MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

MICHIGAN'S EXPERIENCE IN THE USE OF POZZOLITH AND HP-7 ADMIXTURES FOR CONCRETE PAVEMENT CONSTRUCTION

A symposium containing reports and factual data concerning 4 experimental pavement projects in which the admixtures Pozzolith and HP-7 were included for study in relation to scale prevention.

Research Projects Involved:

39 B-11 (2)
39 B-8
42 B-15 (1)
42 B-15 (2)

Research Laboratory
Testing and Research Division
Report No. 212
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FOREWORD

This symposium brings together, for easy reference, pertinent information concerning Michigan's program of testing the proprietary admixtures Pozzolith and HP-7, intended to prevent concrete pavement scaling. Between 1938 and 1942, the following four experimental concrete pavements, containing such admixtures, were constructed: 1) Project M 61-27, C5 on M-126 in Muskegon Heights; 2) The Michigan Test Road Durability Project on M-115 between US-10 and M-66 in Clare and Osceola Counties; 3) Project M 82-110, C1 on M-56 between Belleville and US-112; and 4) Project F 71-24, C1 in Rogers City on US-23A.

Included in the symposium are original reports and portions of original reports containing paving mixture and construction data, and the results of laboratory and field tests performed on the concrete admixtures used in the above projects. The findings of condition surveys are also presented. In most instances, original material is included exactly as written, without eliminating duplicate information. For each project, a synopsis is presented which summarizes the information in the original reports.

THE MUSKEGON EXPERIMENTAL PROJECT
PROJECT M 61-27, 05 - M-126, MUSKEGON HEIGHTS

CONTENTS

SYNOPSIS

The above material includes paving mixture and construction data for the Muskegon Heights project as well as compressive strength data for cylinders made from the concrete mixes used, and the results of two condition surveys. The concrete containing Pozzolith had a sticky, rubbery texture and was hard to finish. Its compressive strengths both at 7 and 28 days, were appreciably greater than those of regular concrete. After 16 years, a condition survey showed extensive scaling on the sections constructed with regular concrete, while the section containing Pozzolith was free from scaling.

Excerpts from Report by C. H. Cash, Oct. 28, 1938

The field construction work on Project M 61-27, C5 was carried out in September, 1938. The project consisted of 1.387 miles of 20-ft. concrete pavement located on M-126 in Muskegon Heights and running from Peck Street Southeast to Getty Avenue. The purpose of the project was to determine the effect which blending portland cement with a natural cement or pozzolanic material would have upon the resistance of concrete pavement to surface scaling. The Pozzolith admixture was used upon a super-elevated curve from Station 39+73 to 40+23, while standard portland cement concrete and portland natural cement blends were used on the remainder of the project. It was expected that reasonably heavy applications of calcium chloride would be required for ice removal on the section containing Pozzolith.

Pozzolith admixture was added to the mix at the rate of 2 pounds per sack of cement. Before the admixture was used, 25 gallons of water were required to produce concrete having a 1-inch slump. The addition of Pozzolith caused the slump to increase to 4 inches. The water added at the mixer was then reduced to 20 gallons per batch and the resulting concrete had a slump of 1-3/8 inches as compared to a slump of 1-3/4 inches in the standard concrete. No attempt was made to correct the mix to compensate for the decrease in water required.

The concrete containing Pozzolith had a sticky, rubbery texture, due apparently to an increase in the bond between the particles of aggregate. This was particularly noticeable in the slump tests. Instead of the concrete slumping into a dome-shaped pile, the top of the cone retained its original shape and the bottom portion became cylindrical in shape. In the case of the 4-inch slump, the pile of concrete was cylindrical for almost its entire height. The sticky consistency was undoubtedly due to the action of the plasticizing agent which is said to break up the agglomeration of

cement particles. Although the mix was homogeneous and free from segregation, it was difficult to finish because of its rubbery texture. The coarse aggregate content could probably have been increased, although the mix was not as workable as one containing a portland-natural cement blend.

The proportions of materials used in the standard and pozzolithic mixes are given in Table I, while Table II shows the compressive strengths at 7 and 28 days of concrete cylinders made from the two mixes. Table I indicates that the water-cement ratio was decreased in the pozzolanic mix. The decrease was believed caused by the action of the plasticizing agent. Table II reveals that the concrete cylinders made of pozzolithic admixtures had higher compressive strengths, both at 7 and 28 days, than those made with the regular mix.

TABLE I

	Type of Mix		
	Standard	Pozzolith	Standard
Station	30+80 - 39+73	39+73 - 40+23	40+23 - 43+84
Proportion by weight	1:2.40:4.32	1:2.40:4.32	1:2.40:4.32
Weights per sack Cement			
Gravel	406.5	406.5	406.5
Sand	224	224	224
Water	41.0	34.0	41.0
Weight per cu. yd. of Concrete			
Gravel	2236	2236	2236
Sand	1232	1232	1232
Water	225	187	225
Portland cement	517	517	517
Pozzolith	0	11	0
W/C	.657	.545	.657
b/bo	.80	.80	.80
a/c	2.83	2.83	2.83
Slump, inches	1-3/4	1-3/8	1-3/4

TABLE II

Compressive Strength

Regular		Pozzolith	
7 day	28 day	7 day	28 day
3580	4495	4145	5745
3250	4625	4345	5890
4200	4440	4335	5750
3875		4065	
3410		3970	
3960		3875	
3070	4325		
3620	4180		
4170	3310		
2775			
3510			
2905			
Average 3527	4229	4123	5795

Excerpts from Highway Research Report 78
E. A. Finney, December 10, 1945

In the attempt to eliminate scaling from concrete pavements, several construction features were considered in the Muskegon project. These features are described below:

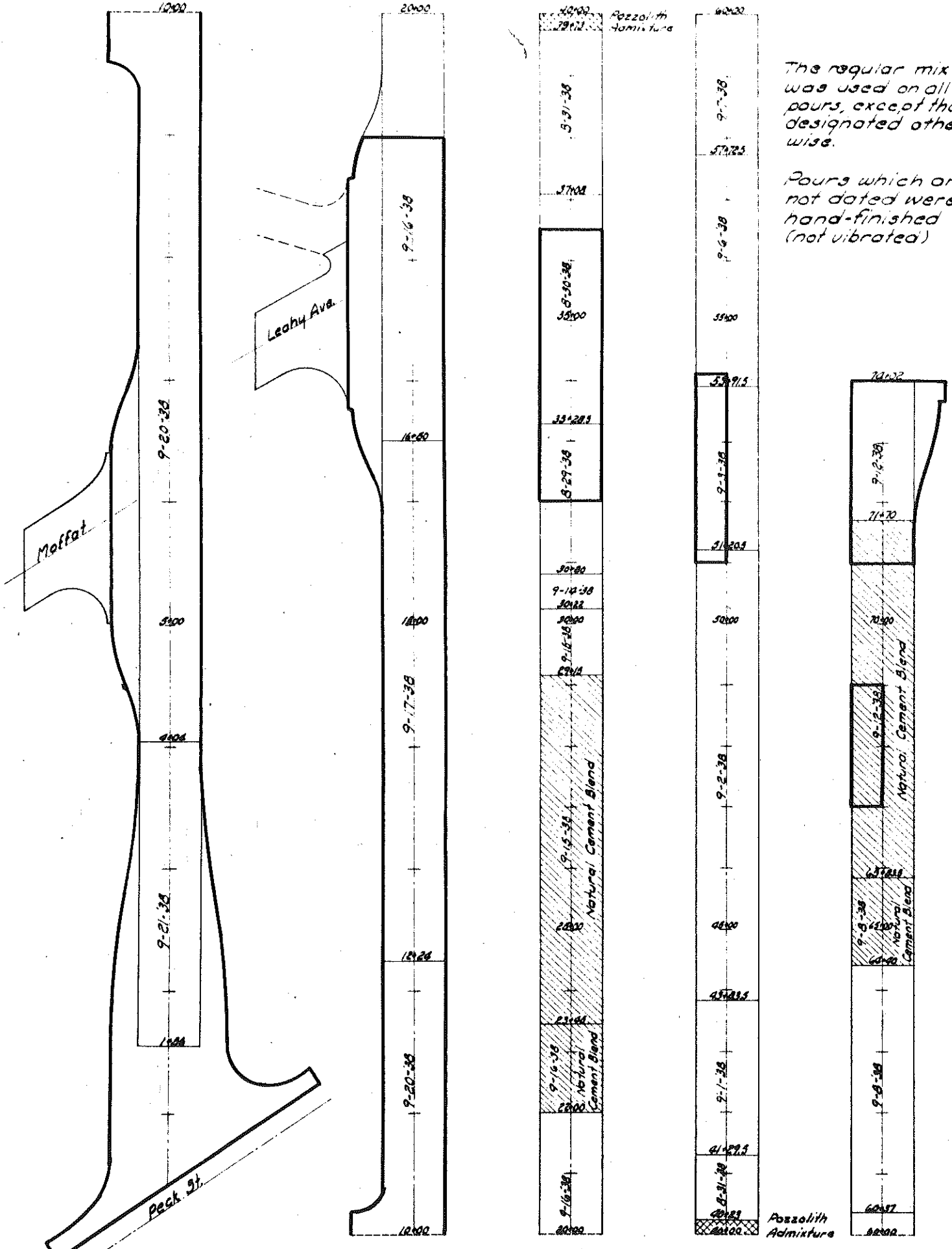
1. The application of a bituminous membrane material to the surface for the purpose of curing and, at the same time, sealing the surface against penetration of chloride salt solutions which influence scaling.
2. The use of proprietary admixtures such as Pozzolith to produce a more durable concrete pavement.
3. The blending of natural cement with portland cement to reduce surface laitance and, consequently, scaling.
4. By brooming the surface to remove the excess mortar and laitance coat which forms on the surface of the pavement due to manipulation of the fresh concrete.

The results from the recent condition survey of the Muskegon project, as shown in Figures 2 and 3, as well as the results from other subsequent experimental work conducted by the Department and embodying the same features, clearly indicate that none of the methods outlined above will prevent scaling of concrete pavements.

In Figures 1 amd 2 it may be observed that considerable scaling has occurred on both lanes between Stations 0+00 and 19+00, and from 31+00 to 36+50; on the east lane only between Stations 51+00 and 54+00 and from 66+00 to 68+00; and again over both lanes from Station 71+00 to the end of the project at Getty Avenue. The worst scaling has occurred between Peck Street and Leahy Avenue, Stations 0+00 to 19+00. This is probably due to the fact that frequent and heavy chloride-sand applications are necessary

because of the many intersections in that particular area. The same condition prevails at the Getty Avenue end of the project. Scaling in the other areas was observed to be sporadic and of no serious consequence at the present time. No scaling was noted on the area containing Pozzolith but that test section is so short that it is of no value in establishing a criterion in this respect and, therefore, must be discounted. The use of bituminous membranes, as well as the brooming process did not prevent scaling of concrete pavement surfaces.

VIBRATED CONCRETE POURS 61-27



The regular mix was used on all pours, except of those designated otherwise.

Pours which are not dated were hand-finished (not vibrated)

Figure 1

METHODS OF CURING AND FINAL FINISHING 61-27

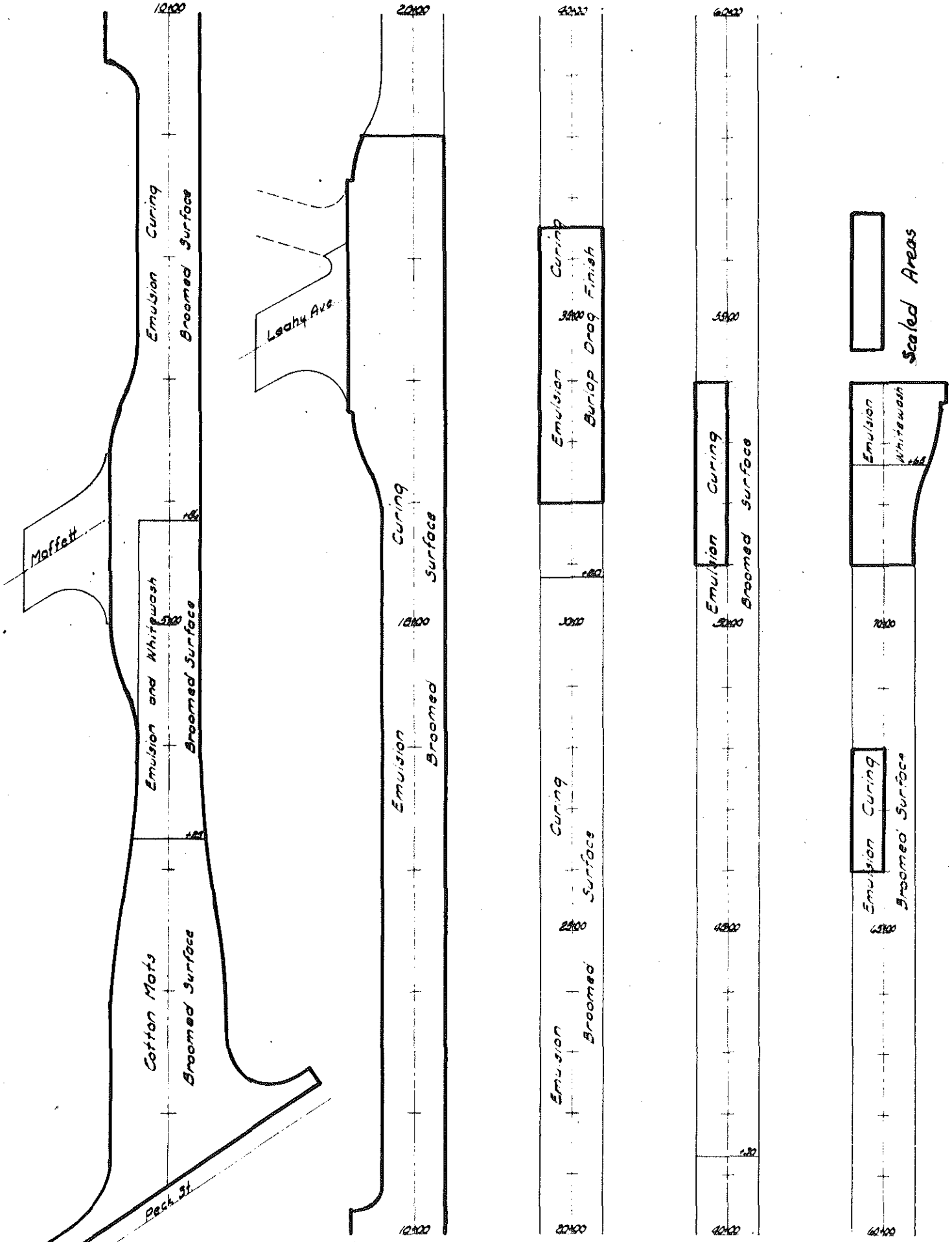
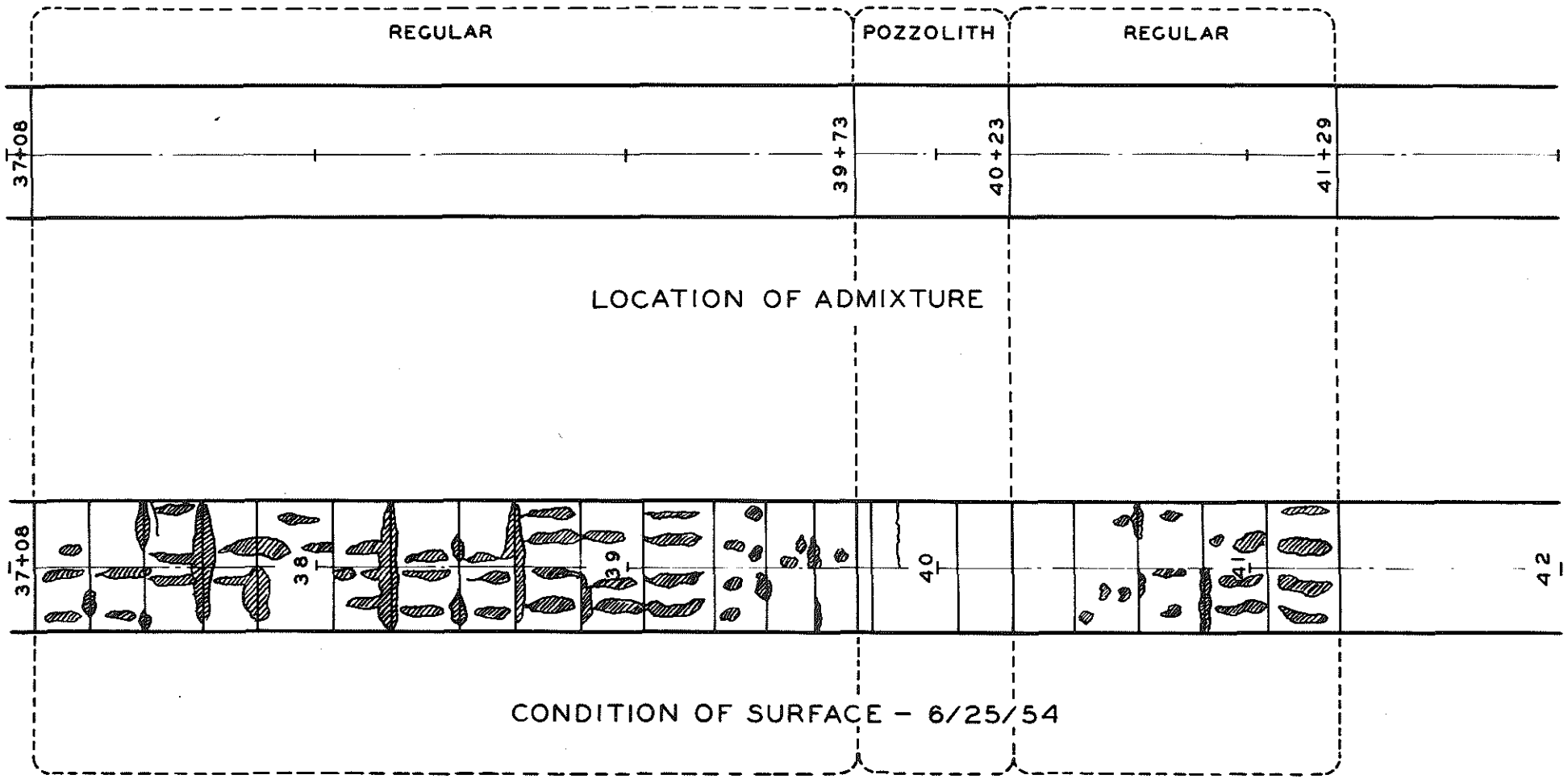


Figure 2

Condition Survey by Arthur A. Smith, June 25, 1954

On June 25, 1954, a second condition survey was carried out. Again, the section containing Pozzolith was found to be free of scaling. The sections constructed of regular concrete showed even more severe scaling than in 1945. Figure 1, a condition survey drawing, shows the difference in the condition of pavement made from the two types of concrete. The results of these condition surveys indicate clearly that Pozzolith effectively controls concrete pavement scaling, even on pavement subjected to calcium chloride treatments for the removal of snow and ice.



COMPARISON OF THE CONDITION OF PAVEMENT SECTIONS
CONSTRUCTED WITH AND WITHOUT POZZOLITH ADMIXTURE
PROJECT M 61-27, C5, MUSKEGAN

FIGURE 1

THE MICHIGAN TEST ROAD EXPERIMENTAL PROJECT
F 18-20, C3 and C4 and F 67-27, C6

Contents

SYNOPSIS

The above material includes the results of various laboratory and field tests conducted on plain concrete and concrete containing anti-scaling proprietary admixtures (Orvus, Vinsol Resin, Pozzolith, and Plastiment) which was used in the Michigan Test Road Durability Project. Also included are the results of a condition survey conducted in 1954 by Arthur A. Smith. These tests show that Orvus, Vinsol Resin, and Pozzolith markedly reduce scaling and deterioration, with the first two being especially effective. Cores taken from concrete containing admixtures were found to resist freezing and thawing deterioration equally well at the top and bottom of the core, whereas ordinary concrete proved much weaker at the top than at the bottom. Compressive and flexural strength tests showed that the standard concrete was appreciably stronger at 28 days than concretes containing Orvus, Vinsol Resin, or Pozzolith, but weaker than concrete containing Plastiment. The condition survey reveals an average scaling of 3.1 percent on the plain concrete section; and 0.02, 0.07, 0.01, and 0.40 percent, respectively, for the sections containing Orvus, Vinsol Resin, Pozzolith, and Plastiment.

Excerpts from Highway Research Reports
P-51; P-52; P-58; 18; and 21; and Report Entitled
"The Michigan Test Road"

In May, 1940, the administration of the Michigan State Highway Department, realizing the need for a comprehensive evaluation of modern theories of design and construction practice of concrete pavements, decided to let contracts for the construction of an experimental concrete pavement to be located on M-115 between US-10 and M-66, in Clare and Osceola counties. The test road is divided into two test sections. One section, 10.1 miles in length, is devoted to a study of the many principles and factors incidental to design and construction. The remaining 7.7 mile section is utilized for a study of durability factors.

As part of the durability project, several sections of the pavement were constructed using concrete containing various additives and admixtures in order to check their ability to prevent the pavement from scaling.

The admistures used and the location within the durability project of the concrete sections containing them are presented in Table I.

TABLE I

Admixture	Quantity (lb/s.c.)	Station Beginning	Station Ending	Length in feet
Pozzolith	2	416+09	428+80	1271
Plastiment	1	440+10	452+10	1200
Orvus	0.015	464+10	476+10	1200
Orvus	0.015	488+10	499+55	1145
Vinsol Resin	0.0375	511+83	536+65	2482
Vinsol Resin	0.0375	548+00	572+58	2458

The workability of the concrete containing Pozzolith was fair to poor, bleeding was noticiable, and at an air temperature of 50°F, 18 hours of setting time was required before the forms could be removed. This concrete finished poorly. Plastiment produced similar results, except that the workability and finishing of concrete containing it were fair.

The workability and finishing qualities of concrete containing Vinsol Resin varied from fair to good, depending upon the weather conditions. High temperatures tended to produce a sticky concrete having a cohesiveness unlike standard concrete. Puddling, straightedging, and floating of the concrete became more difficult, and although the floats were steel shod, the difficulties were not entirely overcome. Bleeding was noticeable at times, but the concrete was entirely free of laitance or segregation of the constituents. The workers soon became familiar with the idiosyncrasies of concrete containing Vinsol Resin and modified their handling methods so as to overcome these difficulites. Once this had been done, Vinsol Resin Concrete proved quite satisfactory as a paving material. Concrete containing Orvus was very similar to Vinsol Resin concrete, except that its workability and finishing qualities were better and it bled less.

To determine the effectiveness of the various admixtures in resisting the action of calcium chloride upon concrete, accelerated freezing and thawing tests were conducted on 3 by 12 feet test panels located along the outside edge of the pavement slab. Two methods of testing were used. In the first, the panel was flooded with water which was allowed to freeze overnight. The next morning the ice was decomposed by distributing 5 pounds of calcium chloride over the test panel, the panel flushed, reflooded, and the cycle repeated. The second method of test consisted of applying a 10% calcium chloride solution to the surface of a panel and permitting it to remain in place for five days. Following this period the solution was removed, the panel flushed, and clear water applied for a freezing cycle over the weekend, after which the calcium chloride cycle was repeated. Table II presents the results of these tests. It can be seen that Pozzolith was very effective in reducing scaling - almost as effective in fact, as the air-entraining agents, and conderably more so than Plastiment.

TABLE II

Admixture	Cycles	Scale, Percent	Degree of* Scaling
Orvus	93	0	0.0
Vinsol Resin	93	0	0.0
Pozzolith	93	6	0.1
Plastiment	61	56	0.9
None (average of 5 test areas)	—	—	8.4

Degree of Scaling = $\frac{\text{percent scale}}{\text{No. of cycles}}$

Supplementing the field tests, laboratory freezing and thawing tests were conducted on core samples taken from the pavement and on beams and cylinders molded on the project during construction.

Each core was cut transversely into three sections approximately 2 inches thick representing the top, middle, and bottom portions of the pavement. The top and bottom sections were further divided into two equal segments. One segment from the top and bottom of each core was reserved for freezing and thawing in a 10 percent solution of calcium chloride, while the remaining segments were frozen and thawed in water for comparison purposes. The middle sections were not tested. At the time of test, the cores were 21 months old.

Samples were usually examined at the end of each five cycles for evidence of scaling and failure of bond between mortar and aggregate. The specimens were also struck lightly with a hammer and the sound or ring noted. Tests were continued until concrete had completely disintegrated or specimens could be easily broken by being tapped lightly with a hammer. The results of these tests are presented in Table III. Two interesting facts may be observed from this data. In the first place, the cores taken from air-entraining concrete show considerably greater resistance to freezing and thawing action than those from ordinary concrete; and, second, the air-entraining concrete resists deterioration equally at top and bottom of the core, whereas ordinary concrete is considerably weaker at the top than at the bottom.

TABLE III

Admixture	CYCLES FOR COMPLETE DISINTEGRATION: 10% Calcium Chloride Top	10% Calcium Chloride Bottom	10% Calcium Chloride %Var.	Water Top	Water Bottom	Water % Var.
Orvus	140	206	-32	205	205	0
Orvus	55	130	-58	110	200	-45
Vinsol Resin	145	186	-22	175	170	+3
Vinsol Resin	185	165	+13	200	200	0
Vinsol Resin	130	165	-21	205	200	+3
Vinsol Resin	130	145	-10	215	200	+8
Pozzolith	186	176	+6	200	155	+29
Plastiment	60	65	-8	135	190	-29
Plastiment	95	55	+73	135	135	+0
Standard	45	65	-31	120	135	-11
Standard	35	78	-55	120	195	-38
Standard	50	35	+43	80	110	-37
Standard	45	70	-36	70	135	-48

The cylinders used in laboratory freezing and thawing tests were 4 inches in diameter and 16 inches long, while the beams were 3 inches thick, 6 inches wide, and 15 inches long. These specimens were subsequently subjected to a freezing and thawing cycle in the laboratory, being frozen at -20± 2°F and thawed in water at 70-80°F. Each cycle was approximately 24 hours in length.

After every five cycles, specimens were tested for fundamental frequently by the sonic, or dynamic, method of determining modulus of elasticity. Freezing and thawing was continued until deterioriation had progressed to a predetermined value of the fundamental frequency or to a definite percent drop in the modulus of elasticity. The results of these tests, summarized in Table IV, show that the durability of the Pozzolith mixture was excellent.

TABLE IV

Admixture	5-month-old beams* Cycles to 50% reduction	5-month-old beams* Cycles to Complete failure	1- year-old beams Cycles to 50% reduction	1- year-old beams Cycles to Complete Failure
Orvus	43	80	40	90
Vinsol Resin	45	80	--	--
Pozzolith	43	93	38	150
Plastiment	25	48	15	90
None	30	60	20	85

* The cylinders proved unsatisfactory for freezing and thawing studies, and were excluded from the tests.

For each type of concrete mixture, 6 by 12 inch cylinders and 6 by 8 by 24 inch beams were prepared for 7 and 28 days compression and flexural tests, respectively. The results of these tests, presented in Table V, show that the compressive and flexural strengths of concrete containing Pozzolith were somewhat lower at 28 days than those of the plain concrete. Pozzolith strengths were appreciably higher than those of the air-entraining concretes at both ages, but lower than the strengths of Plastiment.

TABLE V

Admixture	Compressive Strength		Flexural Strength	
	7 days Psi	28 days Psi	7 days Psi	28 days Psi
Orvus	2608	3728	389	562
Vinsol Resin	2845	3867	508	529
Pozzolith	4000	4249	538	617
Plastiment	4655	6080	465	807
None	3543	4587	567	702

As a check upon the results obtained by running compression tests upon molded cylinders, 6-inch concrete pavement cores were obtained and tested in a similar manner. These tests, summarized in Table VI, show that concrete containing Pozzolith is again appreciably stronger than the air-entraining concretes but not as strong as either standard concrete or Plastiment admixture concrete.

TABLE VI

Admixture	Compressive strength (20 months) Psi
Orvus	3962
Vinsol Resin	4010
Pozzolith	4730
Plastiment	6320
None	5375

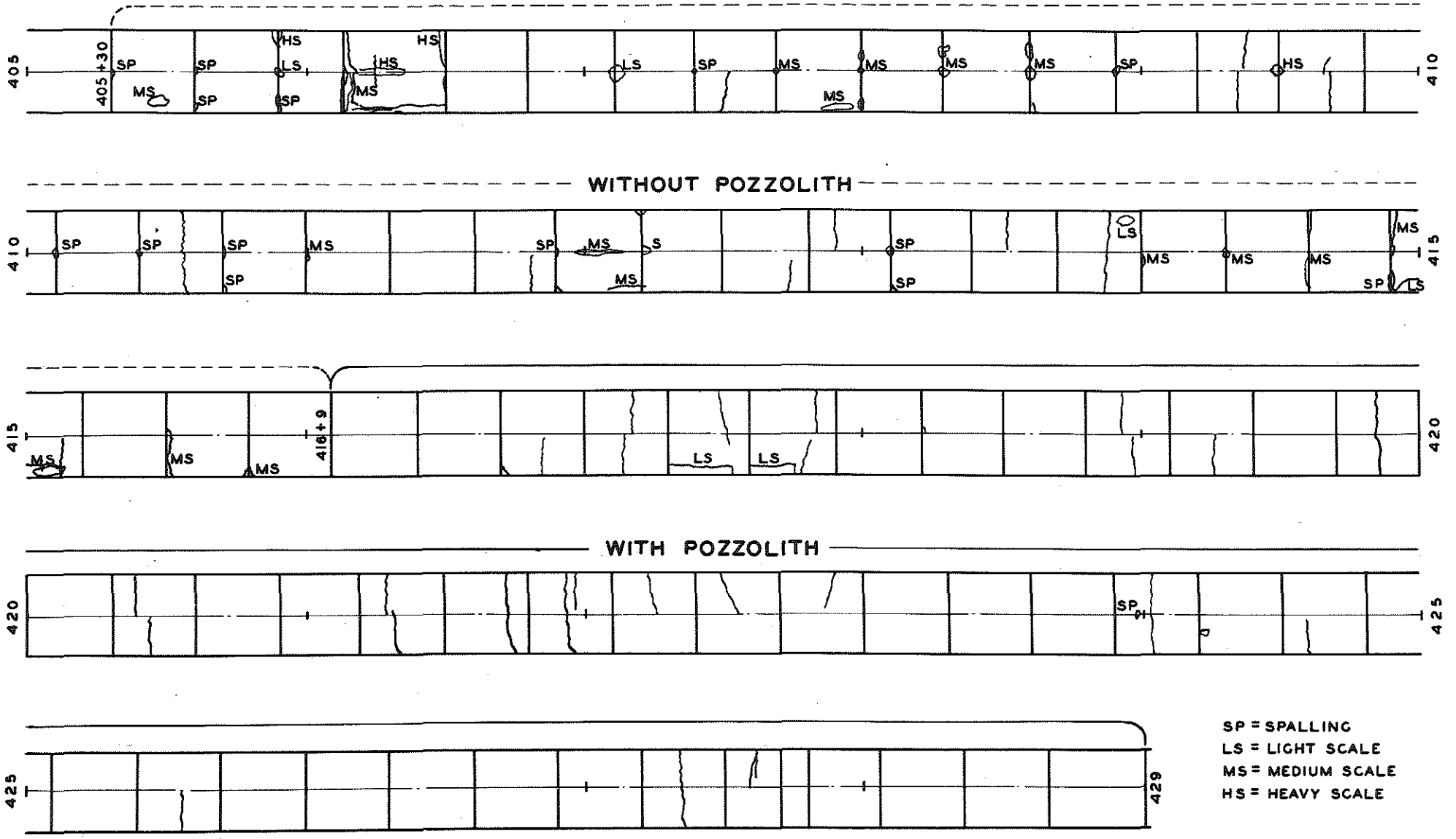
Condition Survey by A. Smith, April, 1954

The most recent condition survey of the Michigan Test Road Durability Test Section was carried out in April, 1954, by Arthur A. Smith. The purpose of this survey was to note any new cracking which had occurred since the January, 1950, survey and to evaluate the percentage of scale per pavement slab. Table I gives the results of this evaluation. Figure 1, a condition survey drawing, compares the section containing Pozzolith and a typical section constructed without admixtures, while Figure 2 shows the surface condition of the Pozzolith section.

TABLE I

Admixture	Percent of Scaling
Orvus	0.02
Vinsol Resin	0.07
Pozzolith	0.01
Plastiment	0.40
None (average of 15 sections)	3.10

The percentage of scaling on the individual sections constructed without the use of admixtures ranged from a low of 0.59 percent to a high of 7.7 percent. Eleven of the sections showed 1.9 percent or more of scaling. In addition, one section, not used in the above comparison, had about 70 percent scaling. These figures show clearly that Orvus, Vinsol Resin, and Pozzolith are very effective in preventing concrete pavement scaling.



COMPARISON OF THE CONDITION OF PAVEMENT SECTIONS CONSTRUCTED WITH AND WITHOUT POZZOLITH ADMIXTURE

MICHIGAN TEST ROAD-DURABILITY SECTION

FIGURE 1

Figure 2. General view of durability project section containing Pozzolith. Taken at middle of section looking south. Note absence of scaling.

THE BELLEVILLE EXPERIMENTAL PROJECT
PROJECT M 82-110, C1 BETWEEN BELLEVILLE AND US-112

Contents

SYNOPSIS

The above material includes paving mixture and construction information for the Belleville project, flexural and compressive strength, sonic modulus, and time of set data, and the results of two condition surveys. The HP-7 mixes were harsh, somewhat hard to finish, and showed considerable bleeding; Vinsol Resin mixes tended to be wet, finished satisfactorily, but showed some bleeding later. Flexural and compressive strengths, were increased by HP-7 and by a combination of Vinsol Resin plus one pound of calcium chloride per sack of cement, but decreased by other Vinsol Resin admixtures; moduli were decreased by all Vinsol Resin admixtures but increased slightly by HP-7. Vinsol Resin decreased markedly the setting time of concrete, while HP-7 increased it somewhat. Condition surveys showed all sections of the pavement, including those constructed without admixtures, to be free of scaling and in generally excellent condition.

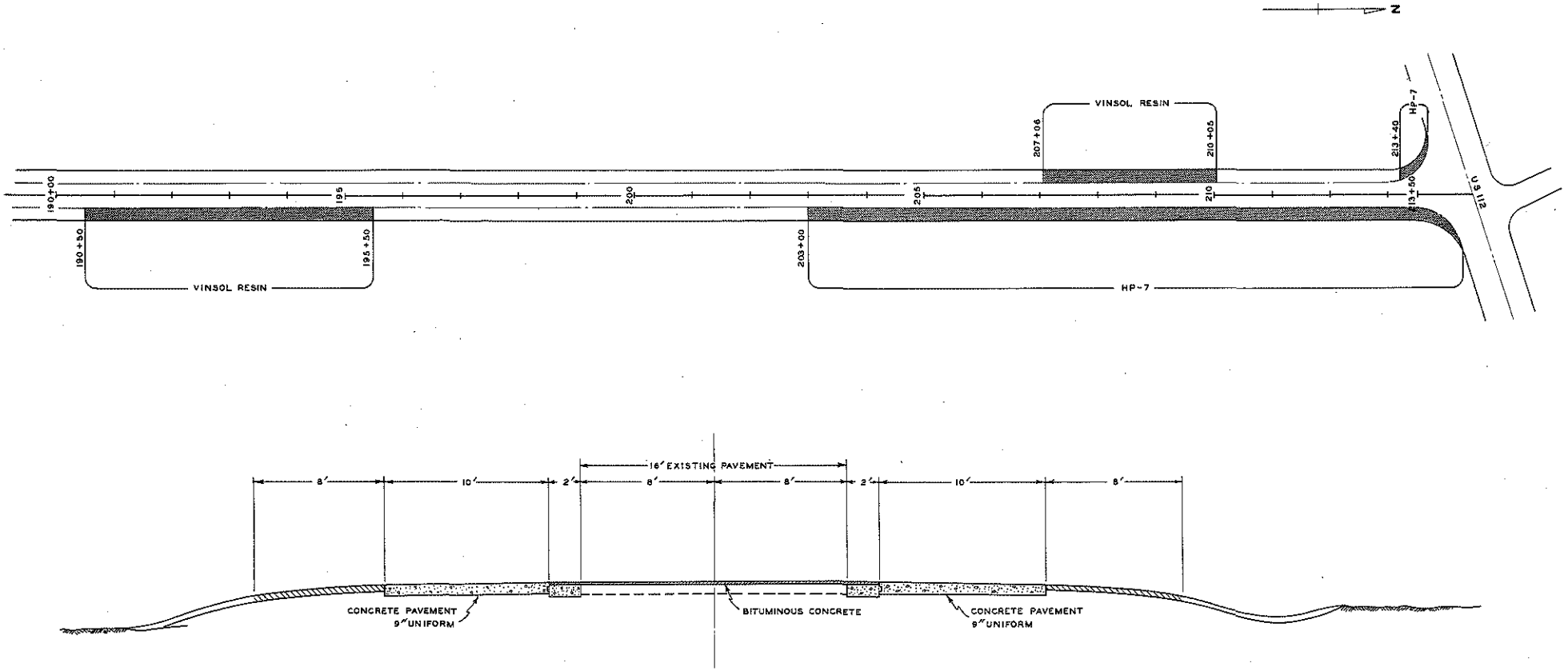
Excerpts from Engineer's Field Reports

Construction Project M 82-110, C1 is located in Wayne County between the town of Belleville and US-112. Paving operations were carried out in late 1942 by A. J. Rehmus of Bay City, using fine and coarse aggregates supplied by the American Aggregates Corporation of Green Oak, and Petoskey Portland Cement. The construction consisted of two 10-foot wide concrete lanes on either side of an already existing 16-foot concrete pavement that had been widened to 20 feet and resurfaced with bituminous material. See Figure 1 for a cross-sectional view of the roadway.

The new lanes were of 9-inch uniform non-reinforced concrete with 1-inch wide expansion joints at 120-foot intervals. These joints were constructed without load-transfer devices. In order to divide the pavement slabs into shorter lengths, dummy joints were located at 20-foot intervals between the expansion joints.

Designated sections of the project were constructed with concrete containing HP-7 or Vinsol Resin and varying amounts of calcium chloride as admixtures. There are seven Vinsol Resin test sections. The first, (V-1) running from Station 207 + 06 to 208 + 05 in the left lane (L) of the new construction, contains 0.375 pounds of Vinsol Resin per barrel of cement and two pounds of calcium choloride per sack of cement. In the second section (V-2), located between Stations 208 + 05 and 209 + 05 L, the calcium chloride content has been reduced to one pound for each sack of cement, while the third section (V-3), between Stations 209 + 05 and 210 + 05 L, omits the calcium chloride entirely.

Sections V-4 through V-7 are located in the right hand lane of the new construction. The first of these, located between Stations 194 + 50 and 195 + 50 R, is a control section. The other three, extending from Station 190 + 50 to 194 + 50 R, contain concrete identical in composition



FINISHED SECTION SHOWING RELATION OF WIDENING TO EXISTING PAVEMENT WITH CAPPING

TO APPLY FROM STATION 132+93 TO 163+31 AND FROM STATION 186+80 TO 213+00

MAP SHOWING
LOCATION OF EXPERIMENTAL SECTIONS CONTAINING VINSOL RESIN AND POZZOLITH HP-7
ON M-56 BETWEEN ECORSE ROAD AND US-112

CONSTRUCTION PROJECT M 82-110

FIGURE 1

to that used in Sections V-1, V-2, and V-3.

There are three HP-7 test sections, located between Stations 213 + 40 and 213 + 99.8 L (the end of the project) and between 203 + 00 and 213 + 99.8 R. The concrete in each of these sections contained one pound of HP-7 per sack of cement and no calcium chloride. Table I presents concrete design information for each test section while Figure 1 shows the location of the sections within the paving project.

In consistency, the mixes containing HP-7 were harsh, somewhat hard to finish, and showed considerable bleeding. The concrete without Vinsol Resin or HP-7 was also somewhat harsh, but not hard to finish. There was some bleeding but this was probably due to excess water in the mix. In contrast, the Vinsol Resin admixtures tended to be wet, the wetness increasing with increases in calcium chloride content. All of these mixes finished satisfactorily but showed some bleeding later.

Beams and cylinders for flexural and compressive strength tests, and sonic beams for sonic modulus and freezing and thawing tests, were made from each of the concrete mixes used in the test sections. In addition, time-of-set determinations were carried out on each mix, using the Burggraf method.

Table II Summarizes the results of flexural and compressive strength tests and Table III the results of sonic modulus tests. These results show clearly that flexural and compressive strength are increased by HP-7 and with one exception decreased by Vinsol Resin. This exception occurs with the concrete containing one pound of calcium chloride per sack of cement, which has higher compressive and flexural strengths than standard concrete. Sonic Moduli were decreased by all Vinsol Resin admixtures but increased slightly by HP-7.

The results obtained in the time-of-set determinations are presented graphically in Figure 2. It can be seen that Vinsol Resin decreases

TABLE I

DESIGN INFORMATION FOR CONCRETE USED IN VINSOL RESIN AND HP-7 TEST SECTIONS

Series	Station	Design Proportions of Materials per sack of cement: Fine Aggregate	Coarse Aggregate	Water	Admixtures	Slump, inches	Weight per cu. ft.
V-1	207+06 to 208+05 L	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl cement. 2 lb. $CaCl_2$/sack of cement	3	
V-2	208+05 to 209+05 L	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl cement 1 lb. $CaCl_2$/sack of cement	2-1/4	
V-3	209+05 to 210+05 L	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl cement No $CaCl_2$	2-1/4	
HP-7-1	213+49 to 213+99.8 L	211 lb.	373 lb.	50.6 lb.	1 lb. HP-7 per sack of cement	3-1/2	152.32
HP-7-2	--- 213+99.8 R	211 lb.	373 lb.	50.6 lb.	1 lb. HP-7 per sack of cement	1-3/4	149.43
HP-7-3	203+00 to - R	211 lb.	373 lb.	50.6 lb.	1 lb. HP-7 per sack of cement	2-3/4	149.03
V-4	194+50 to 195+50 R	211 lb.	373 lb.	50.6 lb.	No Vinsol Resin Emulsion or $CaCl_2$	3	152.44
V-5	193+50 to 194+50 R	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl cement No $CaCl_2$	2-1/2	146.43
V-6	191+00 to 193+50 R	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl. cement 1 lb. $CaCl_2$ per sack cement	2-1/2	146.50
V-7	190+50 to 191+00 R	211 lb.	373 lb.	50.6 lb.	0.375 lb. V.R.E./bbl. cement 2 lb. $CaCl_2$ per sack cement.	3	144.98

TABLE II

FLEXURAL AND COMPRESSIVE STRENGTHS OF BEAMS AND CYLINDERS MADE FROM CONCRETE CONTAINING VINSOL RESIN AND HP-7

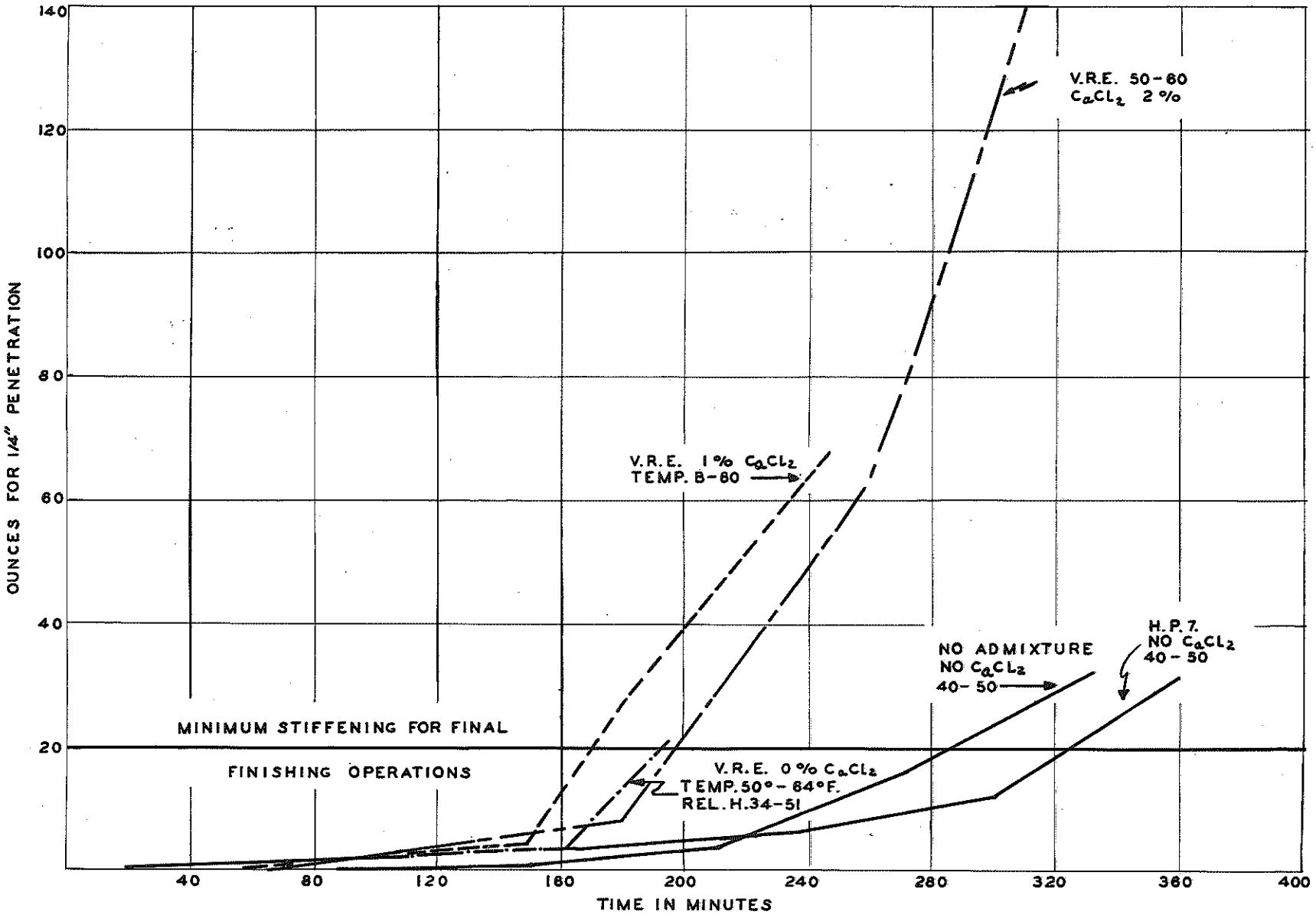
Admixture	STRENGTH			
	Flexural		Compressive	
	7 day	28 day	7 day	28 day
HP-7	550	633	2583	4127
Vinsol Resin:				
No. Calcium Chloride	335	504	1693	2988
1# $CaCl_2$/ sack cement	401	622	2260	3641
2# $CaCl_2$/ sack cement	330	516	1800	2433
Average	361	547	1917	3021
No Admixture	431	536	2348	3532

TABLE III

Sonic Modulus Tests
on Beams Made From Concrete
Containing Vinsol Resin and HP-7

Series	Weight (gms)	Measured December, 49 Sonic (cps)	Modulus (10^6 psi)	Measured June, 1954 Sonic (cps)	Modulus (10^6 psi)
V-1	10,477	2043	4.37	2088	4.57
V-2	10,791	2138	4.81	2200	5.23
V-3	10,473	2080	4.48	2110	4.66
V-4	10,397	2315	5.87	2360	5.57
V-5	10,655	2025	4.37	2075	4.59
V-6	11,129	2193	5.11	2285	5.81
V-7	10,595	2058	4.49	2100	4.68
HP-7-1	11,299	2325	6.11	2458	6.83
HP-7-2	11,717	2384	6.54	2455	7.01
HP-7-3	10,886	2188	5.21	2273	5.62
Average Vinsol Resin 2 lb. $CaCl_2$/ sack cement	------	2051	4.43	2094	4.62
1 lb. $CaCl_2$/ sack cement	------	2166	4.96	2243	5.52
0 lb. $CaCl_2$/ sack cement	------	2053	4.43	2093	4.62
Average HP-7	------	2299	5.95	2396	6.48
Average No Admixture	------	2315	5.87	2360	5.57

markedly the setting time of concrete, while HP-7 admixture increases it somewhat.



TIME OF SET DETERMINATION RESULTS
H P-7 AND VINSOL RESIN EXPERIMENTAL PROJECT, BELLEVILLE

FIGURE 2

Report by Roy Fulton, April 11, 1952

Mr. A. Hagenbuch made a survey of this project on April 9, 1952, and found no scaling on this project. He said very little cracking had occurred and the project as a whole was in very good shape.

Condition Survey by A. A. Smith and L. Kiwala, June 24, 1954

A condition survey made June 24 by A. A. Smith and L. Kiwala showed the roadway to be free of scaling throughout the entire length of the project. Because of the generally excellent condition of the pavement, no conclusions can be drawn from this project regarding the effectiveness of HP-7 and Vinsol Resin as scale preventatives. In time, however, differences may develop in the condition of the concrete pavement sections. If this occurs, evaluation of the admixtures will then be possible.

THE ROGERS CITY EXPERIMENTAL PROJECT
US-23 - PROJECT F 71-24, C1

Contents

SYNOPSIS

The above material includes design and construction details for the Rogers City project and the results of modulus of rupture tests on beams made from the several concrete mixes. The results of condition surveys, skidding tests, air content of concrete, and compressive strength determinations made in 1952 and 1953 are also included. The concrete containing HP-7 proved extremely sticky and difficult to finish. Bleeding was practically absent from all mixes regardless of the HP-7 content or whether the mix was wet or dry. The 7-day modulus of rupture strengths for concrete containing 1 pound of HP-7 per sack of cement averaged slightly higher than the strengths for plain concrete, while the 28-day strengths of all the concretes containing admixtures were lower. These results, however, are open to question becuase of great variations in the strengths of individual beams made from the same mix. The condition surveys showed that scaling and pitting were extensive on the plain concrete sections, but the sections containing HP-7 were in excellent physical shape. The skidding factor was found to be 0.38 - under the minimum value recommended by the AASHO. The air content of the plain concrete averaged 2.21 percent and that of the HP-7 concrete 5.9 percent. The average compressive strength of the plain concrete was 5037 psi. as compared to 4410 psi. for the concrete containing HP-7.

Undated report by Donald R. MacPherson, Master Builders Company

All concrete with same consistency

Type of Mix	Aver. Cement Factor Sks. per Cu. Yd.	Av. Mix Proportions per Sack of Cement: Fine Agg. lbs.	1" 4 A Agg. lbs.	2½" 10 A Agg. lbs.	Ave. W/C Gal. per Sack	Aver. Unit Weight p.c.f.	Aver. Ratio Sand to Total Agg.	Av. Modulus of Rupture of 6x8x36-in. beams: 7 days	28 days
Plain	5.5	219.5	162.5	162.5	5.76	144.8	40.4	630*	685*
HP-7	5.0	234.5	183.7	183.8	5.99	141.1	38.9	620	685
HP-7	5.0	234.5	183.7	183.8	6.04	141.0	38.9	615	645
HP-7	5.0	234.5	183.7	183.8	5.43	———	38.9	625	750
HP-7	5.0	234.5	183.7	183.8	5.65	———	38.9	660	655
			Aver. HP-7 Mixes		5.76	141.1	38.9	630	685
HP-7	5.5	219.5	162.5	162.5	5.13	140.8	40.4		

* Each value the average of 8 tests on 4 beams, one-half of which were poured on different days. All other values the average of 4 tests on 2 beams. Each set of values represents different days pouring operations.

This tabulation shows average values taken from Table I for the plain 5.5 sack mixes and the 4, 1-lb. HP-7 mixes with reduced cement content. The significance of the data in the above tabulation is summarized as follows: -

1. With a 9% reduction is cement, 1/2 sack per cu. yd. in the HP-7 mixes, the average water-cement ratio for both the plain and HP-7 concrete, at equal consistency, is the same. This effect is accomplished principally through the cement dispersing agent.

2. The average 7 and 28-day modulus of rupture values for all 1-lb. HP-7 mixes are equivalent to the corresponding values for the plain mix which contains 1/2 sack cement more per cu. yd. This was accomplished while the unit weight per cu. ft. of the HP-7 concrete was reduced about 3.7 lbs., viz., an increase in air content.

3. The substantial reduction in unit weight or the increase in air-content of the HP-7 mixes is about what could be expected. The amount of entrained air should give marked durability to the HP-7 mixes in freezing and thawing scaling.

4. When 1-lb. of HP-7 was used as a straight addition to the basic 5.5 sack mix, the water-cement ratio was reduced about 11% when equal consistency was maintained.

5. It can be concluded on the basis of the data contained in the above tabulation (obtained on concrete poured under job conditions in the field), that through the use of HP-7 in the amount of 1-lb. per sack of cement, equal flexural strengths can be maintained in concrete mixes which have been designed with 1/2 sack cement per cu. yd. less than corresponding plain mixes, and also the unit weight will be reduced 3-4 p.c.f. while the water-cement ratio is held essentially constant at the same consistency.

In addition to the physical data reported herein, scaling resistance tests on the plain 5.5 sack mix, 1-lb. HP-7 5.0-sack mix, and 1-lb. HP-7 5.5-sack mix are being made at the present time. The specimens being used for this purpose are sections from the broken beams which were cast during paving operations. Therefore, these beam sections represent the actual job concrete. The beam sections are being exposed to alternate freezing with water and thawing with calcium chloride.

REPORT ON EXPERIMENT WITH HP-7 ADMIXTURE
US-23A, ROGERS CITY - PROJECT F 71-24, C1

(Undated report by Roy Fulton)

Project M-71-24, C1, located at Rogers City on M-65 connection to US-23, was selected for experimentation with the admixture designated HP-7.

HP-7 is a powdered chemical compound, manufactured by the Master Builders Company of Cleveland, Ohio, to be used as an admixture in concrete for the purpose of preventing bleeding. Its properties are said to produce both those of cement dispersion as obtained from their product, Pozzolith, and impermeability and workability from a wetting agent such as Orvus. The powder is grayish-brown in color and rather light in weight. Fifty pounds of HP-7 is contained in a bag approximately the size of a regular cement bag. It is claimed the material is not deliquescent. However, the containers used for measuring the powder rapidly became caked and required frequent cleaning.

Approximately 7 tons of the powder were shipped for use on this project. It was used throughout with the exception of about 654 lineal feet of pavement and the intersection at the west end of the job.

Originally, the project was set up for the usual cement content of 5.5 sacks of cement per cubic yard of concrete, but in order to compensate the contractor for the additional time and labor to do the experimental work without increasing the budget for the job, the cement content was reduced to 5.0 sacks.

According to the Master Builders' representative, the savings made possible by the use of HP-7 through a reduced cement content and lower water-cement ratio and an improved quality of concrete would justify the extra cost of the powder. This powder was furnished at $105.00 per ton f.o.b. Cleveland. Shipping charges approximated $11.80 per ton, making a total of $116.80 per ton on the job. At the prescribed rate of application of HP-7, the cost of it per cubic yard of

concrete for 5 sacks of cement (the lowest cement content permitted) per cubic yard would be $0.292. However, the saving in cement is only approximately $0.25 per cubic yard of concrete at current prices. The water-cement ratio for the concrete, using HP-7 and 5 sacks of cement per cubic yard, was actually slightly higher than the regular paving mix without HP-7 and a cement content of 5.5 sacks per cubic yard.

During the process of crew organization, the first 654 feet of pavement were placed, using a regular pavement mix of 5.5 sacks of cement per cubic yard of concrete, relative water content, 1.215 and b/bo of 0.76. The proportions for the remainder of the pavement were modified and adjusted to provide for changes resulting from the use of the admixture.

The cement was obtained from the Petoskey Portland Cement Company and the aggregates (crushed limestone and stone sand) from the Michigan Limestone and Chemical Company. The proportioning plant was located on the Limestone Company premises in close proximity to the plant stock piles and the cement was added near the job from bags. The HP-7 was distributed in its original packages at intervals along the pavement for convenient accessibility by the operator.

The admixture was dumped directly on top of the batch in the skip of the mixer. At first it was weighed for each individual batch but as this proved too slow and inconvenient for rapid production, metal containers were calibrated for the correct amount. Thereafter, the admixture was proportioned by volume. Care was necessary to prevent unequal quantities since the powder tended to compact in the measuring cans if they were jarred or roughly handled. After the operator became accustomed to the work, no particular difficulty was experienced except in keeping the cans clean to provide full measure. A considerable amount of powder was wasted in the dipping process, especially when progress was rapid. Other losses occurred by mishandling and carelessness in other phases of the operations.

During the first 654 feet of pavement, HP-7 was added to a few batches at the recommended rate of 1 pound per sack of cement to establish the probable reduction of water and the approximate reduction in unit weight of concrete. As was expected, without altering the design quantities but adding 1 pound of HP-7 per sack of cement, the mix became quite fluid and allowed reducing the water-cement ratio from 5.95 gallons to 5.13 gallons per sack of cement. At the same time, the actual tested weight dropped from 144.80 pounds to 140.75 pounds per cubic foot of concrete, or a reduction of 4.05 pounds. A second test resulted in a reduction of 4.55 pounds. On the basis of these tests, the design relative water content was changed from 1.215 to 1.15 to give the proper consistency. Also, the fine aggregate was reduced to compensate for the reduction in unit weight of concrete.

Beginning with the continual use of HP-7, the cement content was changed from 5.5 to 5.0 sacks per cubic yard as per agreement. One pound of HP-7 per sack of cement was used throughout the project except during two periods in which the amount was changed to 1-1/4 and 3/4 pounds for comparative purposes. The mix test data are shown in Table I which includes the various constants for the design, the proportions, water-cement ratio, and unit weight tests.

As the tests progressed, it was soon evident that the true reduction in unit weight was much less than the designed amount of 4.5 pounds. Even with an increased amount of HP-7, the reduction was less than 3 pounds. At this point, the proportions were changed to provide for a reduction of two pounds per cubic foot of concrete. The yield more nearly checked the design yield as shown in the second series of tests for mix No. 5 of June 4, in which the theoretical weight was 140.81 pounds per cubic foot and the actual test weight was 141.10 pounds per cubic foot.

For mix No. 7, the fine aggregate was altered from 234 pounds per sack of cement to 236.2 pounds which gives a theoretical weight of 141.22 pounds per

TABLE I

M 71-24 C1

Cement - Petoskey — Sp. Gr. 3.15
Fine Aggregate - Michigan Lime & Chemical Co. — Absorption 2.66% — Sp. Gr. 2.52
Course Aggregate - Michigan Lime & Chemical Co. — Absorption 2.39% — Sp. Gr. 2.52

Date	Mix No.	Chart No.	Cement Content	RWG	b/bo	Station to Station	Unit Wt. of Coarse Agg. lb/cu.ft.	Cement lb/sack	Fine Agg. lb/ Sack	4A lb/ Sack	10A lb/ Sack	Water Comp. lb/sk	Water Actual lb/sk	WC Cal. /Sack
June 2	1	52-11-14A	5.5	1.215	0.76	36+79 30+25	87	94	219.5	162.5	162.5	63.2	63.2	5.95
June 2	2	52-11-14A	5.5	1.215	0.76	31.5 ft. between above stas.	87	94	219.5	162.5	162.5	63.2	56.3 59.0	5.13 5.45
June 3	3	52-11-14A-3	5.0	1.15	0.76	30+25 29+10	86 86 86	94 94 94	254 229.6 229.6	176.2 176.2 176.2	176.3 176.3 176.3	65.9 65.3 65.3	 62.5 66.7	6.08 5.76 6.27
June 3 and June 4	4	52-11-14A-3	5.0	1.15	0.76	29+10 24+90	86 86 86	94 94 94	254 229.6 229.6	176.2 176.2 176.2	176.3 176.3 176.3	65.9 65.3 65.3	 63.7 65.9	6.08 5.91 6.17
June 4	5	52-11-14A-5	5.0	1.15	0.78	24+90 21+90	86 86 87	94 94 94	248 237 234	181.5 181.5 183.7	181.5 181.5 183.8	65.6 65.3 64.9	 65.3 64.9	6.04 6.04 5.99
June 4	6	52-11-14A-5	5.0	1.15	0.78	21+30 20+10	87 87	94 94	248 234	181.5 183.7	181.5 183.8	65.6 64.9	 64.9	6.04 5.99
June 4	7	52-11-14A-5	5.0	1.15	0.78	20+10	87 87	94 94	248 236.2	181.5 183.7	181.5 183.8	65.6 64.9		6.04 5.99

TABLE I Continued

HP-7 lb. per Sack	Theoret. Unit Wt. lb. per Cu. Ft.	Actual Unit Weight of Concrete-lbs. 1	2	3	4	Average	Designed Reduction lb. per Cu. Ft.	Actual Reduction or Increase in Unit Weight lb. per Cu. Ft.
0	142.68	144.7	144.7	145.0		144.80	0	2.12 lb. increase (144.80 - 142.68)
1	141.27	138.6	142.9			140.75	0	1.93 lbs. decrease (142.68- 140.75)
1	141.82	140.9	139.6			140.25	0	2.43 lb. decrease (142.68- 140.25)
	141.93							
1	136.78	141.5	140.2	143.1		141.60	4.5	0.33 lb. decrease (141.93 - 141.60)
1	137.60	142.4	139.6			141.00	4.5	0.93 lb. decrease (141.93 - 141.00)
	141.93							
1 1/4	137.00	139.4	139.3			139.35	4.5	2.58 lb. decrease (141.93 - 139.35)
1 1/4	137.41	138.2	136.0	142.1	140.1	130.10	4.5	2.83 lb. decrease (141.93 139.10)
	142.70							
1	140.61	142.5	143.8	140.9		142.40	2.0	0.30 lb. decrease (142.70 - 142.40)
1	140.61	141.4	141.1	140.8		141.10	2.0	1.60 lb. decrease (142.70 - 141.10)
	142.70							
3/4	140.81	141.2	140.6	142.4	141.1	141.33	2.0	1.37 lb. decrease (142.70 - 141.33)
	142.70							
1	141.22	This mix used toward end of job because it more nearly checks yield obtained in last tests of June 3. (141.10)						

cubic foot of concrete and a close check on the last yield test.

Much difficulty arose in the control of the water at the mixer throughout the project. Due to the schedule of the Michigan Limestone Company, the aggregates were stocked at varying intervals during the progress of the job resulting in very wet aggregates at different times during the day. Whenever this occurred, the batches would come out extremely wet which required an adjustment of water at the mixer. As the aggregates became drier, the water again had to be adjusted. Thus, the fluctuation continued during the life of the pouring operations.

The b/bo factor was increased because there was evidence of over-sandedness in the mix. Due to the high void content of limestone, the mix normally provides a greater volume of mortar than for natural aggregate. Then, when HP-7 is added and the mortar becomes correspondingly more fluid, the excess of mortar becomes highly evident. The finishing machine tended to push and waste mortar over the forms until that adjustment was made.

Final finishing was done by means of a straight edge and a hand float. A 10-foot box float was provided but its weight, coupled with the extreme stickiness of the mixture, made its use very difficult. The finisher complained to the point of refusal upon its use and only a short portion was actually floated with the 10-foot float.

HP-7 was varied from the prescribed amount of 1 pound per sack of cement to 1-1/4 pounds and to 3/4 pounds for purposes of comparison of mixes and for strength tests. Bleeding was practically absent in all mixes regardless of whether the amount of HP-7 was 3/4, 1, or 1-1/4 pounds per sack of cement, or whether the mixes were wet or dry. The weather at the time was warm and dry which also tends to reduce bleeding. Further, the slab was laid on a very sandy subgrade. All of these factors must be considered when arriving at the true merits of the admixture.

Modulus of rupture tests were made on the several mixes, a tabulation of which is shown in Table II. A considerable fluctuation of beam strengths resulted from the several mixes. Part of it may be attributable to the fluctuation in the moisture content of the aggregates, and part may be due to uncertain curing and rough handling, although the uncertain curing occurred only after the age of 7 days, except for Series 10, Table II. The more probable cause may be due to incomplete distribution of the HP-7 in the concrete. The Project Engineer reported that beam series 10 and 11, Table II, were made of concrete of very wet consistency (4-in. to 6-in. slump) for hand finishing which may have permitted a more thorough mix resulting in higher average strengths. All beams were molded by the same inspector to reduce, as far as possible, the personal element in technique.

The following conclusions were reached as a result of observations made during pouring operations:

1. HP-7 powder appears to be slightly deliquescent, judging from the way it quickly coated up the dipping container.
2. The cost of HP-7 powder was slightly more than the savings in the reduction of cement. The difference was $0.042 per cubic yard.
3. The water-cement ratio was higher using HP-7 powder and a reduced cement content than when using regular concrete paving proportions.
4. Proportioning the HP-7 powder by weight was the most accurate method but, due to the rate of progress, it was too time-consuming, making it necessary to proportion by volume.
5. Proportioning by volume induced the following variations:
   a. Rapid measurements resulted in over - and under-quantities.
   b. Jarring or compacting from vigorous handling resulted in varying quantities.
   c. Spillage was prevalent in rapid handling.

TABLE II

Series	Date Molded	HP-7 lb./Sack	Cement Sacks/Cyd.	W/C Cal./Sack	b/bo	7 Day * lb./Sq.In.	28 Day * lb./Sq. In.
1	6-3-42	0	5.5	5.95	0.76	637.5	630+
2	6-3-42	1	5.0	5.76	0.76	750.0	602
3	6-4-42	1 1/4	5.0	5.91	0.78	522.5	604.5
4	6-4-42	1	5.0	5.99	0.78	621.5	683.5
5	6-4-42	3/4	5.0	5.99	0.78	542.5	590.5
6	6-5-42	1	5.0	6.04	0.78	612.5	644 +
7	6-5-42	1	5.0	5.64	0.78	610.5	688.5
8	6-6-42	1	5.0	5.65	0.78	731.0	672
9	6-6-42	1	5.0	5.65	0.78	660.0	653+
10	6-7-42	1	5.0	5.43	0.78	561.0**	707
11	6-7-42	1	5.0	5.43	0.78	625.5***	748
12	6-8-42	0	5.5	5.57	0.78	622.5	743.5

* Each value represents 4 individual breaks unless otherwise indicated.

** Beams poorly cured

*** 6 Day beam

\+ Breaks

d. Material sticking to measuring cans constantly changed proportions.

6. There was inconvenience due to the HP-7 powder being distributed along the pavement ahead of operations, and the material was constantly subject to breakage and loss.

7. The concrete in which HP-7 powder was used developed stickiness that was not evident in regular concrete, making hand floating very difficult.

8. Beam series Nos. 3 and 5, Table II, indicate that deviation from the prescribed quantity of HP-7 may adversely affect strength.

9. The use of HP-7 powder permitted less total water per cubic yard of concrete.

10. The use of HP-7 powder permitted slightly smaller quantity of fine aggregate per cubic yard of concrete for an increased b/bo (.78) and a still smaller quantity for b/bo (.76) and retained good finishing qualities.

11. HP-7 powder prevented bleeding in concrete with all concentrations used on this project.

A further comment on the merits of HP-7 powder as compared with the wetting agent Orvus and Vinsol Resin, which is a grinding aid, may be in order here. Orvus paste is supplied at a cost of from $.25 to $.30 per pound, depending upon whether it is furnished in cartons or in bulk. The paste is diluted to such a quantity that the cost per cubic yard of concrete is $.017 to $.021 for the material. Vinsol Resin ground into the cement may be furnished at no extra cost. Both Orvus and Vinsol Resin are successful in eliminating bleeding. The water-cement ratio is decreased approximately 0.3 gallon per sack of cement from a regular pavement proportioning design and the finishing qualities are good.

Report by Roy Fulton, April 10, 1952

A short survey was made of this project on September 13, 1951, to observe the general condition of the surface with respect to scaling. The admixture HP-7, manufactured by the Master Builders Company, was used to prevent scaling in the concrete in which both fine and coarse aggregates were crushed limestone.

The admixture was used at the rate of one pound per sack of cement throughout, except for one section of no HP-7 and one section each of 3/4 and 1-1/4 lbs. of HP-7.

At the beginning of the job during the process of organizing the crew, a regular paving mix of 5.5 sacks of cement per cubic yard of concrete and no HP-7 was used. This continued from Sta. 36+79 to Sta. 30+25, with the exception of 31.5 feet. Scaling at the rate of 5% to 25% of the surface of individual slabs was noted from Sta. 36+79 to Sta. 30+50. The 31.5-foot section mentioned, in which HP-7 was used, was not identified by station and was not noticed in the inspection.

From Sta. 30+50 east to the end of the project, there was practically no scaling. The cement content of concrete in this area was 5 sacks per cubic yard. HP-7 was used at the rate of 3/4 lbs. per sack from Sta. 20+10 to Sta. 21+30, and 1-1/4 lbs. per sack from Sta. 24+90 to 29+10.

Cracking was not observed in the 1951 survey, but a survey made in 1944 by Mr. E. A. Finney showed corner cracking at Stations 14+00 and 23+50.

Apparently the HP-7 admixture performs well as an air-entraining agent in the amounts used on this project.

In 1942, Project 71-24, C1, located on US-23A in Rogers City, was established as an experimental concrete pavement project containing HP-7, a powdered chemical compound manufactured by the Master Builders Company of Cleveland, Ohio. This project was constructed using both fine and coarse limestone aggregates from the Rogers City Quarry and the HP-7 was added as an admixture to prevent bleeding and subsequent scaling.

The experiment was conducted under the supervision of the Construction Division with Roy Fulton assigned to the project to observe the work. Mr. Fulton has submitted two reports. The first, not dated, covers rather completely all history and construction details. A more recent report by Mr. Fulton, dated April 10, 1952, discloses scaling on the control section between Stations 30+50 and 36+20 in which HP-7 was omitted.

At the request of Mr. W. W. McLaughlin, condition surveys have been made by Messrs. W. C. Broughton and E. A. Finney covering a period between October, 1952 and August, 1953.

In October, 1952 a complete condition survey and skidding tests were made under the supervision of W. C. Broughton. The only scaling to have developed on this project at that time was in the west 600-foot section which contains none of the admixture HP-7. The general condition of the pavement at that time is illustrated in Figure 1.

Skidding tests were made on October 28, 1952 with the following results:

LENGTH OF SKIDDING IN FEET

Station	1	2	3	4	5	6	Average	Factor
4+00	45	44	39	32	29	26	35.83	0.372
21+00	40	32	31	32	36	35	34.33	0.388
							Average	0.38

The average skidding factor was 0.38 which is under the minimum value of 0.40 recommended by AASHO for concrete pavements.

In March, 1953 four cores were taken from the project to check air content and strength of the concrete. Cores were taken from both the treated and untreated concrete pavement. Results are given below:

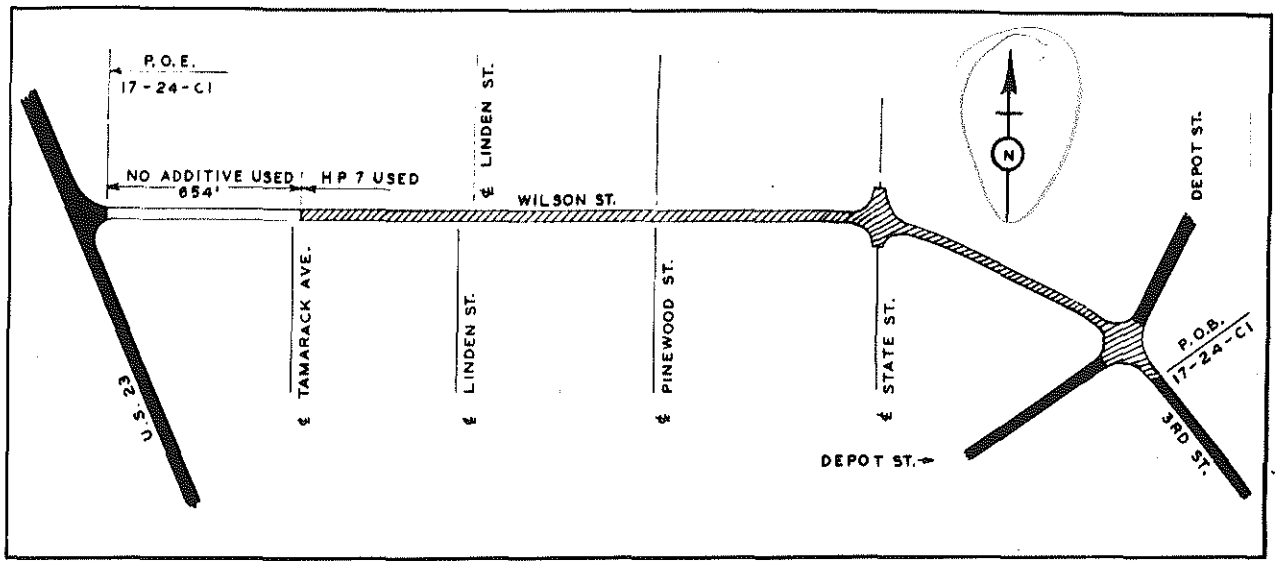
CORE	ADMIXTURE	% AIR	COMPRESSIVE STRENGTH, psi.	
161	HP-7	5.29	5,270)	4410
162	HP-7	6.52	3,570)	
163	Standard	1.55	5,580)	5035
164	Standard	2.87	4,490)	

Core sections from which air-content determinations were made are shown in Figures 2, 3, 4, and 5. Core sections in Figures 2 and 3 contain HP-7. Note size and distribution of air bubbles. Figures 4 and 5 show standard concrete without HP-7. In this case, the air bubbles are few but large and widely dispersed.

On August 9, 1953 pictures were taken of scaled areas by E. A. Finney. These are shown in Figures 6, 7, 8, and 9. Scaling and subsequent deep pitting has become extensive over the west end of this project where HP-7 was not used. The condition of the pavement surface is such that only a regular hot mix asphalt concrete resurfacing course will suffice to do a satisfactory repair job. This work should be done immediately between Sta. 30+20 and 37+00.

The balance of the project is in excellent physical condition. As shown in Figure 1, no scaling has taken place on the HP-7 section and in only a very few instances has cracking been observed.

The project as a whole has the slippery-when-wet characteristics of stone sand concrete as experienced on concrete pavements built with Inland Stone Sand. However, the State Police report that for a least the past three years, there have been no skidding accidents on this project involving wet pavement. The location of the project is in a low speed area, which may account for this fact.



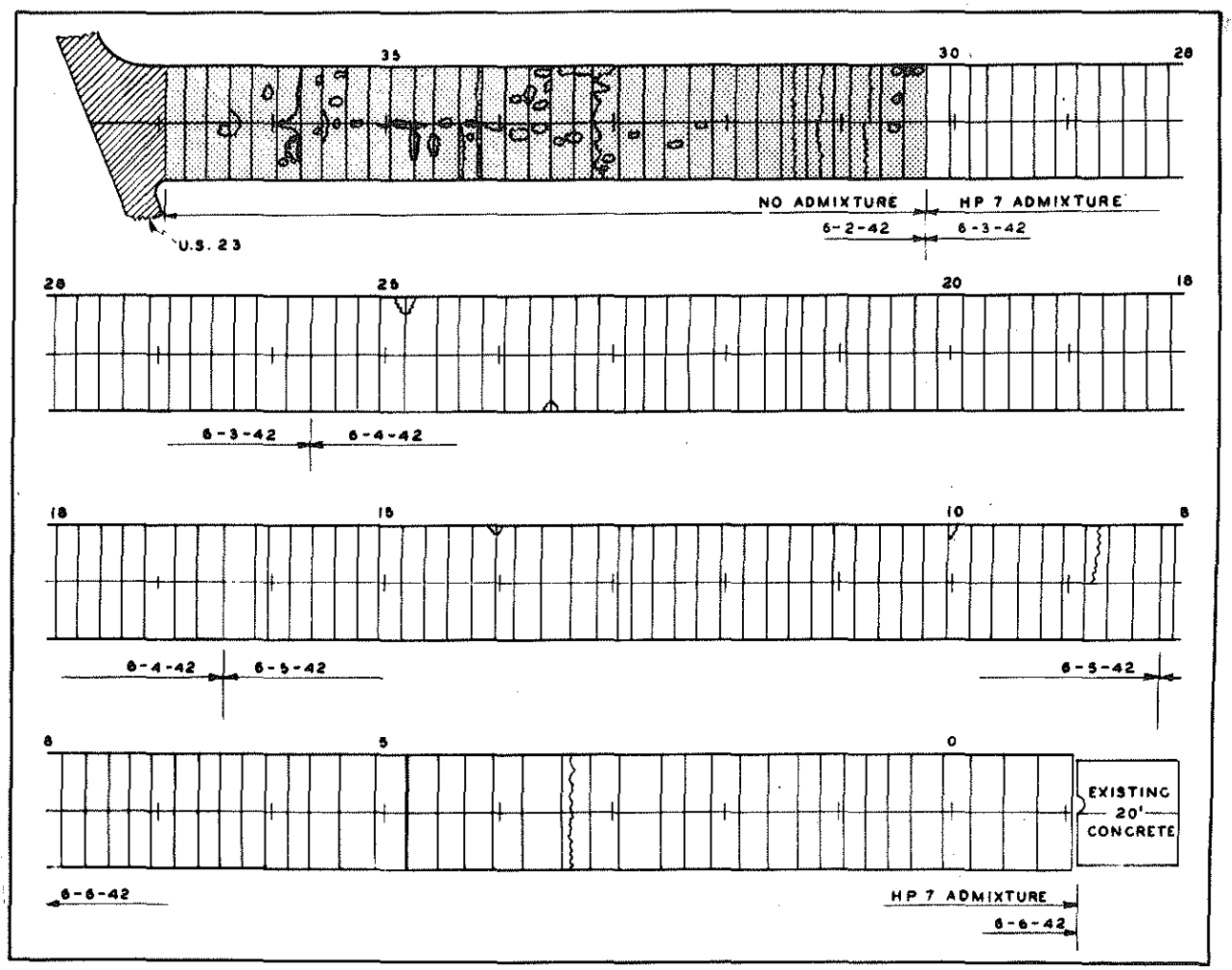


FIGURE 1

LOCATION AND CONDITION SURVEY DATA
HP 7 EXPERIMENTAL PROJECT, ROGERS CITY

Figure 2, Core 161, Containing HP-7

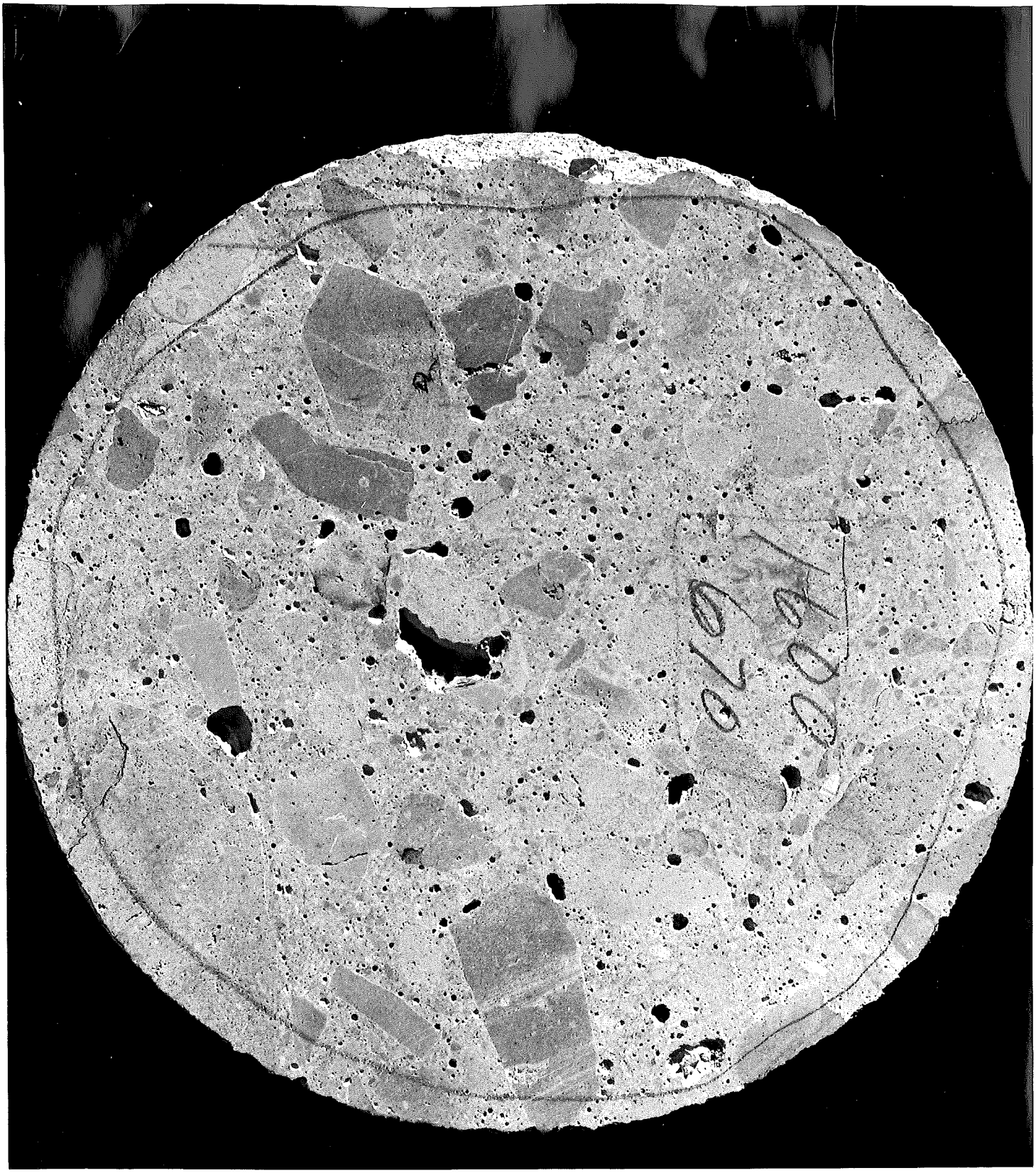


Figure 3, Core 162, Containing HP-7

Figure 4 ,Core 163, Without HP-7

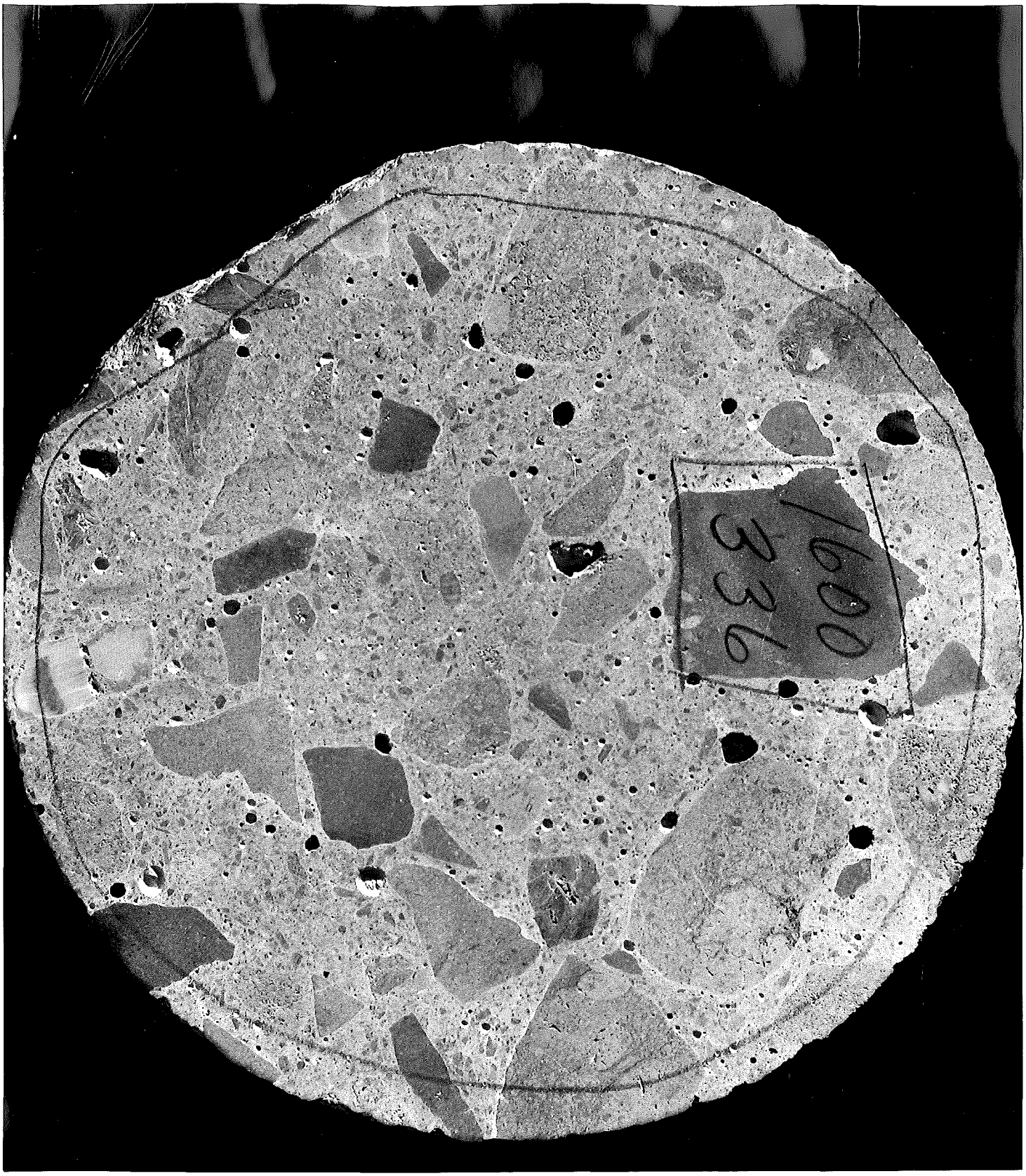


Figure 5, Core 164, Without HP-7

Fig. 6 F 71-24, C1 - Typical scaling at west end of project between Stations 30+20 and 37+00 where HP-7 was omitted.

Fig. 7 Character of scaling and deep pitting 33+00.

Fig. 8 Typical scaling and pitting at Station 34+00.

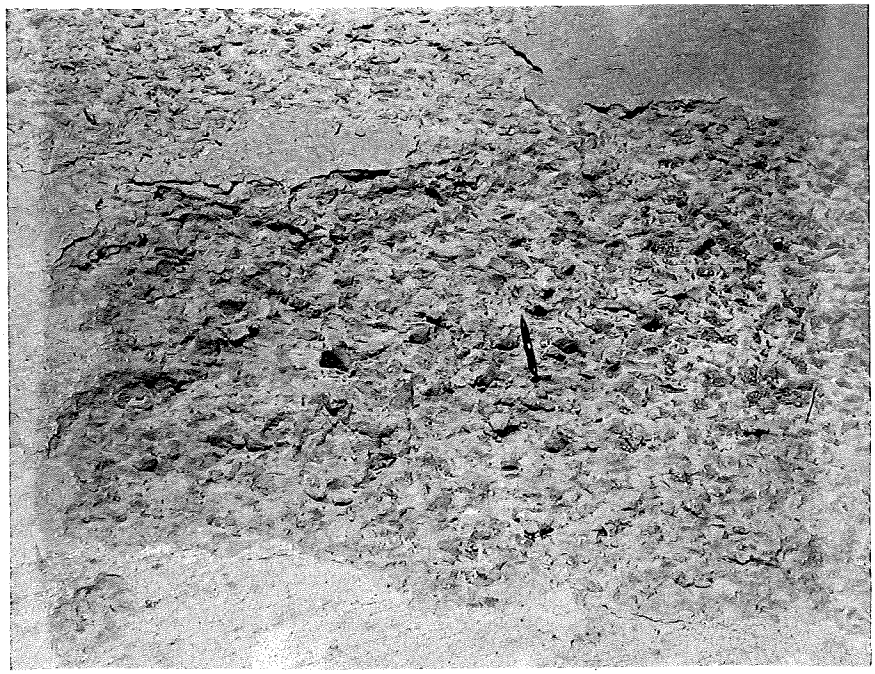


Fig. 9 Close view showing depth of spalling. 34+00.