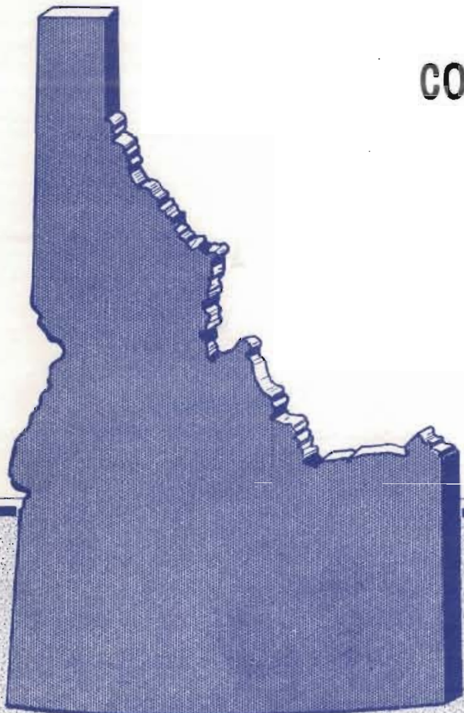
A STUDY COMPARING THE SCALING RESISTANCE OF AIR-ENTRAINED CONCRETE WITH CONCRETE CONTAINING A SILICONE ADMIXTURE



RESEARCH PROJECT NO. 33

AUGUST, 1967

STATE OF IDAHO DEPARTMENT OF HIGHWAYS

A STUDY COMPARING THE SCALING RESISTANCE OF AIR-ENTRAINED CONCRETE WITH CONCRETE CONTAINING A SILICONE ADMIXTURE

Research Project No. 33

August, 1967

Materials and Research Division
Moscow Materials Testing Laboratory
Central Materials Laboratory

State of Idaho

DEPARTMENT OF HIGHWAYS

Boise, Idaho

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ACKNOWLEDGMENTS

This study was initiated by the Idaho Department of Highways jointly with the Dow Corning Corporation of Midland, Michigan, to compare the freeze and thaw resistance of air-entrained concrete with concrete containing Dow Corning 777 Concrete Admixture.

The test specimens were made by Mr. Ronald G. Garitone, Project Inspector, and other District V personnel under the supervision of Mr. Robert Hedlund and Mr. Raymond Olsen of the Dow Corning Corporation and Mr. H. L. Day, P. E., Materials Engineer for the Idaho Department of Highways. The specimens were made from concrete being placed on Project I-90-1(23)62 between Wallace and Mullan. The Moscow Laboratory performed the tests on the samples and prepared the report for the Materials and Research Division.

Mr. Harry Strong supervised the testing done by the Central Materials Laboratory personnel.

SYNOPSIS

The Moscow Materials Testing Laboratory undertook an investigation to compare the scaling resistance to freeze-thaw action and the compressive strength of air-entrained concrete with concrete containing Dow Corning 777 Concrete Admixture. Four beams were made and tested for flexural strength in the field. Twelve prisms were made in the field and tested in the Moscow Laboratory for scaling resistance, weight loss, and change in length. Twenty four cyclinders were made in the field and tested in the Moscow Laboratory for compressive strength.

The concrete containing the silicone admixture reached final set from thirty to thirty-six hours after placement. The flexural strength of the Dow Corning 777 Admixture Concrete was found to be slightly higher after twenty-eight days than that of the air-entrained concrete. The compressive strength of the admixture concrete was found to be approximately 11 per cent higher after thirty days, 14 per cent higher after ninety days, and 15 per cent higher after one year than the compressive strength of the air-entrained concrete. No difference was found in the scaling resistance between the two types of concrete up to approximately 800 cycles. However, beyond that number of cycles, the admixture concrete was found to have a slightly higher resistance to scaling from the effects of freeze-thaw action. No difference in loss of weight or increase in length could be determined between the two types of concrete due to the freeze-thaw action. The range of magnitude in loss of weight and increase in length for both types of concrete was extremely small.

INTRODUCTION

It was discovered several years ago that the addition of certain silicone compounds to concrete was effective in reducing the amount of surface scaling caused by de-icing agents. The silicone admixture also increased the compressive strength of the concrete and caused a marked retardation in the setting time of the concrete. (1), (2).

This project was initiated by the Idaho Department of Highways jointly with the Dow Corning Corporation to compare both the freeze and thaw resistance and compressive strength of air-entrained concrete with concrete containing Dow Corning 777 Concrete Admixture under severe weathering conditions in northern Idaho. Dow Corning 777 Concrete Admixture is a reactive polysiloxane water soluble liquid that is designed to provide improved resistance of concrete to the effects of freeze-thaw exposure and also to provide concrete with improved compressive, flexural and bond strength (3).

To implement this investigation, Mr. Robert Hedlund and Mr. Raymond Olsen, representatives of the Dow Corning Corporation of Midland, Michigan, came to the construction site, Project No. I-90-1(23)62, E.C.L. Wallace - W.C.L. Mullan, on U. S. Highway I-90 in northern Idaho. This project involved the placing of air-entrained concrete pavement on 5.674 miles of 4-lane Interstate Highway. These gentlemen, together with Mr. H. L. Day, P.E., Materials Engineer, Idaho Department of Highways, supervised the use of the admixture and the preparation of both the control and admixture test specimens to be used in evaluating the effectiveness of the Dow Corning 777 Admixture.

CONCLUSIONS

The set retarding effect of the silicone admixture has both advantages and disadvantages on a construction project. It permits great latitude in concrete placement and finishing operations during extended periods of hot weather. However, it prevents early finishing and stripping of forms during periods of cool weather.

Evaluation of the flexural strength test data from the field indicates that the flexural strength of the Dow Corning 777 Admixture Concrete is slightly higher after twenty-eight days than that of the air-entrained concrete.

The results of the compressive strength tests indicate that the compressive strength of the admixture concrete is approximately 11 per cent higher after thirty days, 14 per cent higher after ninety days, and 15 per cent higher after one year than is the compressive strength of the air-entrained concrete. Accordingly, the Dow Corning 777 Admixture Concrete provides a higher compressive strength than does the air-entrained concrete.

There is no difference in scaling resistance between the two types of concrete up to approximately 800 cycles. However, beyond that number of cycles the admixture concrete seems to have a slightly higher resistance to scaling from the effects of freezing and thawing action than does the air-entrained concrete.

Assuming that there are approximately one hundred freezing and thawing cycles per year on a construction project, there would be no difference in scaling resistance between the two types of concrete for a period of approximately eight years. Beyond that approximate period of time the Dow Corning 777 Admixture would provide a moderately superior scaling resistance.

There was no significant difference in loss of weight due to the freezing and thawing action between the two types of concrete. In each case the actual weight loss was very small.

There was no difference in increase in length between the two types of concrete. The range of magnitude of the increases in length for both types of concrete is extremely small.

These conclusions were drawn from the results of both the Moscow and Boise Laboratory testing.

RECOMMENDATIONS

1. The use of the Dow Corning 777 Admixture should be limited to those projects on which the retardation factor in the setting of the concrete would not cause construction problems.

2. Future investigations of this type should include the use of a continuous temperature recording device to measure the dilation of the specimens. (The dilation is the increase in length of the test specimen as it is cooled into the freezing range of the contained water.) Measurement of the change in length is of little value unless it is measured over the entire temperature range of the freeze and thaw cycle.

3. The toxicity of the Dow Corning 777 Admixture should be reduced to a safe level before it is used on a construction project. The degree of toxicity of the admixture used in

this investigation would constitute a safety problem on a construction project due to the hazards involved in the handling of the admixture.

4. As the admixture used in the investigation was quite expensive, a careful economic analysis is needed to justify the use of the admixture on any future construction project.

5. The Dow Corning 777 Admixture should be used only in structures on the State Highway system in areas that are subject to numerous cycles of freezing and thawing.

SCOPE OF THE INVESTIGATION AND METHODS USED

On September 23, 1964, concrete containing Dow Corning 777 Admixture was placed at three transition areas, one from Station 96+38 to 96+75, one from Station 160+80 to 160+92, and one from Station 187+50 to 187+70. Regular air-entrained concrete was placed in the transition area from Station 95+60 to 95+88 to serve as a control section. Test specimens were made as follows from concrete placed in the indicated transition areas:

1. Air-entrained concrete from the control section at Station 95+60 to 95+88:
    a. Four 3" x 3" x 14" prisms designated as Prisms No. 1, 2, 3, 4.
    b. Eight 6" x 12" cylinders designated as Cylinders 1 T through 8 T.
    c. Two 6" x 6" x 30" beams designated as Beams No. 49 and 50.

2. Concrete containing Dow Corning 777 Admixture from the experimental section at Station 96+38 to 96+75:

   a. Eight 3" x 3" x 14" prisms designated as Prisms No. 5 through 12.

   b. Sixteen 6" x 12" cylinders designated as Cylinders 9 T through 24 T.

   c. Two 6" x 6" x 30" beams designated as Beams No. 51 and 52.

The concrete for the prisms was screened over a 1-inch sieve. The concrete for the beams and cylinders was used as delivered to the site. The concrete mix design and other data are shown in Appendix A.

The weather was cloudy and cool with temperature ranging from a high of 66° F. to a low of 41° F. during time of concrete placement. All concrete placed in the roadway and the troweled surface of the prisms were sprayed with Truscon Tru-Cure clear concrete curing compound.

Beams No. 49, 50, 51, and 52 were cured on the job in accordance with ASTM Designation: C 31-62 T, Tentative Method for Making and Curing Concrete Compression and Flexure Test Specimens in the Field. Beams No. 49 and 51 were tested for flexural strength at eight days and Beams No. 50 and 52 were tested for flexural strength at twenty-eight days in the field in accordance with ASTM Designation: C 78-64, Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading). The test results are contained in Table 1, page 12.

The prisms and the cylinders were taken to the Moscow Materials Testing Laboratory and immediately stored in moist air according to ASTM Designation: C 192-62 T, Tentative Method of Making and Curing Concrete

Compression and Flexure Test Specimens in the Laboratory. The cylinders were tested for compressive strength in accordance with ASTM Designation: C 39-64, Standard Method of Test for Compressive Strength of Molded Concrete Cylinders, at 7 days, 33 days, 90 days, 6 months, and 1 year in accordance with the program contained in Appendix B. The prisms were subjected to freezing and thawing tests and scaling tests in accordance with ASTM Designation: C 290-63 T, Tentative Method of Test for Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water, in conformance with the program shown in Appendix B.

Due to equipment limitations, the investigation in the Moscow Materials Testing Laboratory was confined to the following comparisons between the air-entrained concrete specimens and the concrete specimens containing Dow Corning 777 Concrete Admixture:

1. Compressive strength.
2. Resistance to scaling caused by freezing and thawing action.
3. Loss of weight caused by freezing and thawing action.
4. Change in length caused by freezing and thawing action.

The prisms subjected to the scaling test were examined, rated, and photographed at 29, 58, 86, 112, 144, 180, 244, 286, 317, 350, 545, 735, 845, 942, and 1001 cycles of freezing and thawing respectively. The ratings were made according to the Bureau of Public Roads numerical ratings contained on page 44 of Highway Research Bulletin 323, (4) which are listed in Appendix D. The evaluation of the scaling resistance of the prisms is contained in Appendix E. Figures 1, 2, and 3 are photographs showing the condition of the prisms at the time of the different ratings.

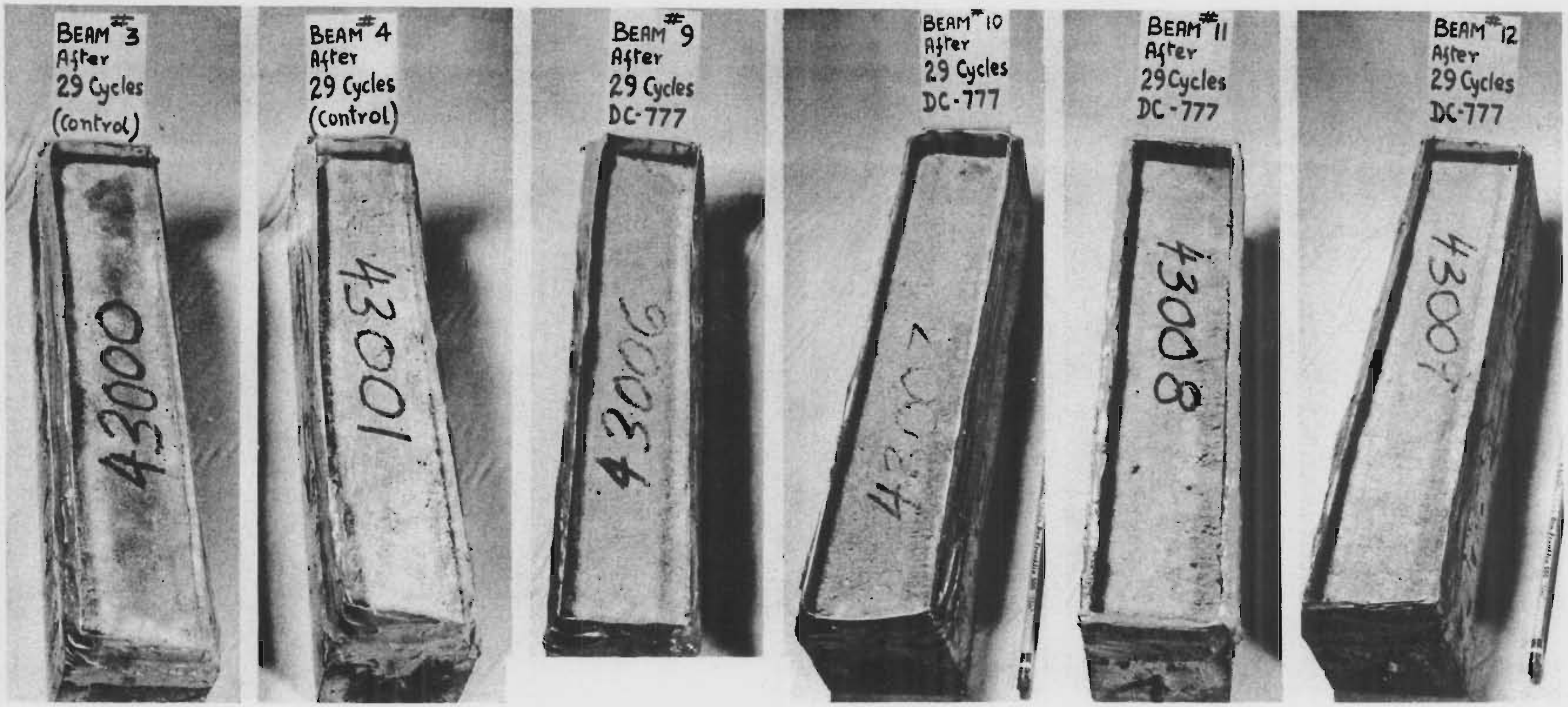

FIGURE I – FREEZE – THAW SPECIMENS AFTER 29 CYCLES SHOWING CONDITION OF SURFACE.

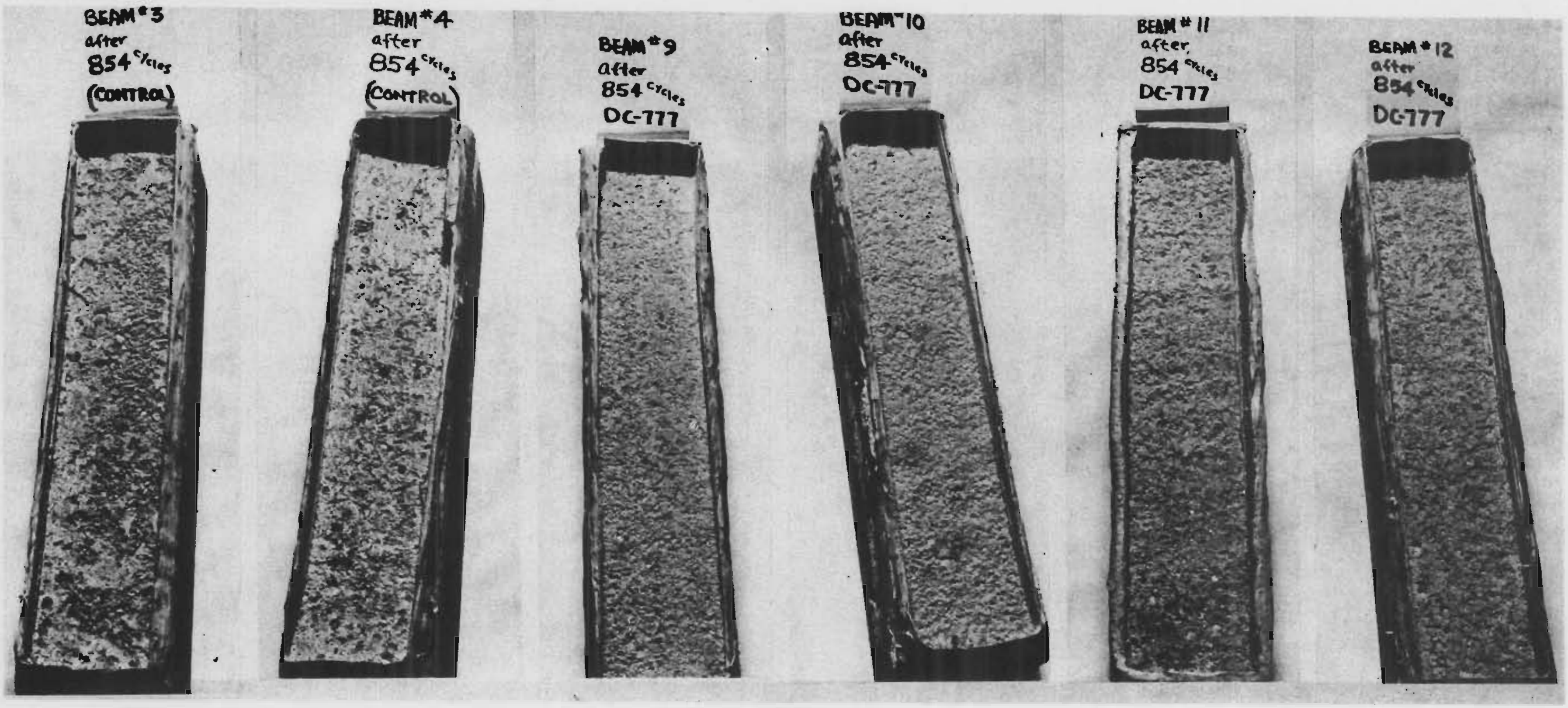

FIGURE 2 – FREEZE – THAW SPECIMENS AFTER 854 CYCLES SHOWING CONDITION OF SURFACE.

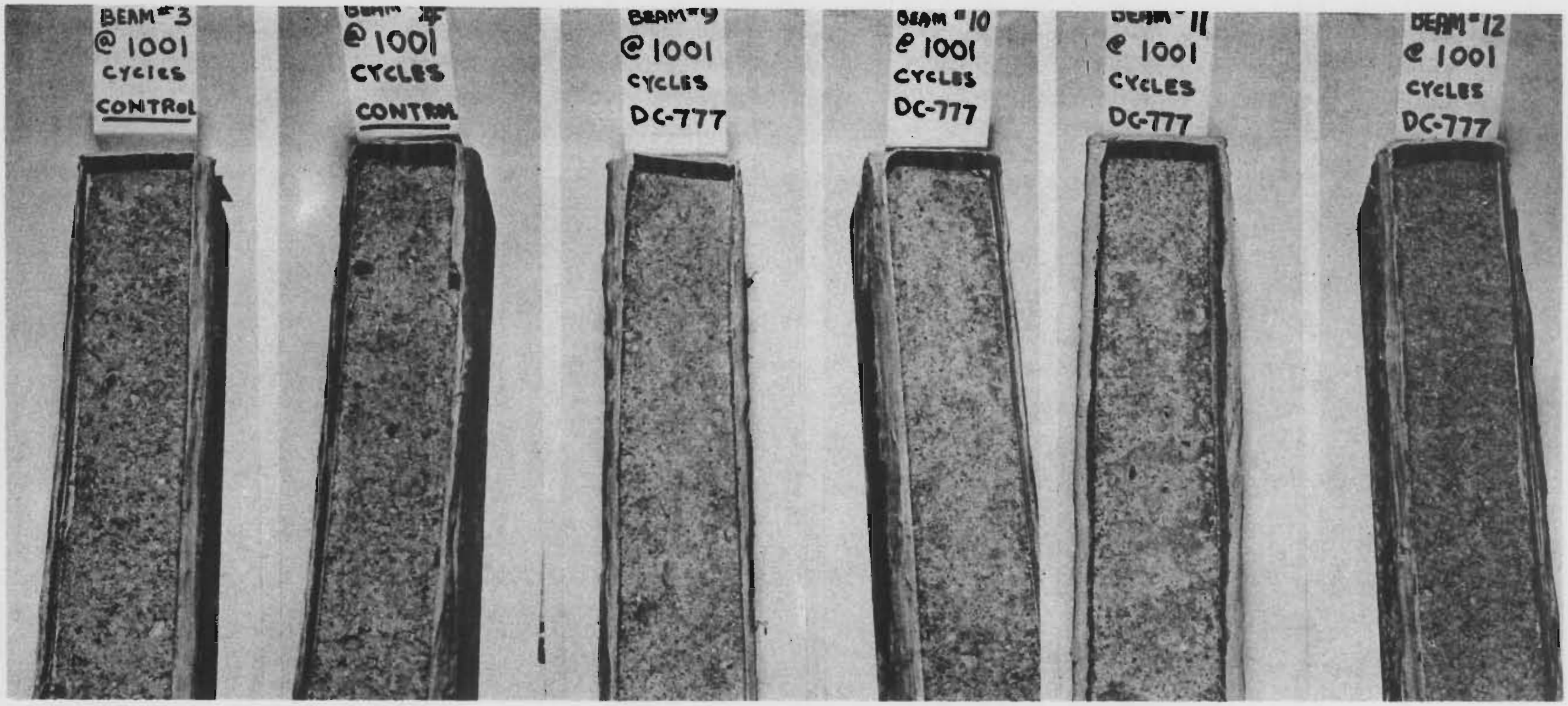

FIGURE 3 - FREEZE-THAW SPECIMENS AFTER 1001 CYCLES SHOWING RELATIVELY MORE EFFECT UPON THE CONTROL SPECIMENS.

The temperatures ranged from a high of 40° F. to 50° F. to a low of 0° F. to minus 10° F. during the freezing and thawing cycles. The time for a complete cycle ranged from four hours to seven hours with the thawing cycle taking from one hour to two hours for completion.

A 10 per cent salt (NaCl) solution was used to effect the scaling action on the top of the prisms at the beginning of the scaling resistance test. The salt concentration was changed to 2 per cent NaCl after 350 cycles of freezing and thawing in an attempt to accelerate the deterioration of the prism surfaces during the remainder of the investigation.

The prisms evaluated for weight loss and change in length due to freezing and thawing action were also examined each time at the cycles indicated above and the change in lengths recorded as shown in Appendix F. The weight loss was evaluated only at the end of the investigation at 1001 cycles and is also shown in Appendix F.

RESULTS OF INVESTIGATION

The concrete containing the silicone admixture had not as yet reached final set by mid-morning the day following placement. According to the Project Inspector's Diary the admixture concrete reached final set from 30 to 36 hours after placement.

The flexural strength test data from the field permits the comparison shown in Table 1, page 12.

Table 1 - Comparison of Flexural Strengths of DC 777 Concrete and Air-entrained Concrete Beams*

Beam No.	Type of Concrete	No. of Days Until Tested	Flexural Strength PSI	Ratio of DC 777 Flexural Str. to Air-Entrained Flex. Str.
49	Air-entrained	8	590	--
51	DC 777	8	540	0.92
50	Air-entrained	28	680	--
52	DC 777	28	710	1.04

* Beam size; 6" x 6" x 30"

The results of the compressive strength tests are shown graphically in Figure 4, page 13. The average compressive strength of two or more concrete cylinders per group provides the comparison made in Table 2, Appendix C.

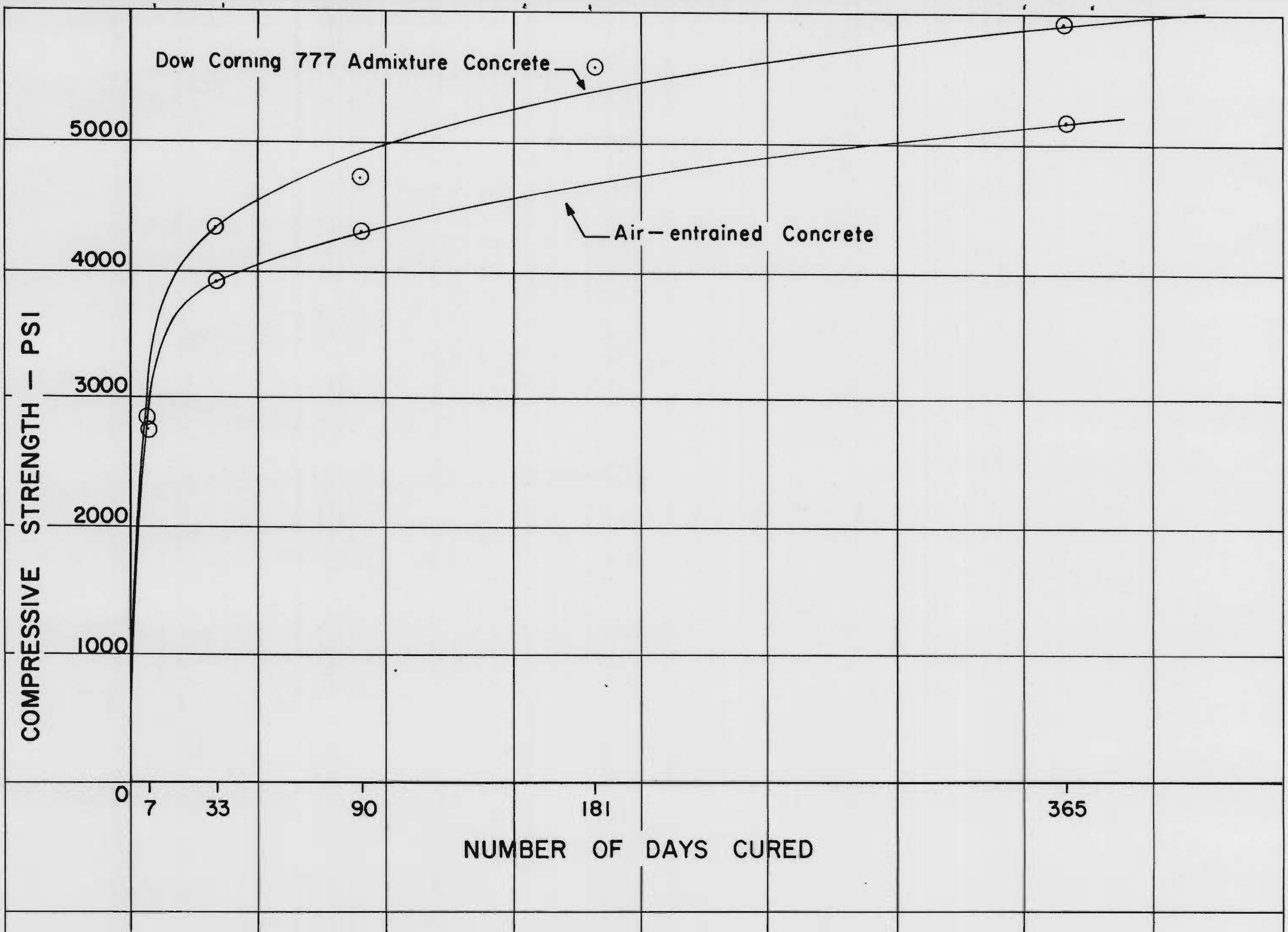

FIGURE 4 — COMPRESSIVE STRENGTH : DOW CORNING 777 CONCRETE vs AIR — ENTRAINED CONCRETE

Analysis of the scaling resistance of the concrete indicates that after 350 cycles of freezing and thawing using the 10 per cent salt solution the deterioration of the surface of the Dow Corning 777 Admixture concrete was approximately the same as that of the air-entrained concrete with a rating of 2 or 3. The concentration of the salt solution was then changed to 2 per cent NaCl and there was no further deterioration of either type of concrete after 545 cycles of freezing and thawing.

At the end of 735 cycles the air-entrained concrete received a rating of 4 while the admixture concrete was rated at 5. However, at the end of 854 cycles the four admixture concrete specimens were all rated at 5 while the two air-entrained concrete specimens received a rating of 6 and 7. These ratings remained unchanged to the end of the investigation at 1001 cycles of freezing and thawing.

The loss in weight by the prisms subjected to the freezing and thawing action ranges from 0.47 per cent to 0.76 per cent. It could not be determined whether the weight loss was due to the freezing and thawing action or to evaporation of part of the water of hydration.

All of the prisms underwent an increase in length during the course of the investigation. The increases in length ranged from 0.013 per cent to 0.033 per cent. As the temperature of the prisms was approximately the same when the measurements were made at both the beginning and the end of the investigation, it is possible that the slight increase in length was due to the freezing and thawing action.

CENTRAL LABORATORY TESTING

To supplement the investigations of the Moscow Laboratory, the Central Materials Laboratory in Boise ran a series of tests in the laboratory to compare the performance of concrete containing the Dow Corning 777 Concrete Admixture with air-entrained concrete. The tests performed were the compressive strength and time-of-set tests, the plastic flow test and alkali reaction reduction (expansion bar and glass jar cracking) tests.

All standard tests were performed according to their respective ASTM Standard Method of Test. The plastic flow test was a Dow Corning Test and was believed necessary because the retarded time-of-set could affect the placement of concrete on steep slopes. The glass jar cracking test has been used by the state previously to test for alkali reaction. It gives no measurable results.

RESULTS OF LABORATORY TESTS

The Central Laboratory testing gave results similar to those of the Moscow Laboratory for the tests which were similar. The Dow Corning 777 Concrete Admixture increased the compressive and flexural strength of concrete when compared to air-entrained concrete, it retarded the setting of concrete and it had no effect upon the expansion of the concrete, compared to air-entrained concrete.

Both the bar expansion test and the glass jar cracking test indicated that Dow Corning 777 had no more effect in reducing alkali reaction than did the air-entraining agent.

The plastic flow test results were negative with neither the concrete specimens contain Dow Corning 777 nor those containing air-entraining concrete showing any flow or deformation at the end of the test period for any of the test slopes.

Appendix G contains a more thorough explanation of the laboratory testing with an analysis of the results. Tables, graphs, and pictures are used in the analysis.

Test procedures are given in Appendix H.

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3. Project Report on the Development of Dow Corning 777 Concrete Admixture, Dow Corning Corporation, Midland, Michigan.

4. Grieb, W. E., Werner, George, and Woolf, D. O., Highway Research Engineers, Division of Physical Research, Bureau of Public Roads, Resistance of Concrete Surfaces to Scaling by De-Icing Agents, Highway Research Board Bulletin 323, June, 1962.

APPENDIX A

Concrete Mix Design and Data

Coarse Aggregate
2" to 1"

Sieve Size	% Pass.	Specs.
2 1/2	100	100
2	98	95-100
1 1/2	70	35-70
1	4	0-15
3/4	1	-
1/2	1	0-5

F. M. - 8.29

Coarse Aggregate
1" to No. 4

Sieve Size	% Pass.	Specs.
1 1/2	100	100
1	100	95-100
3/4	80	-
1/2	31	25-60
3/8	9	-
No. 4	0	0-10
No. 8	0	0-5

F. M. - 7.11

Coarse Aggregate
Blend - 40% 2" to 1"
60% 1" to No. 4

Sieve Size	% Pass.	Specs.
2 1/2	100	100
2	99	95-100
1 1/2	88	-
1	62	35-70
3/4	48	-
1/2	19	10-30
3/8	5	-
No. 4	0	0-5
No. 8	0	-

F. M. - 7.59

Sand
3/8" to No. 100

Sieve Size	% Pass.	Specs.
3/8	100	100
No. 4	99	95-100
No. 8	79	-
No. 16	52	45-80
No. 30	33	-
No. 50	16	10-30
No. 100	3	2-10

S. E. - 82

F. M. - 3.18

Moisture - 5.2%

Combined F. M. of Sand and Coarse Aggregate Blend - 5.83

CONCRETE DATA

	Control Mix	DC 777 Mix	DC 777 Mix
Station	95+60 - 95+88	96+38 - 96+75	187+50 - 187+70
Slump	2 1/2	2 1/4	7 1/2
% Air	5.6	7.6	7.6
Admixture	Protex AEA	DC 777	DC 777
Quan. Admix.	2 3/4 oz./C.Y.	0.3 lb./SK	0.3 lb./SK
Cyl. Nos.	1T thru 8T	9T thru 24T	-
Prism Nos.	1 thru 4	5 thru 12	-
Beam Nos.	49 and 50	51 and 52	-

BATCH QUANTITIES - 1 C. Y.

	Control	DC 777
Sand	1377 lb.	1377 lb.
1" - 2"	787 lb.	787 lb.
No. 4 - 1"	1180 lb.	1180 lb.
Water	20 gal.	19 gal.
Cement	564 lb.	564 lb.
AEA	2 3/4 oz.	None
DC 777	None	1.8 lb.

Cement - Ideal Type II - A Low Alkali

APPENDIX B

Moscow Laboratory Test Procedure
For Dow Corning 777 Concrete
Admixture Investigation

I. Specimens (Made on 9/23/64)

1. Cylinders: 1T through 8T - Control

   9T through 24T - DC 777 Admixture

2. Prisms: No. 1 through No. 4 - Control

   No. 5 through No. 12 - DC 777 Admixture

II. Procedure

1. Cylinders: Cure in accordance with ASTM Designation: C 192-62 T.

   Test for compressive strength in accordance with ASTM Designation: C 39-64 as follows:

   a. 1T, 2T, 9T, 10T, and 11T, @ 7 days (9/30/64)

   b. 3T, 4T, 12T, 13T, 14T, and 15T, @ 28 days (10/21/64)

   c. 5T, 6T, 16T, 17T, and 18T, @ 3 months (12/23/64)

   d. 19T, 20T, and 21T, @ 6 months (3/23/65)

   e. 7T, 8T, 22T, 23T, and 24T, @ one year (9/23/65)

2. Prisms: Cure in the moist room for sixteen days in accordance with ASTM Designation: C 192-62 T.

a. Soak in water for three days (10/9/64 - 10/12/64)

b. Start the Freeze-Thaw Test on prisms No. 1, 2, 5, 6, 7, and 8 according to ASTM Designation: C 290-63 T on 10/12/64

c. Mold a one-half inch high edge around the top (troweled surface) or prisms No. 3, 4, 9, 10, 11, and 12 with joint sealer compound

d. Place a one-half inch minus depth of 10% salt solution on top of prisms No. 3, 4, 9, 10, 11, and 12 and place the prisms in the Freeze-Thaw Machine with the other prisms on 10/12/64

e. Examine all prisms every thirty cycles or whenever any sign of additional scaling is evident. Measure the prisms in the comparator and check the weight loss on prisms No. 1, 2, 5, 6, 7, and 8. Flush prisms No. 3, 4, 9, 10, 11, and 12, rate them for scaling condition, and photograph. Refill the top surface of prisms No. 3, 4, 9, 10, 11 and 12 with fresh 10% salt solution. Turn prisms No. 1, 2, 5, 6, 7, and 8 ninety degrees clockwise and return all prisms to the Freeze-Thaw Machine in a different location

f. Continue procedure (e) for 1000 cycles

APPENDIX C

Table 2 - Comparison of Compressive Strengths of Concrete Cylinders

No. of Days Until Tested	Number of Cylinders Tested Control	DC 777	Control (Air-entrained) Concrete - Average Compressive Strength-PSI	DC 777 Concrete - Average Compressive Strength-PSI	Ratio of Compressive Strength of DC 777 to Control
7	2	3	2750	2820	1.02
33	2	4	3900	4330	1.11
90	2	3	4300	4710	1.10
181	-	3	-	5590	-
365	2	3	5160	5920	1.15

APPENDIX D

Numerical Ratings for Visual Observations

of the Extent and Depth of Scaling

0 - No scaling.

1 - Scattered spots of very light scale.

2 - Scattered spots of light scale with mortar surface above coarse aggregate removed.

3 - Light scale over about one-half of the surface.

4 - Light scale over most of the surface.

5 - Light scale over most of the surface with a few moderately deep spots where the mortar surface is below the upper surface of the coarse aggregate.

6 - Scattered spots of moderately deep scale.

7 - Moderately deep scale over one-half of the surface.

8 - Moderately deep scaling over entire surface.

9 - Scattered spots of deep scale with the mortar surface well below the upper surface of the coarse aggregate.

10 - Deep scaling over entire surface.

APPENDIX E

Table 3 - Evaluation of Scaling Resistance

No. of Freeze-Thaw Cycles	Rating of Scaling Resistance					
	Control Prism No. 3	Control Prism No. 4	DC 777 Prism No. 9	DC 777 Prism No. 10	DC 777 Prism No. 11	DC 777 Prism No. 12
0	0	0	0	0	0	0
29	1	1	1	1	1	1
58	1	1	1	1	1	1
86	1	1	1	1	1	1
112	1	1	1	1	1	1
144	1	1	2	2	2	2
180	1	1	2	2	2	2
224	1	1	2	2	2	2
286	1	1	2	2	2	2
317	1	1	2	2	2	2
* 350	2	2	2	3	2	3
545	2	2	2	3	2	3
735	4	4	5	5	5	5
845	7	6	5	5	5	5
942	7	6	5	5	5	5
1001	7	6	5	5	5	5

* Salt solution changed from 10% NaCl to 2% NaCl to accelerate deterioration of prism surfaces.

APPENDIX F

Table 4 - Evaluation of Change in Length of Prisms

No. of Freeze - Thaw Cycles	Increase in Length of Prisms in Inches at Temperature of $75^\circ \pm 5^\circ$ F.*											
	Control Prism No. 1	Control Prism No. 2	Control Prism No. 3	Control Prism No. 4	DC 777 Prism No. 5	DC 777 Prism No. 6	DC 777 Prism No. 7	DC 777 Prism No. 8	DC 777 Prism No. 9	DC 777 Prism No. 10	DC 777 Prism No. 11	DC 777 Prism No. 12
0**	14.916	15.082	14.977	15.012	15.096	15.042	15.070	15.051	15.093	14.976	15.109	15.053
29	0	0	<u>0.001</u>	<u>0.001</u>	0	0	0	0	<u>0</u>	<u>0.001</u>	<u>0.001</u>	<u>0</u>
854	0.003	0.002	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.006	0.003	0.002
1001	0.003	0.002	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.005	0.003	0.002
Total Increase in Length - Inches	0.003	0.002	0.003	0.003	0.004	0.003	0.002	0.002	0.002	0.005	0.003	0.002
Total Increase in Length - Per cent	0.020	0.013	0.020	0.019	0.026	0.019	0.013	0.013	0.013	0.033	0.019	0.013

* Underlined figures indicate readings when temperature varied more than 5° F. from 75° F.

** Figures are length of specimens in inches at beginning of test

Table 5 - Evaluation of Loss of Weight by Prisms

	Control Prism No. 1	Control Prism No. 2	DC 777 Prism No. 5	DC 777 Prism No. 6	DC 777 Prism No. 7	DC 777 Prism No. 8
Initial Saturated Surface Dry Weight, lbs.	10.82	10.76	10.60	10.90	10.54	10.85
Final Saturated Surface Dry Weight, lbs. (After 1001 Cycles of Freeze-Thaw)	10.74	10.70	10.55	10.83	10.46	10.77
Loss of Weight, lbs.	0.08	0.06	0.05	0.07	0.08	0.08
Loss of Weight, Per cent	0.74	0.56	0.47	0.64	0.76	0.74

APPENDIX G

Supplemental Laboratory Testing

To supplement the investigations of the Moscow Laboratory, the Central Materials Laboratory in Boise performed a series of tests in the laboratory to compare the performance of concrete containing the Dow Corning 777 Concrete Admixture with air-entrained concrete. The laboratory tests performed in Boise were the compressive strength and time-of-set tests, the plastic flow test, and alkali reaction reduction test.

Twenty (20) 1" x 1" x 10" expansion bars and forty-eight (48) glass jar samples were made to test for alkali reaction reduction (expansion test), twelve (12) time-of-set (penetration) tests were run, sixty (60) compressive strength test cylinders were made up and broken, and sixteen (16) plastic flow tests were run. All standard tests were performed according to their respective ASTM Standard Method of Test. The plastic flow test is a Dow Corning Test and was believed necessary because the retarded time-of-set could affect the placement of concrete on steep slopes. The glass jar expansion test has been used previously by the State to test for alkali reaction. It gives no measurable results.

This phase of the project was conducted entirely in the laboratory using laboratory mixes and methods. It supports quite well the conclusions of the field investigation done by the Moscow Laboratory.

The differences in expansion between the bars containing Dow Corning 777 and those containing an air-entraining agent were very small. The results are shown in the following table:

Table 6 - Expansion Bar Test For Alkali Reactivity

Mixes		Source of Aggregate: TF-21	Source of Aggregate: Ore-3
		Maximum Increase In Length - Inches	
Plain - W/AEA		+0.0007	+0.0007
1% NaOH	*5% Glass - No Air	+0.0018	--
1% NaOH	W/AEA	+0.0014	+0.0022
1% NaOH	0.1 #/SK DC 777	+0.0012	+0.0036
1% NaOH	0.2 #/SK DC 777	+0.0012	+0.0027
1% NaOH	0.3 #/SK DC 777	+0.0012	+0.0060

* 5% ground glass added to increase reactivity

The test was only conducted over a 3-month period and the results cannot be considered decisive.

The experience with the glass jar expansion test was similar. Only one jar broke in less than 40 days. This jar contained a mix of aggregate from Pit Ore-3 and 1% NaOH with no additive or air-entraining agent. The following table gives the results of this test:

Table 7 - Glass Jar Test For Alkali Reactivity

	Mixes	Source of Aggregate	
		TF-21	Ore-3
		Days to First Crack	
	Plain - W-AEA	None	165
	*5% Glass - No Air	56	--
1% NaOH	W/AEA	173	29
	0.1 #/SK DC 777	87	55
	0.2 #/SK DC 777	67	44
	0.3 #/SK DC 777	136	44

* 5% ground glass added to increase reactivity

The penetration test, to determine the time-of-set of the concrete, indicated that final set occurred at between 43 and 54 hours after mixing. Figures 5, 6, 7, and 8 are plots of the results of these time-of-set tests. The "penetrations" referred to on the figures are the series of penetrations made with Proctor needles as outlined in Appendix H under Test Procedures.

In spite of the set retarding effects of the Dow Corning 777 Admixture there was no flow or deformation observed during the Plastic Flow Test at slopes up to 9 per cent. Figure No. 9 shows the Plastic Flow molds at the conclusion of the test.

Compressive strengths approximately 12 per cent greater than those for air-entrained concrete, with aggregate from Pit Bk-141, were

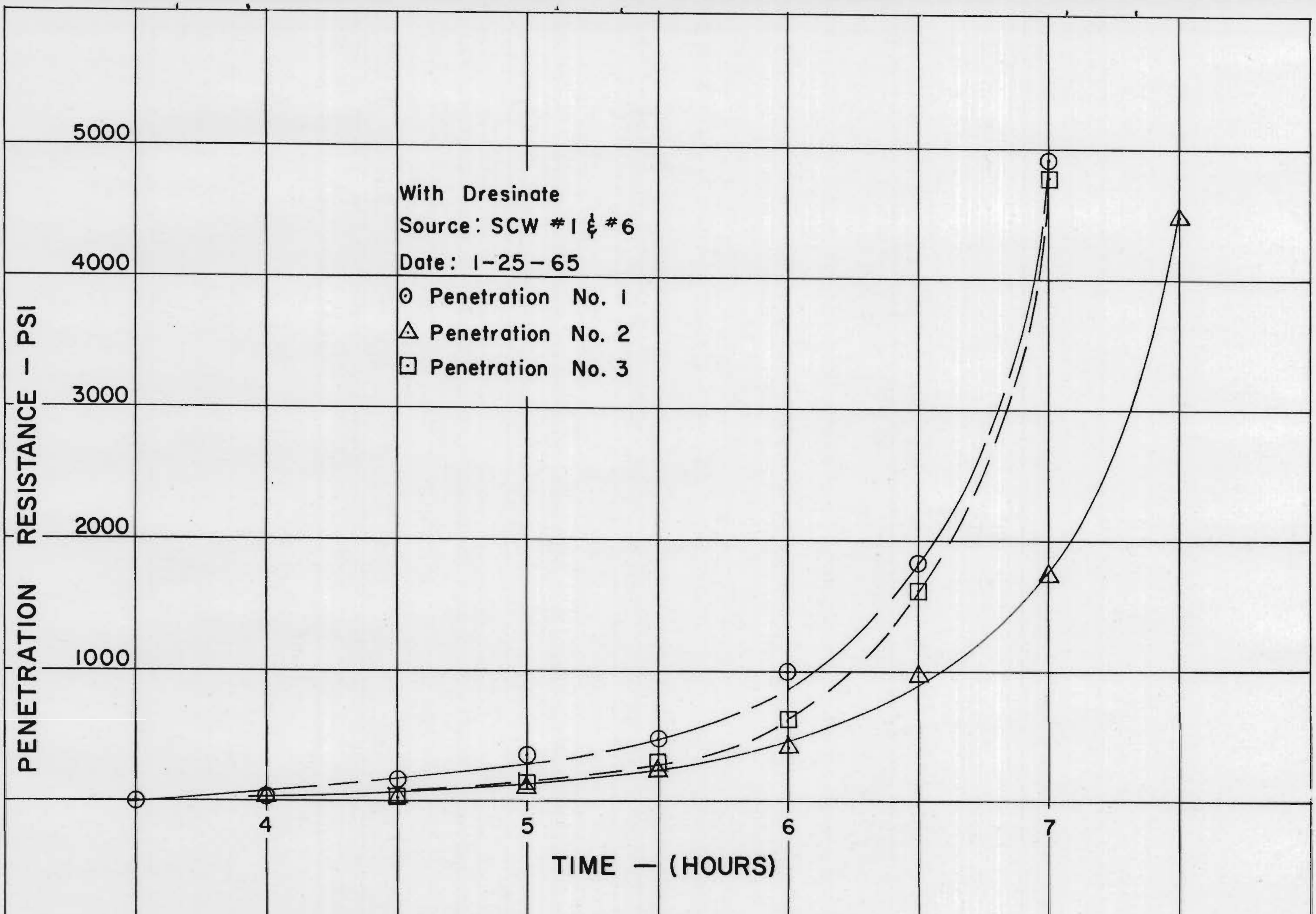

FIGURE 5 — TIME OF SET TEST

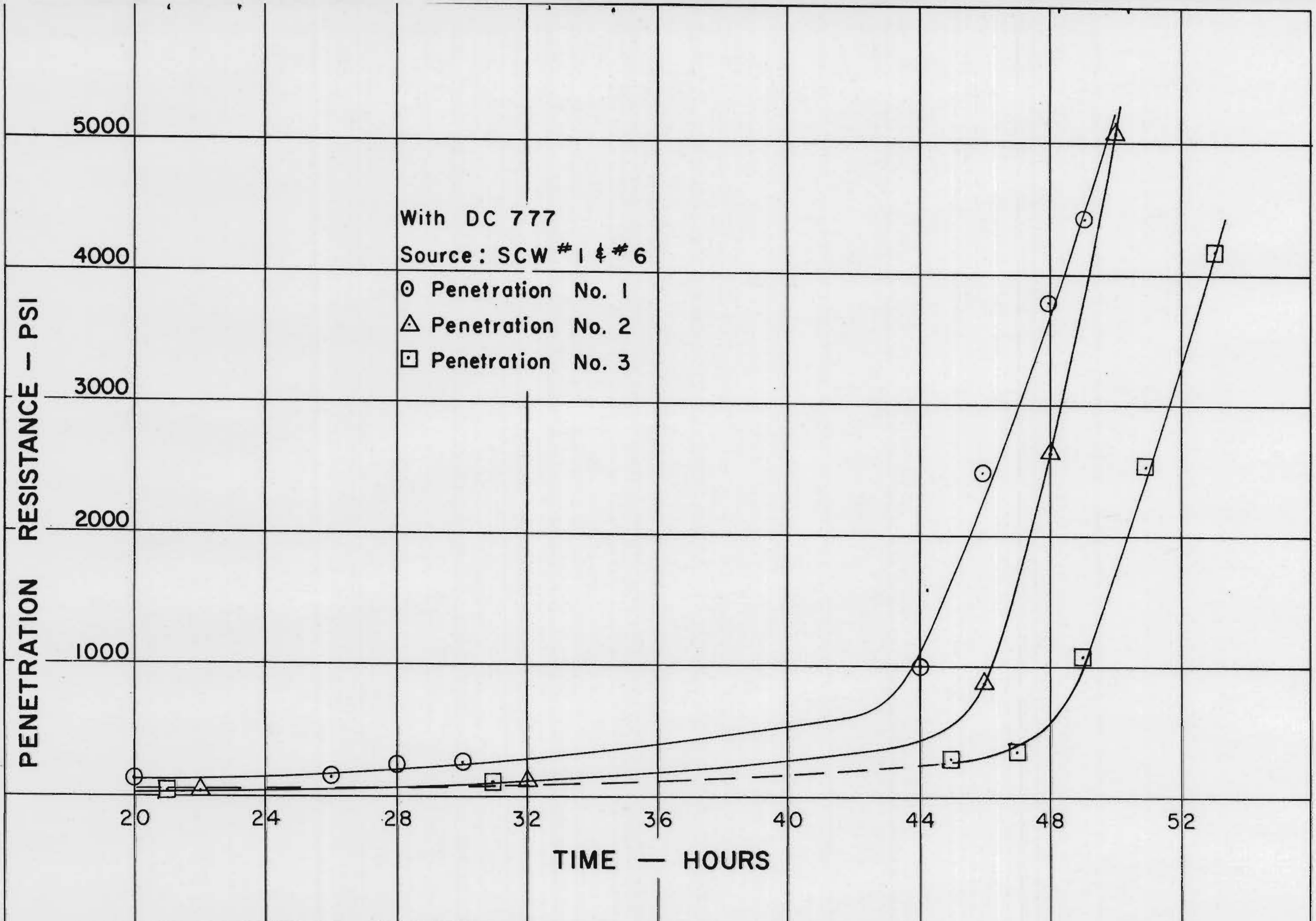

FIGURE 6 — TIME OF SET TEST

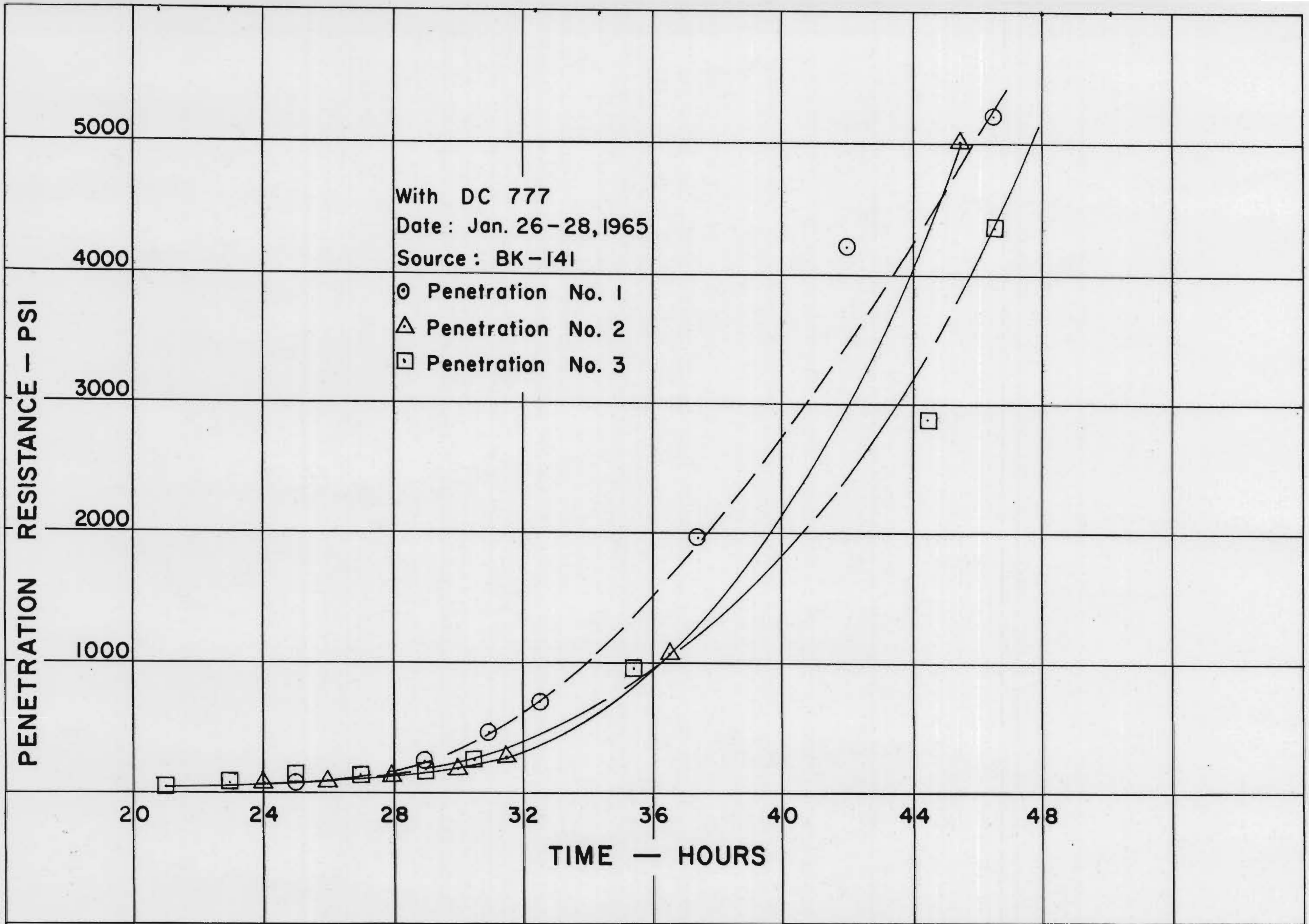

FIGURE 7 — TIME OF SET TEST

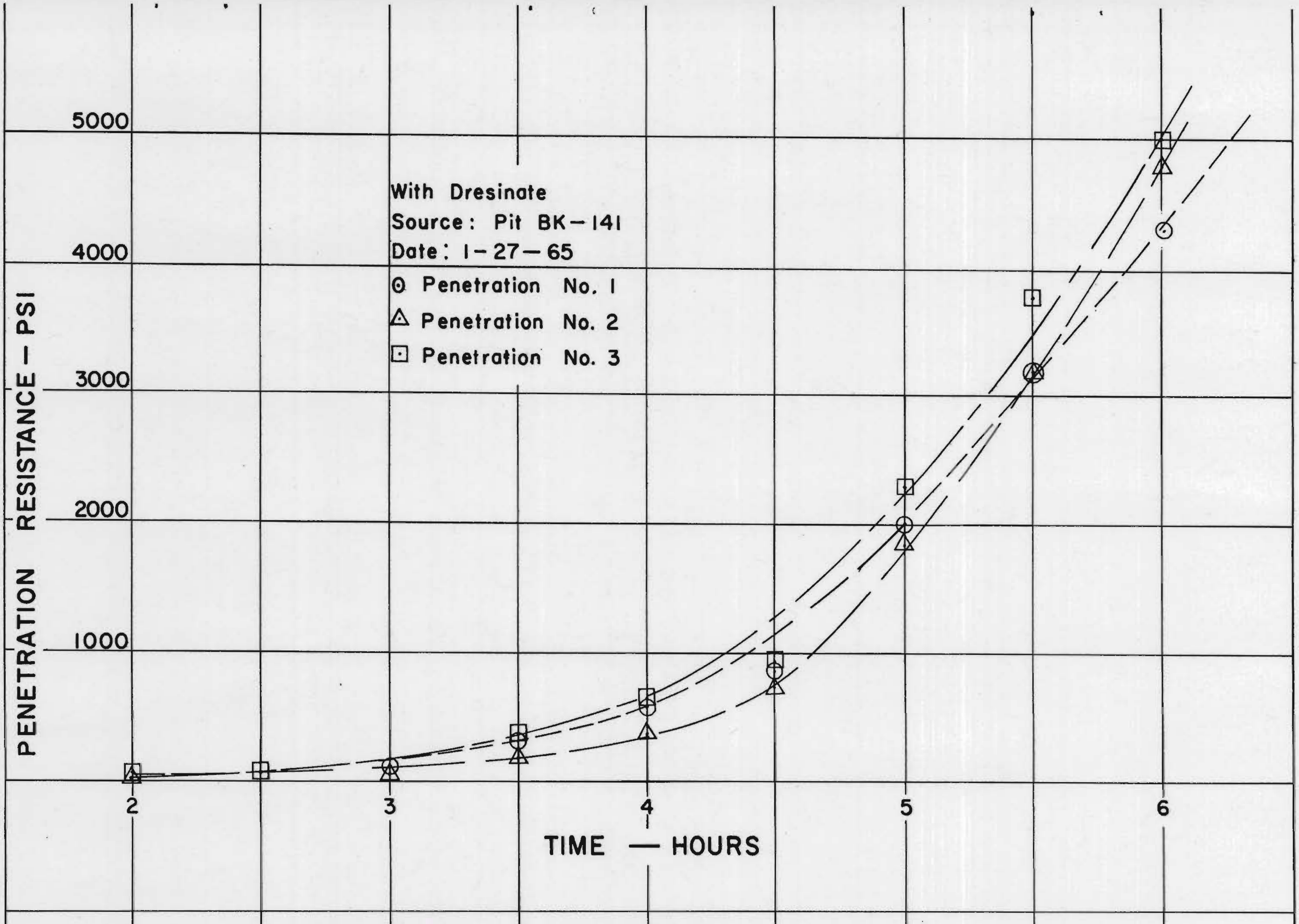

FIGURE 8 — TIME OF SET TEST

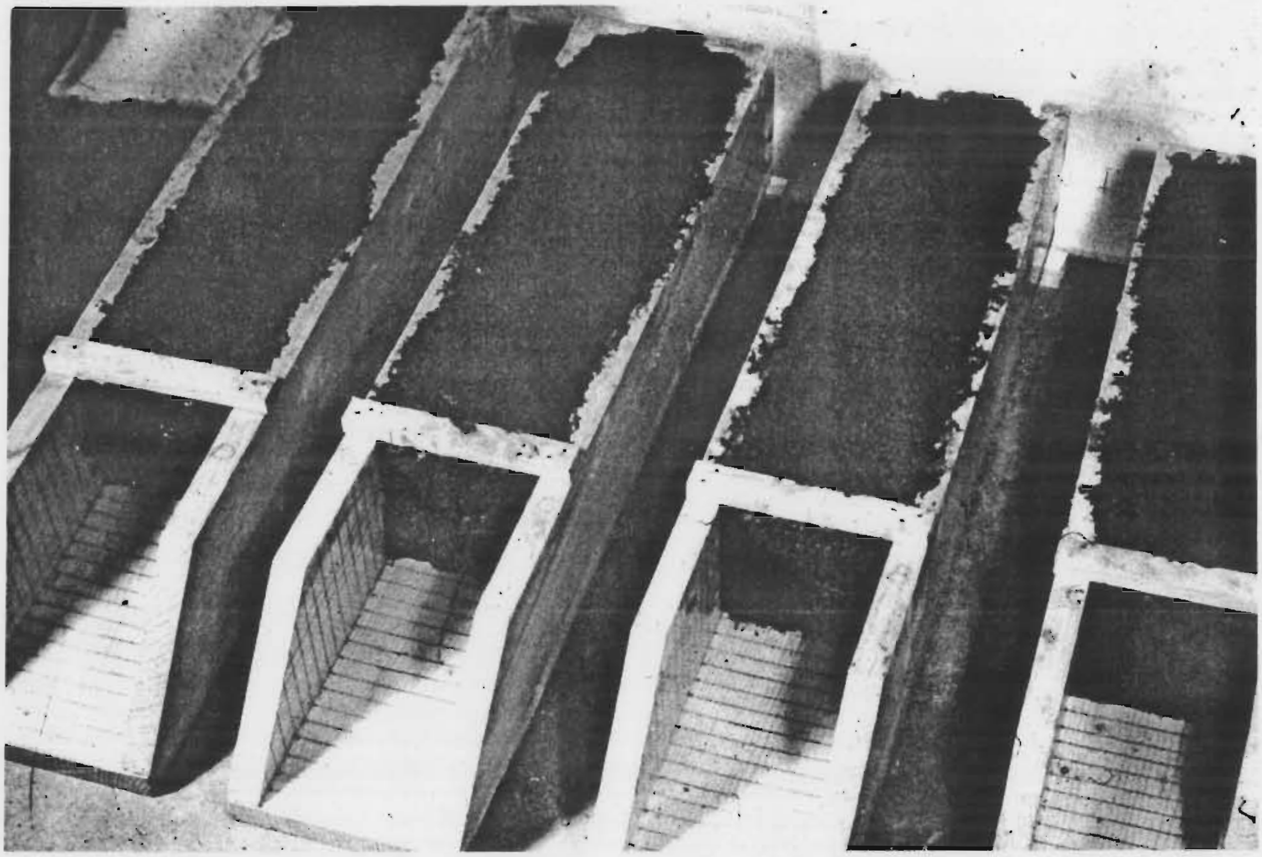

Figure No. 9

Plastic Flow Test

obtained using the Dow Corning 777 Admixture. This difference was at both seven and twenty-eight days curing periods. With aggregate from the Washington No. 1 and No. 6 pits an almost unbelievable 30 per cent difference in compressive strength was observed. This is an average of the seven and twenty-eight day strengths. These results are summarized in the following table:

Table 8 - Compressive Strength Test

Aggregate Source	Number of Cylinders Tested	Average wt. per cu. ft.	Average Compressive Strength 7-day, psi	Average Compressive Strength 28-day, psi	Additive
Bk-141	6	146.6	3,660		DC 777
	9	145.7		5,080	DC 777
	6	146.1	3,280		Dresinate
	9	145.8		4,540	Dresinate
Wash. St.	6	146.6	3,320		DC 777
No. 1 &	9	145.6		4,110	DC 777
No. 2	6	144.9	2,510		Dresinate
	9	144.5		3,230	Dresinate

CONCLUSIONS (Boise Lab Tests)

The results of these tests support the conclusions from the field investigations that the Dow Corning 777 Admixture:

1. Had a definite effect in retarding the final set of the concrete.
2. Increased the compressive strength of concrete significantly.

From the results of the short period of testing for alkali reaction it appears that the Dow Corning 777 Admixture has no effect in reducing this reaction. However, a longer test period would be required before a definite conclusion can be drawn.

There appears to be no effect upon the flow characteristics of concrete by the use of the Dow Corning 777 Silicone Admixture.

APPENDIX H

Test Procedures

The concrete used in this series of tests was designed in accordance with the Idaho Concrete Manual - 1964, and mixed in compliance with ASTM C 494, Paragraph 11.

The concrete aggregate used came from four (4) different sources. Aggregates from Sources TF-21 and Ore-3 are considered to be reactive and were used in the bar expansion and the glass jar expansion tests. The aggregate from Sources Bk-141 and Washington State No. 1 and No. 6 were used for the compressive strength, time-of-set, and plastic flow tests. Cements used were Eagle, Type I low alkali with Bk-141 aggregate, Ideal, Type II low alkali with Washington State No. 1 and No. 6 aggregate, and Sun, Type I low alkali with aggregate from TF-21 and Ore-3 cement with a high alkali. Content was not available at the time the tests were run, so NaOH was added to the concrete mixes to provide the effect of high alkalinity. Additives used in the mixes were Dow Corning 777, a silicone compound, and Dresinate, an air-entraining agent.

These tests were conducted to determine the effect of the Dow Corning 777 Silicone Admixture upon certain properties of concrete, as compared to air-entrainment. A description of the tests and their results follows:

A. Alkali Reaction Phase

1. Using Ore-3 and TF-21 aggregates each of the following mixes was prepared in sufficient quantities to fill four 1-pint, wide mouth fruit jars and two 1" x 1" x 10" expansion bar molds.

a. With $4\frac{1}{2} \pm \frac{1}{2}$% air

b. With $4\frac{1}{2} \pm \frac{1}{2}$% air with 1% NaOH

c. With 0.1 #/SK DC 777 and 1% NaOH

d. With 0.2 #/SK DC 777 and 1% NaOH

e. With 0.3 #/SK DC 777 and 1% NaOH

2. The Glass Jar portion of this test was conducted as follows:

a. Four jars were prepared for each aggregate and each condition. Two jars of each set were painted with boat glass and two with a non-reactive varnish.

b. The mix was placed in jar, leaving 1-inch clearance at the top. Struck jar on palm of hand to settle contents, capped, and set aside for 20-24 hours to harden. When hardened, added 25-50 cc. water and capped tightly. Turned jar upside down.

c. Jars stored at temperature of 100° - 105° F.

d. Jars inspected daily for cracking. Record kept of first crack and progress of cracking.

3. The Expansion Bar Test is standard and was run in accordance with ASTM C 227 except the mixing was done according to ASTM C 494.

B. Plastic Flow and Retardation Phase

1. Using the aggregate from Bk-141 and Washington State No. 1 and No. 6 the trial mixes were prepared according to ASTM C 494.

a. With 4.5 ± 5% air

b. With 0.3 #/SK DC 777 Admixture, no air

2. Plastic Flow Test performed as follows:

a. The concrete was placed in the mold in two (2) layers and rodded thirty strokes per layer uniformly over the entire surface of each layer.