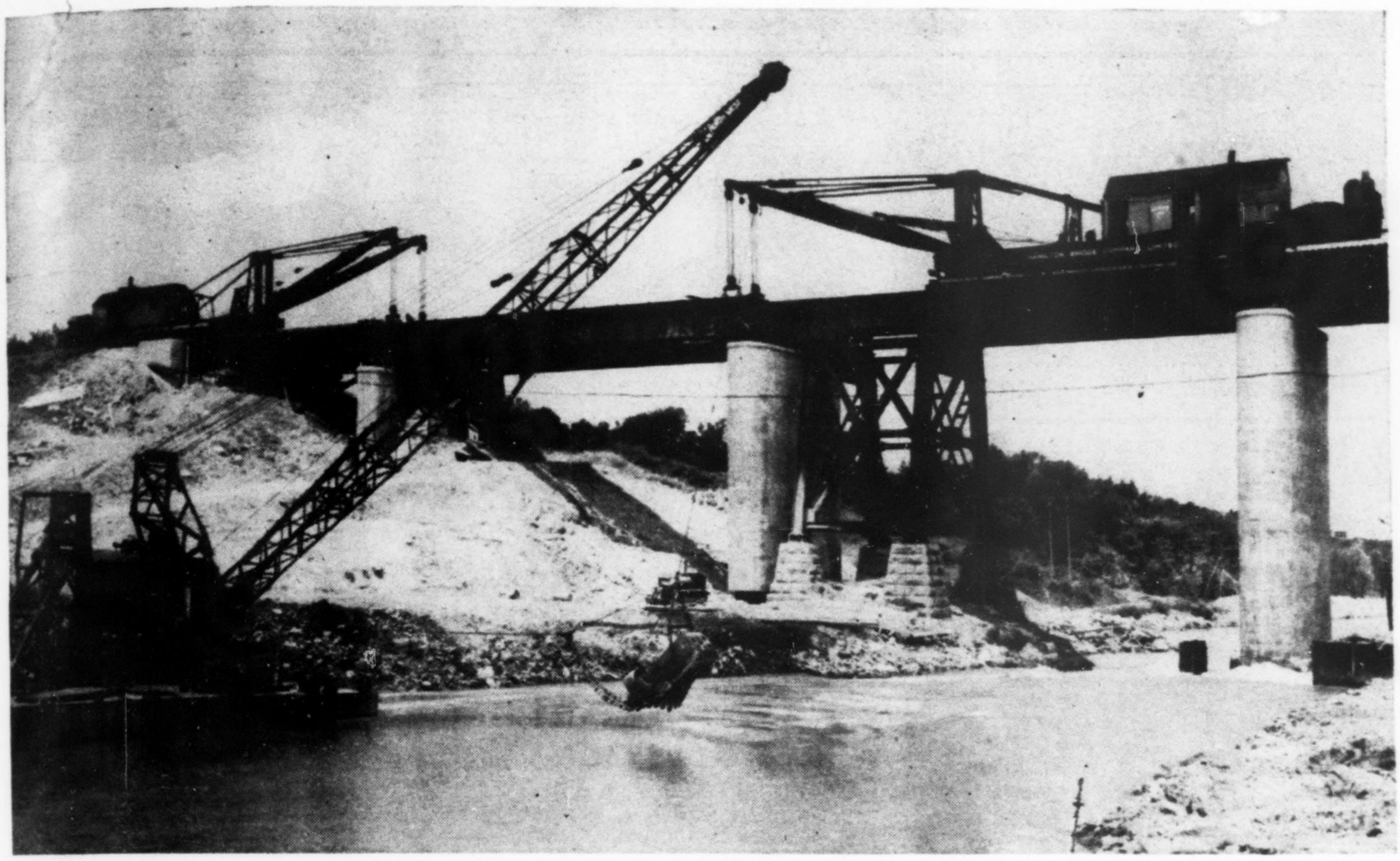

Fig. 1. Derricks shift girders to support on piers built by encasing H-piles in form then filling with aggregate and grout.

New Deep Piers Save Old Bridge

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***Contents in Brief**—Replacing a substructure on spread footings was accomplished by driving H piles and pipe piles to good strata and extending them to near bridge-seat elevation by splicing after driving under the existing superstructure. Piles were encased with concrete made by filling sheetpile cofferdams below ground and conventional forms above ground with dry stone aggregate and adding grout forced in under pressure. For one pier, the section above ground was encased ahead of the lower section and load transferred to it before the excavating below an old footing.*

SWIFT WATER, location adjacent to existing piers, subsurface obstruction from earlier bridges and other physical obstacles made conventional pier design impractical and normal construction difficult for a new substructure to carry an important double-track line of the Canadian National Railway near St. Catharines, Ont., in the Niagara area. The difficulties were overcome by use of long steel piles protected concrete made by grouting a dry stone encasement. An unusual cofferdam was necessary for building one pier in the channel where the water is very swift. Concrete for one pier was started in the middle and built first up, then down.

The work was made necessary by extensive channel enlargement below the DeCew Falls plant of the Hydro-Electric Power Commission of Ontario and is needed to accommodate an increase in discharge from 4,500 cfs. to excess of 9,500 cfs. This added water became available following changing of the course of certain streams so that instead of flowing north into James Bay, they are now diverted into the Great Lakes above Niagara. The water is reused through an enlarged development at DeCew Falls, a part of the Niagara system, where a 265-ft. head has long existed. By widening and deepening the discharge channel the tail-race channel characteristics of the plant have been substantially improved. A description of ingenious methods developed for moving sticky mud in connection with the channel enlargement appeared in *ENR*, Oct. 31, 1946, vol. p. 587.

The existing deck-plate girder bridge, which had three 100-ft. and one 65-ft. span, plus two short spans over tower bents, was capable of carrying Cooper's E-60 loading, adequate, with maintenance, for current

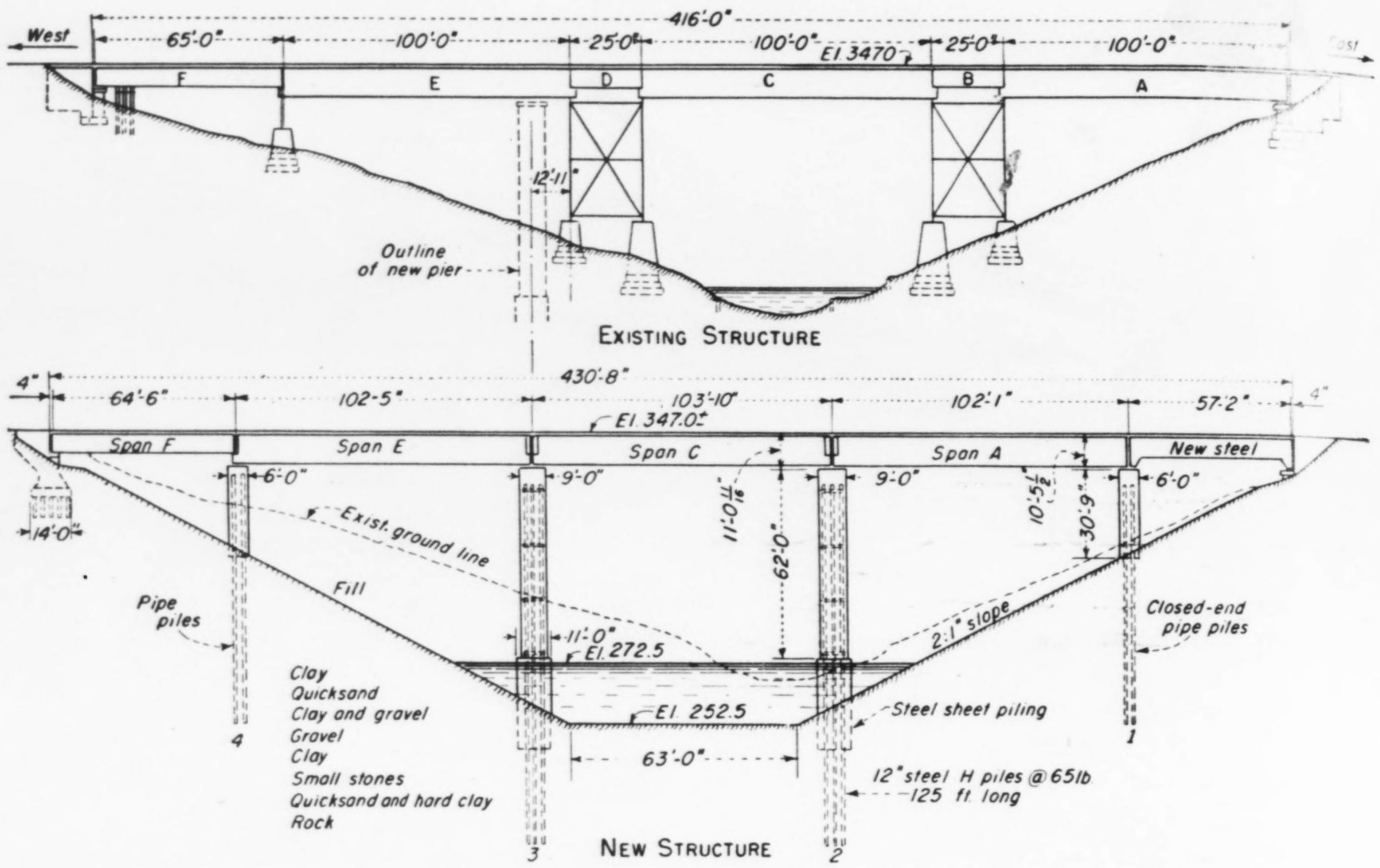

Fig. 2. The superstructure of the old bridge is utilized almost completely in the new structure without the expense of a temporary crossing or delay to traffic. Removal of the old supports was done after the load was shifted to the new piers.

traffic. Independent pairs of girders supported each line of the track.

The bridge was on a long tangent at the tail-race crossing, and it was not desirable, from an operating standpoint, to introduce curves into the lines as would be necessary if a new bridge were built. Also, due to serious shortage of steel, as well as its high cost, it was desirable to utilize the existing structure to the greatest extent possible.

Masonry piers of the old substructure rest on spread footings, which have settled some over the years, so that it was desirable to carry new supports to deeply underlying rock, or at least to virtual refusal of the driven piles. Utilizing the existing structure required placing Pier 2 (Fig. 2) in the old channel where water had a velocity of 10 ft. per sec., which would be further increased by a construction cofferdam. The new Pier 3 would be immediately adjacent to and extend some 40 ft. below the existing supports for one of the tower bents. Vibrations from frequent passage of heavy trains added to the foundation construction difficulties as did the fact that old masonry from earlier culvert and bridge structures at the site left debris difficult to penetrate.

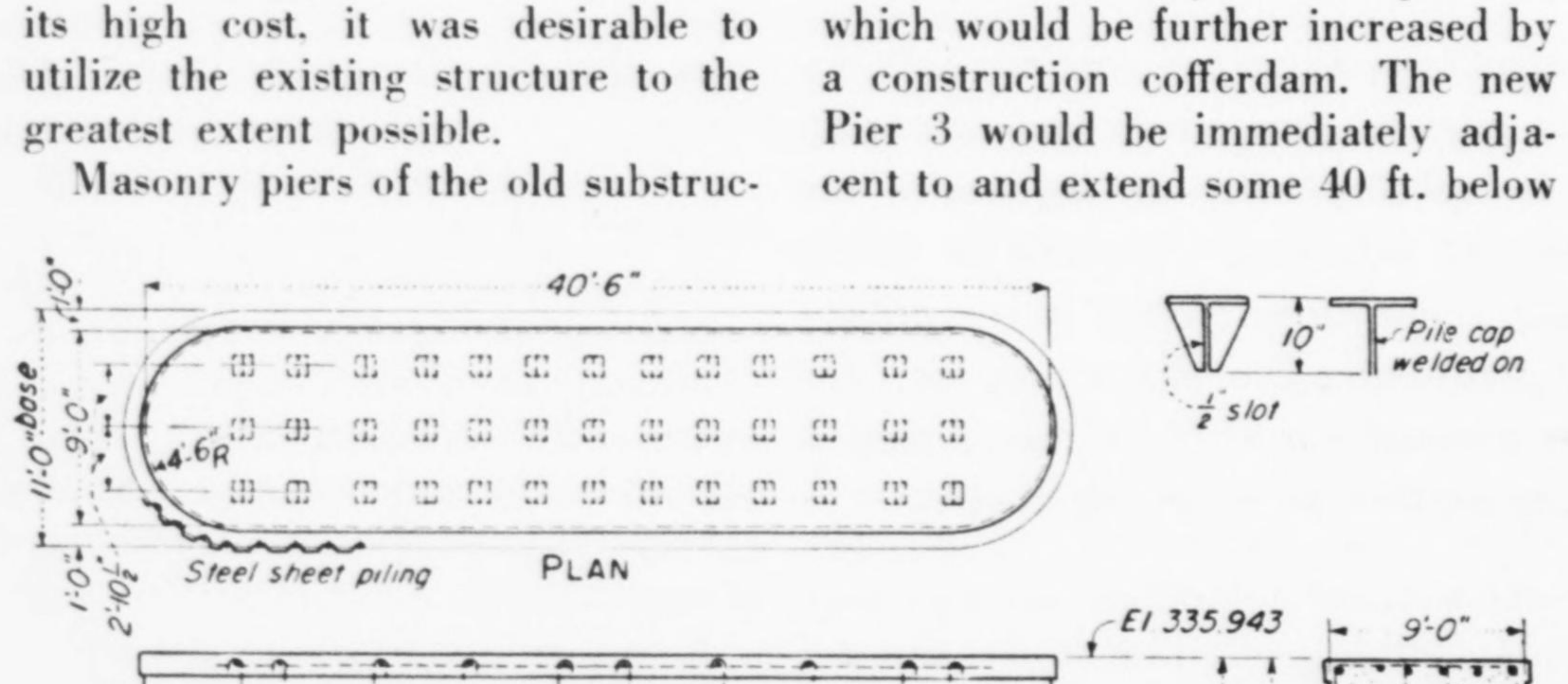

Fig. 3. Details of piers 2 and 3. Encasement was made by filling with dry stone and forcing in grout under pressure.

Pile piers encased in concrete

The design for the bridge, prepared by C. P. Disney, then engineer of bridges, Central Region, for Canadian National Railways, was made to overcome these difficulties. Long steel piles that extended from hardpan to near the bridge seat were planned for the support. By driving the piles in short lengths and welding pieces on as required, the new substructure was built up under the existing bridge. After driving, the piles were encased in concrete made by packing around them with dry stone and then forcing in grout to complete the piers.

Since these were essentially pile piers, merely encased in concrete, they could be made slender all the way to the bottom, thus reducing substantially the weight that is carried by the piles. The concrete also serves as structural stiffening for the piles.

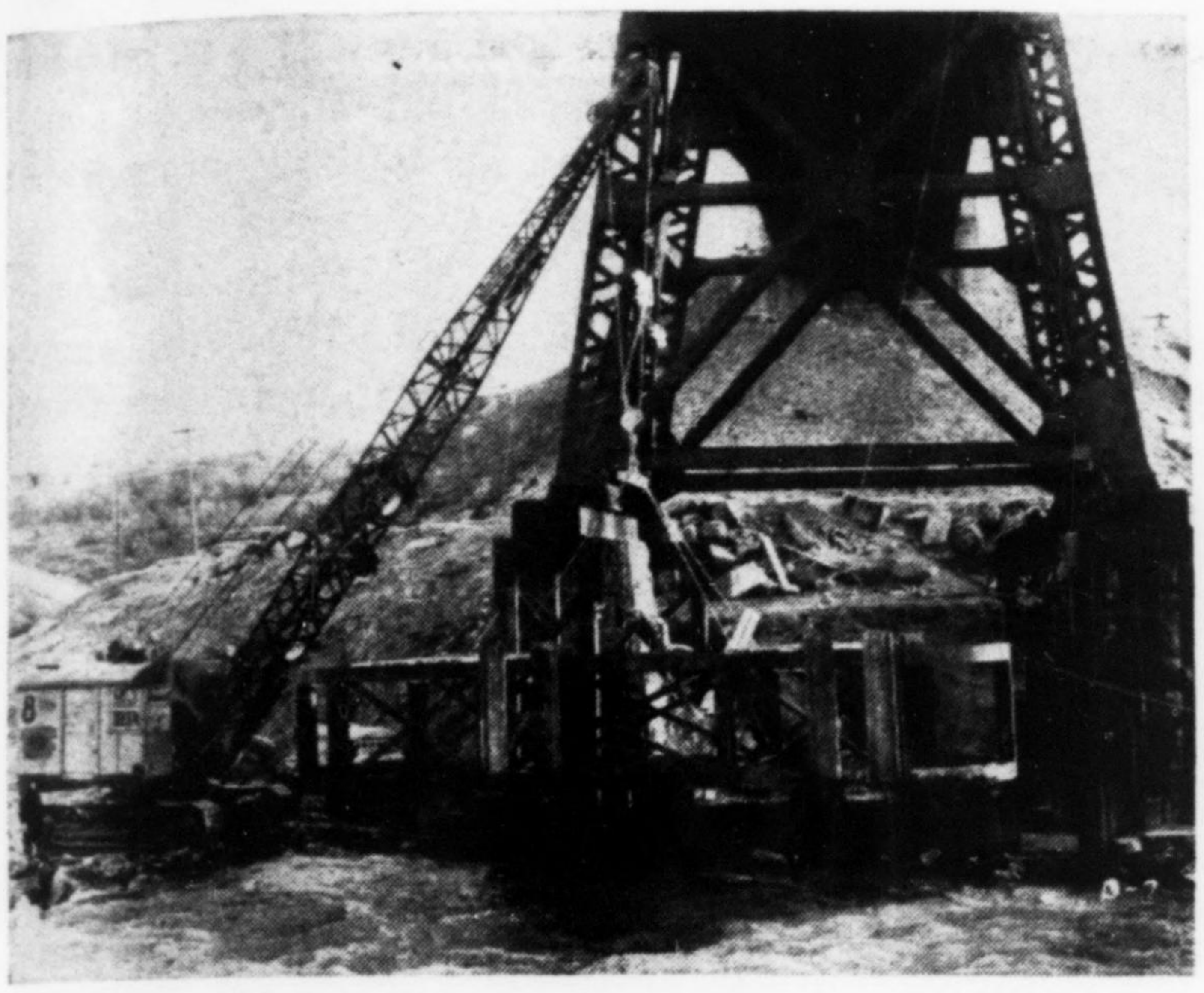

Fig. 4. A cofferdam in swift water was built around a structural frame supported from the existing bridge. Long sheetpiles were started through the interlocks of the short pieces.

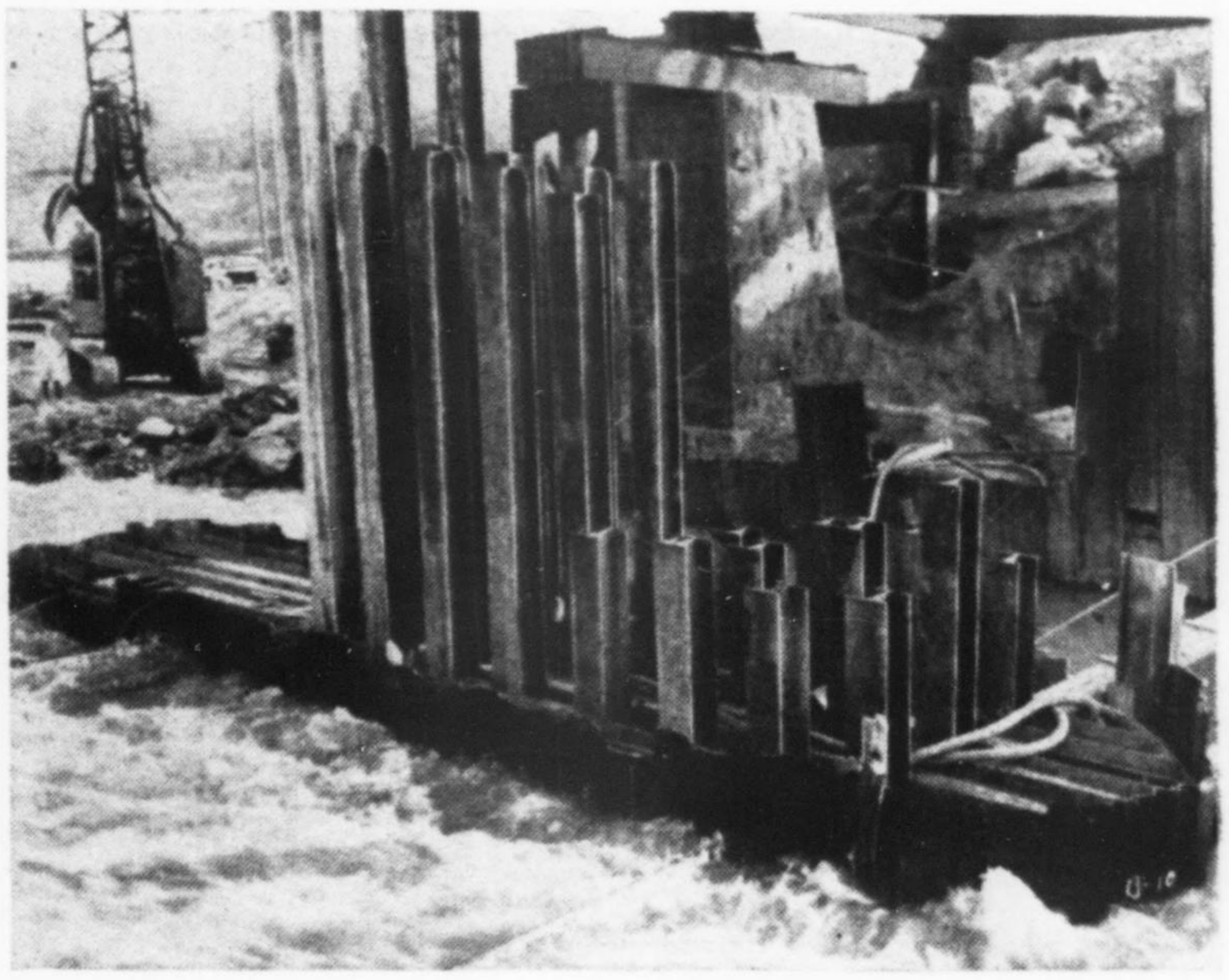

Fig. 5. The structural frame around which the sheet piles were driven also served to hold guides for positioning H-piles. Piles were later extended upward to 6 ft. below the bridge seat.

eliminating the usual heavy bracing.

The principal piers are of two major designs, and methods of construction are substantially different for each of them. Construction of a conventional support at Pier 2 would have required a large water-tight cofferdam, braced and pumped-out to a depth of 30 ft., or more, then piles driven for support. The design devised by Mr. Disney contemplated driving shallow-arched interlocking sheetpiles along the neat lines of the finished pier to well below the bottom of the new channel; it required that the cofferdam be excavated, but not pumped out, and steel H-piles driven to refusal with their tops extended upward to within 6 ft. of the bridge seat.

It will be noted that Pier 2 goes deeply below the existing foundation so that special methods of construction were necessary in the very swift water. Of first importance was prevention of any possible subsidence of the channel-side foundations of the old bridge. Such movement was forestalled by driving bearing piles to firm ground and then installing a grillage under the tower legs, Fig. 4. Next, a line of sheetpiles was driven along the channel line and tied back to the bank. The underwater area at the pier site was cleared of all solid debris that could be picked up with an orange-peel bucket handled by a crane.

Cofferdam in swift water

Building a cofferdam 11 ft. wide by 42 ft. 6 in. long in water having a velocity of 9 mph. presented a problem that required unique methods to overcome. A two-ring steel template for the cofferdam was framed on shore. It was rigidly braced to provide a firm guide for the sheetpiles, while cross bracing inside served as guides for the H-piles driven for bearing. Outside the template frame, short pieces of steel sheetpiling were fastened to serve as guides for the first long sheetpiles, which would be driven down to hold the template.

The existing bridge superstructure was a hindrance to the construction, but since it was there it was utilized effectively in building the cofferdam. To the assembled template, cables were fastened that would swing the frame under the bridge at about the top of the water. A crane picked up the template and set it into position, letting it hang under the bridge from the cables. Horizontal cables, with a turnbuckle in each for adjustment, were used to position the template.

The two-ring frame was supported on the vertical cables slightly above the water line until a sufficient number of long sheetpiles were driven to support it against the rush of the current. The frame was then lowered to its permanent position with the top ring slightly below the water line, and

Fig. 6. Pier 3 was constructed immediately adjacent to existing footings by driving H-piles to bearing materials and extending them upward to near the bridge

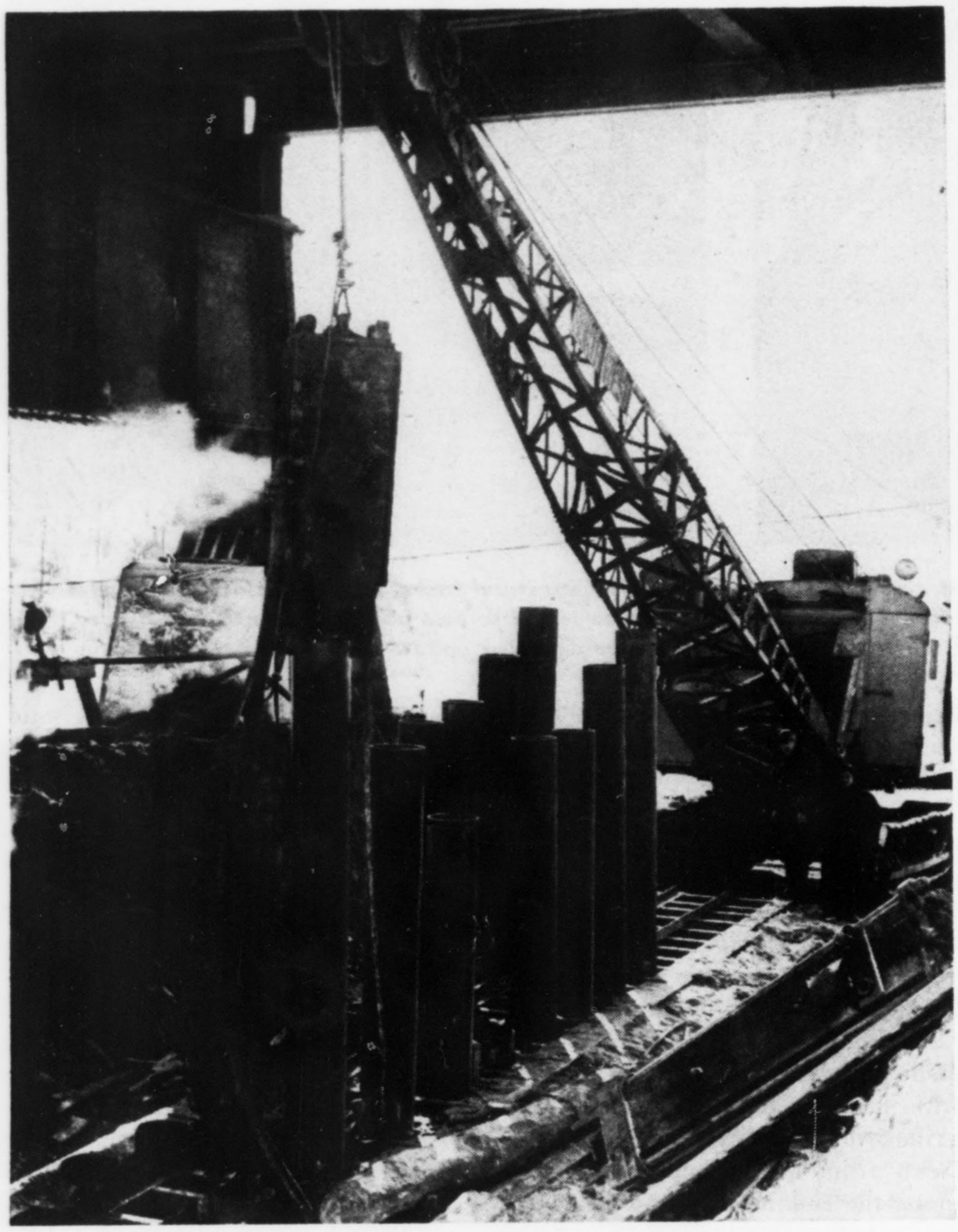

Fig. 8. Piers 1 and 4 rest on pipe piles filled with concrete and, from near the ground line, are encased in concrete.

support transferred from the vertical cables to the driven sheeting. Fig. 5.

Sheetpiles were driven to a depth of 40 ft. followed by excavation inside the cofferdam to a depth of 25 ft. An orange-peel bucket was used through dredging pockets left between the cross bracing of the frames. A steel grid that formed an exact template for the H-beam bearing piles was attached to the horizontal rings of the frame, and through this the bearing piles were driven in lengths as great as it was practical to handle under the existing bridge. They were spliced as required by reinforced butt welds to extend them upward to 6 ft. below the bridge seat.

A frame of $3x3x\frac{3}{8}$-in. angles at 9-ft. spacing was used above the water line to space the H-piles. The heavy bracing of the usual H-pile piers, which requires exact alignment and position of each pile, was made unnecessary by the concrete encasement.

The cofferdam, serving as a form, was filled with carefully graded stone aggregate by dumping from a clamshell bucket and allowing the material to settle through the water. Care was taken to fill around and between the bearing piles.

Grout was made with $4\frac{1}{2}$ bags of portland cement and one bag of a special admixture, made up of finely divided siliceous material and an intrusion agent designed to disperse the cement particles, increase flowability and reduce shrinkage. Mixed with 7 cu.ft. of fine sand and 24 gal. of water, this was forced into the stone through $\frac{3}{4}$ in. dia. pipe, placed to the full depth ahead of filling with stone. Pipes were placed at 5 ft. centers longitudinally with one row on the centerline and a row at 4 ft. on each side in the 11 ft. 6-in. wide pier and were pulled up as filling progressed.

A more satisfactory method of placing grout was found in the use of old 2-in. pipe slotted at 2 ft. centers and set on the pattern described above. A 1-in. hose carried the grout to the full depth of the pipe and was pulled up as the grout filled the pier, a much easier operation than lifting the $\frac{3}{4}$ in. pipe against friction of the stone.

Above the cofferdam, conventional forms were used to encase the pier and this, too, was filled with graded stone, vibrated while being filled. Grouting above the ground was done through vertical pipes and also through $\frac{3}{4}$ in. pipe in the side of the forms. Grout was discharged some 18 in. from the form face.

Pier built up—then down

Pier 3 of the new substructure presented an entirely different problem, since it is located only a few inches from the masonry pedestals of a pier of the old structure. The base of the new pier extends about 40 ft. below the base of the old tower support, and the H-beam piles of the new pier continue some 30 ft. below that. The H-piles were driven through a guide frame that also served as a template for a ring of steel sheet piles driven to 40-ft. depth. It was not practical to excavate this cofferdam, as was done at Pier 2, while the load was supported on the old towers. Yet, it was necessary to develop a load bearing pier and shift the superstructure to it before the existing support was disturbed.

The steel H-pile supports provided the answer. The piles were extended to near the bridge seat elevation and, above the ground line, were encased in concrete made by packing the form with stone and forcing in grout. The concrete was carried on a timber grillage at the ground line forming a spread footing some 2 ft. larger than the pier, and on this the form was built.

After the superstructure was shifted the existing towers and shallow pedestals were removed and the ground sloped to the lines shown on the plans. The sheetpiling around the pier was burned off to plan elevation. Below that level excavation inside the cofferdam was done manually to the depth

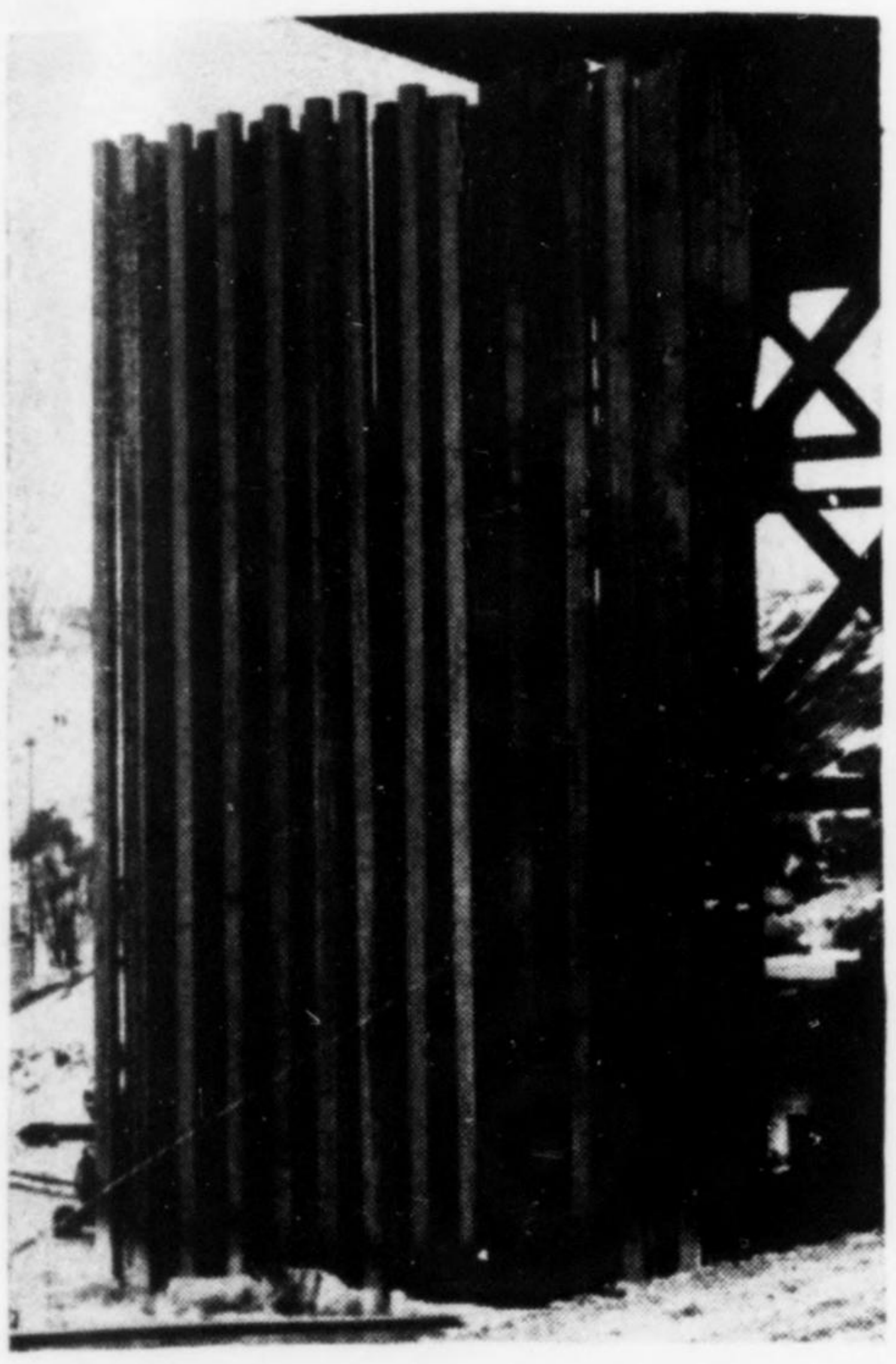

Fig. 7. Only light bracing, welded on in the field, was required to hold the piles properly spaced while being encased with made-in-place concrete.

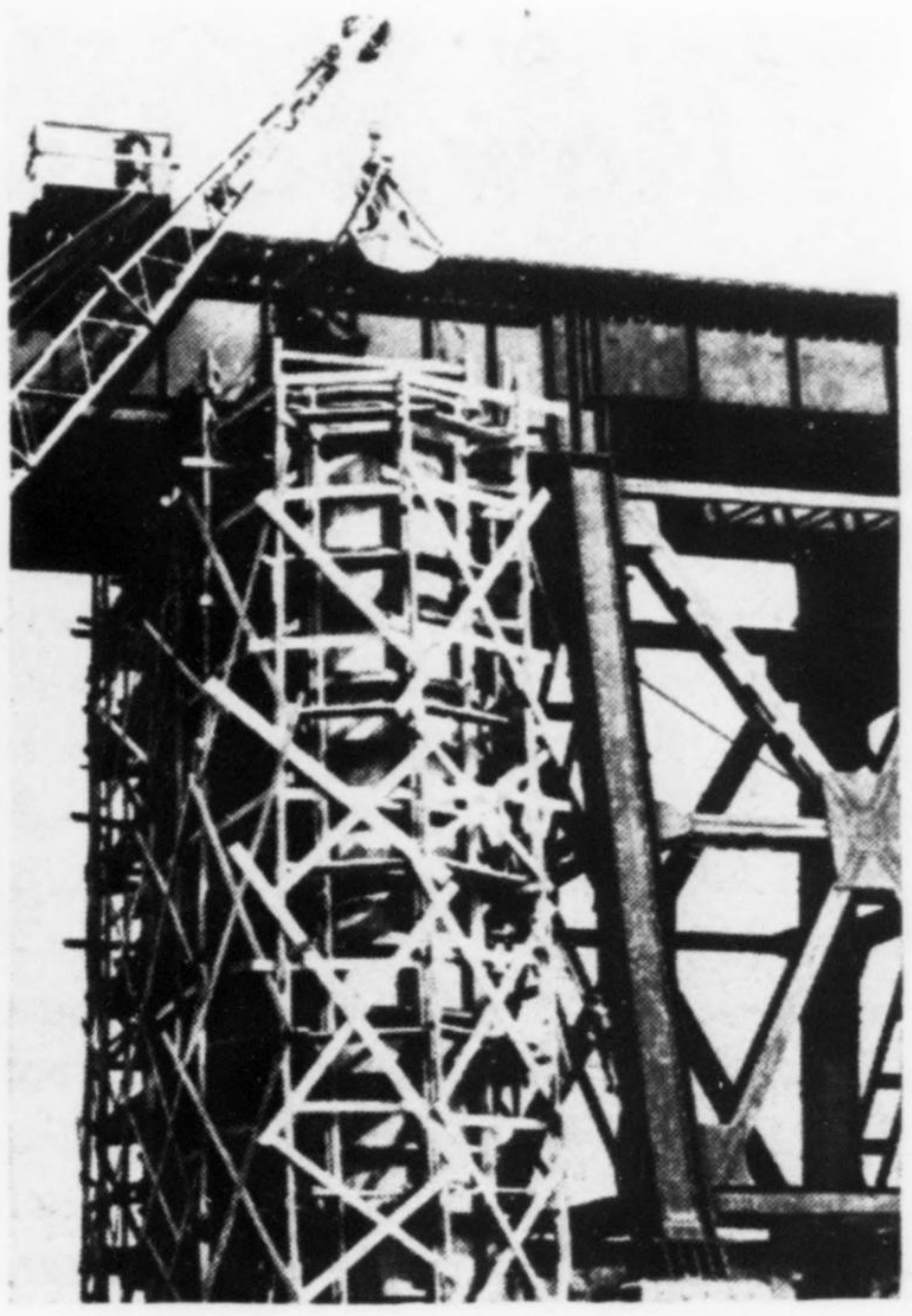

Fig. 9. Graded stone was placed in the pier encasement form by clamshell bucket and grout intruded to complete the pier.

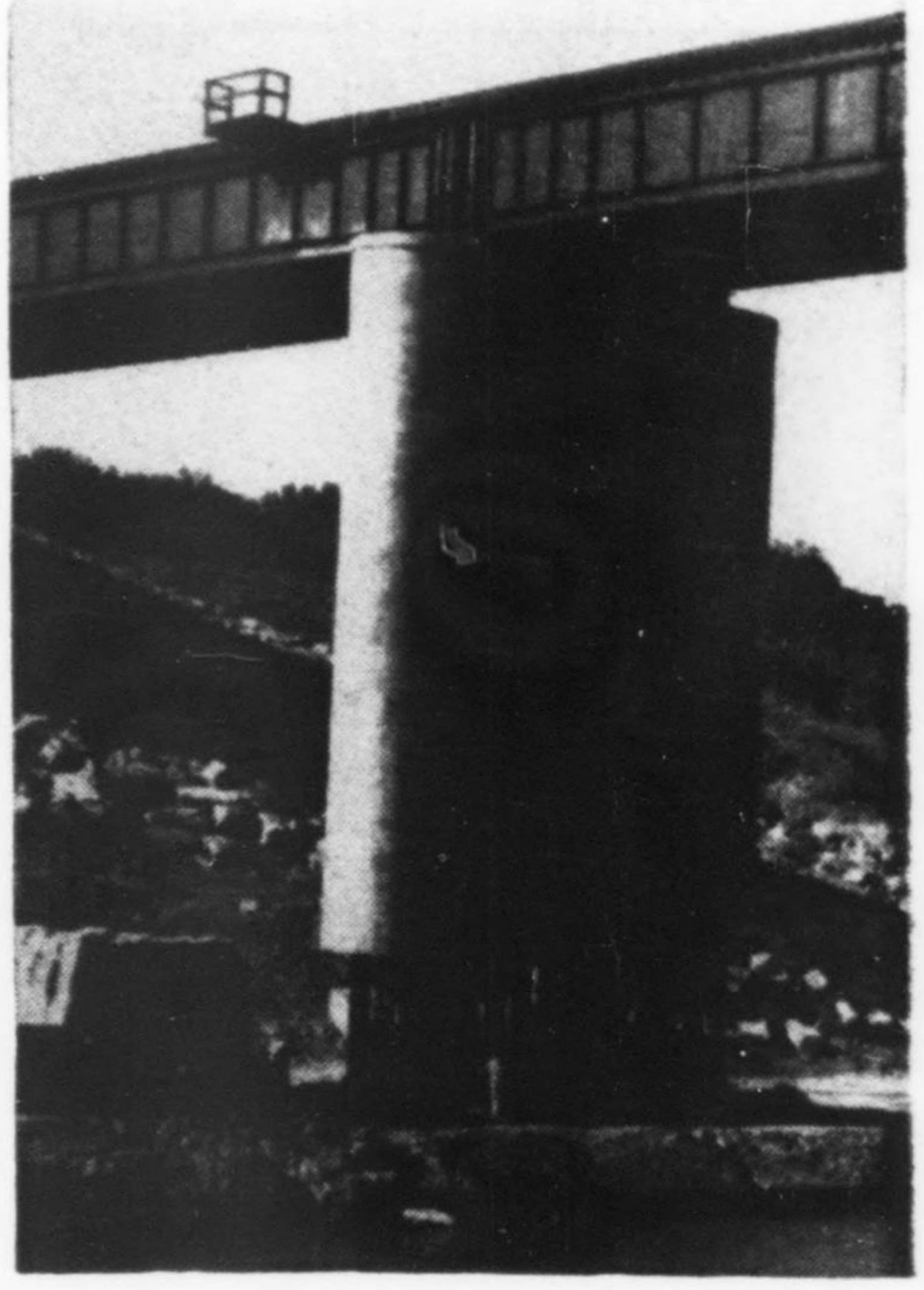

Fig. 10. Excavation below the ground line after the upper section was completed temporarily exposed the bearing piles of Pier 3, while under full load.

of the concrete section of the pier, some 40 ft. below water level. Spoil was lifted out in small buckets. Bracing was progressively installed as the excavation proceeded.

During this period the pier presented a very unusual appearance, as shown in Fig. 10. Above the existing ground line it is a finished pier. Below that level its appearance is that of slender supports for an oversize superstructure.

As soon as excavation was complete the cofferdam was filled with crushed stone. A form was set to connect with the upper part of the pier and, after this was filled with rock, grout was forced in. Forcing grout in under pressure assured full bearing under the existing concrete, but this is not depended upon for load carrying ability as the piles carry the weight of the structure directly into the ground.

For piers 1 and 4, along the slope, pipe piles were driven to good bearings, and filled with the prepacked type of concrete. The pipe piles extend to near the bridge seat and are encased, above the ground line, in the prepacked type of concrete jacket used for piers 2 and 3.

The bridge was built under supervision of Harry Stevens, resident engineer, and K. Huffman, engineer of construction, of the Canadian National Railways.

Construction of the substructure was done by C. A. Pitts General Contractor Ltd. of Toronto for whom M. F. Missiaen was general construction superintendent and E. A. Missiaen job superintendent. S. C. Cooper was field engineer for the contractor. Revamping of the superstructure and transfer from the old piers to the new was done by the Hamiliton Bridge Co., Hamilton, Ont.

New Surveying Specifications Adopted at Cleveland

Sponsored and supported by the City of Cleveland, several surrounding suburbs, the county of Cuyahoga, and the Ohio State Highway Department, the Cleveland Geodetic Survey recently adopted specifications for use of the new Cleveland Geodetic Survey Control by plane surveying methods. This guide will enable city, county, state and private practicing surveyors to make full use of the new system.

In contrast to accuracies of 1 in 5,000 which have been used in the past, the new specifications call for accuracies of 1 in 15,000 for control of streets and roads, and 1 in 10,000 for control of property lines. These accuracies are based upon some 25 miles of test runs made by S. A. Bauer, civil engineer and surveyor of Cleveland, over a period of years, with his field crews. The tests indicate that these accuracies can be readily obtained with the usual instrumentation of the profession.

The new specifications follow the standards of accuracy recommended in the "Technical Standards for Property Surveys" adopted in 1946 by the American Congress on Surveying and Mapping. Being of relatively high order or precision, they were planned to extend the value of the work of the geodetic surveyor to the benefit of the end user—the property owner—without noticeable break. They also permit the continued use of time-honored methods and procedures of the property surveying practitioner.

The specifications are not mandatory at the present time, but it is hoped that they will soon become sufficiently well established that they will be required in all surveys that require official approval.

Copies of the new specifications may be obtained from Prof. G. Brooks Ernest of the Case Institute of Technology and consulting director of the Cleveland Regional Geodetic Survey.