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Massive Reinforced-Concrete Piers
for the N. Y. Port Authority Bridge
over Arthur Kill, Between Eliza-
beth, N. J., and Howland Hook,
Staten Island





Airmap Corp. of America

ELIZABETH BRIDGE CROSSING OF ARTHUR KILL LOOKING TOWARD STATEN ISLAND

Building Substructure of Arthur Kill Bridges

Variable Pier Sinking Methods—Paving Mixers, Cranes and Mast Elevators Concrete 155 Piers Spread Over 15,000 Ft.—A System of Structural Steel Reinforcement

SUBSTRUCTURE WORK on the approaches to the two bridges which the Port of New York Authority is building over Arthur Kill between Staten Island and New Jersey has been notable in three main particulars. Varying soil and subsurface conditions have required an unusual diversity of pier foundation sinking methods, covering in their range unsheeted excavation, open cofferdams, both steel and wood sheeted, and a pneumatic caisson. For pouring the majority of the 155 approach piers, composed each of two shafts connected by an arch and ranging in height up to nearly 130 ft., mobile concreting plants of cranes, paving mixers and elevator masts have been efficiently adapted. Finally, on one contract, and in part on another, a system of structural steel pier reinforcement was used, while all other piers were reinforced by bars as originally planned.

The bridges, which are highway toll structures and whose general characteristics were described in *Engineering News-Record*, Aug. 26, 1926, p. 346, are known respectively as the Outerbridge Crossing, connecting Tottenville, Staten Island, with Perth Amboy, N. J., and the Elizabeth bridge connecting the Howland Hook section of Staten Island with Elizabeth, N. J. The main spans are cantilever truss structures, while the approaches are deck plate girders. In Fig. 1 are shown the locations of the bridges, while in Fig. 2 are given the principal dimensions.

Engineering Considerations—The contracts for the four approaches were let to three contractors, one of whom built both of the Staten Island approaches. Each contractor's task was essentially the same—to erect a series of arched reinforced-concrete piers, distributed over lengths varying from 3,070 ft. on the Elizabeth approach to 4,698 ft. on the Perth Amboy approach. In carrying out the tasks, however, different construction

methods were used, caused largely by variations in foundation conditions.

Borings taken at the main channel pier on the Howland Hook approach (C in Fig. 2) indicated layers of broken shale, sandstone, soft clay and other material that failed to core. Because of the uncertain character and depth of this material, it was necessary to use a pneumatic caisson in constructing this pier, and to carry the excavation to rock at El. —69. Somewhat similar conditions were found at the anchor pier (D), but here the contractor elected to use an open cofferdam, since a dense clay formation sloping up from the channel made the water-

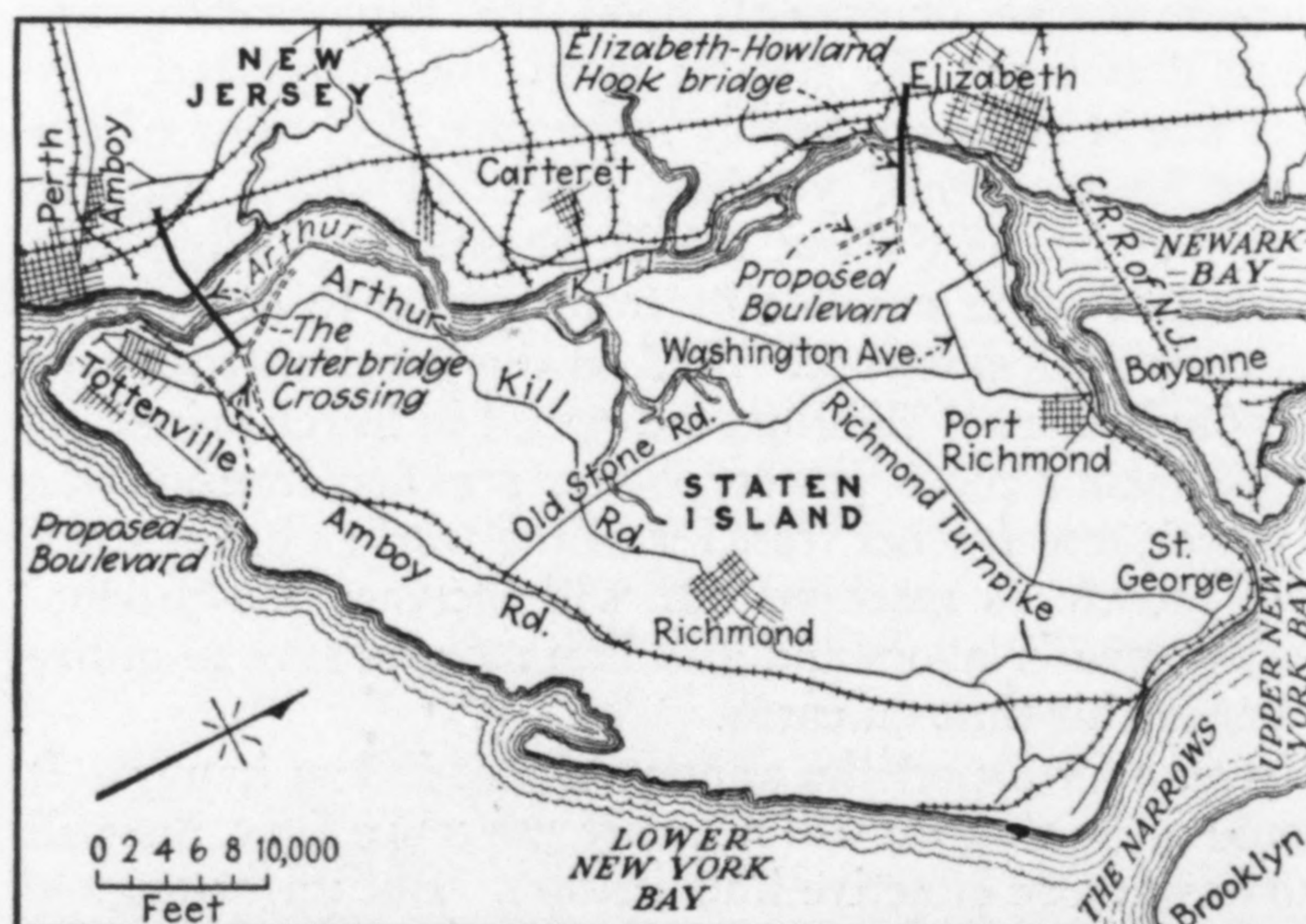


FIG. 1—LOCATION MAP FOR TWO ARTHUR KILL BRIDGES

handling problem not serious. For most of the piers on the Howland Hook approach, wood-pile foundations were necessary, and the excavation was carried only deep enough into the silt, and in some cases red clay, to give the necessary lateral support to these piers.

A few borings taken on the Elizabeth approach indicated rock so near the surface that the specifications called for all piers to rest on rock. However, extreme variability in rock depth was found by the contractor, and since he had then started to use ordinary 2-in. wood sheeting for the shallow depth expected, he continued with it until rock appeared. The first hole was sunk so successfully that wood sheeting was used on all the other approach piers, and this light sheeting of holes, as deep as 50 ft., was one of the important characteristics of this contract. For the channel pier on this approach, it was possible to use an open cofferdam since rock was fairly near the surface. It was, however, necessary to carry this pier about 22 ft. into the rock to provide against a future deepening of the ship channel.

the channel-bottom slit could be dredged easily, the open cofferdam method of construction was adopted.

The subsurface conditions on the Perth Amboy approach were very unfavorable, the silt formation, which continued inland for a distance of about 1,000 ft., containing much decayed vegetable matter. This material looked dry, but when disturbed developed into a jelly-like mud or gumbo. It would stand in almost vertical banks, yet exerted heavy pressure on the sheeting; closely braced steel-pile cofferdams were therefore necessary for piers B and A, and from 1 to 7. Pile foundations were necessary on a number of the piers, and considerable ground water made the use of wood piling possible on the two main piers and on the first nine approach piers. On 13 of the other piers near the center of the work,

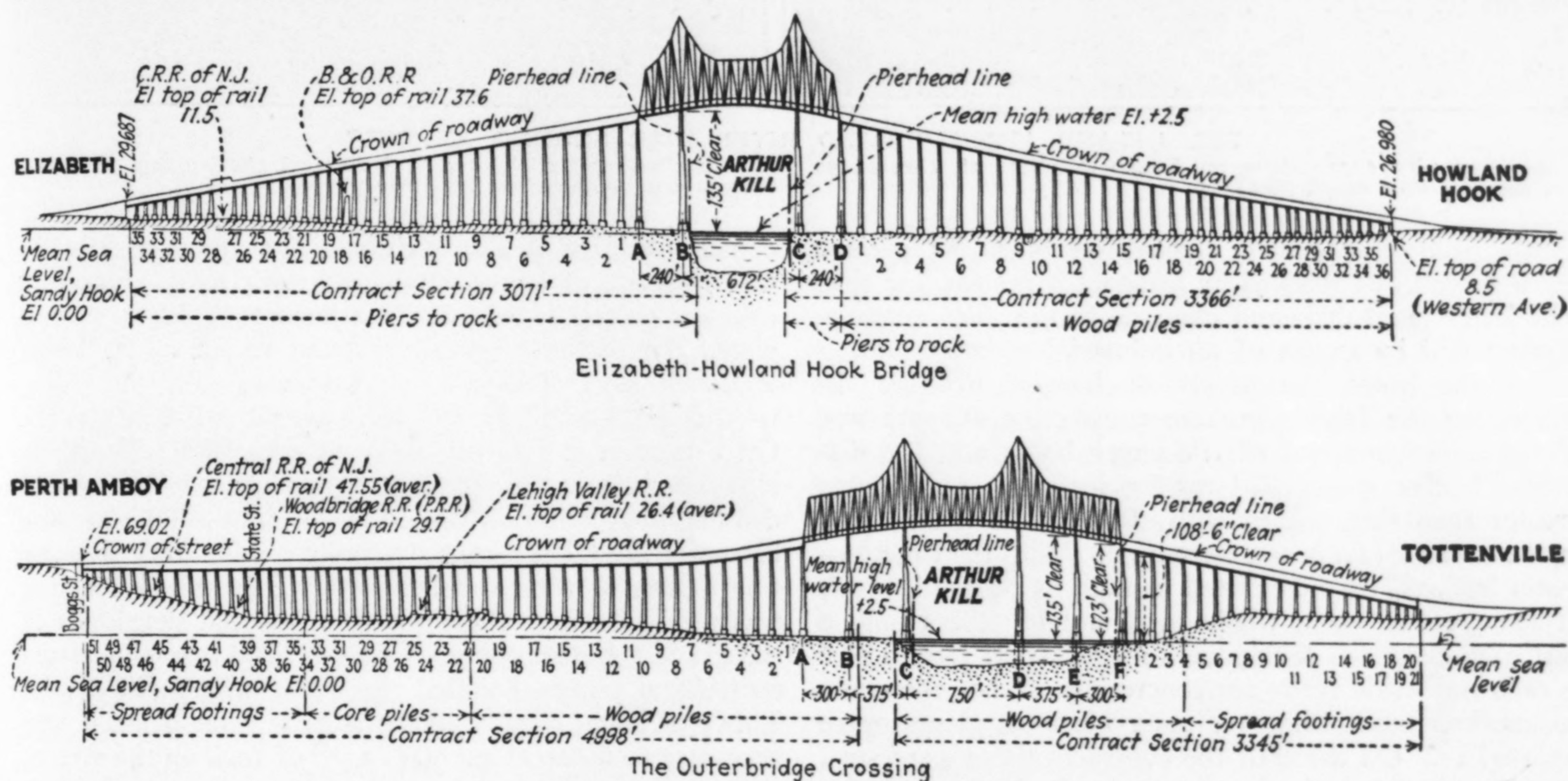


FIG. 2—PROFILES OF ARTHUR KILL BRIDGES

On the Tottenville approach, a firm clay-sand base fairly close to the surface made possible the use of spread footings on all piers except the four nearest the water. Here, pile supports were necessary, as they were on the four channel piers (C, D, E and F), where the subsoil was coarse sand and boulders of unknown thickness. Since

the ground was comparatively dry, and concrete piles were specified. Because of uncertainty as to the refusal depth, the contractor elected to use Raymond concrete piles, whose steel shells could be driven and cut off at the ground surface before the concrete was poured. As against this method, precast piles could have been used, but the contractor felt that it would be difficult economically to order precast piles for the variable and unknown lengths.

Use of Construction Plant and Equipment—Before considering the work on the more difficult of the piers, it is well to visualize the construction plants that were used. Excavation on all of the land piers, for both bridges, was done mostly by crawler cranes operating clamshell buckets. Stiff-leg derrick plants were set up for those piers near the bulkhead line, and floating plants, operating orange-peel buckets, were used to excavate for the channel piers.

Concreting was a mass production job, in which the use of a mobile and flexible plant, consisting of paving mixers, cranes and mast elevators, was practically the unanimous choice. Batch motor-truck delivery, from commercial material yards about a mile from each job, supplied most of the mixers with materials. The exceptions were a batching plant at the dock of the Howland Hook approach, and a central mixing plant, for the

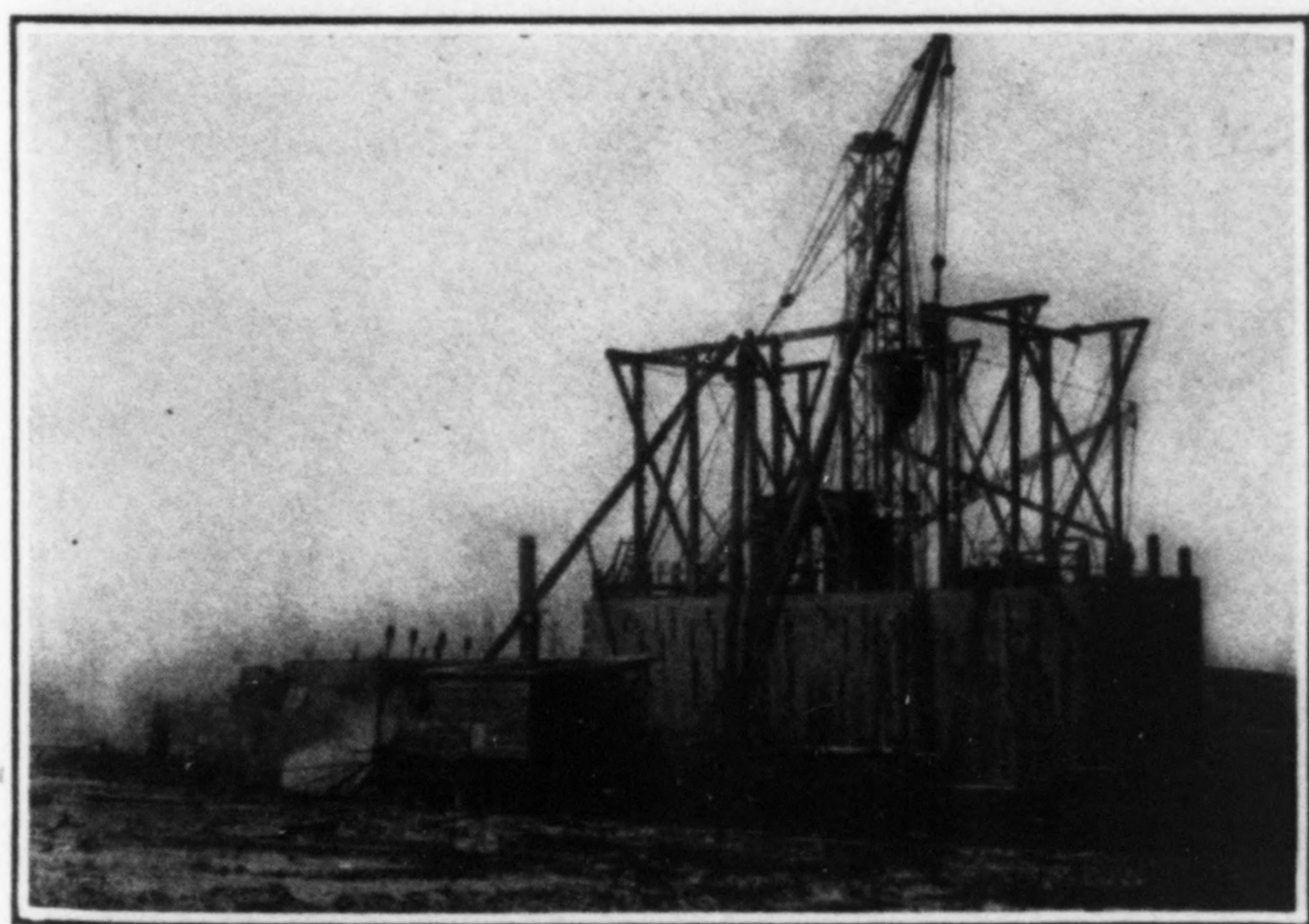


FIG. 3—SINKING PNEUMATIC CAISSON ON RIVER PIER C, HOWLAND HOOK

Note three telfer I-beams for transferring spoil buckets from locks to stiff-leg derrick boom on shore. Steel tower in rear is on floating concreting plant.

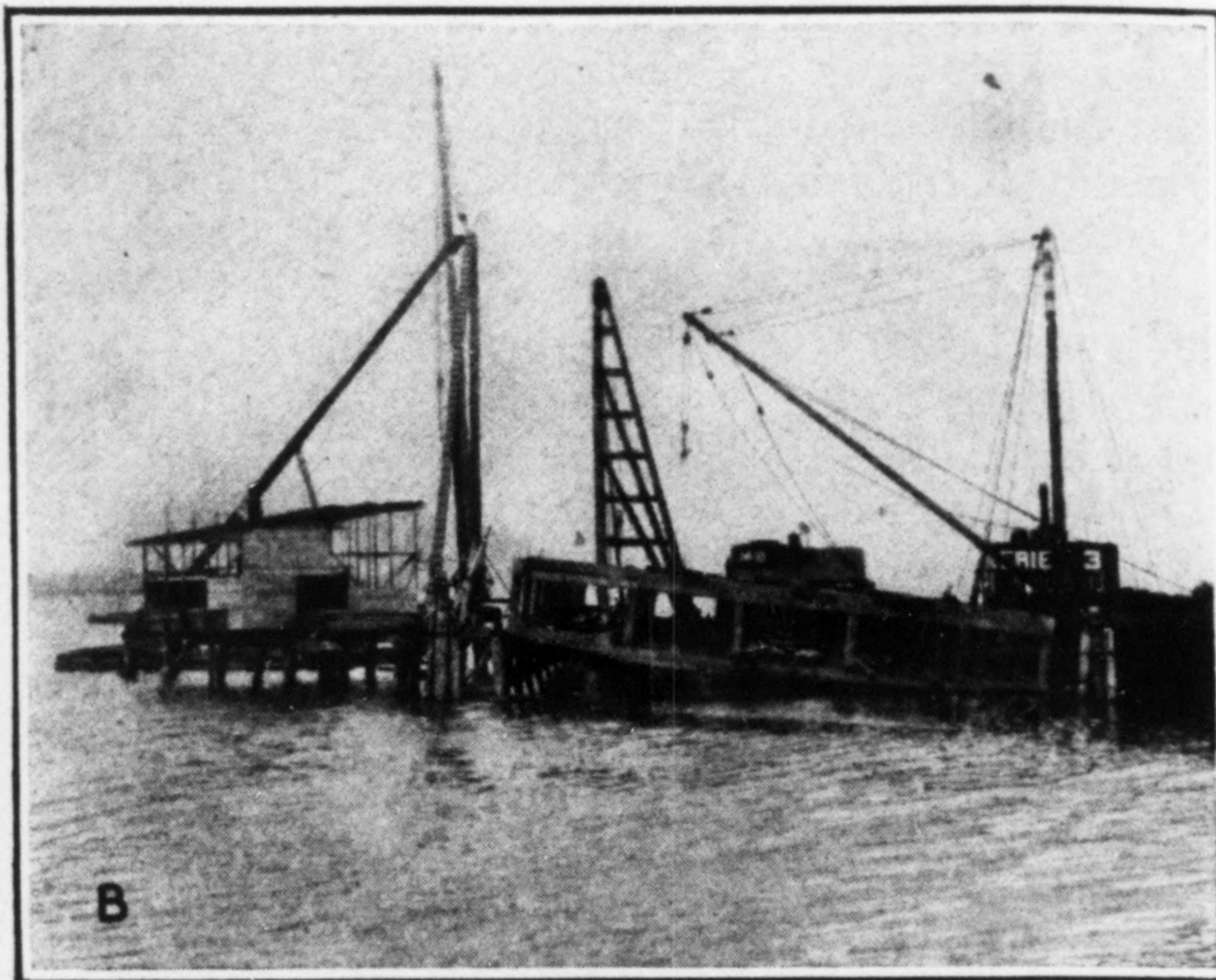
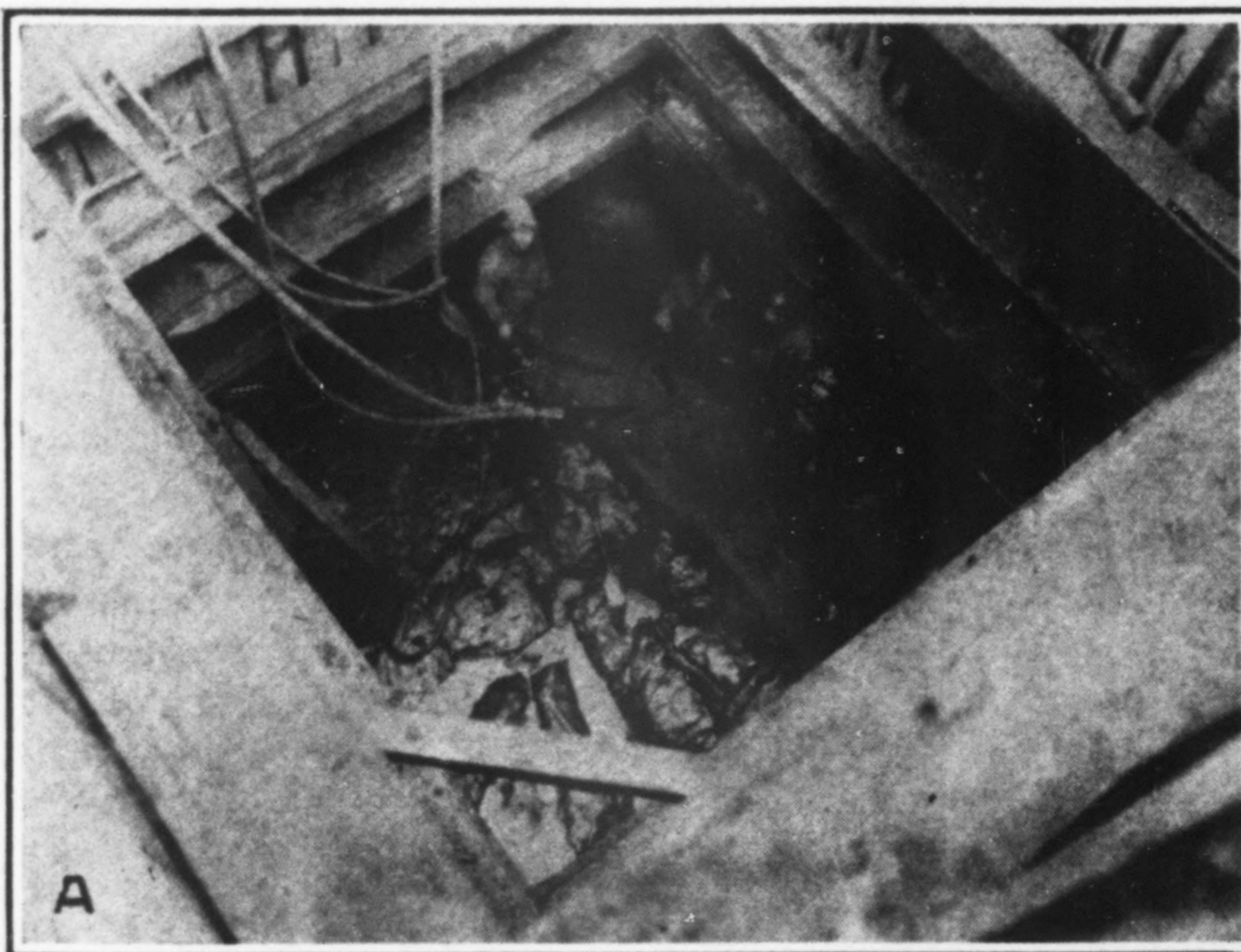


FIG. 4—LAND APPROACH AND RIVER PIER SINKING METHODS

A—Deep pier excavations on Elizabeth approach sheeted to rock with 2-in. wood planking.

B—Distributing the sinking load of steel sheet-piling on cofferdam crib, Outerbridge crossing.

Perth Amboy approach, erected on piles far enough from shore to be reached by material barges at low tide. The latter plant delivered concrete to the piers near the Arthur Kill by means of an industrial railway.

For the bases, the pavers discharged directly. In concreting the plinths on one contract, a support was placed under one end of the paver boom and the discharge bucket was pulled up the incline. For heights greater than this, cranes with 40 to 50-ft. booms, and in one case a 90-ft. boom, were used. With their bottom-dump buckets, they concreted as high as possible, which in some cases was a whole pier, and in others only a part of the shafts. The pavers moved from pier to pier as each was made ready for concreting. When the crane booms became inadequate, mast elevator plants were resorted to. On three of the contracts these were steel mast plants, and on the fourth wooden leads were erected. In some cases, a mast was used for each pier, while in others the mast served two piers by means of counterweight chutes. The maximum tower height necessary was about 160 ft. Electricity, gasoline and steam were used for power, in the latter case a boiler being erected on the dock, and steam piped to the various hoists and pumps. For concreting the river piers, central mixing plants mounted on barges were used.

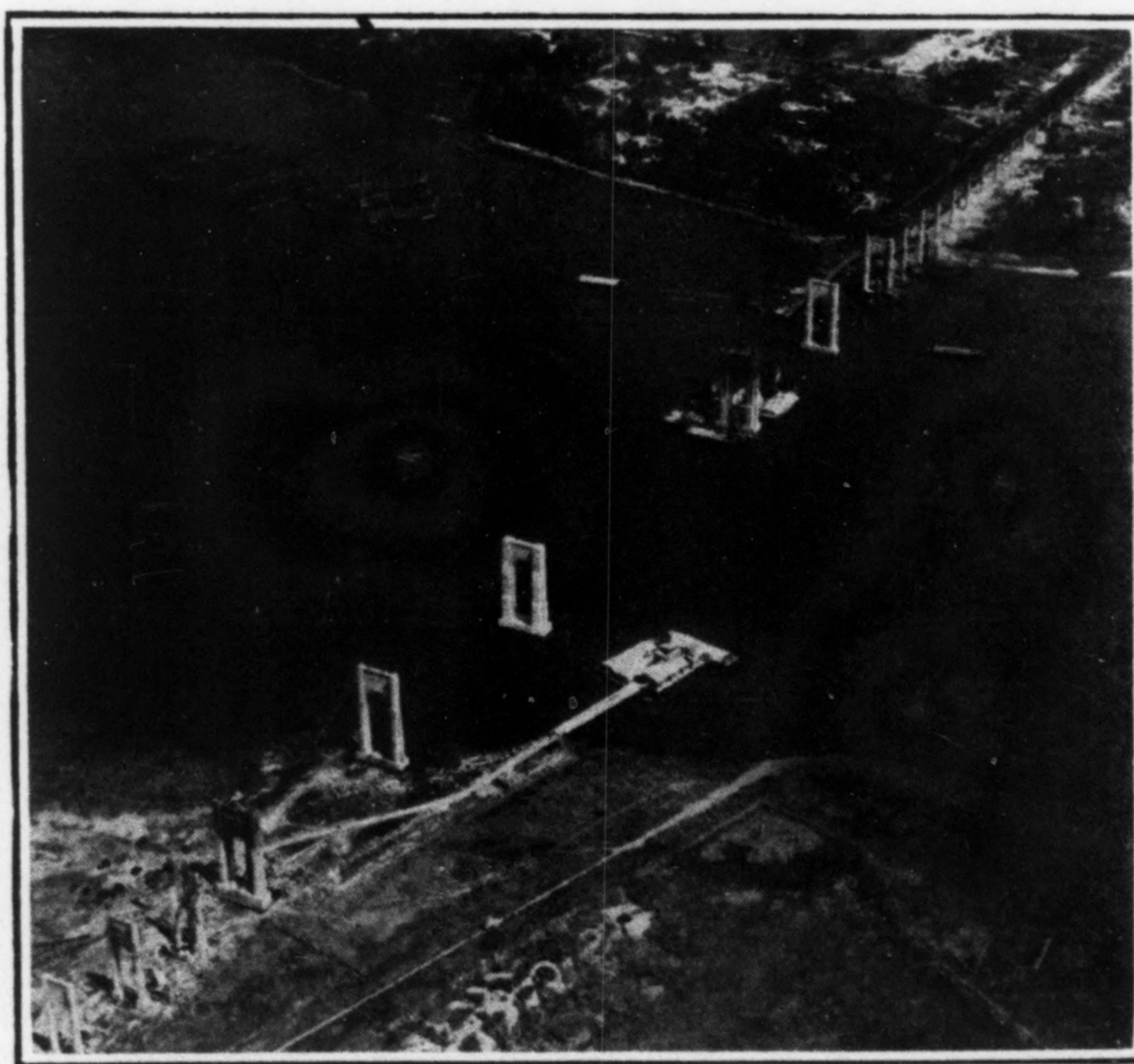
Channel Pier Construction—Piers B and C on the Elizabeth bridge and piers, C, D, E and F on the Outerbridge Crossing can be designated as "channel piers." Both a pneumatic caisson and open cofferdams were used in their construction.

In sinking the pneumatic caisson on pier C, Elizabeth bridge, although the theoretically required air pressure was about 31 lb., only 18 lb. air pressure was found necessary, because of a dense clay stratum overlying the rock. The caisson was of wood, 30x77 ft. in plan and some 75 ft. high. It was built at the yard of the Staten Island Shipbuilding Corporation and floated to the site, which already had been dredged as much as possible. In sinking, air spades were used extensively. The use of three material locks, and of three telpher systems of 12-in. I-beams over them, to carry the mud buckets, speeded up the work. Also, by depositing concrete through the three locks, the caisson was easily kept on an even keel during sinking.

The other five channel piers were sunk by open coffer-

dams. On pier B, Elizabeth bridge, a frame of 12x12's was fastened at low water to old dock piles. Ten-foot columns on top of this, and another set of framing completed the preliminary crib, around which 30-ft. 14-in. arch-web steel sheetpiling was driven. As the piling went down, bracing frames were placed at 5-ft. intervals. On this pier, it was necessary to excavate some 20 ft. into the rock, paving breakers removing the top 5 ft. of disintegrated material, while the 15 ft. of solid rock was blasted with 60 per cent dynamite. The steel sheeting was driven to rock and below this 3-in. wood sheeting was used to reduce the flow of water that developed at the toe of the steel piling. One 4-in. and two 6-in. steam centrifugal pumps handled the water which did get in. This pier being located on the sloping river bank, it was necessary to dump about 800 cu.yd. of rock on the stream side of the cofferdam in order to equalize the inward pressures on the bracing.

For piers C, D, E and F on the Outerbridge Crossing,



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FIG. 5—SUBSTRUCTURE WORK NEARING COMPLETION ON OUTERBRIDGE CROSSING

Perth Amboy contractor's central concreting plant in the foreground. Tottenville contractor's floating plant anchored at mid-channel pier. Steel erection proceeding on the Tottenville approach.

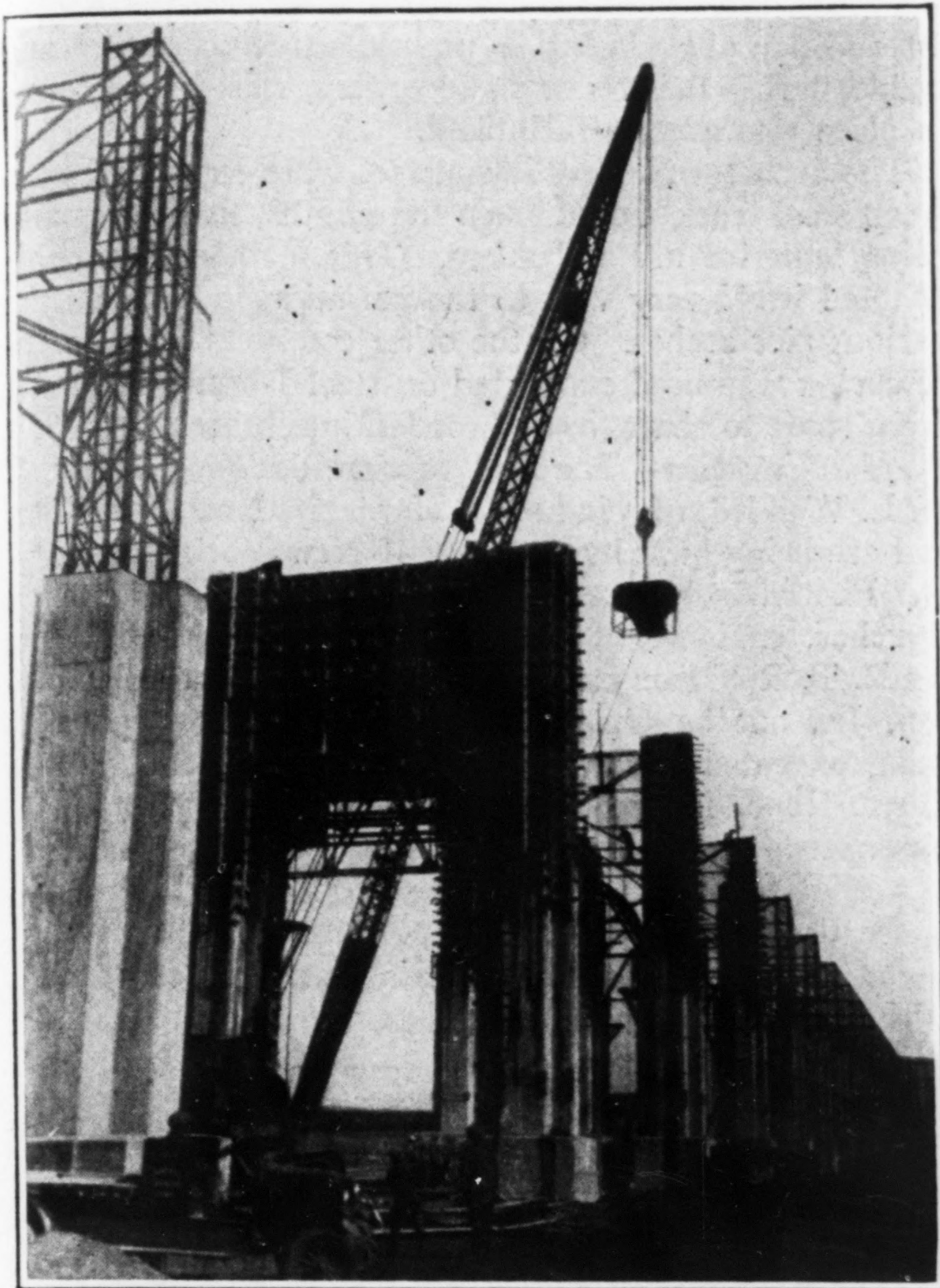


FIG. 6—PLACING CONCRETE WITH 90-FT. CRANE BOOM ON PERTH AMBOY PIERS

wooden cribs were built four tiers high on the shore and floated to place. About two tiers of bracing were added during sinking. Being spotted in the proper location, the cribs were anchored by wood piles driven in several of the pockets, and sunk by weighting with steel piling. Long steel sheetpiling—65 ft. on pier *F* and 75 ft. on piers *C*, *D* and *E*—was driven, around the cribs and to 20 ft. below the bottom bracing frame. The wood pile foundations were driven with under-water steam hammers, 25 ft. into the sand and gravel. Excavation was done with orange-peel buckets as this type best fitted into the pockets of the crib and between the wood piles.

Concreting was done from barges completely equipped as floating plants. Counterweight chutes, from towers on the barges, placed concrete as high as possible, following which mast plants were erected on the plinths for concreting the top portion of the piers. After the seal course had been placed by tremie, one 10-in., two 8-in., and two 12-in. centrifugal pumps, all direct-connected to single-acting vertical steam engines, removed the water. Thereafter the two 12-in. pumps kept the holes dry.

Land Approach Pier Construction—In constructing the land approach piers, the first necessity was access to the sites. On all of the approaches, this was difficult because of marsh land and lack of roads. The worst conditions occurred on the Howland Hook approach where top soil consisted of 5 or 6 ft. of peat and 5 ft. of grass roots and mud, the whole being in a semi-floating condition. This made it necessary to use platforms for supporting all equipment, and to lay a plank construction road as a preliminary to any actual pier building. By careful operation, a crawler crane operating on mats was able to make a fill from the peaty bog. The fill was covered with sand and a 2-in. plank roadway 20 ft.

wide supported on four rows of 12x12-in. sleepers was laid paralleling the bridge approach. On the Perth Amboy contract, too, platforms and plank roads were necessary. One of the reasons why the contractor placed his central mixing plant on piles in Arthur Kill was the difficulty of land transportation of mixing materials and of movement of a paving mixer.

The anchor pier *D*, Elizabeth bridge, required extra heavy construction. Three frames of 12x12's, 5 ft. on centers, were erected on top of the ground, and 15-in. arch-web steel sheetpiling 50 ft. long was driven around them. Braces were added below as excavation progressed to El. —38. Similar methods were used on the first 17 of the approach piers away from the channel, except that straight-web 26-ft. steel piling was adequate. Wood sheeting, 6x12-in. tongued-and-grooved, and 3x12-in. straight lumber, was used on most of the remaining piers, none of which was over 16 ft. deep. On piers 9 and 10, which were on the bank of a small creek, the steel sheeting and wood-pile supports were driven before any excavation was done. Then during excavation braces were placed between the steel sheeting and the pile supports, as well as between the pile supports themselves, to keep the bottom of the steel sheeting from bulging in.

On the Elizabeth approach, where holes 24 to 50 ft. deep were sheeted with 2-in. planking, cross-bracing was used only on the deepest of the holes. The procedure on these piers was to dig only a short distance ahead of the sheeting, tapping it down with small air hammers. Rectangular frames of 10x10's with no cross-bracing were placed on 4-ft. centers. Poling boards were used in some excavations below the vertical sheeting, and in all of the holes air-operated clay spades did excellent service in removing the shale and hardpan overlying the rock.

The unusual soil conditions on the Perth Amboy ap-

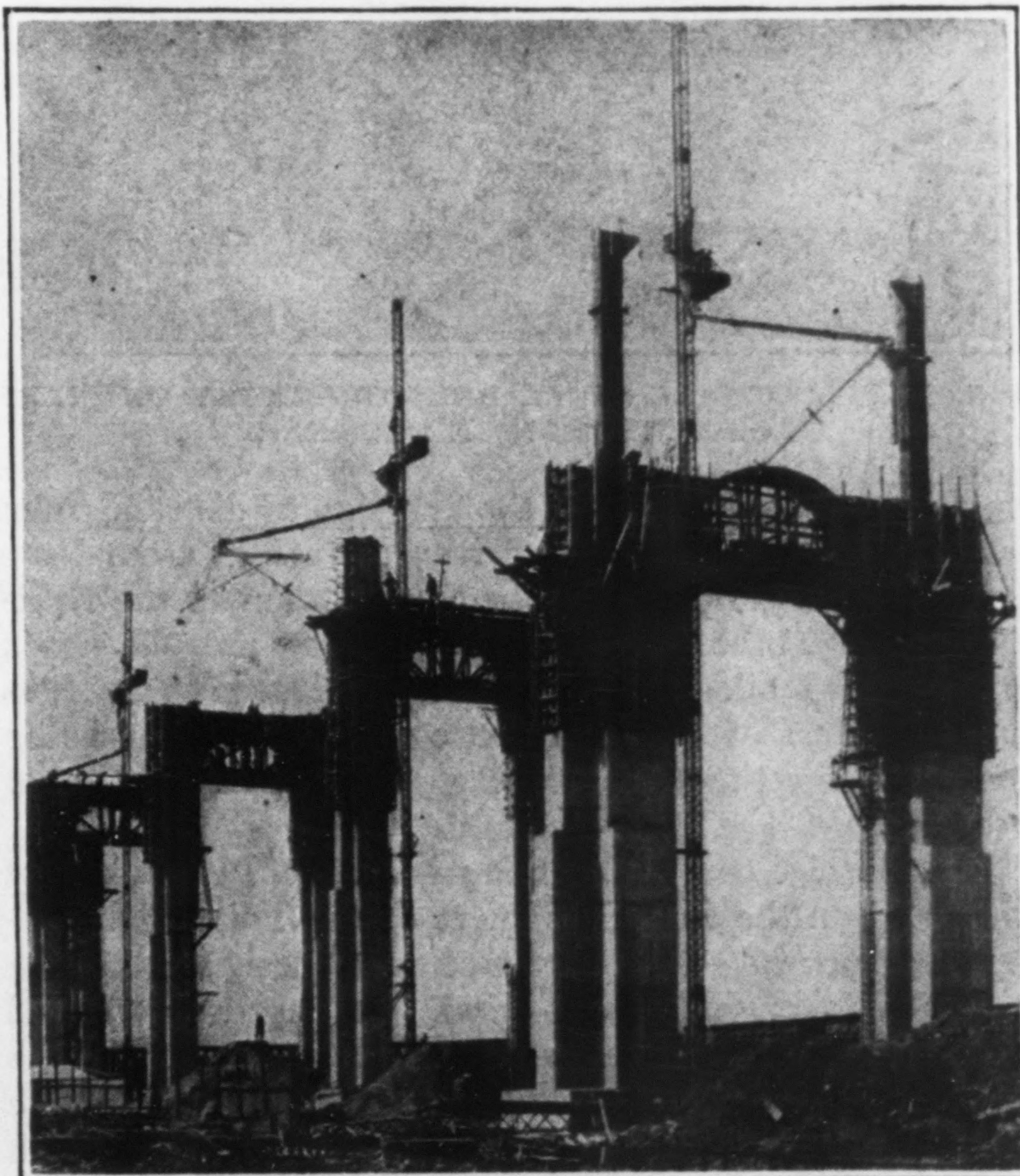


FIG. 7—CONCRETING ELIZABETH PIERS FROM MAST PLANT

On this contract, one mast, by means of counterweight chutes, served two piers, while on other contracts a mast was erected on each pier plinth. On the pier in the foreground, the steel anchorages for the bridge have been placed.

proach, as far back from Arthur Kill as pier 7, required steel-sheeted excavation with extra heavy bracing. On three of the piers, the soil pressure was great enough to cause the lower part of the steel sheeting to come in about 3 ft., and in order to save these holes the seal course of concrete was immediately poured. It was then necessary to drive another row of heavier section steel sheetpiling around the first excavation and to excavate by hand between the two cofferdams. As the excavation progressed, the inner sheetpiling was cut off in about 2-ft. sections and the braces extended to the new sheeting. The successful method finally developed for sinking these holes involved starting the excavation by ordinary methods, driving sheetpiling and placing bracing as the

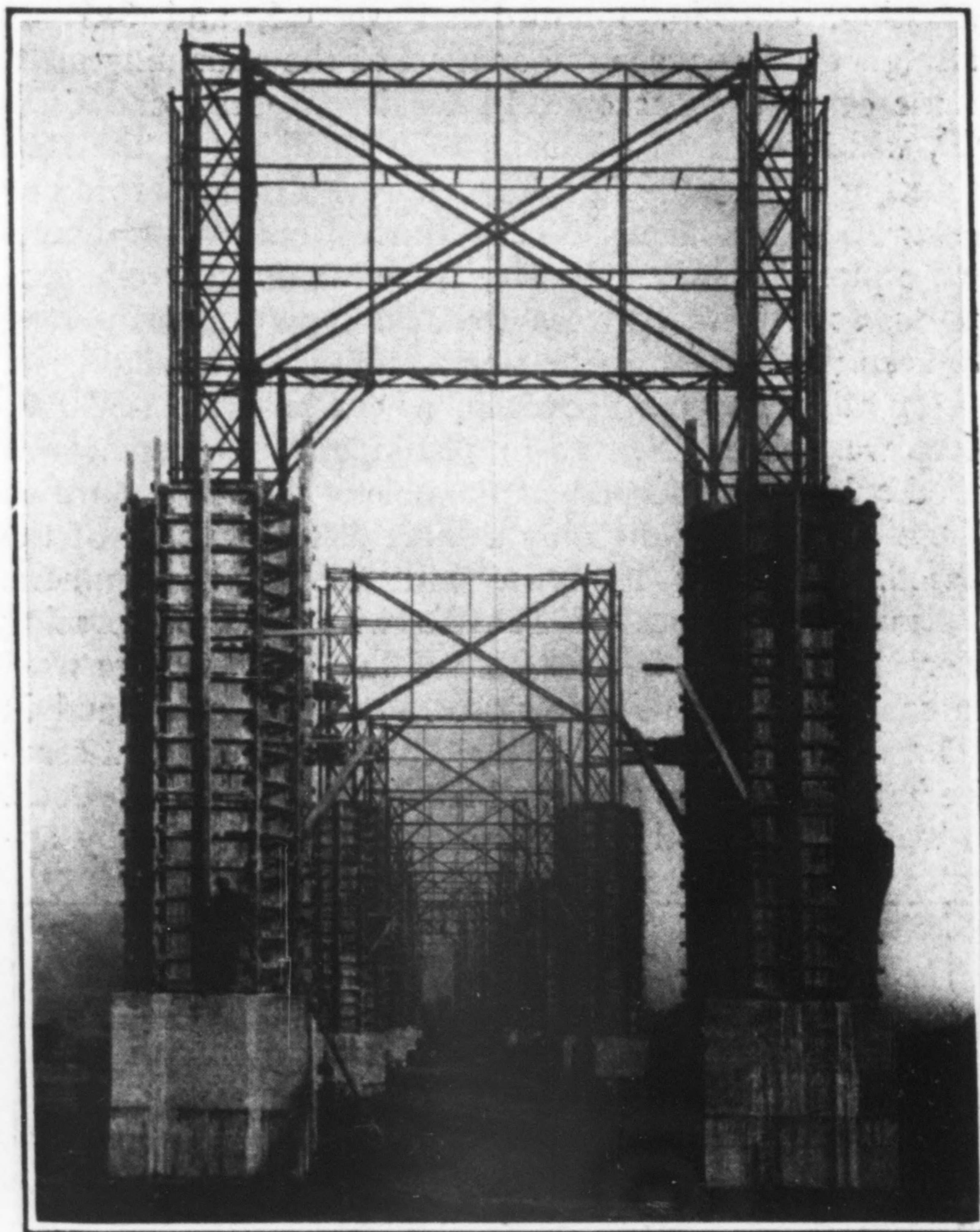


FIG. 8—STRUCTURAL STEEL REINFORCEMENT ON PIERS OF OUTERBRIDGE CROSSING

excavation progressed. At the first sign of distress, three lines of support piles were driven to refusal around the inside of the cofferdam. Then in addition to the regular framing, braces were placed between the pile heads and between piles and the steel sheeting. These piles had the effect of both compacting the soil and assisting the steel sheeting by carrying some of the external pressure.

Structural Steel Reinforcing—On the Perth Amboy piers and on the four river piers of the Tottenville contract, structural steel reinforcement, designed by the contractor's engineer, was used. It has demonstrated a number of advantages, and, although the first cost is larger than for bar reinforcement, the contractor is quite definite in his view that the time saved in erection, in form handling, in concreting, and in earlier completion of the entire work has effected a considerable final saving of profits.

It may be noted from Fig. 8 that the reinforcement when completely erected was a rigid frame. It served to support the formwork for the shaft and for the arch.

In addition, by placing a timber, carrying blocks and tackle, across the top of these towers, raising the forms in place was greatly facilitated.

The arch forms on this contract were supported by a small steel truss shored from the plinths, the shores also being built for use as ladders. This method of support adapted itself very well to the variation in radii on the various pier arches. On the other contracts, wood arch-centering was used supported on steel I-beams spanning from shaft to shaft, or by wooden kneebraces.

Administration—The bridges were designed by Dr. J. A. L. Waddell, of Waddell & Hardesty, New York City, and are being built by the Port of New York Authority. O. H. Ammann, bridge engineer, and William J. Boucher, engineer of construction. Resident engineers are R. T. Robinson on the Elizabeth bridge, and R. Hoppen, Jr., on the Outerbridge Crossing. The contracts being executed are: Howland Hook, Frederick Snare Corp., Randall Cremer, engineer, and D. H. Cameron, superintendent; Elizabeth, Triest Contracting Corp., C. M. Rauterkus, superintendent; Tottenville, Frederick Snare Corp., John Pierson, superintendent; Perth Amboy, Cornell Contracting Co., S. Kent, engineer, and J. O'Keefe, superintendent.

Use of Returned Sludge Speeds Up Water-Softening Reactions

LABORATORY tests made at Columbus and Pittsburgh indicate that the use of returned sludge hastens water softening reaction considerably, according to A. W. Bull in a paper presented before the Southwestern Water Works Association at Hot Springs in October. During winter months, these reactions are apt to be very slow and often incomplete. A number of water softening plants are adding inert sludge from the coagulation basins to speed up the softening reactions.

The tests carried out at Columbus showed that agitation for 19 hr. was necessary to reduce the soap hardness of water to 66 p.p.m. while the same reduction in hardness was secured in 2 hr. by the addition of 50 c.c. of sludge per gallon of water. Adding 100 c.c. of sludge per gallon of water resulted in the same reduction in hardness in 1 hr. The best results were secured with a concentration of sludge of 15,000 p.p.m. The treatment consisted of 11 grains of soda ash and 11 grains of lime per gallon with a temperature of 17 deg. C. That the results were not due to the presence of unused chemicals is shown by the fact that the final alkalinity and causticity were not increased by increasing the amount of sludge used.

At Pittsburgh, with a water unusually high in magnesium sulphate, it was found that the addition of 7,100 p.p.m. of sludge produced good results. The water was apparently softened as easily at 0 deg. C. as at 10 deg. C. and in both cases better than could have been done at 30 deg. C. without the use of sludge.

Another benefit noted from the use of returned sludge and increasing the concentration of solids in water prior to sedimentation is the clear effluent which is obtained. This is because of the increased area of settling solids, which tends to carry down more of the fine material as it settles.

Investigations in large-scale plant operation should be made before final conclusions are drawn, according to the paper, but the results "give encouraging indications as to what may be secured in practice."