CORPS OF ENGINEERS, U. S. ARMY

INVESTIGATION OF THE SUITABILITY OF PREPAKT CONCRETE FOR MASS AND REINFORCED CONCRETE STRUCTURES

TECHNICAL MEMORANDUM NO. 6-330

CONDUCTED FOR

OFFICE, CHIEF OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

OCTOBER 1951
PRICE $1.00

View of work area showing aggregate stockpiles, large block form under construction, and laboratory building in background

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PREFACE

The Waterways Experiment Station was authorized to conduct the investigation reported herein by a letter from the Office, Chief of Engineers, dated 4 April 1949, subject, "Civil Works Investigations - Authorization of Item 612 'Prepakt Concrete and Grouting.'"

The program of testing was based upon drawings, specifications, and an outline of tests prepared by the Norfolk District, CE, and involved the fabrication of two large test structures at the Waterways Experiment Station during April 1949 by the Prepakt Concrete Company.

The Government furnished all plans and specifications, inspection, aggregates, cement, and laboratory facilities. All testing was done by the Waterways Experiment Station.

Mr. J. H. Bowman was project engineer for the Prepakt Company. The investigation was performed at the Waterways Experiment Station by the Concrete Research Division.

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SYNOPSIS

The purpose of the investigation reported herein was to develop data on the suitability of Prepakt concrete for mass concrete dams and for reinforced concrete construction. Prepakt concrete is made by packing the forms with coarse aggregate and then pumping in a cement-base intrusion mixture (grout) to fill the voids.

Two test structures were used in the investigation. The first was a 72-cu-yd test block, analogous to a portion of a dam, the forms for which were filled with coarse aggregate graded from 3/8 to 3 in. This block was grouted in three stages. The second structure was a 15-cu-yd reinforced bridge pier containing aggregate graded from 3/8 to 2 in. and grouted in one stage.

The test program covered the following:

- a. The design of the required intrusion grout mixtures.
- b. The fabrication and testing of preliminary test specimens.
- c. The washing and prepacking of the coarse aggregate.
- d. The construction of forms.
- e. The grouting of the large test structures.
- f. The measurement of heat rise and shrinkage of the 72-cu-yd structure.
- g. Observation of efficacy of intrusion around embedded items and in difficult placement locations.
- h. Inspection of test structure surfaces.
- i. Drilling and inspection of vertical and horizontal cores.
- j. Testing of cores for strength, modulus of elasticity and resistance to natural weathering.
- k. Continued observation of the large specimens and their reactions to natural weathering.

It was found from the observations and tests that placement of 3-in. coarse aggregate in a mass concrete form presented no great difficulty; segregation in the aggregate was not a major problem. Form construction presented no unusual problems. Form pressure remained high for as long as 20 hours, a fact which should be considered in form design. The large block was grouted through horizontal pipes which remained in the block, and was accomplished without undue difficulty. Normal procedure would have been to grout through vertical pipes, which could have either been withdrawn or left in place as was done in grouting the bridge pier. High compressive and flexural strengths were obtained for cores drilled from the block and high compressive strengths for the bridge pier cores. Bond of the Prepakt concrete to precast concrete and to a limestone slab was good where the surfaces were prepared by sandblasting. Bond was poor or lacking where such preparation was not made. Void counts on cut core sections indicated a low void content in the hardened paste, probably owing to the slow pumping schedule which may have permitted the evolution of gas in the intrusion grout to occur in the mixer reservoir and pipelines rather than in the concrete. Permeability tests will be made and reported at a later date.

All findings to date indicate that mass concrete having high strength and adequate durability can be made by the Prepakt method with a portland cement content of less than 2 bags per cu yd, and that a reinforced concrete of good quality can be made by this method with a cement factor of approximately 4.0 bags per cu yd.

INVESTIGATION OF THE SUITABILITY OF PREPAKT CONCRETE FOR MASS AND REINFORCED CONCRETE STRUCTURES

PART I: INTRODUCTION

1. Prepakt concrete is made by packing forms with coarse aggregate and then pumping in a cement-base intrusion mixture (grout) to fill the voids. The purpose of the investigation described in this report was to determine the suitability of Prepakt concrete for mass and reinforced concrete construction and to obtain first-hand knowledge of the problems likely to be encountered in its use. It was proposed to construct, observe, and test two Prepakt concrete model structures, a 72-cu-yd block and a 15-cu-yd bridge pier, to obtain the desired data. Specifically, the following items were to be investigated:

- a. Effects of variation in aggregate grading.
- b. Effects of aggregate segregation.
- c. Difficulty of placing dry aggregate vs fresh concrete.
- d. Effects of spalls and dirt collecting at bottom of successive lifts of coarse aggregate.
- e. Additional operations necessary to insure coarse aggregate of adequate cleanliness and freedom from coatings.
- f. Cost of securing aggregates of the proper grading.
- g. Methods of controlling the consistency and quality of the grout.
- h. Suitable means of embedding such items as penstocks, reinforcement, and gate guides.
- i. Suitable means of determining compliance with specifications.
- j. Effects of using special ingredients: Alfesil and Intrusion Aid.

k. Applicability of present mixture design methods to design of Prepakt concrete.

l. Problems of form construction.

In addition the properties of the hardened Prepakt concrete were to be determined by observations and tests of the structures and of cores drilled therefrom.

PART II: MIXTURE DESIGNS, FORMS, INSTRUMENTATION, AND AGGREGATE PLACEMENT

Mixture Designs

Materials

2. Fine aggregate. Natural or manufactured sand may be used in Prepakt; however, the grading must be somewhat different from that employed in the mortar of conventional concrete. The largest particles of sand should in general not exceed that size which will pass a No. 8 sieve when the minimum coarse aggregate size is 1/2 in., and should not exceed that passing the No. 16 sieve when the minimum size coarse aggregate is smaller. Experience indicates that the ratio between the diameters of the smallest particles in the coarse aggregate and the largest particles in the sand should generally not be less than 4 to 1. A preliminary investigation to determine the most suitable sand grading for Prepakt concrete was made by the Waterways Experiment Station and a report thereof is included as an appendix to this report. It was determined as a result of this preliminary investigation that satisfactory gradings were as indicated in the "desired" range shown in the following paragraph.

3. Limestone sand from Liberty Limestone Corporation, Buchanan, Virginia, was used in the major work. Grading and other physical properties of this sand were as follows:

	Per Cent Passing	
Sieve	Nor-2 G-4 (S) 7	Desired
No. 8	99.8	100
No. 16	91.7	-
No. 30	66.7	60 - 85
No. 50	51.0	25 - 50
No. 100	39.7	10 - 25
No. 200	27.4	0 - 8
FM	1.51	1.40 - 2.05

Bulk Sp Gr SSD	Absorption %	Loss in 5 Cycles $MgSO_4$, %	Relative Strength of Mortar, %	
			3 Days	7 Days
2.83	0.5	1.9	121	121

4. The grading was within the desired range for fineness modulus but contained an excessive amount of material passing the 50, 100, and 200 sieves which doubtless increased the unit water demand of the grout.

5. Coarse aggregate. The coarse aggregate used in Prepakt concrete may be natural gravel or crushed stone, but the grading must be from a limited minimum size to the selected maximum size, which is usually not greater than 3 in. in the case of thin or moderately thick sections. The coarse aggregate may be graded from 3/8 in. or 1/2 in. up to any practicable maximum size in heavy or massive sections.

6. The coarse aggregate used in these tests was a granitic gneiss from the Greystone Granite Quarries, Greystone, North Carolina. It contained a considerable amount of biotite mica which presented a slick surface on at least 50 per cent of its area. The stone was also friable and tended to chip and dust.

7. The stone was used in two maximum sizes, 2-in. material for the reinforced construction and nominal 3-in. (actually about 2-1/2-in.) for the mass concrete.

8. Sieve analyses and other physical properties of the coarse aggregate are summarized on the following page.

Sieve	CRD Serial No. G-11 (1/2- to 2-in.)(Pier) Cumulative % Passing	CRD Serial No. G-11 (1/2- to 3-in.)(Block) Cumulative % Passing
3 in.	100	100
2 in.	100	90.4
1-1/2 in.	79.7	61.1
1 in.	34.5	27.7
3/4 in.	12.1	10.4
1/2 in.	2.4	2.6
3/8 in.	1.1	1.5
No. 4	0.7	0.8
Bulk sp gr, ssd	2.64	2.65
Absorption, %	0.4	0.4
Loss in 5 cycles, $MgSO_4$ %	2.4	0.5
Los Angeles abrasion loss, % grading A	40.3	41.6
Unit wt, lb/cu ft, in 3-1/2-cu-ft measure	94.2	95.5
Voids, %	43.1	42.3
Thin and elongated, %	26.6	28.5

Linear Coefficient of Thermal Expansion x 10^6/Degree F

CRD No.	Description	Parallel to Bedding	Across Bedding	In Plane of Bedding	Avg
G-11	Fine-grained granitic gneiss	3.1	2.6	3.5	3.1
G-11	Coarse-grained granitic gneiss	4.2	4.0	3.6	3.9

9. Alfesil. The Alfesil, or grout filler, was a pozzolanic material (flyash) which combined with the calcium hydroxide formed by hydration of the portland cement, and contributed to long-time strength gain and low volume change in the grout. Alfesil was furnished by the Prepakt Concrete Company in 100-lb bags. It can also be obtained in 75-lb bags,

and can be batched as readily as bagged cement.

10. Results of physical tests of the Alfesil are given below:

Sieve Analysis

Sieve	Cum. % Passing
No. 50	99.9
No. 100	98.8
No. 200	86.4
Blaine Fineness	2805 sq cm/g
Sp gr	2.43

Chemical Analysis, %

R_2O_3 (Fe_2O_3 + Al_2O_3)	2.51
SiO_2	88.78
Loss on ignition	8.13
Heat of hydration (1 g cement + 1.595 g Alfesil) cal per g of mixture,	
7 days	34
14 days	59
28 days	68

Heat of hydration by the heat-of-solution method (fig. 1) on a blend of the cement used in these tests plus Alfesil in the proportions used in

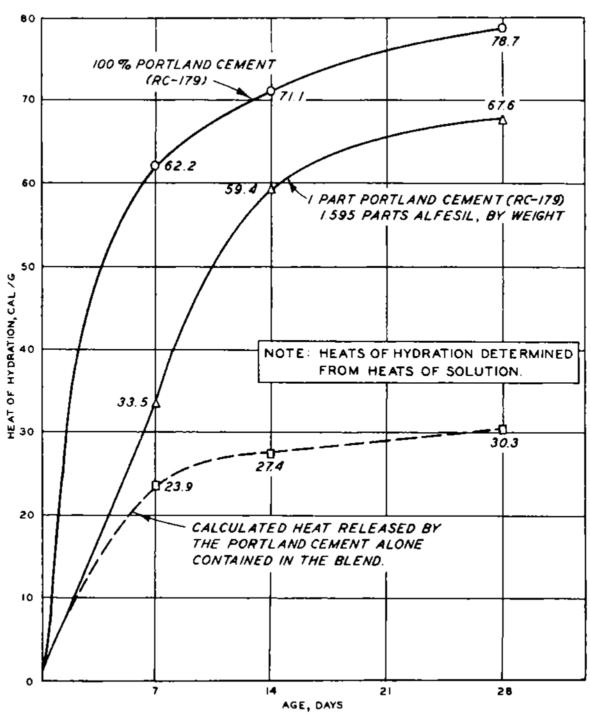


Figure 1. Comparison of heat of hydration of portland cement and portland cement-Alfesil mixture

the large block indicates 34 calories released at 7 days, 59 at 14 days, and 68 at 28 days, per gram of blend. This compares with 62 calories released at 7 days, 71 at 14 days, and 79 at 28 days for the portland cement alone.

11. Intrusion Aid. Intrusion Aid was furnished by the Prepakt Company. It is packaged in small paper bags containing the correct amount to use per batch or per bag of cement, whichever is

more desirable. Its purpose is to promote dispersion of the cement particles, reduce the water requirement for a given consistency, hold the solids in suspension, and react with the alkalies of the cement to produce a gas and cause a slight expansion before final setting.

12. Red ochre. Red ferric oxide (red ochre) was used to color certain stages of the grout to trace its progress and location. A chemical analysis of the pigment showed it to contain 82.2 per cent Fe_2O_3.

13. Cement. The portland cement used conformed to Federal Specifications SS-C-192, Type II, and was obtained in a single shipment. Chemical and physical data on the cement follow:

Chemical Data	%
SiO_2	22.42
Al_2O_3	4.19
Fe_2O_3	3.84
CaO	63.10
MgO	3.27
SO_3	1.92
Loss on ignition	0.75
Insoluble residue	0.14
C_3S	47.31
C_2S	28.68
C_3A	4.61
C_4AF	11.67
Na_2O	0.25
K_2O	0.51
Comb. Na_2O and K_2O as Na_2O	0.59

Physical Data	
Fineness, Wagner	1900 sq cm/g
Fineness, Blaine	3300 sq cm/g
Autoclave expansion	0.05 per cent
Compressive strength	
3 days	2023 psi
7 days	2933 psi
28 days	4408 psi
Time of set, initial	3:40 hr, min
final	4:50 hr, min
Heat of hydration,	
7 days	62 cal/g
14 days	71 cal/g
28 days	79 cal/g

Preliminary tests

14. Several 1-cu-yd cube forms were constructed in which the test aggregate was packed and the contemplated low-cement-factor grout mixes were tried. One cube was made using 6-in. crushed traprock with a void content as low as 25 per cent. The results of these trial tests were satisfactory. Figure 2 shows one of the forms being grouted.

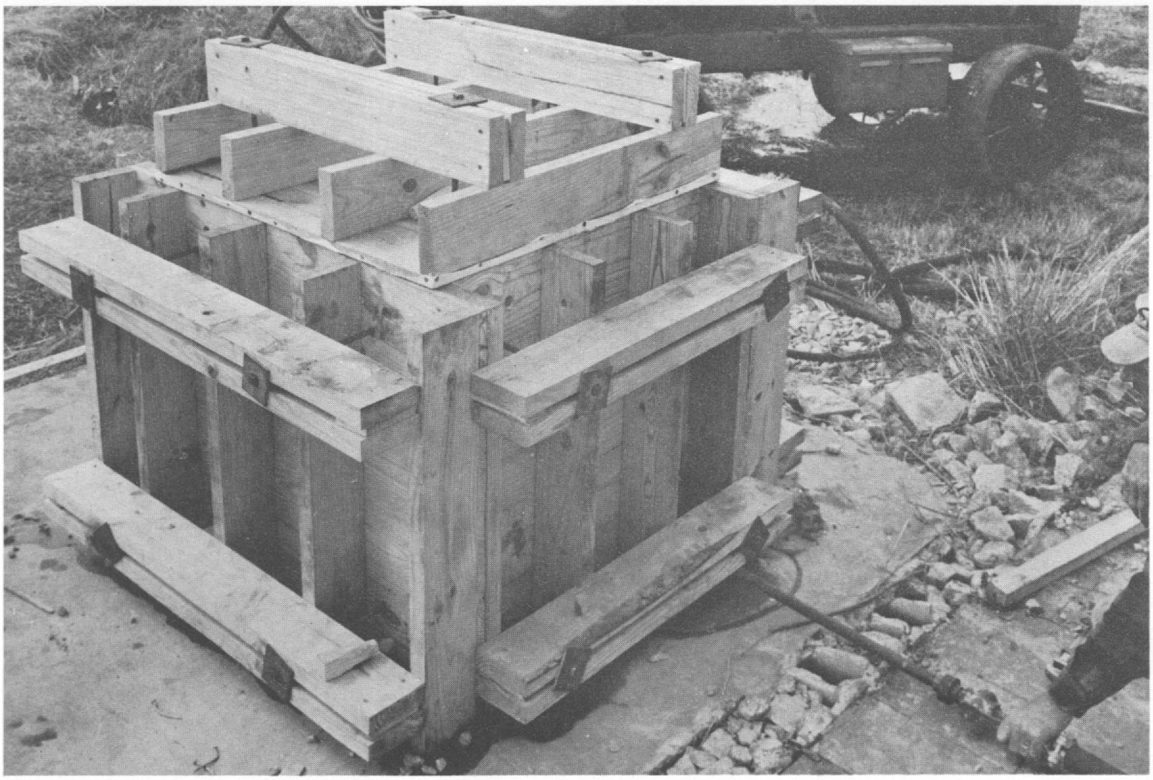


Figure 2. Preliminary 1-cu-yd cube being grouted

Design of grout mixes

15. Mixes. The grout mixtures for the mass and reinforced Prepakt models were designed to produce concrete with a 90-day compressive strength of 2500 and 5000 psi, respectively. Table 1 lists compressive strength test results on 6- by 12-in. grouted cylinders made in connection with the various mixture designs tried. Table 2 shows the final

grout mixtures used in the mass and reinforced models with cement factors calculated on a basis of 42 per cent voids in the coarse aggregate, which according to the laboratory tests and amount of grout mixed and pumped appears to have been approximately the true percentage of the voids.

16. Tests. The following tests were performed on the grouts to assure grout of proper consistency and "pumpability" with controlled expansion and proper time of set:

a. Consistency by flow cone. A 1725-ml sample of freshly mixed grout was put into a cone and allowed to flow from the cone through a 1/2-in.-diameter discharge orifice. Grout suitable for pumping had a viscosity which resulted in a time of efflux from the cone of between 16 and 22 sec.

b. Consistency by torque meter (fig. 3). The sample of grout was placed in a shallow 7-in.-diameter pan and rotated on an electrically driven turntable. A wire spider submerged in the grout sample and suspended from a piano wire received torque from the rotating grout sample. The angle of torque indicated the consistency of the grout. Consistency was controlled during pumping by use of the flow cone and determined with the torque meter as a matter of information.

c. Expansion. A sample of freshly mixed grout was allowed to stand in a 1000-ml graduate for 3 hr, and the increase in volume was measured to determine the expansion.

d. Bleeding. This was determined on the expansion sample. The volume of clear water above the grout at the end of 3 hr was measured and expressed as a percentage of the original volume of grout.

e. Time of set. This was determined by use of Vicat penetration needles.

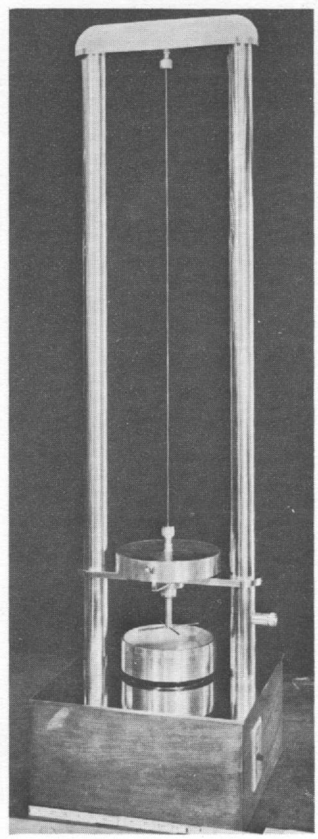


Figure 3. Torque meter for determining consistency of grout

Forms

Features of models

17. The 72-cu-yd test block contained many features and embedded items encountered in dam construction. The bridge pier could well serve as a full-scale heavily reinforced concrete overpass bent. Plates 1-5 show details of the block and plates 6-9 of the pier. Individual features of the models, and corresponding features of prototype structures, were as follows:

Model Feature	Prototype Feature
Inclined 2-ft-diameter wood-stave pipe in test block	Penstock, sluice
Rectangular formed gallery with 90-degree turn, and 8-in. gutter along bottom of the longer element, in test block	Gallery
Reinforcing bars around gallery of test block and in entire bridge pier	Reinforcement
Bond to 36-in.-diameter sandblasted rock slab in base of test block form (plates 10, 11)	Foundation bond
Precast slab forms on one end of test block	Precast slab forms
Inspection after form removal and study of cores from both structures	Quality of concrete
Variation of grout mixtures, tests of cores	Design strength
Measurement of temperature rise in test block	Heat of hydration
Three-stage grouting of test block with a 2-hr delay and a 12-hr delay	Horizontal joints
Waterstop around gallery entrance of test block	Metal waterstops
Rectangular slot blockouts on side forms of test block	Blockouts
Measurement of length change of test block	Monolith

Shelter

18. The batching and pumping equipment, the large block form, part of the intervening area between the stockpiles and test specimens and part of the adjacent area were covered by a large tent during grouting. The tent was provided principally for the comfort of the numerous visitors rather than for construction reasons. The bridge pier form was not under the tent. The covering shelter can be seen in plates 21 and 25.

Form work

19. Forms for Prepakt concrete construction may be similar to those for conventional concrete. Precast concrete slabs are frequently used as forms. The forms must be mortartight and capable of withstanding the pressure exerted by the fluid head of grout before final setting occurs, which, depending upon the mix proportions and temperatures, may take longer than 24 hr. The top of the form is usually closed with a so-called "venting form," which is described and illustrated later in this report, and which acts to prevent the top 4 to 6 in. of aggregate from lifting as grouting is completed.

20. The forms for both block and pier were located on an old concrete floor slab on the site of a demolished building.

Test block

21. Form. The form for the large block was constructed by the Prepakt Company of 2- x 12-in. tongue-and-groove lumber with 2- x 8-in. studs on 16-in. centers. Walers were doubled 2 x 8's. The lower ends of the studs were nailed to 2- x 8-in. plates which were secured by coil tie bolts to the concrete base slab. The gallery was formed of 1- x 6-in.

lumber and the inclined wood-stave pipe (penstock) was formed of 1- x 4-in. tongue-and-groove sheathing with 7 bulkheads of 2-in. material. Plates 12-15 show form construction. The joints in the wood-stave pipe were puttied and shellacked to make them mortartight. The pipe was supported in place at its lower end on one of the 1-in. tie rods which passed through the form as shown in plate 16. The top of the pipe was supported on a 2- x 8-in. plank turned on edge. There were thirty-four 1-in., round reinforcing bars surrounding one leg of the gallery form. The reinforcing was suspended by wires from the tie rods. The whole form was tied together with twenty-one 1-in. horizontal tie rods from side to side, and six 1-in. horizontal tie rods from end to end. The lower surface of each recessed form (blockouts and gallery gutter) was constructed as a venting form.

22. Precast slabs. The east end of the block form was composed of 12 precast concrete slabs 4 in. thick and 2 ft 8 in. on one side by 3 ft 3-7/8 in. on the other. Slab details are shown on plate 17 and erection details on plate 18. These slabs, as shown on plate 19, were actually held in place by means of the 45-degree 1-in. tie rods and six of the long 1-in. horizontal tie rods plus wood blocking from the outside and pipe sleeves and cable clamps on the inside. The slabs are shown after erection on plate 20. Six of the slabs were sandblasted before erection and the other six were only given a wire-brush cleaning. The slabs were precast in the laboratory prior to erection of the form, using No. 4 to 1-1/2-in. chert gravel coarse aggregate with siliceous and glacial sand. The cement was that used in the Prepakt tests, and the concrete had a 6.25-bag-per-cu-yd cement factor, and a 5.5-gal-per-bag water-cement ratio.

The extremely close fit between the slabs when erected made sealing with mortar impossible, and it was necessary to point up crevices with neat cement paste.

23. Form vibrators. Six Type-F, Cleveland Vibrator Company, pneumatic vibrators were used during the course of operations. These vibrators were clamped to the studs of the forms and moved where needed.

24. Grout pipes and wells. Five 2-1/16-in.-diameter (inside) horizontal slotted grout pipes located as shown in plates 3, 4, and 21 were placed in the block form prior to filling with aggregate. The two bottom pipes (A and B) were set with the bottom of the pipe 2 in. above the foundation slab. Two 3-in.-diameter vertical slotted sampling well pipes were located as shown on plate 2 and shown in place on plate 16. All of the above pipes had 1/2- x 12-in. slots on 12-in. centers.

Bridge pier

25. Footing. The footing for the pier was constructed of local ready-mixed concrete. Plate 22 shows the footing being chipped to insure bond prior to construction of the pier form.

26. Pier form. The pier form was of typical wood construction with 2- x 6-in. tongue-and-groove sheathing, 2- x 6-in. studs on 10- to 18-in. centers and double 2- x 6-in. walers. Stages of construction are shown on plates 23, 24, and 25. The form was tied together by use of twenty-eight 1/2-in. coil bolts and ties and four 1/2-in. tie rods. Eight 1/2-in. coil bolts and ties were used to secure in place the top venting form for the beam section of the pier.

27. Venting form. A venting form is used to form horizontal surfaces of Prepakt concrete. It consists of metal lath over the wood

form backing, insect screen over the metal lath and muslin cloth over the insect screen. Such construction permits escape of air and water when the grout is forced against it. Plate 26 is a cutaway view of the underside of the venting form; plate A-2 of the appendix also shows the venting form construction. Plate 27 illustrates grouting through the venting form.

28. Reinforcing steel. Reinforcing was of the size and amount listed in plates 8 and 9 and is shown in place in the form on plate 28. The only deviation from the reinforcing schedule was that the A-1 and A-2 bars were 1-1/2-in. round instead of 1-1/4-in. square.

Instrumentation

Thermometers

29. The following were installed to measure the temperature rise in the block:

a. Unit No. 1, one resistance thermometer plus a thermocouple 5 ft from east face, 2.5 ft from north face and 5 ft off the foundation.

b. Unit No. 2, one resistance thermometer, in same plane as No. 1, but 5 ft from north face.

c. Unit No. 3, one thermocouple on the foundation slab directly below Unit No. 2.

d. Unit No. 4, one thermocouple located in shade outside block for ambient temperature.

Shrinkage gage

30. Two 30- x 4- x 1/4-in. steel plates were placed, as shown in plates 1-4, after filling the test block with coarse aggregate, to form the reference plates for a shrinkage gage. Wooden blocks were set after the grouting was completed and the grout had hardened. Pipe rollers were

placed on the blocks to support a stainless steel reference bar fastened to one plate and in contact with the other through a dial gage reading to 0.001 in. Two mercury thermometers were taped to the reference bar for the purpose of making temperature corrections to the bar length necessitated by atmospheric temperature variations. The whole assembly is shown in figure 4. After grouting, the gage was covered with a wood and tar-paper shelter, approximately 8 in. x 8 in. in cross section, to protect it from the weather. A hinged lid provided access for taking readings. The shelter for the gage can be seen in plate 29.

Aggregate Placement

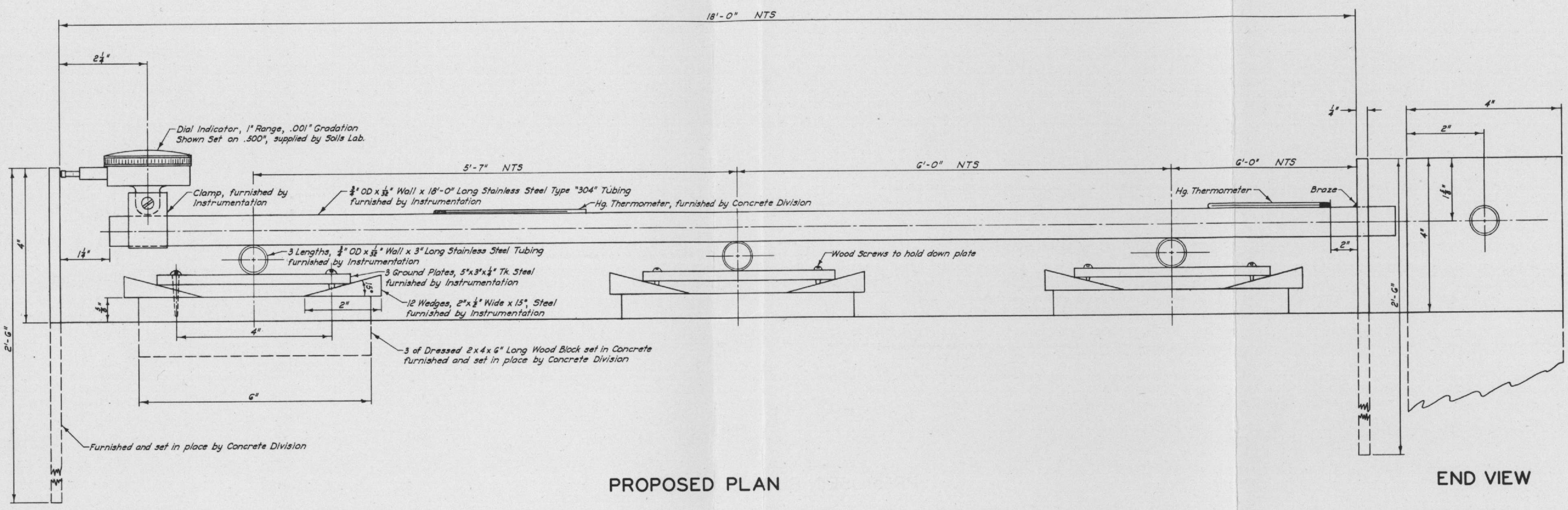
Block

31. Aggregate was placed by crane and 3/4-cu-yd clamshell bucket which, because of tie rods, etc., could not be lowered into the form, but had to be opened above it allowing the stone to drop 11 or 12 ft (plate 30). It became evident after about 4 or 5 yd had been placed in the block form that the stone contained an excessive amount of dust which clung to the wet surfaces of the aggregate particles coating them and all surfaces of the form or embedded items with which it came in contact. Placement was stopped, and the balance of the stone was washed through a portable, gasoline-powered, revolving washer. The stone already in place was washed with a hose and the water drained out through a washout hole. Clamshell placing caused an appreciable amount of breakage and did some damage to the edges and corners of the gallery and blockout forms. Placing aggregate under the gallery, penstock, and mat of 7/8-in. reinforcing bars on 12-in. centers was done by hand-shoveling from the side

and by means of a 3/4-in. blowpipe and compressed air. Plates 31 and 32 show the various steps in the placement of aggregate. The form faces were externally vibrated for three or four short intervals by means of clamp-on, Type-F, Cleveland Pneumatic vibrators to consolidate the stone while the first 10 to 15 yd were being placed. Additional consolidation was effected by walking on the stone and tamping with lengths of reinforcing steel. Plate 33 shows the form after filling. If this type of gallery were to be constructed in an actual structure the coarse aggregate should be placed in the area under the form before the form is constructed.

Pier

32. Stone was rewashed immediately before placing in the pier form. Placing was done with the crane and 3/4-cu-yd bucket permitting the stone to fall through the reinforcing steel. A 3/4-in. blowpipe was used to move stone into the column pedestal sections and around reinforcing steel in the columns themselves. The chamfer strip around the top edge of the form was damaged by stone, some of it falling from as far as 4 ft above the form. The top of the aggregate was leveled off by hand-shoveling and the venting form was set and secured in place. The clamshell bucket used here was too large for satisfactory placement in this relatively small form.



PREPAKT CONCRETE TEST BLOCK
EXTENSOMETER

Figure 4

PART III: GROUTING

Equipment

Mixing and pumping plant

33. The gasoline-powered mixing and pumping plant, shown in figure 5 and plate 34, was a portable unit comprising loading skip, water tank, mixer, agitator-storage tank for mixed grout, and pump with a vibrating screen (to remove trash) through which the grout was passed between mixing and storage tanks. Grout flowed by gravity from the ends of the agitator-storage tank to the two Wagner Simplex steam pumps which had been converted to hydraulic power and were used to pump the grout. The

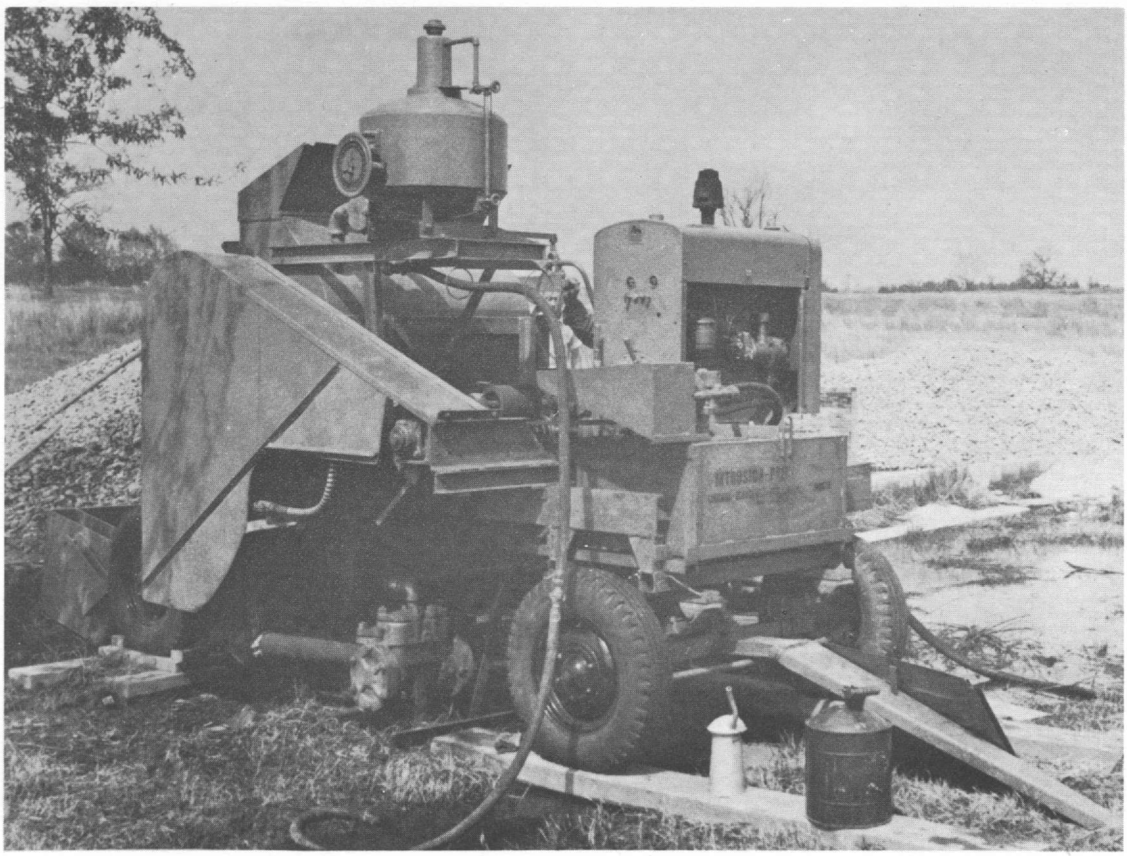


Figure 5. Grout mixing and pumping machine

quantity of grout pumped by each stroke of each pump was determined experimentally prior to grouting the test specimens. The capacity of the unit was sufficient to produce approximately 20 cu yd of Prepakt concrete per hour.

34. The equipment set up for grouting the bridge pier differed from that for the block in that the grout was pumped directly from the batching and mixing plant reservoir to the reservoirs, or tanks, of two triplex pumps from which it was repumped into the pier (fig. 6).

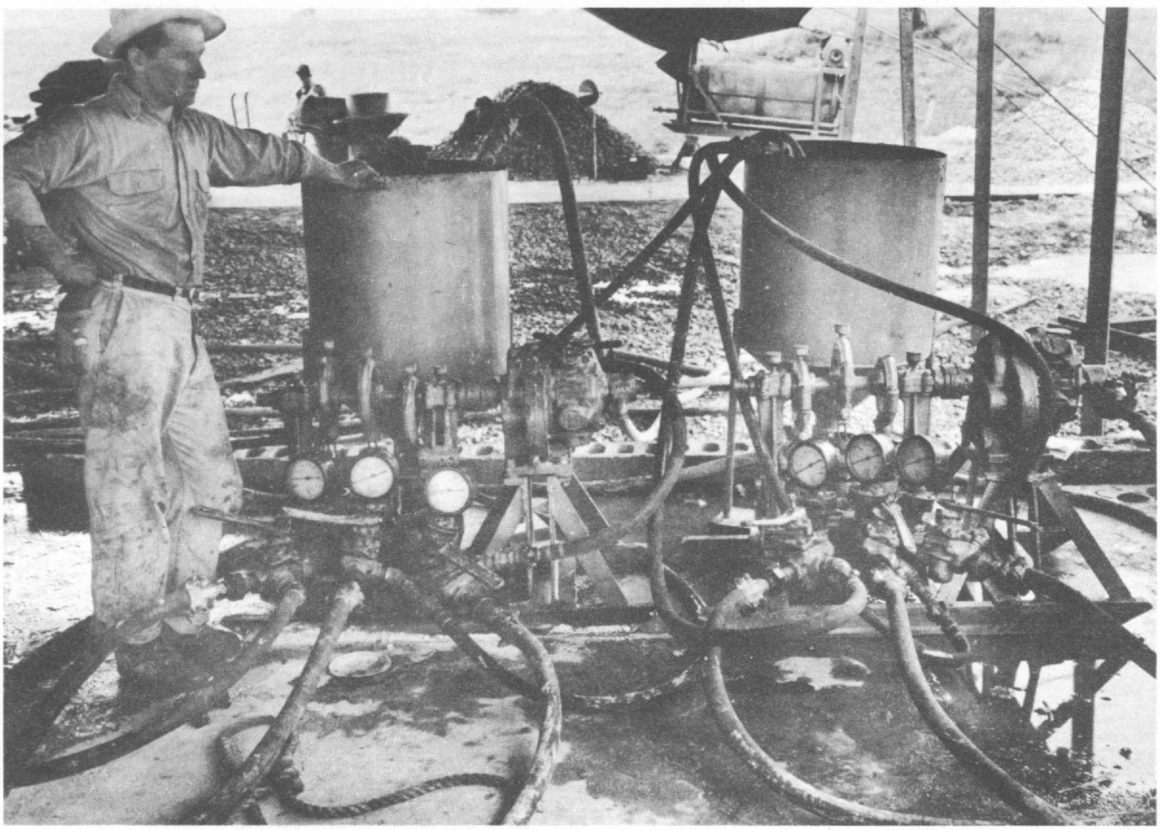


Figure 6. Triplex grout pumps used to grout bridge pier

Batching

35. Batching was done by weight, using wheelbarrows and wheelbarrow batching scale. Cement was handled in bags, the batches requiring

one bag each. Alfesil was received in 100-lb bags and every other bag was split as each batch required 150 lb of Alfesil. The actual material weights used are shown in table 3 for the large block and table 4 for the bridge pier.

Pumping Block

Grouting zones

36. Grouting was done by zones, with the pumping schedule shown in figures 7 and 8. Grouting was started through pipes A and B at zone 7

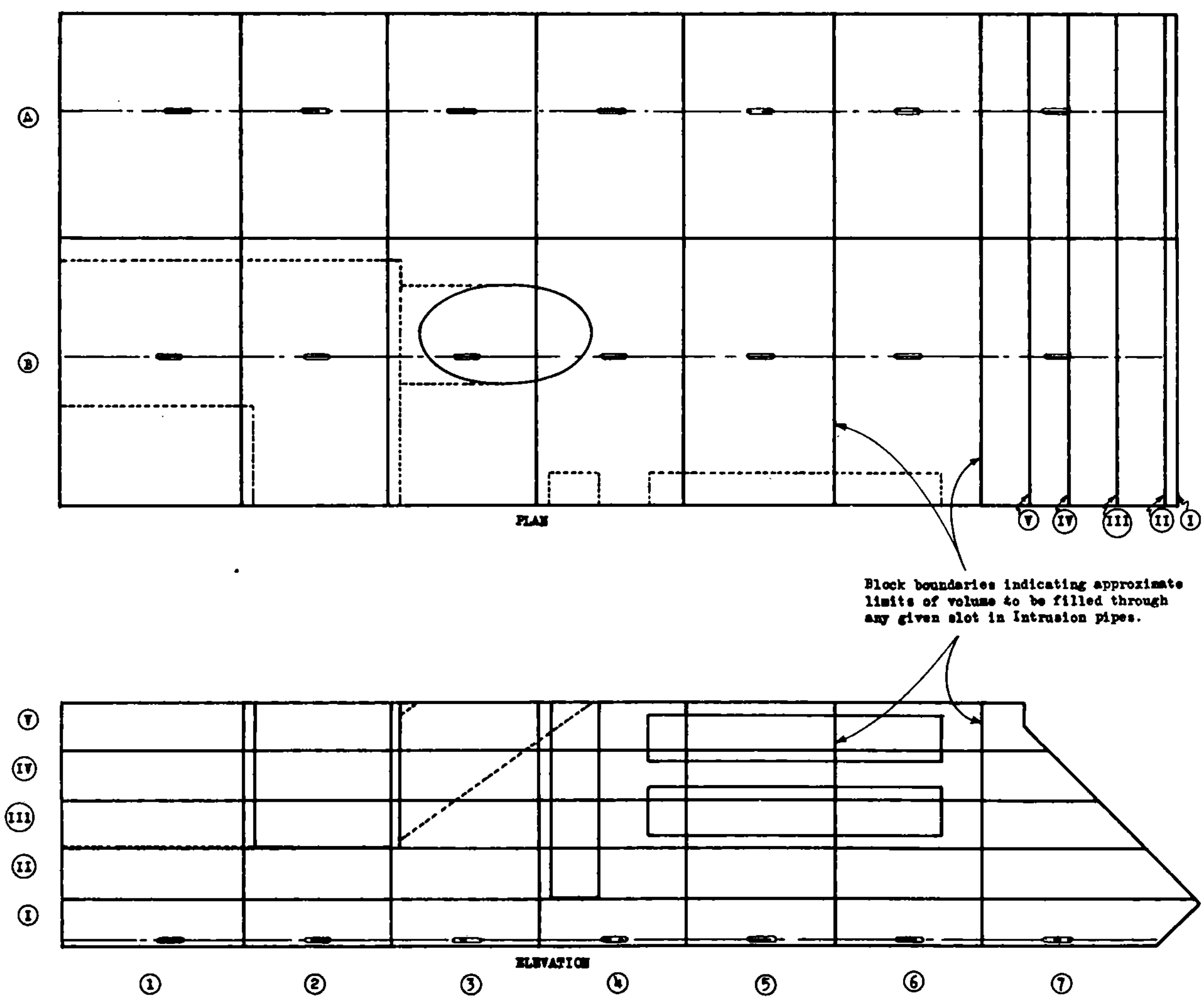


Figure 7. Prepakt concrete test block pumping schedule, lower 5 ft

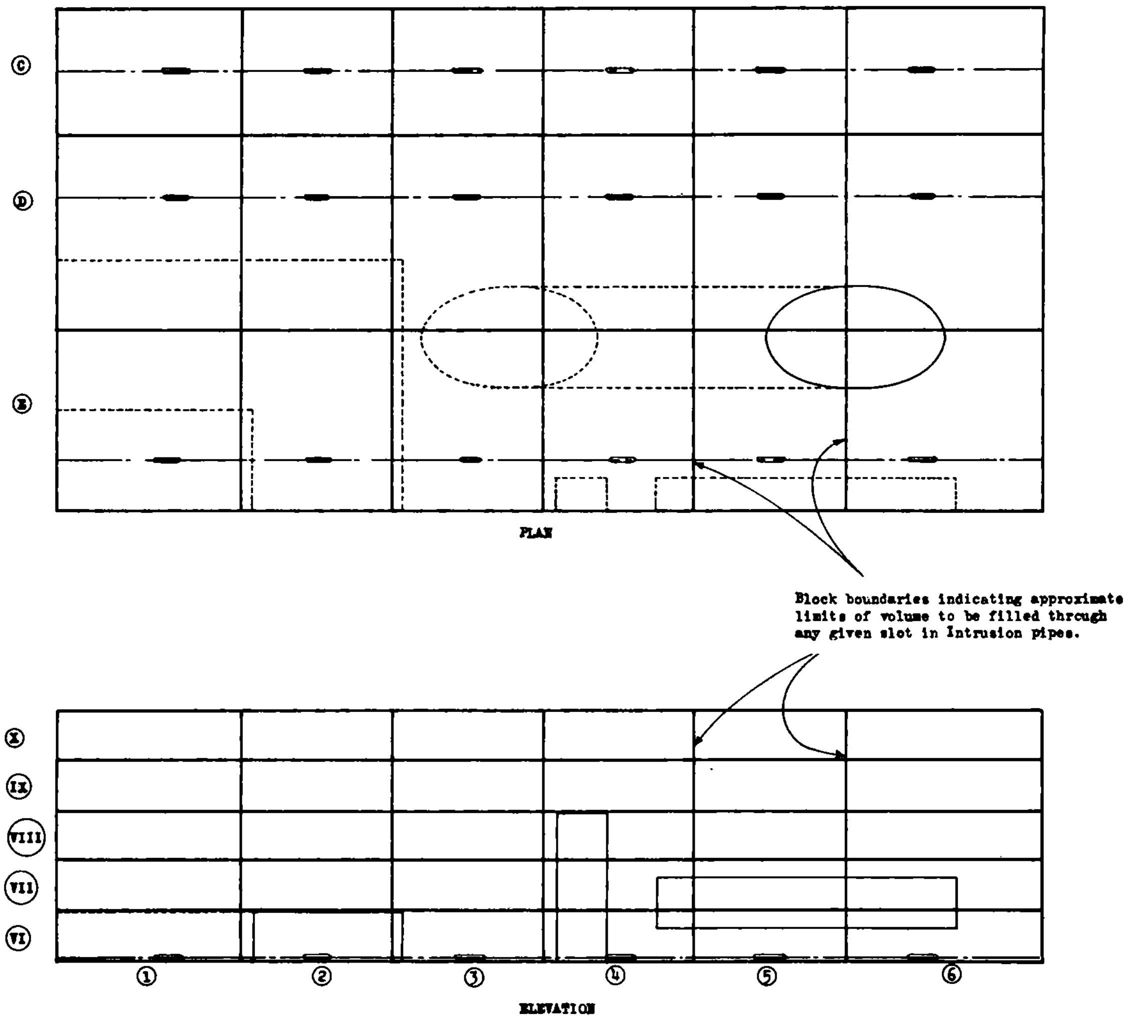
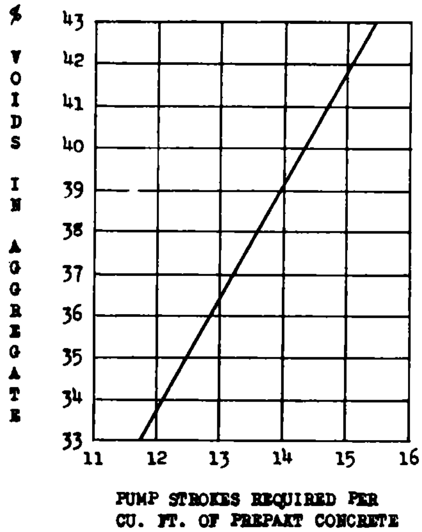


Figure 8. Prepakt concrete test block pumping schedule, upper 5 ft

until the calculated amount of grout had been pumped, according to the quantities given in figure 9, then the insert pipe was moved to zone 6 and the process repeated. Seal between the 3/4-in. insert pipe and the 2-in. grout pipes, slotted at each station, was by means of rubber packers which could be expanded from the outside. This scheme worked well in practice except that occasionally sand wedged between the rubber packer and the pipe making it difficult, but not impossible, to move the insert pipe. Grouting operations through these insert pipes are shown in



Pumping rate for Double acting Simplex Cylinder:
0.84 cu. ft. per min. at 30 strokes/minute or 0.028 cu. ft. per stroke.

TABLE OF QUANTITIES IN LOWER 5 FEET OF TEST BLOCK

Prepakt Concrete in Cu. Ft.

Lift No.	Block No. 1 A	1 B	2 A	2 B	3 A	3 B	4 A	4 B	5 A	5 B	6 A	6 B	7 A	7 B
I	16.67	20.35	13.50	16.50	13.50	16.50	13.50	16.50	13.50	16.50	13.50	16.50	18.00	22.00
II	16.67	20.35	13.50	16.50	13.50	16.50	13.50	15.83	13.50	16.50	13.50	16.50	16.87	20.63
III	16.67	9.26	13.50	2.00	13.50	14.95	13.50	15.43	13.50	15.00	13.50	15.42	12.37	15.40
IV	16.67	9.26	13.50	2.00	13.50	13.45	13.50	15.56	13.50	15.50	13.50	15.78	7.88	9.62
V	16.67	9.26	13.50	2.00	13.50	13.00	13.50	14.98	13.50	15.00	13.50	15.42	4.50	5.50

TABLE OF QUANTITIES OF UPPER 5 FEET

Prepakt Concrete in Cu. Ft.

Lift No.	Block No. 1 C	1 D	1 E	2 C	2 D	2 E	3 C	3 D	3 E	4 C	4 D	4 E	5 C	5 D	5 E	6 C	6 D	6 E
VI	9.27	9.18	7.50	7.50	7.42	0.50	7.50	10.06	8.51	7.50	10.40	8.62	7.50	11.62	10.38	9.77	15.11	13.78
VII	9.27	14.34	13.42	7.50	11.62	10.88	7.50	11.37	10.58	7.50	9.57	7.36	7.50	11.48	9.22	9.77	15.11	13.06
VIII	9.27	14.34	13.42	7.50	11.62	10.88	7.50	11.62	10.88	7.50	10.25	8.58	7.50	10.55	9.60	9.77	15.11	14.14
IX	9.27	14.34	13.42	7.50	11.62	10.88	7.50	11.62	10.88	7.50	11.26	10.44	7.50	9.57	8.43	9.77	15.09	14.11
X	9.27	14.34	13.42	7.50	11.62	10.88	7.50	11.62	10.88	7.50	11.62	10.88	7.50	9.91	8.84	9.77	14.38	13.27

Figure 9. Quantities of grout required per station in test block, and graph of pump strokes required to produce unit volume of Prepakt concrete

plate 21. It required from 12 to 18 min, depending upon the size of the zone, to grout at each station. A grouting dolly, such as shown in plate 35, would be used in horizontal pipes on large-scale grouting in place of the insert packers.

Procedure

37. Planned interruptions. The large block was grouted in three separate lifts with planned interruptions of 2 hr between lifts I and II and 10 hr, 48 min (overnight) between lifts II and III. This plan of interrupted grouting was followed to determine the effect of interruptions on the quality of the resultant Prepakt concrete and to determine if cold joints resulted. There were other occasional delays due to changing pipes, clogging of pump lines between pump and insert pipe, and clogging of the pump itself. These ranged from unrecorded delays of 5 min or less up to 40 min.

38. The grout level was at 2 ft when the 2-hr delay occurred. Two per cent red ochre was added to the grout when pumping was resumed to delineate the junction where the delay occurred. This colored grout was used until 6 to 8 in. of grout had covered the grout pipes (C, D, and E) at the 5-ft level, the point for the scheduled overnight delay. Flexible rubber hoses 2 in. in outside diameter and 20 ft long were inserted into grout pipes C, D, and E and filled with water under pressure to insure that no grout entered the slots of these pipes when the grout from below surrounded them.

39. Pumping on stage three was started the following morning through grout pipes C, D, and E after the rubber tubing in these pipes had been drained of water and the tubing withdrawn. The starting

pressures at the grout pump ranged up to 220 psi with the average starting pump pressure between 30 and 60 psi. The grout had not set overnight. All the insert packers were removed at regular intervals from the grout pipes and cleaned by means of a hose to prevent stoppage from an accumulation of sand around the rubber plugs during the day's grouting. No serious trouble was encountered and no delays occurred during the second day's grouting.

40. Bleeding. Very little bleeding was noticed the first day, but considerable water accumulated overnight and free water began to trickle through small cracks in the roof of the gallery form after about 45 min of pumping on the second day. Two holes were bored into the roof from underneath and an estimated 10 gal. of clear water drained out before the appearance of undiluted grout, at which time the holes were stopped with wooden plugs. Holes were bored in the forms to permit water to escape whenever it was observed trickling through cracks in the forms or in the sampling wells.

41. Vibration. Form vibrators were moved about and operated intermittently with three vibrators in operation on one side at a time.

42. Topping out. Zone grouting from the horizontal pipes was discontinued when grout started flowing over the top of the aggregate in several locations as shown in plate 36. It was also noticed, at this time, that what seemed to be the top 4 to 6 in. of coarse aggregate was lifting or "floating" on the grout underneath. Grout insert pipes (3/4 in.) were brought to the top of the block and inserted vertically in various places in the unconsolidated coarse aggregate. Grout was then pumped through these pipes and the pipes were moved around until

the entire top surface had been grouted. The grouting of this top layer was not as efficiently done as the grouting of the major portion of the block and consequently some air pockets developed between the zone of rising grout below and the grouted region above. The level of coarse aggregate in the form was 4 to 6 in. above the edge of the form at the finish of grouting operations, figure 10. This lifting could have been prevented by use of a top venting form or a slotted form or other means which would have restrained the aggregate. The test procedure, however, specified that no restraint was to be applied to the top of the test block.

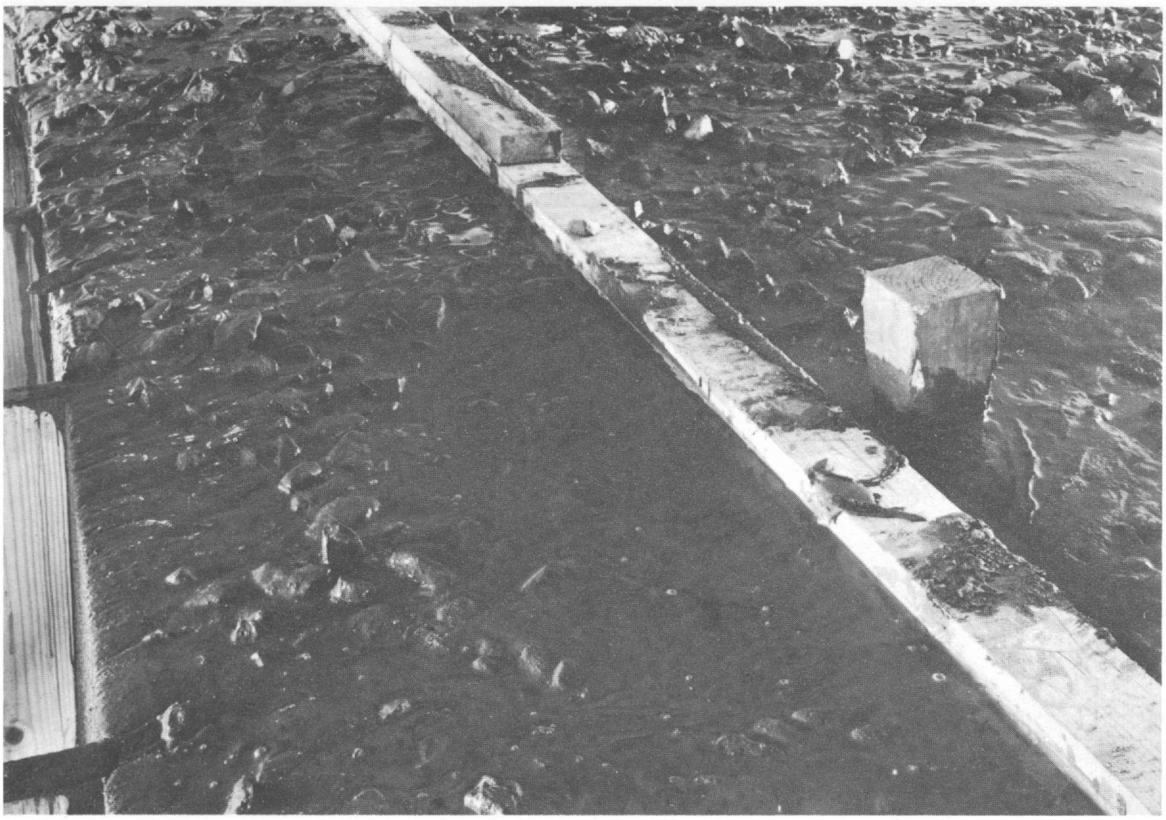


Figure 10. Test block at completion of grouting

43. Grouting the penstock. The penstock opening, after form removal, curing, and inspection, was bulkheaded at the lower end, filled with

coarse aggregate of the same size as that used in the main block, and grouted when the block was 7 days old to determine what bond could be obtained between hardened and fresh Prepakt concrete. The mixture used for this work had the proportions of portland cement:Alfesil:sand, of 1:1.06:3 by weight with a water-cement ratio to cementing medium of 0.49, and 2 per cent Intrusion Aid by weight of cement. A 3/4-in.-diameter pipe extended from the top to the bottom of the penstock for grouting, and was withdrawn as the level of the grout rose. A form vibrator was used on the bulkhead for about 5 min after the form contained about 5 ft of grout. Grouting of the penstock required 1 hr, 15 min.

Yield

44. The amount of grout entering the large block could not be determined exactly. However, computation of volume from the form measurements, taking into account the embedded items, and the lifting of the coarse aggregate as the top of the form was reached during grouting operations, indicated a volume of approximately 71.9 cu yd.

45. Determinations of voids in the coarse aggregate made in a 1-cu-ft measure on a dry rodded basis indicated a void content of 42.3 per cent. Determinations made in a 1-cu-yd box indicated a void content of 38 per cent.

46. The amount of grout entering the block was 31.5 cu yd, by count of pump strokes, which, based on a volume of 71.9 cu yd, indicated a void content of 43.8 per cent. The volume of grout mixed was 35.4 cu yd from the sum of the solid volumes of the materials batched, which indicated a void content of the block of 49.2 per cent. This latter void content is believed to be too high since some grout wastage

occurred during pumping and at the end of each day's work.

47. The possible cement factors based upon the void contents as determined by methods mentioned above are as follows:

2.06 bags, 49.2 per cent voids,

1.83 bags, 43.8 per cent voids,

1.77 bags, 42.3 per cent voids,

1.59 bags, 38 per cent voids.

48. It is believed that the true figure lies somewhere between 38 per cent and 42.3 per cent voids. This means that the portland cement factor per cu yd of Prepakt concrete in the large block was between 1.6 and 1.8 bags per cu yd.

Grout tests and specimens

49. Moisture content of the sand was determined frequently. These data and other batching data are shown in table 3. Consistency was checked and controlled by very frequent determinations with the flow cone at the mixer. A flow of approximately 20 sec was maintained. Samples of grout were extracted from the sampling wells periodically and tested for consistency, temperature, bleeding, expansion, and time of set. The samples extracted from the wells had undoubtedly been influenced by time, travel through the aggregate mass, and bleeding water which had collected on top of the grout. Data on these samples are also contained in table 3.

50. About 3 cu ft of mixed grout and coarse aggregate were removed from the top of the block and molded into four 8- x 16-in. test cylinders. An attempt was made to have them represent as nearly as possible the Prepakt concrete in the block.

51. It had been intended that a number of Prepakt cylinders would

be pumped at the time the large test specimens were made. However, these test specimens were not pumped until a week after the large block and bridge pier had been completed. Four 8- x 16-in. cylinders containing 3-in. stone (as used in the large block) were pumped with the same grout mixture that was used in the large block. Compressive strength test data on the molded and grouted specimens are contained in table 5.

Pumping Pier

Procedure

52. Vertical pipes. The pier was grouted through six 3/4-in. vertical pipes inserted at regular intervals through the top venting form (plate 27). Four of the pipes extended only to the soffit of the beam section while two pipes extended to the bottoms of the column sections. Each pipe was connected to an outlet of one of the triplex pumps. Pipes were raised as grouting progressed, however the ends of the pipes were kept submerged in grout at all times.

53. Pumping. Total pumping time for the pier was approximately 3-1/2 hr. Pumping was begun through the two pipes extending into the columns. The grout level had reached the soffit of the beam after about one hour and the pipes were raised 3-1/2 ft. Pumping was resumed starting in the pipe nearest the east end of the beam. At succeeding intervals of about ten minutes each, pumping was started in the other pipes working from east to west.

54. Grout reached the underside of the venting form at the east end first and as the grout level progressed, the pipes were successively removed and the openings plugged with wooden plugs. After the form had

been completely filled every other pipe was replaced with a grout pipe and valve to which pump connections were made and pressure of 20 psi applied for about 20 min.

55. Bleeding. Water that collected in the form from the washed aggregate or from bleeding was worked by the progress of the grout from the east to the west end of the beam section where it was allowed to escape through 1/2-in. holes drilled through the form. It is estimated that 4 or 5 gal. of water were drained off.

56. Vibration. Four form vibrators (same as used for the block) were used sparingly during grouting of the pier to aid consolidation and flow of grout into the aggregate. Leaks developed in the column sections of the pier (plugged with dry cement from the outside), and any excessive vibration would only have added to the difficulty.

Yield

57. More grout was mixed than was required to completely fill the form. Therefore it was impossible to determine the yield and calculate the cement factor of the concrete. Table 2 gives an estimated cement factor based on 42 per cent voids in the coarse aggregate which is believed to be conservative. The cement factor would be 4.4 bags of portland cement per cu yd of Prepakt concrete with this void content.

Grout tests and specimens

58. Temperature, consistency, expansion, bleeding, and time of set tests were made on grout samples and the results are shown in table 4. Four 6- x 12-in. cylinders for compressive strength testing, which contained the pier coarse aggregate and grout mix, were pumped about a

week after the pier was completed. Test results on these cylinders are shown in table 5.

PART IV: RESULTS OF TESTS AND OBSERVATIONS OF THE MODEL STRUCTURES

Temperature Rise in Block

59. Atmospheric and block temperatures were obtained daily at 8:30 a.m. by means of the units described in paragraph 29. The maximum temperature rise, caused by heat of hydration of the cement and Alfesil, was found to be 25 F. Table 6 shows the temperatures obtained for a period of 45 days within the block, and for a period of 15 days on the slab and in the air. Figure 11 is a graph of these temperatures for 15 days and shows that the maximum temperature occurred on the 5th day. The temperature rise of 27.2 F was adjusted to 25 F because the temperature of the grout on the 2nd day was approximately 4 F higher than on the 1st day. The rise in temperature on the 13th, 14th and 15th days, recorded by the unit located 2 ft 6 in. from the outside surface, is believed to have

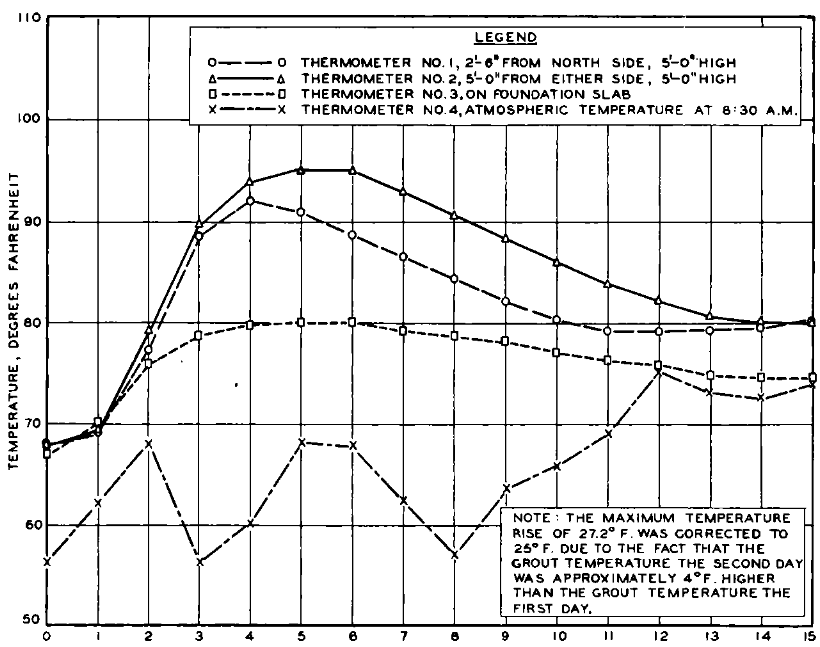


Figure 11. Temperature of Prepakt test block

resulted from the general warming of the weather at this period as shown by the ambient temperature record. The maximum temperature rise of 25 F is somewhat higher than would have been expected for the amount of portland cement contained in the large block. However, an examination of the heat of hydration data on the cement alone and the cement and Alfesil together (paragraph 10) in the proportions entering the block indicates that the Alfesil contributed considerably to the heat evolution.

Shrinkage in Large Block

60. Length-change measurements were made daily for 45 days by means of the apparatus shown in figure 4. Temperature measurements were taken at two positions along the stainless steel tube for the purpose of making corrections necessitated by the thermal expansion of the metal. Corrections were later made for a thermal coefficient of expansion of the concrete of 3.9×10^{-6} determined through a temperature range of approximately 35 and 135 F on two 16-in.-long by 10-in.-diameter core sections drilled from the block. Table 7 shows the recorded measurements and corrections necessary to obtain the percentage length change. Figure 12 shows the progressive shrinkage for the 45-day period. A freehand curve

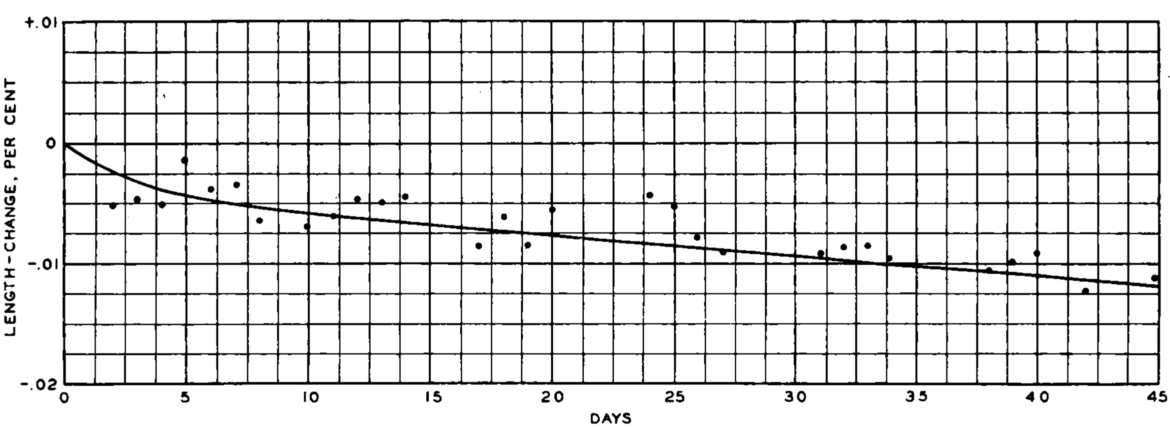


Figure 12. Length-change of Prepakt test block, measured by 18-ft stainless steel reference bar

was drawn through the scattered points and the value of 0.0120 per cent shrinkage for 45 days was taken from this curve. This shrinkage value appears to be quite low; however, it should be pointed out that the maximum shrinkage had not been reached, as evidenced by the continuing slope of the curve when readings were discontinued. There are no comparable data on conventional low cement factor concrete obtained by means of similar apparatus with which to compare this value. Shrinkage measurements on small prisms (3-1/2 x 4-1/2 x 16 in.) of concrete wet screened from 6-in., 2-1/2-bag, traprock quartz-sand concrete at time of maximum shrinkage, which occurred between 90 and 150 days, gave values of 0.031 to 0.071 depending upon the grading of the sand and air content of the concrete(1). Prof. R. E. Davis of the University of California, Berkeley, California, found the drying shrinkage of 3- x 3- x 40-in. prisms of Prepakt concrete at 2 months averaged 57 per cent as much as that of regular concrete with an average value of 0.033 per cent for Prepakt and 0.058 per cent for conventional concrete.

Stress in Form Tie Rods

Strain gages

61. The Prepakt Concrete Company, for their own information, replaced three of the 1-in. tie rods located along the 5-ft waler, one at 12 ft, one at 14 ft, and one at 18 ft from the front (west) end of the form, with 3/4-in.-diameter coil tie rods. A pair of SR-4 strain units

(1) Waterways Experiment Station, "Effect of Sand Grading on the Properties of Mass Concrete," T.M. 6-307, January 1950, p. 13.

were wired together in series to form one gage with one unit of the gage being cemented to the top and one to the bottom of the rod, near the end of each rod, between the anchor plates and nuts and the form sheathing on the south side of the form. The gage assembly was sandwiched between the two timbers which made up the waler.

Stresses

62. Observations were made after the aggregate had been placed and at various times during and after grouting to determine, if possible, the stresses developed in these tie rods. The readings indicate, that maximum stresses occurred at the end of the third stage of grouting after the form had been completely filled, and that considerable stress remained in the rods 20 hr after completion of the grouting and presumably after the concrete had set in the neighborhood of the tie rods. The relatively high stresses as late as 20 hr after the grouting had been completed may have resulted in part from expansion of the block caused by heating due to hydration of the cementing medium and to swelling of the wood forms from the curing water. It would have been expected that the stresses indicated would drop to zero upon removal of the forms. Compression in the rod was indicated, however, for gages 1 and 3. Gage 1 did show zero stress 6 days after form removal. Gage 9 at that time showed tension of 88 psi and gage 3 showed an indicated compression of 227 psi. Test results are presented in table 8.

Curing

Block

63. The block top was covered with a layer of damp sand with a

minimum thickness of 2 in. the day after pumping was finished. The openings into the gallery and penstock were closed off with roofing paper to prevent drafts through them. A wooden box covered with roofing paper was placed over the entire shrinkage gage installation. The block, with sand and shelter over shrinkage gage, is shown on plate 29. Perforated pipelines were placed along the length of the south edge of the block for water curing. After the forms were removed from the north and west sides of the block those surfaces were given a thorough spray coating of good quality curing membrane. The south side was cured by leaving the water-drenched form in place for 14 days. The east end, being precast concrete, needed no curing.

Pier

64. The bridge pier was covered with a tarpaulin the day after grouting and was kept covered during the entire curing period. A single perforated pipe ran along the center line of the beam section and provided water to keep the form wet and prevent opening of the seams for the full curing period of 14 days.

Form Removal

Block

65. The north and west forms were removed when the test block had reached an age of three days. The south side form of the block was loosened at 13 days and removed at 14 days.

Pier

66. All forms were loosened at 13 and removed at 14 days.

Appearance of Block Surfaces upon Form Removal

North side

67. The top 6 to 8 in. showed evidence of aggregate lifting producing slight scattered stratified zones with small elongated void zones. The appearance was somewhat the same as that induced by boundary friction in preventing normal settlement in conventional concrete. The zone from about 5-ft elevation to within 6 or 8 in. from the top contained surfaces which were generally very good. The lower 5-ft zone contained surfaces that were fair to good. There was evidence of general under-vibration, which was shown by 8 small patches (6 sq in. to approximately 10 sq in.) of incipient honeycomb in the bottom 6 in. Numerous isolated, very shallow elongated voids 1/2 sq in. to 3 sq in. in area, where the grout did not quite fill in between the aggregate particles next to the form, were noted above this bottom 6-in. zone. The north side is shown on plate 37 with more detailed views on plates 38 and 39.

West end

68. The appearance of the west end was very similar to that of the north side. One patch of mortar skin, about 30 sq in. in area, stuck to the form and came off in stripping. Plate 40 is a view of the west end after form removal and spraying with curing compound.

South side

69. The top 18 in. of this side showed evidence of the form moving away from the concrete mass, or of the concrete lifting and moving away from the form allowing an accumulation of water to collect next to the form face (plate 41). The surface in this region was rough and uneven

with wavy water lines. The surface was also soft and powdery and could be rubbed off with the bare hand. Three small areas of incipient honeycomb were present near the base. There was considerable sticking of the mortar to the forms on this side as evidenced by the scaled patches. The area to the left of the waterstop visible in plate 42 was typical. It is believed this could have been prevented by use of a somewhat less absorbent form material, a heavier coating of oil and possibly by stripping earlier than 14 days. There was much less evidence of under-vibration on this side. A general view of the south side of the block is shown on plate 43.

Gallery

70. Gallery surfaces were generally very good. Form marks were sharp and clear. Corners were filled out with no sticking of mortar to forms and no soft, powdery areas. Four areas varying from about 8 sq in. to 30 sq in. and about 1/8 to 1/4 in. in depth failed to fill out under the long leg of the gallery form. One place in the surface of the bottom of the gutter, about 5 sq in. in area, stuck to the form and pulled away. Plates 44 and 45 are views into the gallery; surface texture of the surrounding Prepakt is also evident.

Penstock and waterstop

71. Penstock surfaces were very good. Plate 46 is a view looking upward into penstock. Concrete filled out around the waterstop very well. Plates 42 and 45 show the condition of the waterstop and concrete around it.

Blockouts

72. Generally the surfaces of both the vertical and horizontal

blockouts were good. Corners and edges were sharp. However, there was evidence in places of water having been against the form face as shown by washed sand grains at the 4.5- to 5.0-ft elevation on the west and south faces of the vertical blockout. See plates 41, 47 and 48.

Junction between precast slabs and Prepakt

73. The junction between the precast concrete slabs and the Prepakt concrete was intimate and without apparent cracks (plate 49).

Appearance of Pier Surfaces upon Form Removal

74. The bridge pier surfaces were generally better than those of the test block. Surfaces on the column footings and columns up to the beam sections were very good. There was some evidence of under-vibration on the north side of both footings and on the west side of the east footing. The top 12 in. of the west end of the beam section showed evidence of water being trapped against the form. The surface along this zone was etched to 1/2-in. depth in places. The lower southwest corner on the west side showed an area of approximately 1-1/2 sq ft where water was trapped against the form. There was some slight scaling on the south vertical face of the beam section near the center of the span, which may have been caused by dust from the coarse aggregate coating the form prior to grouting. Plates 50 and 51 show all vertical and sloping surfaces.

Appearance of Block and Pier Surfaces, 1 April 1951

75. Surface crazing developed to a considerable extent in both the block and bridge pier, characterized by a jagged gridlike pattern (figure 13). The crazed condition developed quite early after removal of the

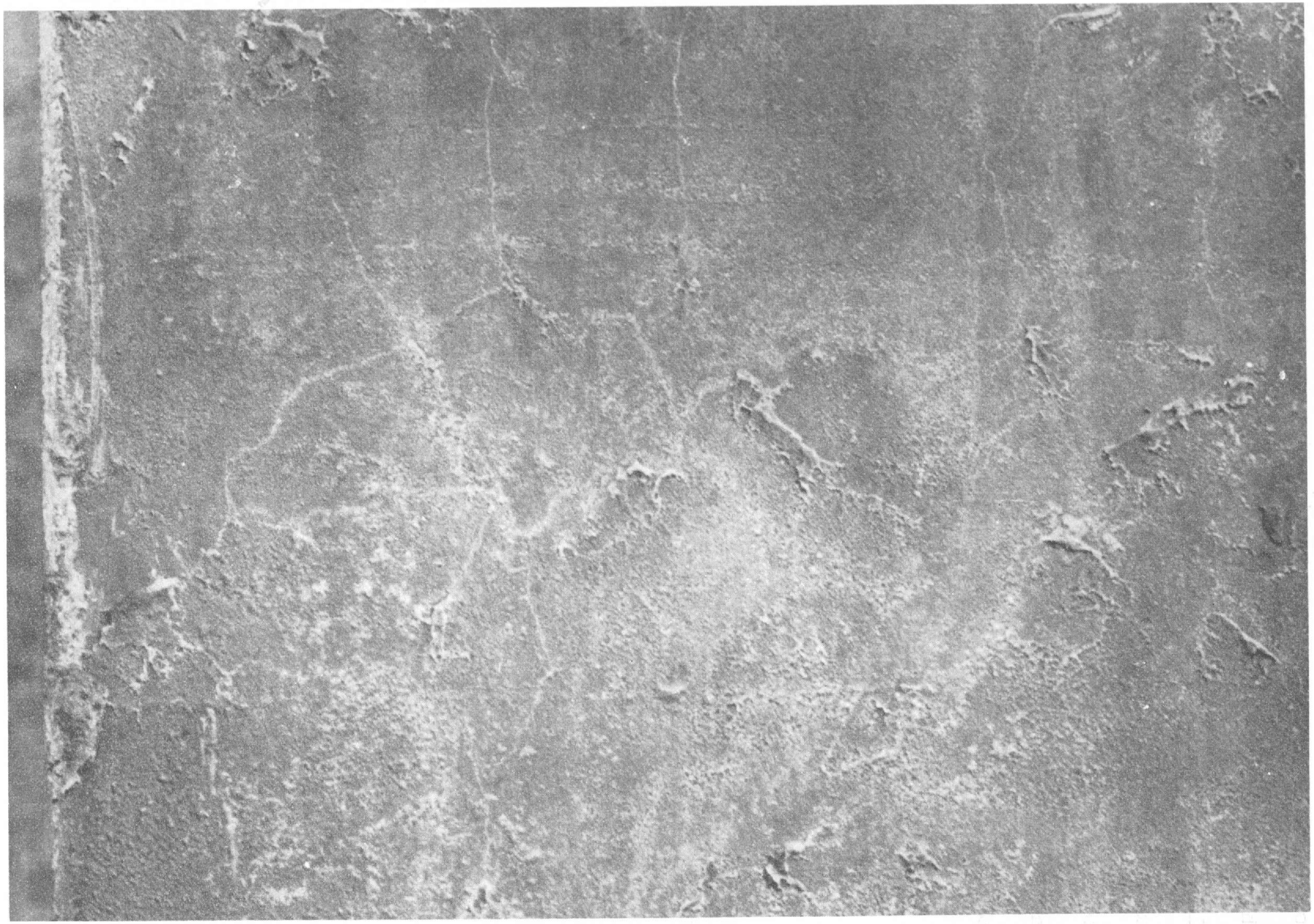


Figure 13. Typical crazing approximately natural size as it occurs on both block and bridge pier.

forms and is evident in the area above the uppermost horizontal blockout shown in plate 41 which was photographed earlier than one month after the block had been grouted. Rather deep cracks developed on the battered surfaces of the column footings on the bridge pier. These cracks appeared to be purely shrinkage phenomena as exploratory core holes into the battered surfaces indicated a preponderance of mortar and a lack of coarse aggregate packed against the form surfaces.

PART V: DRILLING AND TESTING OF CORES FROM THE MODEL STRUCTURES

Drilling

Block

76. A total of 22 diamond drilled cores were extracted from the large block for inspection and test purposes. Nine of these were drilled from top to bottom of the block. One was drilled parallel with the axis of the penstock but offset so as to intersect both penstock and block Prepakt. Twelve were drilled normal to and through the precast slabs. Figure 14 shows the location of those drilled from the top of the block, and figure 15 is a view of the precast face after extraction of the cores. Figure 16 shows the rig used to drill cores from the block at work on the pier. The following tabulation lists the core number, diameter,

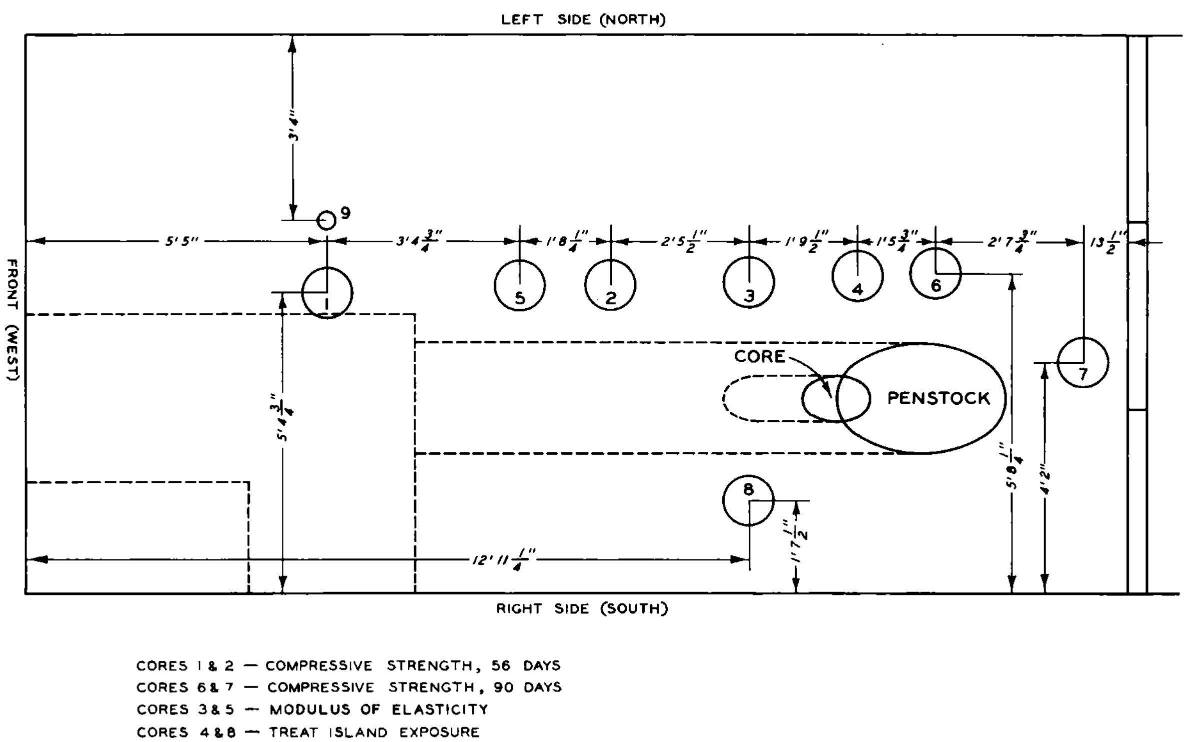


Figure 14. Location of cores, large Prepakt block

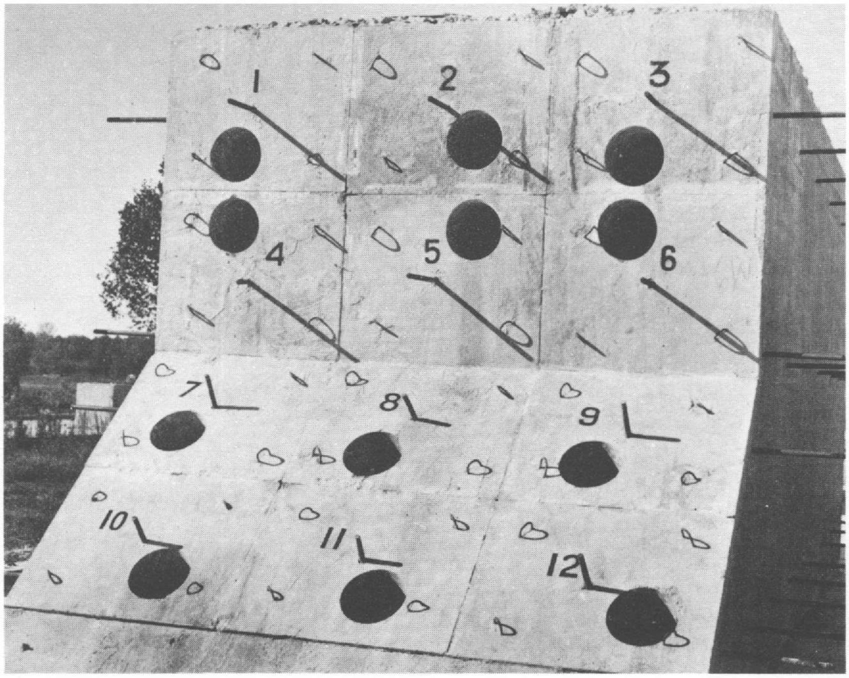


Figure 15. Back face of Prepakt block after extraction of 10-in. cores through the precast slabs.

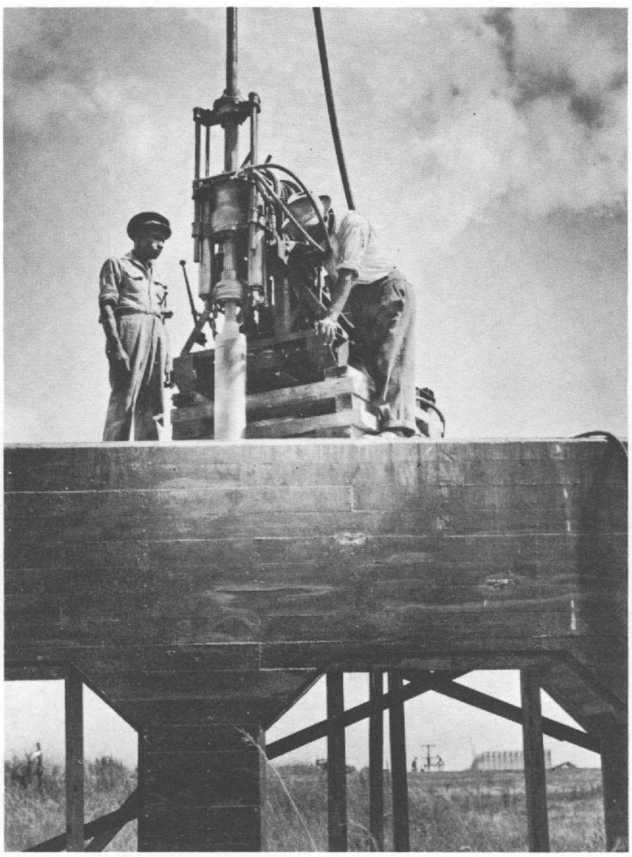


Figure 16. Drilling cores from Prepakt bridge pier.

approximate length, and purposes for which drilled.

Drilled Vertically

Core No.	Diam In.	Approx Length, Ft	Purposes for Which Drilled
1	10	10	Compressive strength tests
2	10	10	Compressive strength tests
3	10	10	Modulus of elasticity tests
4	10	10	Natural weathering tests (Treat Island)
5	10	10	Modulus of elasticity tests
6	10	10	Compressive strength tests
7	10	10	Compressive strength tests
8	10	10	Natural weathering tests (Treat Island)
9	4	10	Petrographic examination
10	10	4.3	Petrographic and bond of Prepakt to Prepakt examinations

Drilled Normal to Precast Slabs

Core No.	Diam In.	Approx Length, Ft	Purposes for Which Drilled
1-S*	10	12	Bond condition examination
2-W*	10	40	Bond condition examination and flexural strength tests
3-W	10	12	Bond condition examination
4-S	10	12	Bond condition examination
5-S	10	40	Bond condition examination and flexural strength tests
6-W	10	12	Bond condition examination
7-S	10	12	Bond condition examination
8 S	10	12	Bond condition examination
9-W	10	12	Bond condition examination
10-S	10	12	Bond condition examination
11-W	10	12	Bond condition examination
12-W	10	12	Bond condition examination

* S indicates sandblasting of slab before grouting, W wire brushing.

Table 9 gives a further breakdown of the disposition of the 10-in. cores taken clear through the block. Plates 52 and 53 show, in detail, cores 5 and 8 which are typical in appearance of all cores from the block. Plates 54 and 55 show cores drilled through the precast slabs, and plate 56 is a view of the penstock core.

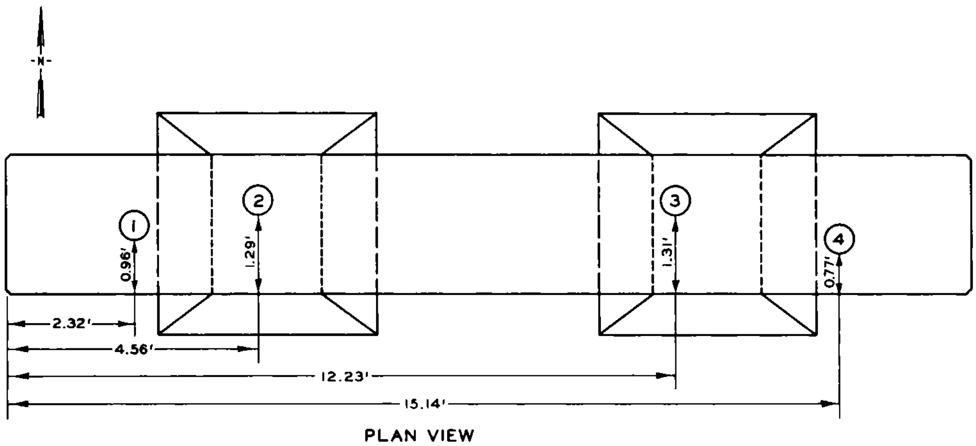


Figure 17. Locations of 6-in.-diameter bridge pier cores

Pier

77. Four 6-in.-diameter cores were drilled from the pier, according to locations shown in figure 17. Numbers 1 and 4 were through the beam section and 2 and 3 were through both beam and column. Plate 57 shows all of core 2, and plate 58 is a closeup of one section of core 2. This core was typical of those drilled from the pier. The purposes for which the pier cores were drilled are stated below:

Core Section	Core Depth from Top, Ft	Length, Ft	Purposes for Which drilled
1A	0.0 - 1.5	1.5	Compressive strength test at 90 days
1B	1.5 - 2.6	1.1	Compressive strength test at 90 days
1C	2.6 - 3.8	1.2	Compressive strength test at 90 days
2A	0.0 - 1.9	1.9	Compressive strength test at 90 days
2B	1.9 - 3.7	1.8	Compressive strength test at 90 days
2C	3.7 - 5.7	2.0	Compressive strength test at 90 days
2D	5.7 - 7.5	1.8	Compressive strength test at 90 days
2E	7.5 - 9.3	1.8	Compressive strength test at 90 days
3A	0.0 - 1.9	1.9	Compressive strength test at 90 days
3B	1.9 - 3.7	1.8	Modulus of elasticity test
3C	3.7 - 5.4	1.7	Compressive strength test at 90 days
3D	5.4 - 7.5	2.1	Compressive strength test at 90 days
3E	7.5 9.3	1.8	Modulus of elasticity test
4A	0.0 - 1.8	1.8	Modulus of elasticity test
4B	1.8 - 3.9	2.1	Modulus of elasticity test

An additional core was taken into the pedestal section of the west column to determine grout condition under the battered form surface where shrinkage cracks had appeared, and disclosed a mortar thickness of 1-2 in. where the aggregate was not packed tightly against the overhanging form.

Laboratory Tests

Compressive strength

78. Cores from block. Cores 1 and 2 were cut into 20-in. lengths and tested for compressive strength at 60 days. Cores 6 and 7 were similarly cut and tested at 90 days. After testing to a point where cracks were visible in the specimens they were set aside in the laboratory air until 182-days age when they were crushed to complete failure in the compression machine in order to develop the failure pattern for photographing. It will be noticed from the results in table 10 that there was in some cases a considerable gain in strength over the original test results, due probably to autogenous healing and continued pozzolanic reaction between the Alfesil and lime from the cement, and that the compressive strength results were extraordinarily high for the low (less than 2.0 bags per cu yd) portland cement factor of the concrete. The minimum strength at 60 days was 2320 psi, the maximum strength was 4275 and the average was 3245. At 90 days the minimum strength was 3310 psi, the maximum was 5085 and the average was 4105. Data given in table 5 for cylinders molded from Prepakt grout, block mix, plus coarse aggregate show an average compressive strength of 3815 psi at 90 days. Plates 59 and 60 show some of the cores broken down to show failure pattern.

79. Cores from pier. Three 12-in. sections were cut from core 1,

five from core 2, and three from core 3, and tested in compression at 90 days. These cores were also set aside and at an age of 182 days were broken down in the compression machine preparatory to photographing. The minimum strength obtained was 5285 psi and the maximum was 7820 with an average of 6710, all of which are extraordinarily high for concrete with a portland cement content of less than 4.5 bags per cu yd. The strengths obtained when the cores were completely broken down were, in all but one case, equal to or greater than the original values. Test results are shown in table 11. Plate 61 shows failure patterns developed by sections of cores 1, 2 and 3.

80. Special tests were made on 2-in. cubes containing the mixtures of Alfesil, sand, and water indicated below, because of the high strengths obtained on cores from the test structures.

Compressive Strength, 2-in. Cubes, psi

Series	Material	28 Days	90 Days	180 Days
A	Alfesil + water	103	160	Not made
B	Sand + water	0	0	0
C(1)	Alfesil + sand + water	108	125	112
C(2)	Alfesil + sand + water	147	178	142

(1) Proportions Alfesil to sand used in block
(2) Proportions Alfesil to sand used in pier

From the above tests the Alfesil itself appears to have some strength-gaining properties even though the strength results shown are quite low. The addition of sand to the mortar did not contribute materially to the strength developed. However, none of the above tests indicate conclusively that the high strength obtained in the concrete from the test structures can be attributed to the Alfesil or to a reaction between the Alfesil and the fine limestone sand.

Modulus of elasticity

81. Cores from block. The modulus of elasticity was determined by dynamic means on five sections of core 3 and four sections of core 5, and the results are shown below:

Dynamic Modulus of Elasticity, $E \times 10^{-6}$ psi

Core 3		Core 5	
Section 3A	= 4.7	Section 5A	= 5.2
3B	= 5.0	5B	= 4.4
3C	= 4.7		
3D	= 3.9	5D	= 4.3
3E	= 4.6	5E	= 5.1
Avg	= 4.6	Avg	= 4.8

These values appear to be normal.

82. Cores from pier. The modulus of elasticity was determined dynamically on each of the two sections of cores 3 and 4, with results as follows:

Dynamic Modulus of Elasticity, $E \times 10^{-6}$ psi

Core 3		Core 4	
Section 3B	= 4.8	Section 4A	= 4.6
3E	= 4.5	4B	= 4.5

These values appear to be a little low considering those obtained on the cores from the large block. It would be logical to assume the modulus of elasticity of the higher strength bridge cores would be somewhat higher than the lower strength cores from the large block.

Flexural strength of beams sawed from cores

83. The horizontal cores taken from holes 2 and 5 through the precast slabs of the test block furnished specimens for determining the

bond of precast concrete to Prepakt specimens and for the sawing of 6- x 6- x 30-in. beams for flexural strength tests. One beam was tested in flexure with third-point loading at an age of 154 days and one at an age of 187 days. Strengths were quite high, but not out of line considering the high compressive strength of the same concrete. The beam cut from the core drilled through slab No. 2 is shown in plate 62 after testing. Test results follow:

Flexural Strength of 6- by 6- by 30-in. Beams Cut from Horizontally Drilled 10-in. Cores

Beam No.	Test Age, days	Break		Modulus of Rupture, psi
5	154	1		700
5	154	2		640
			Avg	670
2	187	1		695
2	187	2		765
			Avg	730

Bond condition

84. Bond between precast and Prepakt concrete. The combination precast and Prepakt cores extracted to show bond with the Prepakt (plates 54 and 55) were examined petrographically for apparent bond condition and those findings are described in paragraph 97 and table 13. The composite cores that had not separated at the bond plane were tested in flexure after the examination, using an outrigger device to produce a 30-in. span and loading the joint plane to failure. An additional test was made on the Prepakt concrete itself, in cases where the length of core permitted, to determine the strength of that material for comparison with the strength of the bond at the joint. The bond was stronger in one case (core 1-S)

than the precast concrete which failed at 492 psi.

85. Only one of the wire-brushed-treated joints developed an appreciable bond, while all the sandblast-treated joints had good bond except one. The bond of the Prepakt concrete to the precast concrete was in excess of 70 per cent of the Prepakt concrete flexural strength when the surface of the precast concrete was prepared beforehand by sandblasting. Failure was partly in the joint plane and partly in the Prepakt concrete when appreciable bond was developed. The test results are summarized in table 13.

86. Bond between the grout and the chipped concrete of the base of the pier was sharply defined and intimate as shown by an inclined core drilled through the toe of the bridge-pier footing into the concrete of the base.

87. Bond between new and old Prepakt. Plate 56 shows the core taken along the axis of the penstock and intersecting the junction of the block and plug. Lack of bond will be noted between the new and older Prepakt. No preparation of the older Prepakt surface was made prior to grouting the Prepakt plug. Such preparation should be made where it is desired to bond new to old Prepakt.

88. Bond between Prepakt and rock. The bond between a sandblasted section of limestone rock core (plate 10) placed in the bottom of the block form (plate 11) and the Prepakt grout was found to be good by examination of core 5, section E (plate 52). The contact between grout and limestone was a gently curving plane with visible differences in elevation of about 1-1/4 in. The bond was very close, and at magnifications up to 60X (see figures 18 and 19) no opening between limestone and

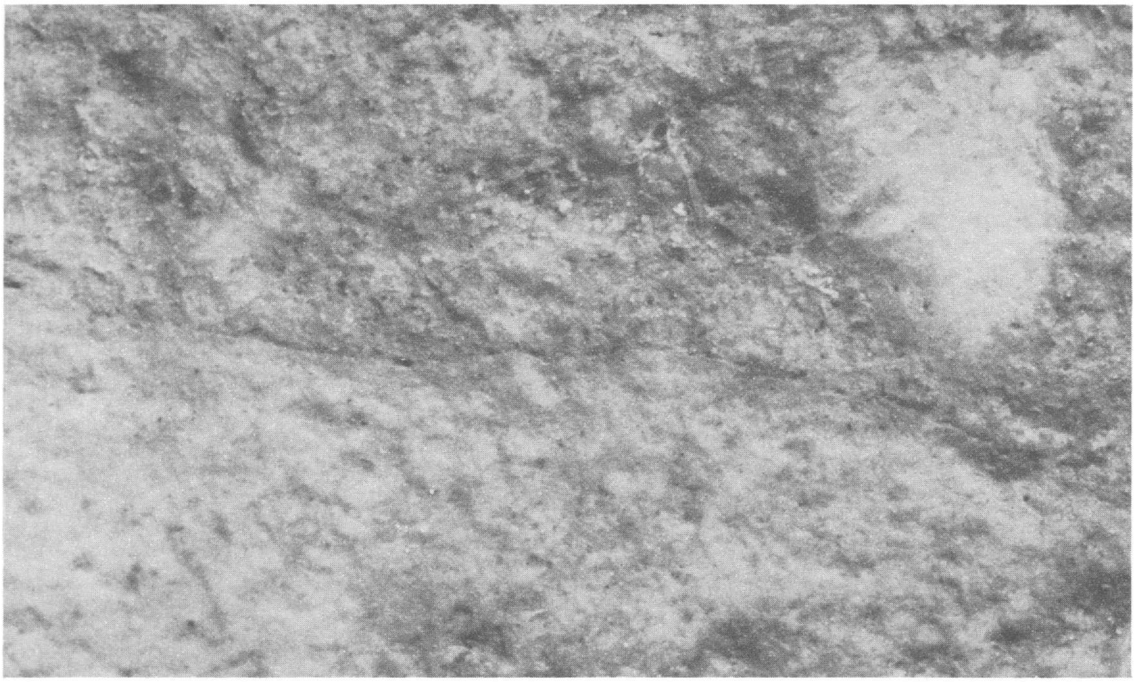


Figure 18. Surface of 10-in. core as drilled, 24X, showing contact between Prepakt grout above and limestone slab.

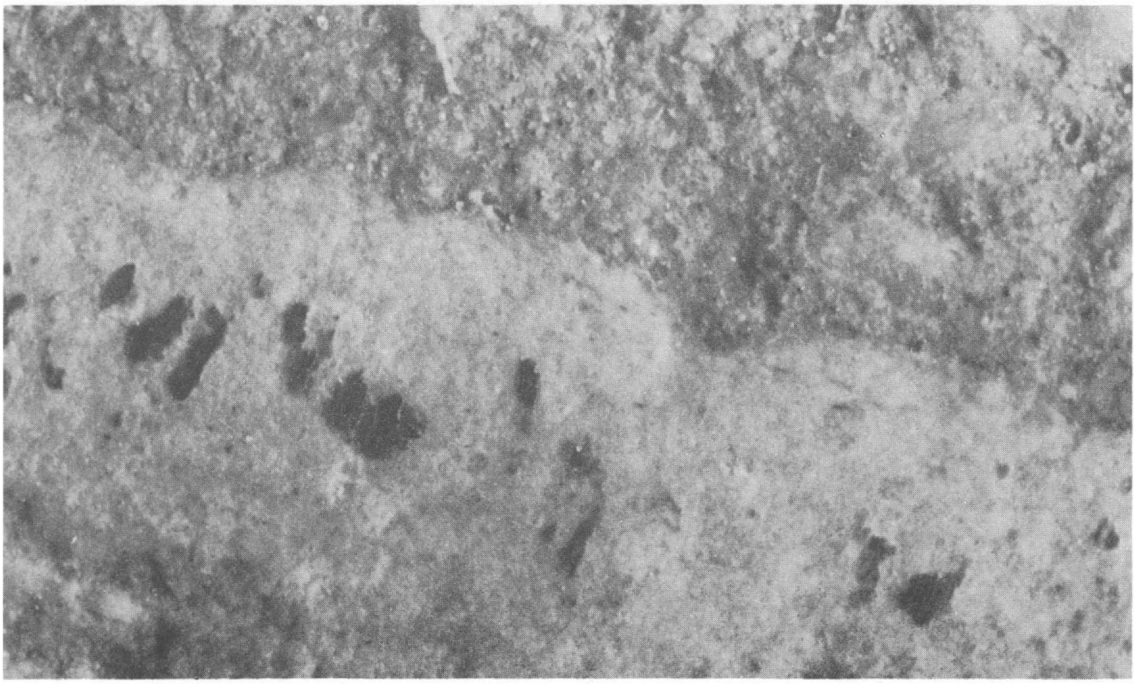


Figure 19. Surface of 10-in. core as drilled, 24X, showing contact between Prepakt grout above and limestone slab.

grout could be detected, except for a few small elongated voids on the contact.

Natural Weathering at Treat Island

89. Four 10- by 16-in. core sections from core 4 large block and five 10- by 16-in. sections from core 8 (table 9) were installed at half-tide elevation on the exposure rack at the Treat Island exposure station in Cobscook Bay, Eastport, Maine, during October 1949. Here the specimens were exposed to the air by the falling tide and covered with sea water by the rising tide. They underwent alternate cycles of freezing-and-thawing when the air temperature was below 28 F. The cores have gone through two winters of exposure to date (spring 1951), approximately 200 cycles of freezing-and-thawing, and all showed an increase in dynamic modulus of elasticity; also visual inspection indicated no deterioration.

Petrographic Examination

Samples

90. The samples subjected to examination are identified below.

Core Number		Diameter, In.
1-12 S and W	Drilled through vertical and inclined pre-cast slabs facing the east end of the test block	10
9	Drilled vertically through the test block, at a point 5-1/2 ft east of the west end and 3 ft 4 in. south of the north side	4
Unnumbered	Drilled along the wall of the penstock and including the penstock boundary as a curving plane parallel to the long axes of the cores, depths 0-1.4 and 1.4-3.2	10

Core Number		Diameter, In.
5-E	Drilled into limestone slab placed in bottom of form	10
2	Broken and sawed sections from core 2 drilled vertically in west column of bridge pier	6
3	Four 20-in. sawed sections and broken sections of core 3 drilled vertically in east column of bridge pier	6
5	Inclined core into west footing and foundation of bridge pier	6

Procedure

91. All of the cores and beams were examined megascopically. Many were wetted and examined using the stereoscopic microscope. Several polished surfaces were prepared and examined using the stereoscopic and metallographic microscopes.

Results

92. Only the results of the examination of core 9 (the one taken specifically for that purpose) are reported in detail herein. Summary results are given in subsequent paragraphs on all cores examined.

93. Core 9. This core represented the whole depth of the test block and permitted comparison between the concrete produced in the three stages of grouting, and examination of part of the boundary surface between stages 1 and 2 and 2 and 3. There was no bond between the bottom of the core and the foundation. The bottom 6 in. of the core was deficient in coarse aggregate as compared to the higher sections. The same condition was found in cores from the original Prepakt panels. (See appendix hereto.) The core from the foundation to 7.9 ft represented

gray grout of stage 1. The grout was dense and low in gas voids, but the concrete contained many irregular voids up to 1 in. long located between closely packed aggregate particles. All of the grout up to 7.9 ft was gray except for a patch of red which filled a 1-in. opening near the top of the gray layer. The section was broken, in extracting the core, on a sharp irregular boundary between the gray and the red grout. The core, from depths 7.9 to 5.8 and 5.8 to 4.9 ft, represented red grout of stage 2. The red grout contained more gas voids than that of stage 1, and filled the interstices between coarse aggregate particles more completely. Some parts of the core surface had excessive quantities of coarse sand in the grout; these areas are adjoined above by patches of grout containing no sand retained on the No. 30 sieve. Apparently this situation came about when the grout was forced into a narrow aperture between coarse aggregate particles. The more fluid constituents squeezed through the aperture, the larger sand particles were left behind and formed a porous barrier through which the finer sand and paste moved. The areas deficient in coarse sand are not generally areas of incomplete filling. Apparently the main mass of the grout by-passed these pockets through other channels. The boundary between the upper surface of stage 2 and the lower surface of stage 3 occurred in the middle of a core section at a depth of 4.7 to 4.9 ft. It was an irregular curved surface with no crack at the boundary. The contact was sharp and well defined, with some interfingering. Some parts of the upper 2 in. of red grout were deficient in coarser sand; the lower part of the gray grout of stage 3 contained a normal amount evenly distributed. Filling was more complete in the upper part of the red grout than in the lower part of stage 3. Stage 3 was represented by 3 pieces of core from depths 4.7 to 0.0 ft. All of the core from stage 3 contained more and better distributed gas voids than the core from stage 1. The filling was generally complete, but there were irregular voids between coarse aggregate particles in close contact in the core from depths 1.8 to 1.0 ft. The section from depths 3.5 to 1.8 contained a few areas deficient in coarse sand.

94. Gas void content. Void content determinations were made by means of the microscope. Two specimens from the bridge pier and four specimens from the test block were counted. The results are contained in the following tabulation:

Specimen Location	Voids in Grout, Per Cent	Prepakt Concrete, Per Cent Voids*
Bridge pier core 5, inclined core into west footing containing a large volume of grout without coarse aggregate	7.9	3.3
Bridge pier core 2A, drilled vertically into west pier, about 3/4 in. below top	3.7 (see par. 95 below)	1.6
Test block core 9, 4 in. diameter, elevation 9 ft, gray grout of stage 3, Specimen 1	10.3) 10.9 avg	4.6
Specimen 2	11.4)	
Test block core 9, elevation 5.4, red grout at stage 2	10.5	4.4
Test block core 9, elevation 1.6, gray grout at stage 1	7.7	3.2

* Based on 42 per cent grout content.

95. The specimen from bridge pier core 2A is probably not representative; the value is almost certainly too low and it is believed that the 7.9 per cent value is nearer to the proper order of magnitude than

the 3.7 per cent value. The values for the three stages of the test block agree qualitatively with observations on the other core sections.

96. Horizontal and inclined cores through precast slabs. The results of examination of the 6 horizontal and 6 inclined cores drilled through the precast slabs are reported in table 12.

Summary of findings

97. The cores (paragraph 90) were examined with special attention to bond, segregation in the grout, distribution of coarse aggregate, and distribution and type of voids. The general condition of all cores was excellent as can be judged from the photographs. A summary of the findings follows:

a. Bond of grout to coarse aggregate. Bond of grout to coarse aggregate was excellent and uniform all around coarse aggregate particles in the test block and the bridge pier where grout filling was complete. Entrapped air voids were commonly found between coarse aggregate particles in point contact where filling was not complete. Almost no evidence of underside voids could be found in areas where filling was complete. The coarse aggregate contained a rather high percentage of flat and tabular particles. The elimination of air pockets is more difficult where such particles are closely packed, with a large number of flat surfaces arranged in subparallel positions normal to the direction of grout movement, than it would be with more equant aggregate.

b. Bond to precast slabs. Bond to the 6 sandblasted slabs was close and intimate in 5 of the 6 cores extracted; bond to the 6 wire-brushed cores was intact in only two cases, and one of these had a narrow crack around approximately one-third of the core.

c. Bond to limestone slab. The close contact of grout and slab is shown in figures 18 and 19.

d. Bond between penstock wall and filling. Apparently bond was not achieved between parts of the filling and the wall, as the core showed a fine crack along part of the boundary. Bond was achieved in some parts of the filling.

e. Bond to steel. The contact between grout and steel was intimate and uniform all around the bar, and no evidence of subsidence could be found in any case examined in cores from the test block and bridge pier.

f. Bond to conventional concrete. Bond to the roughened concrete of the bridge pier footing was close and intimate.

g. Segregation in the grout. The sand retained on the No. 16 and 30 sieves was concentrated and the finer sand and paste squeezed through the porous barriers where several coarse aggregate particles adjoined with restricted opening between. Such areas of concentrations of coarser sand adjoining areas without coarse sand occurred in cores from the test block and bridge pier.

h. Distribution of coarse aggregate. Scattered areas were found in cores from both the block and the bridge pier which were deficient in coarse aggregate. They were largest in cores taken through the inclined precast slabs and in the toe of the bridge pier footing. The packing of coarse aggregate was not as close in the Prepakt of the block and pier as it was in the Prepakt panels made earlier (see appendix).

i. Distribution and type of voids. The following differences are conspicuous when broken surfaces of Prepakt from the test block and bridge pier are compared with broken surfaces of air-entrained concrete: The Prepakt does not contain fine aggregate coarser than the No. 8 sieve, and contains a relatively small amount of fine aggregate retained on No. 16. Accordingly, the sand grains are further apart and the areas of paste are larger. The round gas voids have a smaller maximum size than the air voids in air-entrained concrete. The average size of round voids is smaller than in air-entrained concrete, and the voids are separated by larger areas of paste.

Permeability

98. It is believed that the permeability to capillary water and to water under pressure should be lower for Prepakt than for conventional concrete of comparable cement factor or even of considerably higher cement factor. This is indicated by the appearance of the Prepakt concrete under magnification and from the apparently excellent bond condition

existing between coarse aggregate and surrounding mortar. Tests for permeability will be made and reported at a future date.

Proposed Demolition of the Models

99. It is felt that examination of the core specimens has provided all the information which could be obtained by demolition of the models, and that valuable data can be gained by permitting them to remain exposed to natural weathering. In addition, maintenance of the essential integrity of the models will permit further coring or extraction of other test specimens at a later date if desired. Consequently the original plan to demolish the models with hand tools has been abandoned. However, a large spall from the top edge along the south side of the block was broken off for examination. This was done after the concrete was several weeks old. A Roc-jac, which is a hydraulically-powered, slim, cylindrical instrument containing nine 1-1/2-in.-diameter pistons moving normally to the long axis of the instrument and capable of exerting a total of 150 tons thrust, was inserted into core hole 8 and a piece of concrete was wedged loose. This large spall had an outside area of about 30 sq ft, approximately 18 in. thick in the center feathering to 0 thickness at the ends, and was approximately 9-1/2 ft long by approximately 3-1/2 ft wide. The fracture plane was quite straight and passed through aggregate particles as often as it passed around them indicating a uniform texture, high tensile strength, and good bond condition between aggregate and grout.

PART VI: SUMMARY OF RESULTS

100. Form construction presented no unusual problems; however, forms must be rigid and mortartight and capable of withstanding the stresses induced by the grout over long periods of time, since form pressures remained high for as long as 20 hr.

101. Variation in coarse aggregate grading did not appear to be critical as long as an excessive amount of material passing the designated minimum (3/8 or 1/2 in.) sieve size was avoided. An excessive amount of undersize would block the grout channels between the coarse aggregate particles. Variation in grading in the coarse aggregate would only result in small variation in the void content of the aggregate mass and consequent variation in mortar content; however, the quality of the Prepakt concrete itself would be relatively unaffected.

102. Procurement and placement of coarse aggregate presents no particular difficulty. The coarse aggregate must be limited in minimum size, must be clean and free of chips, and must be handled so as to prevent breakage and excessive segregation. The procurement of sand most suitable for Prepakt concrete requires special processing as it must be a material with a fineness modulus between 1.50 and about 2.00 with practically all of the material passing the No. 16 sieve.

103. Cost of the specially graded aggregates should not be appreciably greater than for good quality, clean, concrete aggregates.

104. No particular difficulty was experienced in placing the coarse aggregate in the forms by means of a clamshell; however, it is believed that considerably less aggregate breakage would have resulted had the

tie rods been spaced so as to permit lowering the bucket into the form. Use of elephant trunks should be considered in large-scale work or, if the aggregates are particularly brittle and must be dropped from 5 ft or higher, some sort of movable rock ladders might be appropriate to help eliminate spalls. Washing and screening prior to placement would eliminate spalls and dirt. Dry aggregate is difficult to place under obstructions, such as gallery forms; however, the compressed air jet is very efficient in forcing the aggregate into tight places. The dry aggregate also tends to fall away from sloping surfaces. Vibration of the forms aids in aggregate consolidation; however, internal vibration of the dry aggregate mass is not practicable nor effective. Walking on the mass, and tamping with wooden tampers are effective in producing consolidation. It is not believed that placing large quantities of coarse aggregate is any more difficult than is the placement of mass concrete.

105. It was expected at the beginning of the tests that some difficulty might arise because of segregation when the coarse aggregate was placed in the form, since it was stockpiled and handled as 1/2- to 3-in. material for the block and 3/8- to 2-in. material for the bridge pier. Apparently no such difficulty was experienced. The aggregates were handled by a clamshell bucket and placed in relatively shallow layers. Any visible evidence of segregation in the large block was corrected by means of shovels or a compressed air blowpipe. Cores from both block and pier showed no evidence of segregation in the coarse aggregate. It is not believed that one size group could have been so successfully handled had the maximum size of the aggregate been 6 in., but possibly a conveyor belt method of placement could have been used, with the

material divided into two sizes and blended together on a placing belt by two feeder belts.

106. Fine aggregate grading is not critical, however the top grain size should pass the 16-mesh sieve and the fineness modulus should be between 1.50 and 2.00.

107. Embedded items and reinforcing steel may be placed as is done with conventional concrete; however, any supports and blocking used to hold items in place must be of such a nature and material that they can be left in place permanently. Gallery forms and penstock tubes can be supported on steel frame work embedded in the aggregate or on the form tie rods as was the short wood-stave tube in the present tests. Mats of horizontal reinforcing steel can be supported directly on the aggregate.

108. Grout quality must of necessity be controlled through control of consistency. Grout that is too thick will not pump and grout that is too thin will bleed excessively, segregate, and give trouble in pumping. Consistency can be controlled through variation in the water content of the grout as mixed, and can be determined in a matter of seconds by means of the flow cone at the mixer. The consistency torque meter, a more exact instrument for measurement of consistency, is applicable to use in the laboratory, and can be set up for field use where a shelter and firm level base are provided for the instrument. Measurements for time of set are important in providing knowledge of the hardening characteristics of the grout and in computing stresses involved in form design, and are obtained through the use of a Vicat apparatus.

109. The storage handling and batching of Alfesil presented no special problem, and it can be batched as easily as bagged cement. The

amount of Intrusion Aid used was quite small and presented no handling problem. It seems evident from results obtained that the Alfesil itself has some strength-gaining properties and in combination with the lime from the cement contributes considerably toward long-time strength gain. However, the Alfesil must be considered relative to heat-generating properties; for use in a massive structure, adiabatic temperature rise studies should be made to determine rate of heat generation as well as the amount of heat liberated.

110. Some of the concepts involved in concrete mixture designs do not hold in designing Prepakt concrete; however, the concept of water cement ratio does. The lower the ratio of water to cementing medium, the higher is the compressive strength, and the less the bleeding and drying shrinkage. In conventional concrete the cement factor can be calculated in advance. In Prepakt concrete the cement factor is less definite and a little more difficult to compute since the amount of grout used depends directly upon the void content of the aggregate, and variations in grading and degree of compaction will influence void content by several per cent. Previously held ideas as to the strength which might be expected from certain portland cement factors and from certain water-cement ratios will probably need revision. The use of Alfesil contributes toward heat evolution, and while not to the same extent as an equivalent amount of portland cement, it must be taken into account in design work.

111. Equipment needs in manufacturing Prepakt concrete are simple and for large-scale work less expensive than for conventional concrete.

112. The large block was grouted through horizontal pipes which remained in the block, and was accomplished without undue difficulty.

Normal procedure would have been to grout through vertical pipes, which could have either been withdrawn or left in place as was done in grouting the bridge pier.

113. Compliance with the specifications can best be obtained by close inspection of aggregate grading, form construction, grout quality, and general workmanship. Cores offer suitable means for evaluating the finished product.

114. Compressive and flexural strengths of Prepakt concrete in this investigation are quite high relative to the portland cement content. The rate of strength gain of Prepakt concrete is, however, slower than for conventional concrete, 90-day strengths being essentially equivalent to 28-day strengths of conventional concrete.

115. Bond strength between Prepakt and conventional concrete and stone is excellent where adequate preparation of concrete and stone surface is made. Bond of new to old Prepakt where the old had not been roughened was poor or non-existent.

116. Intimate contact between grout and embedded steel and between grout and coarse aggregate particles was indicated by microscopic examination.

117. Means must be taken to prevent lifting of aggregate near the top of a form as grouting progresses. The venting form is satisfactory, when firmly anchored, in preventing lifting of aggregate and in forming a satisfactory horizontal finished surface.

118. Vertical surfaces of Prepakt concrete compare favorably with conventional concrete.

119. Delays of up to approximately 11 hr during pumping had no

apparent deleterious effects since the setting time of the grout in these tests exceeded 20 hr.

120. Intrusion around reinforcing steel and other embedded items and in difficult locations was complete.

PART VII: CONCLUSIONS

121. The investigation described herein indicates that Prepakt concrete is a suitable material for use in both reinforced and mass concrete construction.

122. Its use presents no particular difficulties in the procurement and handling of suitably graded materials, nor in the construction of forms or the grouting of the aggregate mass.

123. The qualities of the Prepakt concrete compare favorably with those of conventional concrete.

TABLES

Table 1

PREPAKT, 6- x 12-IN. CYLINDERS
PRELIMINARY MIXES

Port. Cem. B/cy*	Mix Proportions Cem:Filler:Sand	Ratio of Water to Cem+Filler	Aggregates Fine	Aggregates Coarse	Age, Days	Compres. Strength Psi
4.0	2:1:3 vol	0.42	Liberty	Buggs Isl	90	6890
3.7	2:1:3 vol	0.42	L.Stone	L.Erie Gvl	7	2345
3.6	2:1.06:3 wt	0.45	Mtrls Serv	Mtrls Serv	7	2980
3.6	2:1.06:3 wt	0.45	Corp	Corp	60	4750
3.03	3:3:7 vol	0.46	Liberty	Buggs Isl	7	3215
3.03	3:3:7 vol	0.46	L.Stone	Buggs Isl	7	2950
2.8	1:1:3 wt	0.48	CRD Std	CRD	21	2885
2.8	1:1:3 wt	0.48	+20%	Std	28	3280
2.8	1:1:3 wt	0.48	Blow Sand	Std	90	4960
2.78	1:1:3 wt	0.48	CRD Std	CRD Std	21	2340
2.78	1:1:3 wt	0.48	CRD Std	CRD Std	28	2765
2.78	1:1:3 wt	0.48	CRD Std	CRD Std	90	3645
2.67	1:1:3 wt	0.52	Liberty	Buggs Isl	14	1785
2.67	1:1:3 wt	0.52	L.Stone	Buggs Isl	28	2930
2.67	1:1:3 wt	0.52	L.Stone	Buggs Isl	90	4160
2.32	1:1:4 wt	0.56	Liberty	Greystone	14	2240
2.32	1:1:4 wt	0.56	L.Stone	Granite	28	3180
2.32	1:1:4 wt	0.58	L.Stone	Granite	14	1810
2.32	1:1:4 wt	0.58	L.Stone	Granite	28	3035
2.32	1:1:4 wt	0.58	L.Stone	Granite	28	2855
2.0	1:2:3.9 vol	0.48	Liberty	Buggs Isl	7	1900
2.0	1:2:3.9 vol	0.48	L.Stone	Buggs Isl	14	2300
1.825	1:1.065:4 wt	0.58	Liberty	Greystone	7	1715
1.825	1:1.065:4 wt	0.58	L.Stone	Granite	14	1980
1.825	1:1.065:4 wt	0.58	L.Stone	Granite	28	4215
1.76	1:1.596:5 wt	0.60	Liberty	Greystone	7	1110
1.76	1:1.596:5 wt	0.60	L.Stone	Granite	14	1570
1.76	1:1.596:5 wt	0.60	L.Stone	Granite	28	2675
1.76	1:1.596:5 wt	0.60	L.Stone	Granite	60	3510
1.76	1:1.596:5 wt	0.60	L.Stone	Granite	90	4365
1.7	1:1.5:5 wt	0.60	Liberty	Greystone	7	1200
1.7	1:1.5:5 wt	0.60	L.Stone	Granite	12	1695

* Cement factor varies with voids in the stone, which were determined prior to grouting.

Table 2

GROUT MIXTURES

	Test Block		Bridge Pier	
	Lb per Batch	Sol Vol, Cu Ft	Lb per Batch	Sol Vol, Cu Ft
Portland Cement	94.0	0.478	188.0	0.956
Alfesil	150.0	0.961	100.0	0.641
Sand	470.0	2.661	282.0	1.595
Intrusion Aid	2.4	negligible	2.8	negligible
Water	146.4	2.346	121.0	1.940
	Sub-Total	6.446	Sub-Total	5.132
	Expansion 3%	+0.193	Expansion 2%	+0.103
	Bleeding 1.3%	-0.084	Bleeding 1%	-0.051
	Net	6.555	Net	5.184
Proportions by wt, Cement:Alfesil:sand:	1:1.596:5		1:0.533:1.5	
Cement factor, bags port. cement/cu yd*	1.73		4.37	
Portland cement plus Alfesil, lb/cu yd*	422.1		629.3	
Water-cement ratio, gal/bag of port. cement	17.6		7.3	
Water-cement + Alfesil ratio, by weight	0.60		0.42	
Gal of water/cu yd*	30.9		33.1	

* Based on 42 per cent voids in coarse aggregate.

Table 3

BATCH WEIGHTS, AND GROUT DATA, TEST BLOCK

Material	Net Wt Lb	No. Btchs	Time	Grout Temp F	Grout Sample					Expansion, %				Bleeding, %				Setting time, hours, minutes		Delays, reason	Time of Delays	Delays Duration	Total Pump Strokes	Apparent Volume grout cu ft by pump strokes
					No.	Temp F	Time	Consistency Torque	Flow Cone, Sec	1 Hr	2 Hr	3 Hr	4 Hr	1 Hr	2 Hr	3 Hr	4 Hr	Initial	Final					
First Stage, Elev. 0 to 2.0 ft																								
Cement	94.00		10:15 a.m. to 11:00 a.m.	66	1	68.5	10:52 a.m.	182	35	-	-	-	-	-	-	-	-	-	-					
Alfesil	150.00			64																				
Sand	460.00	12		54																				
Intrusion Aid	2.44			60																				
Water (net)	162.00			52																				
Cement	94.00		11:10 a.m. to 12:00 M	67	-	-	-	-		-	-	-	-	-	-	-	-	-	-					
Alfesil	150.00			65																				
Sand	464.00	6		58																				
Intrusion Aid	2.44			62																				
Water (net)	152.00			56																				
Cement	94.00		12:00 M to 1:35 p.m.	-	2	72.0	12:49 p.m.	97	23	2.34	3.01	3.01	2.89	0.33	0.54	0.97	1.19	20:30	27:00	Pump "A" line clogged	12:42 p.m. to 12:53 p.m.	11 min.		
Alfesil	150.00			-																				
Sand	470.00	14		-																Pump "A" pipe changed	1:06 p.m. to 1:20 p.m.	14 min.		
Intrusion Aid	2.44			-																Pumps "A" and "B" clogged	1:35 p.m. to 2:15 p.m.	40 min.	6,212	173.9
Water (net)	151.00			-																and mixer shut down				
Second Stage, Elev. 2.0 to 5.5 ft — After 2 hour delay, red ochre added to grout.																								
Cement	94.00			65	3	69.0	4:06 p.m.	92	-	2.78	3.89	4.12	4.12	0.87	1.07	1.17	1.49			Resumed pumping at	3:35 p.m.			
Alfesil	150.00		3:35 p.m. to 9:24 p.m.	65	4	69.0	6:14 p.m.	78	18	0.78	1.11	1.11	1.11	0.88	1.43	1.76	1.98	22:00	27:00	Batch mixed in error without water	4:50 p.m. to 5:08 p.m.	18 min.		
Sand	487.00	46		59	5	67.5	7:43 p.m.	101	-	-	-	-	-	-	-	-	-	-	-	Pump "B" line clogged	5:38 p.m. to 5:52 p.m.	14 min.		
Intrusion Aid	2.44			64														-	-	Pump "B" line clogged	6:00 p.m. to 6:35 p.m.	35 min.		
Water (net)	133.00			56																Pump "A" line clogged	7:50 p.m. to 8:20 p.m.	30 min.		
Coloring	2.50																			Changed to different grout pipe in block	8.20 p.m. to 8.36 p.m.	16 min.	10,163	284.6
Third Stage, Elev. 5.5 to 10.0 ft — After overnight delay of 11 hours and 10 minutes, uncolored grout																								
Cement	94.00		8:30 a.m. to 2:20 p.m.	64	6	66.0	8:31 a.m.	76	-	2.54	3.42	3.53	3.53	0.65	0.96	1.28	1.60	24:00	30:00	Pump "B" line clogged	11:43 a.m. to 12:10 p.m.	27 min.		
Alfesil	150.00			64	7	71.0	9:58 a.m.	89	15	-	-	-	-	-	-	-	-	-	-	Pump "A" line clogged	11:53 a.m. to 12:15 p.m.	22 min.		
Sand	462.00	65		60	8	74.0	11:21 a.m.	126	20	2.83	3.49	3.71	3.59	0.11	0.21	0.63	0.84	22:30	26:00	Pump "A" line clogged	12:55 p.m. to 1:18 p.m.	23 min.		
Intrusion Aid	2.44			64	9	71.0	11:52 a.m.	158	-	1.43	1.87	1.87	1.76	0.32	0.43	0.97	1.08	21:00	25:30	Both pumps down waiting to top out block	1:30 p.m. to 1:47 p.m.	17 min.		
Water (net)	154.00			69	10	73.0	11:50 a.m.	128	-	2.96	3.73	3.95	3.95	0.32	0.53	0.74	1.06	21:00	25:30					
					11	70.0	12:25 p.m.	78	-	-	-	-	-	-	-	-	-	-	-					
					12	75.0	1:32 p.m.	114	-	1.32	2.20	2.64	2.64	0.33	0.43	1.07	1.42	-	-				13,662	382.5
Grand Average								110	22	2.12	2.84	2.96	2.95	0.48	0.70	1.07	1.33	21:48	26:48			Total	30,037	841.0

Table 4

BATCH WEIGHTS, AND GROUT DATA, BRIDGE PIER

Material	Net Wt lb	Number Batches	Time	Grout Temp F	Grout Sample			Consistency Torque	Flow Cone Time, Sec.	Expansion, %				Bleeding, %				Setting Time, hours, minutes		Delays, reason
					No.	Temp. F	Time			1 hr	2 hr	3 hr	4 hr	1 hr	2 hr	3 hr	4 hr	Initial	Final	
Cement	188.00		3:30 p.m. to 3:45 p.m.	66	13	77.5	3:30 p.m.	108	20	2.44	2.66	2.55	2.33	0.22	0.32	0.65	0.98	12:00	14:30	
Alfesil	100.00			70																
Sand	262.00	2		63																
Intrusion Aid	2.44			72																
Water	138.00			72																
Cement	188.00		3:45 p.m. to 6:30 p.m.	65	14	74.0	4:00 p.m.	68	-	0.22	0.22	0.12	0.12	0.33	0.55	0.99	1.21	13:00	16:30	
Alfesil	100.00			70	15	77.0	4:30 p.m.	120	-	0.99	0.99	0.88	0.77	0.11	0.22	0.44	0.65	-	-	Grouting stopped from
Sand	268.00	24		63	16	72.0	5:05 p.m.	226	-	3.09	3.76	3.76	3.76	0.32	0.64	0.75	1.17	-	-	5:25 p.m. to 5:37 p.m.
Intrusion Aid	2.44			71	17	75.0	5:47 p.m.	126	-	2.48	2.91	2.91	2.80	0.21	0.63	0.94	1.15	-	-	to inspect level of grout
Water	139.00			72																near venting form closely.
				Average		75.1		129.6°	-	1.84	2.11	2.04	1.96	0.24	0.47	0.75	1.03	12:30	15:30	

NOTE: No accurate estimate could be made of amount of grout used because pumping was by duplex pump to reservoir for 2 triplex pumps which supplied pressure for grout lines; excessive amount was mixed and an indeterminate amount wasted after form had been filled.

Table 5

COMPRESSIVE STRENGTHS OF MOLDED AND GROUTED CYLINDERS

Cylinder No.	Age at Test, Days	Psi	Maximum Size of Aggregate	Size of Cylinder, In.	Grout Mix
1879	7	805	3 in.	8 x 16	1:1.596:5
1880	28	2590	3 in.	8 x 16	1:1.596:5
1881	45	3390	3 in.	8 x 16	1:1.596:5
1882	90	4000	3 in.	8 x 16	1:1.596:5
1883	7	750	3 in.	8 x 16	1:1.596:5
1884	28	2260	3 in.	8 x 16	1:1.596:5
1885	45	2800	3 in.	8 x 16	1:1.596:5
1886	90	3550	3 in.	8 x 16	1:1.596:5
1887	7	880	2 in.	6 x 12	1:1.596:5
1888	28	2495	2 in.	6 x 12	1:1.596:5
1889	45	2930	2 in.	6 x 12	1:1.596:5
1890	90	3890	2 in.	6 x 12	1:1.596:5
1891	7	2975	2 in.	6 x 12	1:0.53:1.5
1892	28	4285	2 in.	6 x 12	1:0.53:1.5
1893	45	5340	2 in.	6 x 12	1:0.53:1.5
1894	90	5105	2 in.	6 x 12	1:0.53:1.5

Note: Cylinders 1879-1882 were molded from material removed from top of large block after finish of grouting, balance of cylinders were grouted after aggregate had been prepacked in molds.

Table 6

TEMPERATURE READINGS, PREPAKT TEST BLOCK

Days	Thermohm 1*	Thermohm 2**	Thermo-couple 1*	Thermo-couple 2**	Thermo-couple 3#	Thermo-couple 4##
0	67.3	71.8	67.8	67.8	66.9	56.3
1	68.0	68.0	69.1	69.2	70.0	62.1
2	76.9	78.1	77.4	79.1	75.9	68.0
3	87.9	89.1	88.5	89.7	78.7	56.3
4	-	-	92.0	93.8	79.8	60.0
5	-	-	91.0	95.0	79.9	68.1
6	87.8	95.0	88.7	94.7	79.8	68.0
7	86.0	93.1	86.5	92.9	79.2	62.2
8	83.8	91.1	84.3	90.2	78.7	57.0
9	81.0	88.3	82.0	88.4	78.0	63.5
10	79.8	86.0	80.2	85.9	77.0	65.7
11	-	-	79.1	83.8	76.2	69.0
12	-	-	79.0	81.9	75.7	75.4
13	79.4	80.8	79.1	80.4	74.8	73.0
14	79.3	80.3	79.5	80.0	74.5	72.5
15	80.0	80.0	80.0	79.9	74.5	74.0
16	79.7	80.0				
17	79.2	79.8				
18	-	-				
19	-	-				
20	77.7	78.1				
21	78.1	78.0				
22	78.7	78.0				
23	79.2	78.3				
24	80.9	79.4				
25	-	-				
26	-	-				
27	83.0	82.7				
28	83.7	83.7				
29	82.4	84.0				
30	81.2	84.8				
31	80.6	84.3				
32	-	-				
33	-	-				
34	81.0	81.9				
35	81.6	82.1				
36	81.9	82.0				
37	82.3	82.0				
38	-	-				
39	-	-				
40	-	-				
41	85.2	83.1				
42	85.1	83.2				
43	84.7	83.7				
44	-	-				
45	83.0	83.8				

* Located 5.0' from rear, 5.0' from top and 2.5' from north side.

** Located 5.0' from rear, 5.0' from top and 5.0' from north side.

\# Located on foundation slab directly below No. 2.

\## Located in air, in shaded position.

Note: Readings made at 8:30 a.m.

Table 7

LENGTH-CHANGE MEASUREMENTS REFERENCE BAR, LARGE BLOCK

1 Days	2 Date, 1949	3 Gage Read-ing	4 Apparent change	5 Temper-ature Change of rod	6 1st Correc-tion*	7 Correct-ed gage reading	8 Actual length change	9 Air temper-ature	10 Temper-ature change of air	11 2nd Correc-tion**	12 Corrected length change	13 Length change, per cent
0	April 15	.503000	0	0	0	.503000	0	62.3	0	0	0	0
1	16	.495000	- .008	+ 6.6	+ .013686	.508686	+ .005686	66.5	+ 4.2	- .003538	+ .002148	+ .0010
2	17	.496000	- .007	+ 2.9	+ .006013	.502013	- .000987	74.2	+11.9	- .010024	- .011011	- .0051
3	18	.482000	- .021	+10.4	+ .021565	.503565	+ .000565	74.8	+12.5	- .010530	- .009965	- .0046
4	19	.481000	- .022	+ 9.9	+ .020528	.501528	- .001471	73.7	+11.4	- .009603	- .011074	- .0051
5	20	.502000	- .001	- 2.1	- .004354	.497646	- .005354	59.3	- 3.0	+ .002527	- .002827	- .0013
6	21	.490000	- .013	+ 4.7	+ .009745	.499745	- .003255	67.0	+ 5.7	- .004801	- .008056	- .0037
7	22	.492000	- .011	+ 3.9	+ .008087	.500087	- .002913	67.5	+ 5.2	- .004380	- .007293	- .0034
8	23	.475000	- .028	+12.5	+ .025920	.500920	- .002080	75.9	+13.6	- .011456	- .013536	- .0063
10	25	.463000	- .040	+20.5	+ .042509	.505509	+ .002509	82.4	+20.1	- .016939	- .014430	- .0067
11	26	.467000	- .026	+17.8	+ .036910	.503910	+ .000910	78.7	+16.4	- .013815	- .012905	- .0060
12	27	.482000	- .021	+10.1	+ .020943	.502943	- .000057	74.0	+11.7	- .009856	- .009913	- .0046
13	28	.475000	- .028	+11.1	+ .023017	.498017	- .004983	68.9	+ 6.6	- .005560	- .010543	- .0049
14	29	.470000	- .033	+14.6	+ .030274	.500274	- .002726	70.0	+ 7.7	- .006486	- .009212	- .0043
17	May 2	.464000	- .039	+16.3	+ .033799	.497799	- .005201	78.2	+15.9	- .013394	- .018595	- .0086
18	3	.454000	- .049	+23.3	+ .048315	.502315	- .000685	77.0	+14.7	- .012383	- .013068	- .0060
19	4	.448000	- .055	+28.6	+ .059450	.507450	+ .004450	89.0	+26.7	- .022492	- .018042	- .0084
20	5	.446000	- .057	+29.3	+ .060756	.508756	+ .005756	83.0	+20.7	- .017437	- .011681	- .0054
24	9	.453000	- .050	+27.7	+ .057439	.510439	+ .007439	82.0	+19.7	- .016595	- .009156	- .0042
25	10	.476000	- .027	+11.9	+ .024676	.500676	- .002324	73.0	+10.7	- .009013	- .011337	- .0052
26	11	.471000	- .032	+13.0	+ .026957	.497957	- .005043	76.4	+14.1	- .011877	- .016920	- .0078
27	12	.460000	- .043	+17.1	+ .035458	.495458	- .007542	76.0	+13.7	- .011540	- .019082	- .0088
31	16	.450000	- .053	+23.3	+ .048315	.498315	- .004685	80.0	+17.7	- .014910	- .019595	- .0091
32	17	.446000	- .057	+25.8	+ .053499	.499499	- .003501	80.0	+17.7	- .014910	- .018411	- .0085
33	18	.446000	- .057	+26.0	+ .053913	.499913	- .003087	80.1	+17.8	- .014994	- .018081	- .0084
34	19	.444000	- .059	+27.2	+ .056402	.500402	- .002598	83.5	+21.2	- .017858	- .020456	- .0095
38	23	.446000	- .057	+26.4	+ .054743	.500753	- .002247	90.0	+27.7	- .023334	- .025581	- .0105
39	24	.447000	- .056	+25.5	+ .052877	.499877	- .003123	84.0	+21.7	- .018280	- .021403	- .0099
40	25	.453000	- .050	+20.6	+ .042716	.495716	- .007284	77.2	+14.9	- .012552	- .19836	- .0092
42	27	.441000	- .052	+25.8	+ .053499	.494499	- .008501	84.0	+21.7	- .018280	- .026781	- .0124
45	30	.468000	- .035	+ 8.4	+ .017400	.485400	- .017600	70.0	+ 7.7	- .006486	- .024086	- .0112

* The product of the coefficient of expansion of stainless steel and the effective length in inches, ($9.6 \times 10^{-6} \times 216$ in., length of gage) per degree.

** The product of the coefficient of expansion of Prepakt concrete and the effective length in inches, ($3.9 \times 10^{-6} \times 216$ in.) per degree.

Table 8

STRESSES IN THREE-FOURTHS-INCH COIL BOLT AND TIES
FORM PRESSURE ON TEST BLOCK
(Grout)

Gage No. 1			Gage No. 9			Gage No. 3			
Gage Reading	Strain Micro-Inches	Stress lb	Gage Reading	Strain Micro-Inches	Stress lb	Gage Reading	Strain Micro-Inches	Stress lb	Remarks
5570	0	0	6520	0	0	5600	0	0	Aggregate in place; just before grouting started.
5605	35	320	6550	30	267	5645	45	409	First 1-1/2' of grout
5605	35	320	6450	-70	-620	5630	30	273	End of first stage (2-1/2')
5540	-30	-274	6400	-120	-1062	5565	-35	-319	During 2nd stage (Lead wires were wet)
5655	85	778	6660	140	1240	5690	90	820	Beginning 3rd stage
5710	140	1281	6710	190	1681	5720	120	1091	End of 3rd stage (still pumping)
5640	70	641	6620	100	885	5660	60	546	2 hr after end 3rd stage
5640	70	641	6650	130	1150	5660	60	546	4 hr after end 3rd stage
5650	80	732	6670	150	1328	5680	80	728	20 hr after end 3rd stage
5545	-25	-229	6570	50	442	5590	-10	-91	Immediately after 2 sides were stripped
5535	-35	-320	6510	-10	-88	5590	-10	-91	5 days after; bars bonded to Prepakt
5570	0	0	6530	10	88	5575	-25	-227	6 days after; bars bonded to Prepakt

Gage Factor:
#1 = 9.15
#9 = 8.85
#3 = 9.10

Total axial load in lb per micro-inch strain-indicator reading. Each gage was made up of a pair of SR-4 units, one mounted on top side and one on underneath side of rod. Gages were attached to rods between sheathing and walers.

All gages attached rods tied to the 5' waler on right and left sides of form.
#1 = 12' from front
#9 = 14' from front
#3 = 18' from front

Table 9

IDENTIFICATION AND DISPOSITION OF 10-IN. VERTICAL CORES

Core Section	Core Depth from Top, Ft	Length, Ft	Disposition
1A	+0.2 - 1.9	2.1	Compressive strength at 60 days
1B	1.9 - 3.9	2.0	Compressive strength at 60 days
1C	3.9 - 7.0	3.1	Compressive strength at 60 days
1E	7.0 -10.0	3.0	Compressive strength at 60 days
2A	+0.3 - 1.7	2.0	Compressive strength at 60 days
2B	1.7 - 3.7	2.0	Compressive strength at 60 days
2C	3.7 - 5.6	1.9	Compressive strength at 60 days
2D	5.6 - 7.6	2.0	Compressive strength at 60 days
2E	7.6 - 9.8	2.2	Compressive strength at 60 days
3A	(+0.2 - 0.2 (1)	0.4	- - - - -
	(0.2 - 2.2	2.0	Modulus of elasticity
3B	2.2 - 4.0	1.8	Modulus of elasticity
3C	4.0 - 6.3	2.3	Modulus of elasticity
3D	6.3 - 8.4	2.1	Modulus of elasticity
3E	8.4 -10.0	1.6	Modulus of elasticity
4A	+0.2 - 2.1	2.3	Treat Island exposure
4B	2.1 - 4.2	2.1	Treat Island exposure
4C	4.2 - 6.0 (2)	1.8	- - - - -
4D	6.0 - 8.2	2.2	Treat Island exposure
4E	8.2 - 9.9	1.7	Treat Island exposure
5A	+0.2 - 2.0	2.2	Modulus of elasticity
5B	2.0 - 4.0	2.0	Modulus of elasticity
5C	4.0 - 5.7	1.7	Modulus of elasticity
5D	5.7 - 7.6	1.9	Modulus of elasticity
5E	7.6 - 9.6	2.0	Modulus of elasticity
6A	+0.3 - 1.6	1.9	Compressive strength at 90 days
6B	1.6 - 3.8	2.2	Compressive strength at 90 days
6C	3.8 - 5.7	1.9	Compressive strength at 90 days
6D	5.7 - 7.5	1.8	Compressive strength at 90 days
6E	7.5 -10.0	2.5	Compressive strength at 90 days
7A	+0.3 - 1.7	2.0	Compressive strength at 90 days
7B	1.7 - 3.8	2.1	Compressive strength at 90 days
7C	3.8 - 5.8	2.0	Compressive strength at 90 days
7D	5.8 - 7.7	1.9	Compressive strength at 90 days
7E	7.7 - 9.8	2.1	Compressive strength at 90 days

(Continued)

Table 9 (Cont'd)

Core Section	Core Depth from Top, Ft	Length, Ft	Disposition
8A	+0.1 - 1.8	1.9	Treat Island exposure
8B	1.8 - 3.7	1.9	Treat Island exposure
8C	3.7 - 5.8	2.1	Treat Island exposure
8D	5.8 - 7.9	2.1	Treat Island exposure
8E	7.9 -10.0	2.1	Treat Island exposure

(1) Poorly consolidated crust
(2) Section broken, not tested

Table 10

COMPRESSIVE STRENGTH, 10- x 20-IN. DRILLED CORES

TEST BLOCK

Core No.	Depth from Top, Ft	Age Days	Psi	Retest (1) Age, Days	Retest (1) Psi	Retest Rel. %
1A	+0.2 - 1.9	60	3395	-	-	-
1B	1.9 - 3.9	60	3630	-	-	-
1C	3.9 - 7.0	60	2320	182	2800	121
1E	7.0 -10.0	60	2885	182	3360	116
2A	+0.3 - 1.7	60	3435	182	3880	113
2B	1.7 - 3.7	60	4275	182	4930	115
2C	3.7 - 5.6	60	3325	182	3870	116
2D	5.6 - 7.6	60	2805	182	3320	118
2E	7.6 - 9.8	60	3115	182	3845	123
		Average	3245			
6A	+0.3 - 1.6	90	4610	-	-	
6B	1.6 - 3.8	90	5085	182	5320	105
6C	3.8 - 5.7	90	3310	182	3750	113
6D	5.7 - 7.5	90	3235	-	-	-
6E	7.5 -10.0	90	3955	182	4325	109
7A	+0.3 - 1.7	90	4375	182	4400	101
7B	1.7 - 3.8	90	4180	182	4275	102
7C	3.8 - 5.8	90	3815	182	4010	105
7D	5.8 - 7.7	90	4315	182	4640	107
7E	7.7 - 9.8	90	4165	182	4580	110
		Average	4105			

(1) Specimens were prepared for photographing, to indicate type of failure, by crushing to destruction in testing machine, at which time load necessary to effect destruction was noted.

Table 11

COMPRESSIVE STRENGTH, 6- x 12-IN. DRILLED CORES

BRIDGE PIER

Core No.	Depth from Top, Ft	Age, Days	Psi	Retest (1)		
				Age, Days	Psi	Rel. %
1A	0.0 - 1.5	90	6660	182	7240	109
1B	1.5 - 2.6	90	7475	182	7390	99
1C	2.6 - 3.8	90	6720	182	7570	113
2A	0.0 - 1.9	90	5285	182	5790	109
2B	1.9 - 3.7	90	6605	182	6850	104
2C	3.7 - 5.7	90	6855	-	-	-
2D	5.7 - 7.5	90	7045	182	7045	100
2E	7.5 - 9.3	90	6395	182	6530	102
3A	0.0 - 1.9	90	6035	-	-	-
3C	3.7 - 5.4	90	6910	182	7800	113
3D	5.4 - 7.5	90	7820	-	-	-
		Average	6710			

(1) Specimens were prepared for photographing, to indicate type of failure, by crushing to destruction in testing machine, at which time load necessary to effect destruction was noted.

Table 12

CORES DRILLED THROUGH PRECAST SLABS INTO PREPAKT TEST BLOCK

Core No.	Preparation of Precast Slab	Bond after Drilling	Grout Stage and Color	Condition
1-S	Sandblasted	Bonded	III-gray	Slab and Prepakt well bonded; surface of slab slightly rough.
2-W	Wire-brushed	Not bonded	III-gray	Surface of slab very smooth; no adherence of grout to slab.
3-W	Wire-brushed	Not bonded	III-gray	One area approximately 1 by 1-1/4 in. where thin film of grout adhered to slab.
4-S	Sandblasted	Bonded	II, III-red and gray	Slab and Prepakt well bonded, sharp intimate contact; one small patch of red grout.
5-S	Sandblasted	Bonded	III-gray	Slab and Prepakt well bonded, sharp intimate contact.
6-W	Wire-brushed	Bonded	III-gray	Slab and Prepakt well bonded; a few small voids in grout along plane of contact.
7-S	Sandblasted	Bonded	II-red	Slab and Prepakt bonded; along about one-quarter of the periphery a line of voids up to 1/2 in. long; otherwise the grout filling is complete.
8-S	Sandblasted	Not bonded	II-red	Slab has very thin layer of grout adhering to it. Prepakt is low in coarse aggregate and contains large grout areas.
9-W	Wire-brushed	Not bonded	II-red	Slab has a semitranslucent film of red grout adhering to it, and one grout area about 1 by 2-1/2 in. by 3/4 in. at one edge. In the Prepakt core there are fairly large volumes of grout without coarse aggregate (difficulty in packing coarse aggregate under inclined form). The end of the Prepakt core cast against the slab shows flow structure in lines of voids.

(Continued)

Table 12 (Cont'd)

Core No.	Preparation of Precast Slab	Bond after Drilling	Grout Stage and Color	Condition
10-S	Sandblasted	Bonded	I-gray	Void 1.3 in. long on periphery; otherwise excellent bond. Filling in Prepakt somewhat incomplete; coarse aggregate not too tightly packed.
11-W	Wire-brushed	Bonded	I-gray	One void about 1/2 in. long on periphery; very narrow crack around about one-third of periphery. Prepakt very similar to that in No. 10. Stage I gray grout has fewer small round voids than Stage II, Stage III, or bridge pier.
12-W	Wire-brushed	Not bonded	I, II-gray, red	Translucent film of red grout on part of slab core. Joint between red and gray grout is curved irregular surface. Final filling next to slab was in Stage II red grout. The filling in the inner gray end was somewhat incomplete. The lower end of the core intersected the base of the block; bond to the base did not take place in this core.

Table 13

BOND STRENGTH OF PREPAKT TO PRECAST SLABS
CORES TESTED AT BOND PLANE IN FLEXURE, CENTER LOAD, 30-IN. SPAN

Core No.*	Preparation Before Grouting	Modulus of Rupture: Bond Strength, Psi	Modulus of Rupture: Prepakt Strength, Psi **	Bond Strength % of Prepakt	Remarks
1-S	Sandblasted	492+	-		Uncolored. Failure occurred in precast concrete at reinforcing, not at bond
2-W	Wire-brushed	-	730***		Uncolored. Bond failure in drilling
3-W	Wire-brushed	-	-		Uncolored. Bond failure in drilling
4-S	Sandblasted	454	-		Some red color, failed at bond plane
5-S	Sandblasted	482	670***	72	Beam cut from core
6-W	Wire-brushed	55	-		Slight color, failed at bond plane. Bleeding evident at bond plane
7-S	Sandblasted	244	-		Colored grout, failed at bond plane
8-S	Sandblasted	-	-		Colored grout. Bond failure in drilling
9-W	Wire-brushed	-	-		Colored grout. Bond failure in drilling
10-S	Sandblasted	478	534	89	Uncolored. Approx 40% of break was in Prepakt, 60% at bond plane
11-W	Wire-brushed	218	-		Uncolored. Failed at bond plane
12-W	Wire-brushed	-	721		Colored. Failed at bond plane in drilling

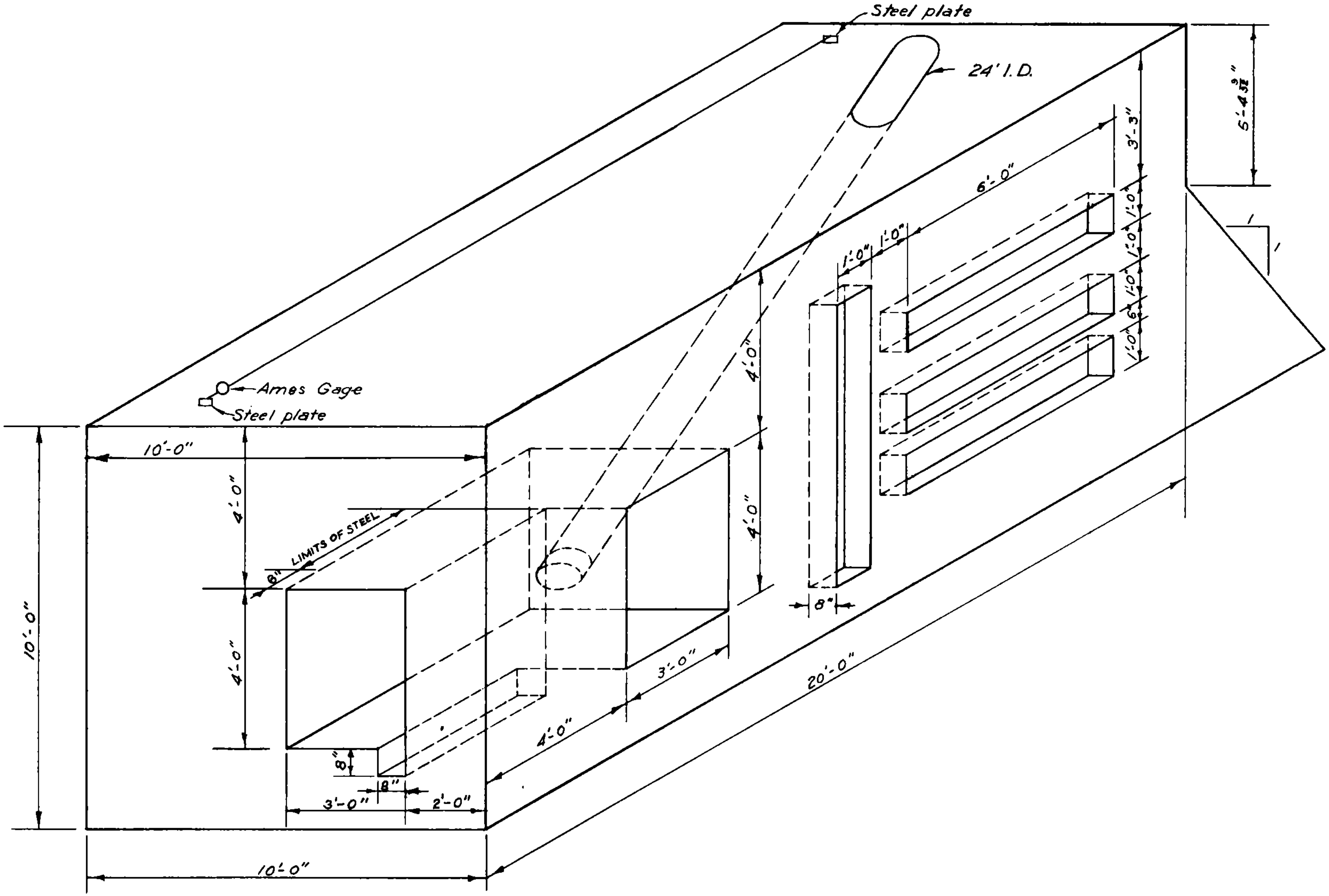
* Cores 1 through 6 drilled horizontally, cores 7 through 12 drilled at 45° to horizontal.

** Tests made where length of Prepakt section of core permitted.

*** 6- x 6- x 30-in. beam cut from core, third-point loading.

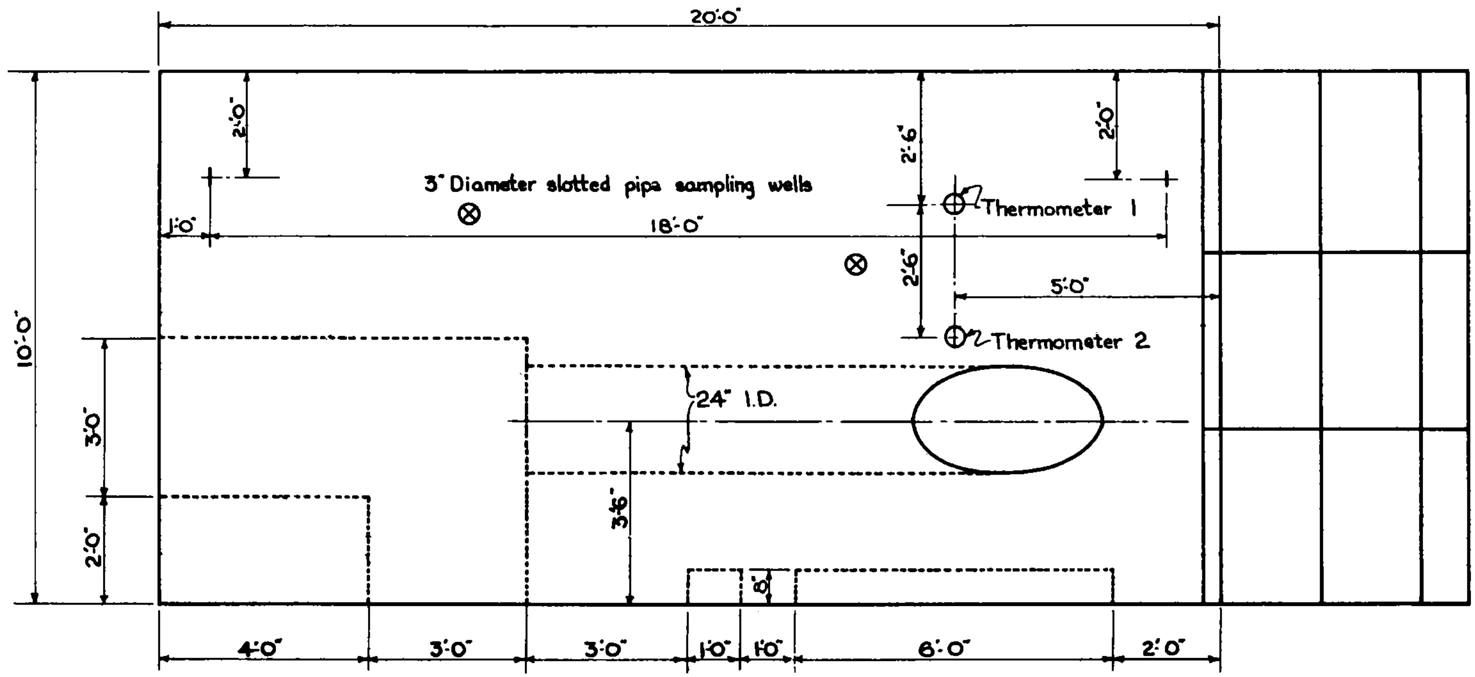
PLATES

PLATE 1



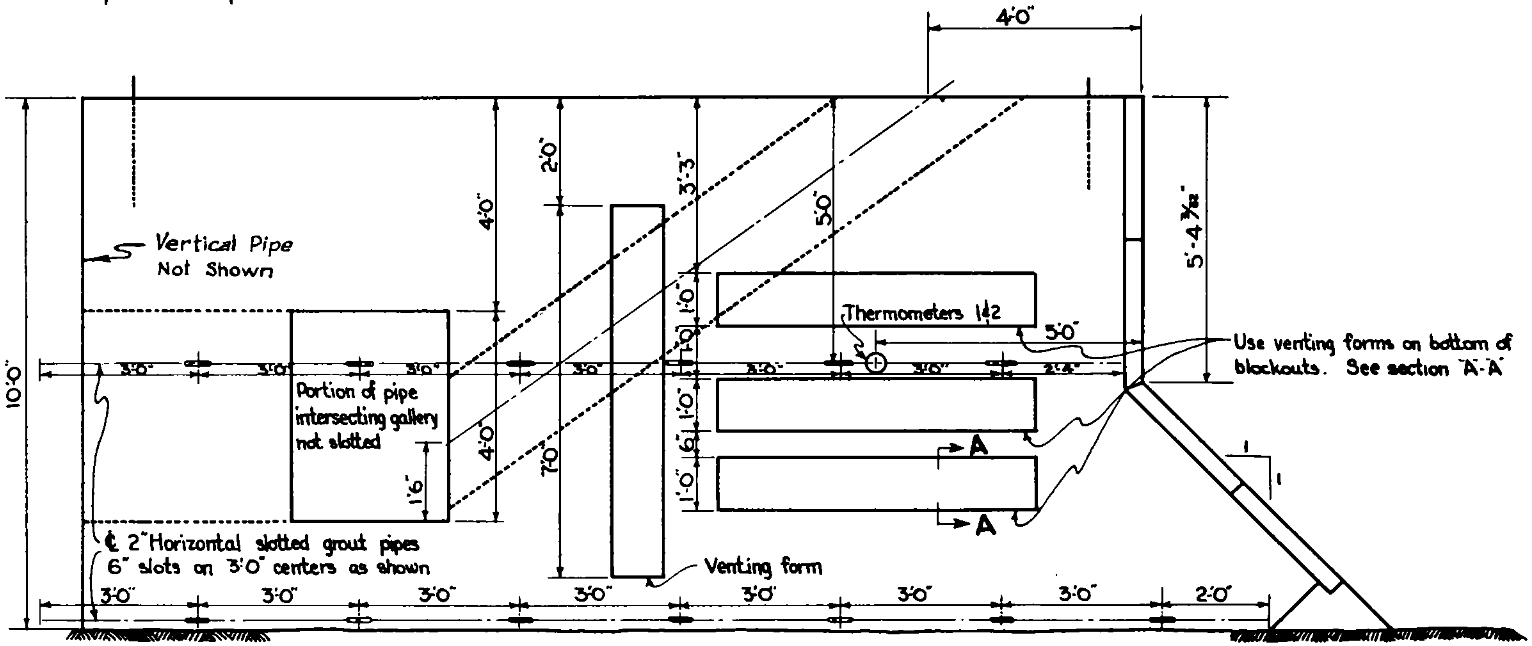
Test block

PLATE 2



Test block, plan view of grouting plan

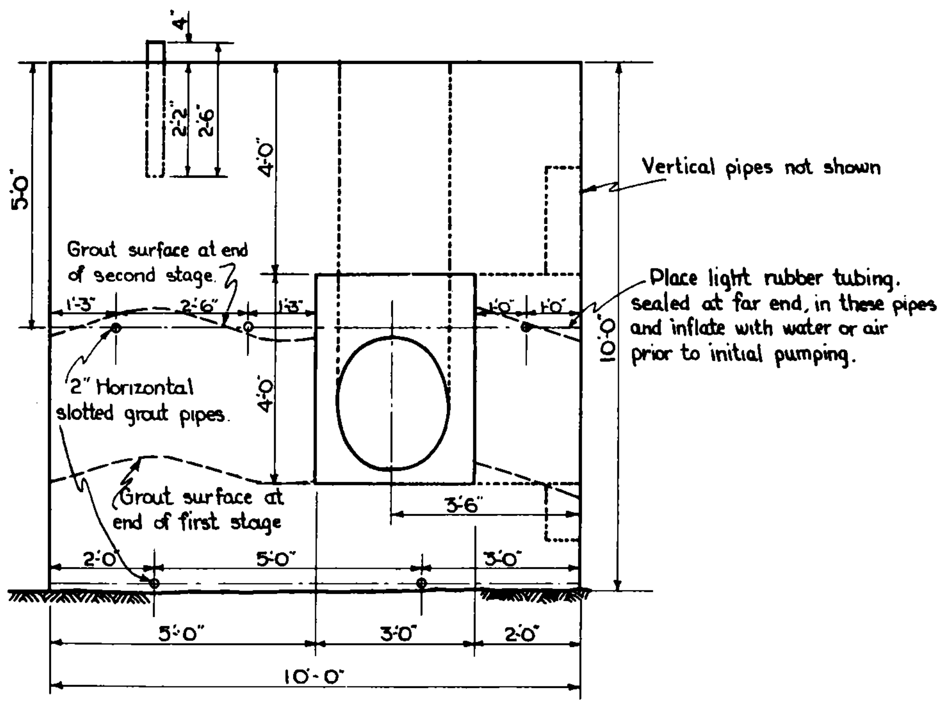
Pipe Fabrication Details:
1. Horizontal pipe slotted ½" × 6" on 3'-0" centers
Slots in bottom of pipe
2. Vertical pipes slotted ½" × 12" on 12" centers
Slots spaced 120° apart.



Side Elevation

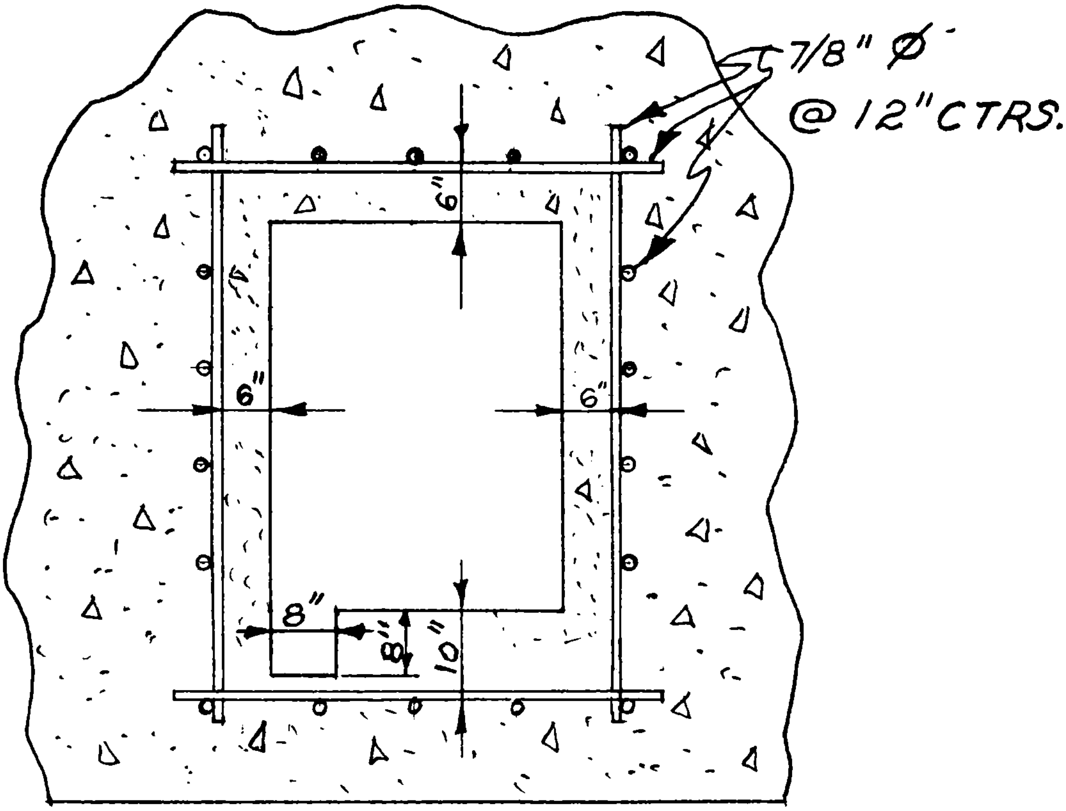
PLATE 3

Test block, side elevation of grouting plan

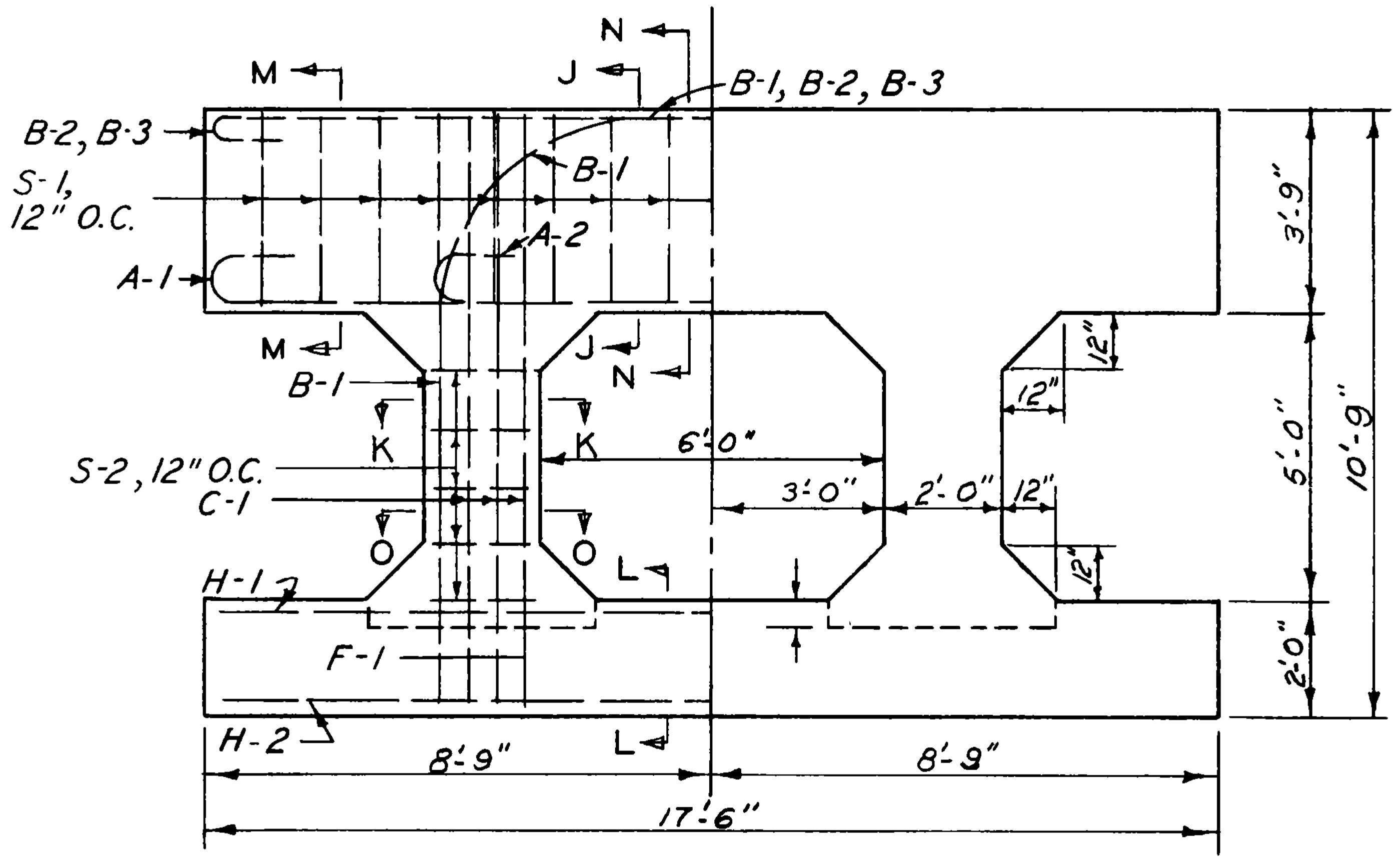


Test block, front elevation of grouting plan

PLATE 4



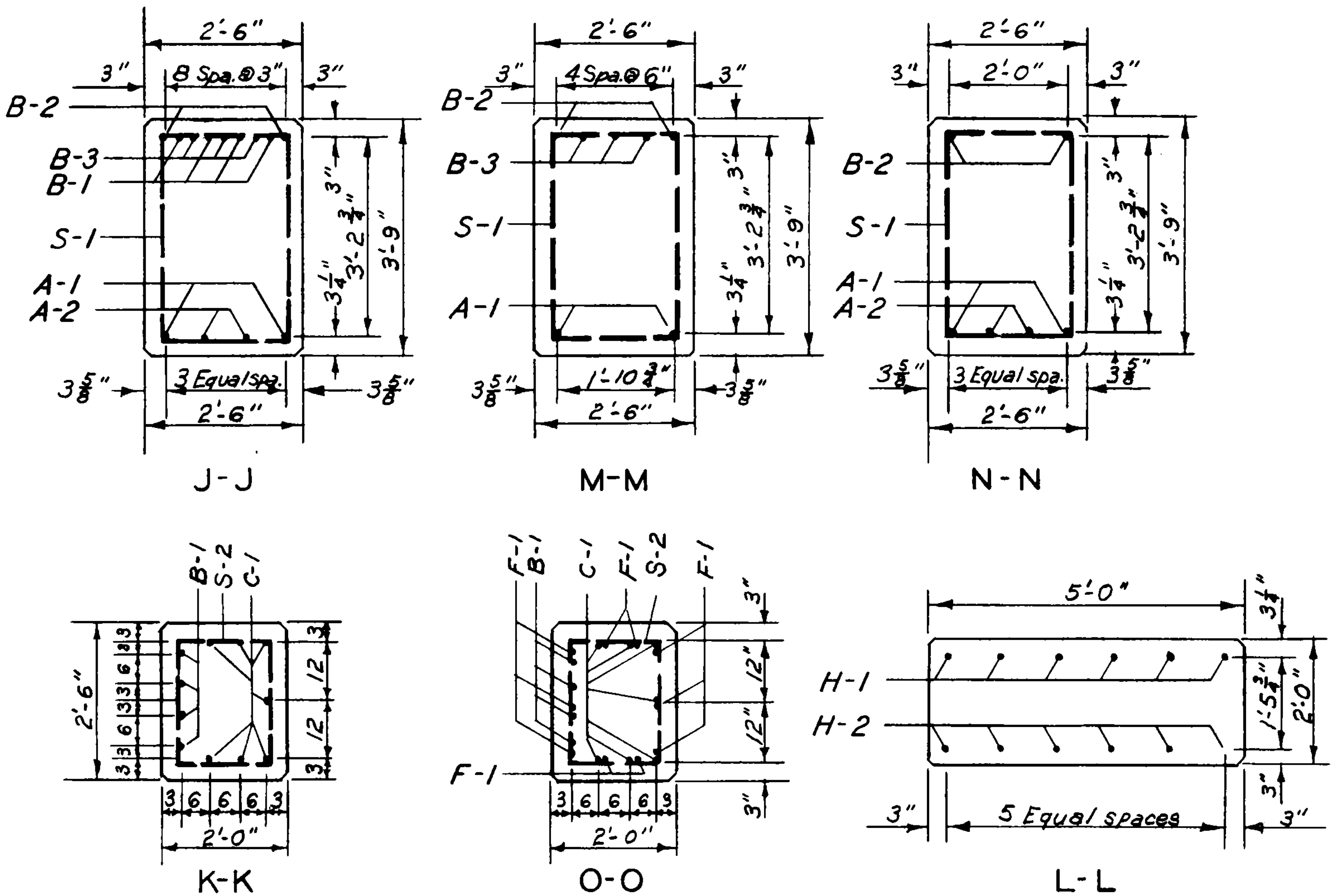
Test block, section through gallery



ELEVATION

Scale $\frac{3}{8}$" = 1'-0"

Bridge pier



Bridge pier sections

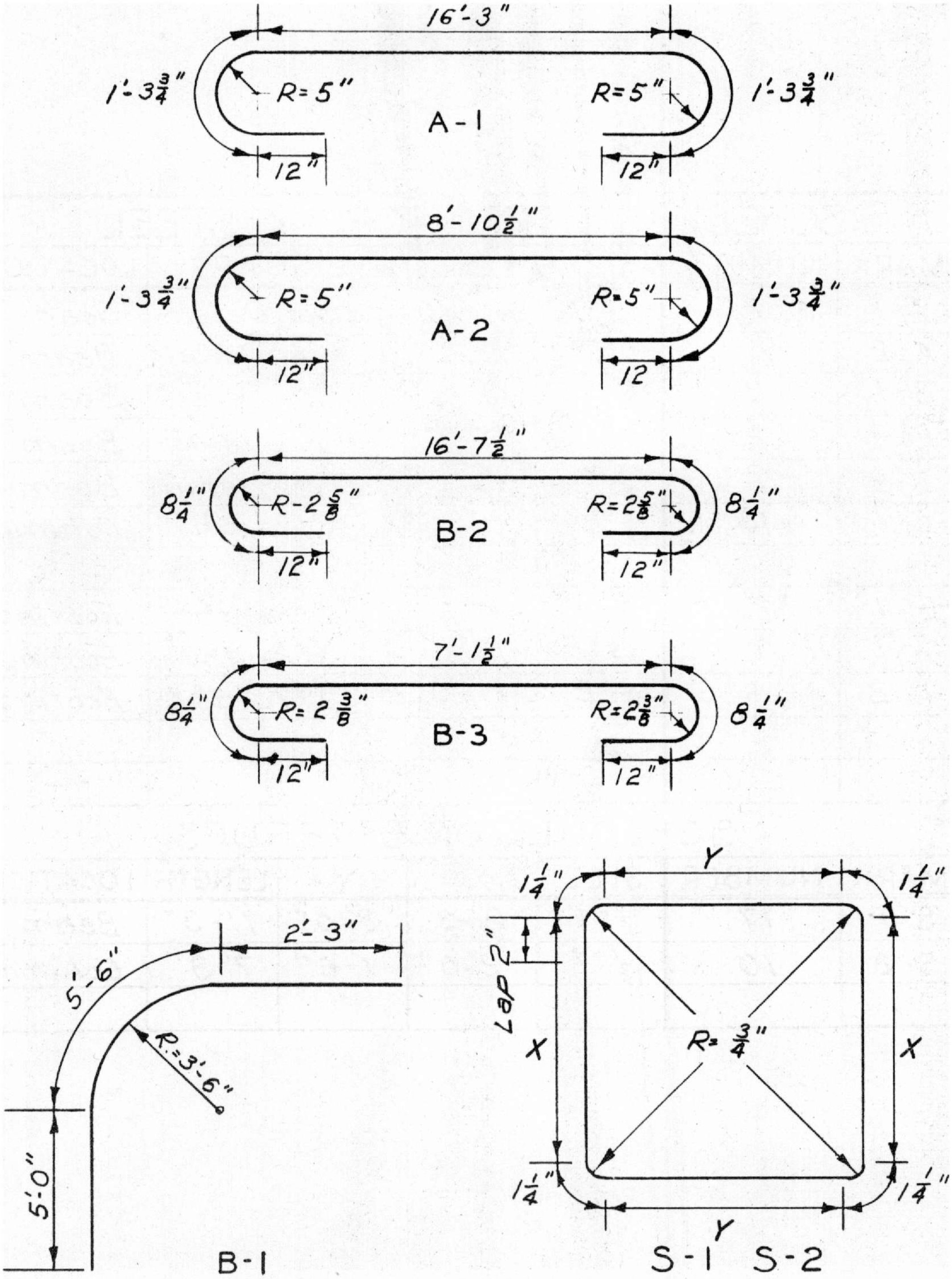
PLATE 7

SCHEDULE OF REINFORCING STEEL					
MARK	NUMBER	SIZE	LENGTH	SHAPE	LOCATION
A-1	2	1 1/4" ø	20'-10 1/2"	See Detail	Beam
A-2	2	1 1/4" ø	13'-6"	See Detail	Beam
B-1	8	3/4" ø	12'-9"	See Detail	Beam
B-2	2	7/8" ø	20'-0"	See Detail	Beam
B-3	6	7/8" ø	10'-6"	See Detail	Beam
C-1	14	3/4" ø	8'-10"	Straight	Columns
F-1	20	3/4" ø	4'-0"	Straight	Footings
H-1	6	1 1/8" ø	17'-0"	Straight	Footings
H-2	6	3/4" ø	17'-0"	Straight	Footings

SCHEDULE OF STIRRUPS						
MARK	NUMBER	SIZE	X	Y	LENGTH	LOCATION
S-1	17	1/2" ø	3'-3"	2'-0"	11'-3"	Beam
S-2	10	1/2" ø	2'-0"	1'-6"	7'-9"	Columns

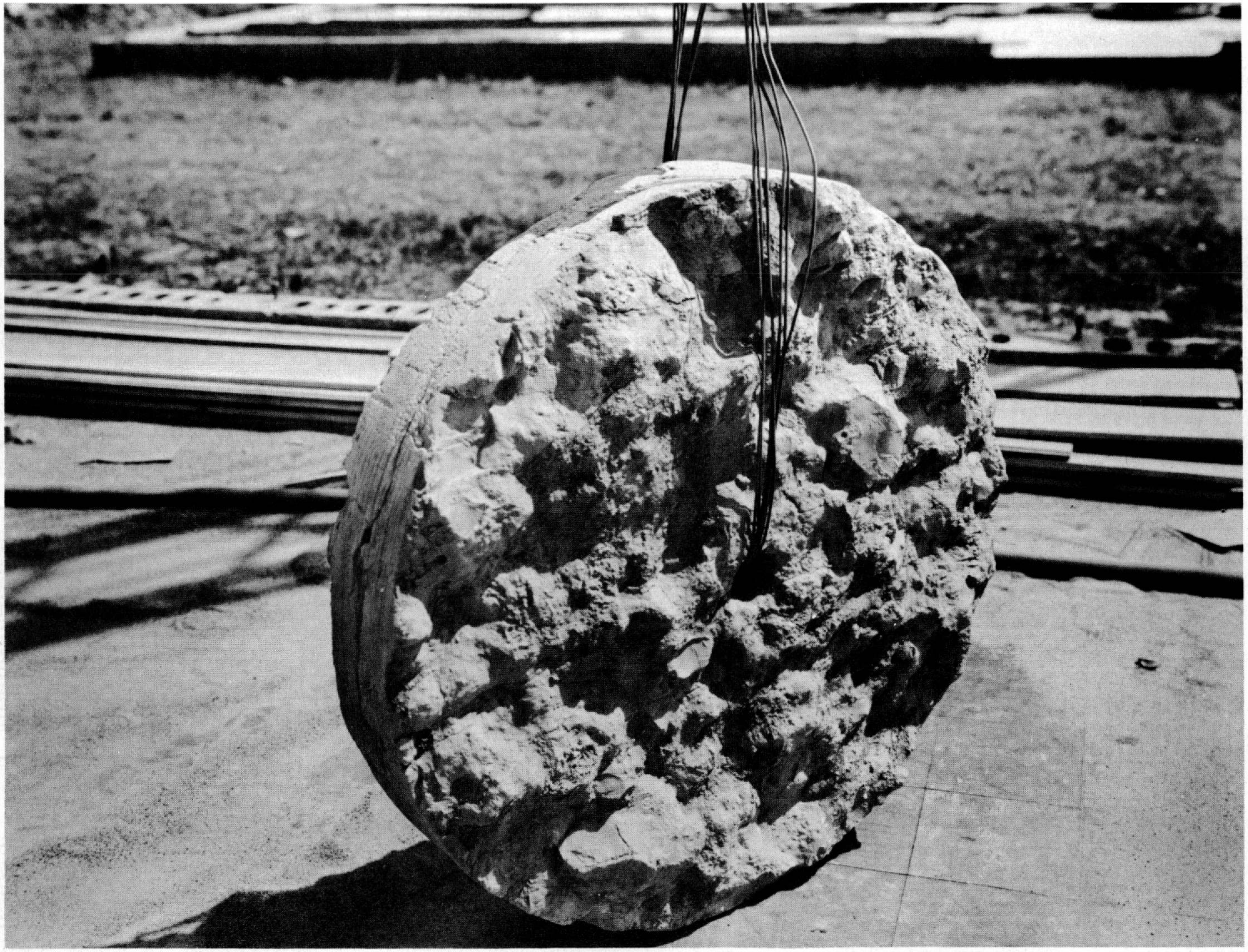
Bridge pier, schedule of reinforcing steel and stirrups

PLATE 8

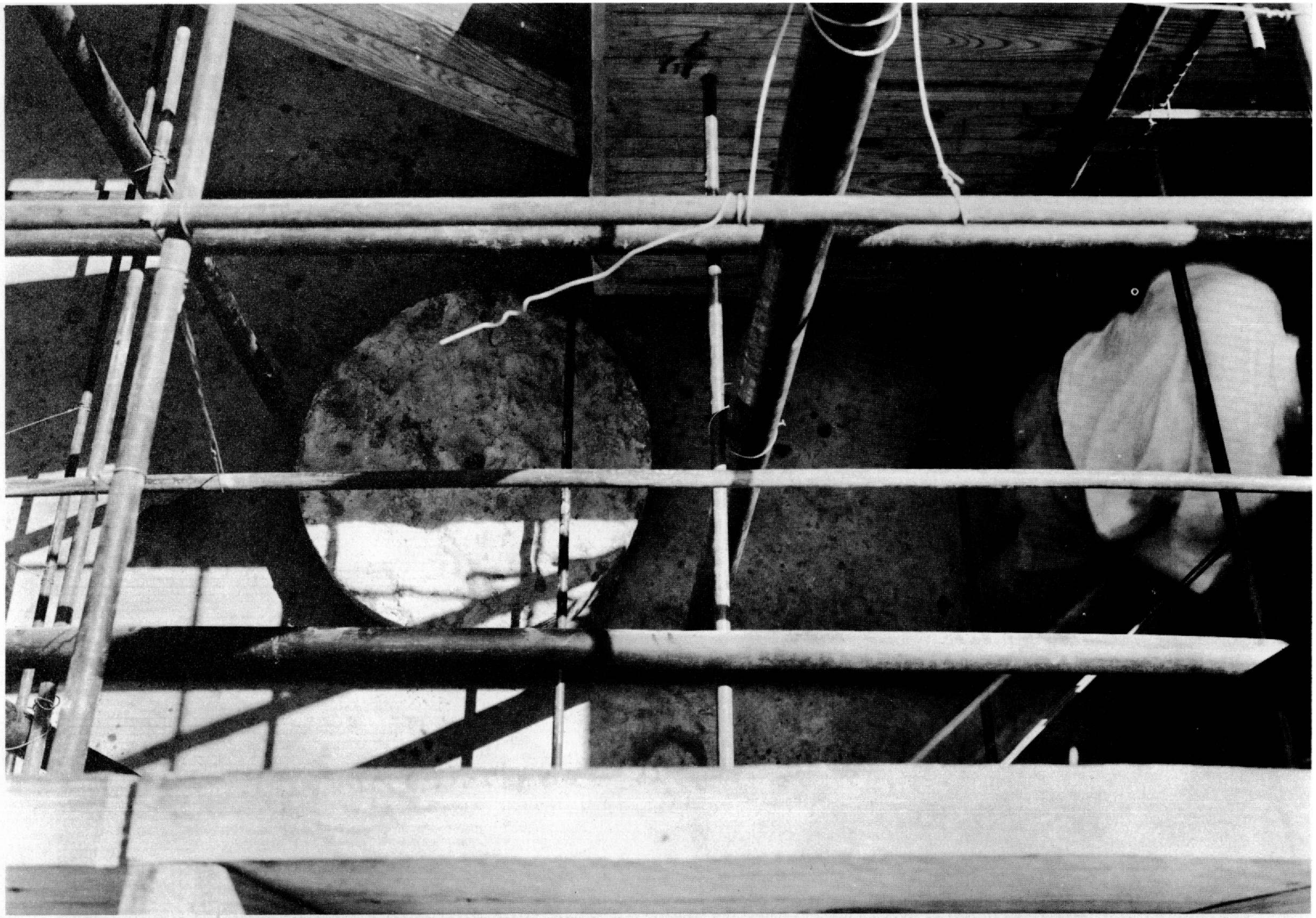


Bridge pier, reinforcing steel details

PLATE 10



Thirty-six-inch-diameter limestone rock core after sandblasting

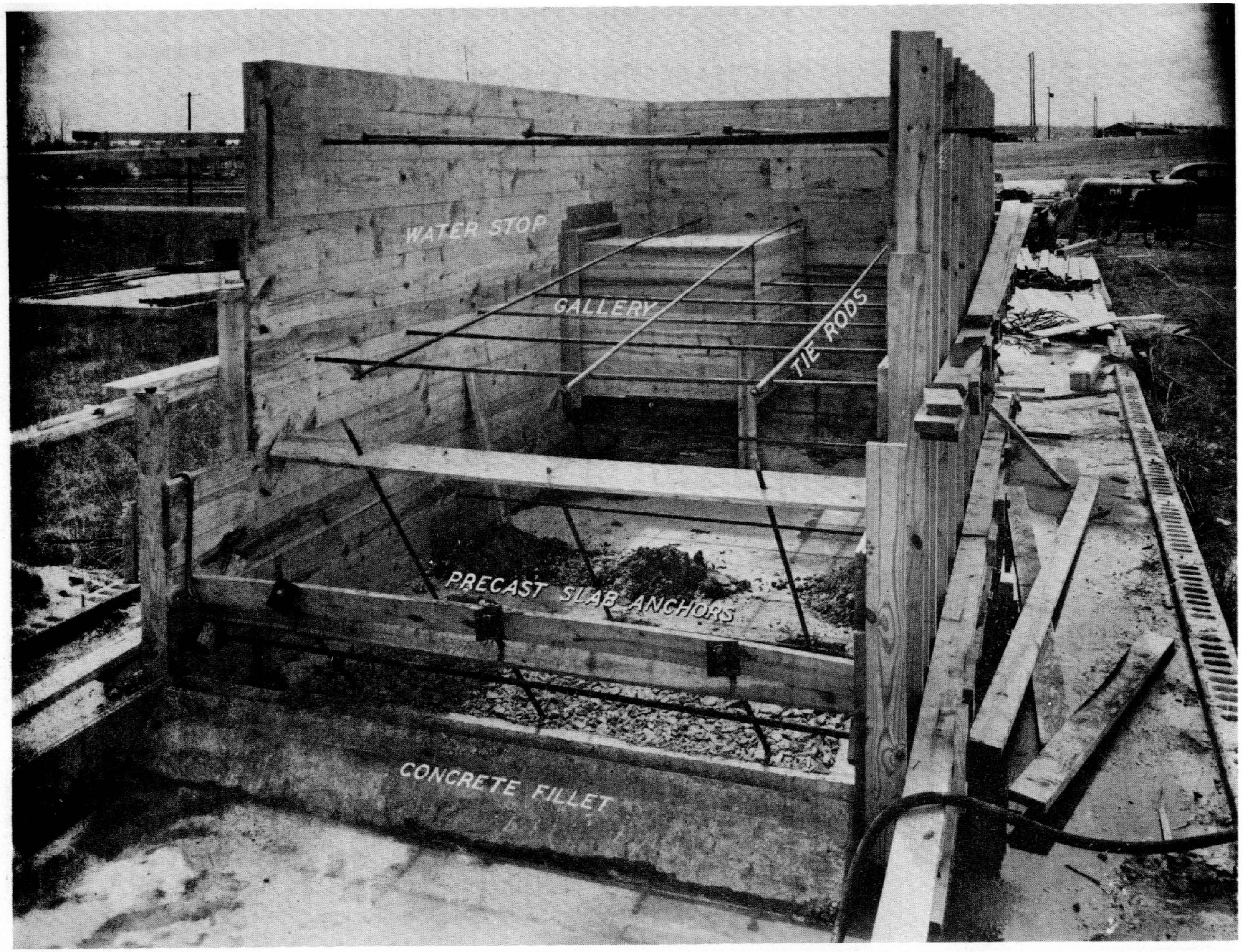


Sandblasted core in place on foundation of test block

PLATE 11

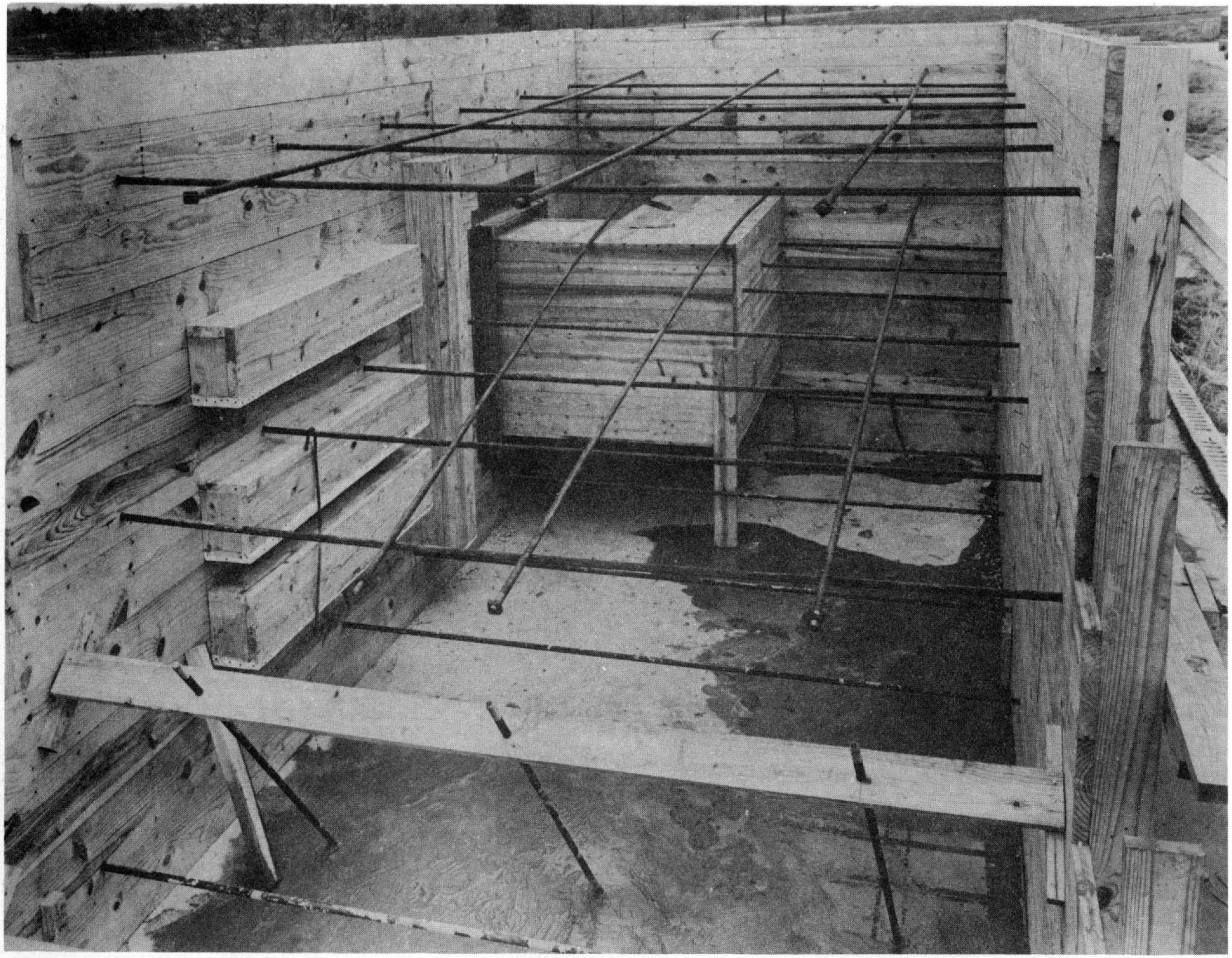
PLATE 12

Form for block under construction



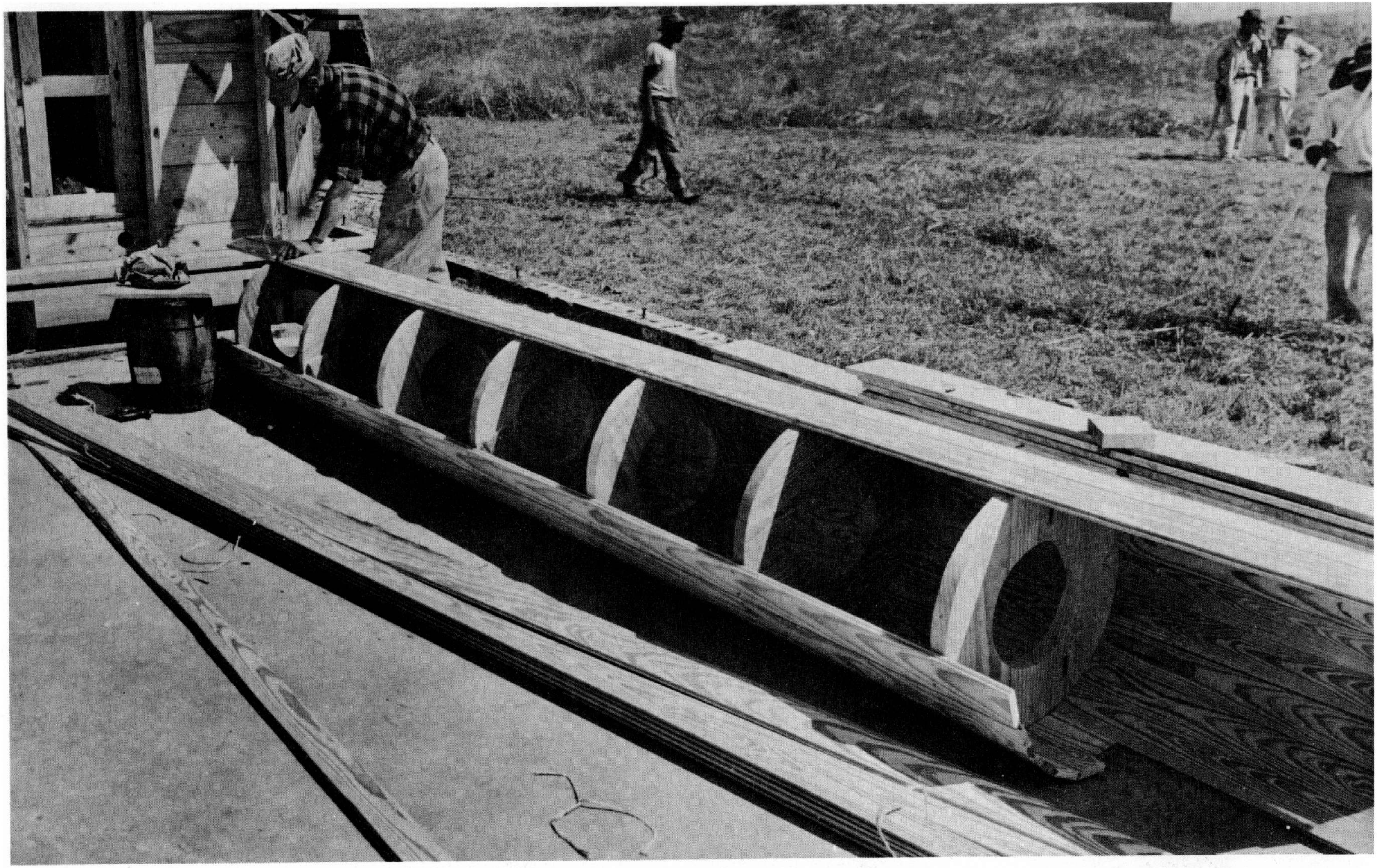
View into block form

PLATE 13

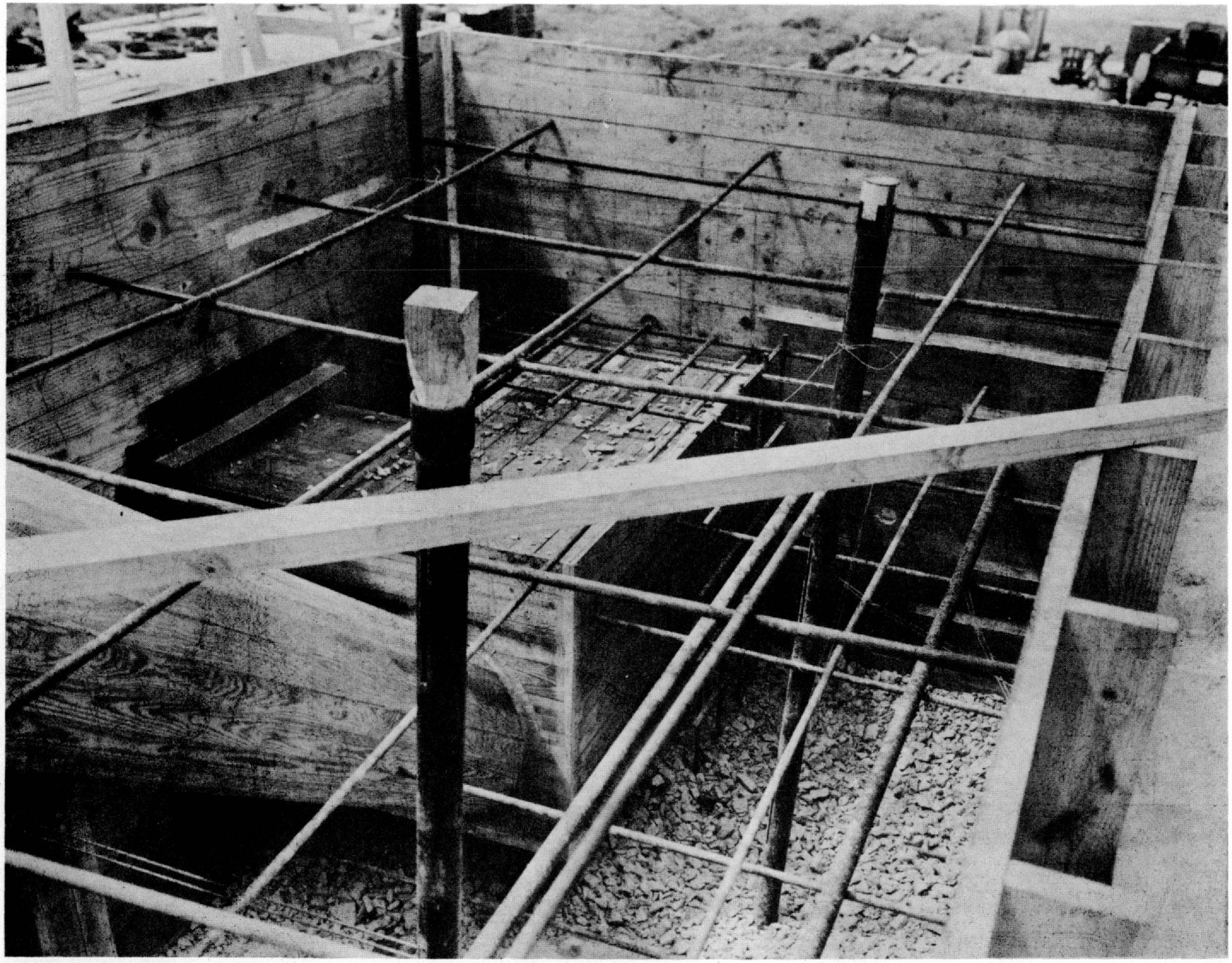


Block form showing blockouts and waterstop in place and after grouting of form anchorages

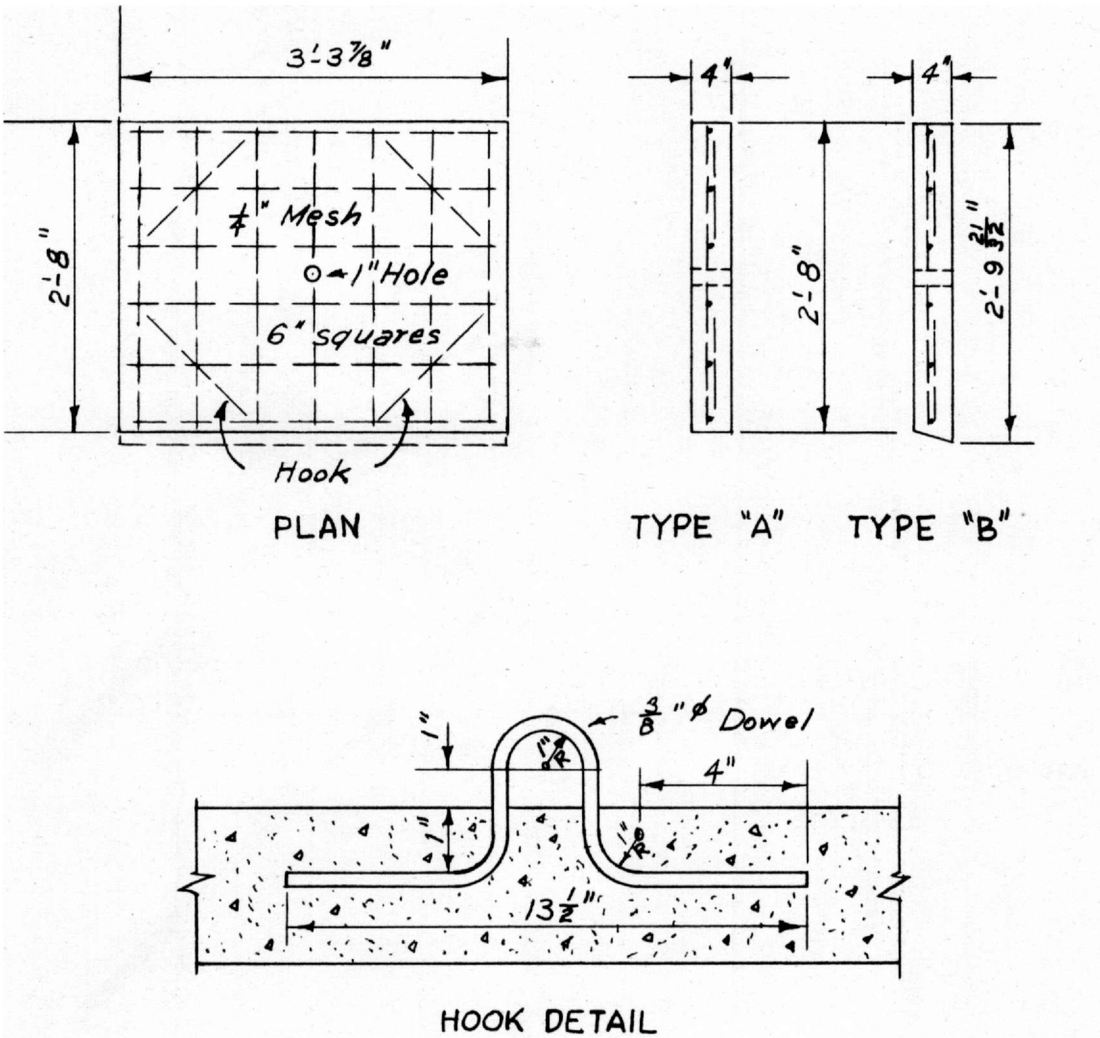
PLATE 15



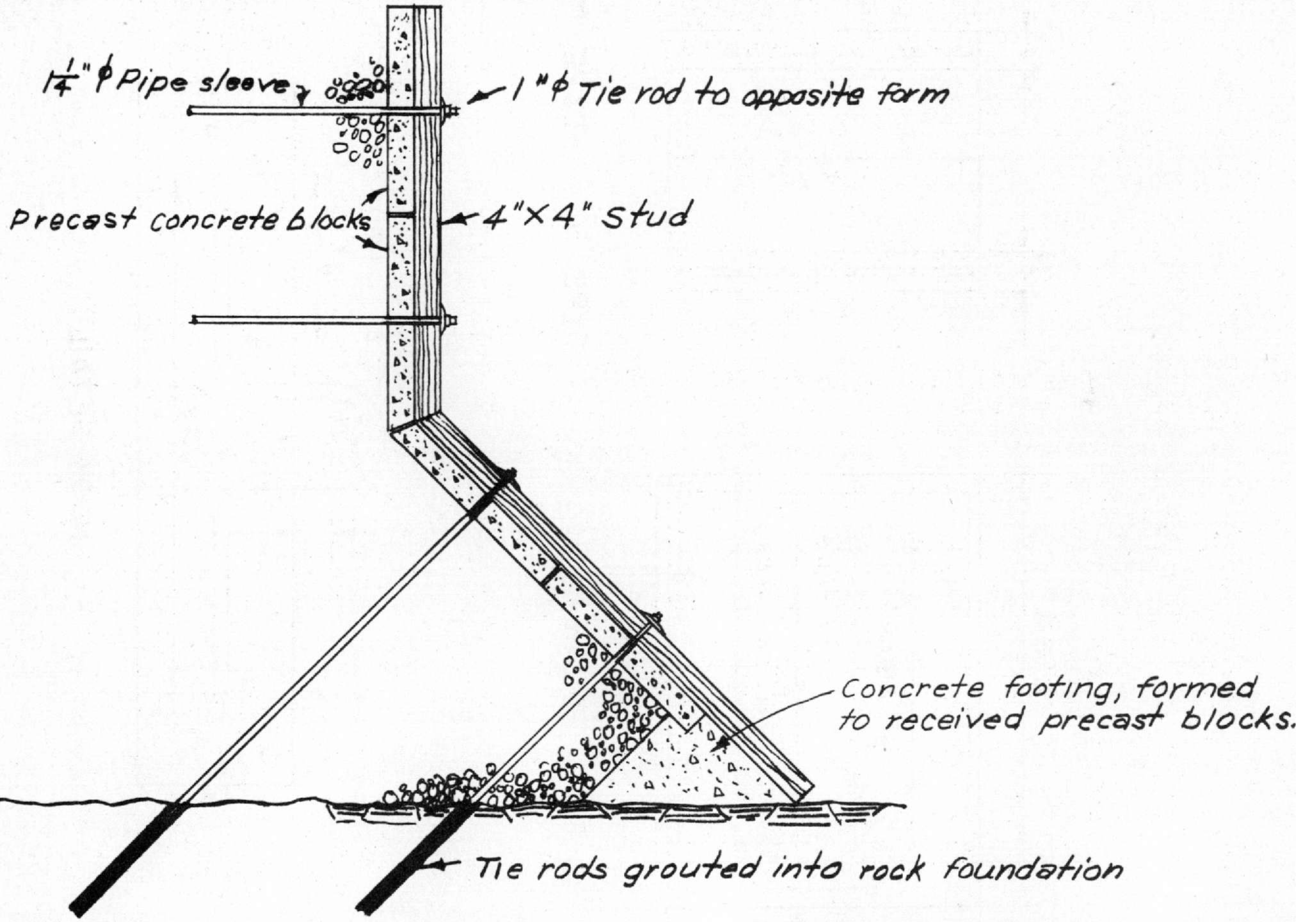
Wood-stave pipe (penstock) under construction



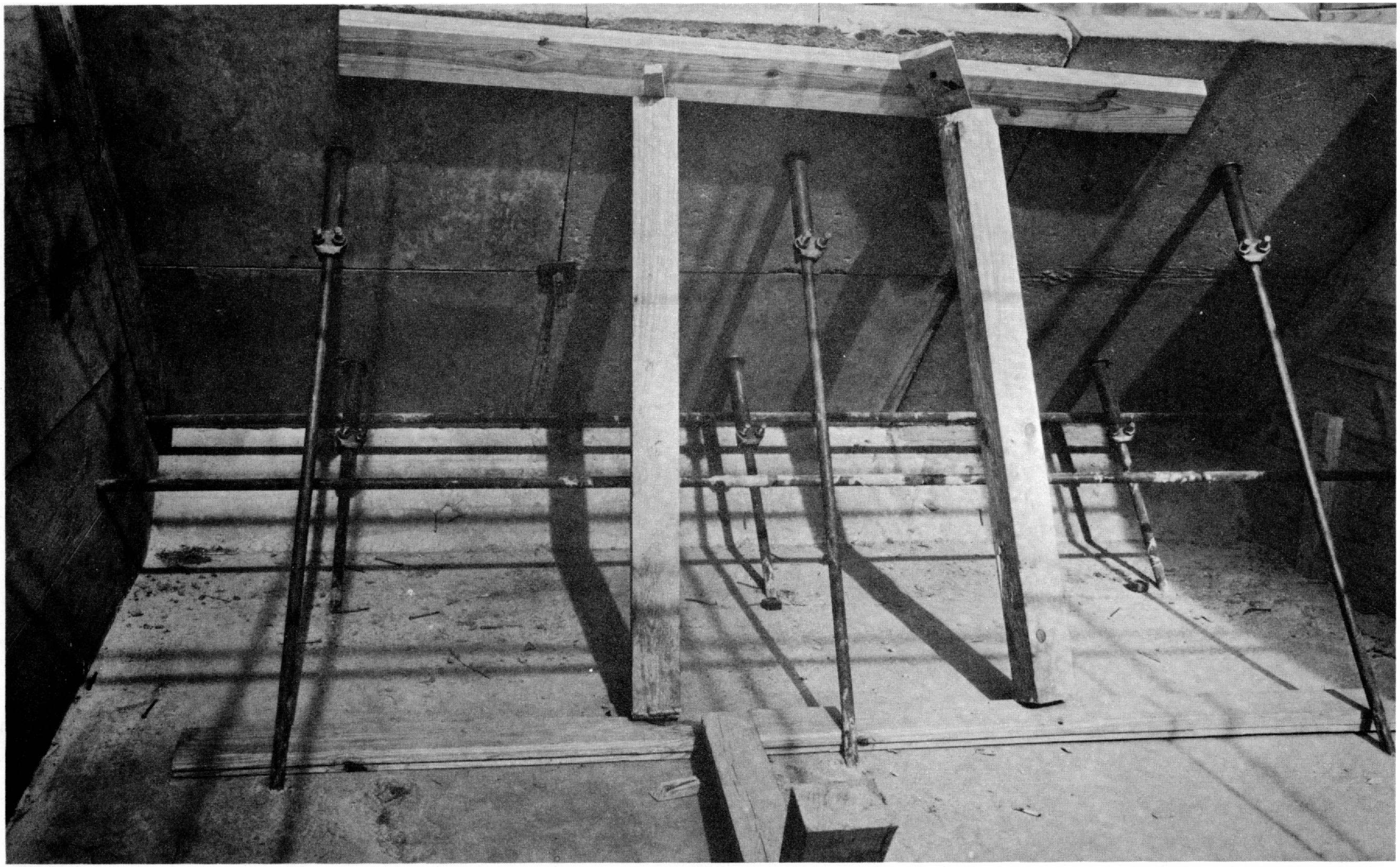
Test block at start of aggregate placement, showing junction between penstock and gallery. Note tie rod passing through penstock and sampling wells



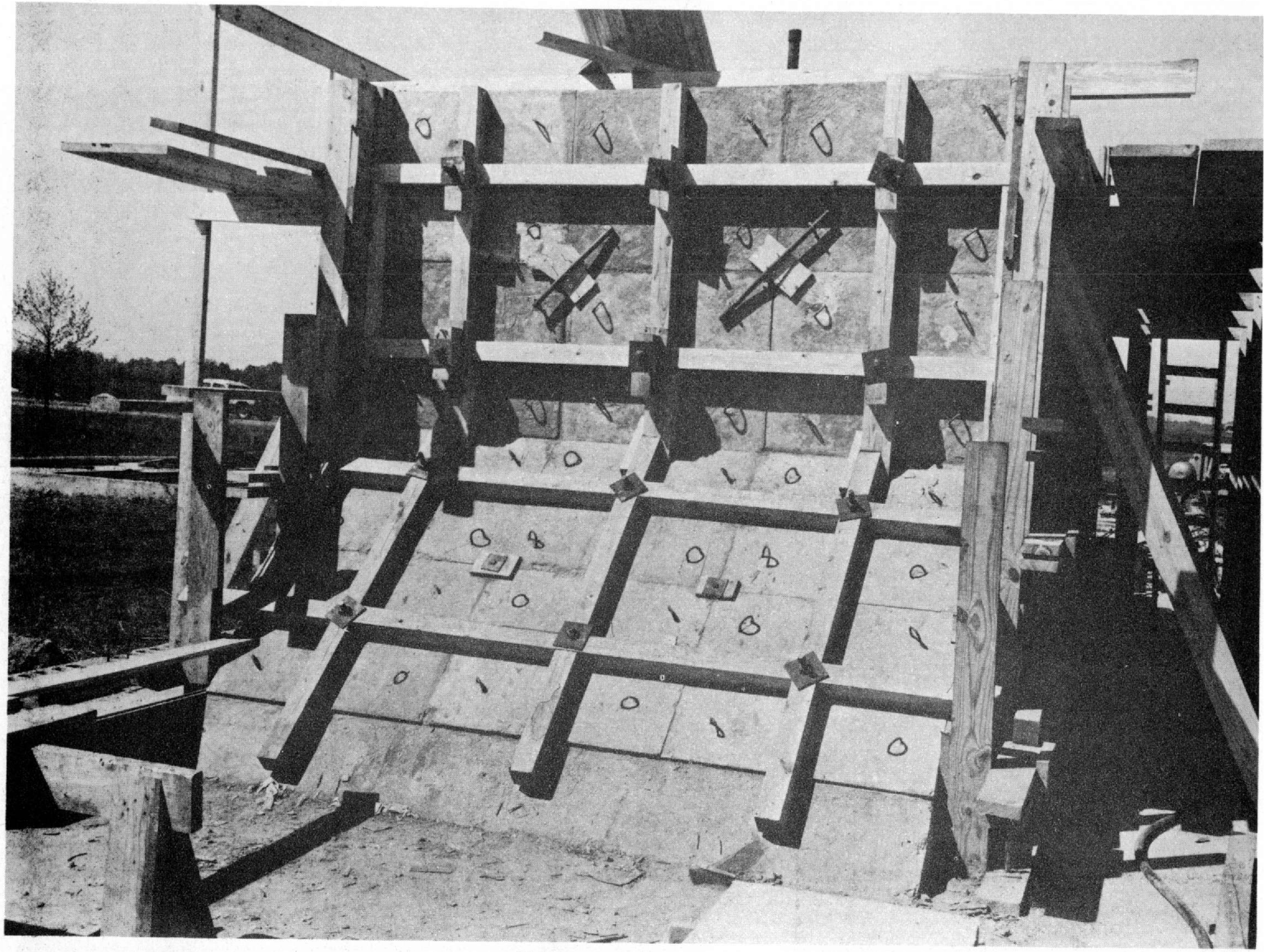
Details of precast concrete slabs for test block



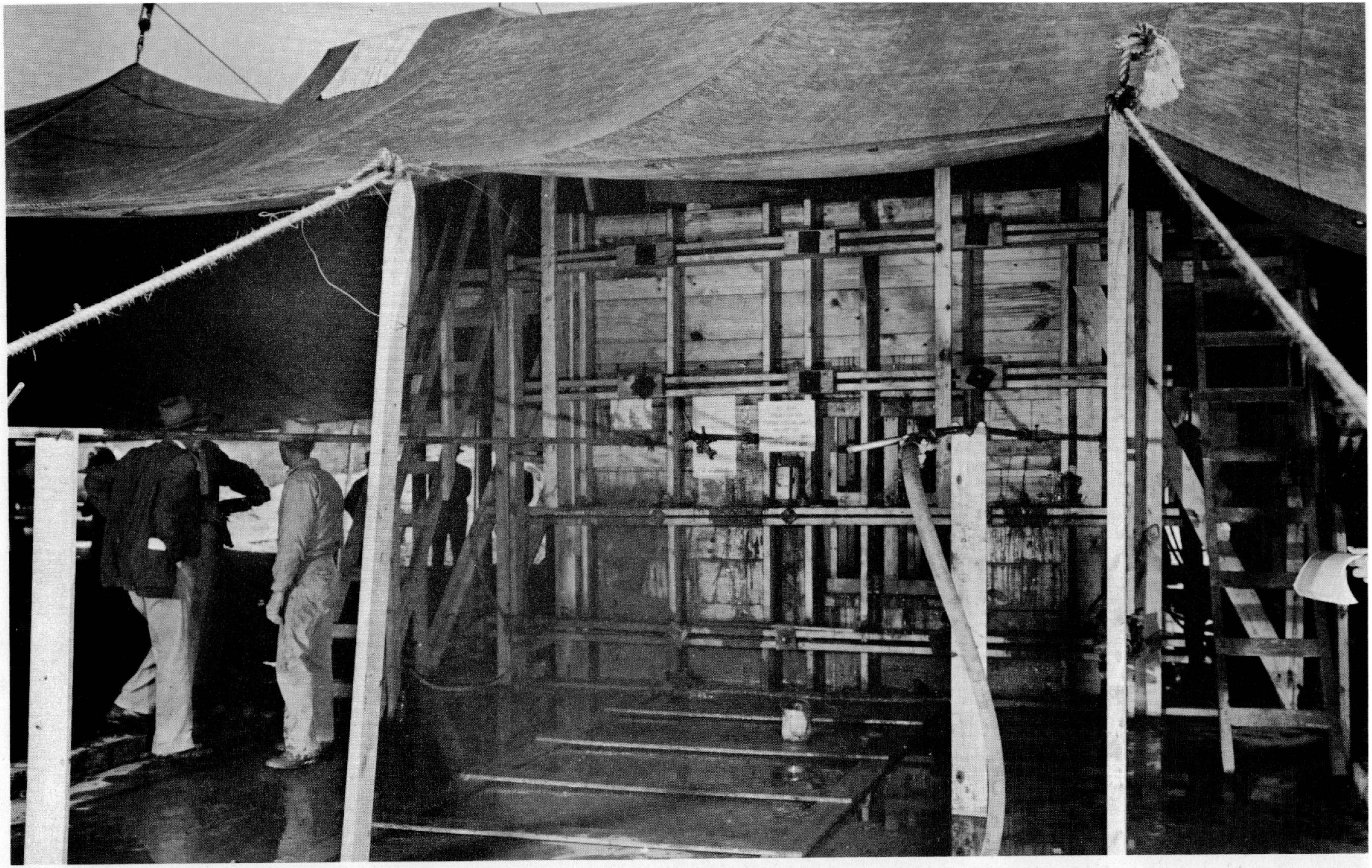
Erection details for precast concrete slabs of test block



Two lower tiers of precast concrete slabs, from inside form supported by 1-in. diagonal tie rods (wood shoring removed prior to placement of aggregate)

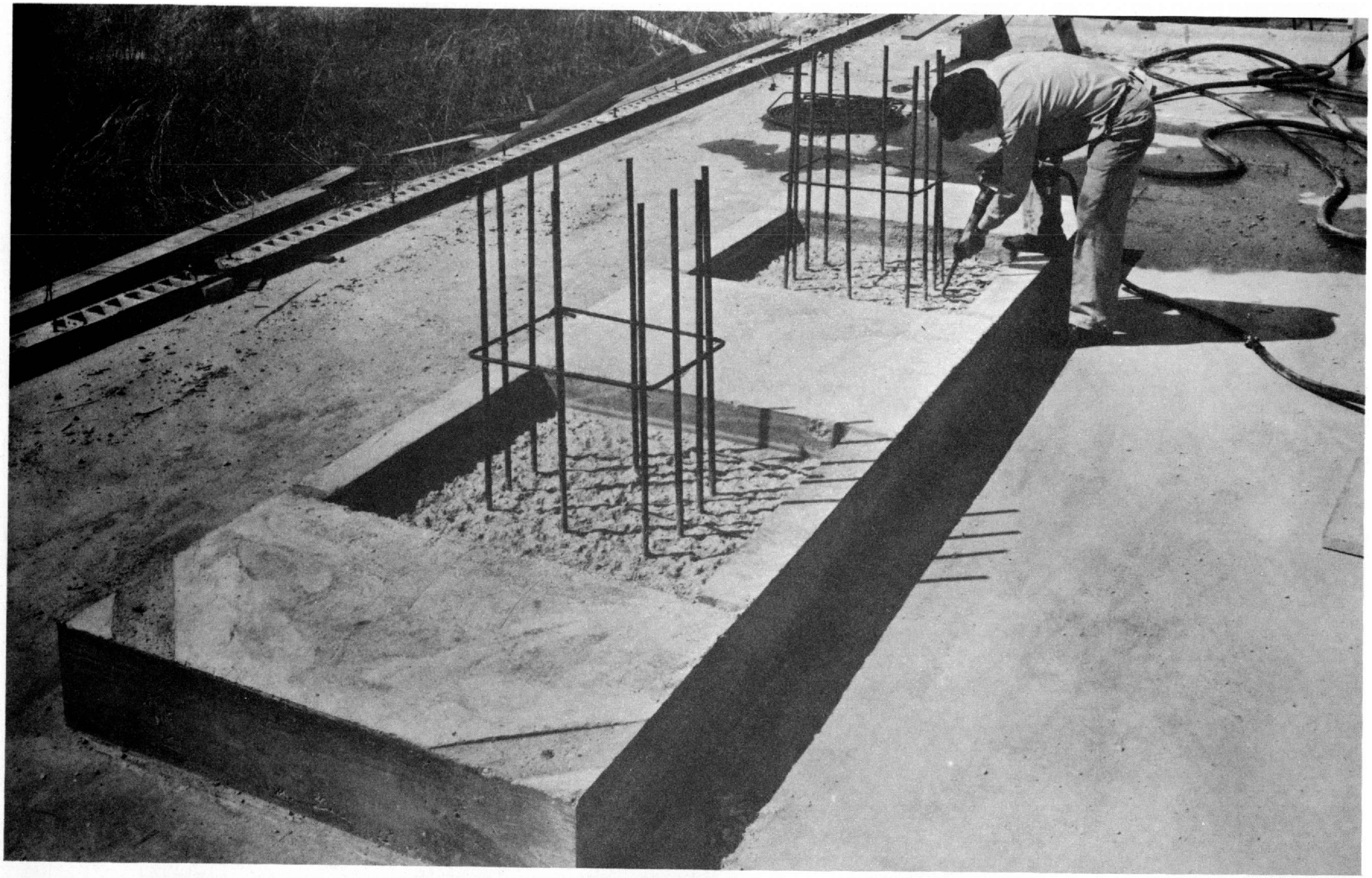


Rear view, precast concrete slabs in place

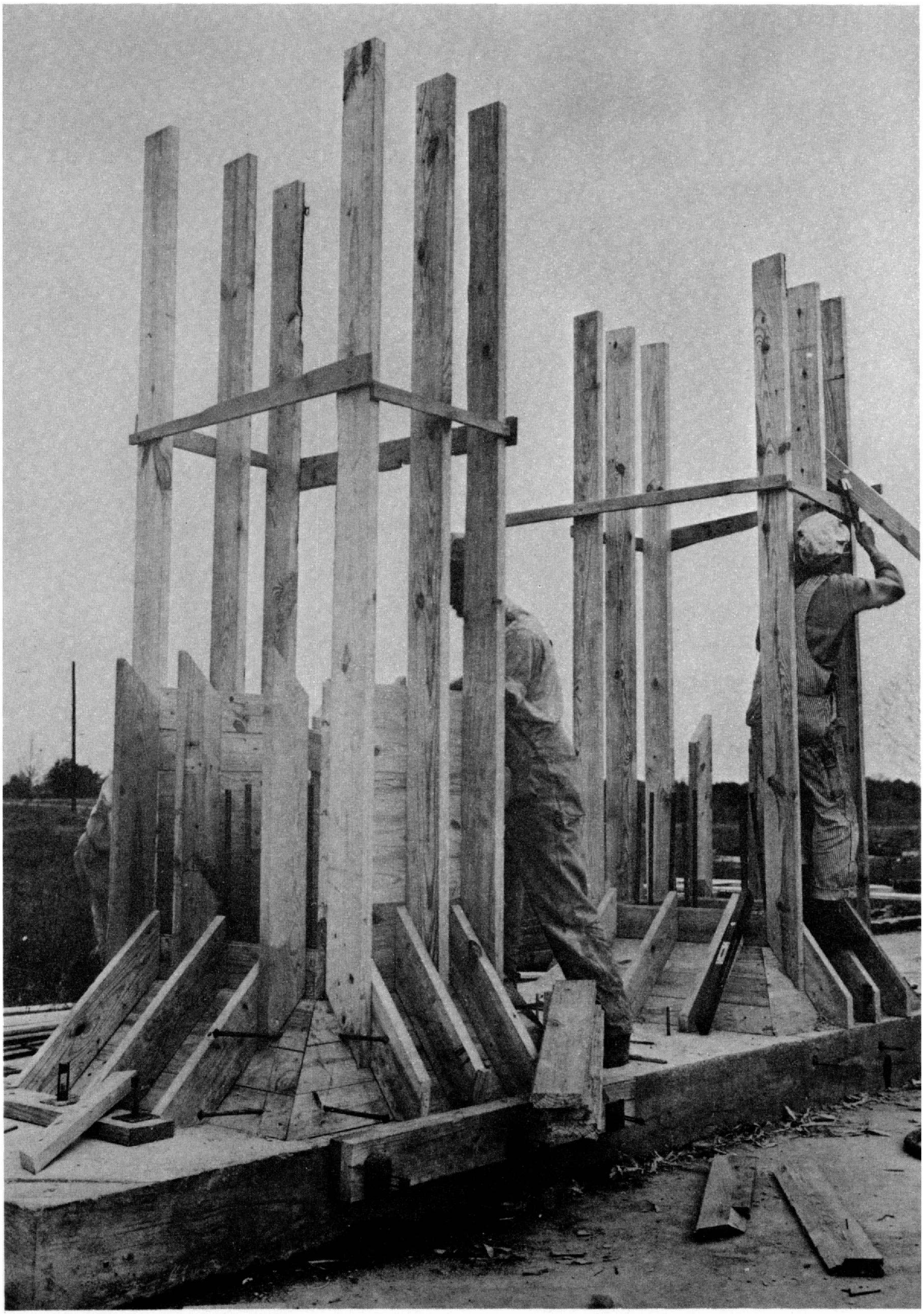


Model being grouted through horizontal pipes at 5-ft elevation

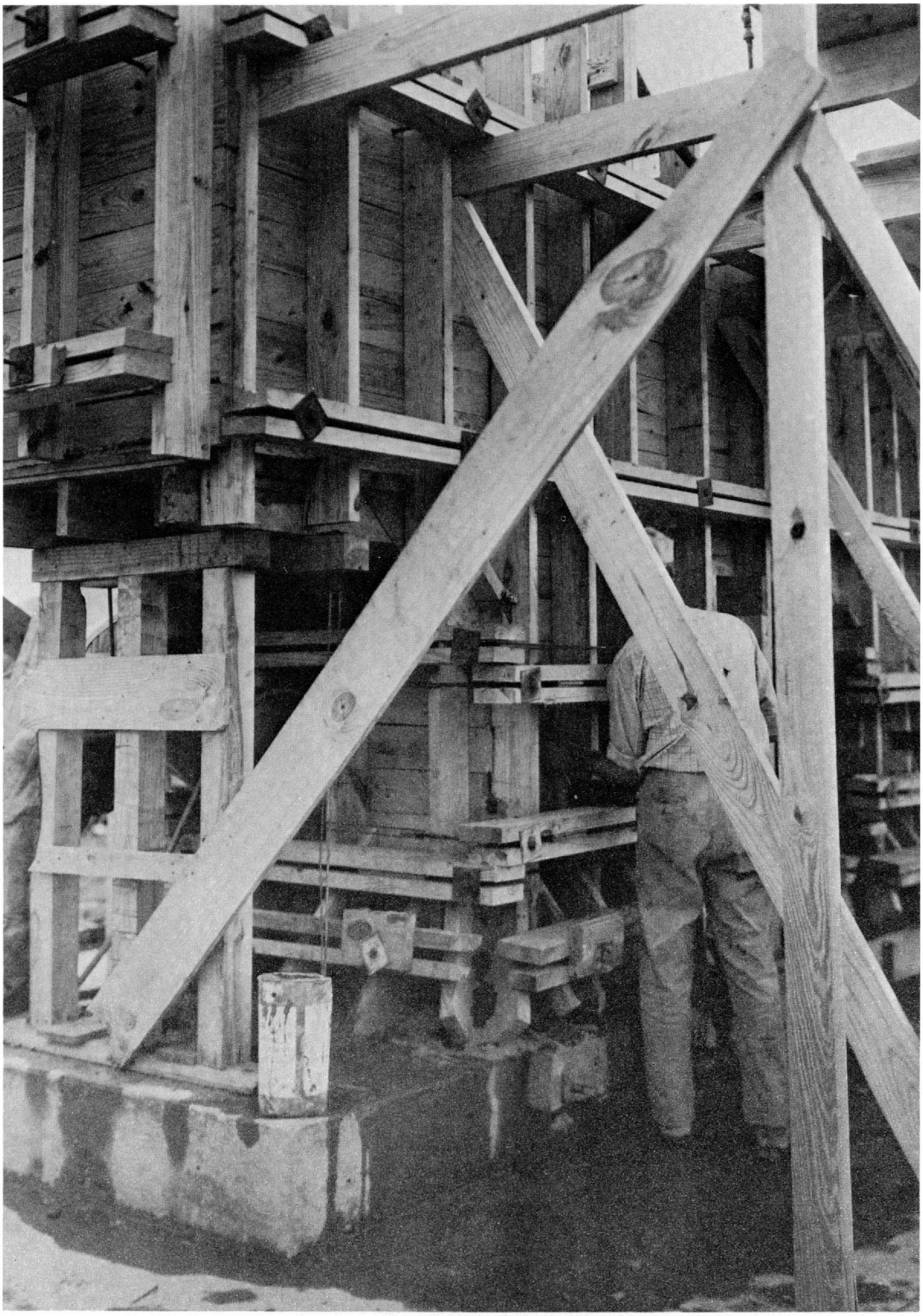
PLATE 22



Preparing bridge pier foundation by chipping with air chisel



Bridge pier form under construction



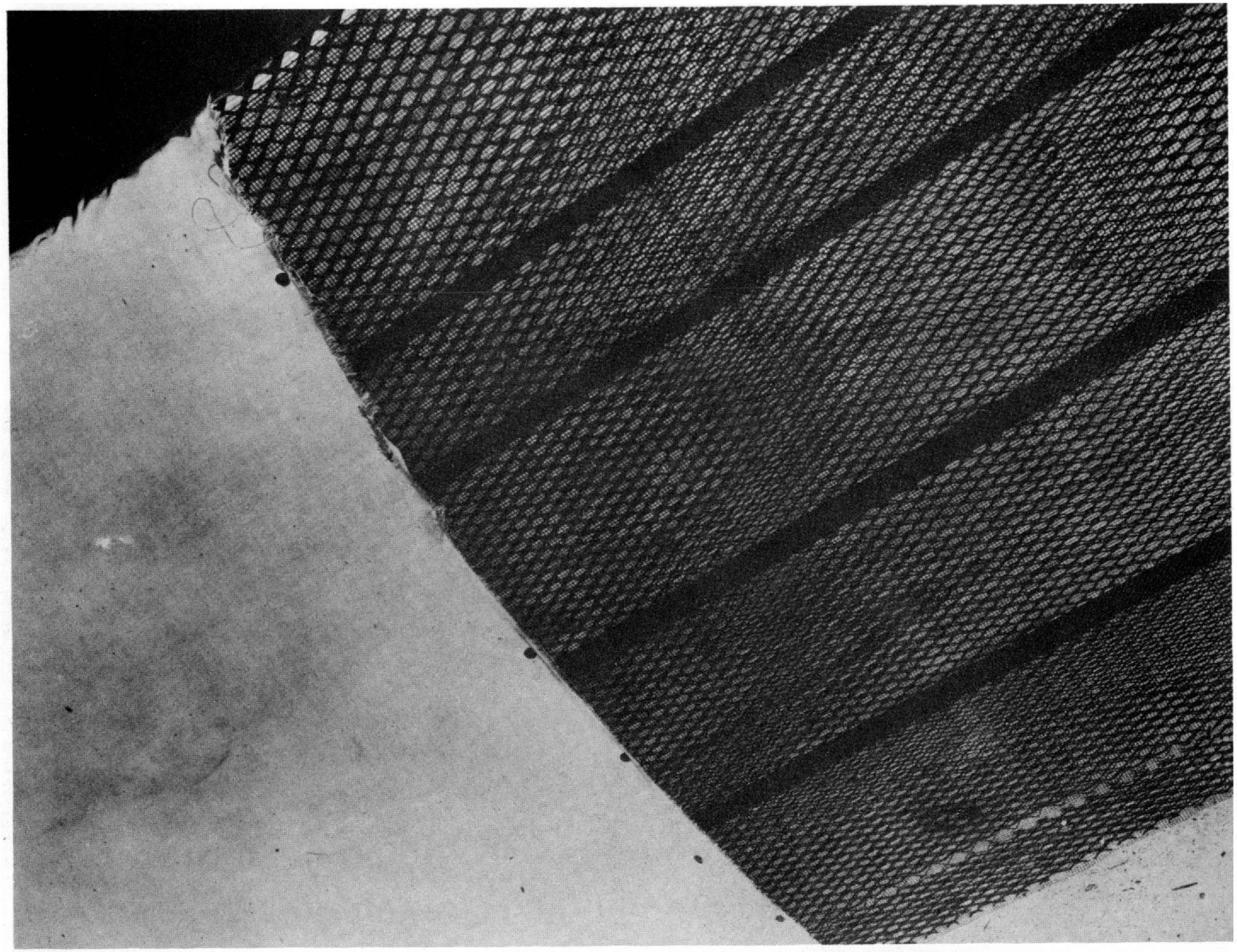
Bridge pier form during grouting. Note type of form construction

PLATE 24

Grouting bridge pier. Tent-covered block and equipment for batching, mixing and placing to left

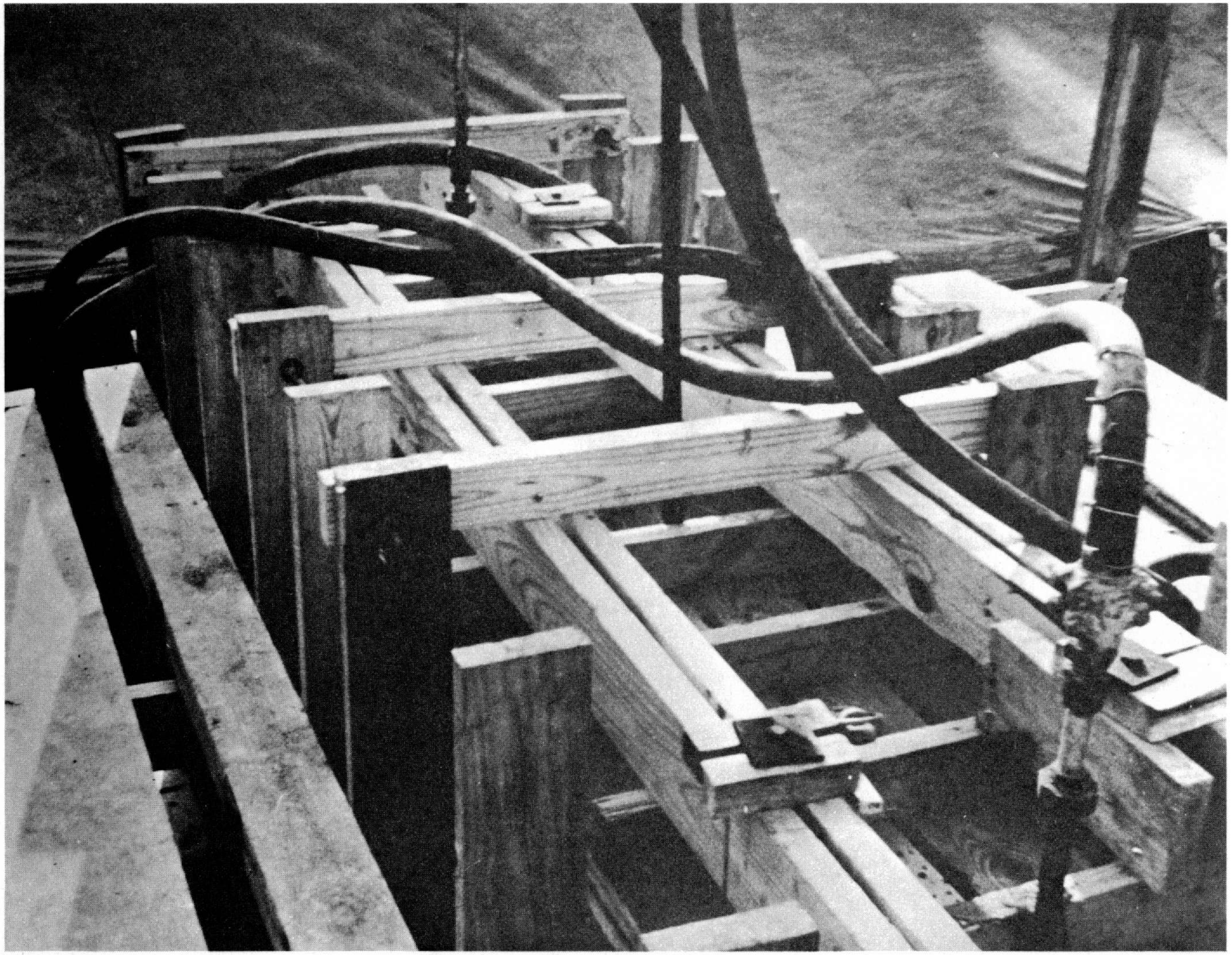
PLATE 25

PLATE 26

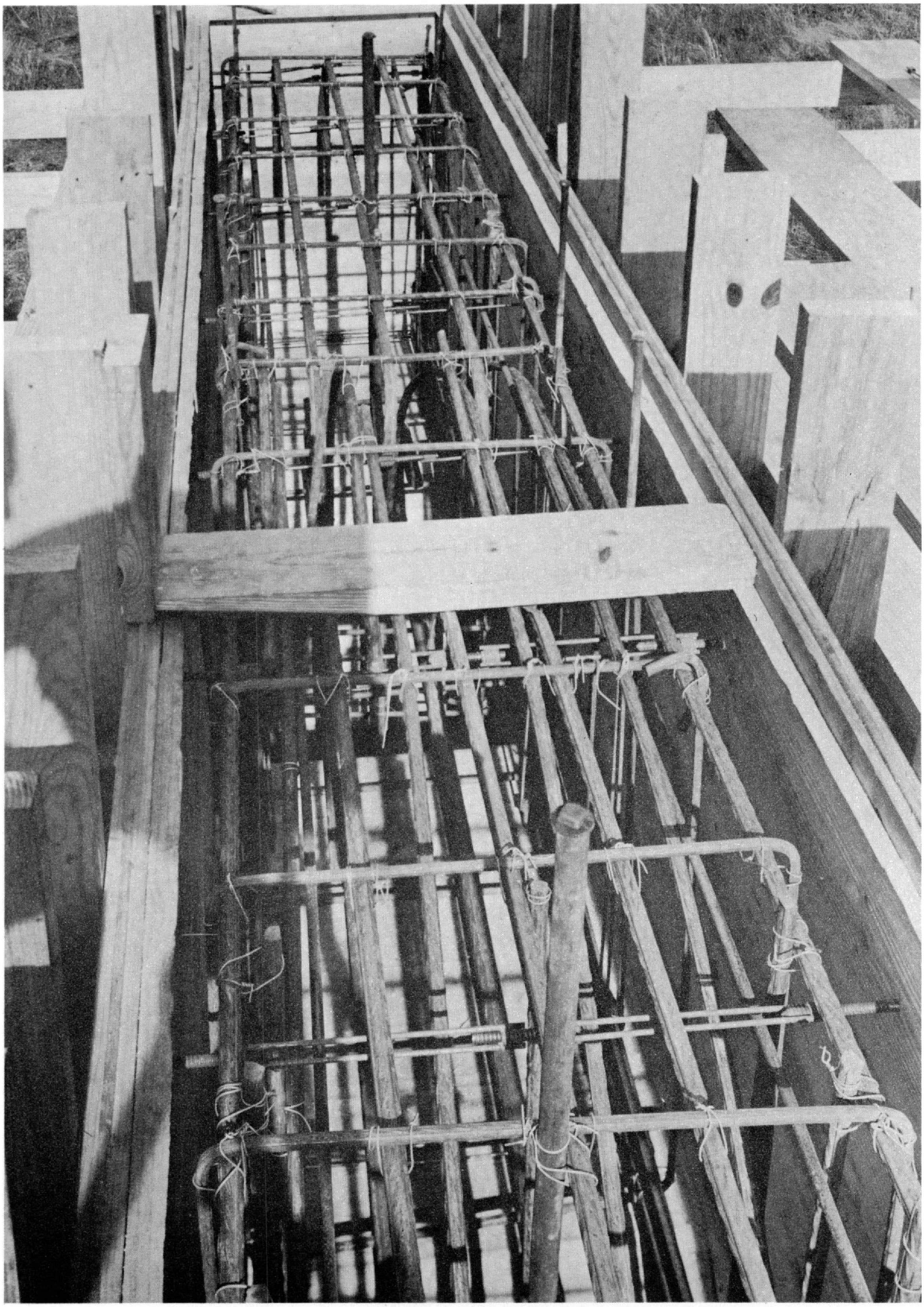


Cutaway view of underside of venting form top of bridge pier

PLATE 27



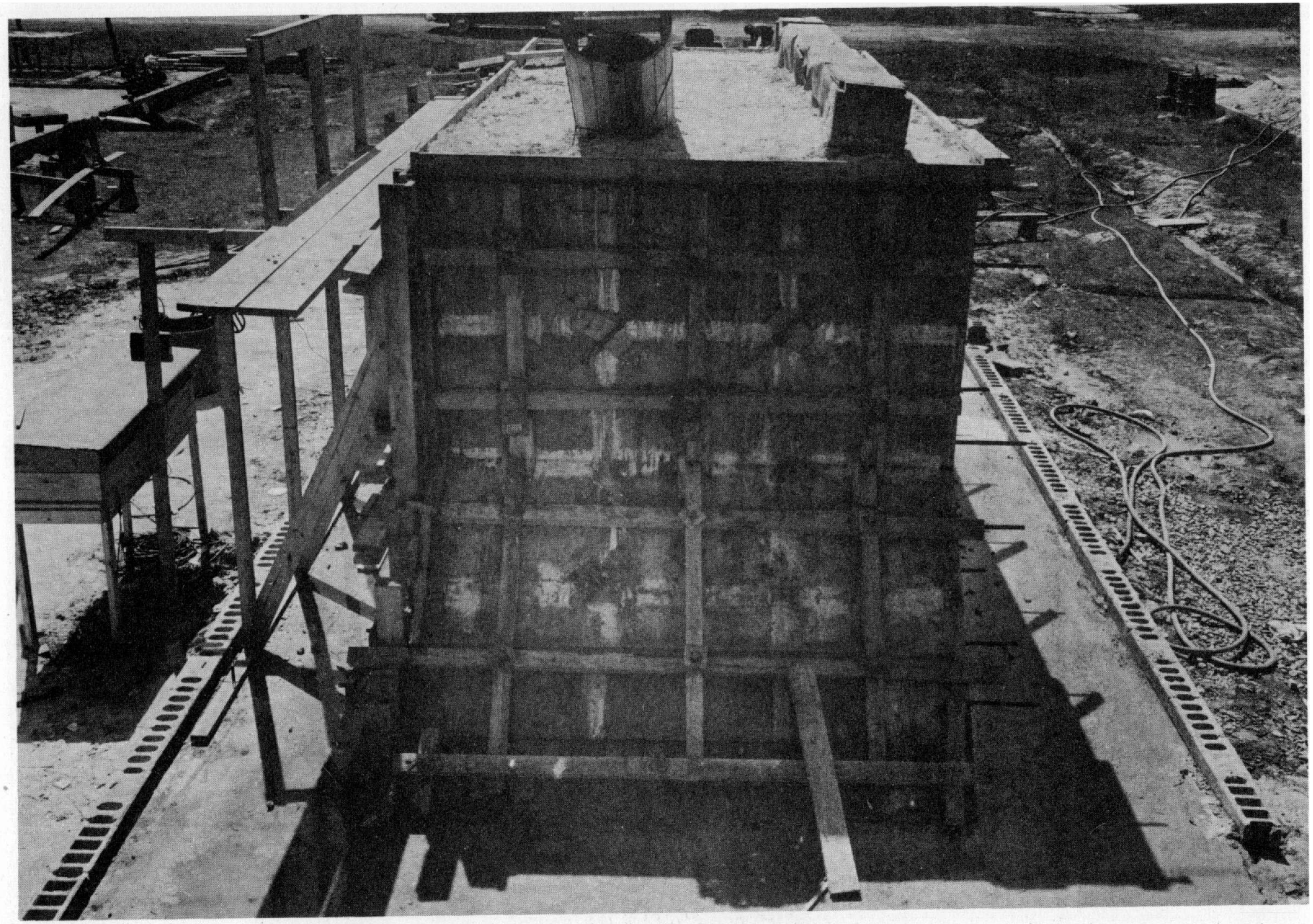
Grouting through top of bridge pier, venting form



View into top of bridge pier form showing reinforcing steel

PLATE 28

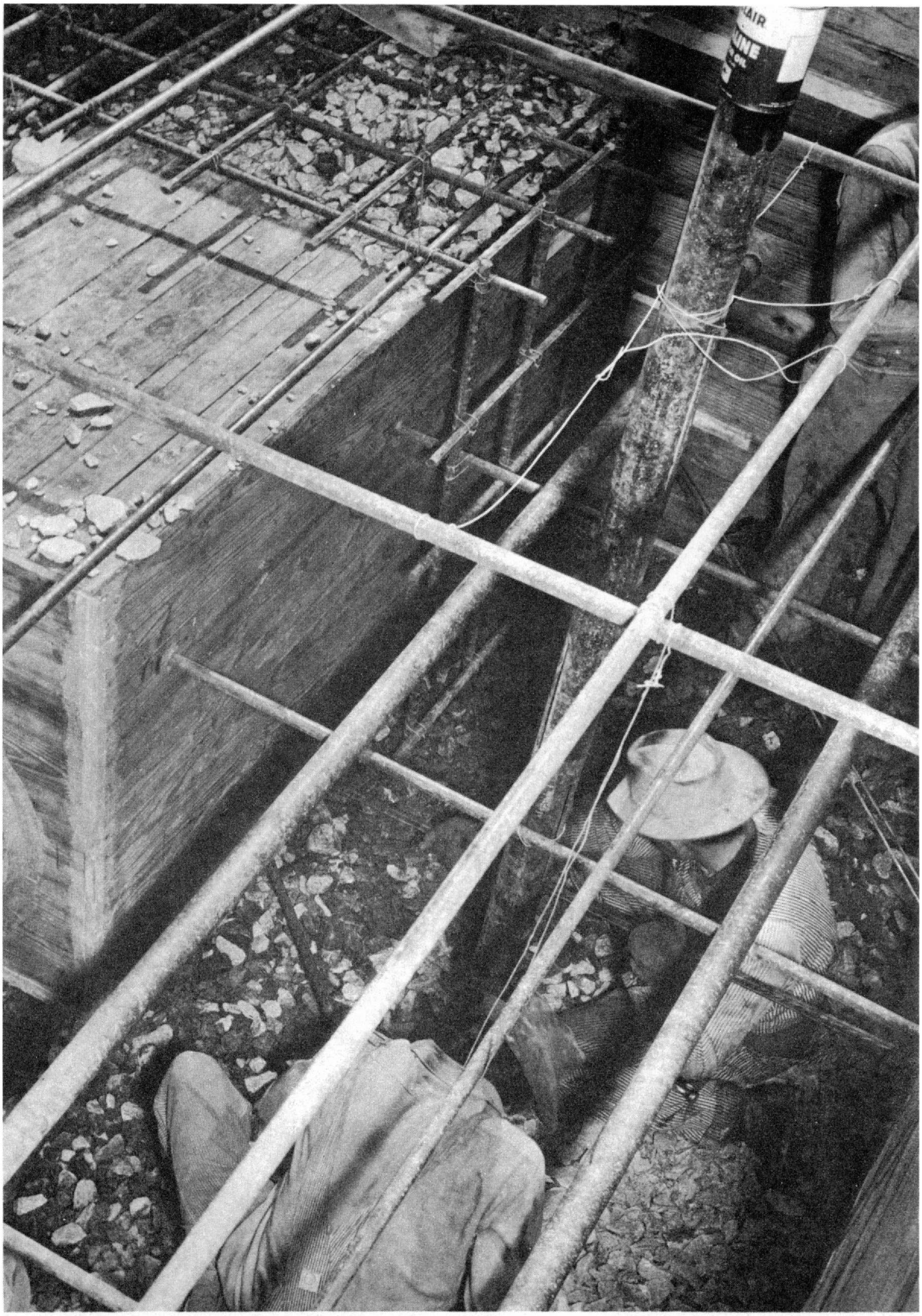
PLATE 29



Top and back of test block after grouting and removal of north side form, with curing sand and gage shelter in place

Placing aggregate in test block

PLATE 30



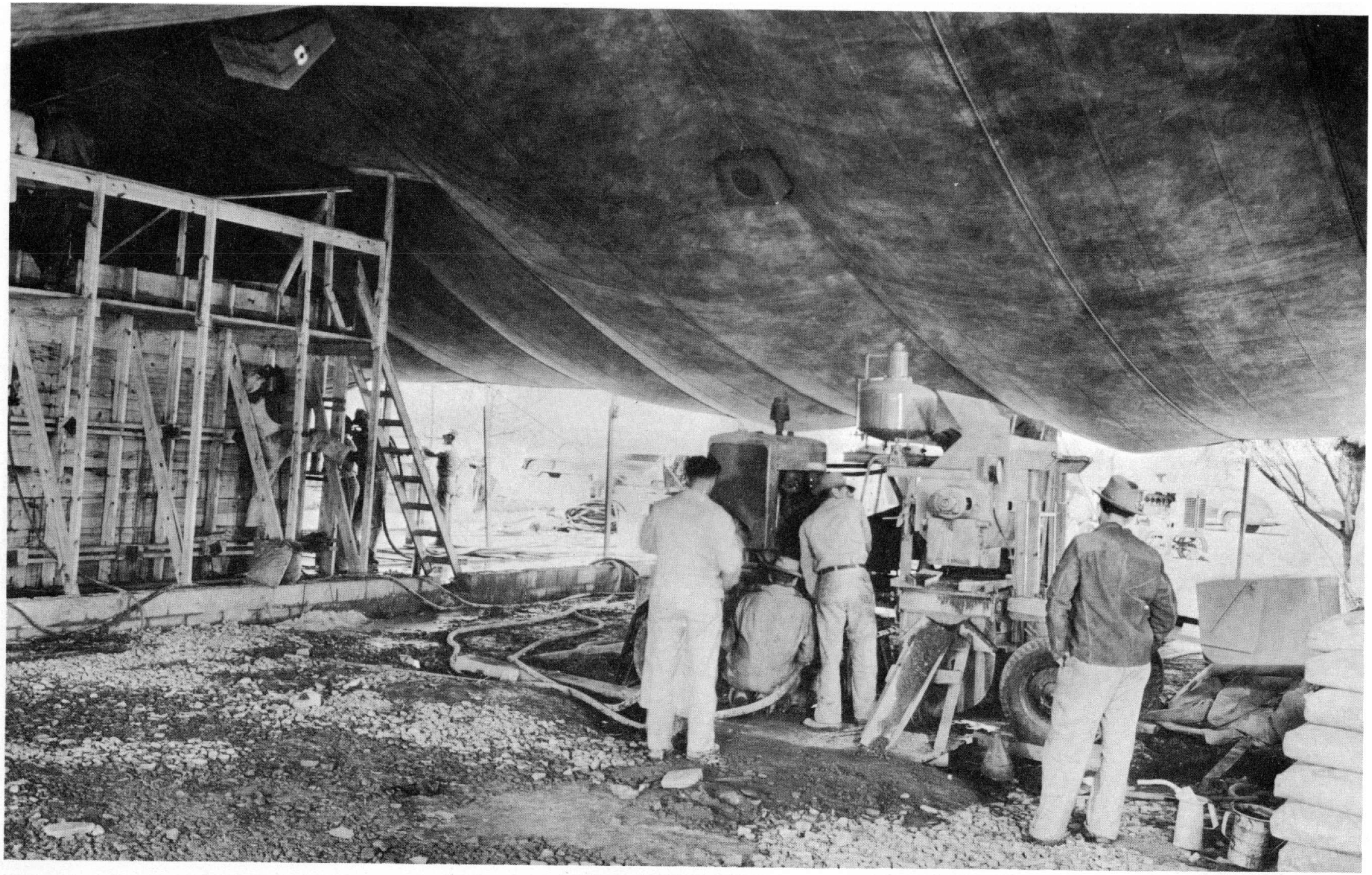
Rodding aggregate under gallery form

PLATE 32

Placing coarse aggregate under blockout with compressed air jet

Test block after coarse aggregate placement

PLATE 33



Grout mixer and pumps in operation

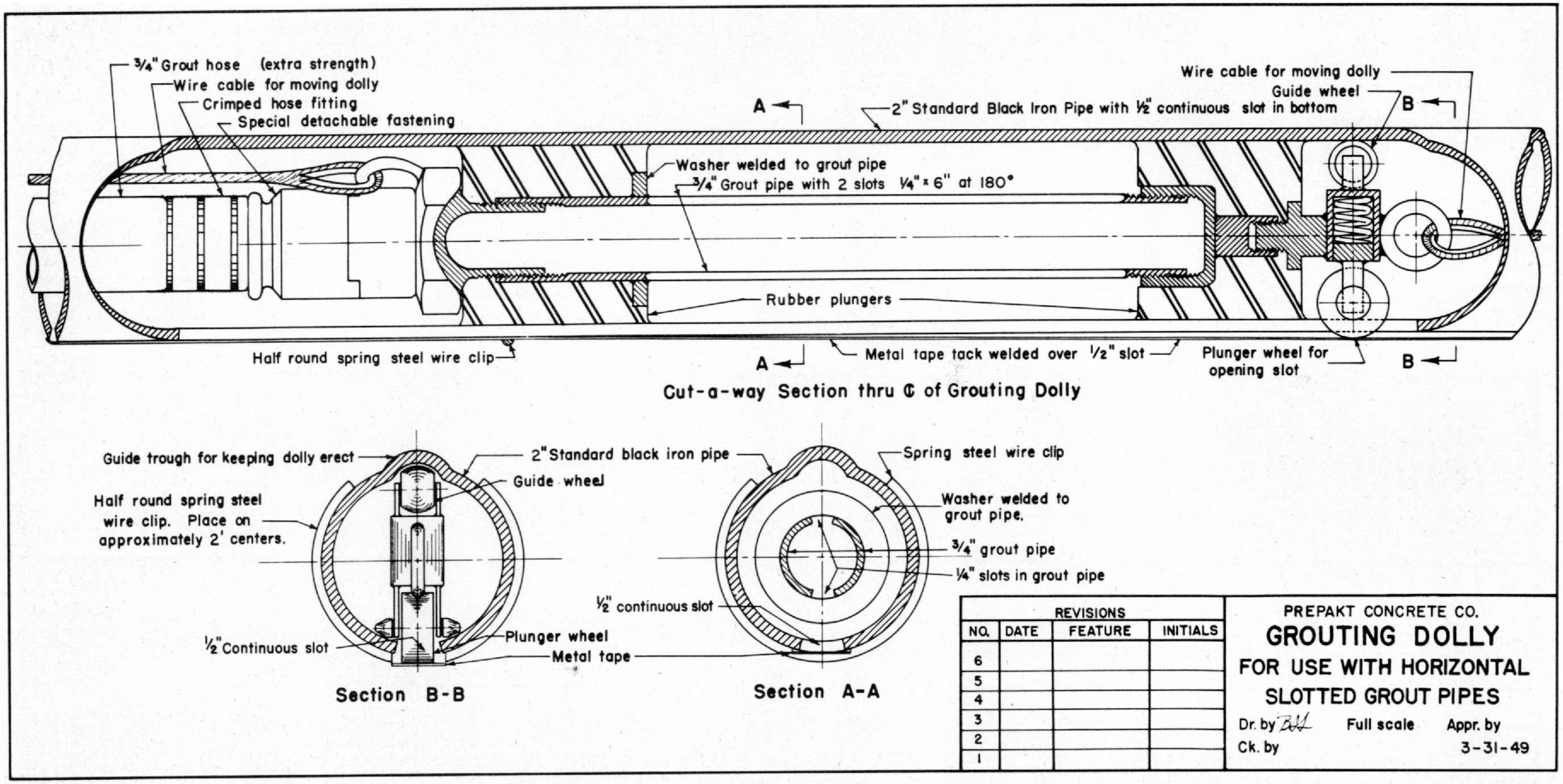
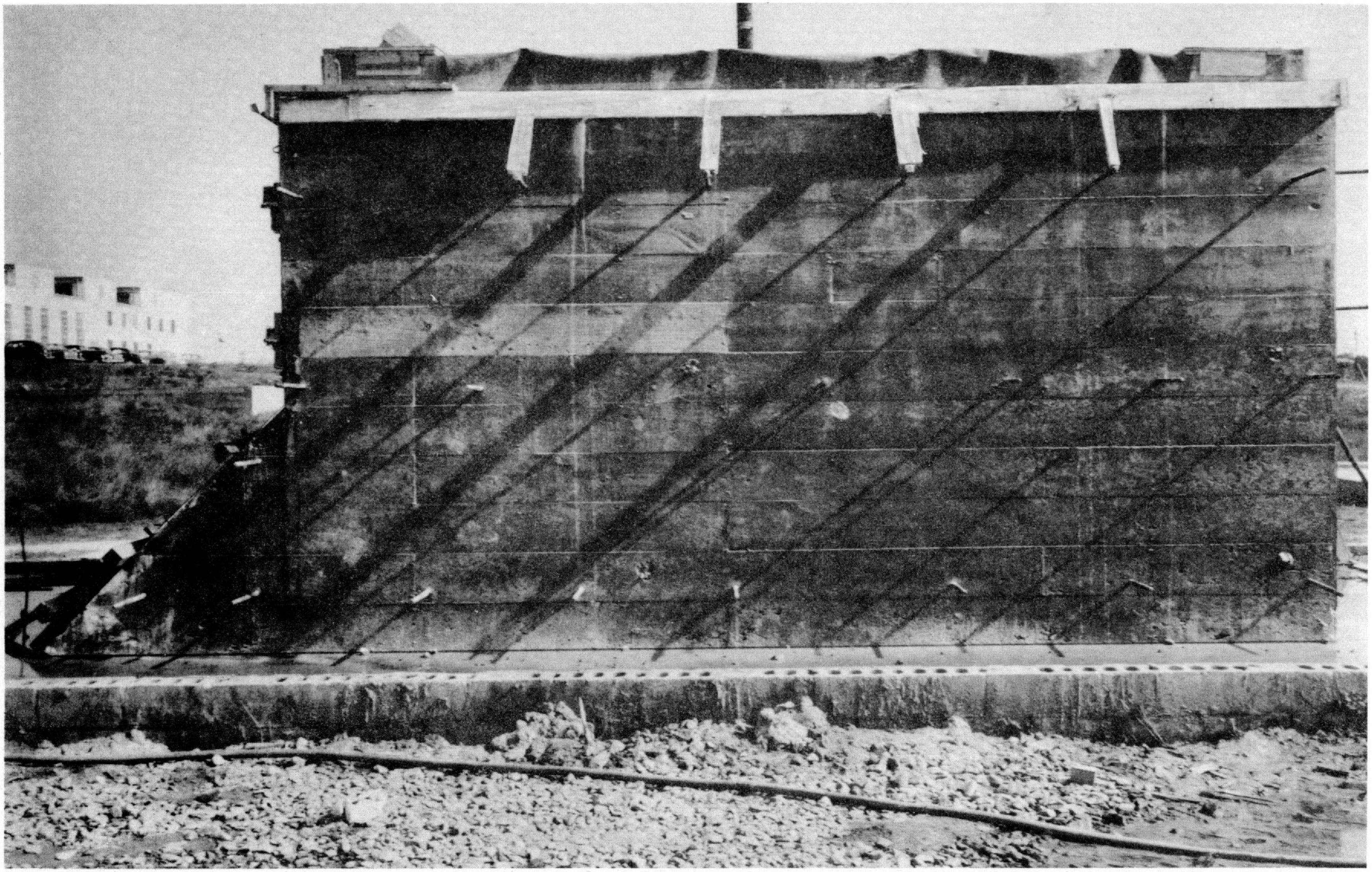

3/4" Grout hose (extra strength)
Wire cable for moving dolly
Crimped hose fitting
Special detachable fastening
A
2" Standard Black Iron Pipe with 1/2" continuous slot in bottom
Wire cable for moving dolly
Guide wheel
B
Washer welded to grout pipe
3/4" Grout pipe with 2 slots 1/4" x 6" at 180°
Rubber plungers
Half round spring steel wire clip
A
Metal tape tack welded over 1/2" slot
Plunger wheel for opening slot
B
Cut-a-way Section thru ℄ of Grouting Dolly
Guide trough for keeping dolly erect
2" Standard black iron pipe
Guide wheel
Half round spring steel wire clip. Place on approximately 2' centers.
1/2" Continuous slot
Plunger wheel
Metal tape
Section B-B
Spring steel wire clip
Washer welded to grout pipe.
3/4" grout pipe
1/4" slots in grout pipe
1/2" continuous slot
Section A-A
REVISIONS
NO. DATE FEATURE INITIALS
6
5
4
3
2
1
PREPAKT CONCRETE CO.
GROUTING DOLLY
FOR USE WITH HORIZONTAL SLOTTED GROUT PIPES
Dr. by B.H.
Full scale
Appr. by
Ck. by
3-31-49

PLATE 35

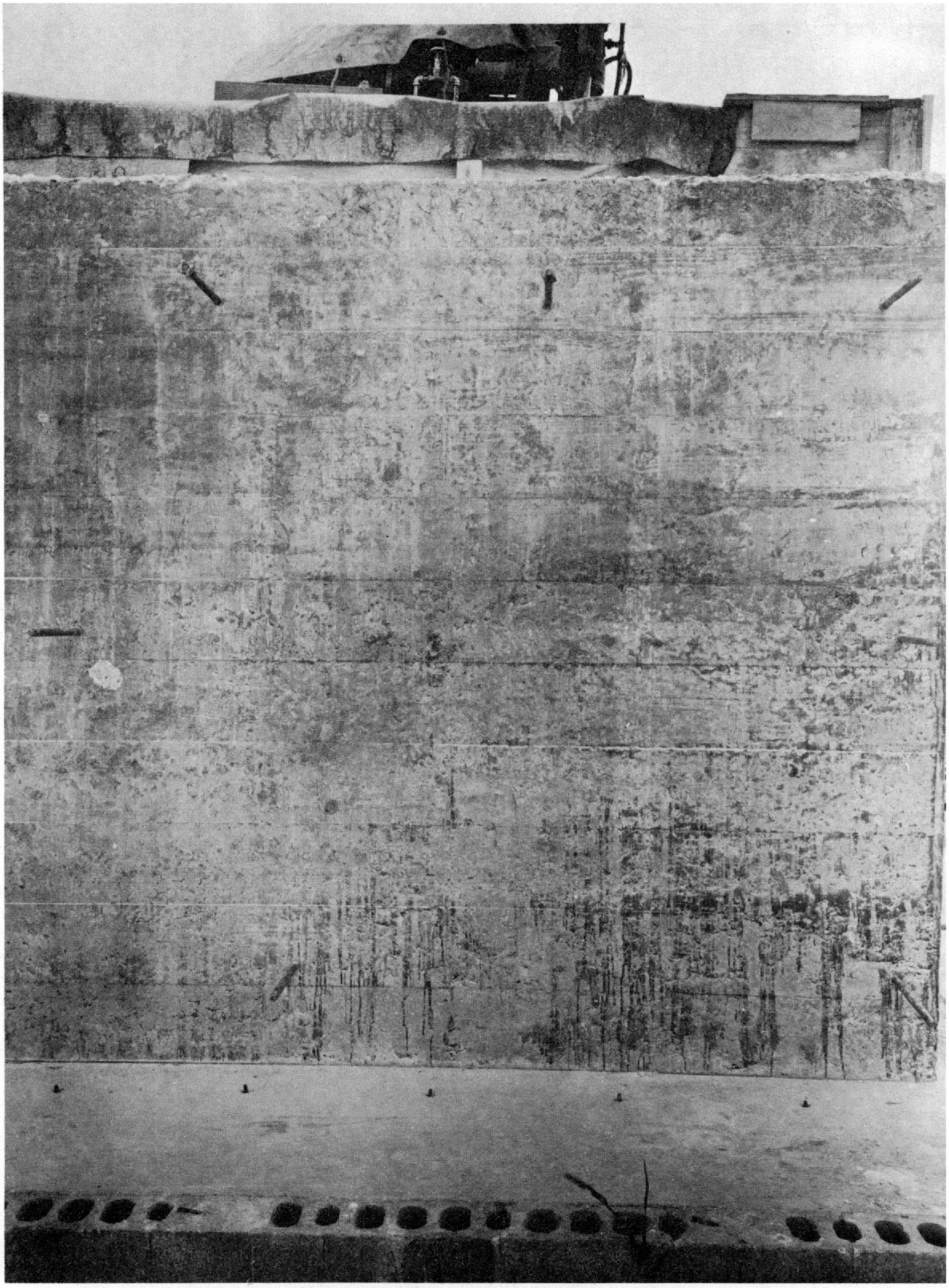
PLATE 36

Grout eruption through coarse aggregate

PLATE 37

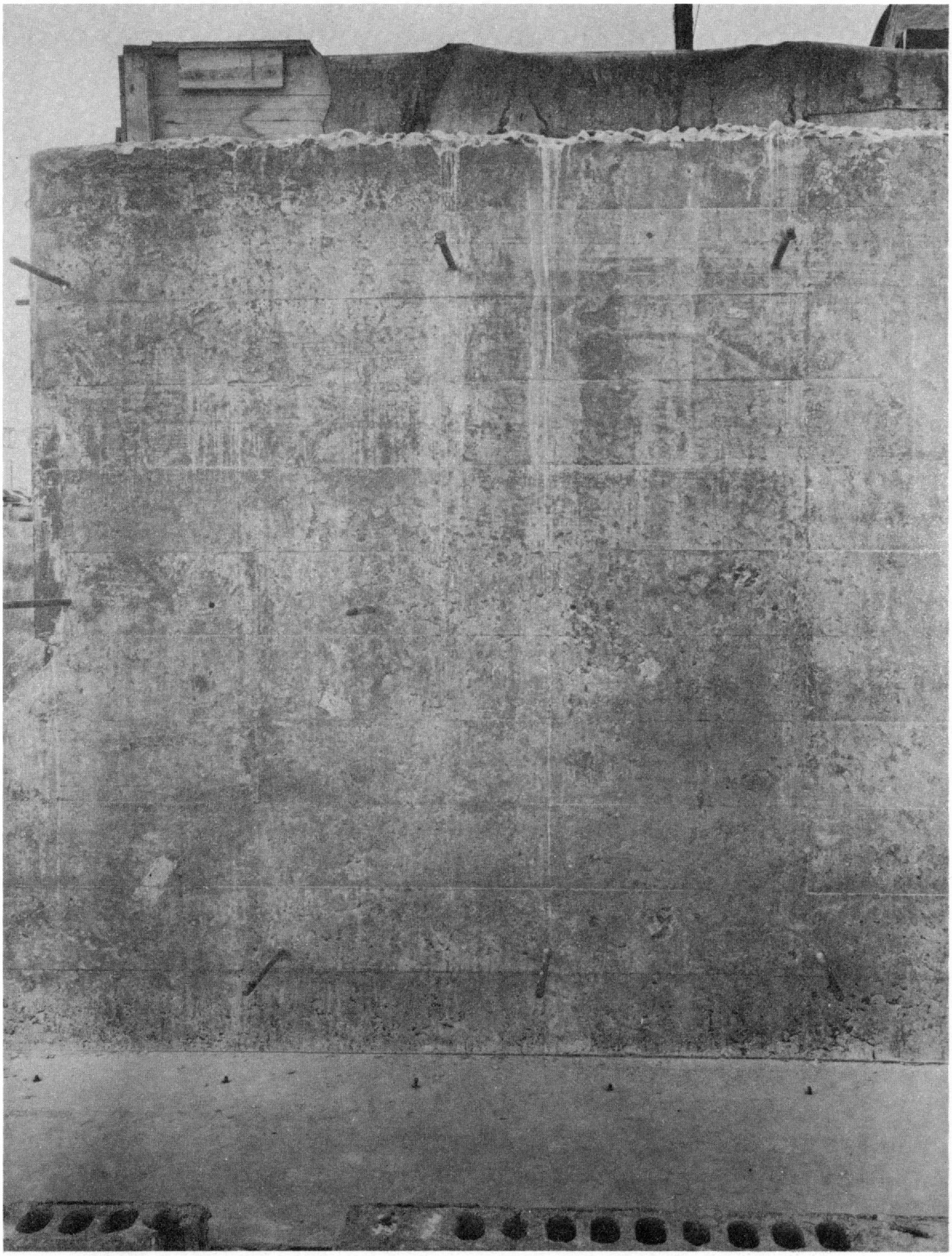


North (left) side of block after stripping and spraying with curing compound

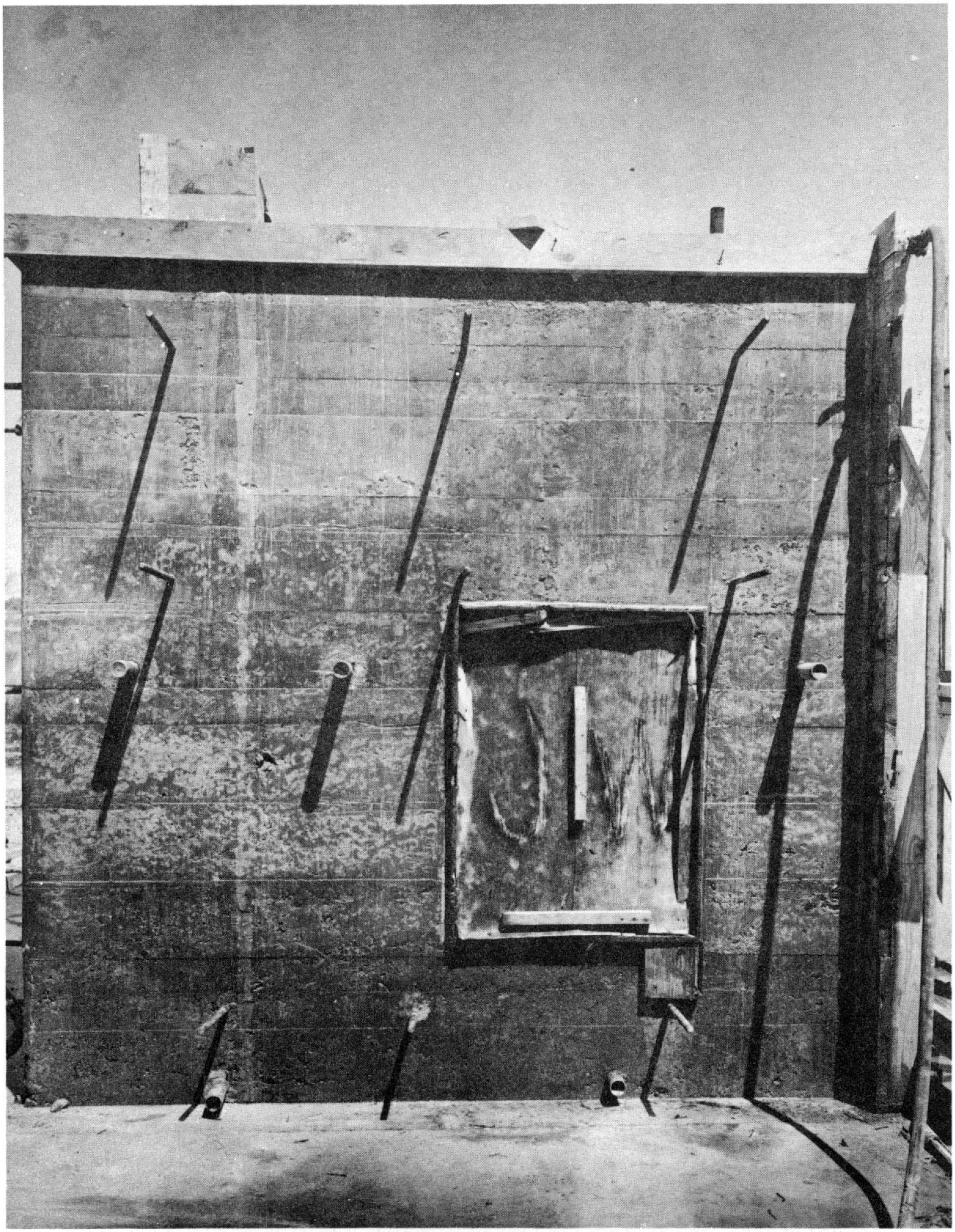


View of west half of north face of block

PLATE 38



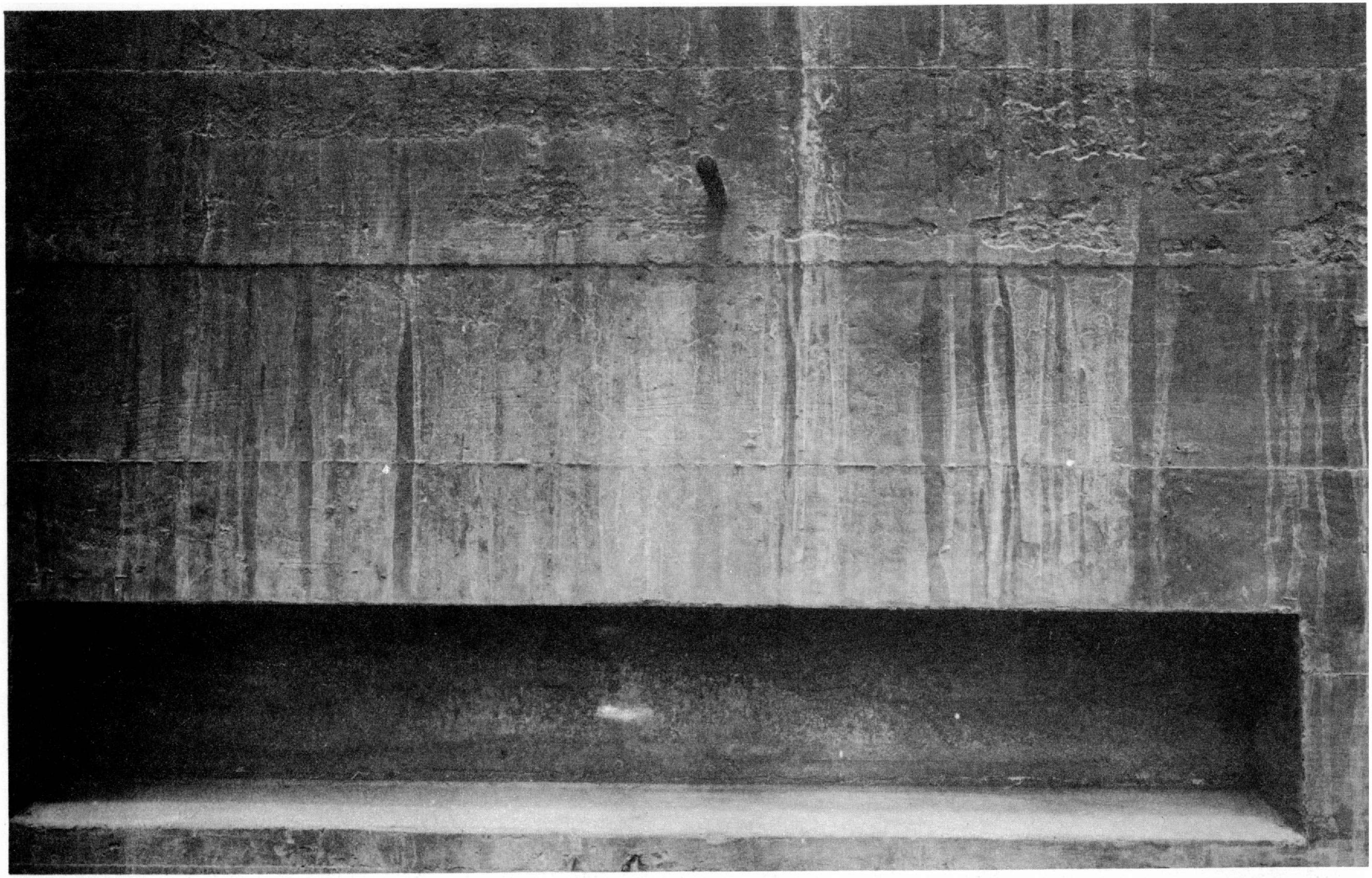
Major portion of east half of north face of block



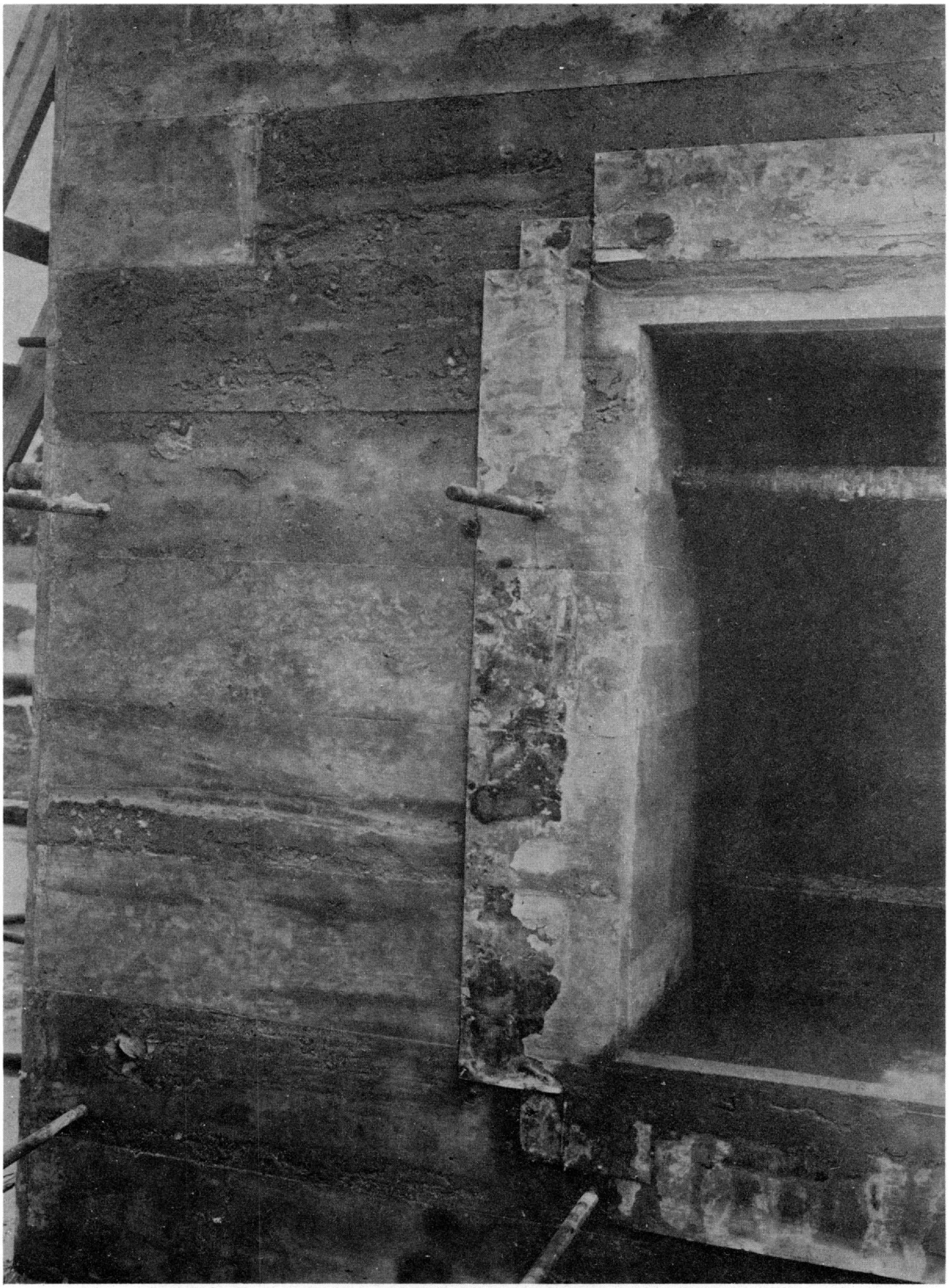
West end (front) of test block after stripping

PLATE 40

PLATE 41



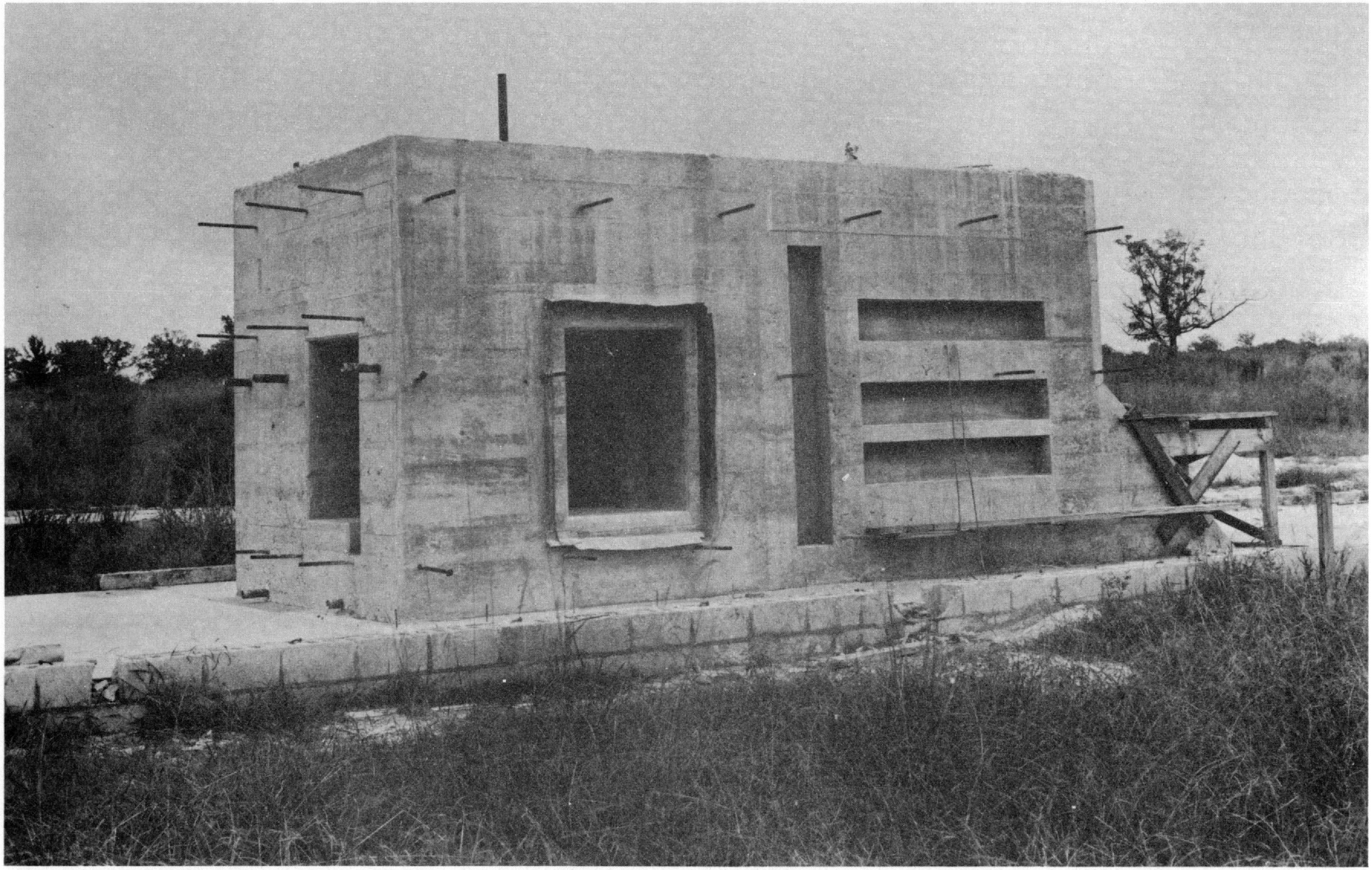
Uppermost horizontal blockout after stripping. The crazing evident in this photograph developed about a month after fabrication of the block



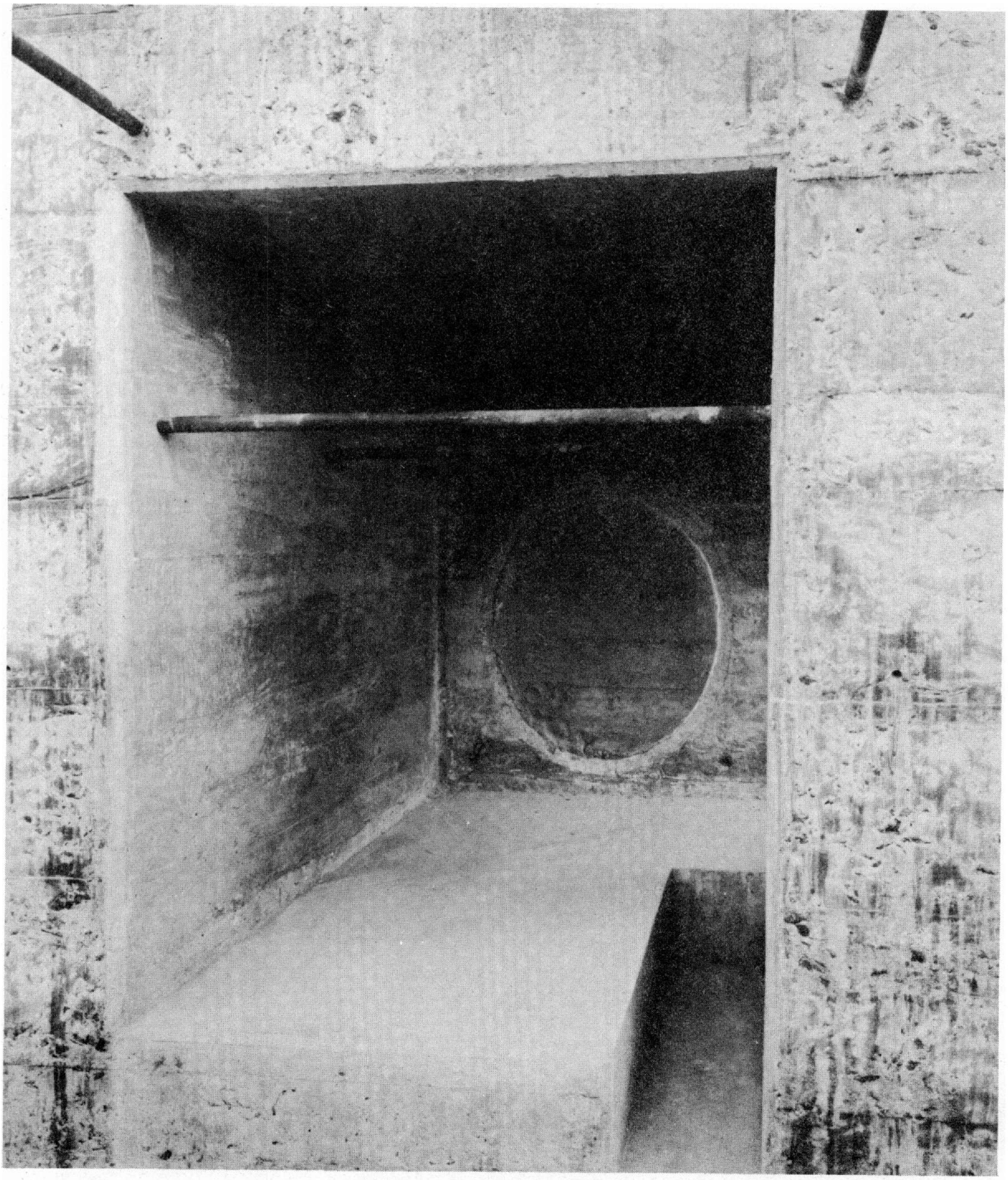
Part of copper waterstop with adjacent area after removal of form

PLATE 42

PLATE 43

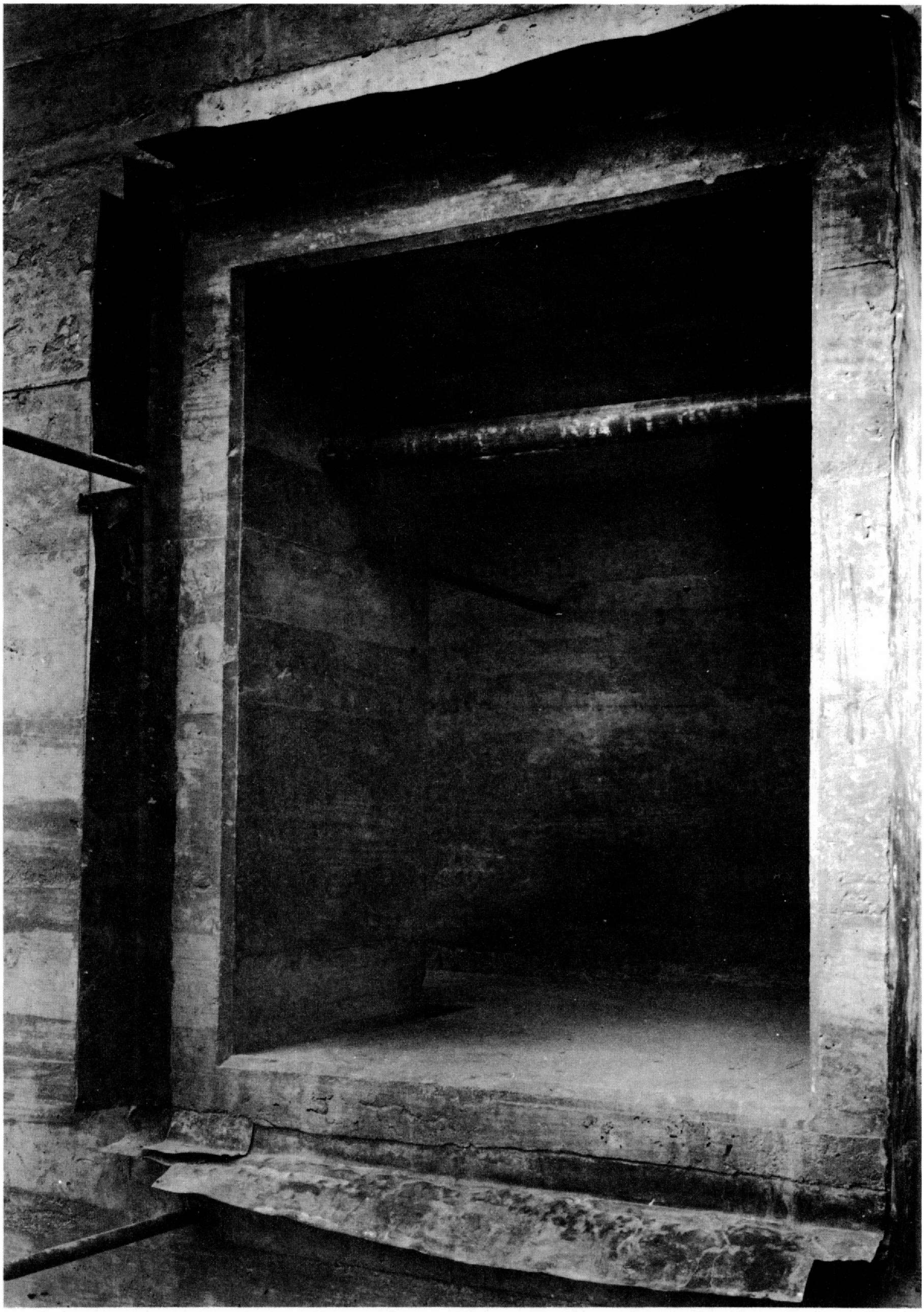


South side of the Prepakt block



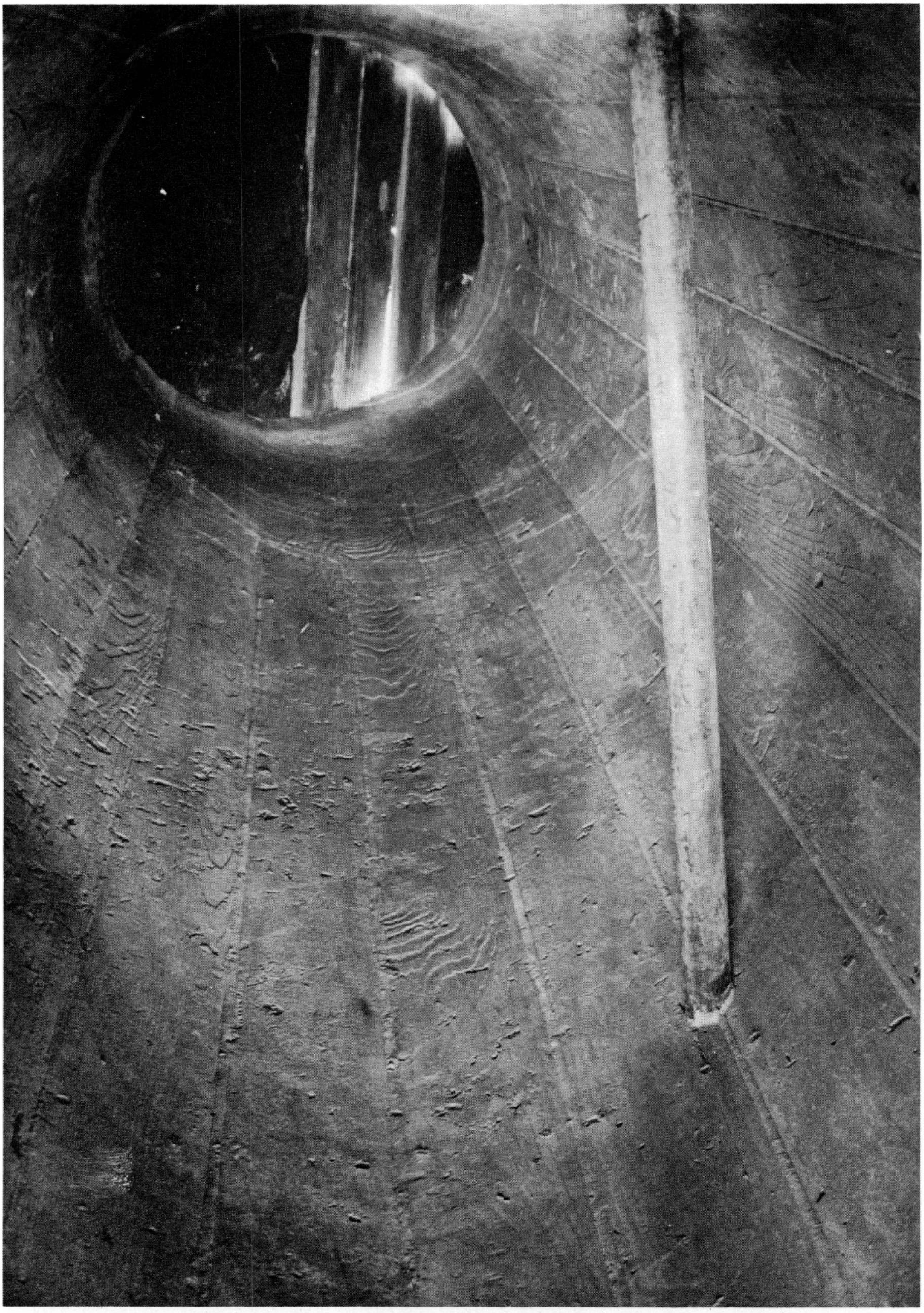
View into gallery from west end showing lower end of penstock following grouting

PLATE 44



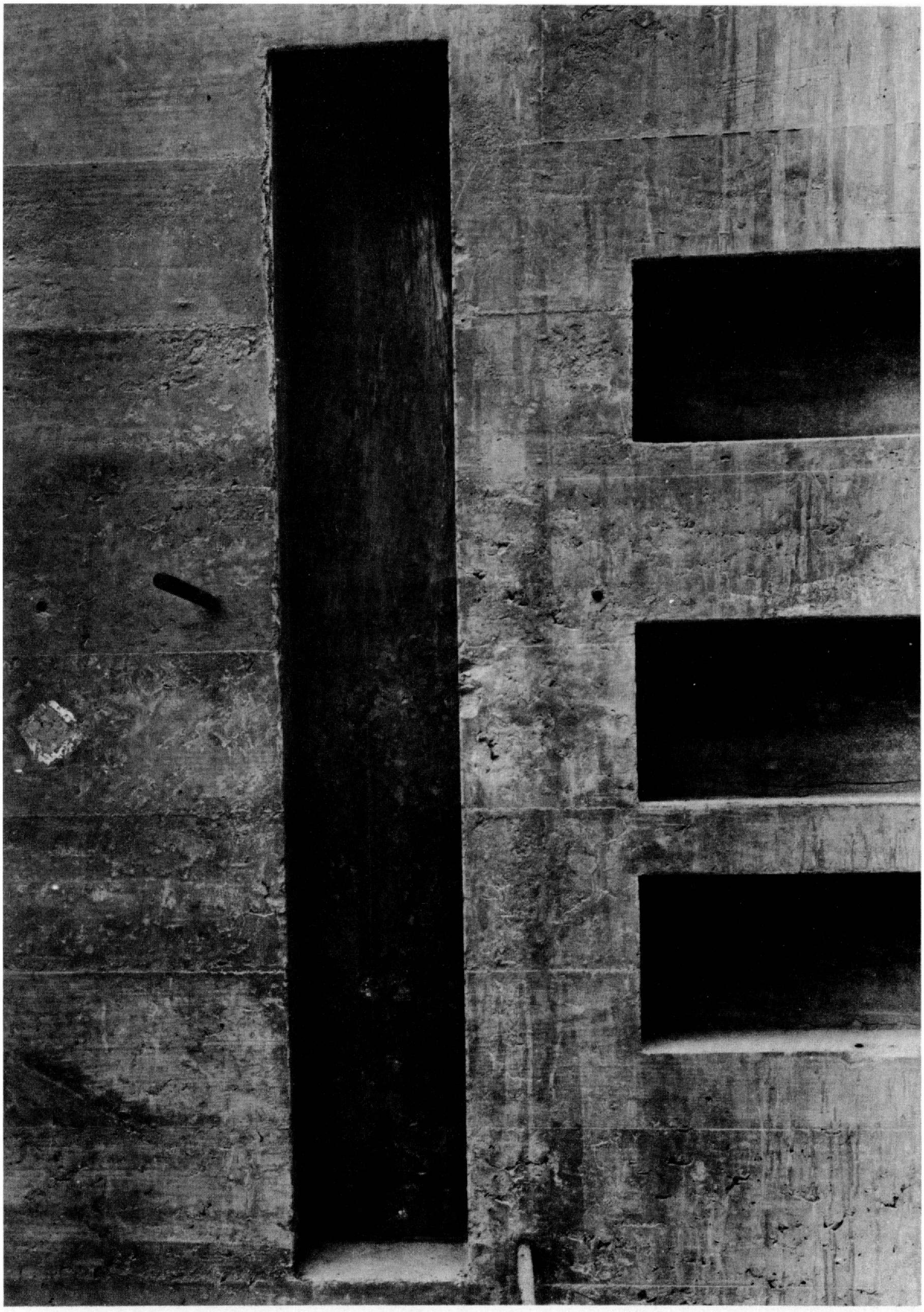
View into gallery from south side showing copper waterstop

PLATE 45

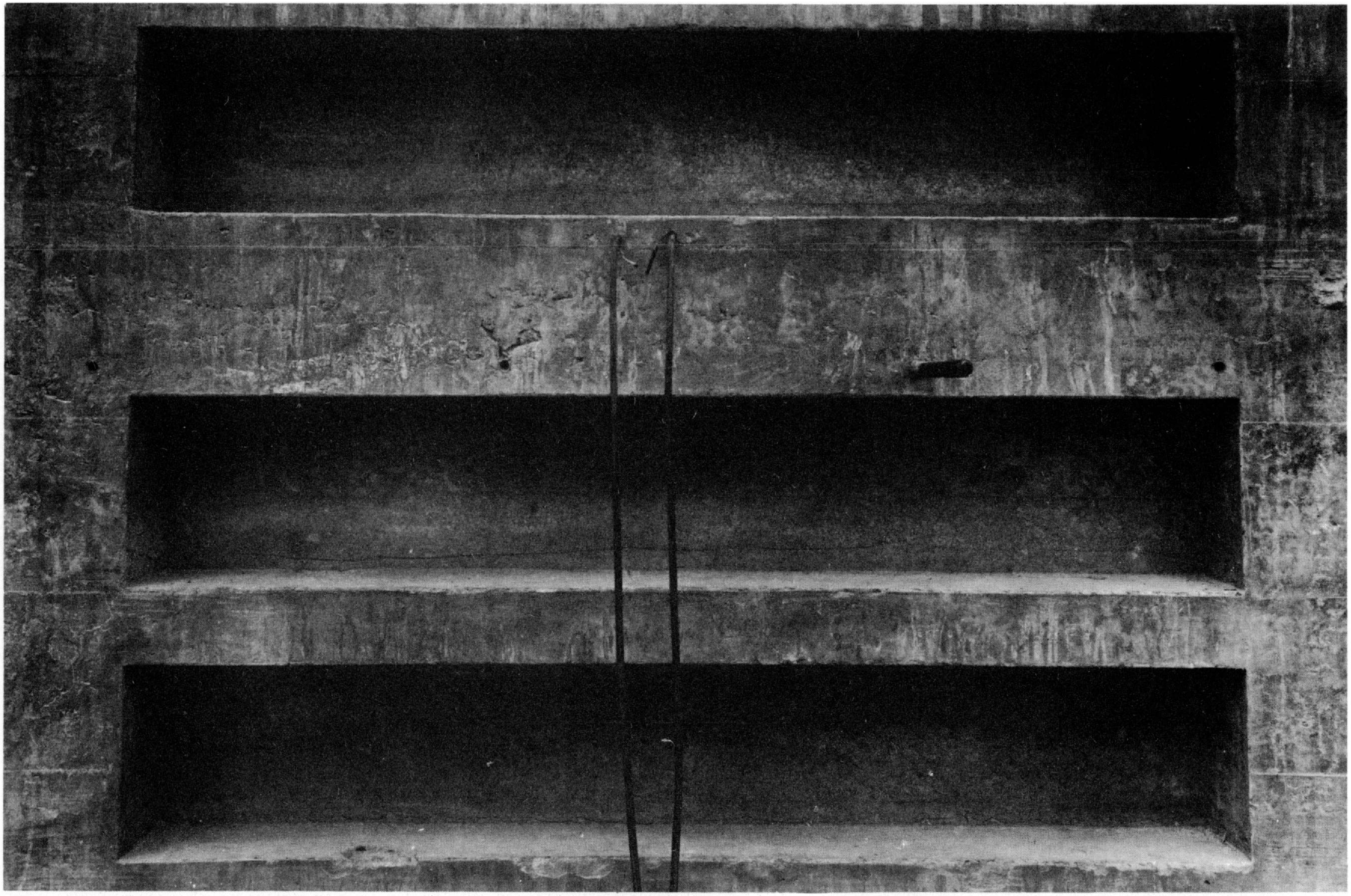


Looking upward into penstock

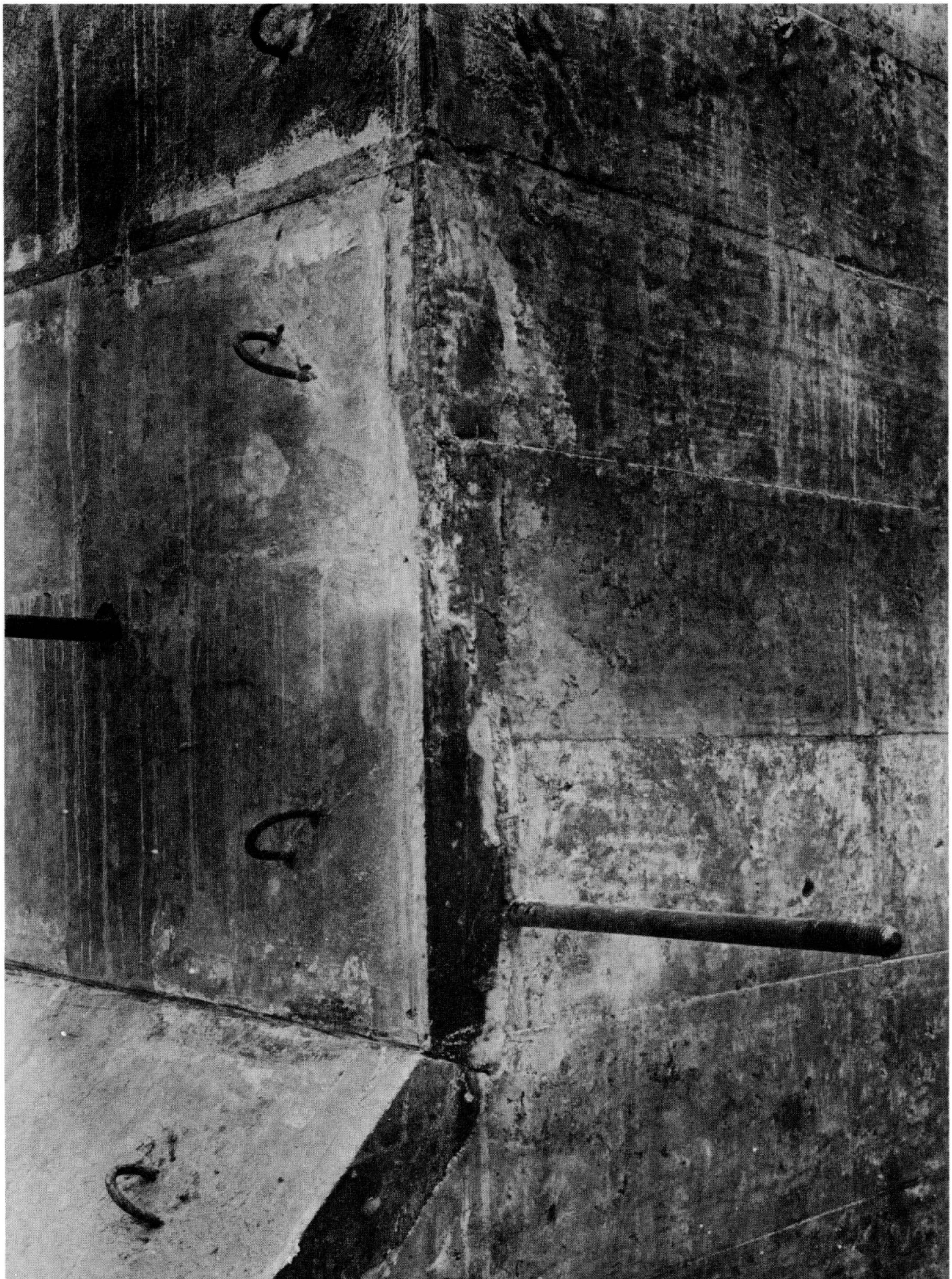
PLATE 46



Vertical blockout after stripping



Horizontal blockouts after stripping

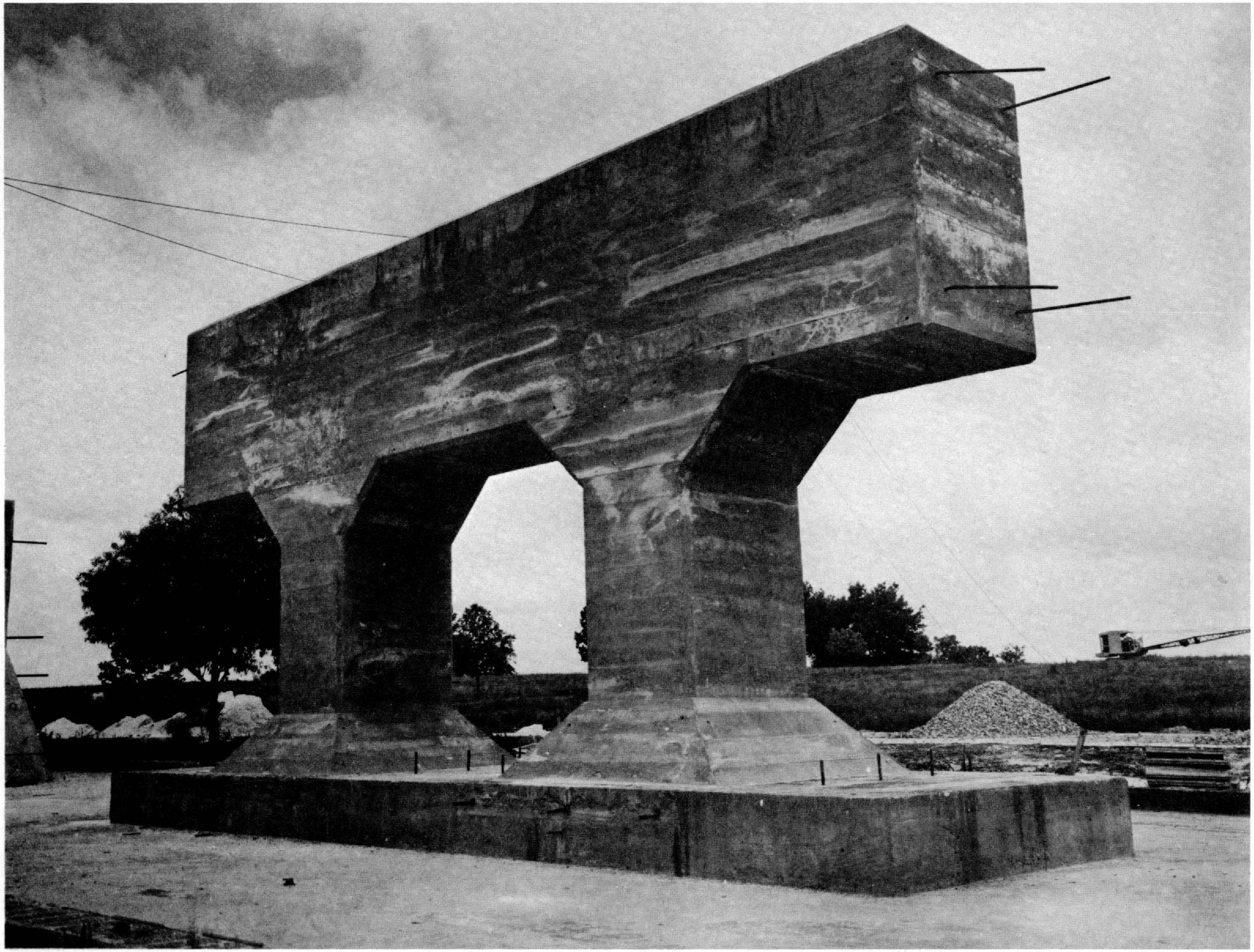


Junction between precast concrete slabs and Prepakt concrete

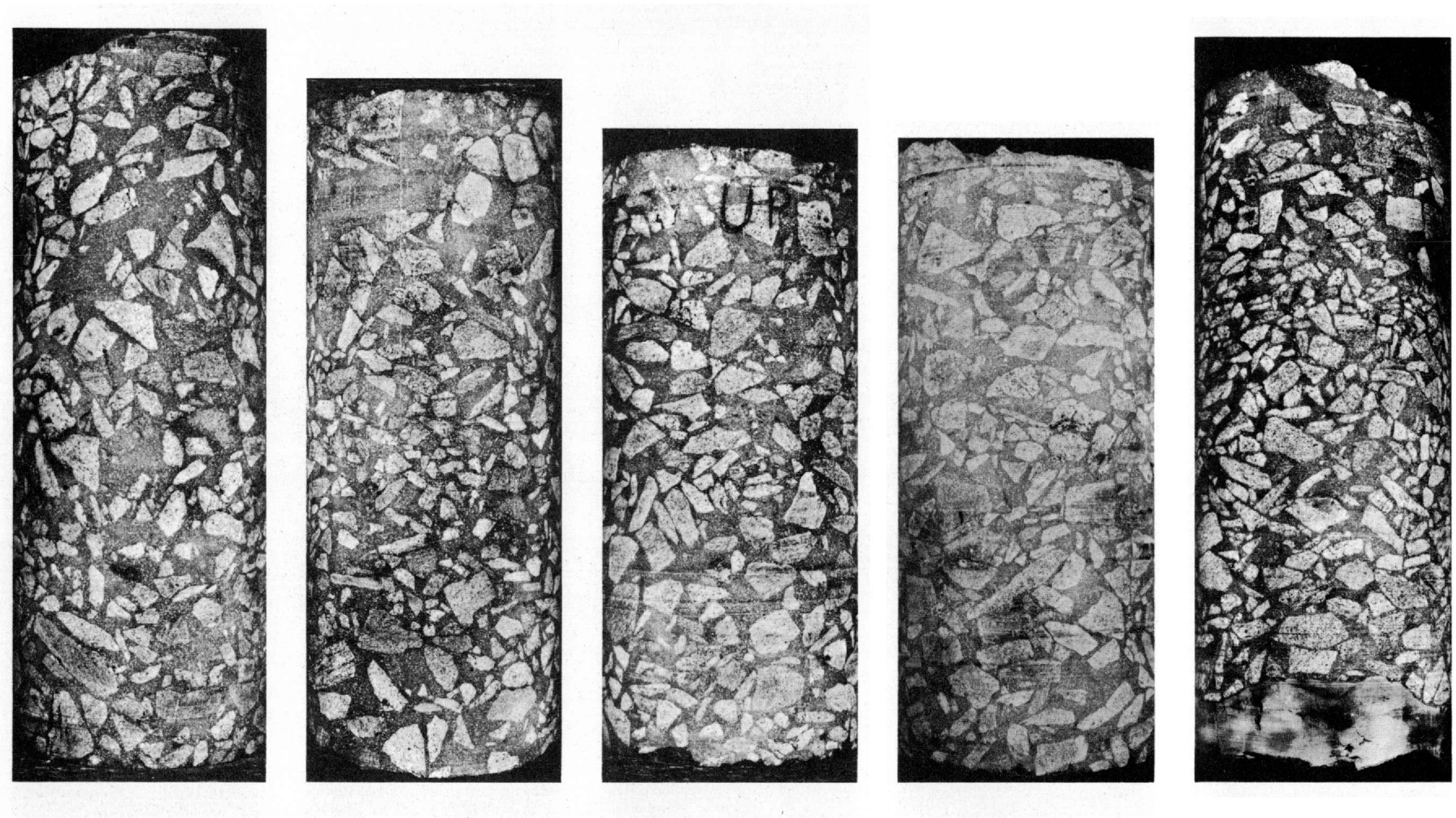
PLATE 50

North side and west end of bridge pier

PLATE 51



South side and east end of bridge pier



Elev +0.2 to 2.0 | Elev 2.0 to 4.0 | Elev 4.0 to 5.7 | Elev 5.7 to 7.6 | **Elev 7.6 to 9.6 (Section E)**

Core sections of test block core 5

PLATE 53

Elev +0.1 to 1.8

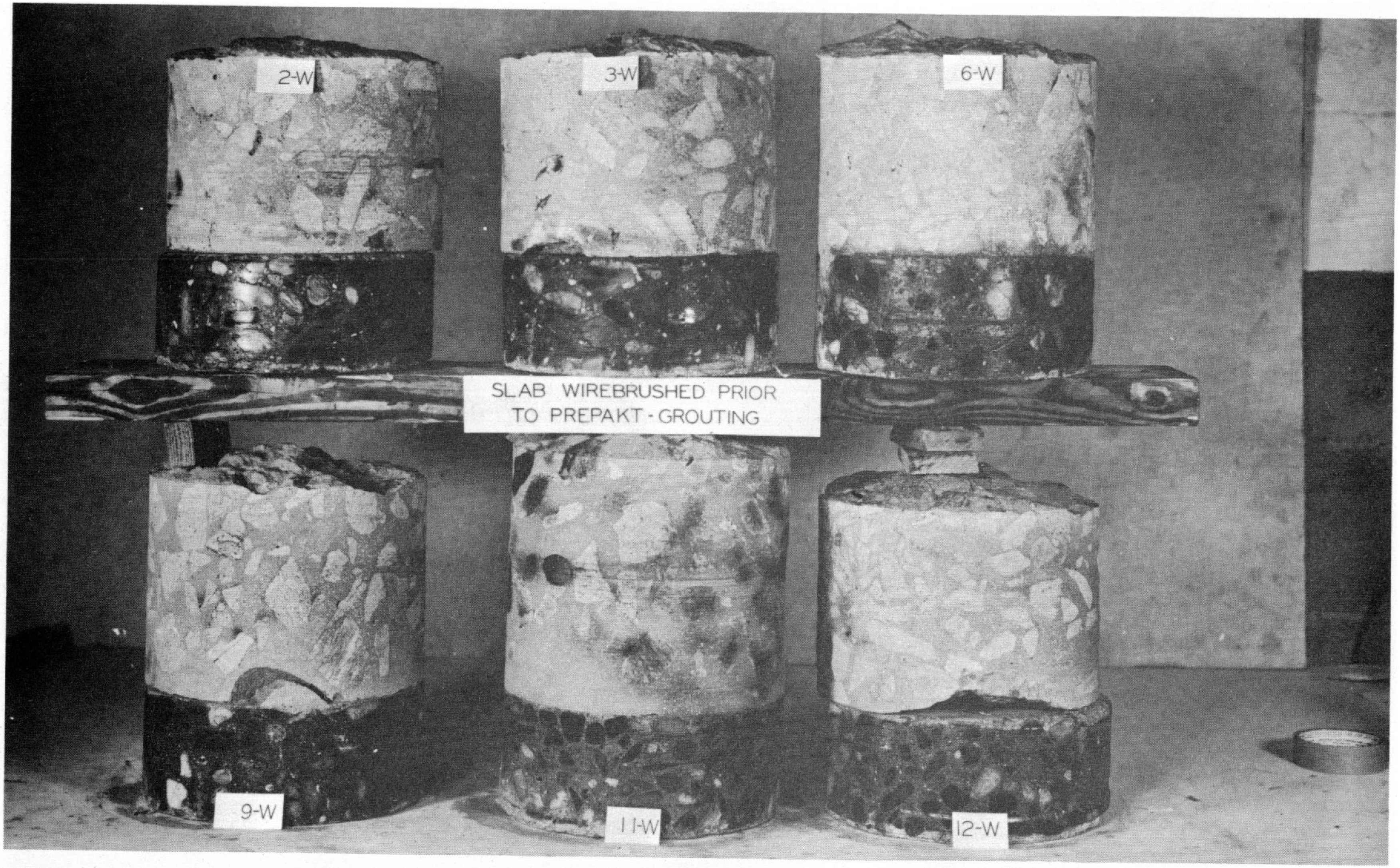
Elev 1.8 to 3.7

Elev 3.7 to 5.8

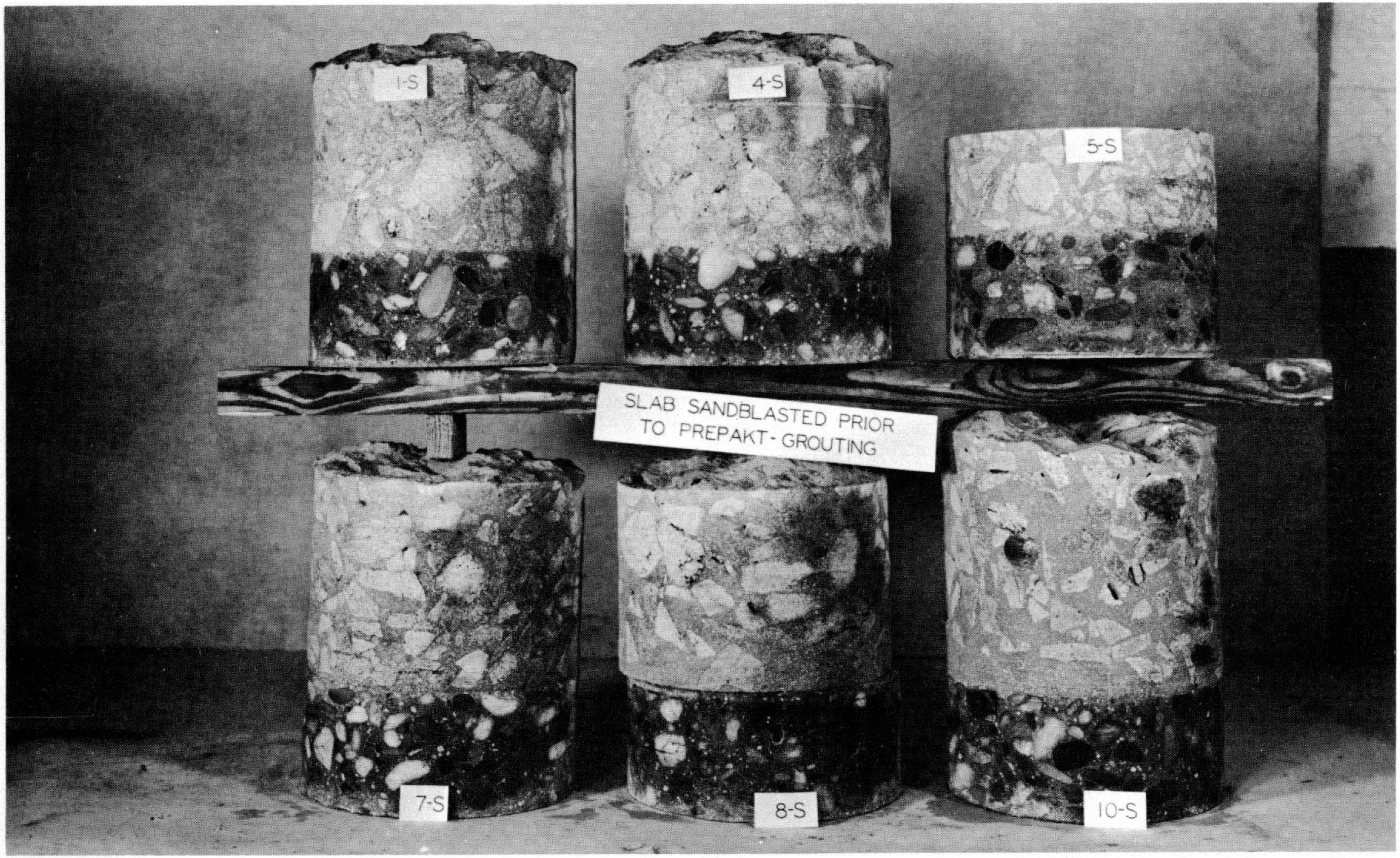
Elev 5.8 to 7.9

Elev 7.9 to 10.0

Core sections of test block core 8



Ten-in. cores drilled through the previously wire-brushed precast slabs into the Prepakt block.
No bond between Prepakt and precast slabs 2W, 3W, 9W and 12W



Ten-in. cores drilled through the previously sandblasted precast slabs into the Prepakt block.
No bond between Prepakt and slab core 8-S

Section of core of Prepakt block to Prepakt plug at elevations 3.0 ft to 4.9 ft with 4.9-ft plane up, showing lack of bond between block and plug

PLATE 56

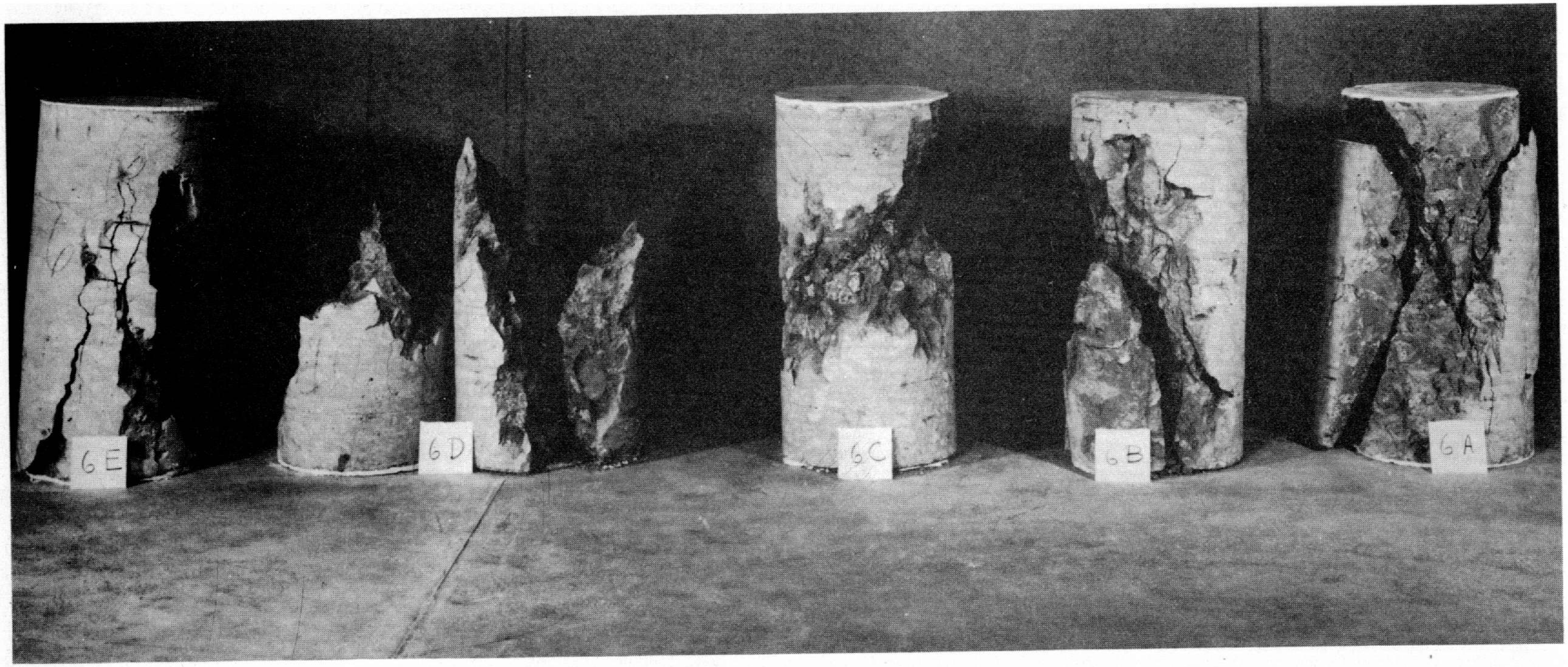
PLATE 57

Core 2 drilled in west column of bridge pier

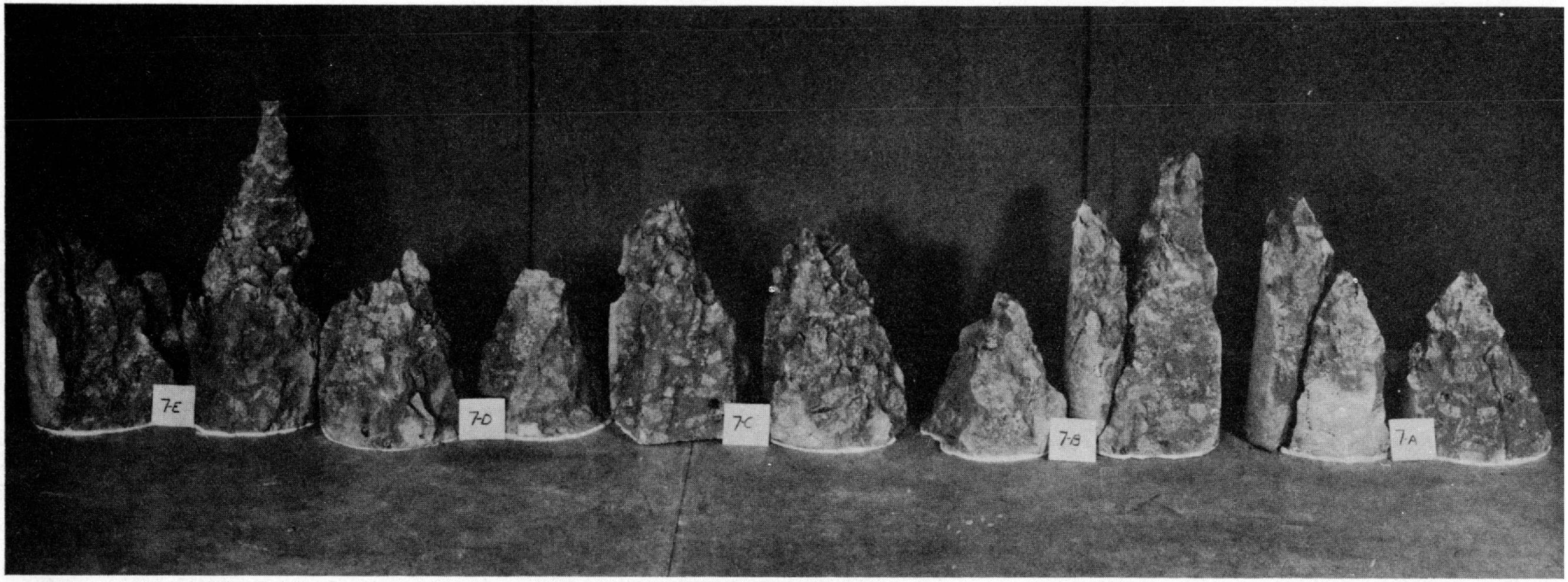
Close-up of section of core 2, near depth of 5.7 ft from top of pier, showing void in coarse aggregate

PLATE 58

PLATE 59



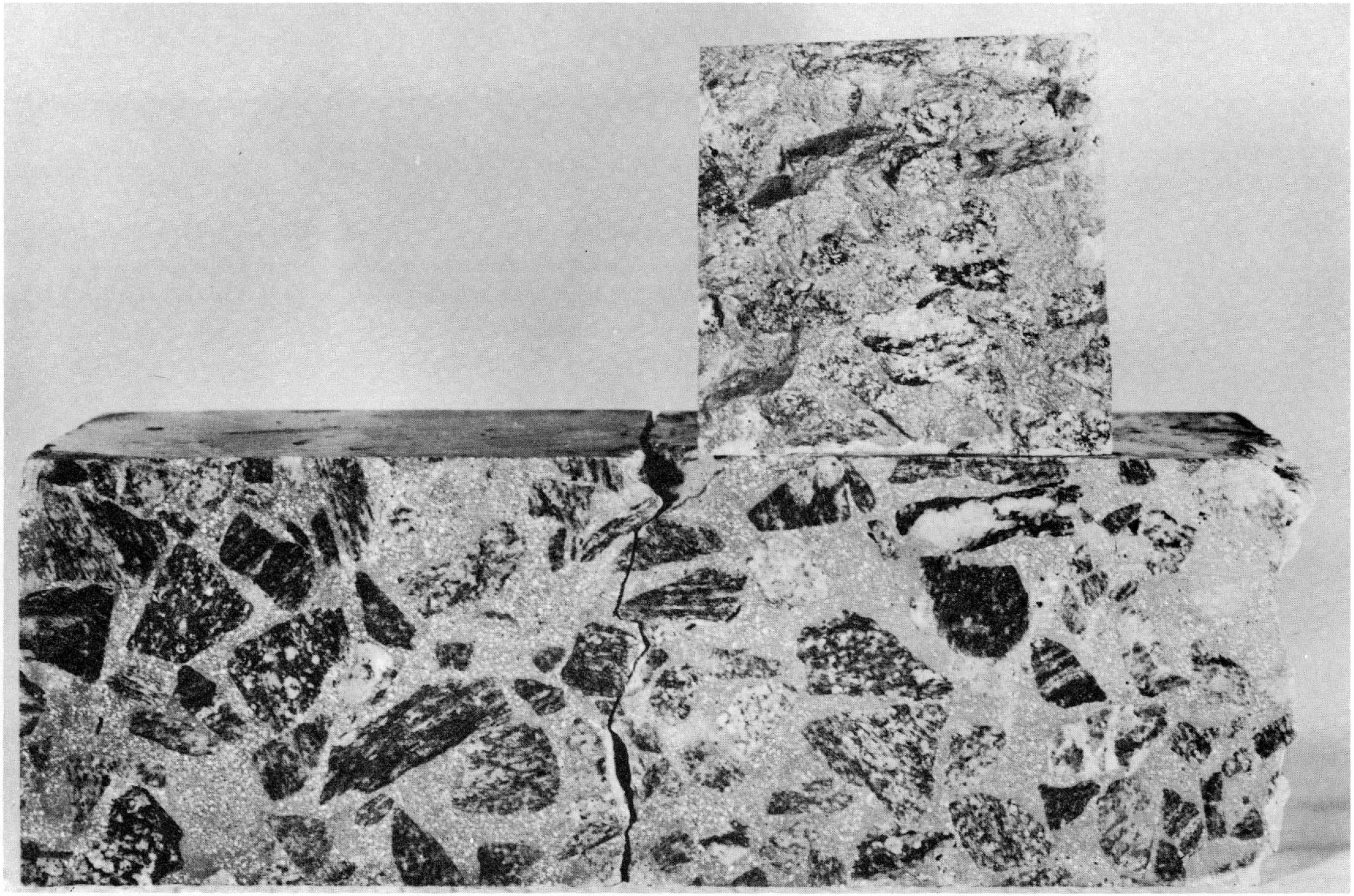
Sections of core 6, 10 in. in diameter by 20 in. long, drilled from Prepakt block and tested in compression at 90 days



Sections of core 7, 10 in. in diameter by 20 in. long, drilled from Prepakt block and tested in compression at 90 days

PLATE 61

Six- by twelve-in. sections from cores 1, 2 and 3, taken from Prepakt bridge pier, after testing in compression at 90 days



Six- by six- by thirty-in. beam cut from horizontal core 2 after testing in flexure by third-point loading at 187 days. View of broken end shows clean break through aggregate particles

APPENDIX

APPENDIX

TESTS TO DETERMINE SUITABLE SAND GRADING FOR PREPAKT CONCRETE

Introduction

1. In October 1948 the Office, Chief of Engineers, directed the Waterways Experiment Station to investigate several different sand gradings for use in Prepakt concrete. A report of this initial investigation ("Preliminary Report of Pilot Tests on Prepakt Concrete Panels," dated 18 February 1949) was reviewed by the Office, Chief of Engineers, and in April 1949 that office authorized check tests to be made using manufactured traprock sand with traprock coarse aggregate and two gradings previously investigated and found to be most suitable with natural sand.

2. The purposes of the former investigation were to determine gradations of sand which would be suitable for use in Prepakt concrete, producing a satisfactory compressive strength, durability, etc., in connection with repair work on structures of the Illinois Waterways of the Chicago District, CE, and to obtain information of general interest relative to suitable gradings of sand for Prepakt concrete. The two investigations have been combined and are treated as a single investigation in this appendix.

Materials

3. The materials used were as follows:

   a. Coarse aggregate. For panels 1 through 5, gravel from near Harvey, Illinois, submitted in two size ranges, No. 4 to

3/4 in., and 3/4 to 1-1/2 in., and for panels 6 and 7, crushed traprock from Plainville, Connecticut, graded from 3/8 in. to 1-1/2 in.

b. Fine aggregate. For panels 1 through 5, natural sand from the same source near Harvey, Ill., as the gravel used in the same panels. The sand as submitted was graded from No. 4 to passing 100. For panels 6 and 7 the sand used was manufactured in the laboratory by means of a cone-type crusher, from the same traprock used for coarse aggregate in panels 6 and 7.

c. Cement. The cement used was laboratory stock type II, from the same mill as that used in the large-scale Prepakt tests.

d. Alfesil. The flyash filler, Alfesil, was provided by the Prepakt Concrete Company.

e. Intrusion Aid. This material was provided by the Prepakt Concrete Company.

Tests

Preparation of gravel

4. The gravel in size range from No. 4 to 3/4 in. was sieved over the No. 3/8-in. sieve, the material finer than 3/8 in. was discarded and the 3/8- to 3/4-in. material was combined with the size range from 3/4 to 1-1/2 in. in the proportion which gave the lowest percentage of voids. The proportions giving the lowest percentage of voids were determined through a series of unit weight tests. Figure A1 is a curve showing results of these tests. The

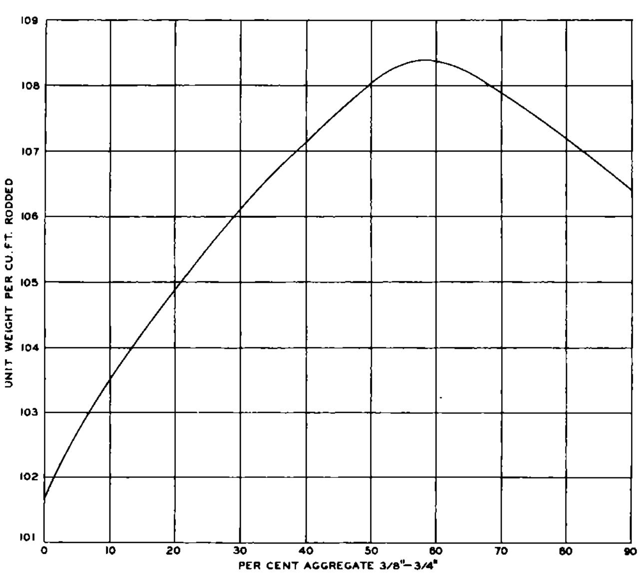


Figure A1. Curve showing results of unit weight tests lowest percentage of voids was found to be 34.6 and the combination of small and large gravel to give this percentage was found to be 60 per cent small and 40 per cent large.

5. The grading of the crushed traprock was predetermined from a grading curve omitting the material passing the 3/8-in. sieve. Unit weight determinations were made to determine the actual percentage of voids existing. Voids were found to be 41.5 per cent.

Physical tests, coarse aggregate

6. Elementary tests were run on both the gravel and traprock with the following results:

	Gravel No. 4 to 3/4 in.	Gravel 3/4 to 1-1/2 in.	Traprock 3/8 to 1-1/2 in.
Specific gravity	2.68	2.66	2.92
Absorption, %	2.0	1.7	0.8
Loss in 5 cycles of $MgSO_4$, %	8.5	8.1	0.7
Los Angeles abrasion loss, %	25.8	-	12
Thin and elongated, %	5.7	2.0	10.0
Soft particles, %	1.3	0.5	0

Sieve	Sieve Analysis Cum. Per Cent Pass.		
1-1/2 in.	100	100	100
1 "	99.4	28.3	63.9
3/4 "	62.5	3.2	42.4
1/2 "	54.3	0.8	16.8
3/8 "	33.7	0.0	0.0
No. 4	1.2		

Preparation of sand

7. Five separate gradings of natural sand were prepared by the following methods:

a. The sand as received was scalped over the No. 8 sieve. The larger sieve sizes were discarded and that which passed the No. 8 was used in panel 1.

b. The sand as received was scalped over the No. 16 sieve. The material retained on the No. 16 was discarded and that which passed the No. 16 was used in panel 2.

c. The sand as received was sieved over the No. 30 sieve. The material larger than the No. 30 sieve was discarded and that which passed was used in panel 3.

d. Sand as received was sieved into component sieve fractions. The material larger than the No. 16 was discarded and the smaller sieve size, recombined to a fineness modulus of 1.35, was used in panel 4.

e. Sand as received was sieved into its component sieve sizes, recombined to a fineness modulus of 1.70, and used in panel 5.

f. The manufactured traprock sand was sieved into its component sieve sizes and an attempt was made to recombine it, for panels 6 and 7, into the gradings that were used with natural sands in panels 4 and 5, respectively. The actual recombined gradings differed somewhat from the corresponding natural sand gradings. The gradings used in grouting the test panels follow:

Cumulative Per Cent Passing

Sieve	Panel Number						
	1 (1)	2 (1)	3 (1)	4 (1)	5 (1)	6 (2)	7 (2)
No. 4							
" 8	100				100		100
" 16	80.7	100		100	95.4	100	95.3
" 30	42.2	51.5	100	84.2	68.9	83.5	71.1

Cumulative Per Cent Passing

Sieve	Panel Number 1 (1)	2 (1)	3 (1)	4 (1)	5 (1)	6 (2)	7 (2)
No. 50	8.6	9.4	20.3	52.1	42.2	51.8	43.9
" 100	1.1	0.9	2.6	28.8	23.5	29.4	26.9
" 200	0.5	0.3	1.0	9.8	6.7	9.4	7.5
FM	2.67	2.38	1.77	1.35	1.70	1.35	1.63

(1) Natural sand (2) Manufactured traprock sand

Physical tests, fine aggregate

8. Elementary physical tests were run on both the natural and manufactured sands and results are tabulated below:

	Natural Sand	Manufactured Sand
Specific gravity	2.66	2.86
Absorption, %	1.9	1.8
Loss in 5 cycles of $MgSO_4$, %	12.1	2.2
Compressive strength in mortar, %		
3 days	126	105
7 days	134	121
Organic color test	1	-

Specimens

9. The specimens were 12 in. thick by 40 in. high by 50 in. long. Three 6-in.-diameter cores were drilled from each specimen from top to bottom and were later cut into appropriate lengths to obtain specimens for compressive strength tests.

Form

10. The form in which the Prepakt concrete panel specimens were cast was made of 7/8-in. plywood reinforced with steel angles and contained a plexiglas front to permit full observation of grouting progress. This form was equipped with a venting top which was fastened in place to prevent the aggregate from rising during grouting while still allowing escape of air and water as grouting progressed. Plate A-1 shows the form partially filled with gravel, and plate A-2 the venting top with cloth and screen wire turned back to illustrate construction.

Equipment

11. Equipment for the tests, except the panel form, was supplied by the Prepakt Concrete Company and consisted of a grout mixer of 33-gallon capacity, containing two perforated mixing blades driven by a 3/4-hp electric motor, Wagner Simplex steam pump with rubber piston and rubber-faced valves for pumping the grout, and miscellaneous items such as hoses, valves, flow cone, etc. The flow cone was used to determine consistency of the grout. Glass graduates were used in determining expansion of the grout and a Vicat apparatus was used for determination of the setting time. Plates A-3 and A-4 show the grout mixer and grout pump.

Grout proportions

12. The grout proportions used for all panels were as shown below:

Proportions		Weights, lb
Cement	- 1.00	94.00
Alfesil	- 0.53	49.82
Sand	- 1.50	141.00
Water	- 0.69	64.86
Intrusion agent	- (variable)	

Compacting the coarse aggregates in the form

13. Coarse aggregate was hand-shoveled into the panel forms in shallow horizontal layers and consolidated by externally vibrating the forms using a small Syntron type V-4 vibrator, by tapping the exterior of the form with a rubber mallet, and by tamping the shallow layers of aggregate in the form by means of a piece of 2-by-4 lumber. The forms were watertight and were filled with water as the coarse aggregate was added. Plate A-1 shows the form partially filled with aggregate under water.

Mixing

14. The grout was mixed for at least one minute after all ingredients had been added. It was then discharged into the funnel (sump) on the pump for pumping into the coarse aggregate mass.

Prepakt panels

15. All panels were grouted under water.

16. Panel No. 1. An attempt was made to pump this panel with sand that had been scalped over the No. 8 sieve. Results of the trial indicated that the grout did not intrude into the voids in the coarse aggregate in a satisfactory manner. The grout pipe arrangement in this panel consisted of two 20-in.-long, 3/4-in.-diameter horizontal pipes along the bottom of the form entering from each end. Each pipe contained four 1/2- by 6-in. slots in staggered location. Grout would not pump through the pipes, so a hole was made in the back of the form near the bottom and pumping was again attempted not using the pipes. Only about two inches total of intrusion obtained. The grout proportions were altered from

those shown in paragraph 12 to contain one half as much sand, but even this grout did not intrude. Mortar containing this sand was not considered suitable for intrusion pumping. This panel was washed out and discarded.

17. Panel No. 2. Grout for this panel, which contained sand scalped over the No. 16 sieve and having an FM of 2.38, pumped easily but the mix bled very badly. The pipe arrangement for this panel was the same as for panel 1. Grout was pumped alternately through the two horizontal pipes near the bottom. The pipes were not removed prior to the hardening of the grout. The surface of the concrete upon stripping showed considerable sand streaking. Bleeding and sand streaking were apparently due to coarseness of the sand. This sand grading would not be considered satisfactory for intrusion work.

18. Panel No. 3. Grout for this panel contained sand with an FM of 1.77 and pumped easily but had considerable bleeding, probably due to the coarseness of the sand. This was the material that had been scalped over the No. 30 sieve and contained 20 per cent finer than the 50 mesh, and only approximately 3 per cent passing the 100-mesh sieve. This sand grading apparently is not suitable for intrusion grouting. The pipe arrangement for panel 3 was identical with that for panels 1 and 2 except that the pipes were removed approximately 3 hours after grouting had been completed.

19. Panel No. 4. Grout for panel 4 contained sand with an FM of 1.35 and pumped easily. This sand had been separated into sizes smaller than No. 16 and recombined. After stripping, a small honeycomb area was noticed about 4 in. below the top and in the center of the panel. This was probably due to discontinuing the grout a little too soon. The sand grading appeared suitable for use with the Prepakt process. Only one

grout pipe, 3/4 in. in diameter and approximately 25 in. long, was used in this panel. It was notched with four staggered notches each approximately 3/8 in. by 1/2 in. in size. The pipe contained an elbow on the end inside the form which pointed downward. At conclusion of the grouting operation the pipe was unscrewed and removed leaving the elbow in the concrete.

20. Panel No. 5. This panel was grouted using grout containing sand with an FM of 1.70. The sand had been separated into sizes smaller than No. 16 and recombined. The grout pumped easily and apparently did not bleed. The appearance of the panel upon stripping was satisfactory. This sand grading is apparently satisfactory for use with the Prepakt process. Grout pipe arrangement was identical with that of panel 4.

21. Panel No. 6. This panel was grouted with sand having a fineness modulus of 1.35 with grading as shown in paragraph 7. Grout was introduced into the form through a 3/4-in. pipe nipple entering one end of the form about 2 in. above the bottom. No difficulty was experienced in grouting this panel. No water pockets formed on the surface of the panel during pumping and the surfaces of the resulting concrete were satisfactory upon stripping.

22. Panel No. 7. This panel was pumped using manufactured traprock sand having a fineness modulus of 1.66 and grading as shown in paragraph 7. An attempt was made to pump the panel through a pipe sleeve entering one end of the panel about 2 in. above the bottom. However, the passageway plugged after a few minutes of pumping because of the prevalence of small size (approximately 3/8-in.) coarse aggregate near the pipe. A hole was bored in the back of the form near the bottom and the panel was

grouted through this hole. It was necessary to vibrate the form continuously during the grouting process by use of the small Syntron vibrator and by tapping the form itself to prevent the formation of water pockets against the plexiglas surface. Apparently this continued vibration was effective in preventing surface defects.

23. Data on each panel are tabulated on the following page.

Discussion

24. Plate A-5 shows a panel after stripping. Plate A-6 shows three cores drilled from panel 3 which are typical of the appearance of cores extracted from panels 2, 3, 4, and 5. The appearance of the Prepakt concrete in panels 6 and 7 is illustrated in plates A-7 and A-8, respectively. The bottom 6 in. of the aggregate, as placed in the form, was graded from 3/4- to 1-1/2-in. in size so as to form a pervious blanket which would allow easy ingress of grout and prevent stoppage. The bottom layer consequently contained a higher percentage of voids than the aggregate above it. This higher percentage of voids is probably responsible for the generally somewhat lower compressive strength of the bottom core section than the middle section. The top sections being under less restraint exhibited lower compressive strengths than the middle or the bottom. It appears, from the work reported herein, that the gradings of natural sand used in panels 4 and 5 and the grading of manufactured sand used in panel 6 are suitable for use in Prepakt concrete.

Panel Number		1*	2	3	4	5	6	7
Sand FM		2.67	2.38	1.77	1.35	1.70	1.35**	1.63**
Date pumped		Jan. 18	Jan. 18	Jan. 20	Jan. 24	Jan. 27	May 16	May 13
Hour pumped		9:00 a.m.	10:30 a.m.	1:30 p.m.	2:00 p.m.	10:30 a.m.	10:00 a.m.	10:00 a.m.
Consistency		-	15	14	15	16	20	20
Time of set, (initial)		-	7:30	7:30	10:05	13:40	-	-
Time of set, (final)		-	11:10	10:20	15:50	16:05	-	-
Expansion of grout, %		-	9.4	5.5	4.9	3.0	0.0	2.4
Bleed water, % of grout		-	0.9	1.0	1.7	1.0	-	-
Type of intrusion agent		-	AMFB(1)	AMFB(1)	CCC	CCC	CCC	CCC
Intrusion agent, in g/bag		-	298	198.5	567	567	567	567
Approx % voids in form		-	36	36	36	36	42	42
Approx cem. factor b/cu yd		-	3.7	3.7	3.7	3.7	4.3	4.3
Pump pressure		-	0	0	0	20 lb	20 lb	20 lb
Form pressure, est.		-	0	0	0	5 lb	5 lb	5 lb
Vibration of form		-	None	None	Yes	Yes	Yes	Yes
Usability		-	Poor	Poor	Good	Good	Good	Fair
Surfaces		-	Poor	Poor	Fair	Fair	Fair	Fair
Top forms		-	Wood board	Vented, form not tight	Vented, form not tight	Vented, form tight	Vented, form tight	Vented, form tight
Compressive strength, psi, core 6 x 13 in., 28 days	Top		2308	2110	3815	(Not 2515	4160	4285
	Middle		3518	3760	5015	mature) 3570	5105	6305
	Bottom		2762	3460	3870	" 4410	5655	5160

* Grout could not be pumped, panel washed out.
** Traprock sand
(1) Agent AMFB is a concentrated material used only on two panels shown.

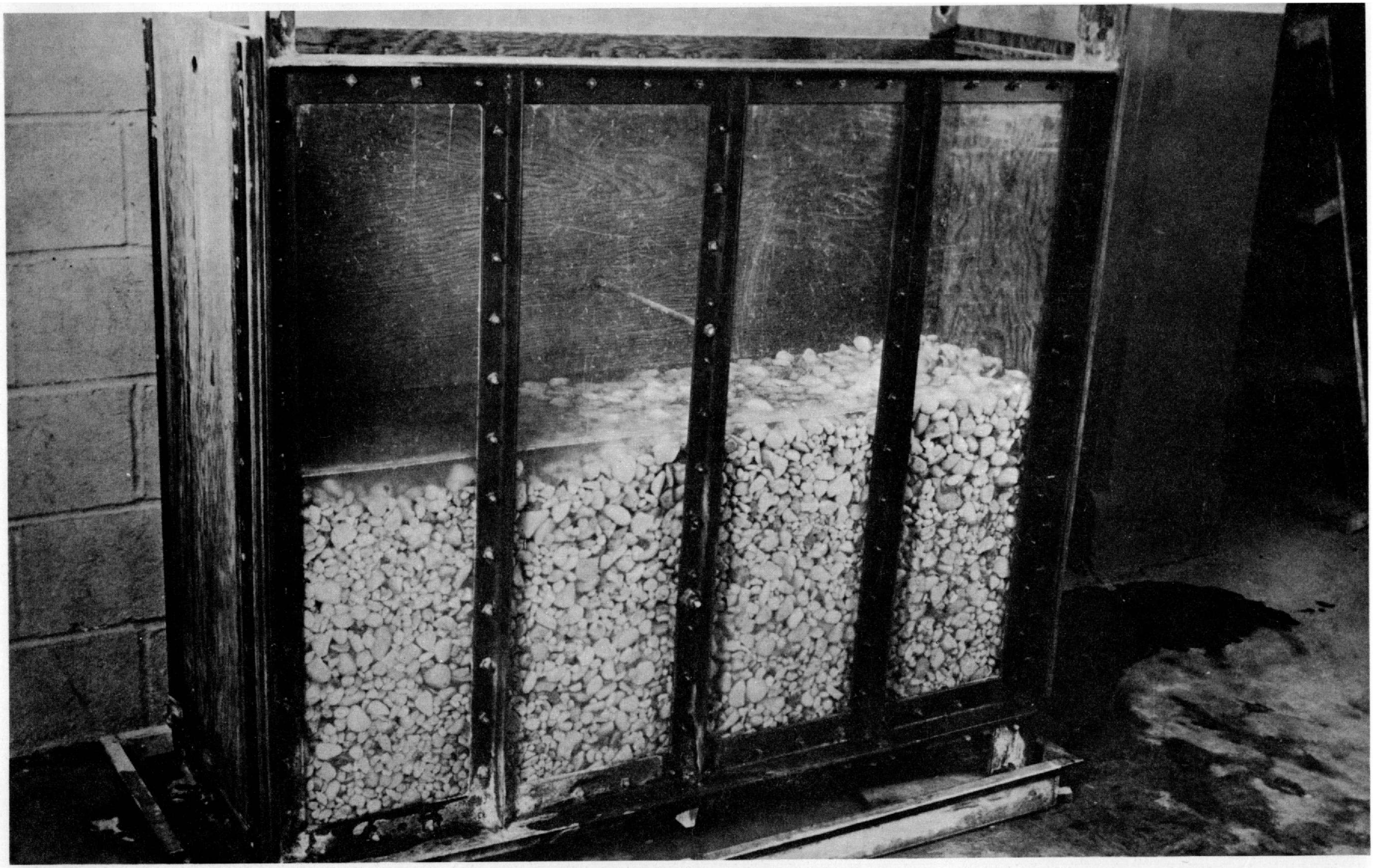
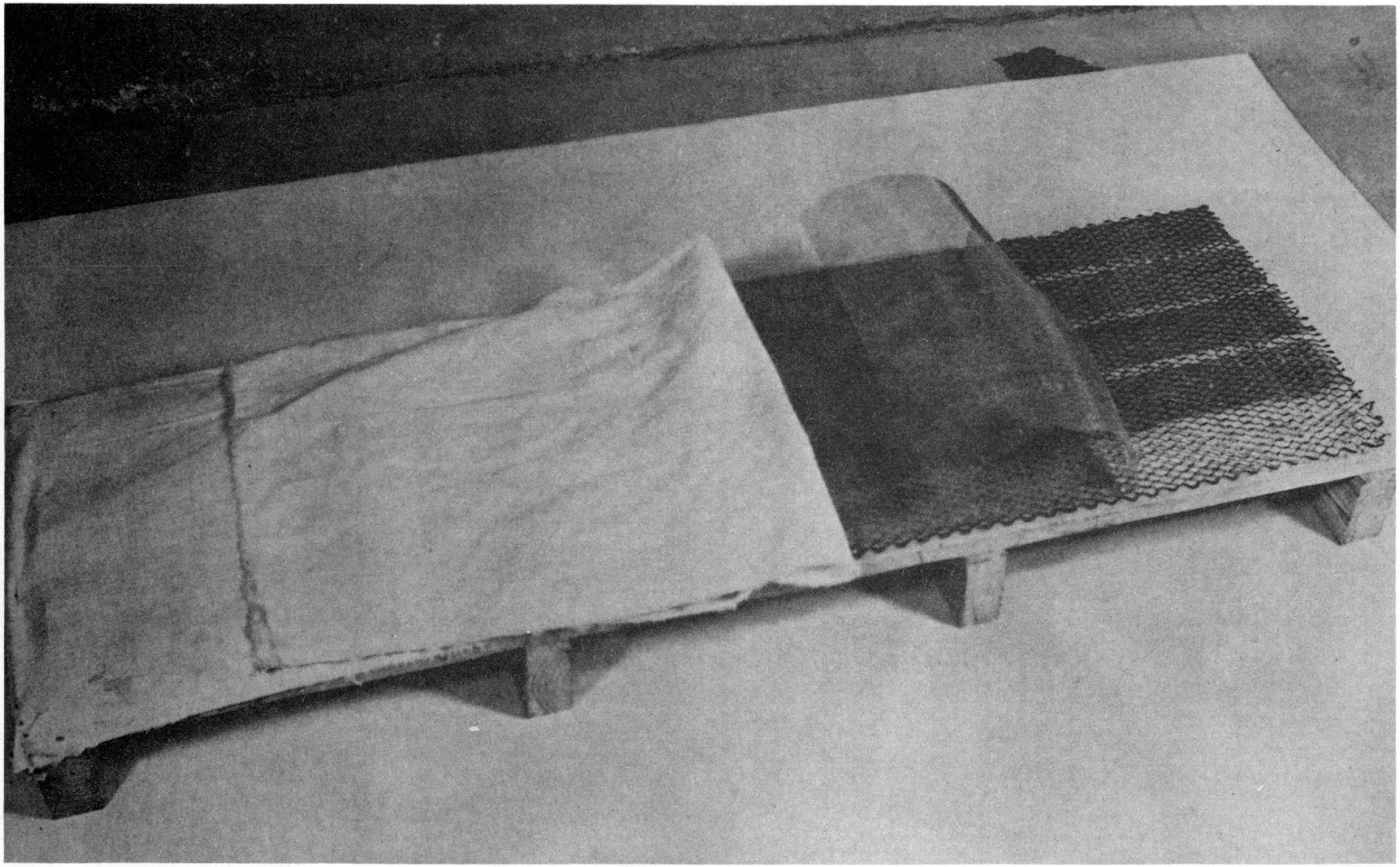


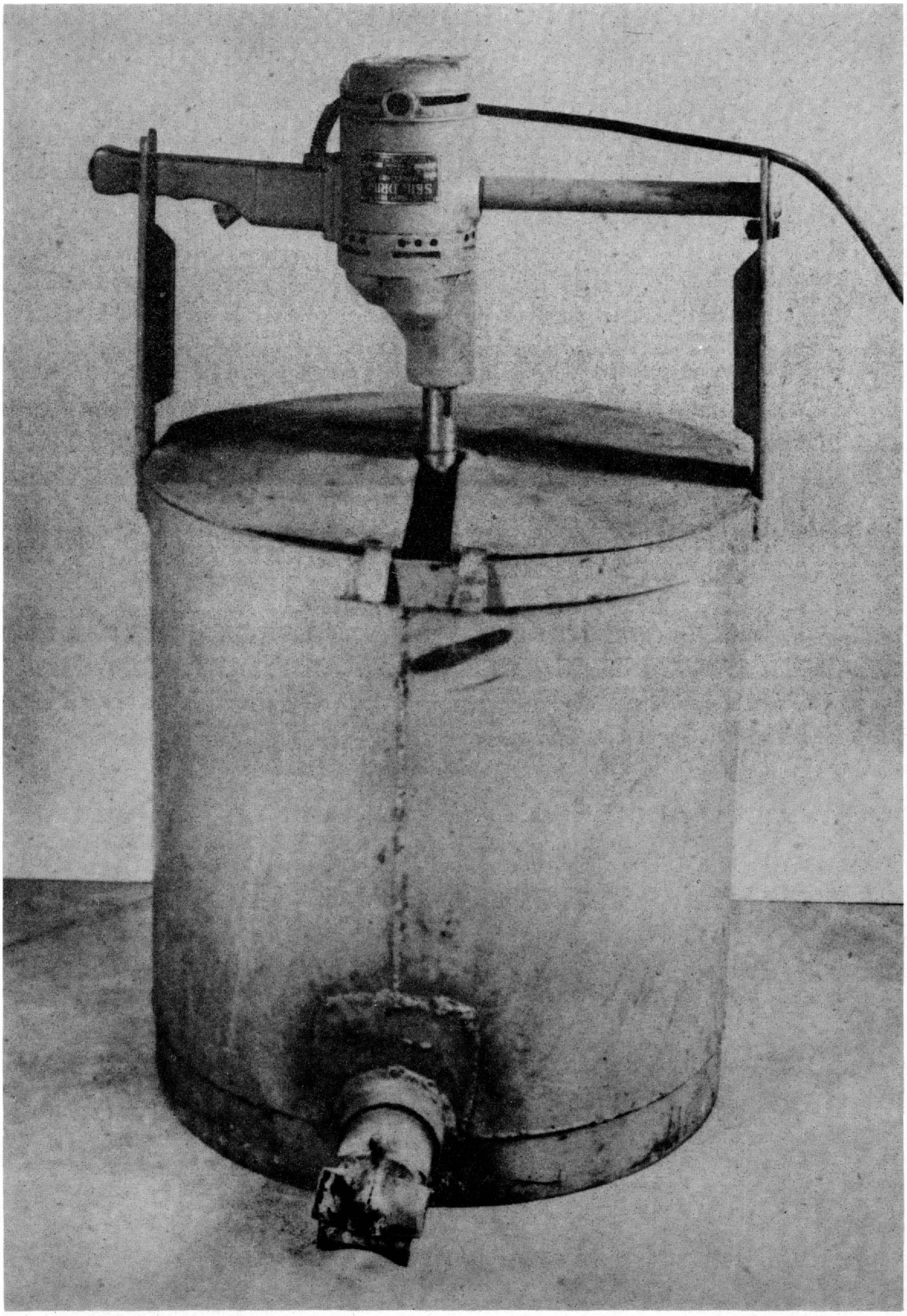
PLATE A-1

Form partially filled with aggregate

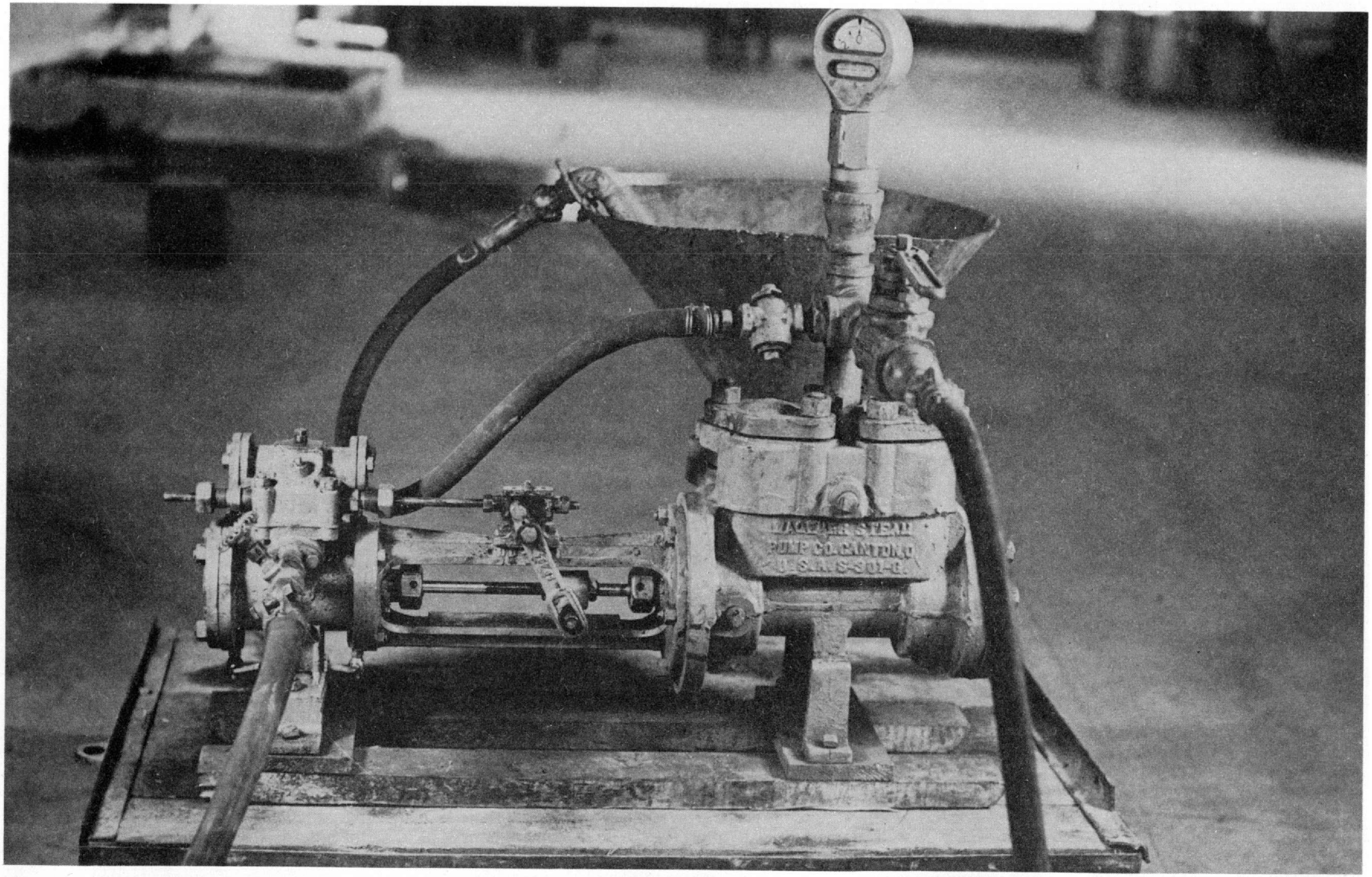
PLATE A-2



Vented form showing construction

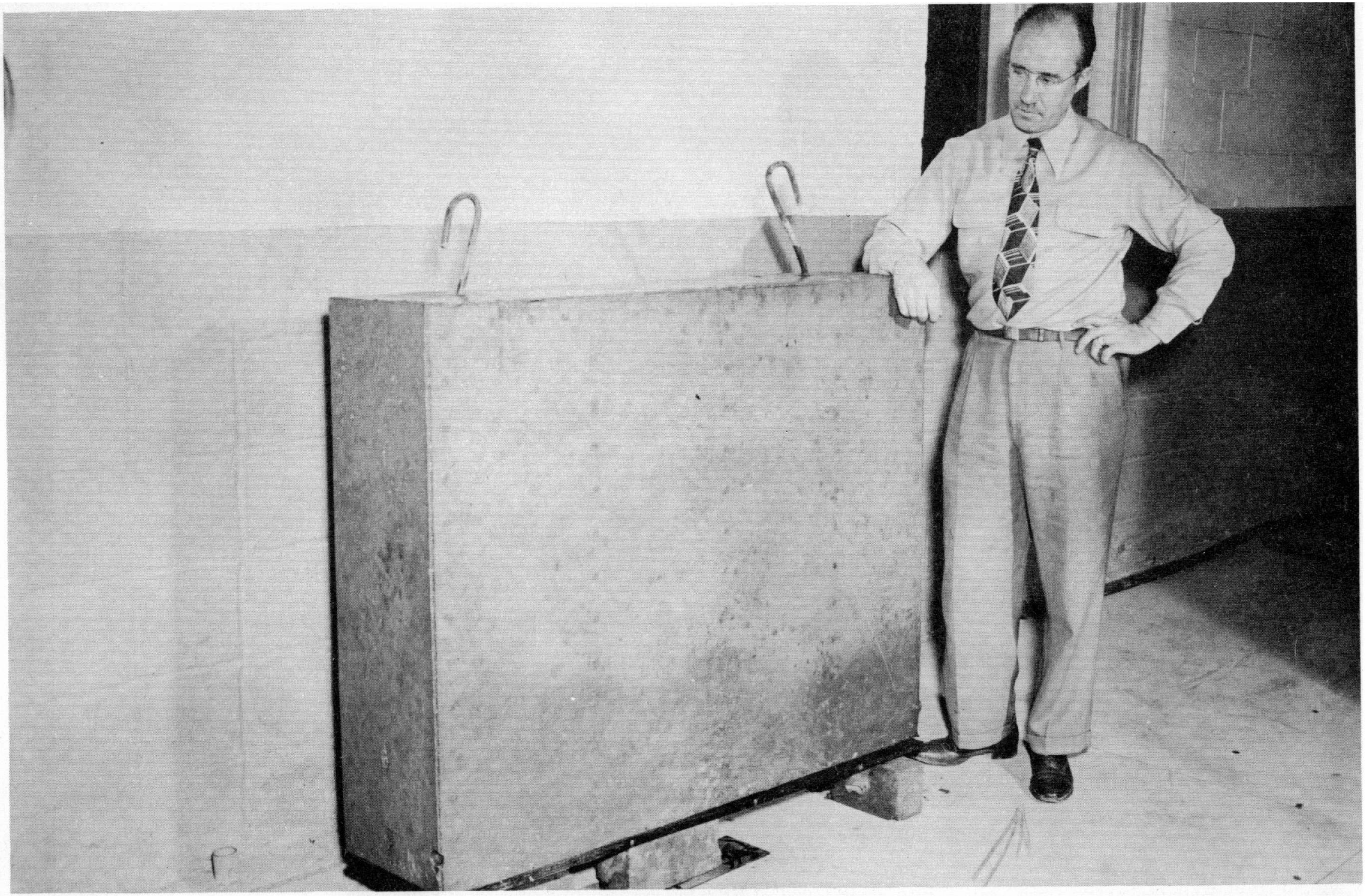


Grout mixer

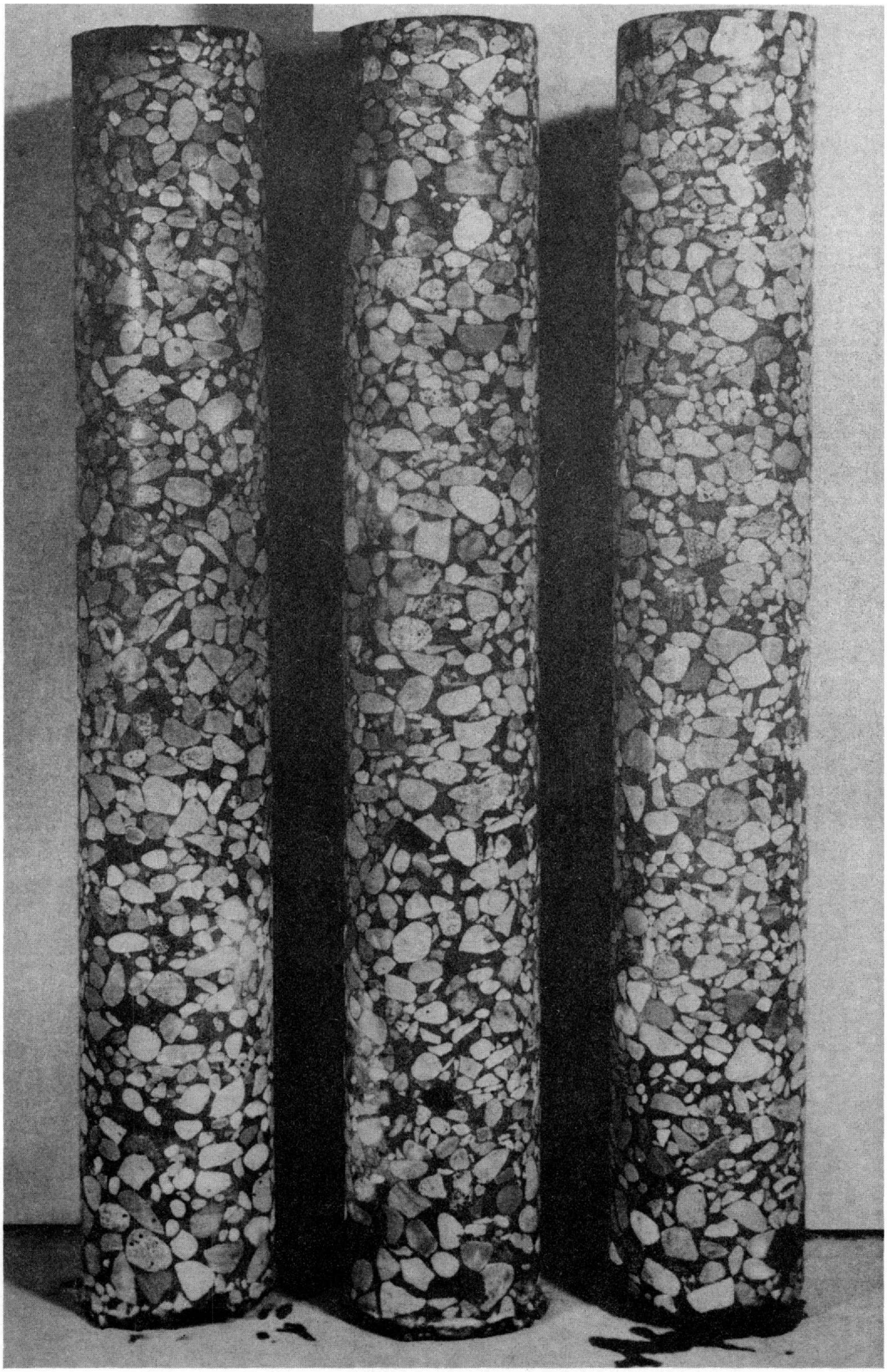


Grout pump

PLATE A-5

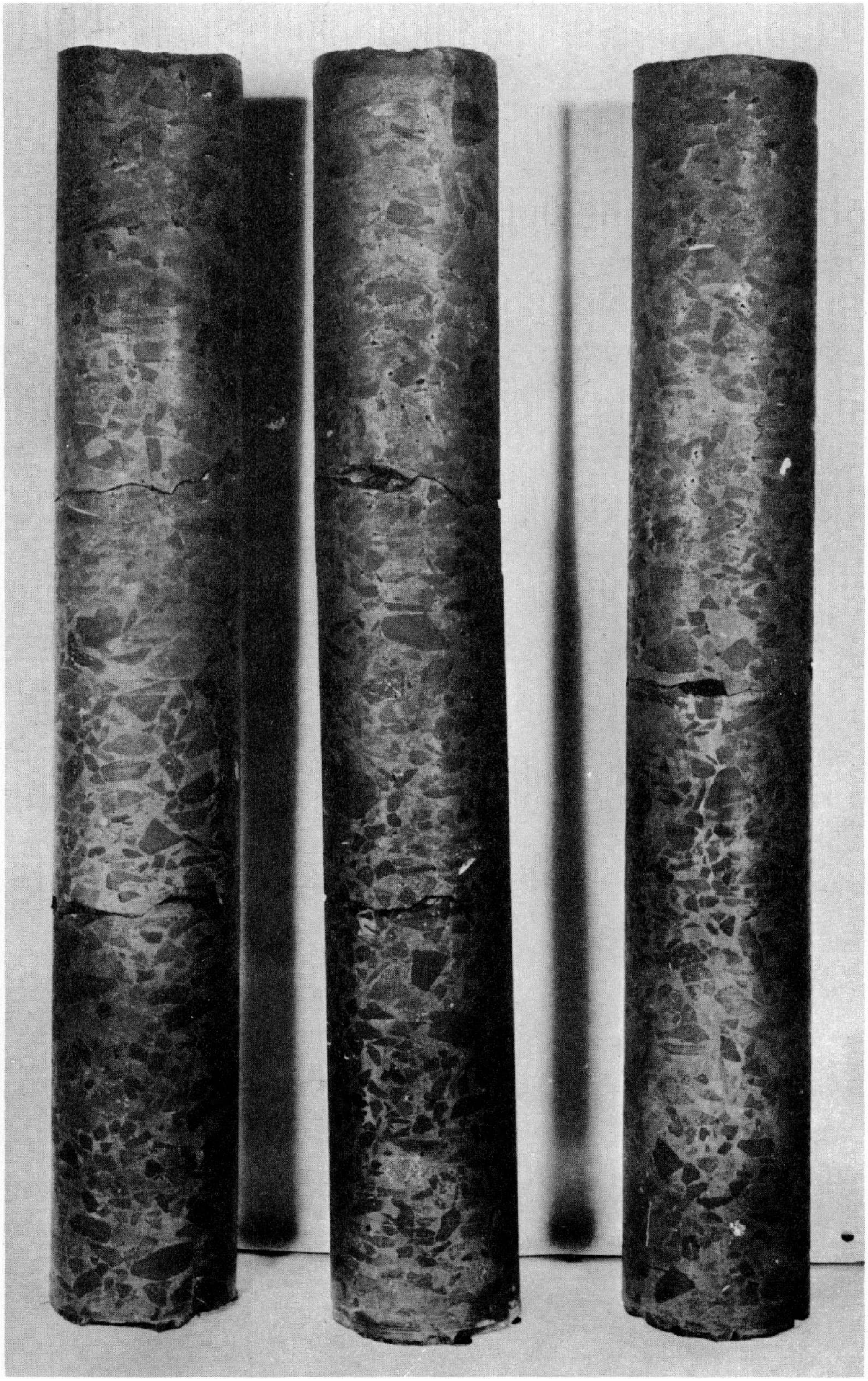


Typical panel after stripping

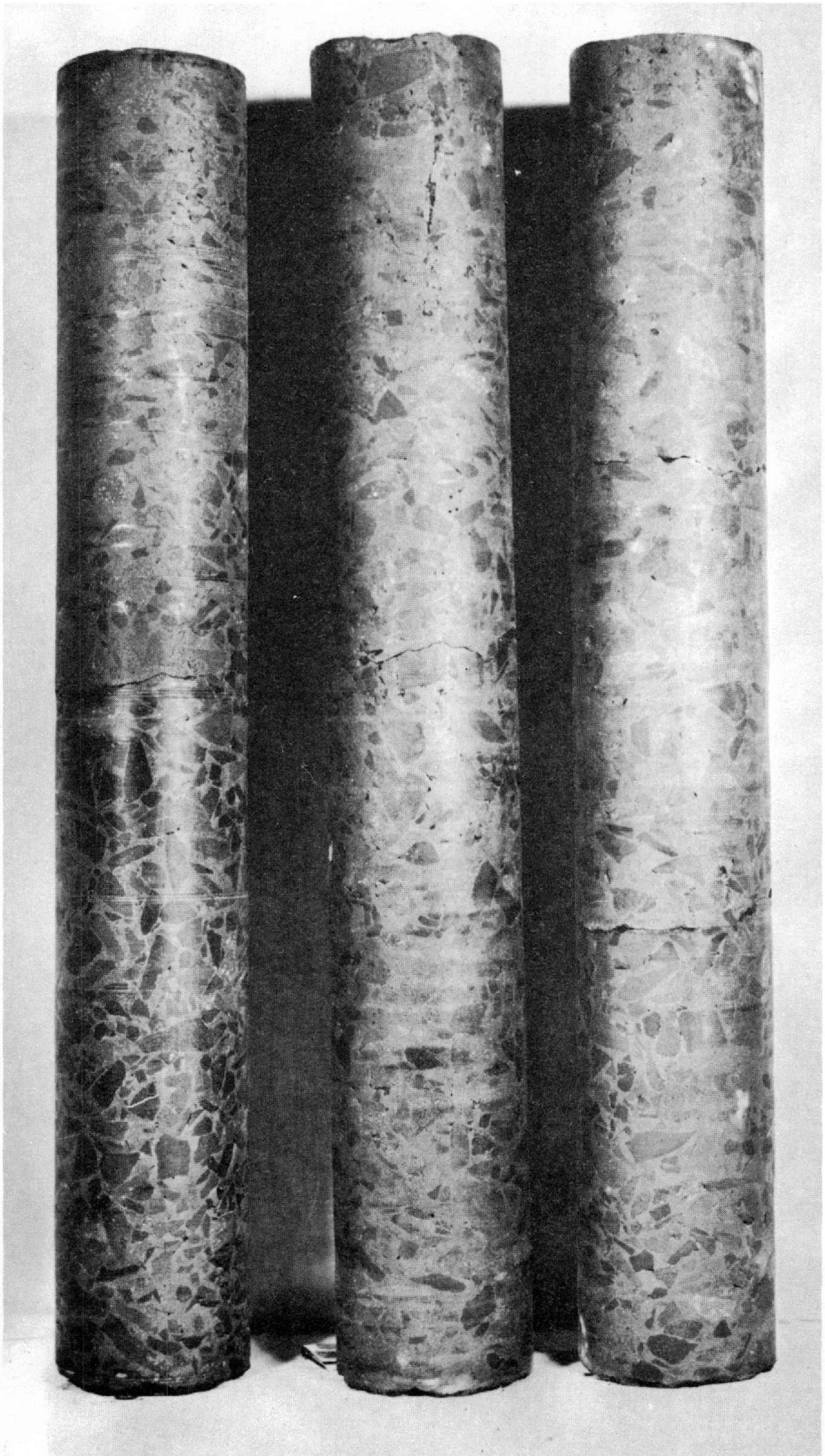


Cores extracted from Prepakt panel, natural sand and gravel

PLATE A-6



Cores extracted from Prepakt panel 6, manufactured sand and crushed stone



Cores extracted from Prepakt panel 7, manufactured sand and crushed stone