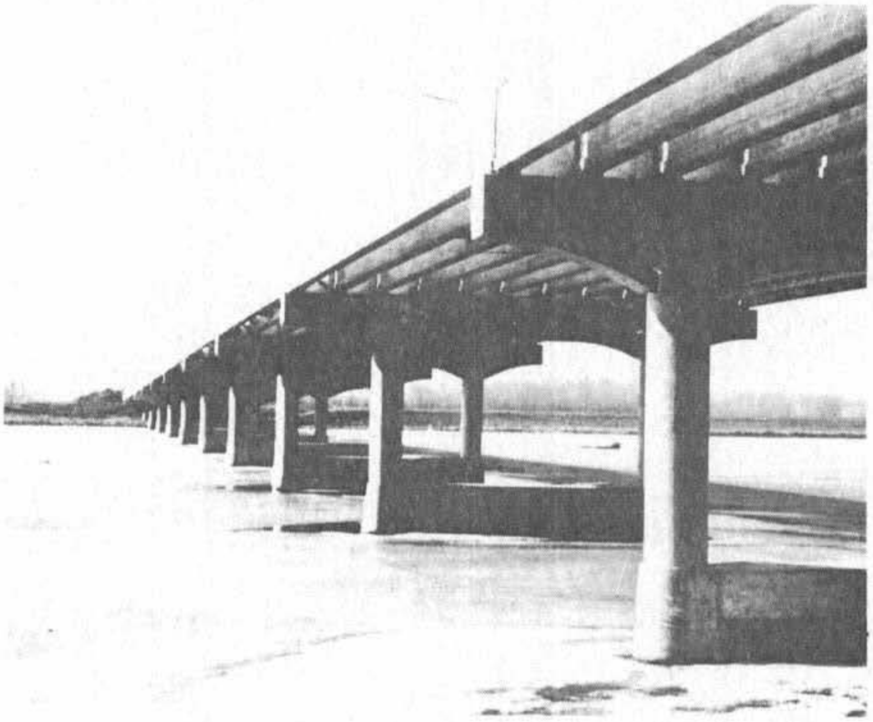
EVALUATION OF DENSE BRIDGE FLOOR CONCRETE USING SUPERPLASTICIZER



IOWA HIGHWAY RESEARCH BOARD

Project HR - 192

CONSTRUCTION REPORT

HIGHWAY DIVISION
December 1977

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by

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INTRODUCTION

Much effort is being expended by various state, federal, and private organizations relative to the protection and preservation of concrete bridge floors. The generally recognized culprit is the chloride ion, from the deicing salt, reaching the reinforcing steel, and along with water and oxygen, causing corrosion. The corrosion process exerts pressure which eventually causes cracks and spalls in the bridge floor.

The reinforcing has been treated and coated, various types of "waterproof" membranes have been placed on the deck surface, decks have been surfaced with dense and modified concretes, decks have been electrically protected, and attempts to internally seal the concrete have been made. As of yet, no one method has been proven and accepted by the various government agencies as being the "best" when considering the initial cost, application effort, length and effectiveness of protection, etc.

RESEARCH OBJECTIVES

This project has the participation of the Iowa Highway Research Board and has two main objectives:

(1) To determine the feasibility of proportioning, mixing, placing and finishing a dense, portlant 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 super water reducing admixture.

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 super 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 (2½ inches clear), it is hoped that protection for the design life of the structure can be obtained.

Evaluation of this experimental concrete bridge floor will include such items as the chloride content of the concrete at the time of placement, chloride content and delamination of the concrete floor at one, three and five years after construction and comparison with a control sample of concrete without super water reducer. These comparisons will include workability, strength, density, water-cement ratio and chloride penetration.

The basis for use of a super water reducer 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 strength obtained at 7 days would be expected in 3 days using a superplasticizer. A dense concrete also has the desirable properties of excellent durability and increased impermeability.

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 in northeast Hardin County on U.S. 20. This construction involves the floor replacement of a multiple span overhead crossing (4-36'x24' I-beam spans plus 2-90'x24' plate girder spans) over the Illinois Central Gulf Railroad with an average daily traffic volume of 2400 vehicles including 537 trucks.

This project involved removal of the existing floor consisting of an 8 inch concrete deck and 2 inch asphaltic concrete overlay. A new 8 inch 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 some short I-beam simple spans of small volumes 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 re-steel 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 conducted by the Office of Construction with the contractor, RoVig Construction Company of Des Moines and his 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 super water reducer and it was decided to use a dosage rate of 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 desirable results could be obtained with a water-cement ratio in the area of 0.31 or 0.32 and an air-entraining admixture dosage of 0.7 fl. oz. of Protex per sack of cement.

The sequence used in loading concrete materials into the mixer was as shown below. This loading sequence was developed through experience working with SWR's in the laboratory and from experience on the thin overlay project constructed during the fall of 1976, FN-20-6(21)--21-07, Black Hawk County.

1. Batch 1/2 water and all of the AEA. (Air Entraining Admixture)
2. Batch all of the coarse aggregate.
3. Batch all of the cement.
4. Batch all of the fine aggregate.
5. Ribbon the SWR into the mix together with the fine aggregate.
6. Add the remaining water.

Three test cylinders were made of one of the trial batches and the 14 day compressive strength ranged from 6540 to 7800 psi.

This trial batch contained:

710 lbs. of cement

1793 lbs. of sand

1160 lbs. of stone

238 lbs. of water (total) - W/C of 0.33

181 oz. of Sikament

6 oz. of Protex (7.1% air)

CONSTRUCTION

On Tuesday, August 30, 1977, at about 9:30 a.m. the contractor started to place the east interior simple I-beam span by pumping concrete utilizing the superplasticizer. The pump was a double piston hydraulically operated pump with 8" piston sizes that reduced to a 5" discharge hose. This 5" hose continued on a boom over the top of the truck to the floor for a distance of about 50 ft. then through a 5" flexible hose about 10 ft. long. This was connected to a 5 ft. reducer, 5" to 4", then about 30 ft. of 4" hose outletting to the floor.

The first batching started about 9:15 a.m. This was a 3 1/2 cu. yd. load with a w/c of 0.31 and an air admixture dosage (AEA) 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 and mixed in an effort to lower the slump and raise the air. The load went out with a w/c of 0.29 and 5% air at the plant.

The tests at the site indicated a slump of 3¼" (required 2½ ± 1½) and an air content of 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. A subsequent test indicated the slump had dropped to 1¼" and the air content had not increased. It was decided to go ahead and try to pump this batch and get the pour started. However, since the batch was approximately 45 to 50 minutes old, the pump would not discharge the load. The load was removed and the pump was cleaned out.

A second 3 1/2 cu. yd. load was batched at 10:30 with a w/c of 0.29 and 1.0 oz./sk. of AEA. The resulting fresh concrete had air of 14.1% being checked at the batch plant and the bridge site. This was far out of specifications and was rejected. We are unable to account for this high air.

This load was introduced into the pump prior to completing the air content test or slump check at the bridge site. The tests at the bridge site confirmed the 14.5% air content and a 7½" slump. The pumping was stopped immediately and none of this load was incorporated.

A third 3 1/2 cu. yd. load was batched at 11:25 with a w/c of 0.30 and 0.75 oz./sk. of AEA. Due to delays in cleaning a plugged pipe line on the concrete pump and checking air (3.5%) and slump (3/4"), the concrete had stiffened considerably. A retempering dosage of Sikament 8 oz./sk., was added at the site and mixed another 40 revolutions. This increased the slump to 4½", permitting part of the load to be pumped. This seemed to move quite well, but a slump loss of 2 3/4" occurred in the next 15 minutes making the pumping more difficult. The pump then plugged again because of the delay in batching out the next load.

Two loads were batched, but the line was still being cleaned out from previous loads. The air dosage was raised to 0.95 oz./sk. of AEA, but the air content stayed in the area of 5%. This compared to 14.1% with a 1.0 oz./sk. AEA dosage in the second load.

At this point, it was decided to discontinue trying to pump super water reducer (SWR) concrete and the east section of the bridge floor was completed by pumping, using a conventional D-57-6 concrete mix proportion without the SWR. No further problems were encountered with this section.

The other half of the investigation provided more acceptable results along with some very definite conclusions and recommendations for future consideration. This placement on the remaining 36 ft. simple span started at about 5:30 p.m. This portion of the floor was placed using two 3/4 cu. yd. buckets to swing the concrete to the deck.

Six cu. yd. loads were batched, starting with a w/c of 0.32 and 1.2 oz. per sack of AEA 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, and resulting air contents were in the range of 5.8% to 7.5% using 1.2 oz. to 1.4 oz. of AEA per sack of cement. The slump varied from 6½" to 2 3/4" and no problems were experienced unloading the trucks or swinging the concrete to the deck.

The contractor used a GOMACO rotating drum finishing machine with a pan float behind the drum.

The concrete containing super water reducer did not react well to vibration after it had been on the deck for 45 minutes or so, but the concrete did flow very well in and around the reinforcing steel.

The mix stayed plastic and was also very sticky. As the rotating drum moved across the deck with the bottom of the drum spinning in the direction of movement, it would be forced to almost throttle down to 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 obvious in the action of the rotating drum, 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 -6.0% grade. Some difficulty in finishing the concrete surface at the expansion joint was experienced due to the concrete retaining its plasticity longer than conventional concrete.

Transverse grooving of this floor surface was difficult because it seemed to crust over after the rotating drum completed its required operation. This may have been due to the 60 minutes or more this concrete was in place on the floor.

The placement of this floor section was completed shortly after 8:00 p.m.

The additional cost of this research project amounted to $3,500. Included in this total was approximately $1,600 for extra labor and pump time for the aborted pumping operation.

EVALUATIONS

Several problems were experienced during this research project that can be eliminated in any future use of a super water reducer for bridge decks, and some of them are as follows:

1. The time from initial batching to placement and screeding should not exceed 30 to 40 minutes. Strike off and screeding should take place not more than 10 to 15 minutes after depositing concrete on the deck.
2. Oscillating type screeds with vibratory capability appear to be necessary for proper placement and consolidation of this type of concrete.
3. Internal vibration is probably not necessary if vibratory screeds are used since the concrete flows quite well around the reinforcing steel. The density could be evaluated.
4. Hand finishing and shaping around 2 of the floor drains was difficult due to the concrete remaining plastic under the top surface crust for 90 minutes or more.
5. Finishing and texturing are almost impossible after 45 to 60 minutes because the surface has a tendency to crust over.
6. Slump is not a good measure of the workability of the super water reduced concrete. The criteria should be what consistency is desirable at the point of placement and finishing. This type of concrete has such a low water cement ratio that higher than normal slumps are not too important.
7. The concrete producer must have accurate knowledge of aggregate moisture contents at all times and of the

type of air-entraining admixture being used.

8. Careful control of proportioning in the plant is most essential.

The flexural specimens of the floor placed using super water reducer indicated early strength gain and higher strengths than conventional floor concrete, as expected. A 3 day break indicated a modulus of rupture of 877 psi; a 7 day break indicated 985 psi; and a 14 day break indicated 998 psi flexural strength. The 28 day break exceeded 1100 psi. This compares to a 680 psi - 700 psi range (7 day break) and 750 psi - 840 psi range (14 day break) for regular bridge floor mix (D-57) on other portions of this bridge.

Concrete cylinders (4½" x 9") tested for compression indicated the following strengths at 28 days.

Using a 0.310 W/C - Ave. strength of 8,950 psi.

Using a 0.300 W/C - Ave. strength of 10,230 psi.

<u>Materials</u>

Cement	Lehigh Type I
Fine Aggregate	Hallett - Geneva
Coarse Aggregate	Weaver - Alden
Super Water Reducer	Sikament
Air-entraining Agent	Protex
Mix Proportion	D-57-6

Cement: 2 truckloads were delivered to the ready mix plant during the day.

Load 1 - Cement temperature 130°F.

Load 2 - Cement temperature 120°F.

CONCLUSIONS

The use of a super water reducer in concrete for bridge decks has advantages that are worth investigating in another field research application using different finishing equipment and slightly different batching sequences. Once the handling characteristics are better understood and controlled, the use of super water reduced concrete for full depth bridge floors may provide an alternate to designers for protection from de-icing chemicals.

Even though a number of problems were encountered, the research demonstrated that conventional equipment may be used but may need to be a different type than was used on this particular project.

It is the opinion of this writer that transit truck mixing and continual agitation reduced the workability of concrete containing a super water reducer. Less agitation or no agitation at all between batching, mixing and placement should extend the time available to manipulate, vibrate and finish this concrete.

RECOMMENDATIONS

It is recommended that this bridge floor mix containing a super water reducer be mixed very fast for 2 to 3 minutes and much less agitation be used after mixing until the time of depositing in the forms and finishing. It appeared that the workability of the concrete was gone after about 30 minutes and there was very little reaction to this mix from vibration after 30 to 40 minutes from batching. Some of the technical data recommend that the super water reducer be added at the last possible moment, be mixed at maximum speed for 2 minutes, and used without delay. This research project pointed out the importance of this recommendation as evidenced by the difficulty of finishing after 30 to 40 minutes from batching. It appears that a different type of finishing equipment is necessary to work with concrete containing a super water reducer. A double oscillating screed machine such as developed for the dense, low slump Iowa System of bridge repair would appear to be more suitable.

It is very important for the finishing operation to stay very close to the concrete placement operation to take advantage of early workability. The strike off should be done within 10 to 15 minutes after placement.

It appears that the equipment and the methods that have been developed for the dense low slump Iowa System would probably work for a full depth bridge deck. I believe the batching operations and the mixing of the concrete have very tight limitations as to the amount of mixing and agitation and the time of use. At this point there is not enough information on the batching, mixing, transporting and finishing to go ahead with developing a set of specifications or guidelines for letting a project of this type. At least one other project utilizing different equipment and different methods should be tried and evaluated before super water reducers can be considered for full depth bridge deck placements.

APPENDIX

TABLE I - BATCH PROPORTIONS - DEVELOPED FROM LABORATORY TESTING

1 cu. yd. Batch Wts. Sikament Mix @ 24 fl. oz./Sk. cement

W/C	Cement	Sand	Stone	Total H_2O (lb)	Sikament (Gal)	H_2O in Agg.	H_2O in Sikament	Net H_2O (lb)	Net H_2O (Gal)	AEA (oz)
.28	710	1849	1196	199	1.42		8.4 lb.			
.29	710	1838	1188	206	1.42		8.4 lb.			
.30	710	1827	1181	213	1.42	63	8.4 lb.	141.6	17	1.4
.31	710	1816	1174	220	1.42	63	8.4 lb.	148.6	17.9	1.3
.32	710	1804	1167	227	1.42	62	8.4 lb.	156.6	18.8	1.2
.33	710	1793	1160	234	1.42		8.4 lb.			
.34	710	1782	1152	241	1.42		8.4 lb.			
.35	710	1771	1145	248	1.42		8.4 lb.			
.36	710	1758	1137	256	1.42		8.4 lb.			

Concrete Bridge Deck

Hardin County

FN-20-5(15)

Ackley, Iowa

RoVig Constr. Co.

Super Water Reducing Agent

Basic Mix D57-6

60% Fine Agg.

40% Coarse Agg.

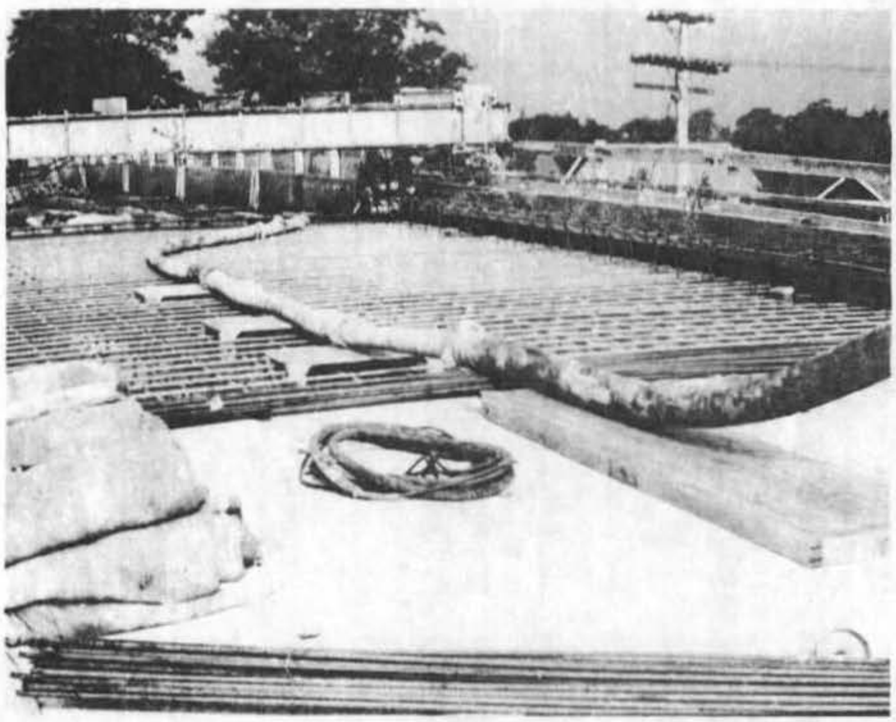
F.A. Sp. G. = 2.66

C.A. Sp. G. = 2.53

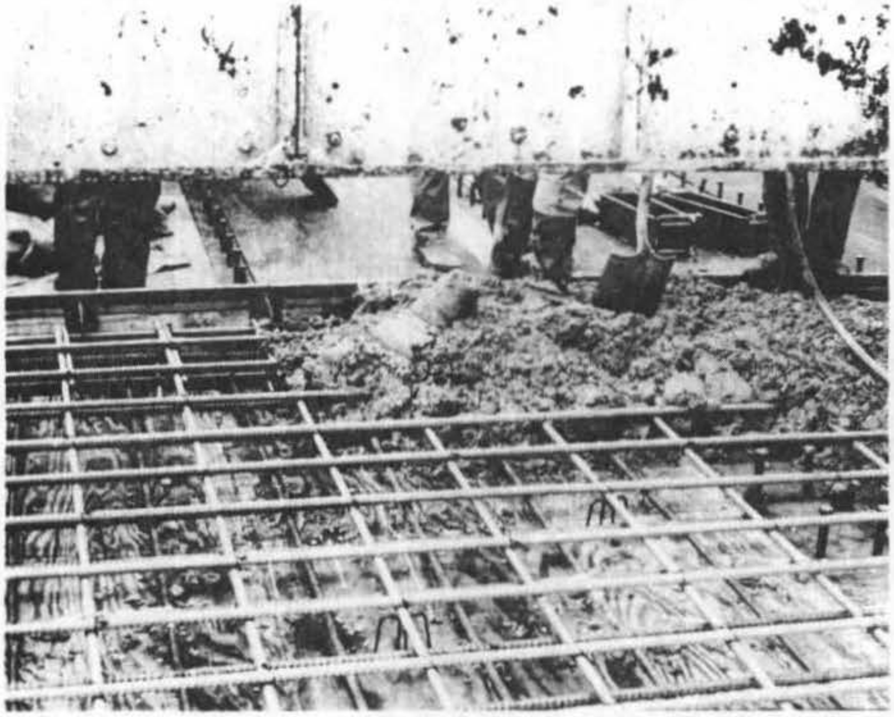
Sikament - 5.9 lb. of H_2O Per Gal.

Protex AEA 0.7 oz. per sack

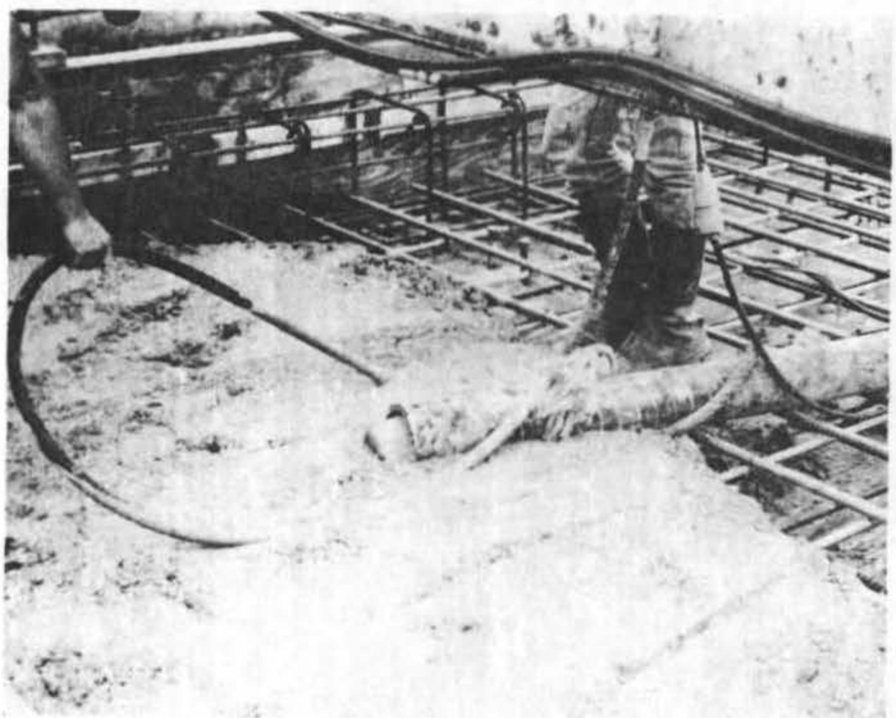
8 inch double piston pump with 5 inch discharge hose to the bridge floor.



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.

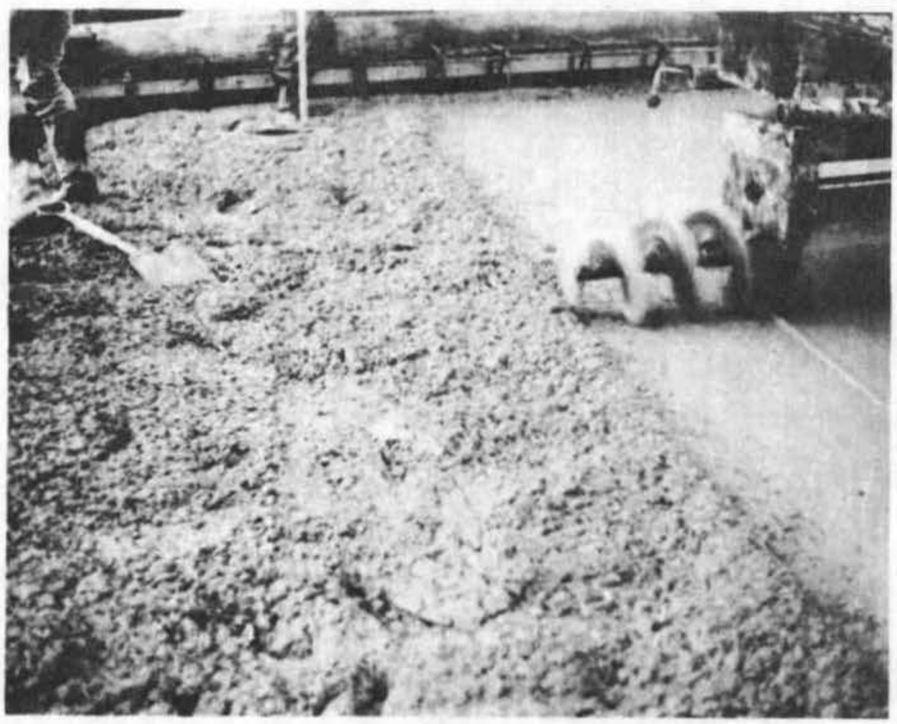


Concrete showing evidence of "stickiness" and loss of workability after 45 to 50 minutes from batching.



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.