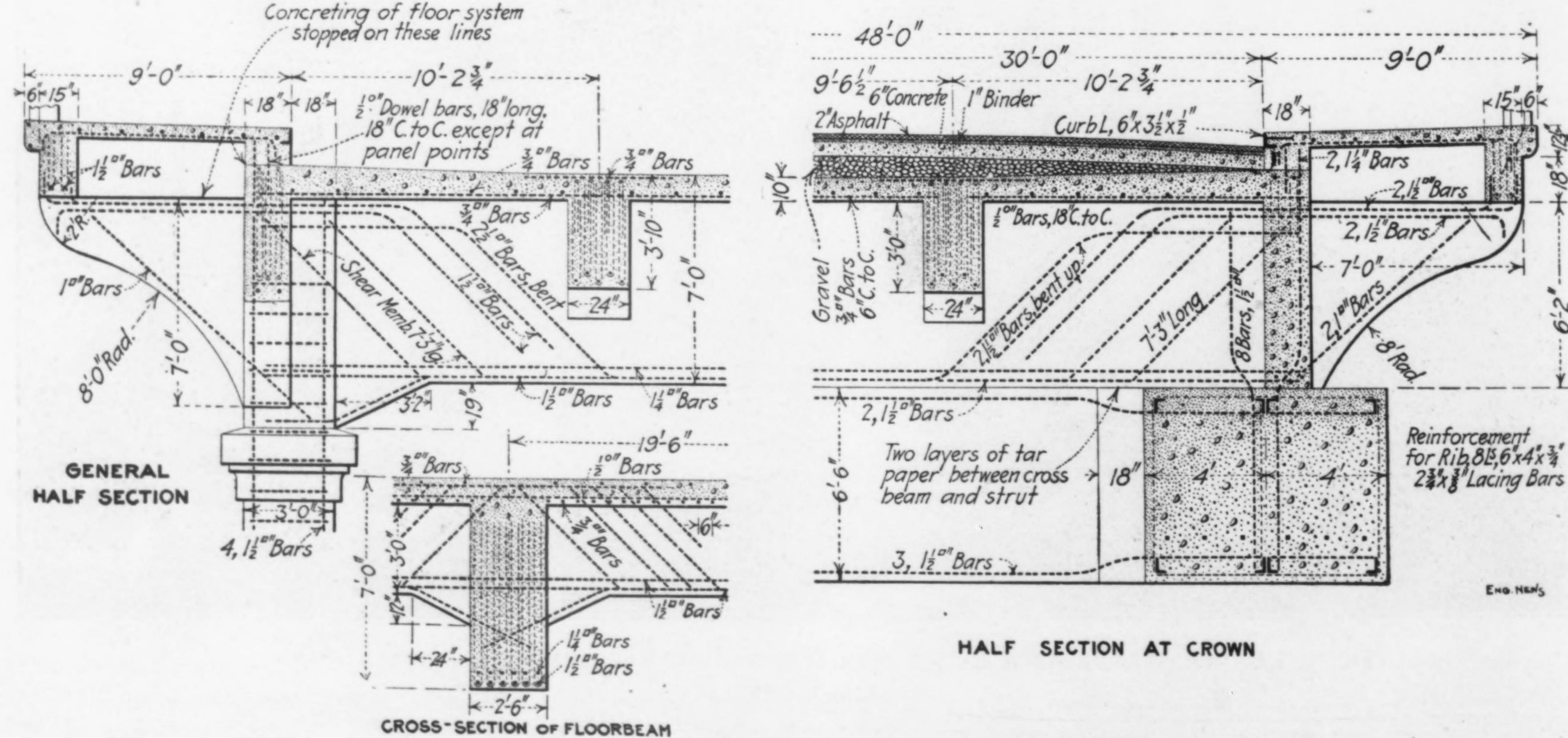


FIG. 3. CROSS-SECTION OF DECK, LARIMER AVE. ARCH BRIDGE

over the haunches.

or center-to-center span of 312 ft. Its clear span is 300 ft. 47% in. face to face of abutments. The center-to-center rise is 70 ft., and the clear rise from lower

bending under the longitudinal expansion their center lines thus coming under the rise to 750 lb. per sq.in. under the worst movements. On this showing, the expan- curbs of the roadway. They are 6½ ft. temperature combinations. The maximum sion joints in the main-span floor of the deep at the crown and 11 ft. deep at the temperature range was taken at 60° F. Larimer Ave. arch were shifted to points skewbacks. The spandrels are articu- Reinforcement—The reinforcement lated, consisting of individual posts, one of the slab and beam work of the bridge MAIN ARCH—The arch has a calculated on each arch rib, at 19½-ft. panel dis- calls for no special remarks except to tance. They carry a reinforced-concrete floor, comprising 30x84-in. floorbeams spaced 19½ ft., and a system of 24x46-in. stringers, with 10-in. reinforced-concrete however, employs large-sized steel angles

say that deformed rods were used everywhere (specified hot-rolled).

The reinforcement of the main rib,

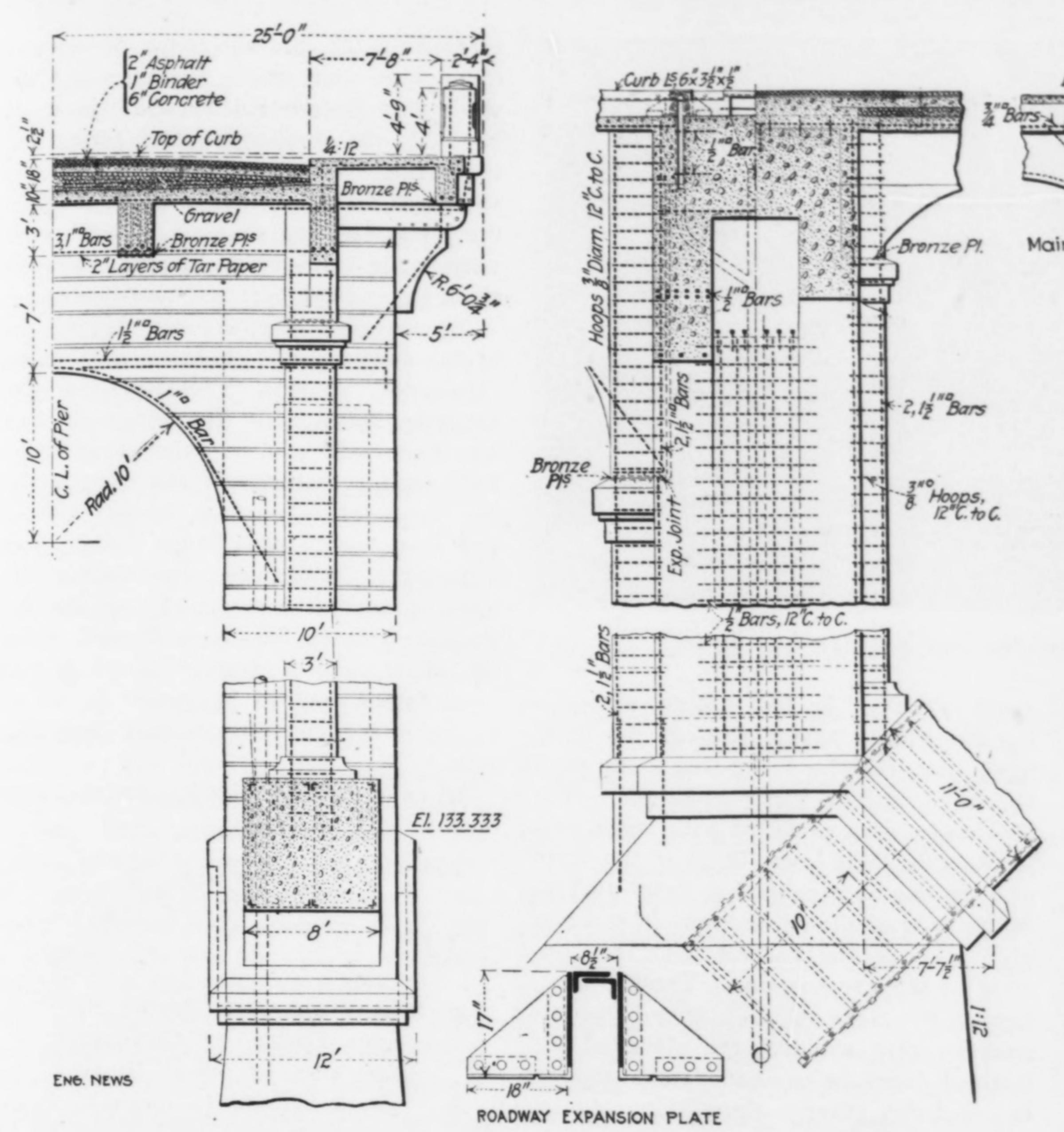


FIG. 4. LARIMER AVE. ARCH: DETAIL AT MAIN PIER, AND EXPANSION JOINT IN FLOOR

extensively, each rib having a longitudi- here are excessive. On account of this nal framework of 8 angles 6x4x3/4 in., experience the expansion joints of the central I-section girder of four angles located at the third panel-point out from and at each corner of the rib section a the main piers. The sidewalk and its single angle, the whole well connected the joint is made strong enough to transmit the full stress of the angles. These splices are placed in the key blocks of the arch, and are field splices, made with turned bolts in drilled holes. The total cross-section of reinforcement in each rib is 55.52 sq.in., constant from end to end of the arch.

The rib reinforcement is supplemented at the points where the columns carrying the roadway rest upon it. The special reinforcement here comprises a group of bent stirrup bars in the rib, vertical bars (prolongations of the column bars) passing nearly through the rib, and a system of horizontal bars to tie the columns into the arch. This is fully shown in the detail sketch Fig. 5.

EXPANSION JOINTS—In the Meadow St. arch the expansion of the roadway was taken up by expansion joints at the piers. On that bridge the longest columns of the roadway have developed cracks which indicate that the expansion movements

forming a deep lattice-girder comprising a roadway in the Larimer Ave. bridge were supporting fascia girder, however, have by transverse flat bars (no diagonal lat- an expansion joint in each panel, to ticing). Where the rib angles are spliced, allow for the more rapid response of these thinner parts of the structure to

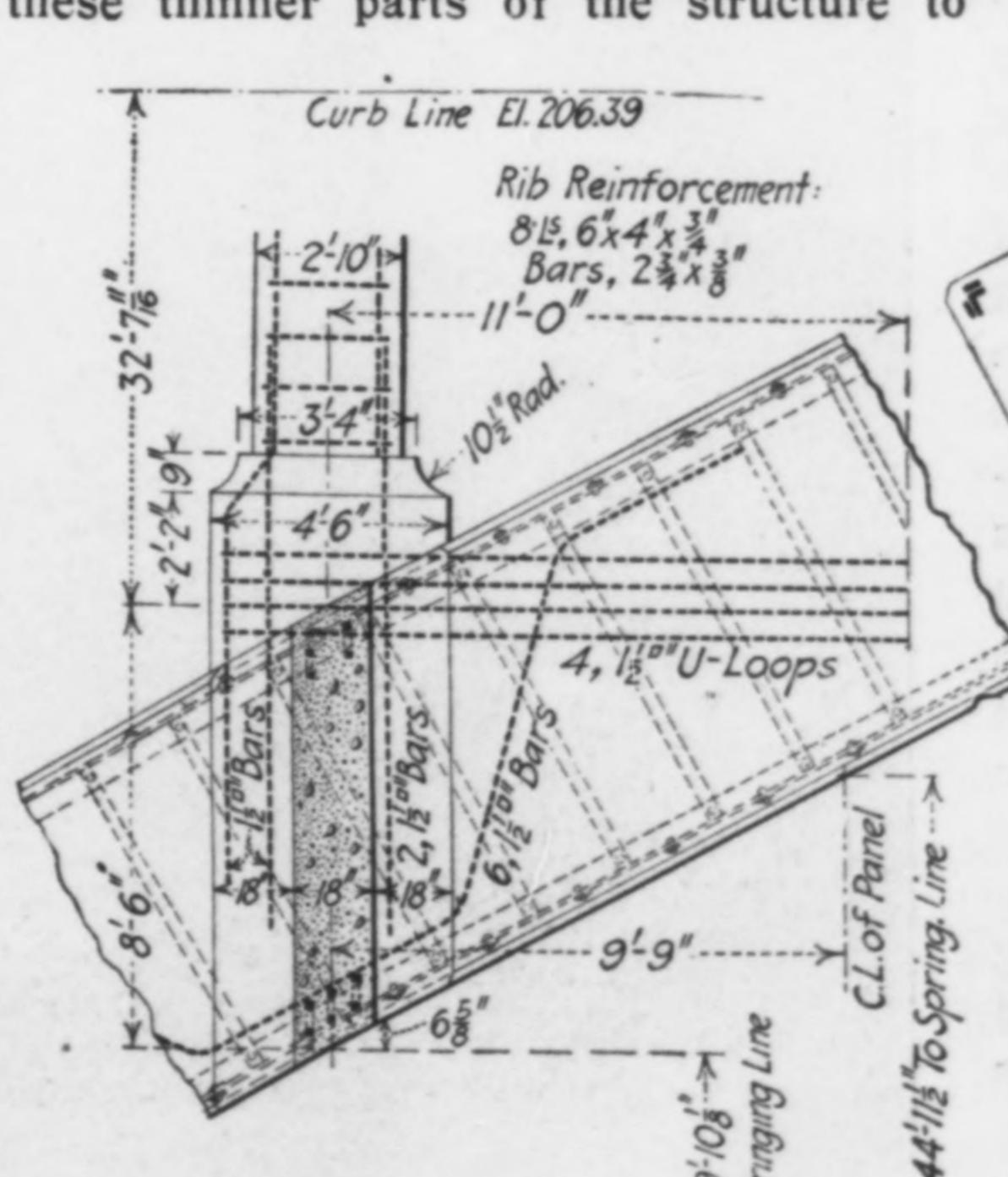


FIG. 5. LARIMER AVE. ARCH: RIB AT PANEL-POINT 3

temperature changes. The expansion of the approaches is taken care of at the land face of the main or abutment piers.

Exp. Joint in

Main Span

of Main Span Deck

Expansion Joints

Diagram showing Location

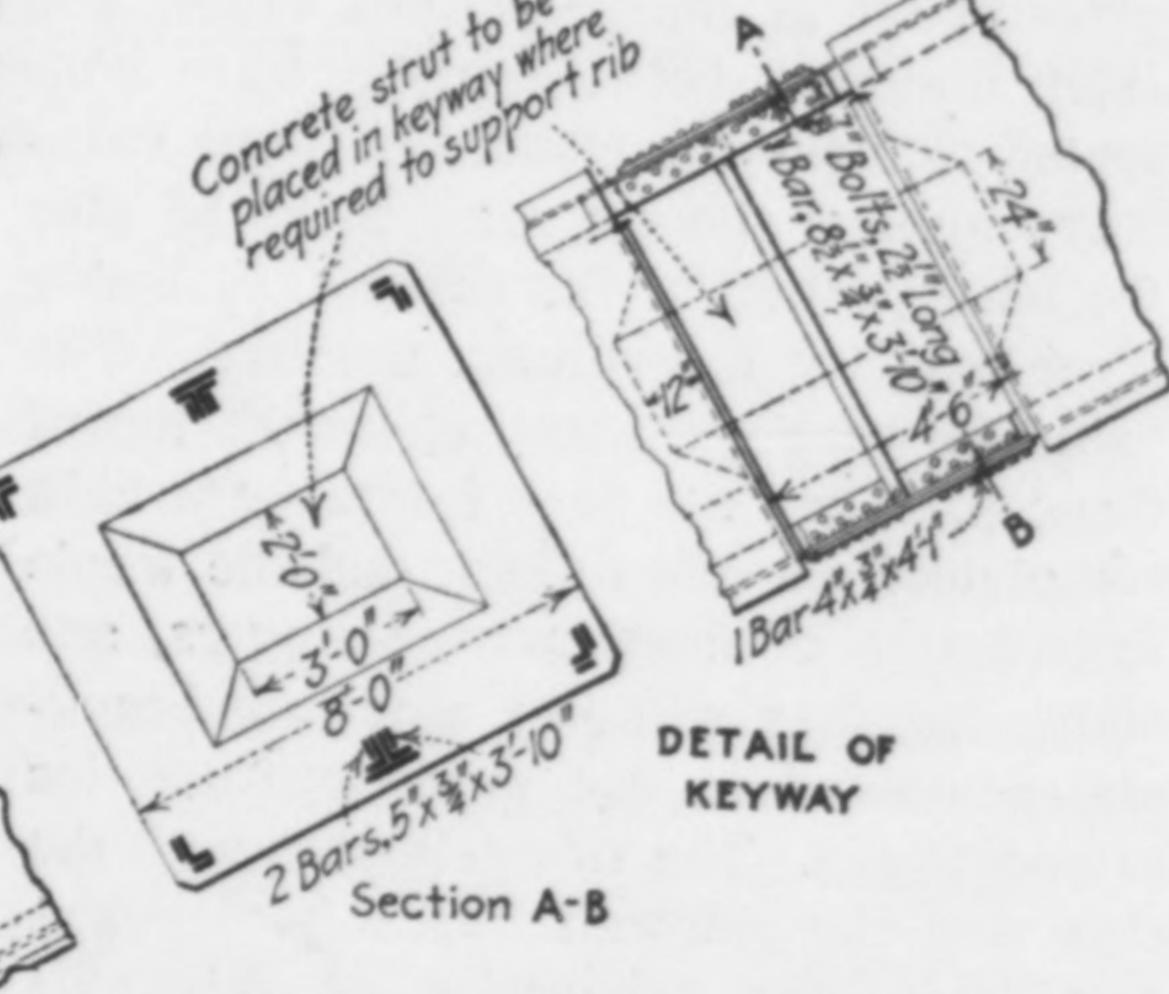
of Expansion Joints

Elevation

The expansion provisions are shown clearly in the drawing, Fig. 4, herewith. The expansion joints in the main span are made by doubling the floorbeam at the expansion joint, and resting the half floorbeam nearer the main pier on a sliding bearing composed of two bronze plates. The lower plate extends over the full width of the column cap, and supports the other half floorbeam direct.

PAVEMENT—The roadway of the bridge is covered with a gravel fill on the concrete slab, 8 in. deep at the center and shading off to nothing at the curbs; a 6-in. layer of 1:3:6 concrete over this; then a 1-in. binder and a 2-in. sheet of asphalt, bringing the final surface at the middle of the roadway width 1 in. below curb level.

APPROACHES—The approaches on either side of the main span consist of what



appear to be semicircular arches, spanning 30 ft. center to center and 25 ft. in the clear. The actual framing, however, involves longitudinal girders of reinforced concrete with the curb girder carried down to form a diaphragm of semicircular arch contour, this diaphragm having reinforcement both at the line of the bottom of its straight girder portion and along the intradosal line of the arch face. The deck construction is in reinforced-

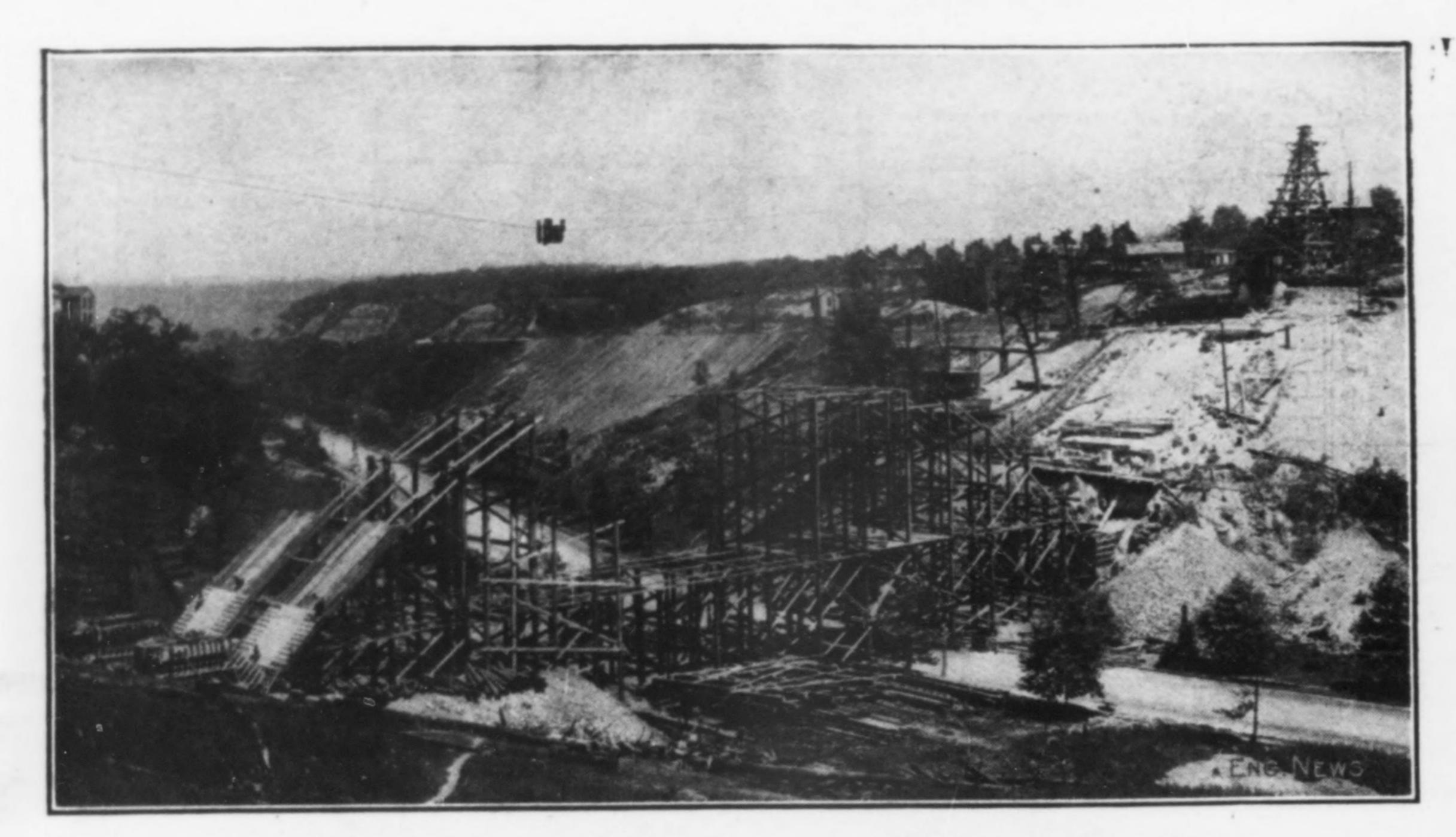


FIG. 6. BUILDING THE CENTERING FOR THE LARIMER AVE. ARCH

main span.

concreting was as follows: The two ribs the key sections were concreted. The were concreted simultaneously, each bulkheads were provided with large pro-

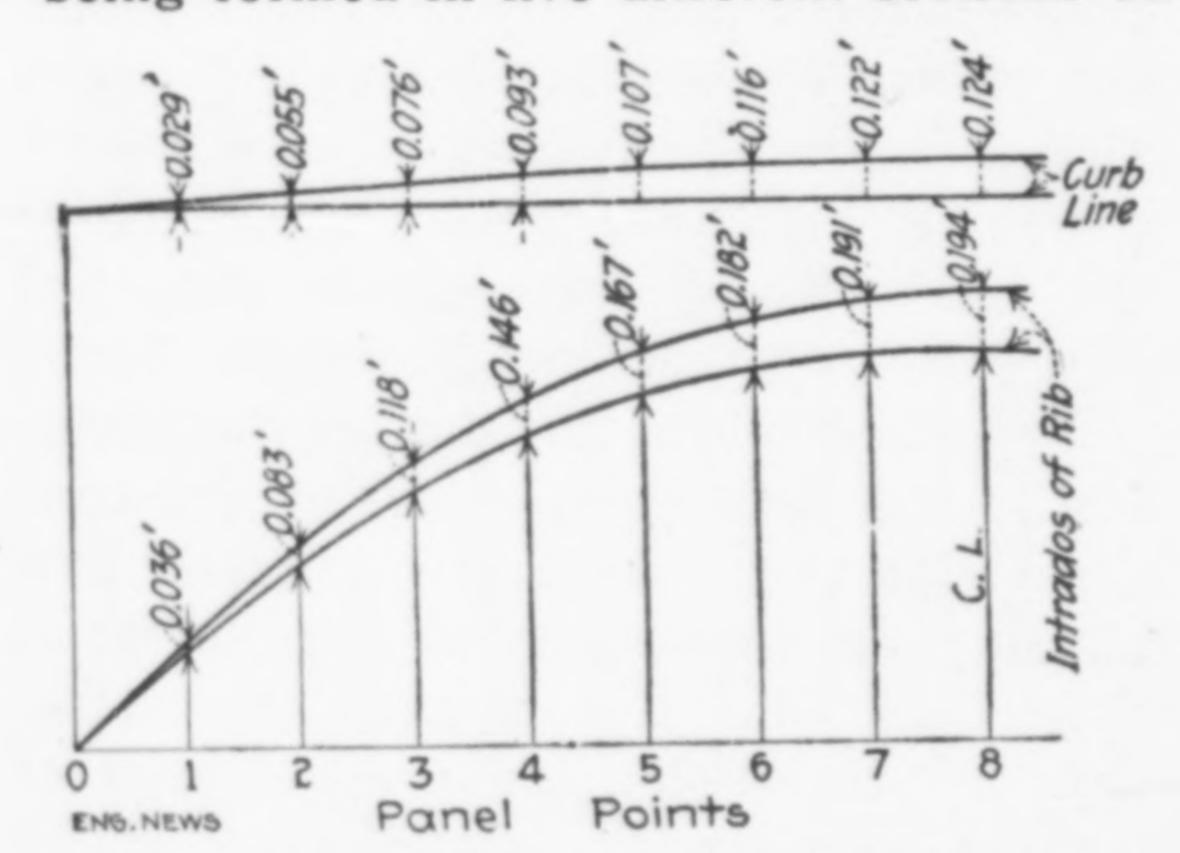


FIG. 7. LARIMER AVE. ARCH: CAMBER DIAGRAM FOR MAIN SPAN

(The cambers given do not include false-work camber.)

either half arch. The sections were placed first in the prescribed order, and later the keys between them were concreted to make the closure. At the roadway columns the rib form included also the base portion of the column, so that a level seat for the column resulted. The cast, up to the top of the cap. Then the floor forms were built complete from end to end, and the whole aggregation of floorbeams, stringers, and slabs, together with the sidewalk brackets, concreted in one consecutive series of operations. The sidewalk slab with the curb and the sidewalk fascia girder was cast later; the separation of this part from the main roadway structure was maintained on account of the expansion arrangements.

For the rib concreting the centering for the two ribs was built complete and the rib reinforcing then placed continuous from end to end. The form walls for the sides of the rib were placed in sections, and closed off at the ends of the sections by bulkheads. The arrangement of the individual sections and the prescribed order of concreting are given by the dia-

concrete slab arrangement as over the gram Fig. 9. The longitudinal reinforc-Forms and Concreting—The order of head, and remained exposed here until mobile. being formed in five different sections on jections on their inner faces in the form of frustums of pyramids to form pockets in the ends of the rib sections in order to give a better engagement with the concrete of the key sections. These projections were made of such shape that air pockets were avoided, the slope of the inclined faces being made steep enough to avoid any reverse slope.

> Each section was concreted in a single day. The top form of the section was laid up as the concreting progressed. Concrete was mixed at a mixing plant at the top of the slope on the east side of the valley and brought to the work in surfaces everywhere were made by spadbuckets by the cableway which may be seen in the construction views.

set, the centers were struck, forms were

erected for the columns to top of cap and these were then cast. At this stage the work was interrupted by the winter of 1911-12; the erection of floor forms and concreting of floor were done in the spring of 1912. In the floor concreting, the joints between successive days' work were made transversely across slab and stringers midway between floor-beams.

MATERIAL—The structural part of the bridge consists of 1:2:4 concrete, using "Universal" cement, river sand, and 1-in. Ligonier limestone. The sidewalk slab was made with 1-in. Ligonier stone in the body, and screenings of the same stone for the wearing surface, troweled hard and then floated with rough wood floats to roughen the surface. In finishing this wearing coat, it was found that the aggregate was too fine to work well under the floats, and a proportion of 1/4- to ½-in. stone had to be mixed in so as ing necessarily passed through the bulk- to make the concrete coarser and less

> All concrete was mixed quite wet, very mushy.

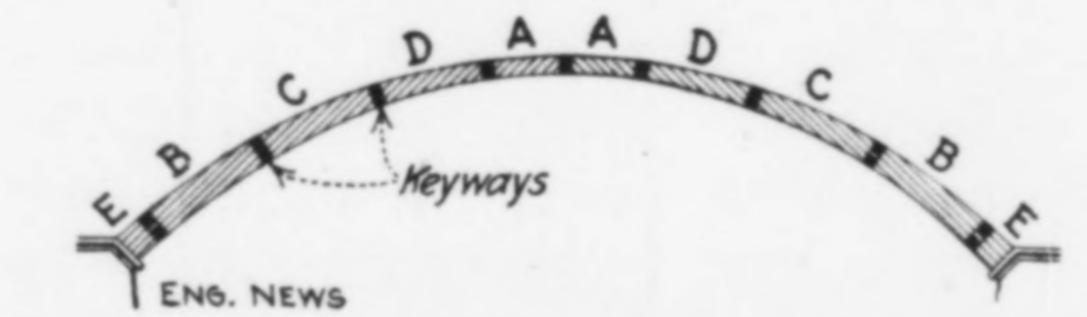


FIG. 9. LARIMER AVE. ARCH: SKETCH SHOWING ORDER OF CONCRETING SECTIONS OF ARCH RIBS

(Section E placed monolithic with main piers. Other sections concreted in order A, B, C, D.)

Surface Finish—The Larimer Ave. arch is noteworthy for the very successful surface finish attained upon it. The main ing back the concrete, and shortly after completion were bush-hammered. A sur-When the ribs were concreted and had face of excellent texture and very uniform color tone was thus secured. The



FIG. 8. LARIMER AVE. ARCH CENTERING, WITH RIB REINFORCING IN PLACE, AND FORMS FOR PARTS OF PIERS AND RIBS (West main pier, looking northeast, Aug. 21, 1911).

bush-hammering operation, a very extensive undertaking inasmuch as the whole bridge was involved, added about 3% to the cost of the structure.

The bush-hammered finish was used for all the main faces, but the bases and caps of columns, skewback coping, and a few other elements of the structure, were rubbed with a carborundum brick and then painted with a very thin cement-sand grout. The resulting texture and color differ slightly from that of the main faces, giving an effective relief and contrast.

A further departure from the general bush-hammering treatment was used in the posts of the roadway balustrade, in order to secure more decorative effects. The balustrade consists of steel railing between concrete posts or piers, connected by bronze fittings. These smooth, hard surface obtained. The ball containing incandescent lamps. panels, however, were treated differently. On the east side of the bridge, between the panels were bush-hammered. This wall erected between the abutment piers. effect of this finish is in every way pleasing and ornamental.

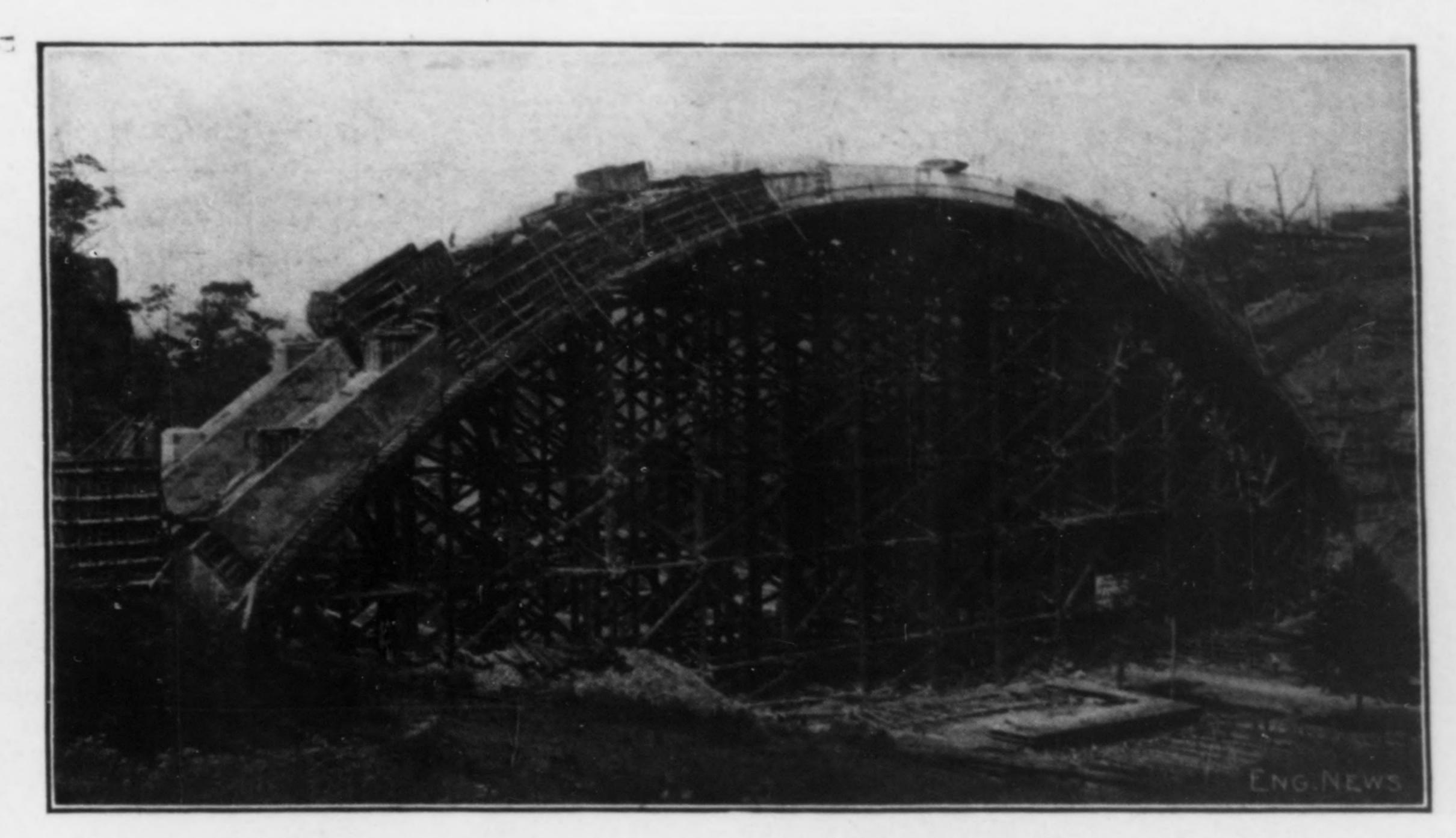


FIG. 10. CONCRETING RIB SECTIONS OF THE LARIMER AVE. ARCH (SEPT. 6, 1911)

their inner and outer faces. The general Bureau of Construction. They are 8 ft. quantities, will bring the total cost of the surface of the post was troweled imme- 8 in. high above the top of the balustrade. diately after stripping the form, and a The bronze shaft carries a ground-glass

In placing the concrete, the stone here the arch abutment piers and in view of was not spaded back from the face, but passers-by on the Washington Boulevard on the contrary was allowed to come into below, a commemorative tablet is to be contact with the form as thoroughly as placed. This will consist of a bronze possible, and after removal of the form inscription plate bolted to a concrete

produced a surface showing the stone ex- GENERAL—The bridge was designed posed in an irregular white mosaic in the and its construction was supervised by gray or bluish cement background. The the Bureau of Construction of the Department of Public Works of Pittsburgh (J. G. Armstrong, Director of the de-ORNAMENTATION — The ornamentation partment; N. S. Sprague, Superintendent of the bridge lies wholly in the propor- of the bureau). Willis Whited was divitioning and finish of its parts and the sion engineer during the design, with detailing of copings, railings, etc. Prac- T. J. Wilkerson as designing engineer. tically the only essentially ornamental latter succeeded Mr. Whited and was in item will be four bronze and granite can- charge during construction. The contract delabra, one to be set over each of the was let to the John F. Casey Co., of Pittsfour main piers. These candelabra were burgh, for the price of \$140,948. Extras,

piers are recessed and paneled on designed by the architect of the city's and variations of actual from estimated bridge to from \$145,000 to \$150,000. O. Stange was superintendent of construction for the contractor.

> The contract was let on Apr. 22, 1911, and work was begun early in May. The contract date of completion was July 1, 1912, but various incidents delayed completion until August, 1912, although the formal opening took place on July 10. In the 1911 season the pier and abutment foundations were built, the main arch concreted, the main plers constructed, and the columns on the main arch placed. The west approach also was constructed during this season. In 1912 the entire deck was formed and concreted, the east approach built and the surface-finish work done.

The Larimer Ave. bridge contains 8525. cu.yd. structural concrete, 892,540 lb. reinforcing steel, and 2233 sq.yd. pavement. The cost per unit is \$208.50 per lin.ft. bridge, or \$4.17 per sq.yd. ground area.

Atherton Ave. Bridges

Two concrete arch bridges are being built to carry Atherton Ave. over the break caused by the lines of the Pittsburgh Junction R.R. and the Pennsylvania R.R. crossing through the Pittsburgh peninsula. The new street connection will provide an important traffic route from Grant Boulevard to the East Liberty section.

The two crossings are a quarter mile apart. The westerly one, the Pittsburgh Junction R.R. crossing, is a single arch span of large size, and therefore its design embodies separation of the arch barrel into rings, open spandrels, and beamand-slab floor construction. The Pennsylvania R.R. crossing has to do with a wider and shallower valley, for which a series of short spans was suitable. This bridge has full-barrel arches, solid spandrel walls, and filling over the arch. The two structures involve about equal quan-



FIG. 11. LARIMER AVE. ARCH: FORMS FOR FLOOR FRAMING AND SLAB (MAR. 18, 1912)

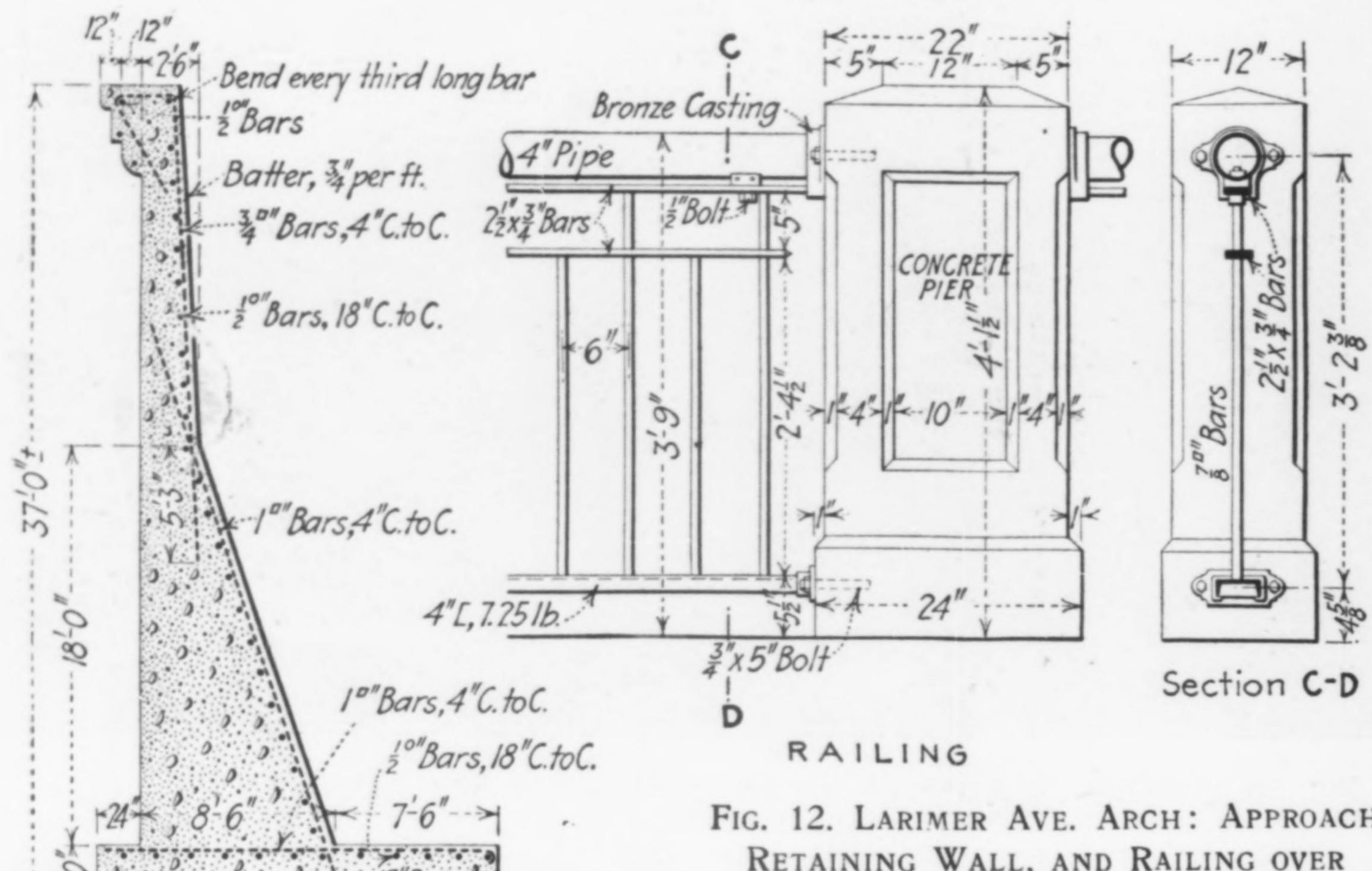


FIG. 12. LARIMER AVE. ARCH: APPROACH RETAINING WALL, AND RAILING OVER BRIDGE

tities of material, however, and cost about the same—a trifle over \$90,000.

SECTION OF RETAINING-WALL

OF ABUTMENT

PITTSBURGH JUNCTION R.R. BRIDGE

The design of the Pittsburgh Junction R.R. bridge, with its 1681/2 ft. large span and its 45-ft. and 60-ft. flanking spans, shown by Fig. 13, is notable for grace of the lateral stiffness of rib and floor. outline and effective simplicity of detailing. Elliptoid curves in the side arches, and a related effect in the large arch secured by the treatment of the ends, gives the structure a bold and full effect. Ribs, posts and quoins are brought out by rustication or false-joints, as against smooth surfaces in the Larimer Ave. bridge.

The structural design of this arch fol-

arrangement of the rib reinforcement and the floor construction.

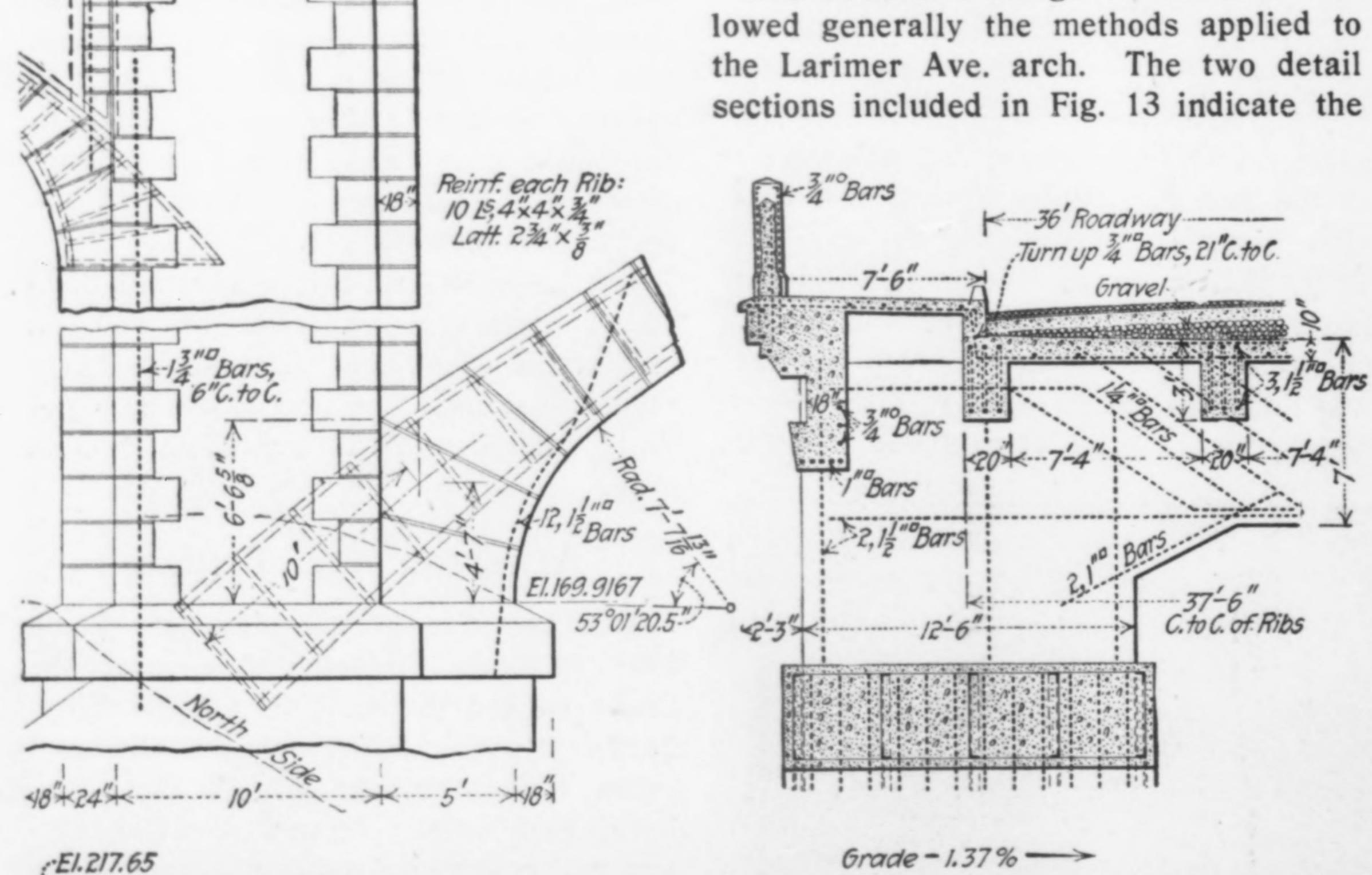
The large arch has a figured span of 177 ft. and a figured rise of 293/4 ft. It consists of two ribs of uniform width, as in the case of the Larimer Ave. arch, but they are wider, and cross-struts are therefore dispensed with (each rib 14 ft. wide, against 8 ft. in Larimer Ave.). The crown thickness is 42 in., the thickness at springing line 68 in. The ribs are $37\frac{1}{2}$ ft. apart c. to c., which brings them nearly but not quite central under the curbs. The sidewalks do not overhang as in the Larimer Ave. bridge.

The deck is 60 ft. wide at piers and abutments, and over the spans is 54½ ft. wide to sidewalks, with a 36-ft. roadway. It is a reinforced-concrete slaband-beam floor on columns $3x12\frac{1}{2}$ ft. resting on the arch ribs. These wide columns, in conjunction with the floorbeams, act as portal frames to conjoin

The spandrel arches disappear near the middle of the span, and a solid spandrel wall replaces them. Pilasters mark the positions corresponding to the columns.

The division of the main arch into two ribs is carried through the main piers, these being pierced by a 19-ft. opening, leaving an 18½-ft. pier on either side. Thus, standing under one of the approach arches a clear view may be had to the opposite abutment. The approach arches also are divided into two ribs, though their spandrels are full walls; however, their floorbeams are set close and no stringers are used.

The main arch ribs were concreted in six sections each, with short key spaces between. The short-radius portion near the skewbacks was concreted as part of the main piers. The rib concrete was carried up at each of the columns to form the bottom block of the column and give a level seat for the column body. The floor was concreted in sections, the forms, however, being built continuous and complete. Both rib and floor forms were set for camber, as in the Larimer Ave. bridge, to take up the deflection due to dead-load; this camber was 0.104 ft. at



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FIG. 13. ATHERTON AVE. BRIDGE OVER PITTSBURGH JUNCTION R.R.

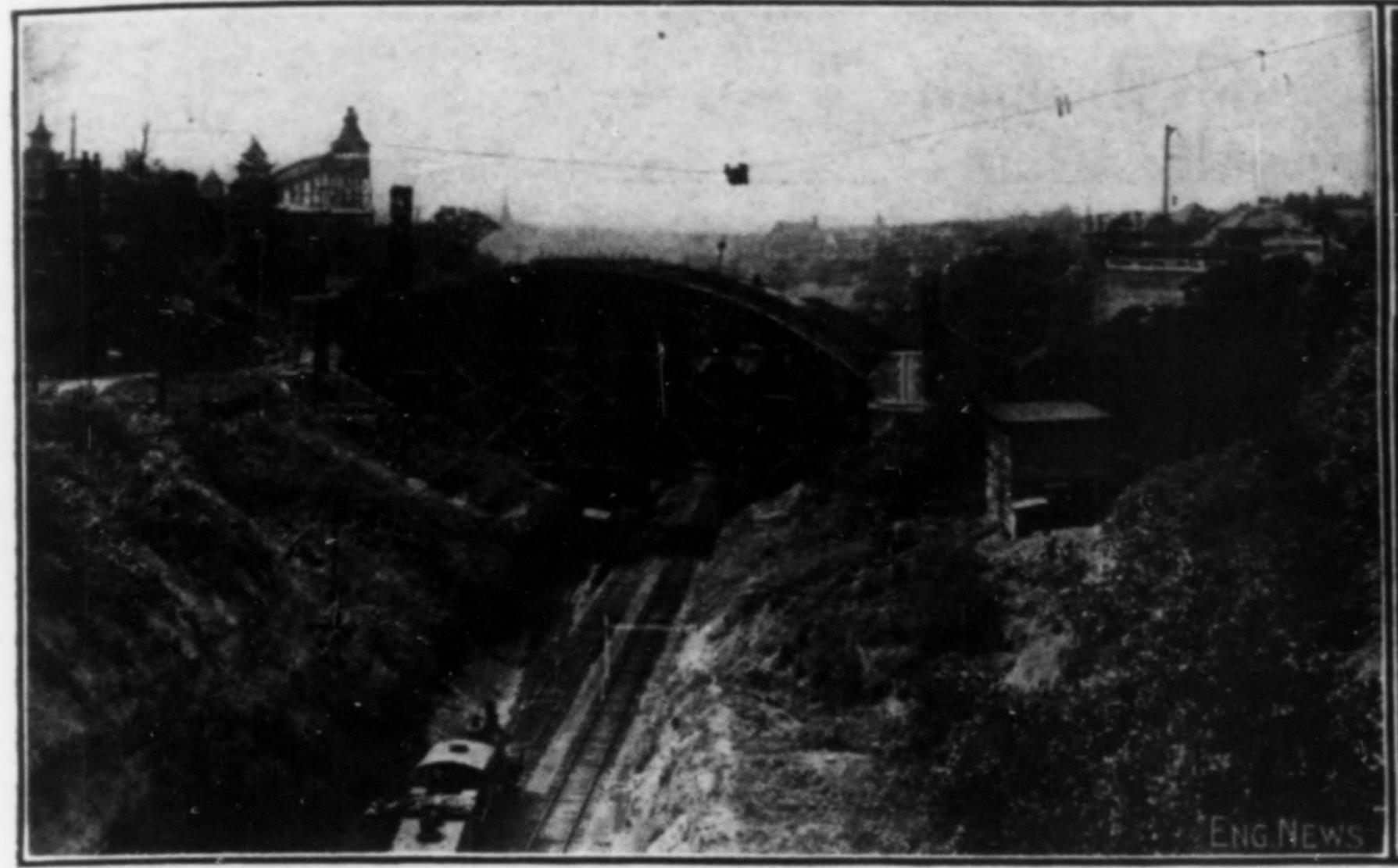


FIG. 14. CENTERING FOR ATHERTON AVE. BRIDGE OVER PITTS-BURGH JUNCTION R.R., SEEN LOOKING NORTH

(A 60-ft. Howe truss over the tracks carries the middle part of the centering. The concrete-distributing tower

FIG. 15. WEST PIERS AND ABUTMENT OF PITTSBURGH JUNCTION RY. BRIDGE, FROM TOP OF MAIN ARCH CENTERING

floor.

stands at the left.)

allowed for.

at the main piers. The stringers of the symmetrical about a line normal to the main span are set in pockets here, on grade, and not symmetrical about the double steel curb as at the expansion arch is 30 in. thick at the crown, with the approach span is divided from the depth of the barrel is 10 ft. 3 in. made by tar paper.

tween are to be bush-hammered.

Co., of Pittsburgh, for a price of \$91,-330. It will be completed this winter. The design was made and detailed by the Bureau of Construction, Department of Public Works.

The bridge contains 7960 cu.yd. structural concrete, 664,000 lb. reinforcing steel, and 1672 sq.yd. paving. The contract price reduced to units is \$3.62 per sq.ft. ground area, or \$217 per lin.ft. bridge.

PENNSYLVANIA R.R. BRIDGE

The bridge over the valley through which the Pennsylvania R.R.'s four-track line passes is structurally much simpler, though not simpler as a piece of contract work. Fig. 16 shows its general features.

It is a series of three 90-ft. skew arches, 49½ ft. wide, over the arch ring, with solid-fill abutments making up the approaches. The arches have full sheet ring, carrying solid spandrel walls, and the interior is to be filled with granulated blast-furnace slag on which the pavement will be laid. The roadway has a fall of 1% eastward, and the springing-lines of

crown for the ribs and 0.089 ft. for the the arches are arranged on the same The spandrels have recessed panels, and slope.

in three sections, crown first and on the 90-ft. span is 21 ft. The intrados haunches afterward: No camber was is a circular segment of about 63½ ft. radius, except that an 11-ft. length at Expansion joints are built in the floor each end is of 35 ft. radius. The form is bronze plates. The slab contains a midspan vertical. The barrel of the points of the Larimer Ave. bridge. On rapid increase in thickness toward the

pier concrete by a construction joint, The barrel is heavily reinforced with rods at extrados and intrados. At interbridges were rubbed and then brushed tice-girder with single-angle flanges ex- \$4.13 per sq.ft. area covered. over with cement wash. The panels be- tends transversely across the arch. The spandrel walls, reinforced by vertical The contract for the bridge was let on rods and anchored to the ring by hori-Aug. 16, 1911, to the Friday Contracting zontal rods, are tied to the girders by counterforts of triangular outline, containing diagonal rods fastened to the upper flange-angle of the girders.

are used, being set normal to the spandrel walls and not in line of the piers.

the solid concrete parapet also has re-The approach arches were concreted The three arches are alike. The rise cessed paneling. The panels are bushhammered.

> The bridge is being built by the Cranford Construction Co., under a contract let Feb. 24, 1912, for \$93,128. A centering of steel arch trusses is used for carrying the arch lagging. Concrete is chuted from a distributing tower located to one side of the bridge on the flat westerly slope.

the landward edge of the pier the slab of piers; at the springing-line vertical the This bridge will contain about 7300 cu.yd. structural concrete (i.e., excluding paving concrete), 419,000 lb. reinforcing steel, and 1500 sq.yd. paving. Its con-The block-jointed surfaces of the vals of about 11 ft. along the span a lat- tract cost amounts to \$246 per lin.ft., or

BRICKBAT CONCRETE

A year ago the Bureau of Construction made some trials to produce a concrete differing in color and texture from ordinary concrete. The bush-hammered panels of the Larimer Ave. bridge, giving The esthetic treatment of the struc- a rough mosaic effect, have been menture is simple. Semi-circular pier-nosings tioned. The effect of a similar treatment when broken brick or terra-cotta was used as aggregate was tried, and attractive results secured. The bush-hammer-

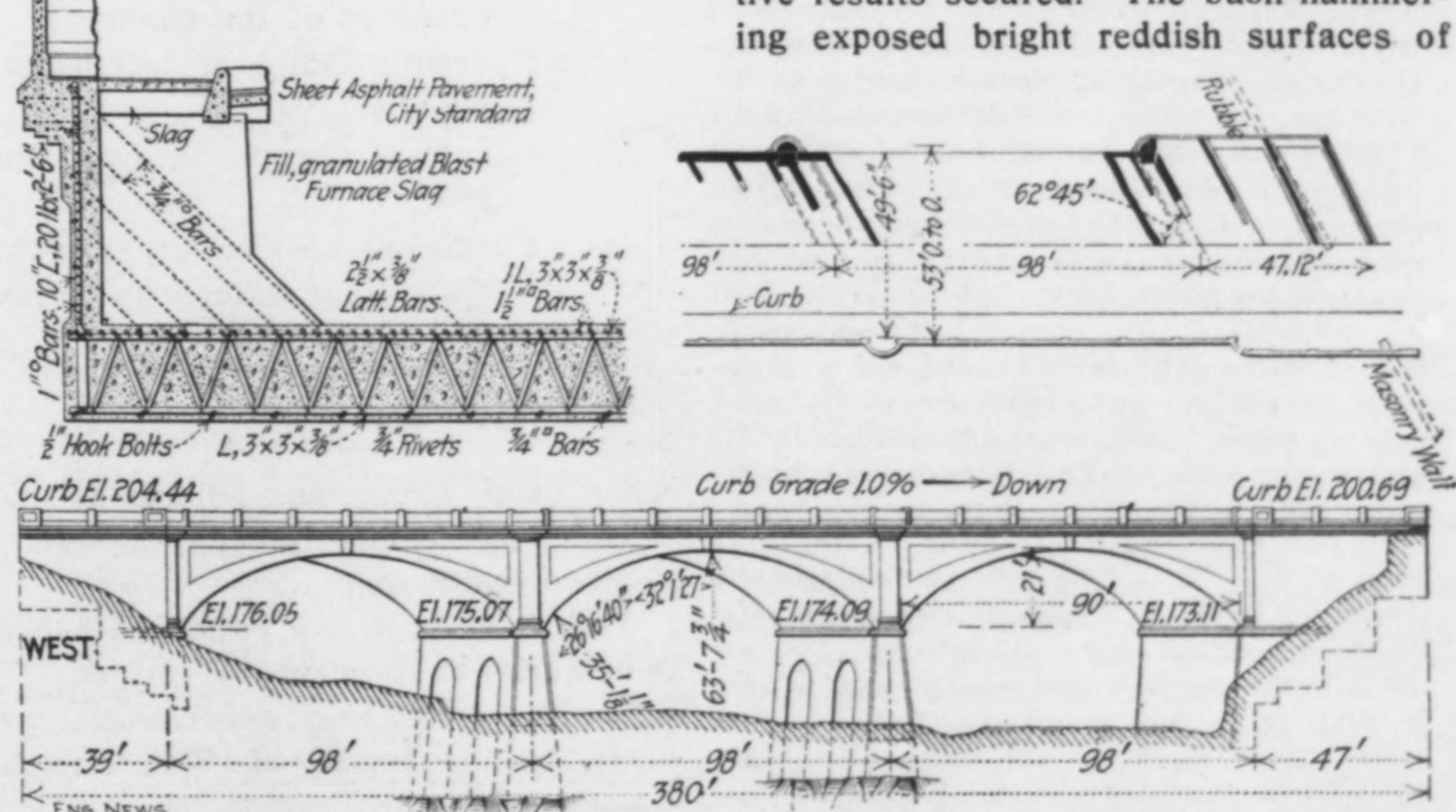


FIG. 16. ATHERTON AVE. BRIDGE OVER PENNSYLVANIA R.R.

the aggregate, contrasting well with the gray cement-mortar parts of the face.

At the same time other sample blocks were made with brick dust in place of sand and gravel. A uniform red surface was obtained, giving an effect much like that of red sandstone.

Brick and terra-cotta débris being available in some quantity in the vicinity of Pittsburgh, it was decided that brickdust and brickbat concrete could be used advantageously in securing desirable architectural effect in bridges of such location as to demand special regard to the artistic.

This material was first specified for a 60-ft. skew-arch bridge on Hoeveler St., whose construction was begun early in autumn, 1912, by the contractor, the C. M. Neeld Construction Co. The arch ring is of Ligonier stone concrete, showing a gray color; the projecting parts of the coping, the balustrade, etc., are of brickbat concrete; the spandrel walls and other panels are of brick-dust concrete. All showing faces will be rubbed to smooth, even-toned surface. Brick concrete will probably also be used in several other concrete bridges to be built in the near future.

City Commission Plan Charters were voted upon at Los Angeles, Calif., and Duluth, Minn., on Dec. 3. At Los Angeles, the proposed charter was rejected, two to one. At Duluth, the proposition carried, and the new charter will go into effect Jan. 3, 1913, although the present city officials will be continued in office until April 3, 1913.

Diamond-drill Borings are being made at Chicago for two intake tunnels under Lake Michigan, as an addition to the water-supply system. One of these tunnels is on the north side, at Bryn Mawr and the other is at 35th St., to serve the stock-yards district. It is desired to have the tunnels in solid rock, and to avoid the seamy and irregular strata, which have caused so much trouble in the earlier tunnels as described in Engineering News. For this reason the dril holes are made deep enough to indicate that there will be solid rock

above and below the tunnel grade. The drilling extends to a distance of three miles from shore in each case, the maximum depth of water being 38 ft. The deepest hole is 138 ft. deep, or about 100 ft. below the bed of the lake. Many boulders are encountered, and large pockets in the rock; also some ledges of rock about 2 ft. thick, which at first appear to be solid rock, but are found to be underlaid by water-bearing sand. The drilling rig is mounted on a platform, 14x14 ft., supported by 65-ft. piles driven until their tops are about 10 ft. above the water. The tripod is of 30-ft. cedar poles, so as to give ample headway for handling 24-ft. lengths of drill rods. The drill is of the Standard Diamond Drill Co.'s make: it is unusually light, weighing only about 350 lb., so that it can be handled easily and taken to and from the work each day on a scow. The work of the lake and land borings is in charge of F. A. Smith, Assistant Engineer in the Bureau of Engineering, of the city of Chicago.

A Theoretical Formula for the Flow of Liquids through Narrow Rectangular Chan-

nels

BY ERNST JONSON*

retical formula for flow of liquids through lowing table gives the calculated as well circular tubes. The practical application as the measured flow of various presof this formula is, however, limited because it presupposes absolute uniformity of flow, a condition which is seldom realized. It is only when the velocity is very small that the disturbances in the flow caused by irregularities in the tube are practically negligible. This formula gives, however, the possible maximum flow in a tube, a quantity which will be approached to the extent that disturbing influences are eliminated.

The writer has developed the theoretical formula for the flow of liquids crometers used in making these measurethrough rectangular channels. This ments could be read only to 1/1000 part formula presupposes that the width of 805 C 534 C W B No cuts Set Nov 15 the channel is only a small fraction of the depth, as is the case with the annular channel between a piston and the inside wall of a cylinder or the expansion joint in a dam. It also presupposes the same conditions as those by which Lamb's formula is governed, namely, that the flow shall be uniform or approximately so. Its practical application is, therefore, limited to very narrow channels or cracks where the velocity of the flow is slight. The limit of applicability of this formula may be determined under any given requirements of accuracy by figuring the theoretical velocity and then determining the corresponding empirical loss of resulting from irregularities in the channel or other disturbing conditions. The formula is as follows:

$$F = \frac{2 p r^3}{3 l u}$$

in which

F = Flow per second per unit of depthof charnel;

p = Difference in pressure at the two openings of the channel;

r = Hydraulic radius or half width of channel;

l =Length of channel in direction of flow;

u = Coefficient of viscosity, which in the case of water may be taken

$$u = \frac{0.000013}{18 + T}$$

when using inches and pounds as units, T being the temperature of the water in degrees Fahrenheit.

This formula is now published because it has been experimentally verified. The following confirming experiments were made by the Board of Water Supply,

City of New York. A bronze piston 6 in in diameter and 8 in. long was placed in a bronze cylinder with a clearance of about 0.002 in. Filtered water at a temperature of 74° F. was then forced through this annular channel under pressures varying from 3.5 to 120 lb. per Lamb's "Hydraulics" gives the theo- sq.in., and the flow measured. The fol-

Pressure lb. per sq.in.	Flow in cu.ir Calculated	n. per sec. Measured
20	0.21	0.14
40	0.42	0.35
60	0.62	0.61
80	0.83	0.83
100	1.04	1.04
120	1.25	. 1.28

The actual micrometer measurement of the diameter of the piston was 5.9971 in., and that of the diameter of the cylinder 6.0007 in., making the width of the annular channel 0.0018 in. Since the miof an inch, and since the general run of the observations indicate that this measurement is somewhat small, it was assumed to be about 1/10000 part of an inch too small, namely, 0.001946 in., and the calculated values are based on this latter figure, which was derived from the flow. In other words, through the formula the flow became a more accurate measure of the width of the channel than the micrometer used.

A second test was made with another piston differing from the first mentioned one in that eight circumferential grooves 3/8 in. wide were cut in its cylindrical surface, thus reducing the remaining head due to lack of uniformity of flow thin annular channel to an aggregate length of 5 in. The diameter of the second piston was 5.9967 in., thus making the annular channel 0.002 in. wide, or, more exactly, 0.001956 in. as derived from the flow of water. The following table gives the calculated as well as the measured flow of various pressures; temperature of water, 74° F.:

Pressure lb. per sq.in.	Flow in cu. Calculated	in. per sec. Measured
20	0.33	0.27
40	0.66	0.57
60	0.98	0.91
80	1.31	1.31
100	1.64	1.64
120	1.97	1.94
Continue	d after 2 days' in	termission
20	0.33	0.31
40	0.66	0.62
2.75	0.07	0.06
3.0	. 0.07	0.06
Continue	d after 1 day's its	nermission
60	0.98	0.90

Previous to this series of tests, another series had been made with each piston differing from the above series in that unfiltered city water was used. The results of these tests are given in the table, "Tests with Plain Piston."

It will be seen in comparing the column of calculated flows with that of the measured flow, that the latter are considerably less than the former, and that when higher pressures are put on the

^{*}Engineer Inspector, Board of Water Supply, 147 Varick St., New York City.



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CEMENT AGE with which is combined CONCRETE ENGINEERING

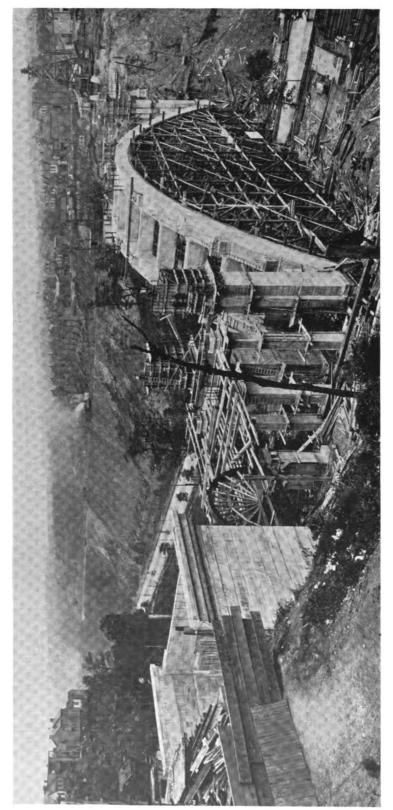
Index Vol. XIII-July-December, 1911

The CEMENT AGE COMPANY, Publishers, NEW YORK CITY

In preparing the index for this volume, we
have endeavored to make the subject matter acces-
sible under the best known heads. As practically
every item deals with cement or concrete in some
way, there has been no attempt to index under
"cement" or "concrete." There is no classification
under tests or testing, and in general none under
design or construction. Look directly for the subject.
"(E)" indicates that the item is found in the
Editorial Department, "(Con.)" in Consultation,
"(Cor.)" in Correspondence, "(Sum.)" in Summary
of Cement and Concrete Literature, "(Briq.)" in
Briquettes, and "(F. N.)" in Foreign Notes. Illus-
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This photograph, taken October 6, 1911, shows the completion of the main arch rib with cross girders. The approach piers and abutments are rapidly nearing completion. The clear span is 312 feet, which makes this structure the longest concrete arch on the Continent. THE LARIMER AVENUE BRIDGE, PITTSBURG, THE LARGEST AMERICAN CONCRETE ARCH.

THE LARGEST AMERICAN ARCH

THE largest concrete arch in magnitude in the world and the second largest in point of span is now under construction at Pittsburg, Pa. This arch forms part of the Larimer avenue bridge over a deep rugged ravine in one of the residential sections of the eastern part of the city. It is 312 ft. clear span. In New Zealand, 12,000 miles away, is a great arch of concrete with clear span of 320 ft., only 8 ft. more than the Pittsburg arch. But as the latter is 50 ft. wide and the one in the antipodes 36 ft., it is seen that the American work is the largest all told. The height of the Pittsburg bridge is 113 ft.

The arch ribs have a rise of 67 ft. and are built on line pressure. With the exception of these ribs, with their angles as mentioned the entire work is reinforced with medium, open-hearth steel rods. Over all the bridge measures 670 ft. with a roadway in the center 30 ft. wide, paved with asphalt, and flanked by concrete sidewalks 10 ft. wide. The roadway is supported on the main arch by means of columns spaced 19 ft. 6 in. center to center. and connected at the top by reinforced concrete girders. The main piers are of cellular or box-like construction. At the western end of the bridge are four approach arches and at the eastern end three, with 30-ft. spans for all. Immediately beyond these are the abutments, which are built in U-form filled with earth.

The roadway has a grade of 1.1 per cent. There will be a steel railing supported by panel-posts of concrete, spaced 16 ft. center to center. Orna-

mental iron electroliers will carry enclosed arcs furnishing ample illumination.

In the entire bridge there will be used about 8,500 cu. yds. of concrete and 436 tons of steel. The estimated cost of the work is \$140,000. The structure is to be opened for foot traffic this fall, but not for vehicular travel until next spring when it is expected the work will be completed.

It may be of interest to know that more than 400,000 lin. ft. of lumber are being used for the false-work.

Chas. H. McAlister, the engineer in charge of the work for the contractors, the John F. Casey Co., sends in the following notes:

The foundations are built upon shale rock. Material is shifted from the Pennsylvania Railroad (Brilliant cut off) to our siding, the cars standing over hoppers which feed side-dumping 4-yd. cars which convey the sand and crushed limestone to the bins over the Smith mixer (capacity 22 cu. ft.) Haynes buckets convey the concrete from the mixing plant about 150 ft. to a point under the Lidgerwood cableway which spans the work longitudinally. The cableway handles the mixture to place.

The reinforcement is the "Diamond bar" and was furnished by the Concrete-Steel Engineering Co. and is mostly 1½ in. and 1¼ in. in the beams. The main ribs are reinforced with six truss rods bent on the work out of 1½ in. bars and the column rods are tied into the main arch rib with 1½ bars bent as U bars. Universal Portland Cement is being used.

We started to pour the arch on August 28 and poured the last of it on September 18. Exclusive of the struts, which have been placed since the 18th of September, there was placed about 1,750 cu. yds. of concrete, mixed 1:2:4. The crown sections of both main ribs were placed first and then the sections at the joints with the main piers. From these last sections the others were placed to the crown. Concrete was brought up on each side of



FIG. 1—THE LARIMER BRIDGE, JULY 15, 1911. SHOWING THE WORK ON THE TIMBER FALSEWORK.

LARGEST AMERICAN ARCH

the ribs symmetrically. The key spaces between sections were 4 ft. 6 in. long and were nine in number on each rib, spaced 37 ft. apart horizontally. They were poured on each rib in one operation.

The false-work for the main arches was completed in two weeks and four days and was designed by Ottomar Stange, general superintendent and engineer for the contractors. N. S. Sprague, superintendent of construction for the city of Pittsburg, is in charge of the work for the city.

The contractors plant for the construction of this work is complete in every detail there being a mill for the form work, a blacksmith and machine shop and an air compressor plant which furnishes power for all the air tools necessary on this work. Fig. 3 shows the voussoirs of the arch ribs about completed and key spaces ready to run.

Concrete at Panama

The Canal Record for September 20 makes the following statement:

In the issue of the Canal Record of September 13, under "Cost of Concrete," the statement is made that the Atlantic Division laid 237.05 cu. yds. of material per hour, and the Pacific Division 352.67 cu. yds. per hour. These figures were taken from a computation made for the chairman's forthcoming annual report, and a revision shows them to have been incorrect. The average amount of masonry laid in the locks per service hour, during the year, was, by the Atlantic Division 260.573 cu. yds. of concrete and large stone; and by the Pacific Division 281.299 cu. yds.

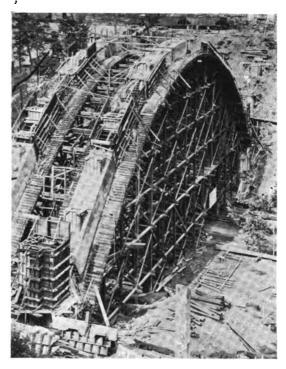


FIG. 3-THE LARIMER BRIDGE, SEPT. 6, 1911.

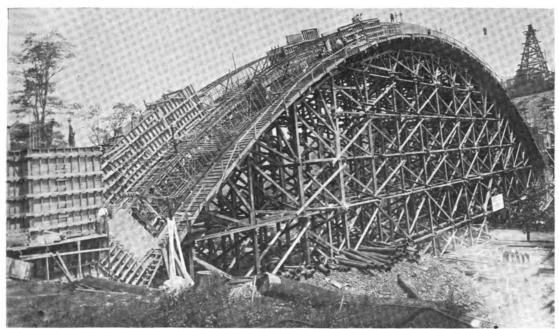


FIG. 2—THE FALSEWORK ON THE LARIMER BRIDGE READY TO RUN.

Following is an analysis by Mr. McAlister of the centering used: Plumb posts in bents (under each arch column), two under each panel point, or four in a bent— 12×12 long leaf yellow pine. Bents are 19 ft. 6 in. centers. Longitudinal braces for each bent are 4×10 , one on each side, bolted through with 1-in. bolts. Sway braces tieing one bent with the other are 3×10 . Cross Braces tieing four plumb posts of bent together are 4×10 . Struts between bents are 8×8 . Caps running the entire length of bent (or across the entire width of bridge are 10×14 and rest on wedges, which in turn are carried on 4×10 on top of plumb posts. Joists carrying arch decking are 4×12 oak. Decking 1s of %-in. tongue and groove flooring. Note also the steel in place, shown in the photograph.

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HIGHWAY ARCH BRIDGES

The Larimer avenue bridge, Pittsburgh, Pa., completed in 1912, is rightfully placed at the head of the list of American bridges. There are two other bridges (both highway bridges) in the world of longer span, but they are of much smaller proportions otherwise; namely, in width and height. The longer span bridges are: one at Rome, Italy, with a span of 328 feet; and the Auckland, New Zealand bridge of 320 feet span. The Larimer avenue bridge with a clear span of 300 feet, 4% inches, a width of 50 feet, and a height of 115 feet, can therefore be justly called the largest concrete arch in the world in point of size and third largest in length of span. The bridge is 670 feet long with a roadway 30 feet wide in the center, flanked by cantilevered concrete sidewalks 10 feet wide.

The arch ribs are five-centered, an approximate parabola, with a rise of 67 feet and intradosal radii of 186 feet, 1 inch, 241 feet $8\frac{1}{2}$ inch, and 216 feet, $10\frac{1}{2}$ inches. These ribs are 8 feet wide and 6 feet 6 inches deep at the crown and 11 feet deep at the haunches

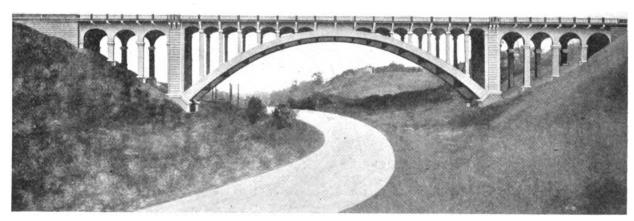
The surface finish of this bridge is very fine as shown by the illustration. The main surfaces were bush hammered and other parts were rubbed with carborundum bricks.

This structure is a very graceful and attractive one in every way. The ornamental copings, hand rails and the excellent proportioning and finish of the bridge as a whole, as well as the various parts, gives it an artistic appearance not possessed by many arches. As an example of economic and esthetic design it stands without peer.

Compared with the first concrete arch bridge built in America (in 1893), the Pine Road bridge at Philadelphia, with two 25-foot spans, one obtains some idea of the progress made in the design of concrete arches in a period of 20 years.

HOW TO ATTACH PLASTER TO CONCRETE

The Aberthaw Construction Co., Boston, Mass., recommend the following method of attaching plaster to concrete. "Make the concrete as porous as possible by omitting sand from the mix and by not spading the



NEW CONCRETE BRIDGE, PITTSBURG, PA. John F. Casey Co., Pittsburg Contractors.

and are spaced 30 feet center to center, cross braced at points of spandrel arch columns. The reinforcement of each rib consists of eight $6x4x\frac{3}{4}$ inch angles latticed together with flat bars to form a deep lattice-girder, with a total section of $55\frac{1}{2}$ square inches. Although the ribs as designed are subject to compressive stress only, the steel was added to provide an added factor of safety and make the entire structure more rigid.

The roadway girders supporting the reinforced concrete stringers and floor slab, are carried by reinforced concrete columns 19½ feet centers, resting on the arch ribs, connected at the top by the circular spandrel arches. The sidewalk is supported by concrete brackets at the spandrel column centers. The approach arches have a clear span of 25 feet and are carried on columns in a manner similar to that of spandrel arches. There are four approach arches at the west end and three at the east end of bridge.

The main piers are of cellular construction with reinforced concrete face walls extending up to sidewalk. The abutments are reinforced concrete U-abutments filled with earth. Ornamental steel hand rails are supported by paneled concrete posts at panel points of spandrels, on the bridge proper, the rail over the abutments being a solid paneled concrete wall.

concrete next to the forms. Where plaster is required underneath a floor or roof if the forms are sprinkled with ½-inch stone before the concrete is placed, a rough surface will be obtained to which plaster will key nicely.

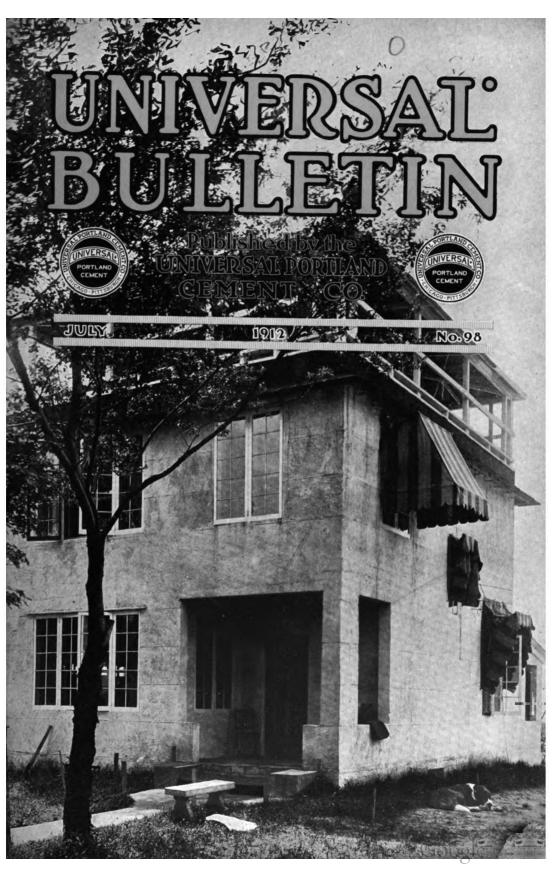
To attach Portland cement plaster to smooth concrete, hack the surface with a point, brush the surface thoroughly to get the dust out, wash it, and in every case make sure that the under concrete is thoroughly wet before the plaster is applied. Otherwise the water will be soaked out of the plaster and the plaster will not adhere. Wash the surface with grout just ahead of the plaster and make sure that the plaster is applied before the grout has time to set.

It is the experience of the Aberthaw Construction Co. that lime plaster is very unsatisfactory for placing on concrete surfaces. The only way they have been sure of a satisfactory result is to use plaster which is principally composed of plaster of Paris.

CORRECTION

The article which appeared on page 123 of our April, 1913, issue entitled "Pulverized Coal as a Fuel," by A. W. Raymond, was copied verbatim from the February issue of Metallurgical and Chemical Engineering. Through error we failed to give this magazine credit.



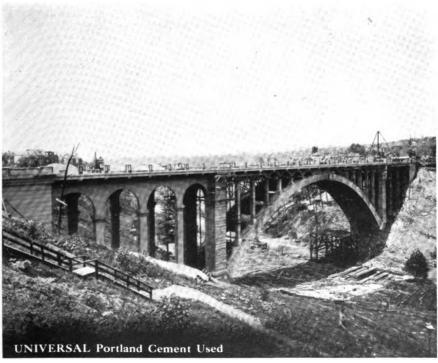


construction in the Northwest to build cement block walled truck warehouses which are low in cost and on account of the insulating air space give excellent protection from heat and cold.

Construction much similar to the garage above has been used in a potato warehouse also at Princeton, Minn. Both were built by Louis Wicen, contractor, of Princeton.

Larimer Avenue (Pittsburgh) Bridge Progress

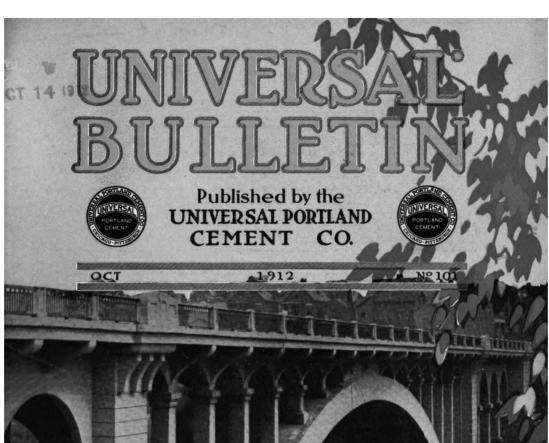
The Larimer avenue bridge at Pittsburgh mentioned in the Universal Bulletins for October, November and December, 1911, and being built by John F. Casey, Contractor of Pittsburgh, is nearing completion. This illustration was taken on May 31st and shows the concrete work complete with the exception of the balustrade. The details of this bridge will be described in a later issue when all surfaces have been cleaned and the bridge thrown open for traffic. It is planned to hold dedication exercises July 10, 1912.



Larimer Avenue Bridge

Pittsburgh, Pa.







The pavement has a thickness of five inches and a width of twenty-six feet over all. There is a curb, six inches high and five inches thick, built on the pavement and anchored to it with steel loops every five feet. The reinforcement used is American Steel & Wire Co.'s No. 7 triangle mesh. There are expansion joints every thirty-three feet, protected with Baker steel plates, the joint being filled with tar.

The pavement was laid in one course using washed gravel. The cement cost \$1.25 per barrel deliverd on the job, the gravel \$1.25 per yard, labor 20 cents per hour and the total cost of the pavement has amounted to \$1.10 per square yard for that part already completed. This is considerably lower than that of any other pavement of equal merit.

Larimer Avenue Bridge, Pittsburgh, Pa.

The municipal bridge crossing Negley Run and Washington Boulevard at Larimer Avenue in Pittsburgh is the second largest arch span in the world and the longest span of this type in the United States, being 670 ft. over all with a clear span of arch of 300 ft. between springing lines, and a rise of 67 ft. At its highest point, the bridge is 115 ft. above the roadway.

The design and type of construction were dictated by several conditions. The gulch was narrow and deep, requiring a bridge without unnecessary piers. It must be light in order to rest safely on the shale foundation. It must, furthermore, be of moderate cost yet suitable to carry boulevard traffic. The narrowness and steepness of the gulch made an arch bridge with a trestle approach especially advantageous. Due to the foundation being of shale, it was necessary to design a structure which would allow a full pressure of not more than six tons per square foot. The design decided upon comprised all the requirements of stiffness, lightness, strength, cheapness and architectural beauty.

The 30 ft. roadway is designed to carry two 35-ton street cars and one 15-ton truck on any place on the floor, assuming 10 tons on the rear axle and 5 tons on the front axle. However, a uniform loading of 150 lbs. per square foot was considered and the condition giving the largest stress taken. The sidewalk which was carried on cantilever brackets projecting from the spandrel columns was computed for a uniform live load of 100 lbs. per square foot. All footings were thoroughly reinforced and the rods from the superstructure were carried into them for a distance sufficient to insure rigidity.

The main arch ribs are 8 ft. wide and have a depth at the crown of 6 ft. 6 ins., which gradually changes to 11 ft. perpendicular to the line of the thrust at the haunches. The main reinforcement consists of eight $6'' \times 4'' \times \frac{3}{4}''$ angles tied together by five $2\frac{3}{4}'' \times \frac{3}{8}''$ bars placed about two feet on centres.

The approach was designed as a reinforced concrete trestle and the arches on the outside shown in the illustrations carry only a small por-

tion of the load and were put in primarily for the architectural effect. The floor system is carried on floor beams 3 feet wide by 7 feet 6 inches deep to the top of the floor and 30 feet long. The floor slab is supported by the two side arches and two stringers.

The abutments and wing walls were designed to resist the load from the earth and fill behind as well as the load from the end section of the approach. Both wing wall and abutments are of the cantilever retaining wall type reinforced with rods in the front and in the back faces and with spread footings running back into the fill and also a projecting toe.

Construction Features

During July, 1911, the old wooden structure which has stood on this location was torn down and the excavation for the main piers commenced. The foundations were carried to a point well below the rotten surface rock to solid bed rock. In no case was the bottom of the footing less than fifteen feet below the general elevation of the ground, at the point where the work was under way. No peculiar difficulties were encountered and at no time was water or unsatisfactory stone found which made extra precautions necessary. The concrete for the main pier footing was placed during the latter part of July, 1911, by means of chutes and the piers carried to the elevation at which the main reinforcing rods of the arch rib ended.

While the forms for the main arch were being placed, the footings



Longest Concrete Span in the United States

Pittsburgh, Pa.





A Masterpiece of Bridge Engineering

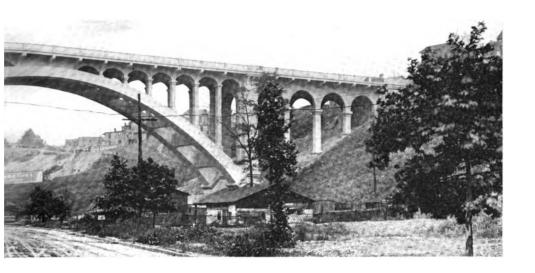
Pittsburgh, Pa.

for the abutment and approach columns were completed. The centers of the main arch were sprung on false work resting on mud sills on the ground and were brought to elevation by driving wedges at the top.

In order to keep the arch from springing out of position while the concrete was being placed, it was necessary to place the concrete in sections about thirty feet long, leaving key-ways between the sections, at which points the reinforcement was left unconnected, until after all the sections were completed. This made it possible to have no initial compression in the steel. The two 8-foot sections immediately adjacent to the piers were first concreted, and were placed simultaneously with the heads of the piers. In this way the action of the arch as a no-hinged structure was insured.

The two 30-foot sections of the crown were next placed and the remaining three sections on each side were placed commencing at the lowest. A 4½-foot key-way divided each section. After the concrete had hardened thoroughly the rib reinforcement was drilled and spliced with plates secured by ½-inch machine bolts. The key-ways were then filled and twenty-eight days after the last concrete was in place, the forms for the arch ring were removed.

Simultaneously with the concreting of the arch section the bases of the spandrel columns were placed. After the arch rings were completed and the centering had been removed, the two rings were held together



by struts eighteen inches wide and the vertical depth of the arch ring. By this method it was possible to make the arch rings considerably lighter than would have been the case if the arches had been self-sustaining. When winter put an end to the concreting, the main arch ribs were completed, the spandrel columns were in place and ready to receive the floor system and the approach supports were finished.

During the winter all the floor forms were erected. Those above the main arch ring were carried on the rings and all the forms for the approach were carried on the support caps.

In the spring of 1912 concreting was aggressively pushed until the completion and dedication on July 10, 1912, exactly one year from the commencement of work.

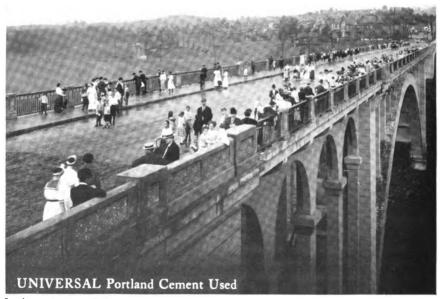
A rough finish was given to the sidewalk throughout its entire length. The pavement is sheet asphalt over the concrete floor slabs. The railing on the bridge and approach is of iron pipe held in place by concrete pedestals placed at every panel point. All work above the elevation of the roadway is panelled. The portion of the railing directly over the wing walls of the abutment is of panelled concrete, the outer portion being given a smooth, trowel finish, while the surface within the panel is given a rough bush hammer finish. All surfaces below the roadway, with the exception of the faces of the two abutments and the column caps and bands around the pedestals, were finished with a bush

hammer, after the remaining work on the bridge had been completed.

The result is an exceptionally attractive surface which is set off by the smooth caps and belt courses at intervals and by the grooves placed twenty-four inches apart in the face of the wing walls and abutments.

The magnitude of the work may be realized when it is understood that there were used in its construction 20,000 yards of sand and gravel, 13,860 barrels of cement, 350 tons of reinforcing bars, 150 tons of structural steel reinforcement for the main arch rib and 1,500,000 feet, board measure, of lumber. Of this amount 300,000 feet, board measure, were used in the false work required to carry the arch and floor system.

This bridge goes a long way to refute the objections so often made to American design that it is not artistic, as it presents a most pleasing appearance from every side and is a testimonial to the executive ability and the efficiency of the engineers and the contractor who constructed it. The work was done under the direction of Mr. N. S. Sprague, Superintendent of the Bureau of Construction, City of Pittsburgh, and under the direct supervision of Mr. T. J. Wilkerson, Division Engineer. The contractor, John F. Casey Co., was represented on the work by his Superintendent, Mr. Ottomar Stange, to whom should be given much credit for the design of the forms and of labor-saving and efficient methods of handling this work.



Larimer Avenue Bridge on Dedication Day

Pittsburgh, Pa.

WHO'S WHO IN ENGINEERING

A BIOGRAPHICAL DICTIONARY OF CONTEMPORARIES

1922-1923

*By*JOHN WILLIAM LEONARD

BROOKLYN BOROUGH - NEW YORK CITY JOHN W. LEONARD CORPORATION

Mem. A.I.M.&M.E., A.A.A.S., Am. Physical Soc. Recreations: Outdoor sports. Clubs: Univer-sity, Harvard (New York), Mohawk Golf, Mo-hawk (Schenectady).

hawk (Schenectady).

FERGUSON, Harold Kingsley, 6523 Euclid Av.; res. 1866 Beersford Road, Cleveland, O. Engr and Builder; b. Albion, Mich., Nov 22, 1883; s. John II. and America P. (Clark) Ferguson, B.S. Ohio Wesleyan Univ., 1905; Phi Beta Kappa; m. Cleveland, O., 1908, Lillian E. Austin; children: Elinor, Kingsley, Ruth, Margery. Wireman Commonwealth Power Co., Jackson, Mich., 1898-1902; timekeeper, estimator, supt, sales engr Austin Co., Cleveland, 1905-07; signalman, office engr, signal supervisor, asst signal engr A. T. & S. F. R. R., Topeka, Kan, 1907-10; commercial engr ry dept, Gen. Elec. Co., Schenectady, N. Y., 1910-12; sec. and v.p. Austin Co., Cleveland, Ohio, 1912-18; pres. H. K. Ferguson Co., Cleveland, since 1918. Dir. Stearns Conveyer Co. Originated scheme of building standard factories by keeping prefabricated structures in stock. Trustee Ohio Wesleyan Univ. Mem. Chamber of Commerce, Cleveland, Ohio. Recreations: Golf, tennis, sailing (Lake Erie). Clubs: Engineers, Bankers, Transportation (New York), University, Athletic Willowick, Canterbury (Cleveland), Manufacturers (Philadelphia). Methodist. Republican.

FERGUSON, Harry F., Springfield, Ill.
Sanitary and Hydraulic Engr; b. Adams,
Mass., Mar. 12, 1889; s. William and Elizabeth
(Donaldson) Ferguson; of Scotch-Irish descent;
ed. grammar and high schools, Adams, Mass.,
1894-1908; Trinity Coll., Hartford, Conn., 1906-08;
S.B., Mass. Inst. Tech., 1912; Alpha Chi Rho;
m. Villa Grove, Ill., Dec. 4, 1920, Zelda Nadine
Henson. Rodman and instrument man, eng dept,
sewer div, City of Boston, summers of 1910-11;
asst on engr corps Pa. R.R., Ft. Wayne, Ind.,
summer of 1912; third, second and first asst
engr Ill. State Water Survey, Oct., 1912-May,
1917; principal asst engr, Mar.-June, 1919; from
July, 1919, principal asst engr, and since May,
1920, ch. sanitary engr, Ill. State Dept of Health.
Writer of articles in Ill. State Water Survey
bulls, Jour. Am. Water Works Assn, Ill. Med.
Journal, Health and Sanitation, and Illinois Health
News. Enlisted, U. S. A., May 13, 1917;
commd 1st Lt Engrs, June 13, 1917; served in
France, 1917-19; honorably discharged Jan. 31,
1919. Mem. Am. Public Health Assn, Am.
Water Works Assn, Ill. Soc. Engrs, asso. mem.
Am. Soc. C.E. Independent Republican. Pro-

FERGUSON, John Ashley, 906 City-County Bldg; res. 1012 Portland St., E.E., Pittaburgh, Pa.
Civil Engr; b. White Pigeon, Mich.; s. Luther Elliott and Mary Jane (Odle) Ferguson; Scotch-Irish descent; father civil engr Univ. of Mich. 1870 (classmate of late Alfred Noble and almost sole survivor of that class of engrs), B.S. in C.E. Univ. of Mich., 1905; m. Pittsburgh, Pa., Oct. 16, 1909, Helen Browne; one dau., Frances Jane. Draftsman Trussed Concrete Steel Co., Detroit, Mich., 1905; McClintic-Marshall Constrn Co., Pittsburgh, Pa., spring 1906; asst city engr, Pittsburgh, fall 1908; chief engr of bldg inspection, Pittsburgh, fall 1912; cons. engr to City Council on bldg code and cons. practice since spring 1915, practising as cons. engr (John A. Ferguson), Pittsburgh, Pa. Developed a new way of designing concrete arches, new plan for bldg regulations more broad and flexible and allowing for advance of art of bldg constrn. Presented papers before Engrs Soc. of Western Pa.: "Recent Practice in Reinforced Concrete Bridge Building in Pittsburgh, Pa." and "Theory and Practice in Writing Building Regulations." Ten years in successive positions, Pittsburgh, each one of unusual interest, such as the design of large reinforced concrete bridges and preparation of Bldg Regulations on an entirely new principle. Mem. Am. Soc. C.E., A.S.T.M., Nat.

Fire-Protection Assn, Am. Concrete Inst, Engra Soc. of Western Pa. Presbyterian.

Fire-Protection Assn, Am. Concrete Inst, Engrs Soc. of Western Pa. Presbyterian.

FERGUSON, John Berton, Hagerstown, Md. Civil Engr; b. Woburn, Mass., Jan. 8, 1877; s. John and Annette E. Ferguson; ed. Mass. Public Schools; S.B. Mass Inst. Tech.; m. Williamsport, Md., Sept. 21, 1904, Beulah L. Darby; one son, John B., Jr. Rodman Met. Sewerage Commn, Woburn, Mass., Summer 1895; draftsman Boston Sewerage Commn, Boston, Mass., summer 1896; rodman B. & M. R.R., summer of 1897; asst and div. engr, B.&M.R.R.R., in Neb., location, constrn, maintenance, 1902-05; asst supervisor, P.R.R., 1905-06; roadway engr and engr maintenance of way Ohio Elec. Ry, 1906-09; senior partner J. B. Ferguson & Co., engrs, architects, constructors, chemists, Hagerstown, Md., since 1909. Mgr Hagerstown Homes Corpn. City engr, Hagerstown, Hagerstown Homes Corpn. City engr, Hagerstown, 1916-22; chief engr sewerage commn, Hagerstown of Comerce, Hagerstown, 1920. Supervising Engr, Constrn Div., U.S.A., 1918-20, Camps Eustis and Wallace, and Balloon Observers School, Virginia. Mem. Am. Soc. C.E., Am. Water Works Assn, Nat. Fire Prevention Assn, A.S.T.M., Nat. Geog. Soc.; trustee Washington County Free Library, Recreations: Archery, cross-country tramping, nat. history, foreign languages. Clubs: Rotary, Hagerstown Country.

guages. Clubs: Rotary, Hagerstown Country.

PERGUSON, Lewis R., 320 Widener Bldg; res. 218 E. Sedgwick St., Philadelphia, Pa., 1880; s. Cons. Engr; b. Philadelphia, Pa., 1880; s. Thomas D. and Rosina (Repp) Ferguson; B.S. Thomas D. and Rosina (Repp) Ferguson; B.S. m. Philadelphia, Pa., 1913, Ethel Hollister; children: Thomas C., William M., James H. Engr Bell Telephone Co., Philadelphia, 1898-1900; rodman Philadelphia & Reading Ry, 1901; supt of dredging River & Harbor Improvement Co., 1901-02; engr Pa. Ry, 1905-06; engr and supt Scofield Eng. Co., 1906-08; asst mgr Drake Drilling Co., 1908-09; chief engr and asst sec. Portland Cement Assn, 1909-18; gen. mgr. Liberty Shipbldg Co., 1918-20; now cons. engr, mem. firm Light, Hollister & Ferguson; pres. Patents Holding Co. Developed concrete ships, constructed three large concrete steamships; numerous patents on concrete machines and concrete devices. Contbr to various publications on use of cement and concrete. Served with U. S. Shipping Bd, E.F.C. in war period. Mem. Am. Soc. C.E., A.S.T.M., Am. Concrete Inst. Clubs: Engineers, Cedar Brook Golf (Philadelphia), Cosmos, University (Washington, D.C.).

FERGUSON, Louis Aloysius, 72 West Adams St, Chicago; res. 1601 Wesley Av., Evanston, Ill.

St. Chicago; res. 1601 Wesley Av., Evanston, Ill.

Elec. Engr, Operating Executive; b. Dorchester, Mass, Aug. 19, 1867; s. Denis and Louisa (Doherty) Ferguson; ed. Boston public schools, Dorchester High School; B.S., Mass Inst. Tech. 1888; m. Dorchester, Mass, June 21, 1892, Martha Sargent Jenkins; children: Louis, Arthur, Martha, Alan. Joined staff Chicago Edison Co., Aug., 1888, immediately after graduation, as engr, Underground Dept, promoted asst elec. engr, Constrn Dept, 1889, elec. engr of company, 1890, gen supt, Chicago Edison Co., 1897-1902, and of Commonwealth Elec. Co., 1898-1902; second v.p. Chicago Edison Co. and Commonwealth Elec. Co., 1902-14; v.p. Commonwealth Edison Co., Chicago, since Feb., 1914. President, Chicago Elec. Meter Co. and the Minerallac Elec Co.; dir. Public Service Co. of Northern Ill., Middle West Utilities Co., Electrical Apparatus Co., Chicago Morris Plan Bank. Has done much notable work in central station practice. Apptd, 1815, Staff Lecturer, Univ. of Wis. Pres. Northwestern Alumni Assn of Mass. Inst. of Tech., 1818-89; pres. N.E.L.A., 1902-03; pres. Assn of Edison Illuminating Companies, 1901-03; pres. A.I.E.E., 1908-09. Clubs: Commercial, University, Mid-Day, Chicago Athletic, Glen View (pres. 1914-15), Old Elm, Electric, Engineers (New York).