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EVALUATION OF "POZICON" FLY ASH CONCRETE ADMIXTURE
INTERIM REPORT

MICHIGAN
HIGHWAY
RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

EVALUATION OF "POZICON" FLY ASH CONCRETE ADMIXTURE
INTERIM REPORT

H. L. Patterson

Research Laboratory Section
Testing and Research Division
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INTRODUCTION

On February 2, 1971, the Department's New Materials Committee approved for further consideration a processed fly ash material called "Pozicon" which was submitted by the Michigan Ash Sales Co., Essexville, Michigan. This firm obtains the fly ash from a coal-burning power plant and processes it to remove the larger ash particles and the residual carbon particles. Upon completion of this process, the resulting product "Pozicon" meets the Bureau of Reclamation's Fly Ash Specification, as well as ASTM C 618 (Type F), and U. S. Corps of Engineers CRD 262 F.

This product is being considered to determine whether its pozzolanic action will effect a significant improvement in the quality of pavement and bridge concrete, while reducing the quantity of portland cement in the mix. Pozzolanic action describes the chemical reaction that occurs between hydrated lime and finely divided non-crystalline, siliceous particles. The product of this reaction is a natural cement which was commonly used in the construction of roads and structures prior to the development of blended calcined cements. Processed fly ash is composed of spherically shaped minute, glassy mineral particles; when used in modern concrete it combines chemically with the free lime that is generated as the cement hydrates. This reaction occurs at normal atmospheric temperatures to form additional cementing materials and thus enhances the strength of the concrete. Pozicon has a loose weight of 75 lb per cu ft, as compared to 94 lb for portland cement.

Although the testing program is not complete at this time, this interim report is being written to inform Department personnel of the initial test results and of the possible potential usage of Pozicon as a partial replacement for portland cement and as an admixture in highway concrete.

TESTING PROGRAM

The various mixes used for the evaluation were as follows: A six sack mix containing Pozicon, which was recommended by the Michigan Ash Sales Co., where 12 percent of the cement was removed and replaced by 100 lb of Pozicon per cu yd of concrete; a standard six sack control mix for comparison; a seven sack mix containing Pozicon where 20 percent of the cement was removed and replaced by an equal weight of Pozicon; a seven sack mix

TABLE 1
CONCRETE MIX DATA: Nominal 6 sack/cu yd

Series No.	Pour Date	Slump, in.	Entr. Air, %	Mix Vol, cu ft	Mix Components, lb/cu yd: Cement	Mix Components: Pozicon	Fine Agg. 2NS sand: Dry wt	Fine Agg. 2NS sand: Absorbed water	Coarse Agg. 6AA gravel: Dry wt	Coarse Agg. 6AA gravel: Absorbed water	Net Mix Water	Net Water-Cement Ratio: W/C	Net Water-Cement Ratio: W/C and fly ash	Total Water lb per cu yd	Admixture, fl oz per cu yd: A-E	Admixture, fl oz per cu yd: Water reducer & retarder
							6 SACK POZICON MIX A*									
A-1	4-19-71	3.1	4.5	2.03	501	101	1149	10	1967	23	230	0.46	0.38	263	12	27
A-2	4-20-71	4.2	6.9	2.17	485	99	1111	9	1904	23	234	0.48	0.40	266	12	26
A-3	4-21-71	4.2	6.4	2.28	492	100	1127	9	1931	23	226	0.46	0.38	258	12	26
							6 SACK CONTROL MIX B									
B-1	5-3-71	4.5	7.0	2.30	557	---	1214	10	1836	21	234	0.42	---	265	10	29
B-2	5-4-71	4.5	5.7	2.26	567	---	1236	10	1870	21	238	0.42	---	269	11	30
B-3	5-5-71	4.0	6.1	2.27	564	---	1230	10	1860	21	237	0.42	---	268	10	30

* 5-1/4 sacks cement + 100 lb Pozicon

TABLE 2
CONCRETE MIX DATA: Nominal 7 sack/cu yd

Series No.	Pour Date	Slump, in.	Entr. Air, %	Mix Vol. cu ft	Mix Components, lb/cu yd: Cement	Mix Components: Pozicon	Fine Agg. 2NS Sand: Dry wt	Fine Agg. 2NS Sand: Absorbed water	Coarse Agg. 6AA gravel: Dry wt	Coarse Agg. 6AA gravel: Absorbed water	Net Mix Water	Net Water-Cement Ratio: W/C	Net Water-Cement Ratio: W/C and fly ash	Total Water lb per cu yd	Admixture, fl oz per cu yd: A-E	Admixture, fl oz per cu yd: Water reducer & retard.
							7 SACK POZICON, POUR C*									
C-1	5-10-71	4.8	6.8	2.29	519	134	1113	9	1829	21	241	0.46	0.37	271	17	28
C-2	5-11-71	3.5	5.3	2.24	530	137	1138	10	1870	21	239	0.45	0.36	270	17	28
C-3	5-12-71	3.0	5.2	2.24	530	137	1138	10	1870	21	239	0.45	0.36	270	17	28
							7 SACK CONTROL, POUR D									
D-1	5-24-71	4.5	8.0	2.30	649	---	1099	9	1804	22	248	0.38	---	279	14	35
D-2	5-25-71	4.3	8.0	2.30	649	---	1099	9	1804	22	248	0.38	---	279	12	35
D-3	5-26-71	4.5	7.4	2.29	652	---	1104	9	1812	22	249	0.38	---	280	12	35
							7 SACK POZICON, POUR E**									
E-1	5-31-71	4.0	5.5	2.27	494	200	1025	9	1913	23	246	0.50	0.35	277	16	26
E-2	6-1-71	4.0	5.5	2.27	494	200	1025	9	1913	23	246	0.50	0.35	277	16	26
E-3	6-2-71	4.2	5.4	2.27	494	200	1025	9	1913	23	248	0.50	0.36	280	16	26
							7 SACK CONTROL, POUR F									
F-1	6-7-71	3.8	5.4	2.26	661	---	1132	10	1858	21	254	0.38	---	285	11	35
F-2	6-7-71	3.2	5.1	2.25	664	---	1137	10	1866	21	254	0.38	---	285	11	35
F-3	6-8-71	3.2	4.7	2.25	664	---	1137	10	1866	21	258	0.39	---	289	11	35

* 5.6 sacks cement + 135 lb Pozicon.
** 5-1/4 sacks cement + 200 lb Pozicon.

containing Pozicon where 25 percent of the cement was removed and replaced by 200 lb of Pozicon per cu yd of concrete; and two, seven sack control mixes for comparison. The first mix is about the same as a standard bridge deck mix used in Alabama; namely, 5.2 sacks of cement plus 94 lb of fly ash. Each of these mixes contained admixtures to entrain air, to retard the set time, and to reduce the required mix water. Each was mixed for five minutes before slump and air content were measured. Complete mix details for all six mixes are contained in Tables 1 and 2. Three pours had to be made for each mix because of the limited capacity of the mixer, and the limited quantity of beam molds.

Peerless Type I portland cement (Detroit) was used in all six series, but the cement used in Series A and B was produced at an earlier date than the cement used in Series C, D, E, and F. It was thought at the time that the second cement might have slower strength gaining characteristics than the first, so some trial cylinders using the latter cement were poured to the Series B proportioning. Three-day compression tests showed no significant strength variation, so it was concluded that the difference must be in the different mix proportioning of each series.

To determine the various properties of the Pozicon and control concretes, the specimens and test intervals described below were used.

Compression and flexural strength were determined from 15, 4 by 8-in. cylinders and 15, 3 by 4 by 16-in. beams. These specimens were tested in groups of three after moist curing intervals of 3 days, 7 days, 28 days, and 12 weeks. The remaining three specimens of each type were tested after a 12 week Simulated Bridge Deck Cure (SBDC) which consisted of one week moist curing, three weeks air drying, three weeks moist curing, two weeks air drying, and three weeks moist curing. The latter cure was included to roughly approximate the natural field curing which occurs during the first year after pavement or bridge deck is poured. Compression and flexure test results are shown in Tables 3 and 4, respectively.

Freeze-thaw durability was determined from 6, 3 by 4 by 16-in. beams; three of these beams were given 14 days moist room curing and the other three were given the SBDC described above. Immediately after curing, these beams were started in rapid freeze-thaw testing in accordance with ASTM C291-67, and were checked for internal disintegration by the periodic determination of their relative dynamic modulus of elasticity; this latter test is also described in the above ASTM standard. At the completion of freeze-thaw testing, the beams will be broken to determine their flexural strength. Currently, the testing of the 14 day moist cured specimens is

TABLE 3
COMPRESSIVE STRENGTH SUMMARY - 4 by 8-in. CYLINDERS
(Cured in Moist Curing Room)

Mix Description	Series No.	Compressive Strength (avg. of 3), psi				
		3 day	7 day	28 day	12 week	SBDC
6 sack Pozicon	A-1	3330	4020	4050	6180	6330
6 sack control	B-1	3260	4130	4800	4730	4790
7 sack Pozicon	C-1	2580	2930	4540	5650	5510
7 sack control	D-1	2920	3710	4550	4790	5060
7 sack Pozicon	E-1	2890	3280	4520	5330	5340
7 sack control	F-1	3810	4230	4680	4940	5680

TABLE 4
FLEXURAL STRENGTH SUMMARY - 3 by 4 by 16-in. BEAMS
(Cured in Moist Curing Room)

Mix Description	Series No.	Flexural Strength (avg. of 3), psi				
		3 day	7 day	28 day	12 week	SBDC
6 sack Pozicon	A-1	582	640	739	---	---
	A-2	---	---	---	754	745
6 sack control	B-1	571	663	736	---	---
	B-3	---	---	---	897	786
7 sack Pozicon	C-1	486	611	676	---	---
	C-3	---	---	---	862	850
7 sack control	D-1	491	582	763	---	---
	D-3	---	---	---	764	799
7 sack Pozicon	E-1	516	568	782	---	---
	E-3	---	---	---	785	840
7 sack control	F-1	610	724	804	---	---
	F-3	---	---	---	782	790

complete and the results are shown in Figures 1 and 2 and Table 5. Figures 1 and 2 show the relative dynamic modulus of elasticity of the beams and Table 5 shows their average flexural strength after 336 freeze-thaw cycles.

TABLE 5
FLEXURAL STRENGTH AFTER FREEZE-THAW TEST
(14 Day Cure in Moist Curing Room)

Mix Description	Series No.	Strength after 336 Freeze-Thaw Cycles, psi
6 sack Pozicon	A-2	403
6 sack control	B-2	679
7 sack Pozicon	C-2	593
7 sack control	D-2	520
7 sack Pozicon	E-2	606
7 sack control	F-2	549

The resistance to surface scaling, caused by de-icing salts, was determined by 6, 9 by 12 by 2-1/2-in. slabs with mortar dikes built around their perimeters. Three of these slabs were given 14 days moist room curing and the other three were given the SBDC. Upon completion of curing, these slabs were allowed to air dry for 14 days before freeze-thaw testing began. The freeze-thaw testing was carried out at one cycle per day between 0 and 75 F, with water or brine ponded within the dikes. The cycles were run in groups of ten with a 3-percent salt solution on the surface through the first seven cycles, and fresh water through the remaining three cycles. After each 20 cycles of freeze-thaw testing, the disintegrated concrete was washed off the surface of the slabs and they were allowed to surface dry before being inspected, rated, and photographed. Currently, the testing of the 14-day moist cured slabs has progressed through 60 freeze-thaw cycles. These results are shown in graphical form in Figures 3 and 4. In the figures, the degree of scale is rated between the numbers 1 and 5: 1 is an unscaled surface and 5 is a heavily scaled surface. The values shown for each series is the average rating of three slabs.

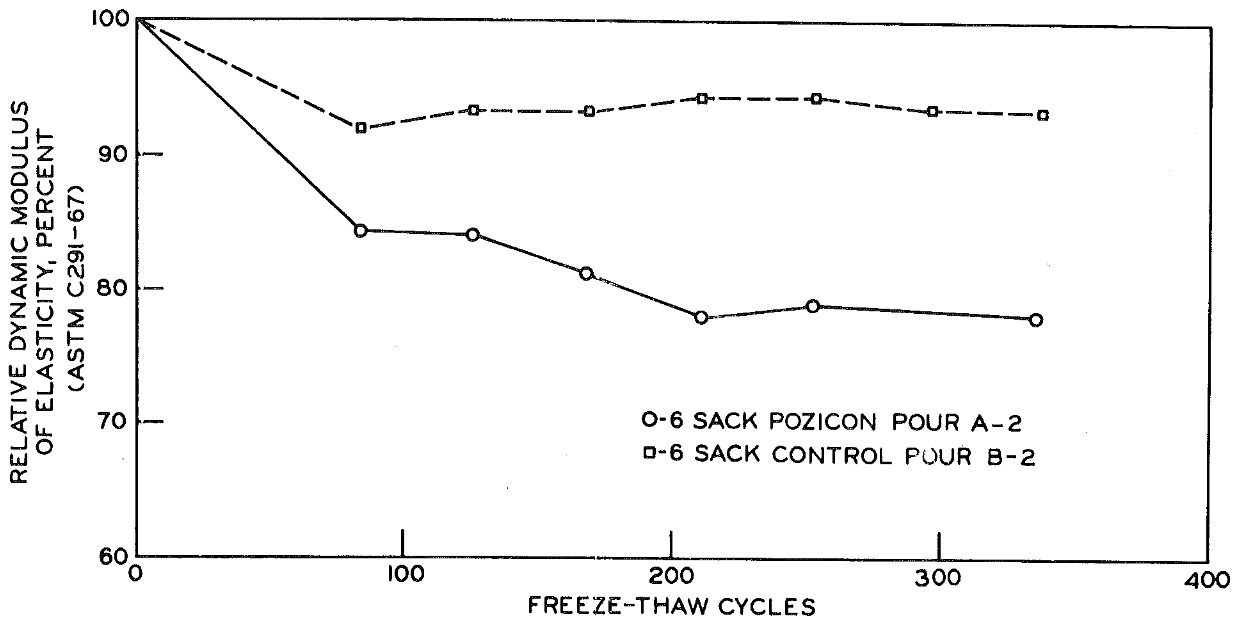

Figure 1. Internal freeze-thaw durability of series A and B concrete beams (3 by 4 by 16 in.) tested immediately following 14 days moist room curing.

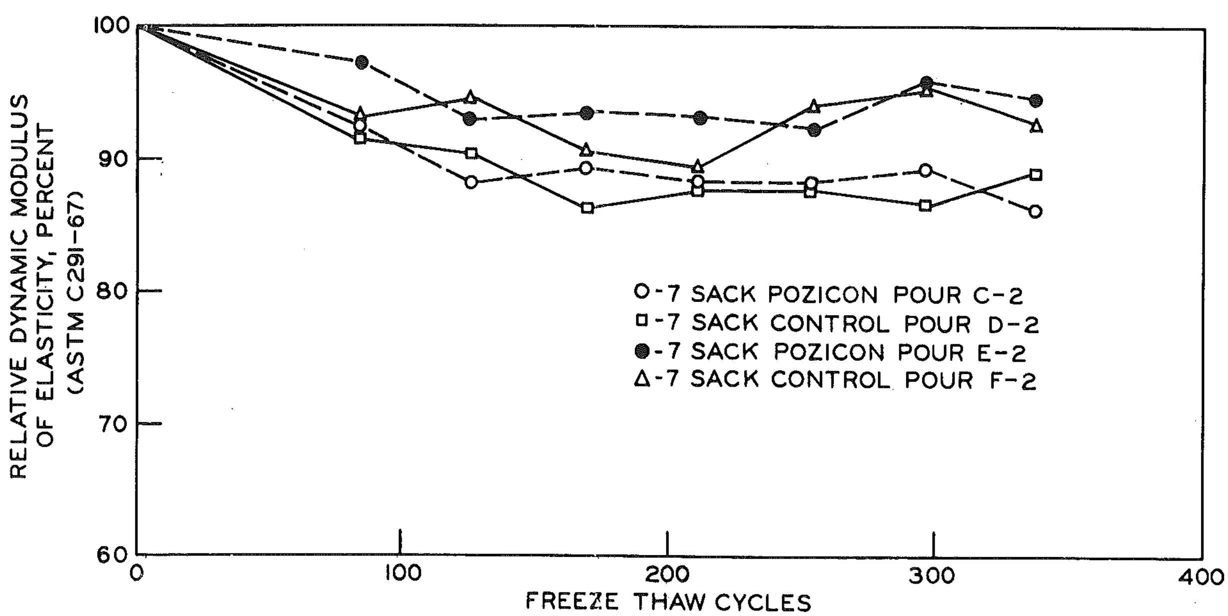

Figure 2. Internal freeze-thaw durability of series C, D, E, and F concrete beams (3 by 4 by 16 in.) tested immediately following 14 days moist room curing.

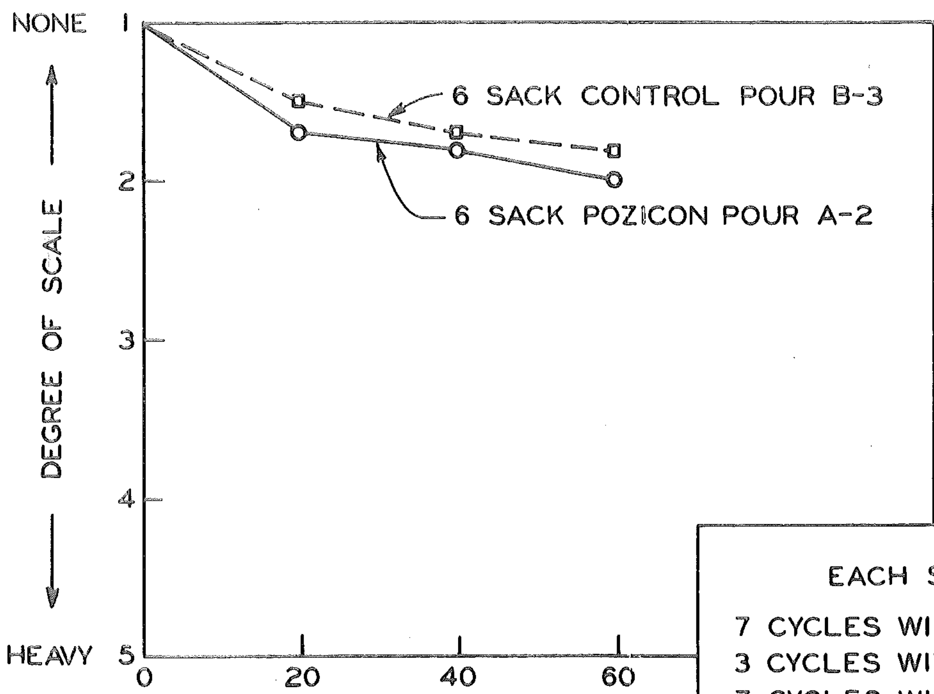

Figure 3. Surface freeze-thaw durability for series A and B scaling slabs cured 14 days in moist room and air dried 14 days prior to freeze-thaw testing.

EACH SET INCLUDES:

7 CYCLES WITH 3% SALT WATER
3 CYCLES WITH FRESH WATER
7 CYCLES WITH 3% SALT WATER
3 CYCLES WITH FRESH WATER

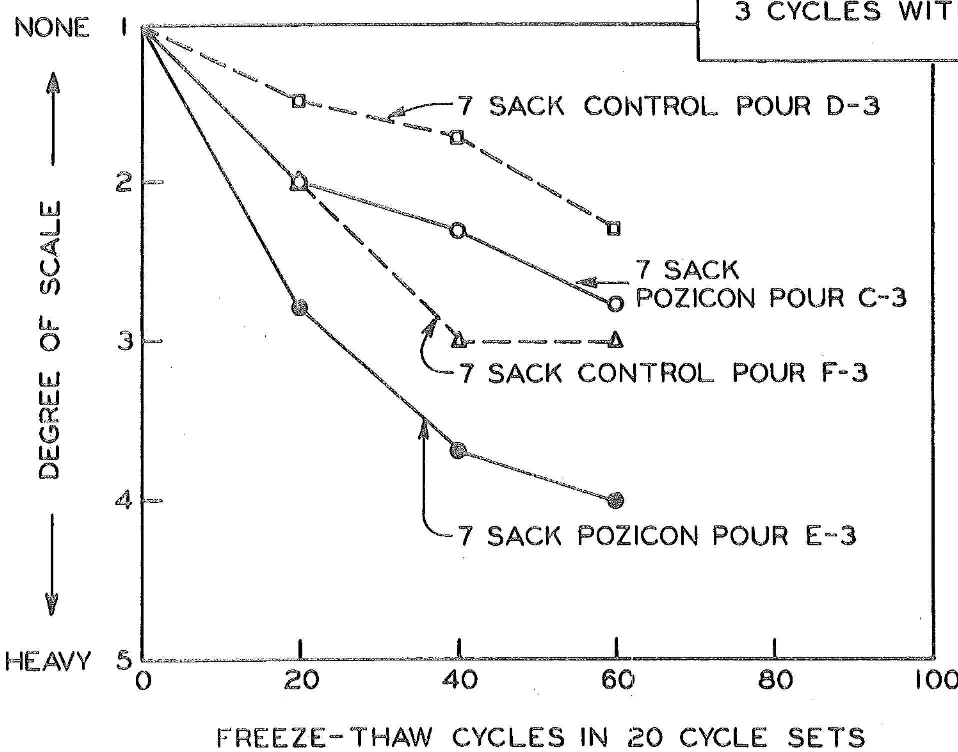

Figure 4. Surface freeze-thaw durability for series C, D, E, and F scaling slabs cured 14 days in moist room and air dried 14 days prior to freeze-thaw testing.

The length and weight variations of the various concretes were determined by 3 by 3 by 15-in. shrinkage prisms that had stainless steel studs embedded in their ends to facilitate periodic length measurements. Three sets of three prisms were cast for each concrete, and were moist cured for 14 days, 12 weeks, and given the SBDC. Following their respective cures, each set of prisms will be allowed to air dry for six months in the laboratory to check their relative shrinkage and weight loss characteristics. Figures 5 and 6 show the length variation graphs through four weeks of air drying for the SBDC specimens; the corresponding weight variation graphs are shown in Figures 7 and 8.

To determine the concrete's absorption and salt penetration characteristics, 3-in. diameter, 6-in. long cylinders were cast and moist cured for 7 days, 12 weeks, and the SBDC. Following each cure, three cylinders were used to determine the concrete's specific gravity and moisture content. The absorption cylinders were allowed to air dry for three weeks before being submerged in a 4-percent NaCl solution where their absorption rate was measured at 6 and 24 hours, and 3 and 7 days. Upon removal from the salt solution at 7 days, their drying rate was measured at the same intervals. Table 6 contains the absorption data for all three curing intervals. The salt penetration data have not been reduced or tabulated at this time.

TEST RESULTS

Concrete Strength

Tables 3 and 4 show that the three Pozicon mixes perform very favorably as compared with the three control mixes. The strength development of Pozicon series A is excellent in the early and long-term cure tests with an unexplainable lag occurring between the 7 and 28 day test intervals. The strength enhancing effect of the fly ash's pozzolanic action becomes very obvious in the long term cures when it is compared with the control B cylinders which cease to gain strength after 28 days. Pozicon Series E performed very well and although Pozicon Series C lags the others in the 3 and 7 day compression tests, it exceeded most of the others in the two long-term cure tests.

Resistance to Freeze-Thaw Deterioration

Figures 1 and 2 and Table 5 show how the 14-day moist room cured concrete performed throughout and following 336 freeze-thaw cycles.

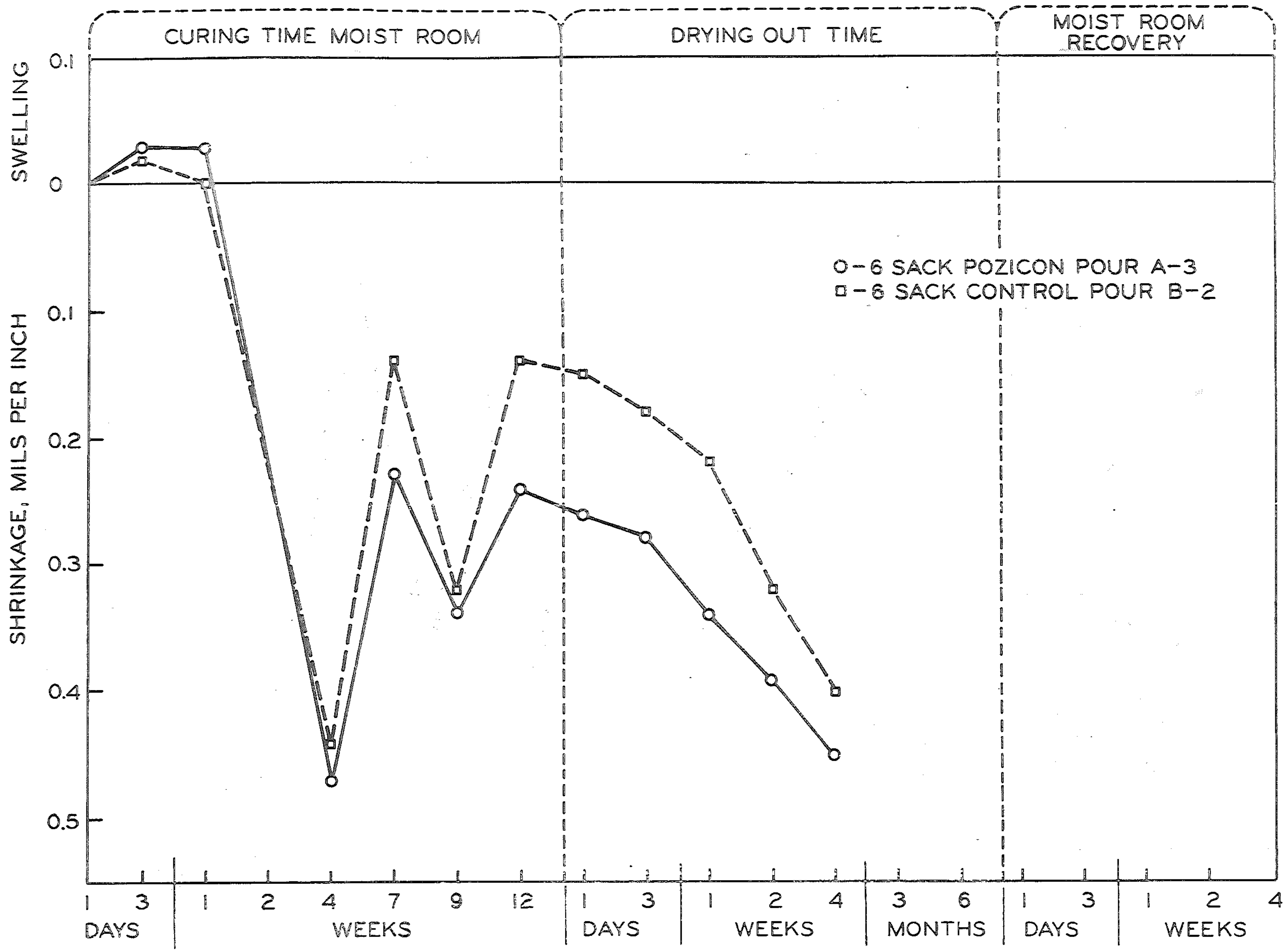

Figure 5. Shrinkage prism length variation of series A and B SBDC prisms.

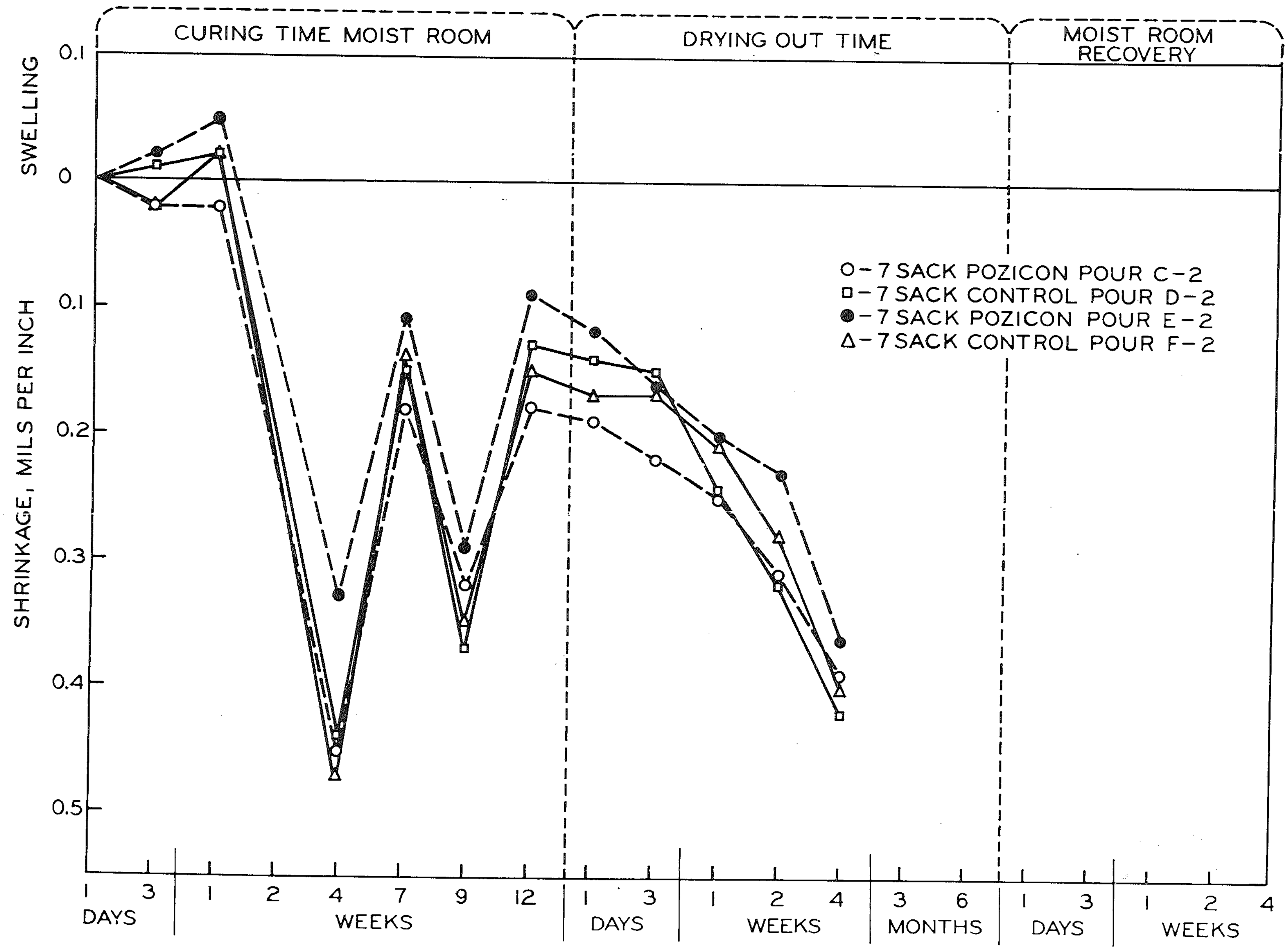

Figure 6. Shrinkage prism length variation of series C, D, E, and F SBDC prisms.

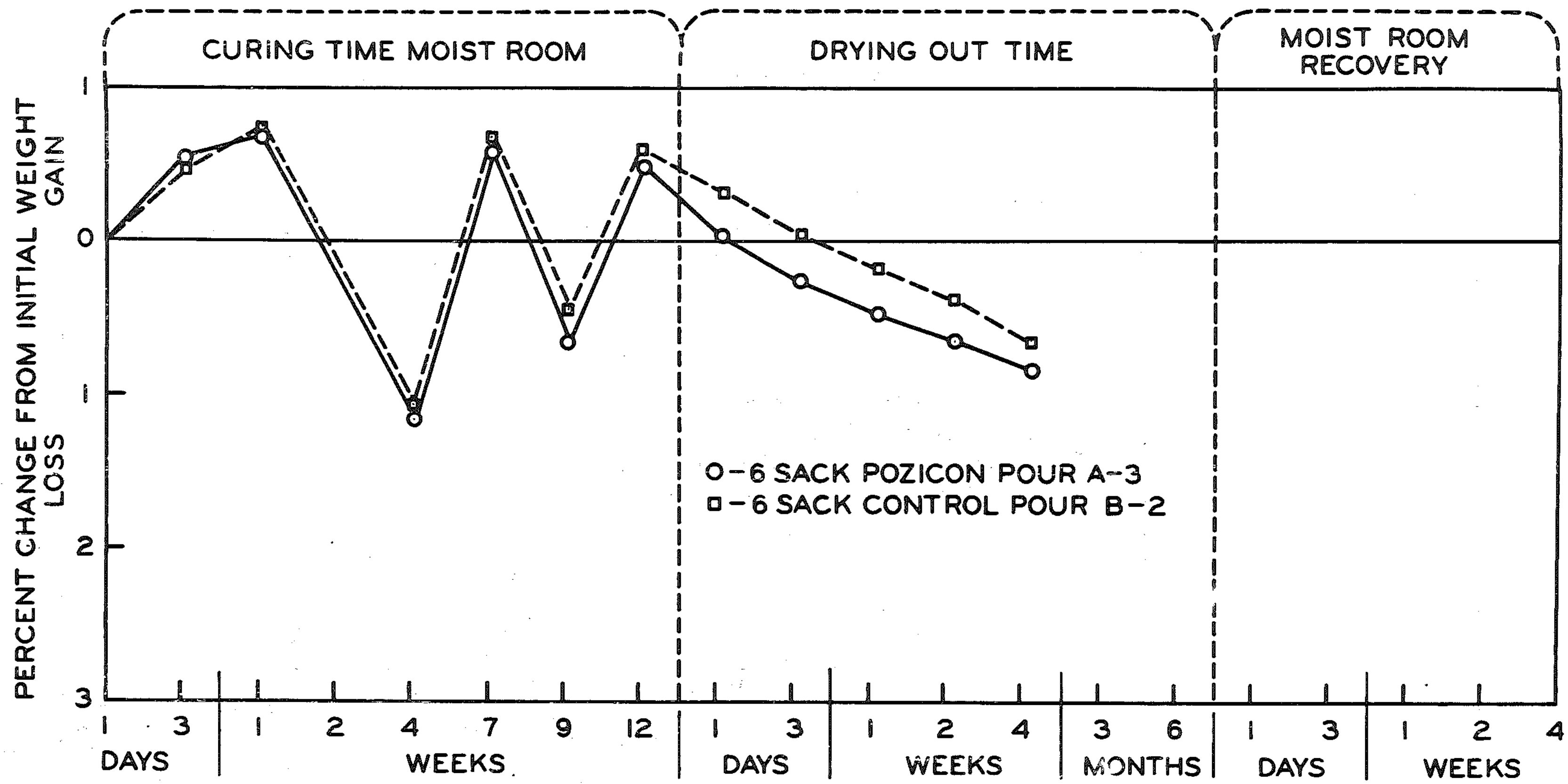

Figure 7. Shrinkage prism weight variation of series A and B SBDC prisms.

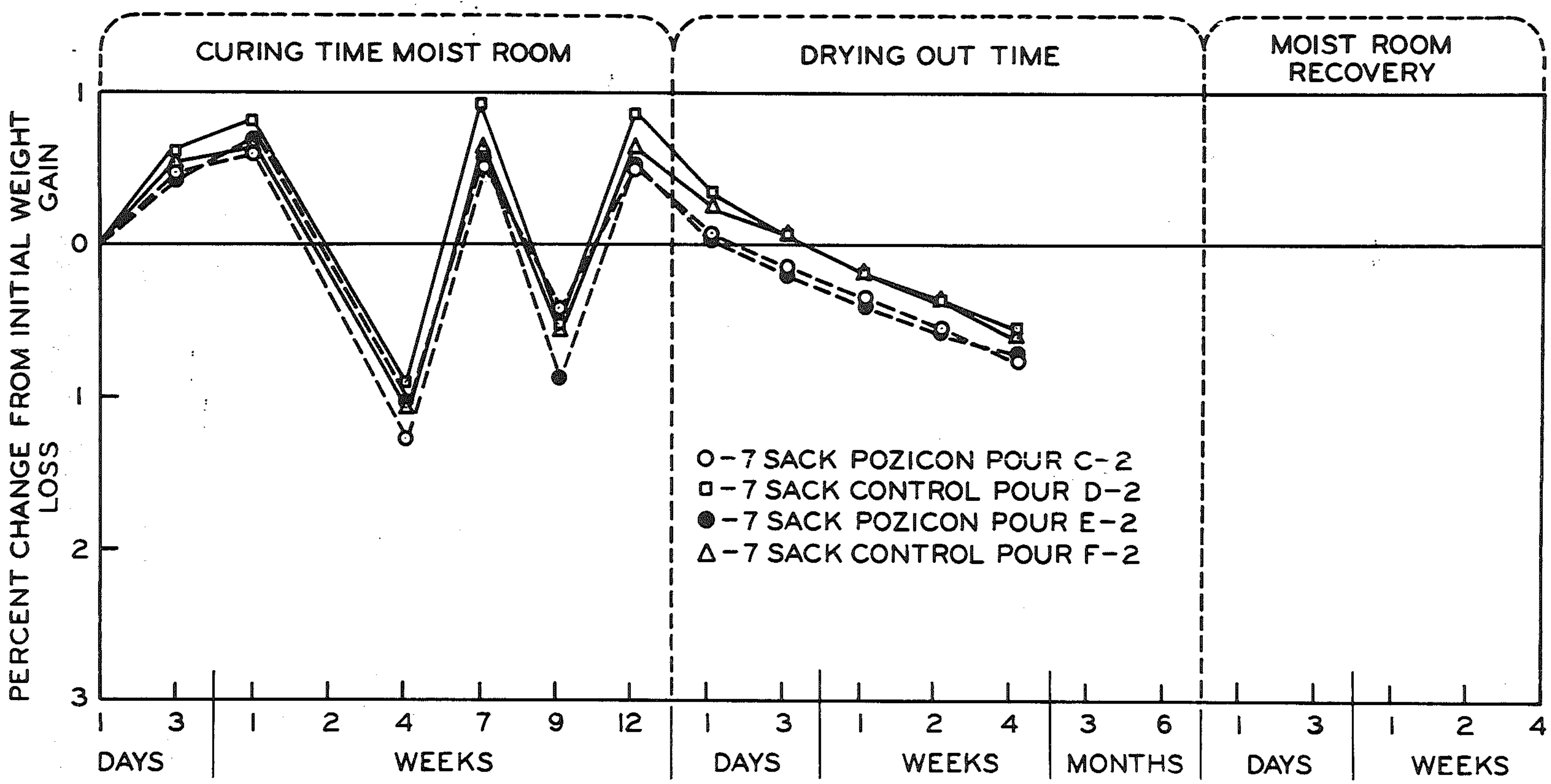

Figure 8. Shrinkage prism weight variation of series C, D, E, and F SBDC prisms.

TABLE 6
3 by 6-in. CYLINDER ABSORPTION CHARACTERISTICS
IN 4-PERCENT NaCl

	Mix Description	Series No.	Net Absorption,* percent				Dryout Reduction,* percent			
			6 hr	24 hr	3 day	7 day	6 hr	24 hr	3 day	7 day
7-Day Cure	6 sack Pozicon	A-3	1.2	1.4	1.7	1.8	1.4	1.2	0.9	0.6
	6 sack control	B-2	1.2	1.4	1.6	1.7	1.4	1.2	0.9	0.7
	7 sack Pozicon	C-2	1.2	1.5	1.6	1.8	1.4	1.2	0.9	0.8
	7 sack control	D-2	0.9	1.2	1.3	1.5	1.3	0.9	0.6	0.5
	7 sack Pozicon	E-2	1.3	1.5	1.6	1.7	1.3	1.1	0.9	0.6
	7 sack control	F-2	1.1	1.3	1.4	1.5	1.3	0.9	0.8	0.5
12-Week Cure	6 sack Pozicon	A-3	0.4	0.5	0.5	0.7	0.5	0.5	0.4	0.2
	6 sack control	B-2	0.3	0.4	0.4	0.5	0.4	0.3	0.2	0.1
	7 sack Pozicon	C-2	0.5	0.5	0.6	0.7	0.5	0.4	0.3	0.2
	7 sack control	D-2	0.4	0.5	0.6	0.7	0.5	0.4	0.2	0.1
	7 sack Pozicon	E-2	0.5	0.6	0.7	0.8	0.7	0.5	0.4	0.2
	7 sack control	F-2	0.4	0.5	0.6	0.7	0.5	0.5	0.3	0.1
SBDC	6 sack Pozicon	A-3	0.4	0.6	0.6	0.8	0.6	0.6	0.4	0.2
	6 sack control	B-2	0.4	0.6	0.7	0.8	0.6	0.5	0.4	0.3
	7 sack Pozicon	C-2	0.5	0.6	0.8	0.9	0.8	0.6	0.4	0.3
	7 sack control	D-2	0.5	0.6	0.7	0.8	0.7	0.5	0.4	0.3
	7 sack Pozicon	E-2	0.4	0.6	0.8	0.8	0.6	0.5	0.3	0.2
	7 sack control	F-2	0.5	0.6	0.7	0.8	0.6	0.6	0.5	0.3

*Percent absorption over pre-test moisture content

** Cure period followed by 21 days air drying prior to pre-test weight measurement.

Figure 1, which shows the relative dynamic modulus of elasticity for the Pozicon Series A and control B beams, indicates that the Pozicon Series A beams lost approximately 22 percent of their initial modulus value, while the control Series B beams lost only 7 percent of their initial modulus value. It is interesting to note in Table 1 that the A-2 pour contained 6.9 percent entrained air while B-2 contained 5.7 percent entrained air; this fact should have favored the A-2 mix. It will have to be assumed that the A-2 mix was more permeable than the B-2 mix at 14 days moist cure, which made it more vulnerable to freeze-thaw breakdown. A longer curing period should benefit the Pozicon mixes with respect to durability as well as strength gain.

Figure 2, which shows the relative dynamic modulus of elasticity for the Pozicon Series C and E, and control D and F beams, indicates that all the beams performed well, but many of the curves--especially the F series--fluctuated up and down over 5 percent. The Series E beams performed consistently the best, dropping a maximum of only 8 percent of their original modulus. The Series C and D beams lost more of their original modulus with a maximum drop of 14 percent.

The information given in Table 5 is the average flexural strength developed by the beams after 336 cycles of freeze-thaw testing. It is in basic agreement with the trend established in Figure 1; that the beams from pour A-2 apparently lost more of their original strength than the beams from pour B-2. It is unfortunate, however, that no other strength data are available from these pours with which we could draw a comparison.

Figures 3 and 4 show the results of testing on the 14-day moist room cured scaling slabs. Currently, testing has progressed through 60 freeze-thaw cycles. The average scale condition for all six series is seen to fall between the 2 and 3 rating except for the extraordinarily superior B Series which is above the 2 rating, and the apparently vulnerable Pozicon Series E which has dropped to the 4 rating. From the present graph it is impossible to predict what the scale rating of the various series will be after 100 cycles, but at the present time it appears that the Pozicon Series A and C are performing creditably in comparison to their controls. It will also be interesting to see how the companion sets of scaling slabs cured with the SBDC method compare with the above 14-day moist cure slabs. The results from these slabs will appear in a later report.

<u>Length and Weight Variation Characteristics</u>

Figures 5 and 6 show the length variation and Figures 7 and 8 show the weight variation of the SBDC prisms. As explained previously, these prisms were alternately moist cured and air dried to more closely simulate field curing than continuous moist curing could. At the end of four continuous weeks of air drying, the Pozicon Series A prisms have shrunk more than their control B prisms, but the Pozicon Series C and E prisms have shrunk slightly less than their control counterparts. At this time it is impossible to predict what the maximum shrinkage of the prisms will be at six months, but the current trends indicate that the control prisms are shrinking faster than the Pozicon prisms.

In their present incomplete stage, the weight variation curves shown in Figures 7 and 8 provide little additional information about the Pozicon and control concretes, other than to show that the weight and length variation curves are quite similar.

The complete data, including the length and weight variation characteristics of the 14-day and 12-week cure specimens will be presented in a later report.

Absorption Characteristics

Table 6 gives the net absorption characteristics of all six concretes for each of the three curing intervals. The figures shown represent only the percentages of brine absorbed over the pre-soaking concrete weight after 21 days air drying, and does not represent the total moisture content of the concrete.

The figures show that little difference exists between the absorption amount and rates of the Pozicon and control concretes for the longer cures; however, as might be expected, the Pozicon concretes with only seven days cure are slightly more permeable than the control concretes. The most noticeable fact in the table is the substantial reduction in the rate of absorption of all six concretes that occur after the concrete becomes fully cured. This fact is one reason why green concrete is much more susceptible to freeze-thaw deterioration than fully cured concrete.

Observations

The Pozicon weaknesses recognized thus far are the lower strength and high permeability characteristics of the short-cured test specimens; the longer cured specimens seemed to have overcome both the strength and permeability problems.

From the test results currently available, it appears that a Pozicon mix similar to the Series C mix might have some possibilities for use in highway construction. Pozicon Series E, because of its susceptibility to spalling, would be unsuitable in any highway application where it would be confronted with de-icing salts; likewise Series A would be undesirable because of its apparent freeze-thaw vulnerability.

The test data measurements will not be completed until next spring, but the performance displayed by the C Series in this report is encouraging enough to justify additional work with variations of the C mix. The next report will be written in the spring and will include the complete testing program data for Series A through F as well as partial test data obtained from any subsequent Pozicon series. From that data it might be possible to make a recommendation for a field application. If quality equivalent to a seven sack mix can be produced with a Pozicon-enriched, five and one-half or six sack mix at a savings in cost, there would be a strong incentive to take advantage of this additional strength for bridge deck construction. Current prices indicate a 75 lb bag of Pozicon is only one-third the price of portland cement per bag.