Winter Construction of Concrete Bridges on Ohio River Boulevard

Winter Expedients and High-Early-Strength Cement Enable $5,000,000 Boulevard With Nine Bridges in Allegheny County to Be Completed 220 Days Ahead of Scheduled Date

By V. R. Covell and P. J. Freeman

Chief Engineer, Bureau of Bridges, and Chief Engineer, Bureau of Tests and Specifications, Allegheny County Department of Public Works, Pittsburgh, Pa.

CENTERS AND ARCH-RIB FORMS, DILWORTH RUN BRIDGE

The Ohio River, from its beginning at the junction of the Monongahela and Allegheny rivers, flows northwest for a number of miles through a narrow valley with steep hillsides deeply recessed by small intersecting gorges accommodating smaller fast-flowing streams on their way to the Ohio. The hillsides forming the north side of the valley are built up throughout a distance of about ten miles from the source of the Ohio. Through this urban portion of the valley, a narrow and in many places a very indirect thoroughfare must accommodate all traffic. These conditions have resulted in severe traffic congestion, due to the narrowness and poor alignment, that has demanded a more modern highway.

Last year the voters of Allegheny County authorized their county officials to proceed with this work by providing a necessary bond issue. Surveys were rushed to completion and a road 19,000 ft., or about 3½ miles, long was located. Practically 75 per cent of the location passes through private property. Nine bridges must be constructed, and among them are five reinforced-concrete arch structures. Four arch spans are 150 ft. in length, three of which form a multiple-arch structure over Spruce Run. One arch has a span of 180 ft., another a span of 219 ft. and the fifth, over Jack's Run, has a single span of 400 ft. For a span of 150 ft. the rise is about 38 ft. and for the 400-ft. span the rise is 86 ft. Each arch is designed with two ribs, the depth of which at the crown is 3 ft. for the 150-ft. span and 8 ft. for the 400-ft. span. In addition to these structures, there are also four steel girder bridges of short spans. About 66 per cent of the cost of the work will be for bridge construction.

The contract was awarded late in July, 1929, and work was begun Aug. 19, 1929, the bridge work being begun at the earliest possible moment because (1) a large yardage of concrete was required in foundations, all of which in any event could safely be placed during the winter; (2) it was very important that the bridges be completed as early as possible to permit immediate completion of the approach fills and thus allow proper settlement before the paving work should begin in 1930; and (3) the project is so spread out that adequate supervision and control of both bridge and road work would be very difficult and costly if all the specialized phases of this work were under way at the same time.

With nine bridges to erect, a definite order of procedure was set up. The smaller bridges with steel girder construction were built first. This construction was not difficult, since no unusually large or specialized equipment was required.

The program for reinforced-concrete arch construction required the building of the open approach spans and decks first. The arch ribs were then placed with the approach deck spans available for stiff-leg derricks having 150-ft. booms. One derrick at each end handled the forms and placed the concrete in the arch ribs, spandrel columns and decks. One mixer was stationed at each end of the bridge and located conveniently for the operation of the derricks. At Spruce Run and Jack's Run, cableways were used because of the long multiple-arch structure at Spruce Run and because of the 400-ft. span at Jack's Run.

The cableway at Spruce Run, with supporting towers and anchors, was first erected. It had 2¼-in. steel cables and was used to place the steel centering and forms and also to carry the 3-cu.yd. concrete buckets. The cables were so cut and the supporting towers were so built that they could be transferred to Jack's Run with practically no alteration.

Forms and Centering

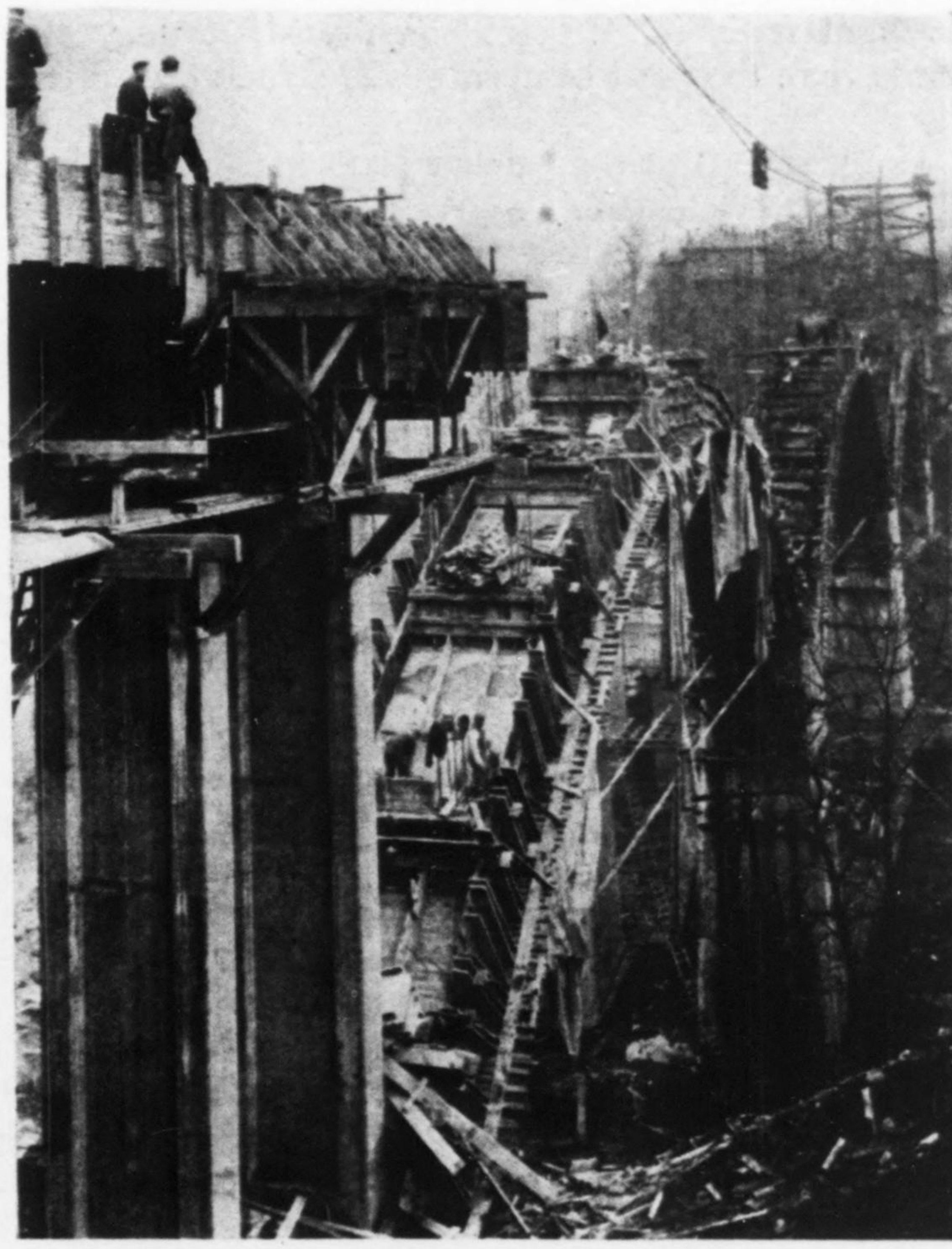
The forms for the arch ribs and spandrel columns were designed to be transferred practically without modification from one arch structure to the one next built. By slight modification which was quickly affected, the steel centering was also built to permit of the same interchange. The 400-ft. arch span over Jack's Run was planned to be constructed last and to use all of the steel centering forms used on all the other arch bridges. The true contour of the intrados of the arch was to be secured by the use of additional formwork or centering, supported by the steel trusses.

The arch-rib forms were built especially tight. Three-ply, ¼-in. veneer board was used to cover 4x4-in. lagging, spaced 6 in. c. to c., and served as the intrados surface form. The side forms were made of 2-in. tongue-and-groove lumber. All seams and cracks were carefully filled with sawdust and glue. Form oil was then applied. These precautions proved adequate insurance against leakages and gave a dense concrete surface, thereby adding to durabiity by guarding against disintegration due to moisture absorption followed by freezing and thawing.

Winter Concreting Plan and Methods

To safeguard and facilitate winter concreting, a 2,000-ton bin for gravel and sand was erected in which 1-in. perforated steampipes were placed at an angle of about 45 deg. upward. The aggregates were transferred by a crane and clamshell bucket from river barges to stockpiles and to heating bins. A 230-ton steel bin, for measuring and loading, was erected underneath and received materials by gravity from the 2,000-ton bin. The total cost of heating the aggregates, including the operation of a boiler and all incidentals, was approximately $25 per day for a daily run of about 400 cu.yd. of concrete.

As a result of an economic analysis made by the contractor, he found it advantageous to use high-early-strength concrete in the arch ribs. The small additional cost was considered of little account in view of the advantages gained in the earlier completion of the bridges and the elimination of delay.



ARCH-RIB FORMS, SPRUCE RUN BRIDGE
Note cableway for constructing this series of three 150-ft. arches.

The cement used was tested beforehand to insure its meeting the specifications adopted by Allegheny County for high-early-strength portland cement. These specifications agree with those proposed by the American Society for Testing Materials, calling for a tensile strength at one day (when mixed 1 : 3 with Ottawa sand) of 275 lb. and at 3 days, 375 lb.

Temperature changes were frequent and rapid and it was considered advisable to guard against the low temperatures by using a concrete developing from 1,800- to 2,100-lb. compressive strength in 24 hours, thereby reducing the curing period to approximately 30 or 40 hours with its attendant reduction in costs. These compressive strengths were developed, using Ohio River gravel in a 1 : 2 : 4 mix. The advantage of gaining high early strength applies also to the keyways, where it was imperative to develop over 2,000-lb. compressive strength as quickly as possible in the face of fairly rapid temperature changes. Any sudden drop or rise in temperature, causing contraction or expansion in the steel centering, would probably have been disastrous to any concrete in the ribs which had not acquired the strength for which it was designed. This plan proved to be not only workable but successful.

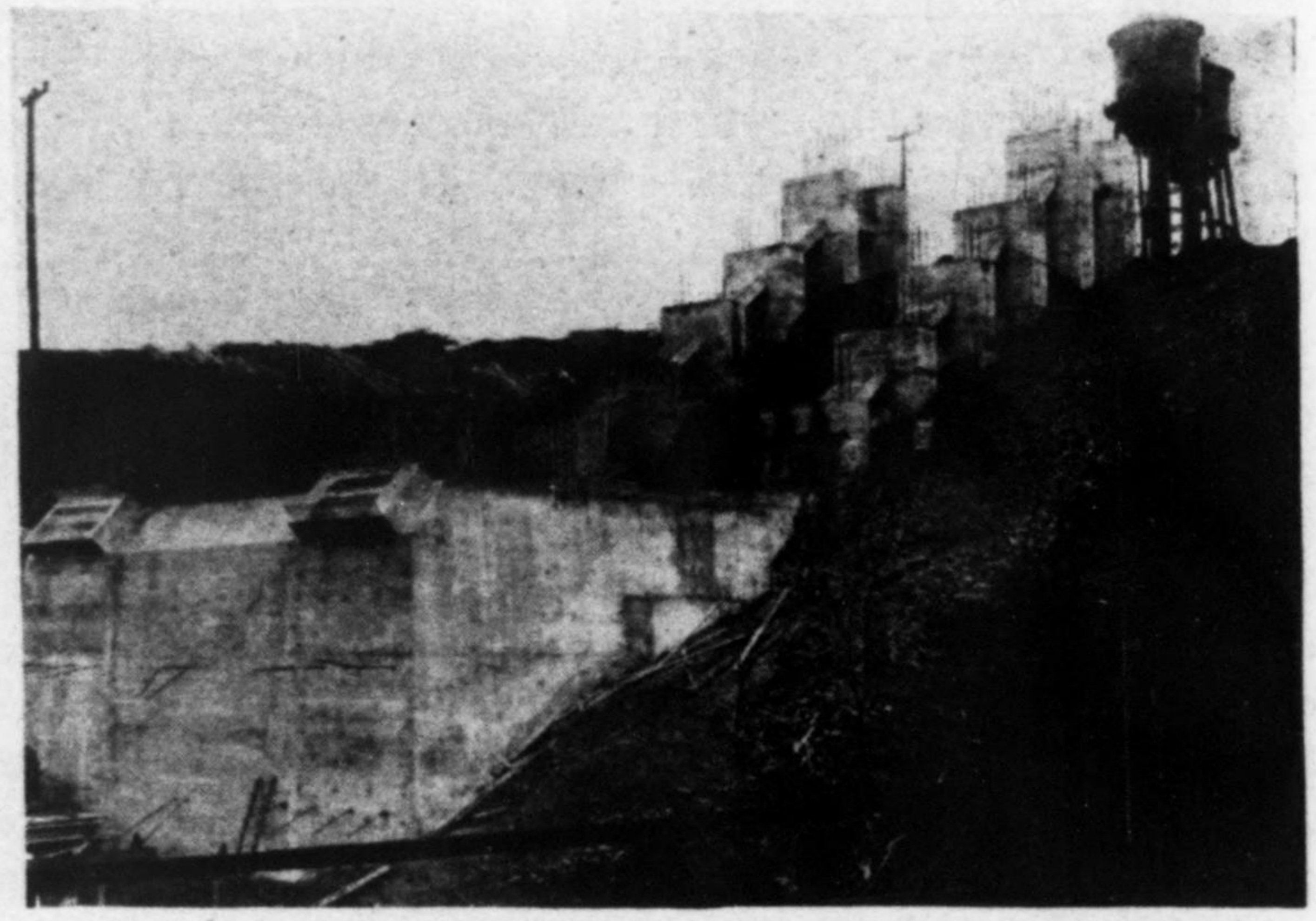
The importance of moving the leased-steel centering from bridge to bridge with as little delay as possible in order to reduce rental charges was also of considerable concern to the contractor. Had the setting advanced more slowly, additional centering would have been required to complete the work within the same time limits. The centering was struck four days after pouring the arch-rib keyways, thereby permitting a saving of 15 to 18 days per arch rib.

The spandrel column forms were placed the day following the pouring of the ribs. The columns were poured from one to two days after placing the keyways, with the result that the bridge deck forms were assembled and ready to be placed on the supporting columns at the time the steel centering was struck on the fourth day.

The inspector at the batcher plant made frequent tests daily to determine the temperature of the aggregates as they were placed in the trucks. Heat was required at all times regardless of the atmospheric temperature, after winter operations began. The average daily air temperature for the months of December, January and February was 29 deg. and the average temperature of the aggregates leaving the bins was 109 deg. The trucks were covered with tarpaulins to prevent the loss of heat. Warm water was used for mixing and in addition an oil burner was operated in the mixer. The average temperature of the concrete, when it was placed in the forms during the three-months period it was poured, was 71 deg. Metal tubes were inserted at various points in the concrete mass and the temperature of the interior of the concrete was taken at various intervals after placing.

All high-early-strength concrete, which was used in the arch ribs throughout, was closely protected by tarpaulins under which perforated steampipes were placed. The average temperature of this concrete at the end of 24 hours, while being enveloped in steam curing on all sides, was 113 deg. At the end of seven days the average temperature had decreased to 53 deg. Steam curing ceased at the end of 48 hours, after which the concrete was exposed to air temperature averaging 29 deg.

The concrete specimens were stored under curing conditions at approximately 70 deg. and were tested for compressive strength at various ages, such as two, three and seven days. Knowing the interior temperature of the mass and the results of tests obtained at 70-deg. curing, the contractor, after applying an ample safety factor, was in a position to judge accurately the time at which the forms might be removed and the centering withdrawn.



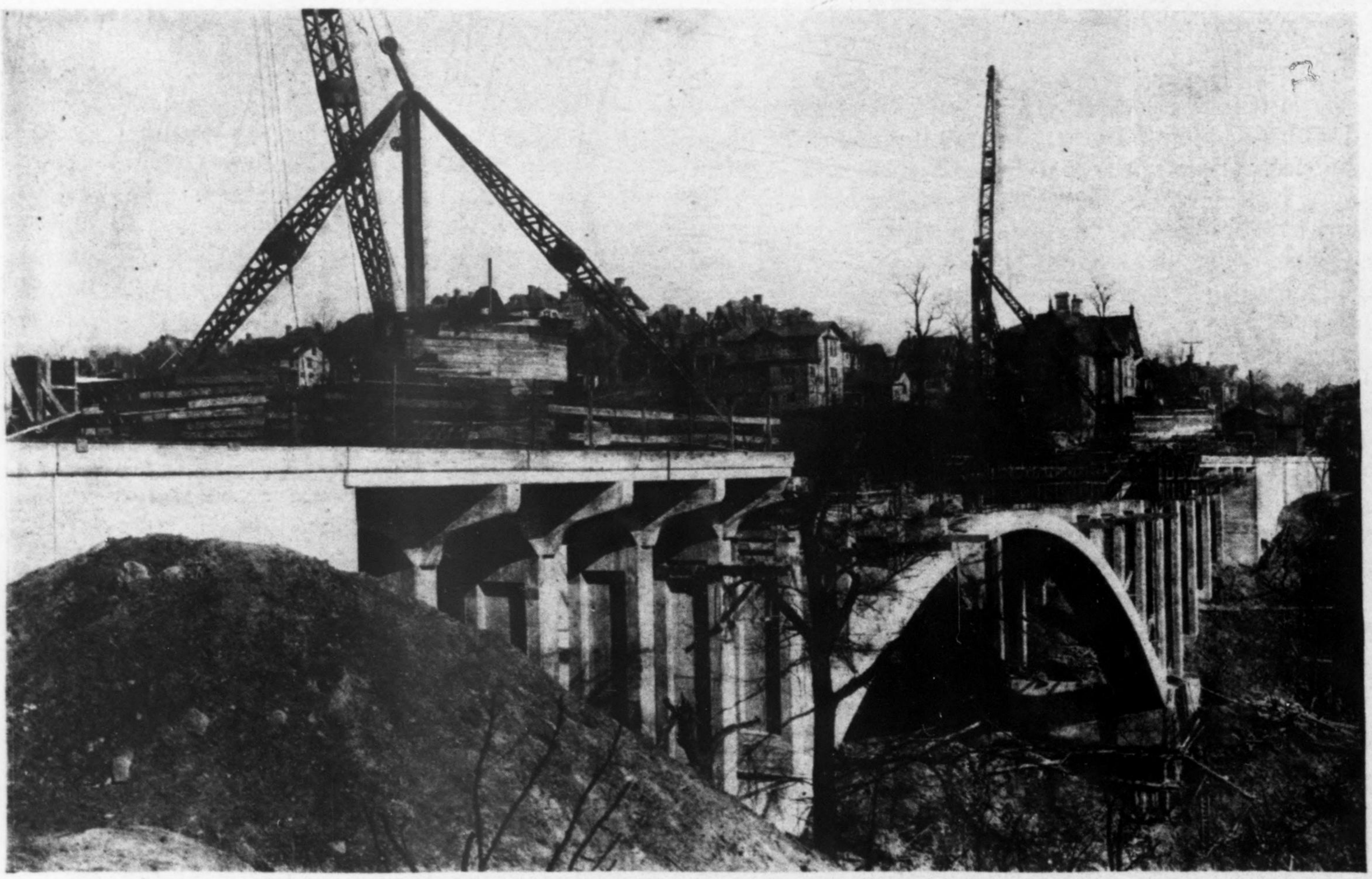
WEST MAIN ABUTMENT STRUCTURE FOR VERNER AVE. BRIDGE

The inspector at the batcher plant made daily determinations of moisture in the sand, and the weight of the batch was adjusted accordingly. The average percentage of moisture content for the three months was 5 per cent, while the maximum was 7 per cent and the minimum 3 per cent.

The concrete materials were mixed for a period of 1½ minutes and delivered to the forms by buckets operated by derrick or by cableway as the case happened to be. Exceptional care was taken in spading the concrete, especially in the arch ribs, where the reinforcing rods were spaced from 6 to 8 in. to and about 4 in. from the intrados surface.

Winter Costs and Savings

The contract involved approximately 100,000 cu.yd. of concrete, 60,000 cu.yd. of which was placed during the winter. It has been demonstrated that winter-bridge



DERRICKS ON APPROACHES, FREMONT ST. ARCH construction can be done efficiently and economically at seasons when other phases of road construction must be at a standstill. The costs of heating aggregates and curing protection have been made negligible. Winter-concrete hazards have been eliminated. The working schedule has been greatly advanced and costs reduced by the use of high-early-strength cement in the arch ribs. These advantages are outstanding not only because they represent conspicuous avenues of obtaining profits by the contractor, but Allegheny County is also gaining the advantages of the earlier use of the investment, which otherwise would have interest or carrying charges amounting to about $615 per day over a total time saved, conservatively estimated to be about 220 days. It is estimated that 20,000 vehicles will use the boulevard daily when it is thrown open. Bearing in mind the usually accepted figures and basis of estimating the saving in car operation and time loss, this saving to the users of the boulevard demonstrates the tremendous advantage to the public of economic management and the efficient application of modern winter-construction methods.

The cost of carrying the job over the winter, including overhead expenses, has been avoided by following the principles of mass production made possible by taking advantage of time-saving methods at stages of the work where delays and holdups would otherwise occur. This program guarantees the completion of the contract as a whole by November, 1930, while the contract time schedule extends to July, 1931. This is a major factor on this project, which, due to its magnitude, involves a large organization and much equipment, all of which will become available for other work seven months ahead of the contract schedule.

Supervision

This project is being carried on under the direction of the Allegheny County Department of Public Works, with Norman F. Brown director. The contractors are Booth & Flinn, of Pittsburgh, Pa., with George Hockensmith, general superintendent, in complete charge.

Foaming and Odor Control in Operation of Flint Sewage-Works

IN THE second year's operation of the sewage-works of Flint, Mich. (see *Engineering News-Record*, Sept. 6, 1928, p. 357), foaming was reduced by circulation, and odor practically eliminated by a special method of chlorination. In the annual report of Harry E. Johnson, chemist in charge, to H. C. McClure, city engineer, appear the following data on these points as well as certain operating figures:

The Imhoff tanks removed 62.5 per cent of suspended solids during the first half of the year and 74.6 during the latter portion, as compared with 55.5 and 74.8 per cent removal for corresponding periods of 1928. The average reduction in organic matter in the sludge due to liquefaction and gasification was 66 per cent, while the reduction in dry solids was 23.4 per cent. The organic content of the raw sludge was 71.1 per cent.

The labor hours per cubic yard of the dry sludge handled averaged 0.57 for the season. A total of 25,725 cu.yd. of wet sludge was drawn, 23,310 cu.yd. to the beds and the remainder to adjacent low ground. The amount of sludge removed from the beds was 8,357 cu.yd., making a reduction of 64 per cent due to shrinkage. The number of bed fillings was 210, the average number per bed during the season being 5.25. The average drying time was 29.5 days per bed.

Pumping costs per capita connected were 13c. for labor, 11.8c. for power and 1.2c. for supplies. Treating costs for the same items were 14.3c., 1.8c. and 2.6c. On the million-gallon basis labor cost for pumping was $4.59, power $4.14 and supplies $0.43, while the treatment costs were $5.01, $0.66 and $0.91 respectively for the same items. There was a reduction of $0.72 in pumping costs and an increase of $0.07 per million gallons in the treatment cost over 1928. The unit cost of purchased power was 1.61c. per kilowatt-hour and that of power generated locally 1.21c. Handling dried sludge cost 28.7c. per cubic yard.

Foaming—The foaming-control treatment consisted principally of a series of experiments in which the sludge was circulated by means of air lifts. The conclusions to be drawn from the experiments are that a small amount of circulation by air is helpful in promoting balanced digestion, principally by preventing heavy scum formation. Too frequent circulation (with air) produces a bulky sludge, although no other objection has been noted. One or two hours' treatment once a month will keep the scum down and promote uniform digestion without bulking of sludge. Circulation of sludge has been entirely successful in Flint in combating foaming troubles, as it provides a means of keeping the foam under control by mechanical action and at the same time rapidly brings the digestion to a balanced state by making it possible to hold the partly digested sludge until digestion is more complete.

Odor Control—As a result of the work done to date the following plan for odor control during the current year has been decided upon: (1) Prechlorination of the raw sewage at the pumping station to retard decomposition in the pressure main and tanks, to destroy odors at the pumping station and tanks and to reduce the chlorine demand at the treatment plant. This treatment is to be intermittent, taking place only during the peak daily flows. (2) Postchlorination of the tank effluent shortly before discharge into the stream. This treatment is to be continuous and complete.

River Studies—The immediate oxygen demand causes by far the greatest load on the stream. The amount of oxygen required to satisfy this initial demand may be as high as 500 lb. per hour at times, while the amount available in the stream may drop as low as 40 lb. per hour. It would take an enormous aeration rate to satisfy the initial demand without a depletion of oxygen. It is this rapid using up of oxygen at the start that causes a septic zone in the stream. However, after the initial demand is satisfied the rate of demand drops off to 12 lb. per hour, while the rate of re-aeration in the stream continues at about 25 lb. per hour. At the backwater of the dam the aeration rate drops off to about 8 lb. per hour, but the difference in the rates of supply and demand is not sufficient to cause a depletion of oxygen in the period of time (six hours) required for flowing through this zone.

As chlorination of sewage, to a point where a substantial residual is obtained, completely satisfies the immediate oxygen demand, it follows that this treatment would relieve the immediate load on the stream, and as the rate of absorption is less than the rate of re-aeration, no diminution in the amount of dissolved oxygen in the stream should occur.