# Strength Specifications Used for Large Concrete Bridge

**Abrams Method of Proportioning Concrete Used on the C.C.C. & St. L. Ry. Bridge Over the Great Miami River at Sidney, Ohio—Both Premixed and Separate Aggregates Used**

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THE adoption of a concrete arch, ballasted deck bridge for the new double-track crossing of the Great Miami River at Sidney, Ohio, by the C. C. C. & St. L. Ry. is indicative of the present tendency in railroad bridge design, particularly when, as in this case, the bridge is within the limits of a city. This new bridge is on a relocated portion of the railroad where existing structures do not limit the design and where rock foundations make it possible, without excessive cost, to use fairly long span arches. Some features of the design are notable and are given below but the principal interest in this bridge is centered in the construction methods, particularly the method of proportioning concrete.

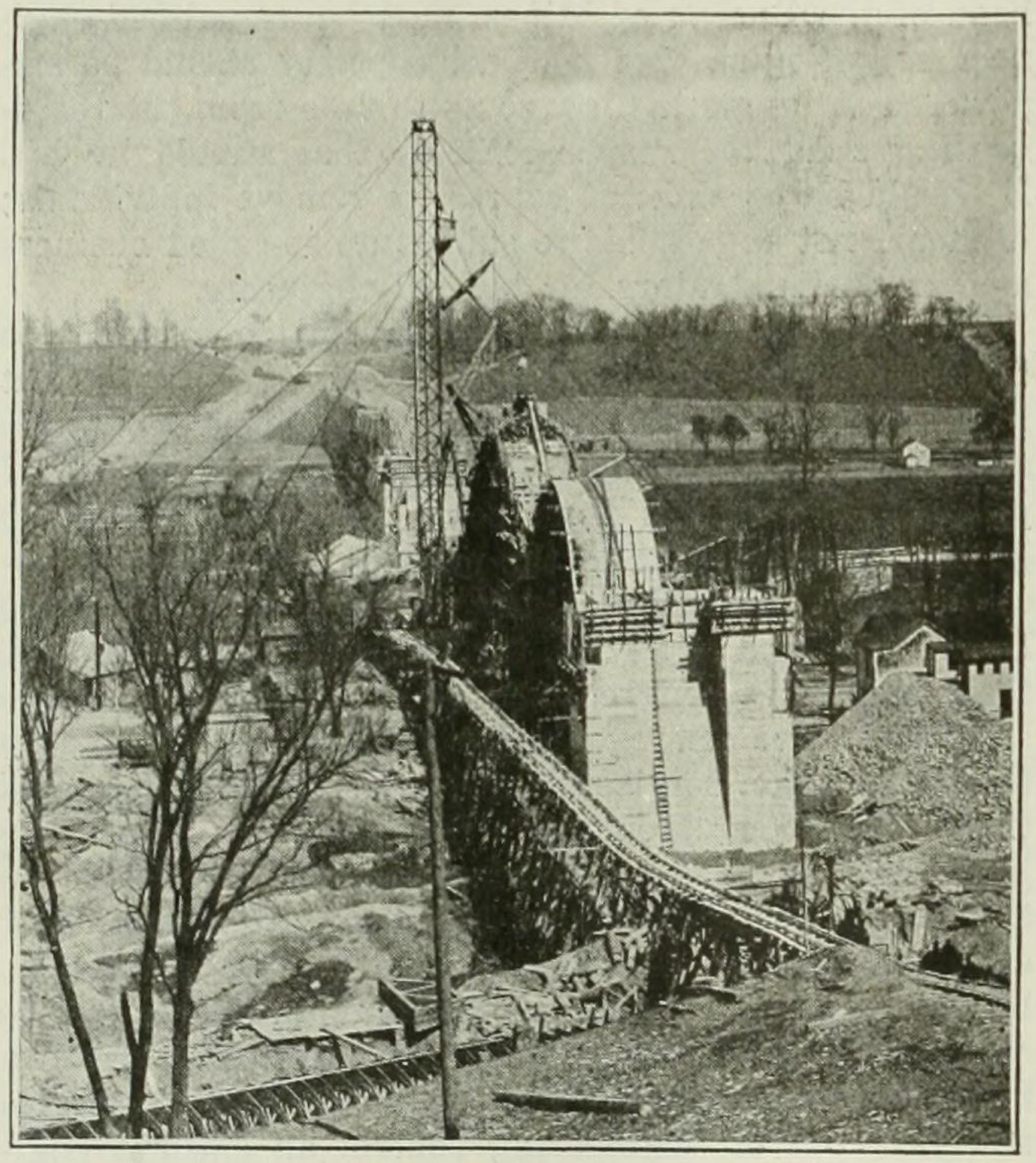

FIG. 1—VIEW SHOWING LOCATION OF CONSTRUCTION PLANT

*Design*—The structure, as finally designed, consists of three 140-ft. spans over the river channel and the highway, and one 100-ft. approach span on each end to take the embankment slopes, making the overall length of the structure 780 ft. The height from base of rail to bed of stream is 95 ft. The track will be carried on a ballasted deck which is supported on spandrel arches having a span of 9 ft. 9 in., the top of the parapets being 3 ft. above the rail. The piers are 17 ft. thick at the springing line, with a moderate batter, but piers 1 and 4 are widened near the base to provide for the unbalanced load between the 140-ft. and 100-ft. spans. The footing courses are carried about 2 ft. into the rock, which is a peculiar form of limestone, unstratified, very hard and at least 35 ft. thick, as shown by the deepest test hole. The piers are extended for buttresses, and above the haunches of the arch are hollow. Expansion joints in the floor and parapets are provided at the ends of each span.

The structure was designed for E70 loading, using equivalent uniform loads. This uniform load, considering half of the span loaded, was 10,400 and 10,900 lb. per foot of track for the 140 and 100-ft. spans respectively, and considering the entire span loaded, 8,500 and 8,600 lb. per ft. of track. Specifications impact was used, the impact percentage of the live-load being about 55 per cent for the 140-ft. spans and 68 per cent for the 100-ft. spans.

The 140-ft. arches are three-centered, having a rise of 50 ft.; the thickness is 5 ft. 6 in. at crown and 13 ft. 9 in. at haunches. The 100-ft. spans are semi-circular, and have thicknesses of 4 ft. 6 in. at crown and 10 ft. 9 in. at haunches. There is no tension developed at any section under live and dead-load, but temperature reinforcement was provided at the intrados and extrados, consisting of 1¼-in. square bars 12 in. on centers in the 140-ft. spans and 1-in. square bars in the 100-ft. spans.

Stresses due to a rise of 50 deg. and fall of 30 deg. in temperature, combined with live and dead-load and the effect of rib shortening, were found to be quite large. The intensity of stress at some of the critical sections of the 140-ft. spans is shown in the subjoined table.

DEAD-LOAD AND LIVE-LOAD STRESSES — 140-FT. SPAN

| Section | Live-Load on Entire Span | | | | Live-Load on Half Span | | | |
|---|---|---|---|---|---|---|---|---|
| | Total | + D.L. | L.L. +I | Per Cent of LL+I of Total | z Total | D.L. | L.L. +I | Per Cent of LL+I of Total |
| Crown.... | 375 | 290 | 85 | 23 | 340 | 290 | 50 | 15 |
| ¼ point.... | 340 | 250 | 80 | 24 | 455 | 290 | 165 | 36 |
| Haunch... | 200 | 170 | 30 | 15 | 270 | 170 | 100 | 37 |

TEMPERATURE STRESSES COMBINED WITH DEAD-LOAD, AND LIVE-LOAD ON HALF SPAN — 140-FT. SPAN

| Section | For Rise of 50° in Temp. Concrete | Steel | For Fall of 30° in Temp. Concrete | Steel |
|---|---|---|---|---|
| Crown................ | +675 | 0 | +760 | — 5,500 |
| 15 ft. from skew back... | +700 | —5200 | ...... | ...... |
| At skew back.......... | ..... | ...... | +200 | —10,500 |

The maximum pier reaction is 25,000,000 lb., giving an average pressure on the foundation of 10 tons per square foot. The maximum toe pressure at piers 2 and 4 under unbalanced loading will be 19 tons per square foot.

*Waterproofing and Drainage*—Experience with several structures of this type built about 15 years ago has shown that to avoid deterioration thorough waterproofing and ample drainage are necessary, and considerable study has been given to this detail. The deck will be sharply pitched to drains between the spandrel arches and waterproofed with a membrane, which will be protected with concrete. The fill between the ballast and deck will be of coarse material to permit free passage of water to the drain heads. The expansion joints over the piers and abutments will be flashed and counterflashed with copper, and the tops of the drains fitted with cast-

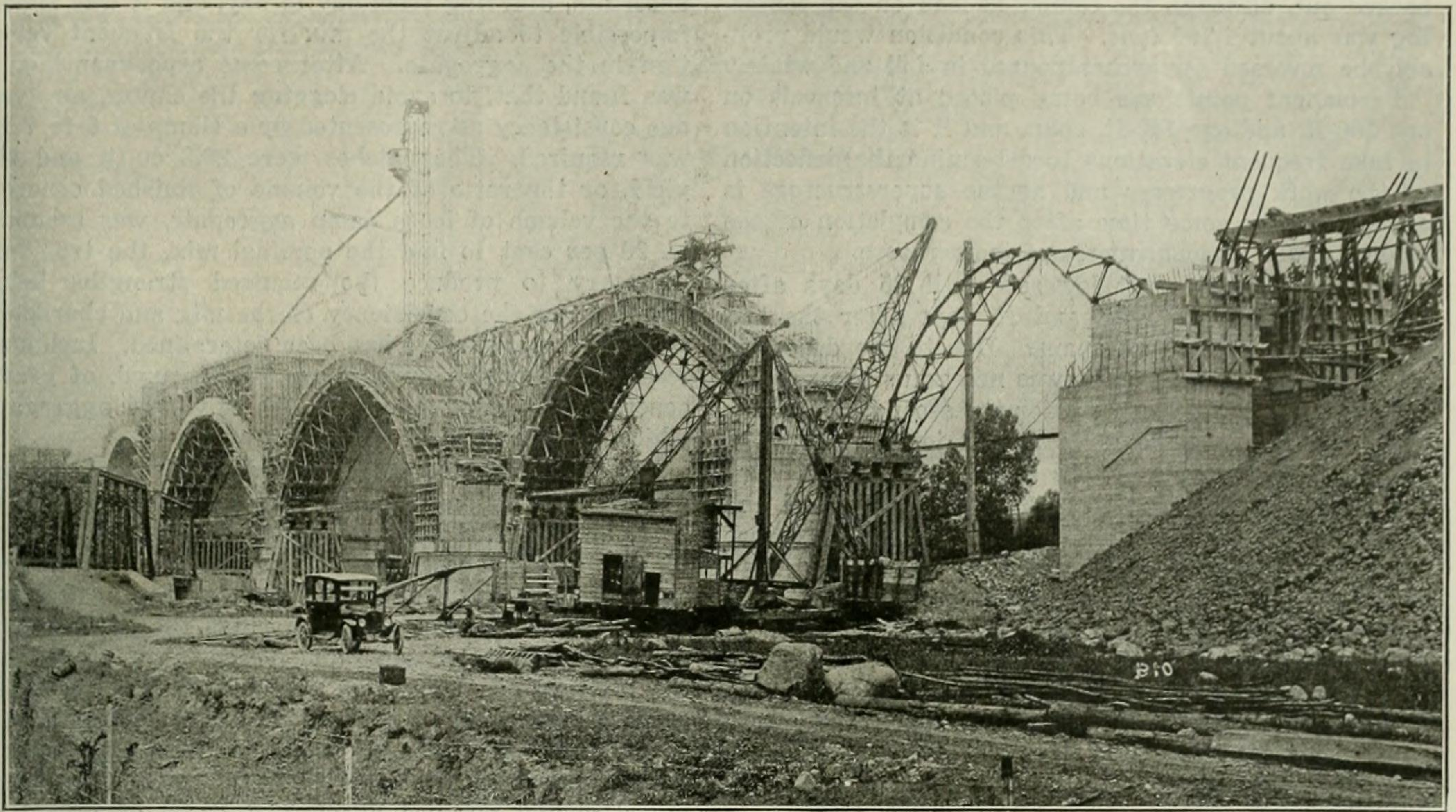

FIG. 2—CONSTRUCTION WORK AT BRIDGE SHOWING ARRANGEMENT OF PLANT AND ARCH CENTERING

iron flanges to flash and counterflash the membrane at this point. The deck drains lead through the pier walls, discharging into a channel on top of the main arches which will carry the water through the piers to the outlet. The lower portion of the chamber in the pier will be waterproofed to prevent seepage in case the outlet drain is clogged.

The structure will contain about 27,900 cu.yd. of concrete and 900,000 lb. of reinforcement.

*Construction Plant*—The arrangement of the contractor's plant for handling the material is interesting, and is shown in some detail in the accompanying sketch. The concrete materials are received on a track from the B. & O. R.R. about 1,000 ft. west of the bridge and on high ground, are unloaded by a locomotive crane and stored in piles over a timber tunnel through which tram cars run. The concrete aggregate is delivered through hoppers to the cars in measured quantities, and the bags of cement are placed on top. The cars run down an incline to the bridge, where the cement is added, and each car, containing one batch, is dumped into a hopper from which the mixer is charged. At first the cement was emptied on top of the aggregate in the car before leaving the tunnel, but it was found that there was some loss during the trip down the incline, especially in windy weather. The cars are operated in two trains, of 4 cars each, on a cable, and from the storage piles to the charging of the mixer practically all of the work is done by gravity. All laborers except those at the forms are under shelter, and continuous mixing and placing of the concrete is limited only by the formwork.

The mixed concrete discharges directly into the hoist of a 150-ft. steel tower and is distributed by chutes to most of the forms. In the abutments it was necessary to rehandle it by bucket and derrick, and for placing the concrete in the end spans and superstructure the chutes discharge into a car operating along an elevated trestle, which empties into distributing chutes. The inclination of the tower chutes was kept within the limits of 1 to 3 and 1 to 2. Each batch of concrete was mixed at least 50 sec. and for longer periods when it had to be rehandled by cars or buckets.

The excavation for the foundation was made by a 7-ton locomotive derrick on the west side and a 20-ton traveling stiff-leg derrick on the east side. These derricks were also used for rehandling the concrete from the chute to the forms which could not be reached by the tower, setting arch centers, etc.

*Steel Centering, Camber and Deflections*—Steel centering was used for all spans. Each set of centers consists of four ribs, which are three-hinged arches with bottom ties. They are made wide enough to pour one half of each arch, 16½ ft., and are rolled sideways, with the lagging intact, for the second half of the ring. Each half of each ring is poured in voussoirs of such size and in such order as to cause no undue reversal of stress in the arch centers. The centering is supported on double timber bents resting on top of the footing courses.

The trusses were cambered about one inch, and to allow for the take-up in the bents and blocking the shoes were set about 1 in. high. After the rings were poured elevations were taken on the 140-ft. spans and it was found that at the crown there was a settlement of about 2 in. and at the shoes about 1 in., verifying the original assumptions. After the centers were lowered (on the spans poured to date) elevations were taken on the arch ring to determine what settlement had occurred under dead-load, but none was apparent. The computed deflection at the crown of the 140-ft. span was found to be only 0.001 ft., and this was probably neutralized by the lengthening of the arch ring under rise in temperature. In fact there is some evidence that the rings had actually lifted themselves from the centers, as the wedges under the shoes were easily backed out, although the computed load on the centering was about 1,700 tons. This condition would probably be reversed for arches poured in fall and winter.

Permanent points are being placed at intervals on one 100-ft. and one 140-ft. span, and it is the intention to take frequent elevations to determine the deflection as the work progresses and as the superstructure is added, and for some time after the completion of the bridge, under various ranges of temperature.

The centers were not lowered until 25 days after pouring of the arch ring, and 15 days after the last pouring on the adjacent spans. Due to the deflection of the centers under load, it was necessary to use some care in adjusting the centers for the second half of the ring in order to avoid a lip at the joint. After the centers were moved over, the inner truss was so near the completed ring that the crown was restrained and it was possible to jack up its bearings and introduce some initial deflection. This left the outer truss about one inch high at the crown, to deflect under load. To conceal a possible lip, a 4x6-in. channel was formed in the intrados where the two halves jointed.

After the concrete is poured an effort is made to keep it damp for at least two weeks. The tops of the arch rings are sprinkled several times daily, and as the deck is completed, the drain holes are plugged and it is flooded.

*Proportioning the Concrete*—Practically all concrete work of the company in past years had been poured under the ordinary specification, using the standard 1:3:6 or 1:2:4 mix, with probably average supervision but without especial care being given to the grading of the aggregate or the consistency of the mix, and some of this concrete has not been entirely satisfactory. It was felt that the importance of this particular structure required some unusual effort to assure the proper mixing and placing of the concrete, and, owing to the large volume, it offered an excellent opportunity to experiment with the method proposed by Prof. Duff A. Abrams, of the Structural Materials Research Laboratories, Lewis Institute, for the design of concrete mixtures. This method had been developed and confirmed in laboratory experiments but had not been used in the field to any great extent and there was some doubt as to the possibility of approaching the laboratory results, but it seemed that at least the mere moral effect of making the tests promised better concrete, and it would determine the practicability of adopting this method on future work, where there was sufficient yardage to justify it, and that possibly some evidence as to correctness or inconsistencies of present specifications and methods could be obtained.

It was decided to use mixes to produce concrete of the following strengths:

| | Lb. per sq.in. |
|---|---|
| Footings | 2000 |
| Piers and abutments | 2500 |
| Arch rings | 3000 |
| Spandrel arches | 2500 |

In the footings, piers and abutments, a premixed aggregate (concrete gravel) was used, of size 0 to 1½ in. The fineness modulus varied from 5.3 to 6.7, with an average of about 5.9. This wide range was probably due to separation of the sand and pebbles in unloading, and as the stockpile was large and the hoppers drew from the center of it the fineness modulus was uncertain, differing from day to day, and it was almost impossible to adjust the mix for the frequent variation in the aggregate. After some experimenting, it was found that, to avoid clogging the chutes, an average consistency as represented by a slump of 6 to 7 in. was required. The batches were 23.3 cu.ft. and the yield, or the ratio of the volume of finished concrete to the volume of loose damp aggregate, was assumed as 90 per cent to find the nominal mix, the true mix necessary to produce the required strengths being known after the consistency of the mix and characteristics of the aggregate had been determined. Including waste there were poured about 10,440 cu.yd. of gravel concrete, requiring about 11,700 cu.yd. of aggregate, which gives a yield of 89.0 per cent.

For the arch rings and spandrel walls separate aggregates are being used, the sand ranging from 0 to ¼ in. and crushed boulders and pebbles from ⅜ in. to 1½ in. The fineness modulus of the fine and coarse aggregates remains quite uniform, averaging 3.2 and 7.8 respectively. For the arch rings the batches consist of 11 cu.ft. of sand and 17 cu.ft. of stone, and the mixture has a fineness modulus of 5.95. For the superstructure there is used 12 cu.ft. of sand and 16 cu.ft. of stone in each batch, the mixture having a fineness modulus of 5.8. The sand and stone when mixed should produce about 23.8 cu.ft. of gravel or 85 per cent by volume. The 23.8 cu.ft. of gravel should produce about 21.4 cu.ft. of concrete (90 per cent) or, the ultimate yield would be $28 \times 0.85 \times 0.90 = 21.4$ or about 76.5 per cent. To pour 4,800 cu.yd. of concrete required about 6,400 cu.yd. of separate aggregates, which gives a yield of 75 per cent. Tests were made on several batches and it was found that 28 cu.ft. of sand and stone would produce about 22.5 cu.ft. of concrete (80 per cent) in the bucket at the mixer, but there would probably be further shrinkage by the time it is placed in the forms.

The accurate determination of the yield is important, as by this factor alone can the nominal or working mix be found after the true mix, for the required strength, is known. It has been determined in the laboratories, but with comparatively small volumes and under somewhat different conditions than those which exist in actual construction. The amount of moisture initially contained in the aggregate materially affects the yield and this must be allowed for.

It was found that the concrete made of separate aggregates could be easily handled in the chutes and forms with a slump of 3 to 4 in. In fact many batches were poured in which the slump was 1½ to 2 in., the average being about 3¼ in. This produces a concrete much drier than it was thought could be handled through the chutes, and much drier than the gravel concrete previously poured with the same equipment. This seemed difficult to explain as the gravel, sand and pebbles were from the same pit, but it is undoubtedly due to the fact that the fineness modulus of the sand and pebbles remained nearly constant and that the mixture was such as to produce a very "workable" concrete, while the gravel varied greatly and was often of such a nature that it required an excess amount of water to make it workable. This same fact was observed in another structure containing about 6,500 cu.yd. of concrete, built under a different inspector. Here the concrete was largely placed by buckets, but to get a good face on finished work required that the gravel

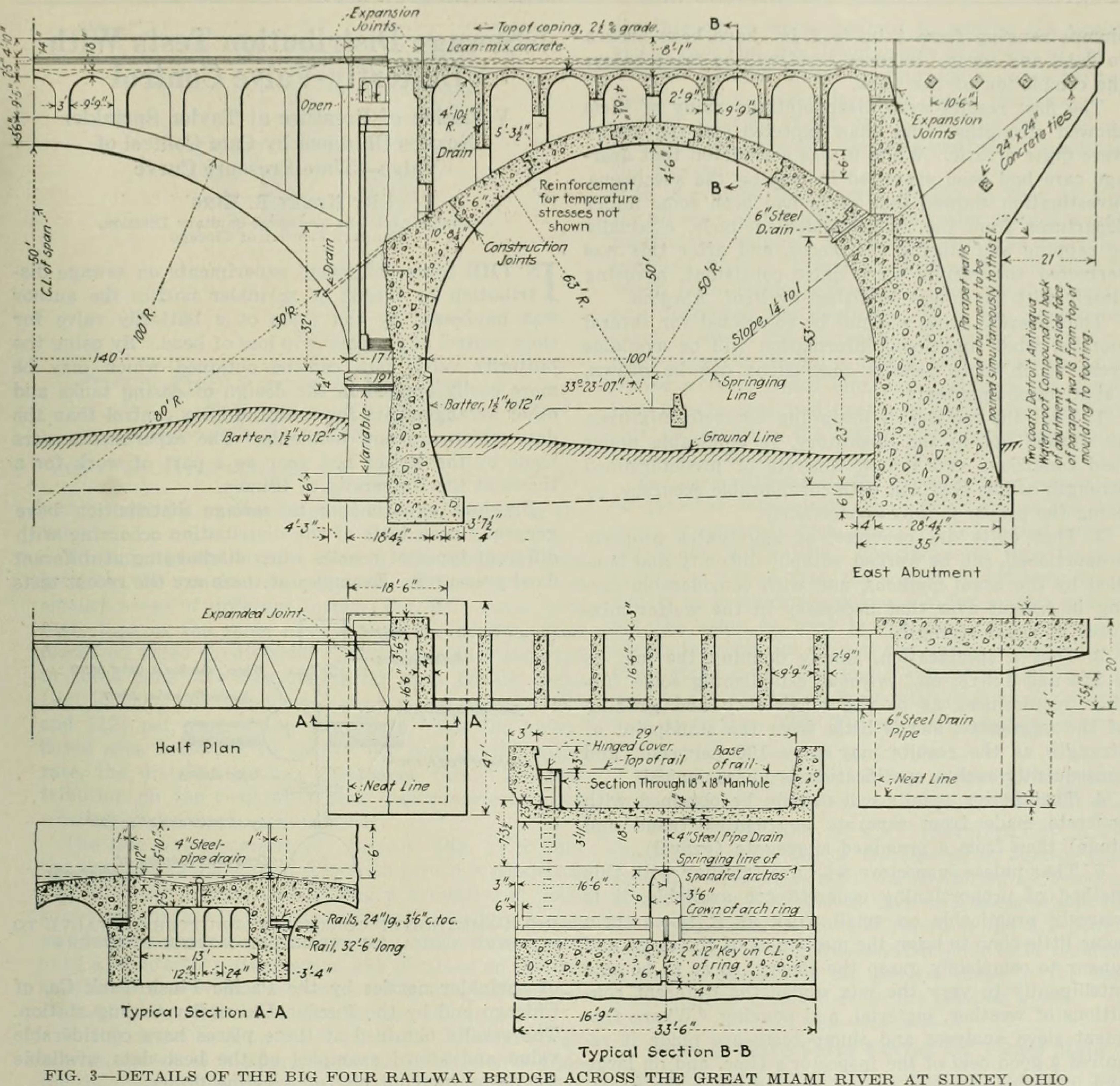


FIG. 3—DETAILS OF THE BIG FOUR RAILWAY BRIDGE ACROSS THE GREAT MIAMI RIVER AT SIDNEY, OHIO

mix have a slump of about 7 in., while the concrete made of separate aggregates worked nicely with a 3-in. slump. In one structure where a premixed aggregate was used throughout, the gravel being handled in small quantities and in such a manner that little or no segregation occurred, the fineness modulus remained nearly constant, it was found that concrete could be mixed with good results to a consistency represented by a slump of 4 in.

Unless it is certain that the grading of the premixed aggregates is proper and will remain fixed, there seems little justification for its use. The ease of handling from a single stockpile is of some advantage, but this is far outweighed by the cost of the additional cement required in the wetter concrete of equal strength, and by the increased workability of the mixture made from the separate aggregates used in the proper proportion.

There has been an almost general condemnation, in which the writer joined, of the tower and chute as a means of distributing concrete, as this method seems to require very wet mixtures and often results in complete separation of the mortar and stone. On this work, however, there has been several thousand yards successfully placed by chutes, much of the concrete being drier than any heretofore handled by other methods and delivered with no separation. Possibly the use of excess water is largely habit and probably the segregation is due to the use of improper materials poorly proportioned and insufficiently mixed.

The Abrams method of designing concrete mixtures was employed on several of the larger structures representing about 50,000 cu.yd. of concrete, and as a check test specimens are made at frequent intervals.

These test pieces are 6x12-in. cylinders, made in accordance with the A. S. T. M. Standard (Serial C-31-21) except that instead of taking the sample from the form it is drawn directly from the discharge of the mixer, so that the actual slump of the sampled batch could be measured. From three to six specimens were made for a day's run, from different batches, stored in wet sand and tested at the end of 28 days. About three hundred specimens, representing various mixes, and slumps ranging from 1 in. to 8 in., have been broken to date, and several hundred tests will be made before the completion of the work.

The first results were disappointing; many of them showed strengths lower than expected and the others were quite erratic. While it was considered that average care had been exercised in making the specimens, investigation showed that there had been some minor departures from the recommended methods, especially in capping and storing the pieces, and after this was corrected the results were quite consistent, agreeing closely with the tables published by Prof. Abrams.

The concrete work will not be completed for several months, when additional information will be available from which more definite conclusions can be drawn, but it seems apparent:

1. That the method of designing concrete mixtures, as worked out in the laboratory, is applicable under field conditions and that a concrete of predetermined strength can be obtained with considerable accuracy, by using the proper mix and consistency.

2. That quite dry concrete, of aggregates properly proportioned, can be worked without difficulty and handled by the usual methods, and with considerable saving in cement over that necessary in the wetter mixtures of equal strength.

3. That a specification, simply defining the mix as 1:2:4 and 1:3:6, etc., without establishing some further requirement as to the consistency and grading of the aggregate, means little from the standpoint of strength as the results may vary 100 per cent, and consequently such a specification is uneconomical.

4. That better results can usually be obtained with concrete made from separate aggregates (sand and stone) than from a premixed aggregate (gravel).

5. That unless inspectors who are familiar with this method of proportioning concrete are available, it is scarcely practicable on small work as it takes them some little time to learn the mechanics of the tests, and longer to completely grasp the theory, so as to be able intelligently to vary the mix under the different conditions of weather, material, and pouring. Where frequent sieve analyses and slump tests are made it requires a good deal of the inspector's time, and on large and important work a special man to make the necessary tests would probably be justified.

The Walsh Construction Co. of Davenport, Iowa, has the general contract for the grading and masonry, and is constructing the Miami River Bridge. The work is being done under the general direction of C. A. Paquette, chief engineer, C. C. C. & St. L. Ry. Co.

## Reports on Decay in Douglas Fir

Because Douglas fir is one of the most important timbers of the United States and because it is very susceptible to diseases caused by four fungi which attack it, the United States Department of Agriculture has made preliminary investigations to determine the extent of such damage and the amount of defective timber. The results of the investigations so far made have been published in the department's bulletin No. 1163, which may be had upon request from the Department of Agriculture in Washington. The facts so far established are that young stands or second growths are relatively immune from decay, but it is not yet known at what age this immunity ceases.

# Sewage Distribution Tests With Butterfly-Valve Control

### Variation of Pressure at Taylor Sprinkler Nozzles Obtained by Cam Control of Valve—Time-Pressure Curve

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IN THE course of recent experiments on sewage distribution by means of sprinkler nozzles the author was impressed by the value of a butterfly valve for close control of variations in loss of head. By using the butterfly valve data can be obtained which may be more easily applied in the design of dosing tanks and other arrangements for trickling-filter control than the data which are now available. The experiments were made by the writer last year as a part of work for a thesis at the University of Illinois.

Previous experiments in sewage distribution have generally been tests of the distribution occurring with different types of nozzles when discharging at different fixed pressures. Examples of these are the recent tests

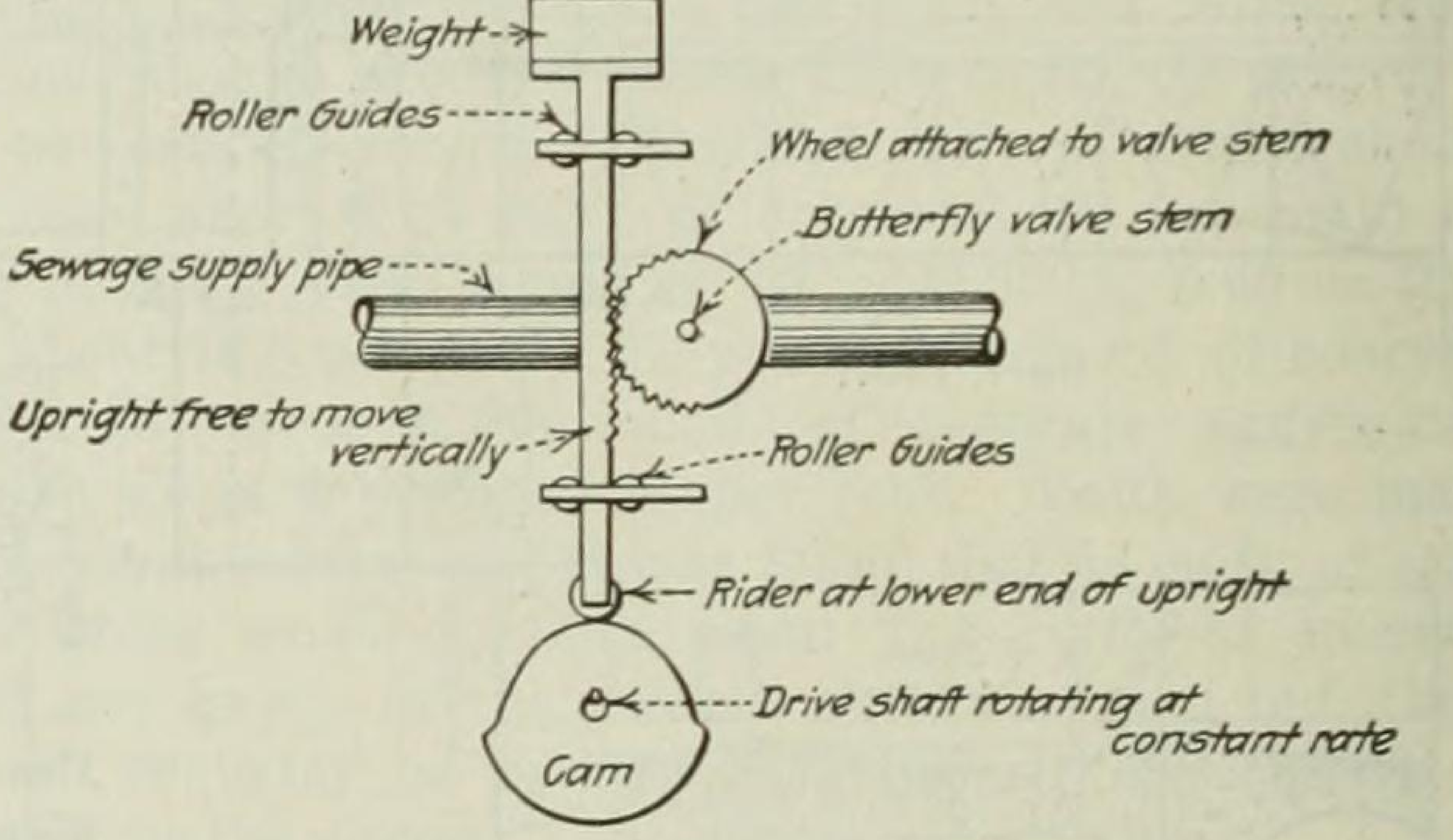


FIG. 1—METHOD OF CONTROLLING BUTTERFLY VALVE TO GIVE VARIABLE SPRINKLER-NOZZLE PRESSURE

of sprinkler nozzles by the Pacific Flush Tank Co. of Chicago and by the Purdue University testing station. The results obtained at these places have considerable value and afford examples of the best data available for designing controls for trickling filters.

Since in the operation of trickling filters a variation of pressure must occur at the nozzles to secure a uniform distribution, some difficulty arises when it is attempted to apply data given for nozzle operation at fixed pressure to conditions of varying pressure. The desired information may be arrived at by a tedious mathematical computation which has proven sufficiently difficult to result in a difference of opinion among engineers as to the proper shapes for dosing tanks.

In the sewage distribution experiments performed by the writer, a battery of three $\frac{15}{16}$-in. Taylor circular-spray nozzles, spaced 14 ft. apart on the apices of an equilateral triangle, was used. Instead of operating these nozzles under various fixed pressures, as has been the usual practice in such experiments, a variation of pressure at the nozzles was effected. To secure this, a butterfly valve (see Fig. 1), operated by a cam revolving at a constant rate, was placed in the supply pipe to the distribution system. Sewage was supplied from a tank in which a constant level was maintained. The butterfly valve served to produce a head loss between the tank and the nozzles, the extent and variation of