EVALUATION OF DENSE BRIDGE FLOOR CONCRETE

USING

HIGH RANGE WATER REDUCER

(SUPERPLASTICIZER)

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-192

MAY 1983

FINAL REPORT

by

RICHARD D. SMITH

Office of Materials
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010
515-239-1392

DISCLAIMER

TABLE OF CONTENTS

RESEARCH OBJECTIVES

The objectives of this research project are:

(1) To determine the feasibility of proportioning, mixing, placing and finishing a dense portland cement concrete in a bridge floor using conventional mixing, placing and finishing equipment.

(2) To determine the economics, longevity, maintenance performance and protective qualities of a dense portland cement concrete bridge floor when using a high range water reducing admixture.

The purpose of a high range water reducing admixture is to produce a dense, high quality concrete at a low water-cement ratio with adequate workability. A low water-cement ratio contributes greatly to increased strength. The normal 7 day strength of untreated concrete would be expected in 3 days using a superplasticizer. A dense concrete also has the desirable properties of excellent durability and reduced permeability.

It is felt that a higher quality, denser, higher strength portland cement concrete can be produced and placed, using conventional equipment, by the addition of a high range water reducing admixture. Such a dense concrete, with a water/cement ratio of approximately 0.30 to 0.35, would be expected to be much less permeable and thus retard the intrusion of chloride. With care and attention given to obtaining the design cover over steel (2½ inches clear), it is hoped that protection for the design life of the structure will be obtained.

Evaluation of this experimental concrete bridge floor included chloride content and delamination testing of the concrete floor five years after construction. A comparitive evaluation of a control section of concrete without the water reducing admixture was conducted. Other items of comparison include workability during construction, strength, density, water-cement ratio and chloride penetration.

BACKGROUND AND PRELIMINARY WORK

Early in 1977, the Office of Materials initiated a request to place a portion of a concrete bridge floor using a superplasticizer. The project site (Hardin County FN-20-5(15)--21-42) is located in the town of Ackley on U.S. 20. Construction involved the floor replacement of a multiple span overhead crossing (4-36' x 24' I-beam spans plus 2-90' x 24' plate girder spans) over the Illinois Central Gulf Railroad. The average daily traffic volume of 2400 vehicles included 537 trucks.

The project included removal of the existing 8 inch portland cement concrete deck and 2 inch asphaltic concrete overlay. The new 8 inch portland cement concrete floor was placed after shear studs were attached to the top flange of the I-beams. This particular bridge was chosen because it included 4 short I-beam simple spans that would lend themselves to a research project. It would provide good comparisons with adjacent spans under the same loadings. The new floor did include epoxy coated reinforcing in the top mat, but this feature did not detract from the basic research objectives. Concrete for one 36 foot approach span was placed using a conventional crane and concrete dump bucket and concrete in another 36 foot approach span was to be placed by pumping.

In May 1977 a planning meeting was attended by the Office of Construction, the contractor, RoVig Construction Company of Des Moines, and the concrete supplier, Welden Bros., Inc. of Iowa Falls.

Preliminary mix designs and trial batches were made in the Office of Materials Laboratory. The contractor elected to use Sikament as the high range water reducing admixture and the dosage rate was set at 24 fl oz per sack of cement. With this information, actual trial batches were made at Welden's Ackley Plant on June 16, 1977. Results of that batching indicated acceptable results could be obtained with a water-cement ratio in the area of 0.31 or 0.32 and an air entraining admixture (AEA) dosage of 0.7 fl oz of Protex (a vinsol resin) per sack of cement. Three test cylinders were made from a trial batch and 14 day compressive strength ranged from 6540 to 7800 psi. The trial mix was based on D-57-6 mix proportion for structural concrete. The aggregate was increased to offset the decrease in water when using a HRWR. Proportions for trial mix and D-57-6 mix are as follows:

	Trial	D-57-6
Cement (lbs.)	710	710
Sand (lbs.)	1739	1696
Coarse Aggregate (lbs.)	1160	1130
Water (lbs.)	238	291
Sikament (oz.)	181	-
Protex (oz.)	6	-

The sequence used in loading concrete materials into the mixer was:

1. Batch 1/2 of the water and all of the AEA.
2. Batch all of the coarse aggregate.
3. Batch all of the cement
4. Batch all of the fine aggregate and ribbon feed the HRWR into the mix with the fine aggregate.
5. Add the remaining water.

This batching sequence was developed from experience gained working with high range water reducing admixtures in the laboratory and from experience gained on a thin p.c.c. overlay project constructed during the fall of 1976, FN-20-6(21)--21-07, Black Hawk County.

MATERIALS

The high range water reducing admixture was Sikament and the air entraining agent was Protex. The fine aggregate came from Hallett at Geneva and the coarse aggregate from Weaver at Alden. The cement was Lehigh Type I. Two truck loads of cement were delivered to the ready-mix plant the day of placement. The cement temperature was 130° F for load 1 and 120° F for load 2.

CONSTRUCTION

On August 30, 1977, at 9:30 a.m. the contractor started to place the east interior simple I-beam span by pumping concrete containing the superplasticizer. The pump was a double piston hydraulically operated pump with 8" diameter pistons that pumped into a 5" discharge hose which was reduced to 4" before outletting to the floor. The concrete was placed using a GOMACO rotating drum finishing machine with a pan float behind the drum.

The first batching started at 9:15 a.m. This was a 3½ cu yd load with a w/c of 0.31 and an AEA dosage of 0.7 oz/sk. The mix had an 8" slump and 4.5% air at the batch plant. One additional cu yd of dry concrete materials was added to the batch and the concrete was mixed in an effort to lower the slump and raise the air. The load left the plant with a w/c of 0.29 and 5% air.

The tests at the site were slump 3¼", (required 2½ ± 1½) and air content 4.6%, (required 6½ ± 1). Additional Protex was added to increase the air content and the batch was mixed an additional 50 revolutions at mixing speed. Subsequent testing revealed the slump had dropped to 1¼" and the air content had not increased. It was decided to pump the batch and get the pour started. However, since the batch was approximately 45 to 50 minutes old and relatively stiff, the pump would not discharge the load. The load was removed and the pump was cleaned out.

A second 3½ cu yd load was batched at 10:30 with a w/c of 0.29 and 1.0 oz/sk AEA. The resulting fresh concrete had 14.1% air at both the batch plant and the bridge site. This was far out of specifications and was rejected. The reason for the high air content could not be determined.

A third 3½ cu yd load was batched at 11:25 with a w/c of 0.30 and 0.75 oz/sk of AEA. The load was delivered to the site, but pumping could not begin until the pipeline was unplugged from the previous attempts. By the time the line was clear, the concrete had stiffened considerably and air content measured 3.5% and slump measured 3/4". A retempering dosage of Sikament, 8 oz/sk, was added at the site and the concrete was mixed another 40 revolutions. The slump increased to 4½", permitting parts of the load to be pumped, but a slump loss of 2 3/4" occurred in the next 15 minutes making the pumping more difficult. The pump became plugged again because of a delay in batching out the next load. At this time it was decided to discontinue pumping high range water reducer concrete. This section of the bridge floor was completed by pumping the standard D-57-6 concrete mix without the high range water reducing admixture as originally planned. No problems were encountered with this section.

The placement of concrete on the remaining 36 ft simple span with HRWR started at 5:30 p.m. This span was placed using two - 3/4 cu yd buckets to deliver the concrete to the deck.

Six cu yd loads were batched; the first one having a w/c of 0.32 and 1.2 oz of AEA per sack and 1.42 gal of Sikament per cu yd. The air content was 6.6% and the slump was 8½". On succeeding loads, the w/c was lowered to 0.31 and 0.30, the AEA was varied from 1.2 oz to 1.4 oz per sack of cement and the Sikament dosage remained the same. The air content for the loads ranged from 5.8% to 7.5% and the slump varied from 6½" to 2 3/4". No problems were encountered unloading the trucks or swinging the concrete to the deck.

The concrete containing high range water reducer flowed very well around the reinforcing steel. However, after 45 minutes on the deck, the mix responded poorly to vibration. The mix remained plastic and was very sticky. As the rotating drum of the finishing machine moved across the deck with the bottom of the drum spinning in the direction of movement, forward speed had to be reduced to nearly zero about 3/4 the way across the deck. One of the features of the superplasticizer is that it releases a large amount of air as the concrete is manipulated This was quite evident as the rotating drum passed over the concrete and was perhaps one of the reasons for its sticking.

This section of the floor was placed from an expansion joint toward the west end of the bridge on a minus 6.0% grade. Difficulty in finishing the concrete surface at the expansion joint was experienced due to the concrete retaining its plasticity longer than conventional concrete and slumping away from the joint.

Transverse grooving of the concrete surface was difficult because it crusted over after finishing with the rotating drum. The problem may have been due to the 60 minutes or more the concrete was in place on the floor. The placement of this floor section was completed about 8:00 p.m.

EVALUATION

Flexural specimens of the concrete placed using high range water reducer gained strength earlier and achieved higher ultimate strength than specimens made from conventional deck concrete (D-57-6). The moduli of rupture at 3, 7, and 14 days were 877 psi, 985 psi, and 998 psi respectively. The 28 day break exceeded 1100 psi. This compared to a 680 psi to 700 psi range at 7 days and a 750 psi to 840 psi range at 14 days for the conventional concrete.

Concrete cylinders (4½" x 9") with high range water reducer tested in compression at age 28 days had an average strength of 8950 psi with w/c 0.310 and averaged 10,230 psi with w/c of 0.300.

Cores were drilled from the two west spans of the deck at age 20 months, 42 months, and 66 months. One span is conventional D-57-6 bridge deck concrete and the other span includes Sikament HRWR. The cores were tested for strength, air content, and chloride content.

After 20 months, the conventional D-57 concrete strength averaged 6860 psi and the HRWR concrete strength averaged 8770 psi. At 66 months there was a slight gain in strength for both types of concrete with the conventional concrete averaging 7070 psi and the HRWR concrete averaging 8820 psi. The HRWR concrete was 1910 psi and 1750 psi stronger than the conventional concrete at 20 and 66 months respectively. The measured air content of the conventional D-57-6 mix cores averaged 6.0% in 1979 and 6.3% in 1983. The cores containing Sikament averaged 5.8% air in 1979 and 6.9% air in 1983.

The chloride content in 1/2" increments is shown in Table I for the top 1½" of concrete. The HRWR concrete appears to be less permeable to chlorides than the conventional D-57-6 concrete.

TABLE I

~~CHLORIDE CONTENT~~

(lbs/cu yd)

Year	Mix	1/2"	1"	1 1/2"
1979	D-57	5.1	2.2	0.5
1979	D-57	2.9	1.2	0.6
1981	D-57	9.34	8.77	2.04
1981	D-57	3.78	1.29	0.45
1981	D-57	8.09	2.95	0.79
1983	D-57	12.17	10.28	4.80
1983	D-57	6.01	2.91	0.95
1983	D-57	11.26	6.58	1.44
1979	HRWR	2.6	0.5	0.4
1979	HRWR	1.0	0.5	0.4
1981	HRWR	7.45	0.57	0.23
1981	HRWR	8.09	3.06	0.19
1981	HRWR	2.95	0.49	0.25
1983	HRWR	8.84	1.81	0.60
1983	HRWR	8.66	2.65	0.87
1983	HRWR	4.88	0.79	0.42

No delamination had been found in the bridge deck at the conclusion of this research project.

CONCLUSIONS

The objectives of the research were fulfilled; it was determined that HRWR concrete can be placed in a bridge deck using conventional mixing, placing, and finishing equipment. **A finishing machine with** two oscillating and vibrating screeds such as was developed for Iowa System dense low slump concrete would be more desirable than the rotating drum finishing machine used on this project.

The HRWR concrete exhibited greater resistance to chloride penetration than the control section, thus having protective qualities which will prevent corrosion for a longer time than conventional D-57-6 bridge deck concrete. **Corrosion prevention will reduce future** maintenance costs for the bridge deck.

HRWR concrete developed greater strength the first few days and the ultimate strength was 24.8% greater than the conventional D-57-6 concrete after 66 months.

Slump is not an acceptable measure of the quality of superplasticized concrete. HRWR concrete has such a low water cement ratio that higher than normal slump is indicative or workability rather than quality. If HRWR concrete is not placed and finished within 30 to 45 minutes after adding the superplasticizer, the effect of the additive is lost, causing the concrete to become difficult to finish.

ACKNOWLEDGEMENTS

The research project was sponsored by the Iowa Highway Research Board, Highway Division, Iowa Department of Transportation.

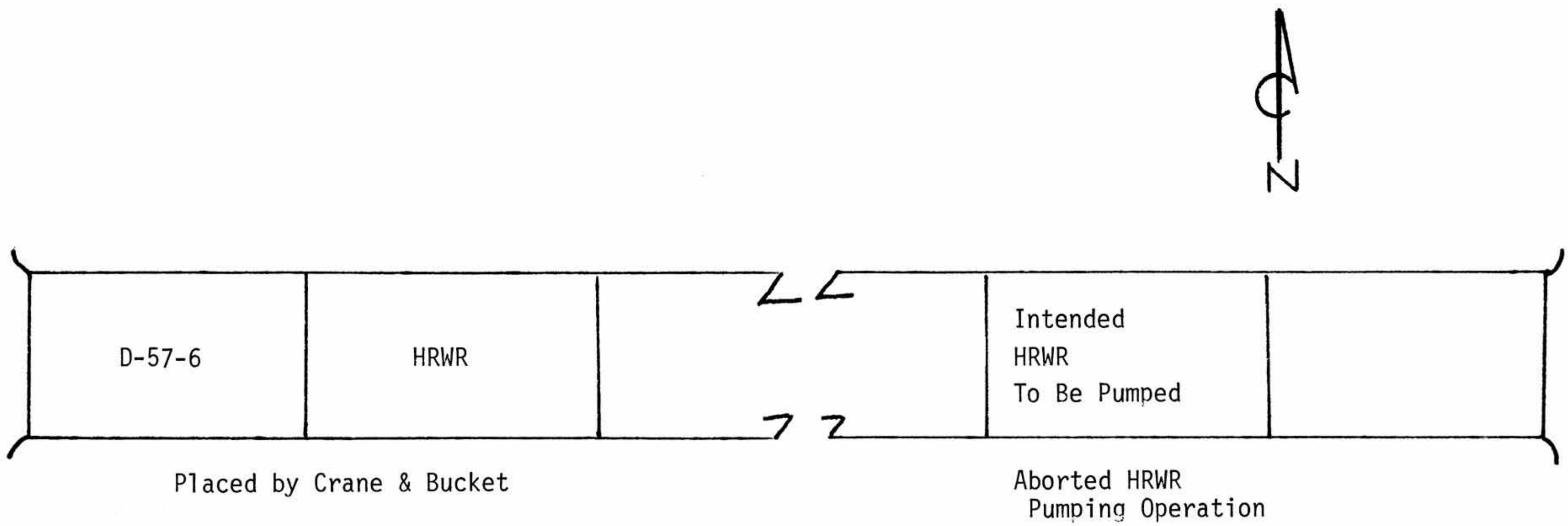
Appreciation is extended to Ralph Britson, former Cement and Concrete Testing Engineer, and Jerry Bergren, former P.C. Concrete Engineer, both in the Office of Materials for their assistance. Mr. Britson provided supervision of testing and proportioning the concrete during the research project.

Gerald Lura, Construction Technician II and many other inspectors from the Marshalltown Construction Residency provided extra effort during this project and their help is appreciated.

RoVig Construction Company and Welden Brothers, Inc. were very cooperative during the frustrating times of placing the experimental bridge deck.

Special recognition is extended to Robert Pratt for his supervision during construction and initial evaluation and reporting.

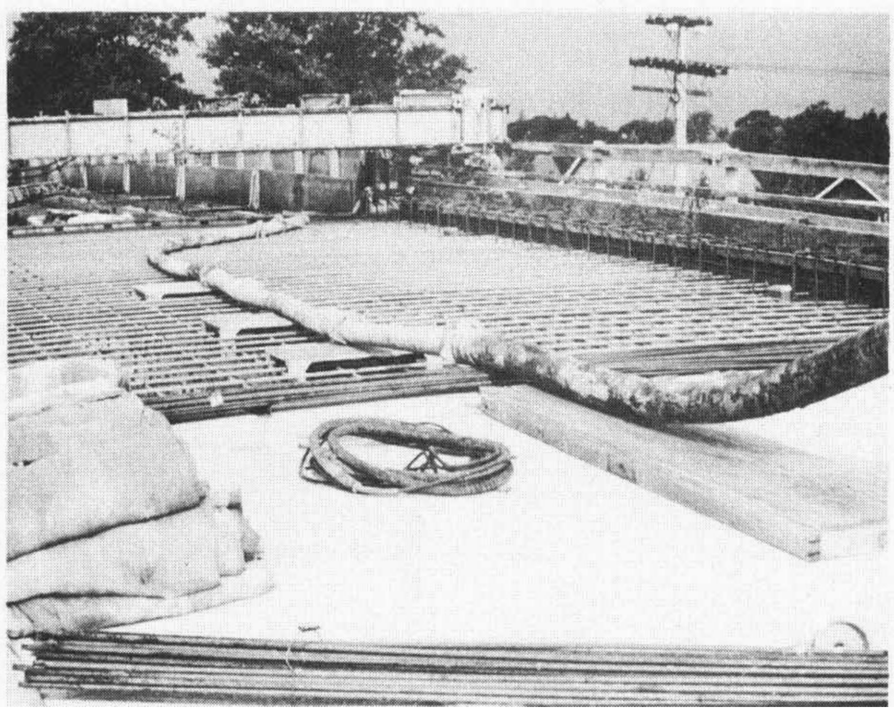
APPENDIX



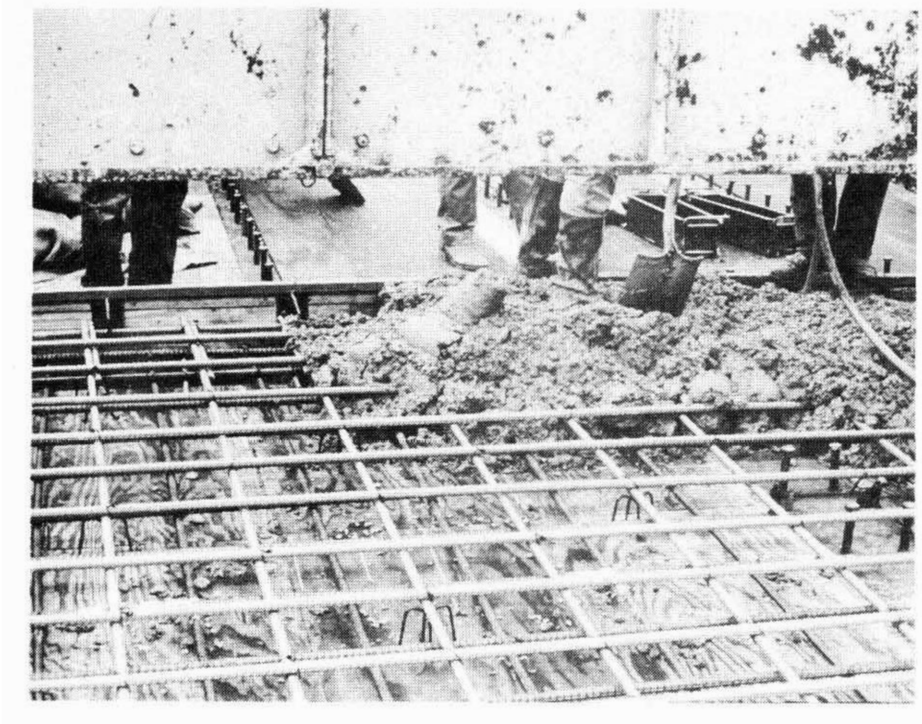
Location of Test Sections

US - 20 Bridge Over ICGRR At Ackley, Ia.

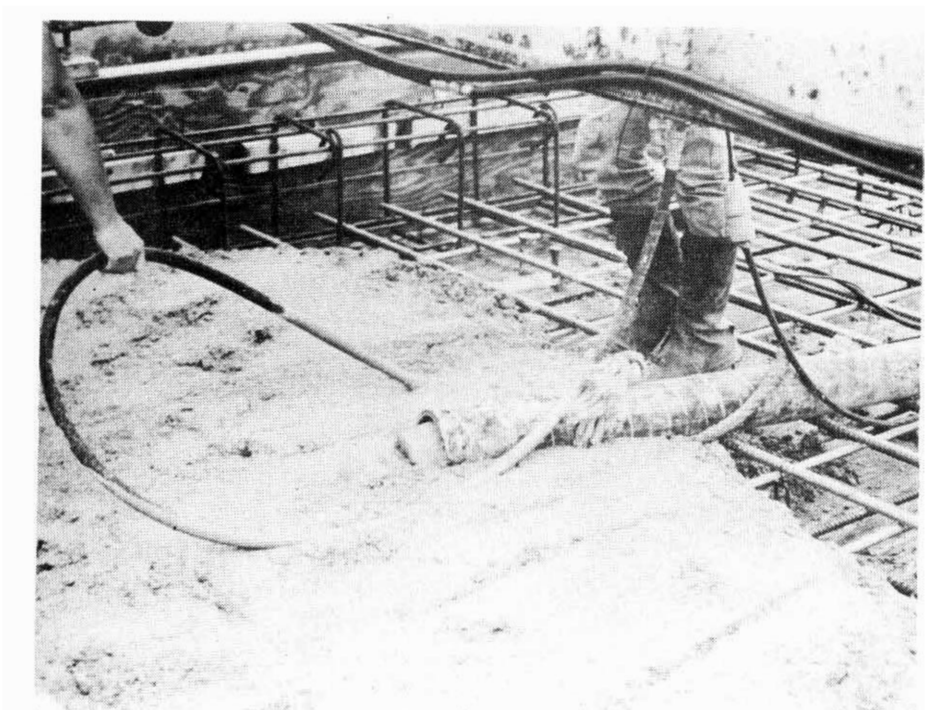
8 inch double piston pump with 5 inch discharge hose to the bridge floor.



5 inch discharge hose, reducer (5" to 4") and 20 ft. of 4 inch hose to the bridge floor - note the supports for the hose from the deck forms.

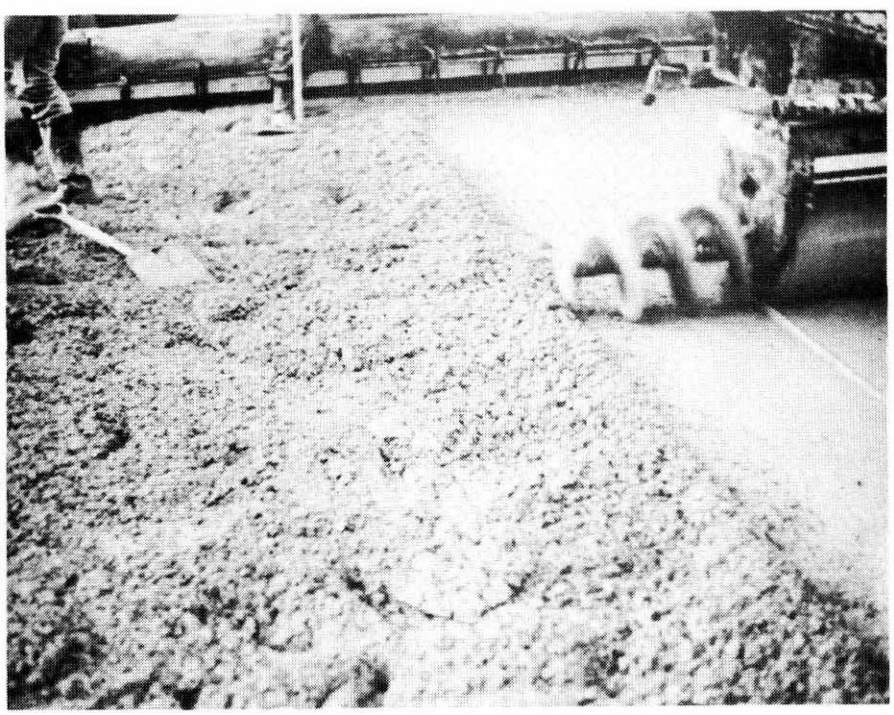


Concrete showing evidence of "stickiness" and loss of workability after 45 to 50 minutes from batching.



Vibrator leaves its mark after 45 to 50 minutes from batching.

Vibrator not too effective after 40 to 50 minutes from batching - note hole left by vibrator in lower left of picture.



Finishing machine consolidates, strikes off and finishes a harsh looking concrete pretty well.