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"POZICON" FLY-ASH PAVEMENT CONCRETE - DEVELOPMENT WORK
Second Progress Report

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"Pozicon" fly-ash pavement concrete, development work, second progress report

"POZICON" FLY-ASH PAVEMENT CONCRETE - DEVELOPMENT WORK
Second Progress Report

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INTRODUCTION

The initial report (MDSHT Research Report R-799), dated December 1971, contains a brief description of the background of Pozicon and its properties. That report also contains the early test results for Pozicon and control mix series A through F, and found that the C mix was apparently the most encouraging of all the Pozicon mixes tested (5.6 sacks of portland cement plus 135 lb of Pozicon per cu yd).

The current report contains the complete test data on the preliminary bridge concrete series A through F and also a subsequent series, L through Q; mixes G through K were exploratory in nature and are not included with this report. Also included is an accelerated series that evaluates the performance of Pozicon in a slip-form pavement concrete. This series was set up to determine whether Pozicon would be beneficial in slip-form paving operations, where consolidation is difficult because of the low slump stiffness of the concrete. It was hoped that the internal fluidizing nature of the Pozicon might aid consolidation, especially where the two-lift placement technique is employed. In this technique, the concrete for the lower lift is spread over the grade with a minimum of vibration; this is done to prevent the rise of bleed water and the resulting possible delamination plane. Next, the steel reinforcing mat is placed on top of the lower lift, and several minutes later the top lift is added; the paving machine then screeds, vigorously vibrates, and finishes the top surface. The difficulty arises in that the bottom lift is never consolidated by direct vibration, but depends upon vibrations that are transmitted down through the top lift; thus the internal fluidity of the concrete governs the degree of consolidation that will occur. Areas vulnerable to poor consolidation may occur between the lifts and throughout the lower lift.

TESTING PROGRAM

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

First and Second Stage

Compression and flexural strengths 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 that occurs during the first year after pavement or bridge decks are poured.

Freeze-thaw durability was determined from six, 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 C666-73 (Part B) 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 Standards. At the completion of freeze-thaw testing, the beams were broken to determine their flexural strength.

The resistance to surface scaling caused by de-icing salts was determined essentially as per ASTM C672-72T, using six, 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 NaCl 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. The degree of scale was rated between the numbers 1 and 5; 1 being an unscaled surface and 5 a heavily scaled surface.

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 during the SBDC. Following their respective cures, each set of prisms was allowed to air dry for six months in the laboratory to check their relative shrinkage and weight loss characteristics. Following the six month dry out measurements, the prisms were placed back in the moist room to check their recovery rate.

To determine the concrete's absorption characteristics, 3-in. diameter by 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.

The salt penetration characteristics, as well as the absorption characteristics, were determined by the use of 3-in. diameter by 6-in. long cylinders. These were also moist cured for 7 days, 12 weeks, and the SBDC. Immediately following the curing interval, these cylinders were prepared to simulate bridge deck concrete. The cylindrical surface was sealed with paraffin to prevent penetrating moisture from migrating to that surface and evaporating, and a dike collar fashioned from a 2-in. length of cardboard cylinder mold was fitted over the top end and sealed around its circumference. The prepared cylinder was then allowed to air dry for 21 days after which a 4-percent NaCl solution was ponded within the dikes and covered with polyethylene to impede evaporation. This solution was continuously maintained on the surface of nine cylinders; penetration depth was then evaluated in groups of three at one, three, and six month intervals. The evaluation technique involved physically stripping the paraffin and dike from the cylinders, sawing off slices, and chemically measuring the salt content of the pulverized concrete. Four slices were cut from each cylinder at depths of 1/4, 1/2, 1, and 2 in. from the top.

Pozicon in Slip-Form Concrete

Compression strengths, specific gravities, and moisture contents were determined from six 4 by 8-in. cylinders that were tested in groups of three at 7 and 28 days. The first group was cured continuously in the moist room prior to the 7-day test, and the second group was given a "special" cure prior to their test, which included 7 days in the moist room, 14 days air drying in the laboratory, and 7 more days in the moist room. The latter "special" cure was included to simulate a 28-day field cure of concrete pavement.

Freeze-thaw durability was determined from three 3 by 4 by 16-in. beams; these were given the special cure described above. Immediately after curing, these beams were started in rapid freeze-thaw testing as described for the other series, and were tested in the same manner.

The length and weight variation was determined by 3 by 3 by 15-in. shrinkage prisms that had stainless steel studs embedded in their ends to facilitate periodic length measurements. One set of three prisms were

TABLE 1
FIRST STAGE 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						Net Mix Water	Net Water-Cement Ratio		Total Water lb per cu yd	Admixture, fl oz per cu yd	
					Cement	Pozicon	Fine Agg. 2NS sand		Coarse Agg. 6AA gravel							
							Dry wt	Absorbed water	Dry wt	Absorbed water		W/C	W/C and fly ash		A-E	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
FIRST STAGE 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						Net Mix Water	Net Water-Cement Ratio		Total Water lb per cu yd	Admixture, fl oz per cu yd	
					Cement	Pozicon	Fine Agg. 2NS Sand		Coarse Agg. 6AA gravel							
							Dry wt	Absorbed water	Dry wt	Absorbed water		W/C	W/C and fly ash		A-E	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.

cast for each concrete and had the same special cure as described for the cylinders. Following the cure, the prisms were allowed to air dry in the laboratory for six months; then back into the moist room for four weeks of recovery.

To determine the beneficial effects of Pozicon as an internal fluidizer, three 6 by 12-in. cylinder molds were used with surface vibration on two independently placed layers of concrete to determine the degree of consolidation that could be obtained. The procedure used was as follows: the molds, cut to a standard pavement depth of 9 in., were filled to a 6-in. depth with concrete which was leveled off but not rodded or vibrated in any way. After the layer of concrete had sat undisturbed for five minutes, more concrete was added to fill the mold to the top. The top surface of the concrete in each mold was then carefully vibrated for an eight-second duration to simulate the vibrations from the passing probe and pan vibrators on a paving machine. This was accomplished with a 1-in. diameter probe type laboratory vibrator which was held in the concrete a depth of 2 in. in a position slightly inclined to the horizontal. It vibrated the concrete for four seconds in each of two positions which were 180-degrees apart from each other. Care was taken that the probe vibrator did not touch any part of the cardboard mold as this would carry vibrations through the cardboard directly to the lower layer. It was thought that this procedure would roughly simulate actual field condition. These cylinders were given the same special cure of the other specimens and were evaluated by sawing each into thirds and independently measuring the volume of permeable voids, the specific gravity, and the absorption properties of each third in accordance with ASTM C 642. Prior to the evaluation, the troweled top surface of each cylinder was ground off with carborundum and the bottom formed surface was sliced off to maintain uniformity between slices.

In this abbreviated evaluation, the flexure beams, scaling slabs, and absorption cylinders were not used.

Concrete Mixes and Preparation - First Stage

This set of concrete specimens was designated A through F and is described in detail in the initial report (MDSHT Research Report R-799). The concrete mix data from that report are given in Tables 1 and 2.

Because of the laboratory rotary mixer's small capacity of 2 cu ft, three batches had to be poured to mold all of the required specimens of any one series. This created the problem of obtaining consistent slump and entrained air values in all batches of the series. The problem was solved by rigidly controlling the coarse aggregate gradation, the batch size, and

TABLE 3
SECOND STAGE MIX DATA

	Mix No.	Pour Date	Slump, in.	Entrained Air, percent	Mix Volume, cu ft	Mix Components, lb/cu yd						Net Mix Water	Net Water/Cement Ratio		Total Water, lb per cu yd	Admixture fl oz/cu yd	
						Cement	Pozicon (fly ash)	Fine Aggregate 2NS Sand		Coarse Aggregate 6AA Gravel							
								Dry Wt.	Absorbed Water	Dry Wt.	Absorbed Water		W/C	W/C + Fly Ash		A-E	W.R. & R.
Control Mix L	L-1	5/22/72	5.0	6.0	2.22	559	---	1,239	10	1,866	22	233	0.42	--	265	4.4	30
	L-2	5/23/72	4.8	5.9	2.22	559	---	1,239	10	1,866	22	233	0.42	--	265	4.4	30
	L-3	5/24/72	5.0	5.8	2.22	559	---	1,239	10	1,866	22	233	0.42	--	265	4.4	30
	L-4	5/24/72	3.0	4.5	0.99	568	---	1,259	11	1,897	22	236	0.42	--	269	4.5	30
Pozicon Mix M	M-1	6/6/72	4.5	6.5	1.92	520	131	1,060	8	1,893	20	241	0.46	0.37	269	17	28
	M-2	6/6/72	4.5	6.2	1.91	523	132	1,066	8	1,904	20	242	0.46	0.37	270	17	28
	M-3	6/7/72	4.8	6.4	1.92	520	131	1,060	8	1,893	20	241	0.46	0.37	269	17	28
	M-4	6/8/72	4.5	6.6	1.92	520	131	1,060	8	1,893	20	241	0.46	0.37	269	17	28
Pozicon Mix N	N-1	6/12/72	5.0	6.8	2.09	511	117	1,097	9	1,875	22	237	0.46	0.38	268	15	28
	N-2	6/13/72	5.0	6.5	2.08	512	118	1,099	9	1,880	22	238	0.46	0.38	269	15	28
	N-3	6/13/72	5.0	6.6	2.08	512	118	1,099	9	1,880	22	238	0.46	0.38	269	15	28
Pozicon Mix P	P-1	6/19/72	4.8	5.9	2.07	515	108	1,115	9	1,906	22	236	0.46	0.38	267	13	28
	P-2	6/20/72	4.5	5.7	2.06	516	108	1,118	9	1,910	22	237	0.46	0.38	268	13	28
	P-3	6/21/72	5.0	5.7	2.06	516	108	1,118	9	1,910	22	237	0.46	0.38	268	13	28
Pozicon Mix Q	Q-1	6/26/72	4.8	6.5	1.92	489	99	1,154	10	1,890	22	228	0.47	0.39	260	15	26
	Q-2	6/26/72	4.8	6.6	1.92	489	99	1,154	10	1,890	22	228	0.47	0.39	260	15	26
	Q-3	6/27/72	4.5	6.9	1.93	488	99	1,150	10	1,884	22	228	0.47	0.39	260	15	26
	Q-4	6/28/72	4.0	6.7	1.92	489	99	1,154	10	1,890	22	228	0.47	0.39	260	15	26

the absorbed moisture in both the fine and coarse aggregate. Since the gradation of the coarse aggregate purchased for this work was at the fine end of the allowable specification limits, the following gradation was used for all mixes in the First Stage.

Sieve Size, in.	Percent Passing
1 - 3/4	20
3/4 - 1/2	23
1/2 - 3/8	27
3/8 - No. 4	30

The moisture content of each batch was rigidly controlled as follows: all aggregate was oven dried, weighed out to the exact proportioning, and pre-soaked in water for 24 hours prior to the mixing operation. To the fine aggregate, the exact weight of the calculated absorption water was added, power mixed to a uniform consistency, and then sealed under polyethylene until concrete mixing time. The oven dry coarse aggregate was submerged in water until mix time; it was then drained, weighed, and the weight of water in excess of the saturated surface dry weight of the coarse aggregate was calculated and subtracted from the required weight of mix water.

For each of these pours, the concrete was mixed for five minutes and then placed in the molds immediately after the slump and air measurements were taken. Master Builders "Pozzolith 100R" water reducer/retarder admixture was used in all the mixes.

Concrete Mixes and Preparation - Second Stage

The mix data for the Second Stage set of mixes are shown in Table 3. These were set up on the assumption that the optimum Pozicon-to-cement ratio lay somewhere in between the ratios of the A and C mixes of the First Stage. In the Second Stage, series L is the control mix and corresponds closely with series B of the First Stage; similarly, series M corresponds with series C, and series Q with series A. The Pozicon-to-cement (P/C) ratio of series N and P were 0.23 for N and 0.21 for P; both series contained 5.5 sacks of cement per cu yd.

In the Second Stage mixes, adherence was made to the theory advanced by the Michigan Ash Sales Co. which maintains that Pozicon increases the internal fluidity of the mix sufficiently to allow a significant reduction in the fine aggregate-to-total aggregate ratio (FA/TA). This reduction was thought to be desirable because it produced a richer mortar and, logically therefore, a stronger concrete. In keeping with this concept, the FA/TA ratios of the Pozicon mixes were set as follows: 0.36 for series M; 0.37 for series N and P; and 0.38 for series Q. The FA/TA ratio of the control mix L was set at 0.40.

As in the First Stage, multiple batches for each set had to be poured to mold all the required specimens. Therefore, the same rigid control was exercised over batch size, coarse aggregate gradation, and aggregate absorbed moisture. The coarse aggregate gradation was held at the middle of the specification requirements and was proportioned as follows:

Sieve Size, in.	Percent Passing
1 - 3/4	28
3/4 - 1/2	26
1/2 - 3/8	24
3/8 - No. 4	22

Since this series of mixes was designed for bridge decks, where the concrete would be delivered to the construction site in transit mix trucks, it was decided a more realistic simulation could be achieved in the laboratory if the time interval between mixing the concrete and placing it in the molds were approximately the same as in the field. Therefore, to simulate this time interval, the concrete was allowed to set for 13 minutes after the initial four-minute mix; to further simulate field procedure, this 13 minute "transit time" was followed by a four-minute mix time, during which "slump adjustment water" was added to replace the free water absorbed by the cement.

A four-minute slump adjustment mix time was found to be necessary to rebuild the entrained air level that was lost during the first two minutes of remixing. It appeared that the concrete which sat in the idle laboratory mixer during the 13 minute transit time had stiffened sufficiently that the first two minutes of remixing 'fractured' it and caused a substantial loss of entrained air. However, after the slump adjustment water was thoroughly mixed in, and mixing continued through four minutes, it was found that the original level of entrained air was restored.

Concrete Mixes and Preparation - Slip-Form Concrete

The results of the Second Phase work indicated a fallacy in the proportioning of the Pozicon mixes from the control mix; the additional reduction of the FA/TA ratio (the percent fine aggregate of the total aggregate by volume) over the straight volume replacement of Pozicon for cement and fine aggregate apparently caused an increased harshness that in turn increased the water requirements. This increased mix water, which diluted the cement paste and increased the ultimate air drying shrinkage, defeated the original intent of producing a stronger concrete with a richer mortar.

The development of these slip-form pavement mixes was prompted by three primary considerations; that all mixes must meet the entrained air and slump requirements of slip-form concrete; that all Pozicon mixes must be kept directly related to the control mix; and, that all Pozicon mixes actually effect a total mix water reduction from the control mix.

With these considerations in mind, a concrete mix design chart for slip-form pavements was adapted to the laboratory aggregate and used as the control mix. From this control the three Pozicon mixes shown in Table 4 were developed. They include: mix BB that contained 5.50 sacks of cement and a weight of Pozicon equal to 15 percent of the weight of the cement; mix CC that contained 5.25 sacks of cement and Pozicon equal to 20 percent; and mix DD that contained 5.00 sacks of cement and Pozicon equal to 25 percent. The control is shown as mix AA in the table.

The three Pozicon mixes were designed directly from the control mix by the following procedure. The volume of cement reduction from the control mix was subtracted from the volume of Pozicon being used, and the remaining Pozicon volume was subtracted from the volume of fine aggregate in the control mix. The FA/TA ratio of the Pozicon mix was then determined from the reduced sand and unchanged coarse aggregate volumes of the control mix. Using the new FA/TA ratio and an estimated W/C ratio (ratio of water-to-cement by weight), the mix proportioning was then recalculated. This mix design would then be perfected by trial and error with adjustments made by varying the W/C ratio and air entrainment admixture level. The final mix design was achieved when the slump and air entrainment fell into design limits.

As with both previous series, the coarse aggregate was oven dried and soaked in absorption water for 24 hours prior to the actual mix time; after draining, the excess moisture remaining was calculated and subtracted from the mix water. To the oven dried fine aggregate, the required absorption water was added, mixed in, and stored in a sealed contained for 24 hours prior to mix time.

The concrete was mixed in accordance with the following procedure; the coarse aggregate was added first, then the cement and Pozicon, and finally the fine aggregate. This order was followed to keep the cement and

TABLE 4

POZICON IN SLIP-FORM PAVEMENT CONCRETE MIX DATA

Mix Designation	Pour Date	Slump, in.	Entrained Air, percent	Mix Volume, cu ft	Mix Components, lb per cu yd										Net Water/Cement Ratio		Total Water lb per cu yd	Admixture, fl oz/ cu yd	
					Cement	P/C Percent Weight	Pozicon (fly ash)	Fine Aggregate 2NS Sand		FA/TA Percent Weight	Coarse Aggregate 6AA Gravel		Net Mix Water					Darex A-E	Pozzolith 200N W. R.
								Wt.	Absorbed Water		Wt.	Absorbed Water			W/C	W/C + Fly Ash			
Control AA	4/2/73	1.8	6.3	1.90	565	--	----	1,084	9	35	2,034[1]	20	227		0.40	----	256	7.5	24
BB	3/27/73	2.0	5.6	1.88	523	15	79	1,054	9	34	2,060[1]	21	222		0.42	0.37	252	14	22
CC	3/13/73	2.0	5.7	1.88	499	20	101	1,048	9	34	2,042	23	224		0.45	0.37	256	19	21
DD	3/19/73	1.8	5.5	1.88	477	25	120	1,056	9	34	2,052	23	218		0.46	0.37	250	20	20

[1] New supply of coarse aggregate.

Pozicon from sticking to the mixer on the bottom and excessively dusting on top. The mixer was then started and the mix water, which contained the admixtures, added over a 10-second interval.

It was originally intended that the concrete be mixed for four minutes, but it was found that this low slump concrete lost its fluidity after three minutes of mixing and began "tumbling" in the mixer drum instead of "rolling." The point where tumbling started was found to be critical because it was at this point that the concrete began losing its entrained air. Therefore, during the mixing of the specimen concrete, the mixer was watched closely and when tumbling began, the concrete was dumped out into a retaining pan.

To simulate actual field conditions, the concrete--after being dumped from the mixer--was covered with polyethylene sheeting and allowed to set for seven minutes in the retaining pan. After this time the first layer was placed in 6 by 9-in. cylinder molds for the consolidation specimens while the slump and air entrainment measurements were made. When the concrete was a total of 15 minutes old, the top layer was added to the consolidation specimens and the concrete was rodded and tapped into the other molds for the remaining specimens.

The abbreviated set of specimens in this series was selected intentionally for two reasons: first, to reduce the volume and thereby eliminate the variations that inevitably accompany multiple batches of concrete; and, second, to expeditiously acquire a set of reliable test results upon which a competent evaluation could be based.

TEST RESULTS

First and Second Stages

As previously described under the slip-form pavement section of concrete mixes and preparation, the importance of keeping the Pozicon mixes directly related to the control mix was not realized when this work was done; hence, the data from Stages 1 and 2 will not be as valuable for determining superior proportioning as had been hoped. By coincidence, however, Pozicon mix C and Control mix D are fairly closely related.

Tables and graphs of the test results from the First and Second Stages are contained in the Appendix of this report.

The compressive strength data contained in Table A-1 of the Appendix indicates that the rate of strength gain of these mixes varies greatly with the proportion of Pozicon used, as would be expected. The values for Pozicon Mix C indicate that its strength gain is slowed through the first seven days, but it does catch up to Control mix D by the 28-day test and surpasses it in later tests.

The flexural strength data in Table A-2 indicate that for the Pozicon mixes there was a more uniform rate of flexural strength gain over the curing interval test times than there was for the compressive strength.

The data from rapid freeze-thaw (F-T) testing for Stages 1 and 2 are shown in Figures A-1 through A-4 in the Appendix and in Table A-3. The graphs shown in Figures A-1 through A-4 show the relative dynamic modulus of elasticity of the F-T beams and Table A-3 gives the strength values of these beams tested in flexure after 336 F-T cycles.

The most reliable observation made from these data was to note the effect that different types of curing had on the freeze-thaw durability of the concrete. The F-T performance following 14 days continuous cure of the First and Second Stage beams is shown in Figures A-1 and A-3, respectively. The corresponding performance following the SBDC is shown in Figures A-2 and A-4, respectively. It was noted that the beams having had the SBDC were much more susceptible to F-T breakdown. The major difference between these cures was the air drying which occurred during the SBDC but not the 14-day continuous moist cure. This air drying and the accompanying shrinkage of the mortar always results in microcracking around the coarse aggregate particles of the concrete and makes the concrete much more vulnerable to freeze-thaw breakdown[1]. The flexural strength data in Table A-3 also confirm this conclusion.

The resistance of the concrete to surface scaling as caused by F-T cycles with de-icing salts is shown in Figures A-5 through A-8. Due to the incompatibility between control and Pozicon mixes and the wide variability of slump and air measurements between various series, the only reliable conclusion that can be drawn from these data is that the proportion of Pozicon in Series E is too high to effectively resist freeze-thaw scaling.

Although the shrinkage graphs, shown in Figures A-9 through A-20 in the Appendix, will not yield a definite recommendation as to the Pozicon mix which shrinks least, it does yield a valuable insight into the effect that various types of cures have on ultimate shrinkage. A study of these graphs

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[1] "Control of Cracking in Concrete Structures," ACI Journal, December 1972.

shows the shrinkage characteristics of the Pozicon concrete to be much more sensitive to the type of cure it receives than is the control concrete. It indicates that the amount Pozicon concrete will shrink varies inversely to its degree of curing; the control concrete, whose shrinkage is less sensitive to curing, is similarly affected, but to a much lesser extent.

Over the 12-week continuous moist cure, the Pozicon concrete modestly swelled as it slowly gained weight with absorbed water. During the six months of air drying, it lost weight at about the same rate as the control concrete, but shrunk at a much slower rate and ended up with significantly less shrinkage.

By contrast, the SBDC and the 14-day moist cure were much less ideal for the Pozicon concrete. The SBDC, which roughly paralleled the 12-week continuous moist cure, subjected the concrete to three weeks of air drying after only one week of moist curing. This disrupted the pozzolanic action at a very vulnerable time and resulted in a residual shrinkage that was never recovered. Two subsequent three-week curing intervals both restarted the pozzolanic reaction and helped reduce the ultimate shrinkage, but the results of the 12-week continuous cure could never be equaled. The 14-day moist cure continued the initial pozzolanic action seven days longer than the SBDC, but it, too, fell far short of the ideal results achieved by the 12-week continuous cure.

A brief description of the chemical activity associated with the pozzolanic reaction provides a better basis for understanding the curing sensitivity of this material. Tricalcium silicate, which comprises 50 percent of Type I portland cement, is unstable in the presence of water; it breaks down into calcium hydroxide, which goes into solution, and a more stable calcium silicate which hydrates (chemically adds water to its molecular structure). If a pozzolanic material such as a silicate or aluminate is present, the calcium hydroxide will slowly combine with it to form additional hydrated calcium silicates, calcium aluminates, or combinations of both. These compounds are stable in the presence of water and are cementitious in nature. This secondary reaction, of course, will not begin until the initial reaction is underway and will continue only in the presence of water. Like most chemical reactions, its speed varies directly with the temperature and inversely to the particle size of the pozzolan. Hence, the reaction speeds to completion fastest with a finely divided pozzolan and a very warm moist atmosphere; at temperatures below 50 F it will almost cease. Because the fly ash pozzolan, Pozicon, will adsorb but not absorb water, its portland-pozzolan cement combination will require less total water than an equivalent weight of portland cement. However, if drying out occurs before the pozzolanic reaction is very far advanced, much more water will be free to evaporate and this will cause an increased shrinkage of the portland-pozzolan cement over that of a portland cement. It becomes obvious that to minimize the shrinkage of a portland-pozzolan cement it will require the best curing conditions it is possible to provide.

The absorption data given in Tables A-4 through A-6 are for 3 by 6-in. concrete cylinders that have been consolidated by rodding and tapping in accordance with the procedures outlined in ASTM C 192. Although this absorption cylinder produced reliable results for the type consolidation that was used, it did not provide the information that was desired. The degree of consolidation desired is that which occurs in bridge deck concrete at the outer limit of influence of a probe type internal vibrator. This information is desired because it is assumed that the problem concrete associated with a 3-1/2 in. maximum slump will occur in areas of marginal consolidation. Hence, a more appropriate test specimen must be developed for future work.

Even though the data in Tables A-4 through A-6 do not provide the information desired, they do provide additional insight into the effect that curing has on the absorption characteristics of concrete. The three types of cures shown (7-day moist, 12-week moist, and SBDC) represent a wide extreme in the degree of curing. It shows that complete curing of both control and Pozicon concretes substantially reduces their degree of absorption. It also shows that intermittently moist long term curing significantly reduces absorption and approaches, but never equals, the reduction achieved by the continuous long term cure.

The results of the salt penetration tests yielded results that, in general, did little but confirm the obvious; that the penetration would be greatest at the contact surface and diminish with depth away from that surface. The evaluation methods, however, were not accurate enough to establish any consistent trends of the design superiority of one concrete over another. Figures A-21 through A-26 in the Appendix show the results of this work for the First Stage tests. Because of the prodigious amount of work required and the dubious value of the results, this test was discontinued after the First Stage.

Pozicon in Slip-Form Concrete

As was stated in the section on concrete mixes and preparation, this slip-form pavement series was proportioned so as to be more closely related to the control mix.

From the 4 by 8-in. cylinder specimens, tests were run after 7 and 28 days of curing. These tests included measurements to determine the fol-

TABLE 5
4 BY 8-IN. CYLINDER TEST DATA
POZICON IN SLIP-FORM PAVEMENT CONCRETE

Pour Designation	Dry Bulk Specific Gravity			Absorbed Water, percent			Compressive Strength, psi		
	7 Day	28 Day Special Cure[1]	Increase	7 Day	28 Day Special Cure[1]	Decrease	7 Day	28 Day Special Cure[1]	Increase
AA (Control)	2.319	2.325	0.006	4.26	3.90	0.36	3,720	4,630	910
BB	2.335	2.340	0.005	4.23	3.51	0.72	3,740	4,600	860
CC	2.300	2.309	0.009	4.37	4.00	0.37	3,490	4,230	740
DD	2.302	2.313	0.011	4.56	3.89	0.67	2,690	3,450	760

[1] 28 Day special cure includes
7 days moist cure
14 days air dry
7 days moist cure

lowing information: the weight of absorbed water in the cylinder, its specific gravity, and its compressive strength. Table 5 data show that Pozicon mix BB was the only one to equal or exceed the performance of the control mix. It also indicates that between the 7 and 28 day tests the increase in specific gravity of the Pozicon mixes varies directly with the proportion of Pozicon. This was predictable, since a greater amount of pozzolanic material was available to react with the strong calcium hydroxide solution that was generated by the hydration of the cement. It is also interesting to note that both Pozicon mixes BB and DD greatly exceeded the Control mix AA in absorbed water reduction between the 7 and 28 day tests; the reason Pozicon mix CC did not do the same is unknown. The compressive strength values indicate that the Pozicon content of 25 percent of the weight of the cement, as contained in mix DD, appears to have reached the point where the pozzolan has substantially retarded the early strengths of the concrete. This point appears to lie somewhere between 20 and 25 percent of the weight of the cement.

The three 3 by 4 by 16-in. freeze-thaw (F-T) beams began testing in the F-T machine immediately following the special cure. Following 336 F-T cycles, the beams were tested in flexure and discarded. Figure 1 shows the relative dynamic modulus of elasticity of the beams expressed as a percent of the initial value; the values for the beams were measured once a week or after every 42 cycles. The flexure test values are shown

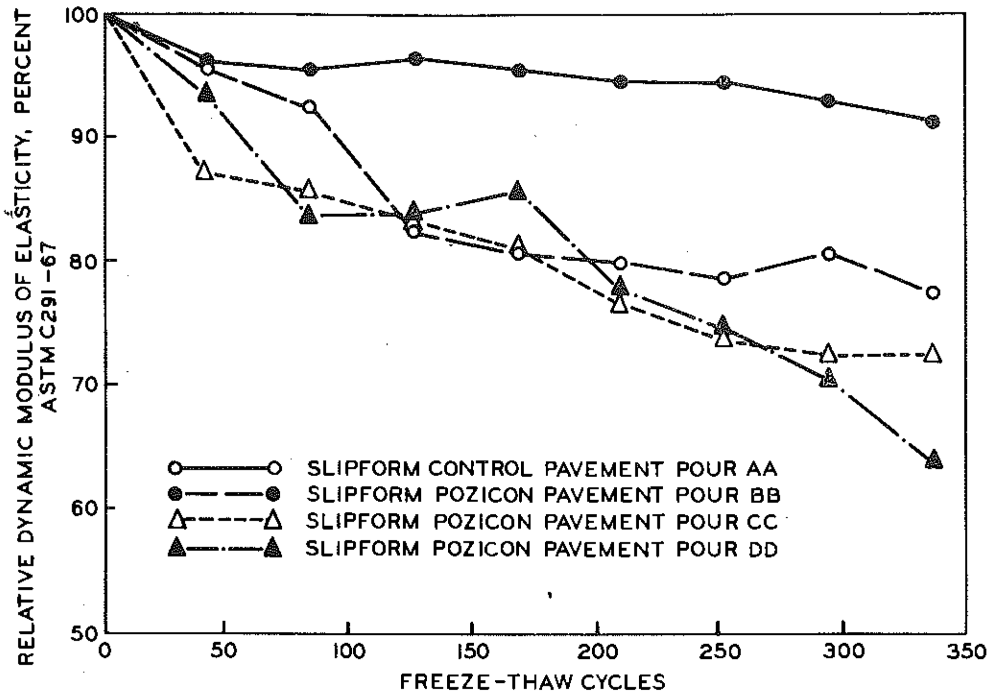


Figure 1. Internal freeze-thaw durability of slip-form pavement series concrete beams (3 by 4 by 16 in.) tested immediately following the four-week special cure.

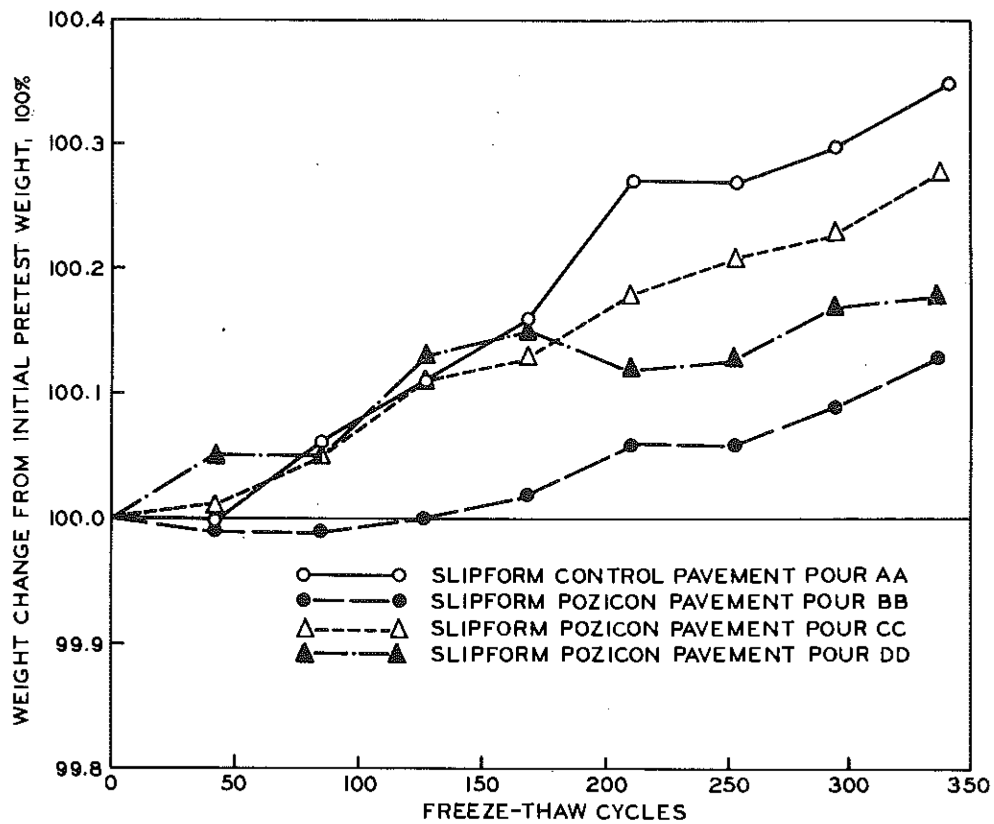


Figure 2. Weight variation of slip-form pavement series concrete beams (3 by 4 by 16 in.) tested in freeze-thaw immediately following the four-week special cure.

in Table 6. Both test results indicate a marked superiority of the Pozicon BB mix over both the other Pozicon mixes and the control mix.

TABLE 6
F-T BEAMS TESTED IN FLEXURE
AFTER 336 F-T CYCLES

Pour Designation	Flexural Strength, psi
AA (control)	405
BB	605
CC	385
DD	310

In this slip-form pavement series, weight measurements on the F-T beams were also taken once a week; these results were expressed as a percentage of the initial weight and are shown in Figure 2. This information is of little value except to note the interesting relationship that exists between F-T and moisture absorption. As deterioration progresses, the concrete "swells" and has a greater capacity to absorb water. It might be possible for the rate of deterioration to be roughly approximated if the percent increase in absorption is known; however, as will be noted, the absorption-deterioration relationship varies with different concrete designs.

The data from the 3 by 3 by 15-in. shrinkage prisms are contained in Figures 3 and 4. These figures show graphs of the length and weight variation of the prisms for each of the slip-form pavement series mixes. Each point on the graph represents the average measurement of three prisms cast for that mix. A study of the length variation graphs in Figure 3 shows that Pozicon mix BB performs consistently the best with the control and the other Pozicon mixes being approximately equal. Figure 4 shows the Pozicon mix BB and Control mix AA as losing the weight of moisture at about the same rate throughout the first 28 days of air drying; however, for the three and six month measurements, the rate slowed for the Pozicon mix BB, but not for the control mix, which continued losing moisture at the same rate.

The 6 by 9-in. cylinder consolidation specimens were cut into thirds and tested in accordance with ASTM C 642. The testing yielded data on the following concrete characteristics; absorption, specific gravity, and permeability. The results of these tests are shown in Table 7 along with a

TABLE 7
COMPARISON DATA OF POZICON IN SLIP-FORM PAVEMENT CONCRETE

Pozicon Series			Average Compressive Strength, psi		28 Day Shrinkage, mil/in.	Freeze-Thaw Beams Percent Initial Strength Return, 336 cycles	Percent Absorption (Avg. of 3 Cylinders) ASTM C 642			Boiled Dry Bulk Specific Gravity ASTM C 642			Percent Permeable Voids (Avg. of 3 Cylinders) ASTM C 642		
Pour Designation	Cement Content lb/cu yd	Pozicon P/C Ratio and lb/cu yd	7 Day	28 Day			Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Control AA	6 Sack 564	--	3,720	4,630	0.45	77.2	4.48	5.00	4.77	2.311	2.274	2.265	10.36	11.38	10.79
Pozicon BB	5-1/2 Sack 517	0.15 78	3,740	4,600	0.39	91.0	4.44	4.62	4.64	2.321	2.293	2.273	10.27	10.63	10.56
Pozicon CC	5-1/4 Sack 494	0.20 99	3,490	4,230	0.45	72.5	4.75	4.65	4.57	2.293	2.286	2.270	10.88	10.62	10.36
Pozicon DD	5 Sack 470	0.25 118	2,690	3,450	0.42	64.0	4.68	4.54	4.54	2.292	2.283	2.273	10.69	10.32	10.35

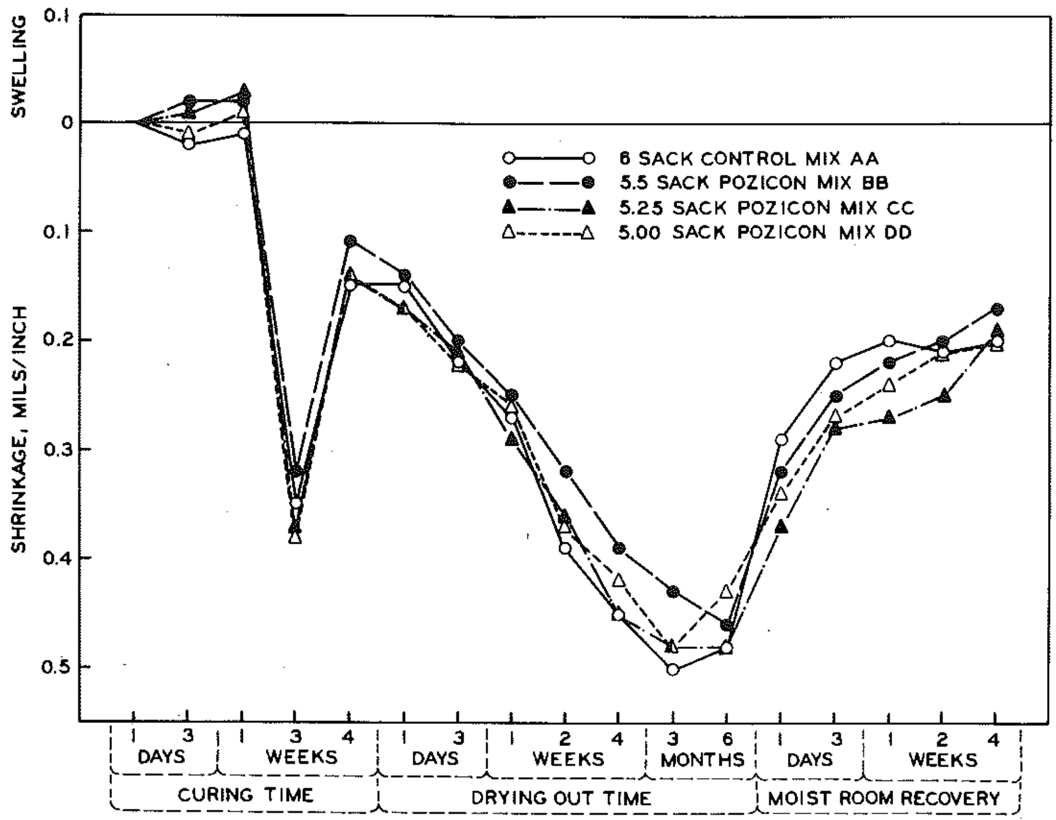


Figure 3. Shrinkage prism length variation of slip-form pavement series following the four-week special cure.

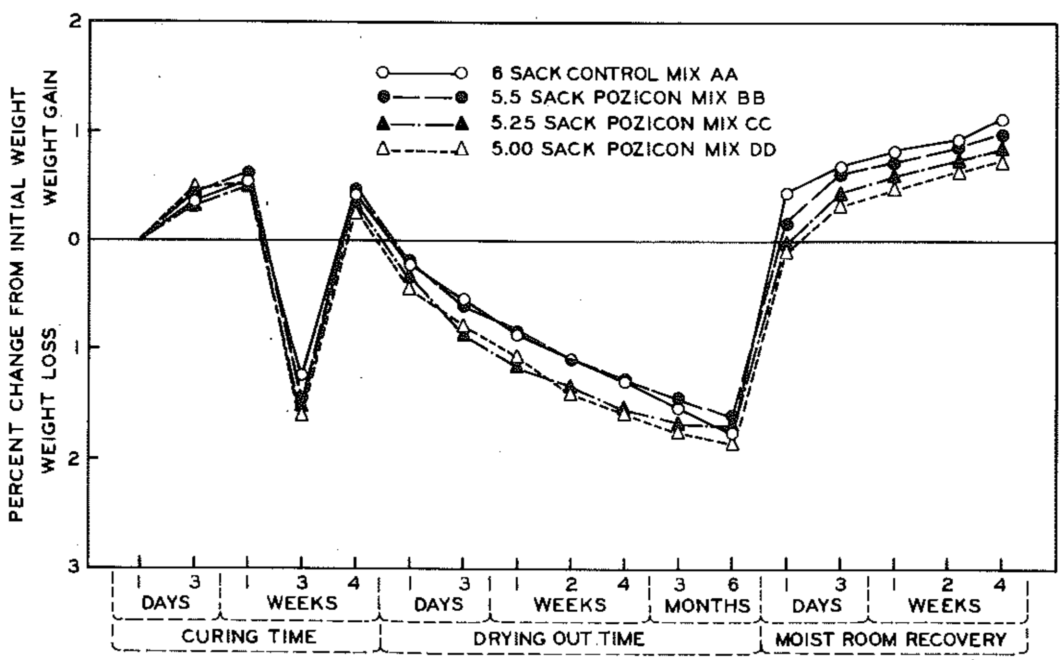


Figure 4. Shrinkage prism weight variation of slip-form pavement series following the four-week special cure.

summary of the other test data. The consolidation data indicate that Pozicon mix BB has the highest specific gravity of any of the other mixes throughout the full depth of the cylinder; it also has the lowest absorption and permeability in the top third. The lowest absorption and permeability in the middle and lower thirds was obtained with Pozicon mix DD, which slightly outperformed mix CC. It would appear that the higher percentage of fly ash in the two mixes imparted to them a proportionally greater internal fluidity and thus obtained this greater compaction. Being that the specific gravity of fly ash is lower than cement, the concrete mixes with the lowest cement content and highest fly ash proportioning should logically have the lowest apparent specific gravity. A check of the apparent specific gravity showed this to be roughly true. The paradoxical element in these data is in the top third of the cylinders of the Pozicon CC and DD mixes; here the specific gravity, the percent absorption, and the percent permeable voids values are higher than in either of the lower two thirds. This seems irrational, but no explanation is evident at this time.

The performance summary contained in Table 7 gives a direct comparison of the four different concrete designs, indicating that Pozicon mix BB is the most superior of all the mixes being rated. It is possible to make comparisons in this case because, as Table 4 shows, the mix designs are all very compatible with only 0.2 in. variation in slump and 0.8 percent variation in entrained air.

CONCLUSIONS

First and Second Stages

The Pozicon series in the First and Second Stages provided very little useful information for determining an optimum proportioning to use in bridge deck concrete; however, they did provide some valuable secondary information about concrete in general and Pozicon concrete in a paving mixture in particular. From the information gathered, it was noted that the proportion of Pozicon in the concrete had a much greater influence on the gain of compressive strength than on the gain of flexural strength. It was also noted that different degrees and intervals of moist curing made substantial differences in the concrete's shrinkage and absorption characteristics and also in its freeze-thaw performance.

From the experience and results of the First and Second Stage work came some conclusions that would be useful in conducting future research work with Pozicon in concrete:

1) The Maintenance of compatibility between the control and experimental mixes is necessary if valid conclusions are to be reached from the work. To produce this compatibility it is necessary to maintain the mortar volume as a constant hence the volumes of cement, sand, mix water, and entrained air of the control must equal the volumes of the cement, sand, mix water, entrained air and Pozicon of the experimental mix. Therefore, the volumes of the coarse aggregates in these mixes must also be equal.

2) The performance characteristics of concrete mixes of the same mix design will vary greatly with significant differences in their slump and level of entrained air. Hence, to maintain comparability between compatibly designed mixes, it is necessary to hold the tolerance range of the slump and entrained air levels as narrow as possible. This can be accomplished in the laboratory by rigidly controlling coarse aggregate gradation, aggregate absorbed moisture, mixing time, and concrete temperature.

3) All test specimens that contribute little useful information, because of poor design or irresolvable difficulty in preparation or testing, should be either eliminated or replaced by a more effective specimen.

4) Although very impressive results can be obtained with Pozicon mixes that have had ideal long-term curing, these results are of academic value only, since they will never be duplicated under normal field conditions. Therefore, any fly ash concrete that is being designed for highway field application must prove itself superior in the laboratory under simulated field curing.

Pozicon in Slip-Form Pavement Concrete

The Pozicon mixes obtained in the slip-form series were all closely related to their control and were also closely comparable in slump and air; thus, they provided an excellent basis for confident comparisons. The test results seemed to support the conclusion that with a properly proportioned concrete mix, enriching the mortar by significantly reducing the FA/TA ratio did not produce the desired effect. It appeared this measure produced a harsher concrete to which additional water was required to restore lost workability. Although the mixes in this slip-form series had a 1 percent reduction in the FA/TA ratio from the control mix (35 to 34 percent) it is not known whether this was necessary or even desirable. Possibly a mix design which held constant the fine and coarse aggregate contents of the control, and simply balanced the Pozicon volume with reduction in cement and water would have produced an even better pozzolan concrete.

For the special cure, which was used in this series to simulate the pavement 28-day field cure, Pozicon mix BB outperformed all the other

Pozicon mixes and even the control mix. It showed superiority in the cylinders, the freeze-thaw beams, and the shrinkage prisms; it also had the highest specific gravity throughout the full depth of the consolidation cylinders. For the lowest permeability and absorption performance in the consolidation cylinders, it was rivaled by mix DD. If a longer term cure had been used, mixes CC and DD would have competed more strongly, and one of them might have equaled or outperformed mix BB.

RECOMMENDATIONS

In mid-summer of 1973, at the completion of all laboratory test work except the long-term shrinkage prism measurements, the results were examined and the outstanding performance of mix BB was noted. A summary of the test results was immediately set-up in a letter to L. T. Oehler, Engineer of Research, recommending that a slip-form pavement project be designated for the experimental field application of Pozicon. Because it was late in the construction season, no suitable pavement project was available for this application, but a field application was ultimately achieved in a slip-form median barrier project on I 75 near the city of Flint. This project was completed and evaluated in the fall of 1973 and is described in detail in MDSHT Research Report R-974. Arrangements were made to include Pozicon field applications in one slip-form paving project which was constructed during the 1974 construction season: results will be reported.

APPENDIX

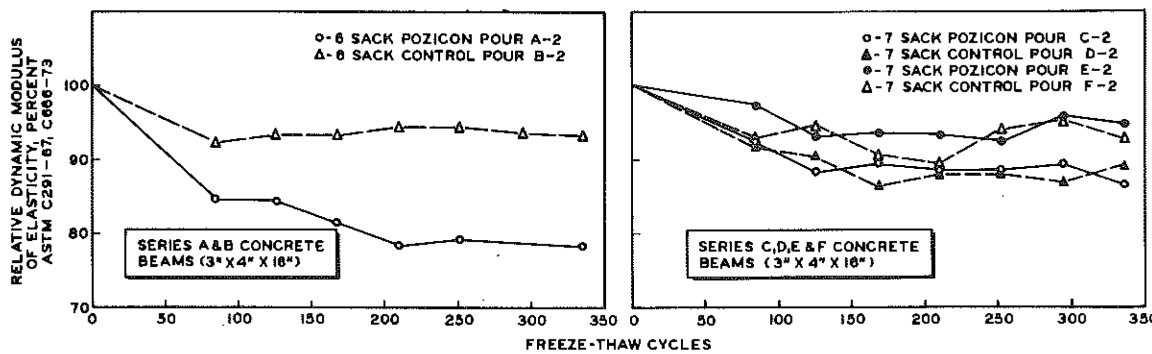


Figure A-1. Internal freeze-thaw durability of first stage tested immediately following 14 days moist room curing.

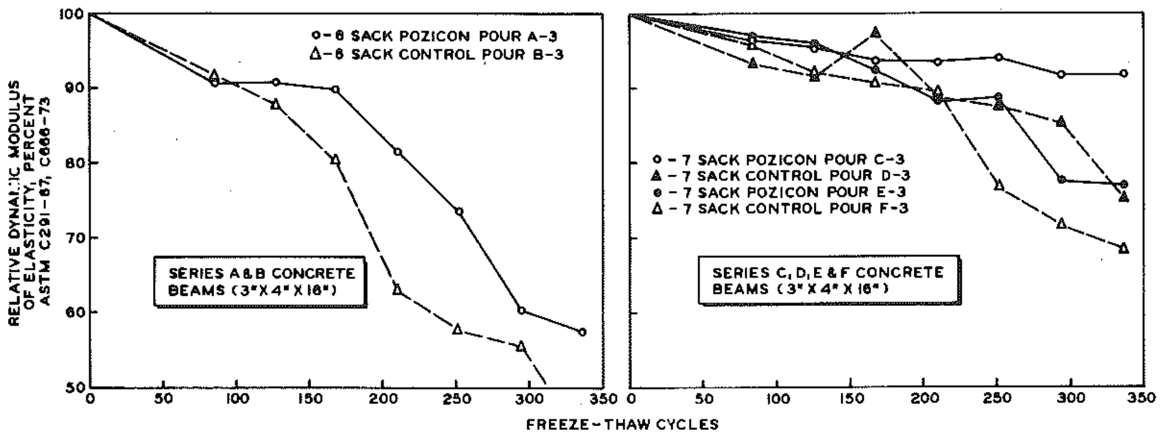
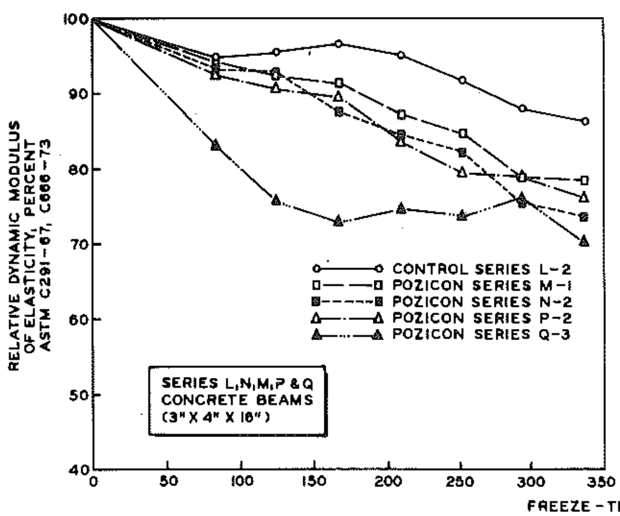


Figure A-2. Internal freeze-thaw durability of first stage tested immediately following the SBDC.



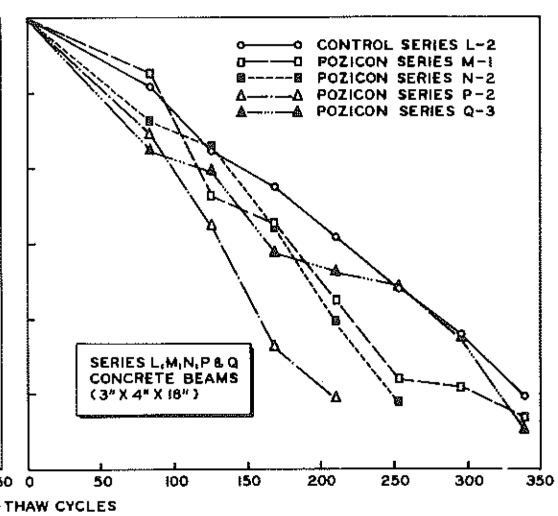
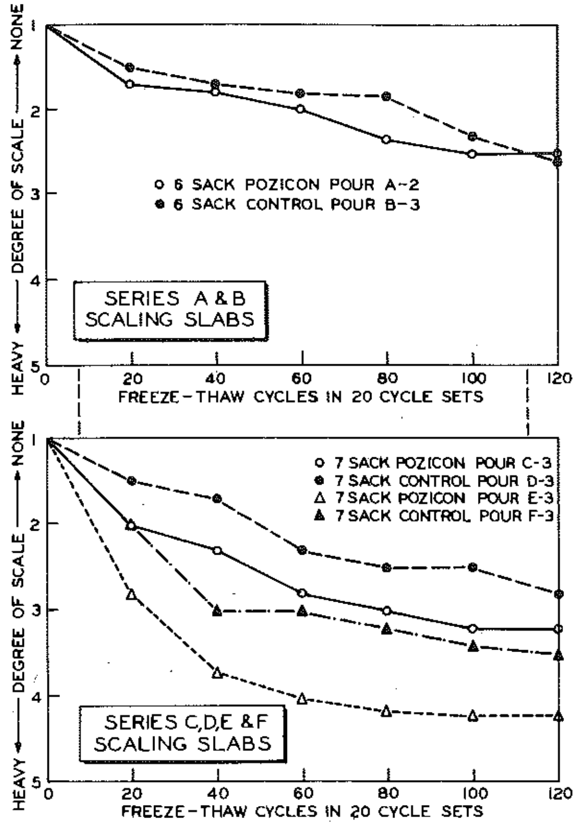
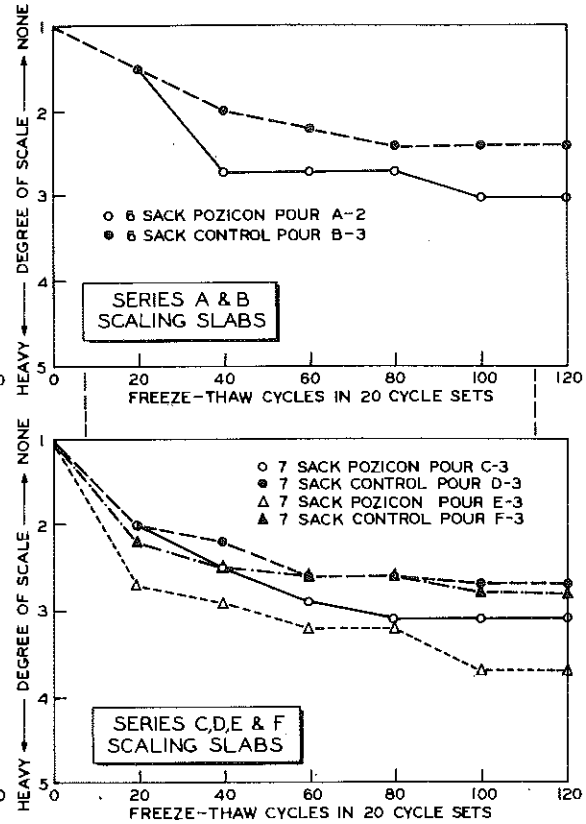


Figure A-3. Internal freeze-thaw durability of second stage tested immediately following 14 day moist room curing.

Figure A-4. Internal freeze-thaw durability of second stage tested immediately following the SBDC.





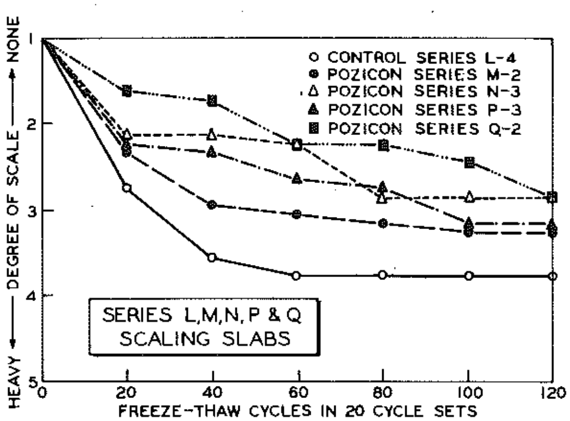
EACH SET INCLUDES

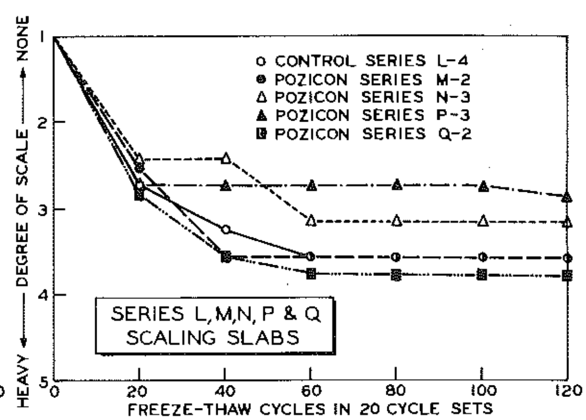
7 CYCLES WITH 3 % SALT WATER
3 CYCLES WITH FRESH WATER

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

Figure A-5. Surface freeze-thaw durability for first stage cured 14 days in moist room and air dried 14 days prior to freeze-thaw testing.

Figure A-6. Surface freeze-thaw durability for first stage given SBDC and air dried 14 days prior to freeze-thaw testing.





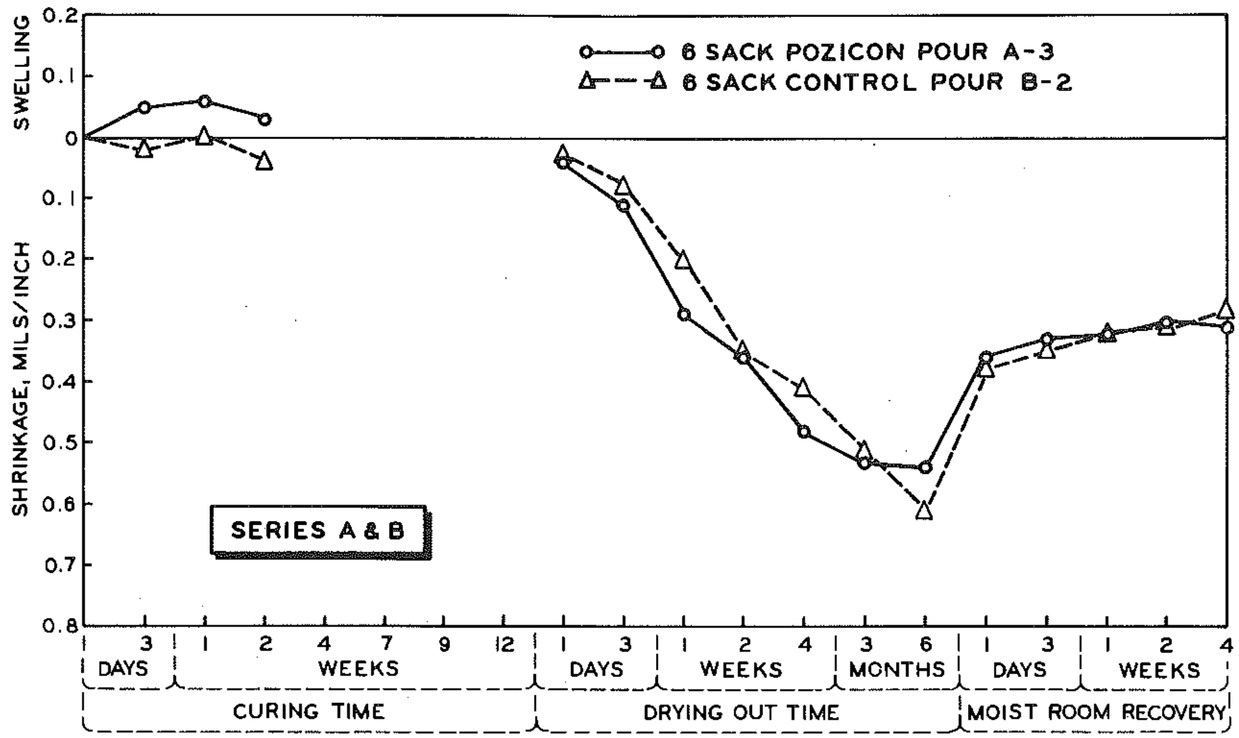
EACH SET INCLUDES

4 CYCLES WITH FRESH WATER
3 CYCLES WITH 3 % SALT WATER
4 CYCLES WITH FRESH WATER

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

Figure A-7. Surface freeze-thaw durability for second stage cured 14 days in moist room and air dried 14 days prior to freeze-thaw testing.

Figure A-8. Surface freeze-thaw durability for second stage given the SBDC and air dried 14 days prior to freeze-thaw testing.



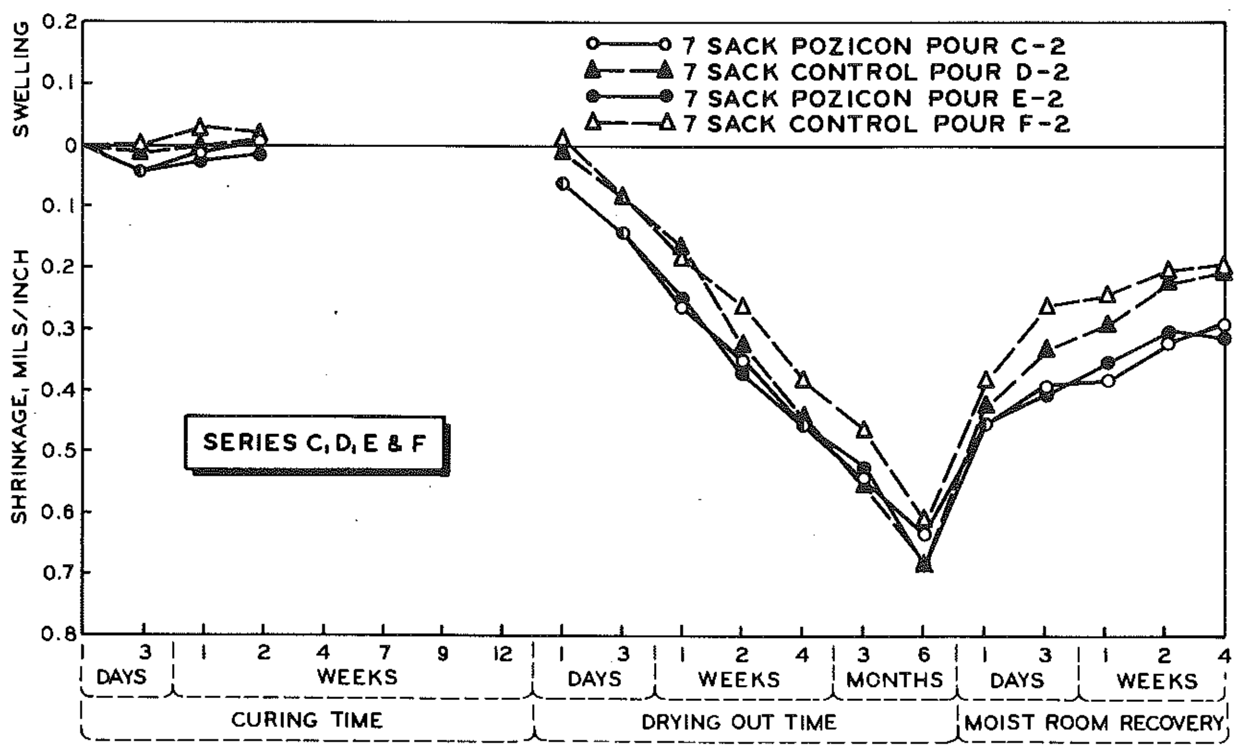


Figure A-9. Shrinkage prism length variation of first stage 14 day cure prisms.

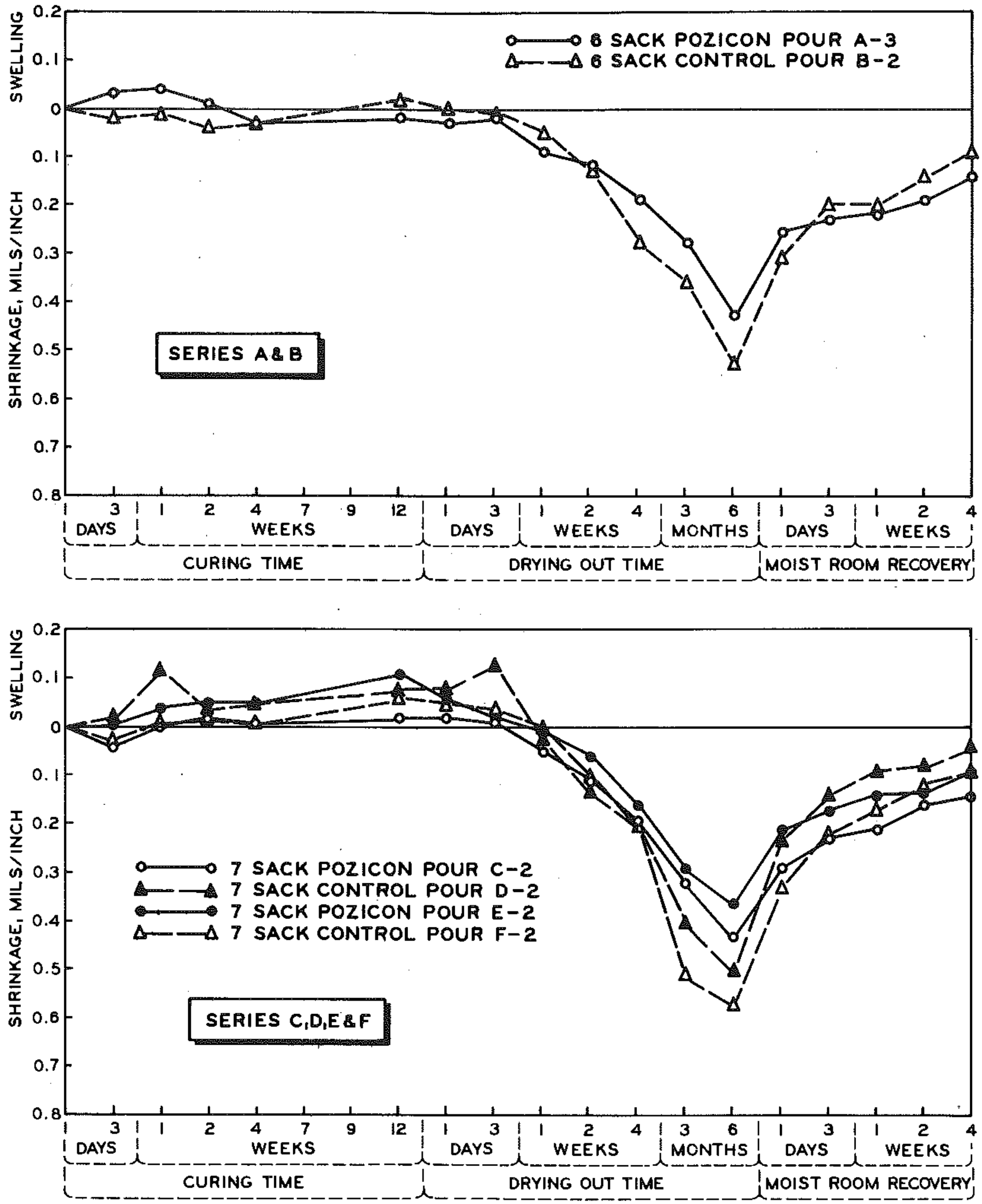
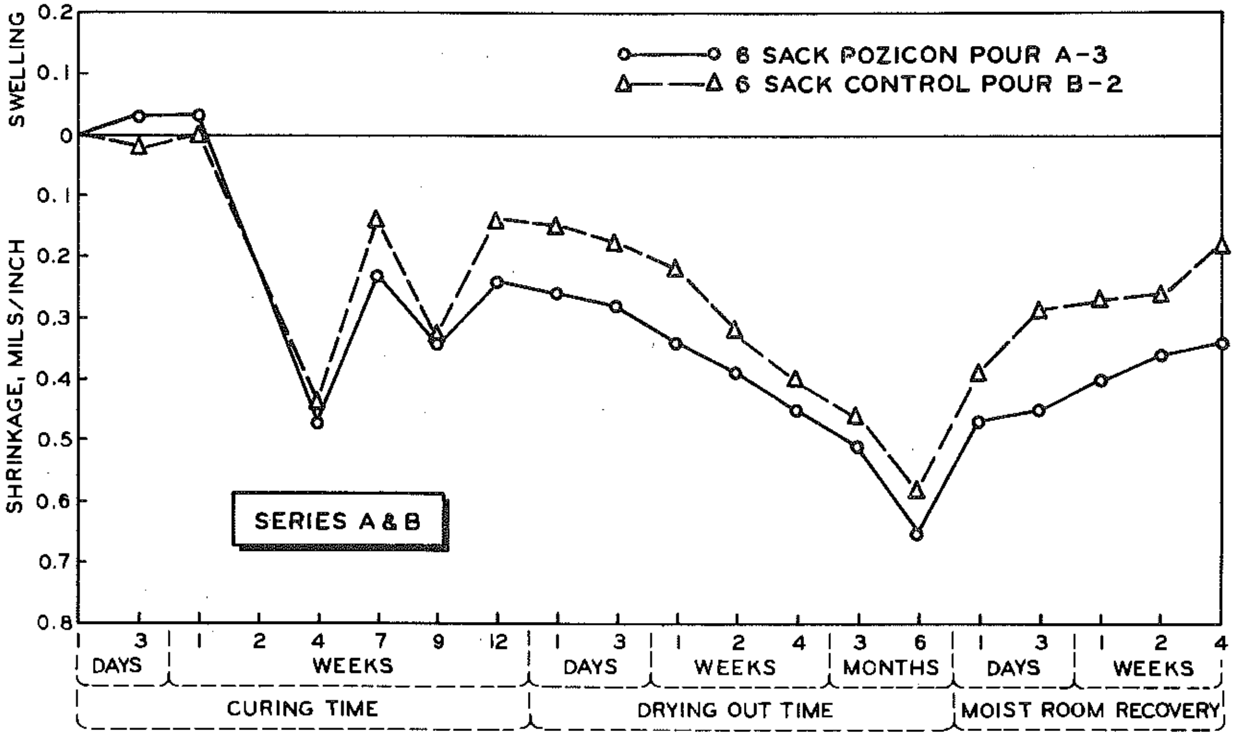


Figure A-10. Shrinkage prism length variation of first stage 12 week cure prisms.



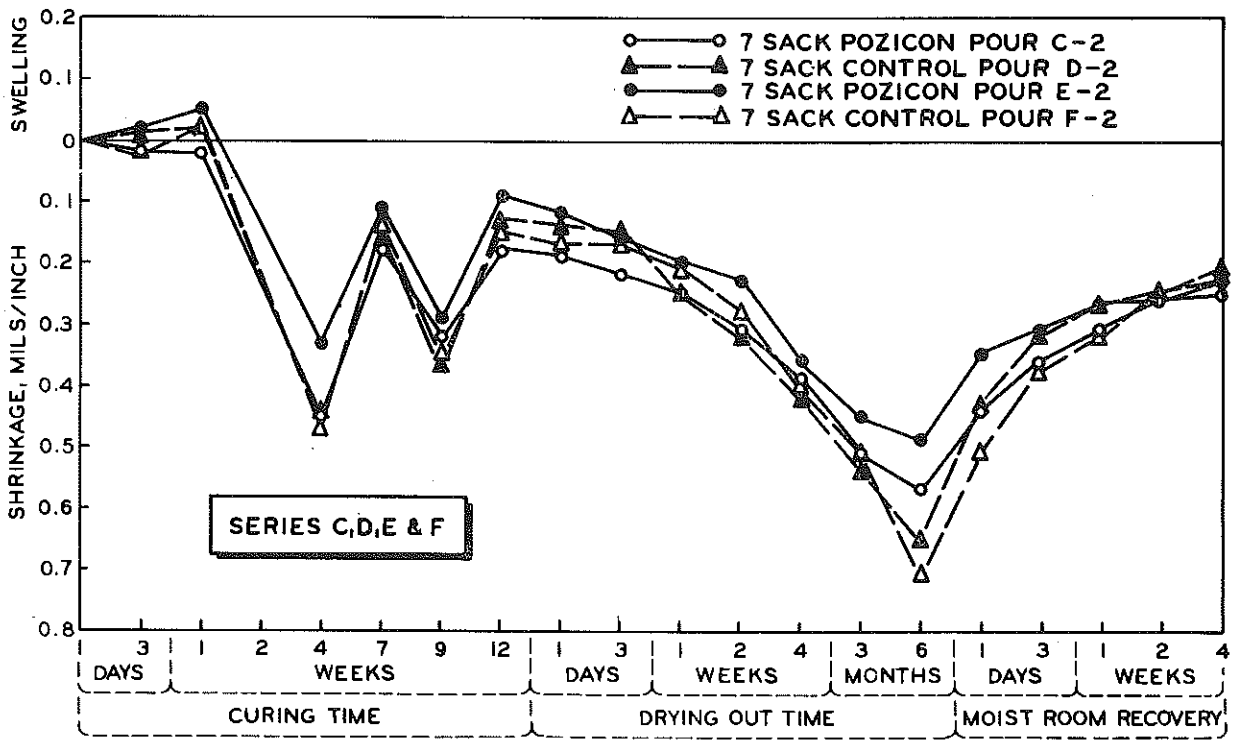


Figure A-11. Shrinkage prism length variation of first stage SBDC prisms.

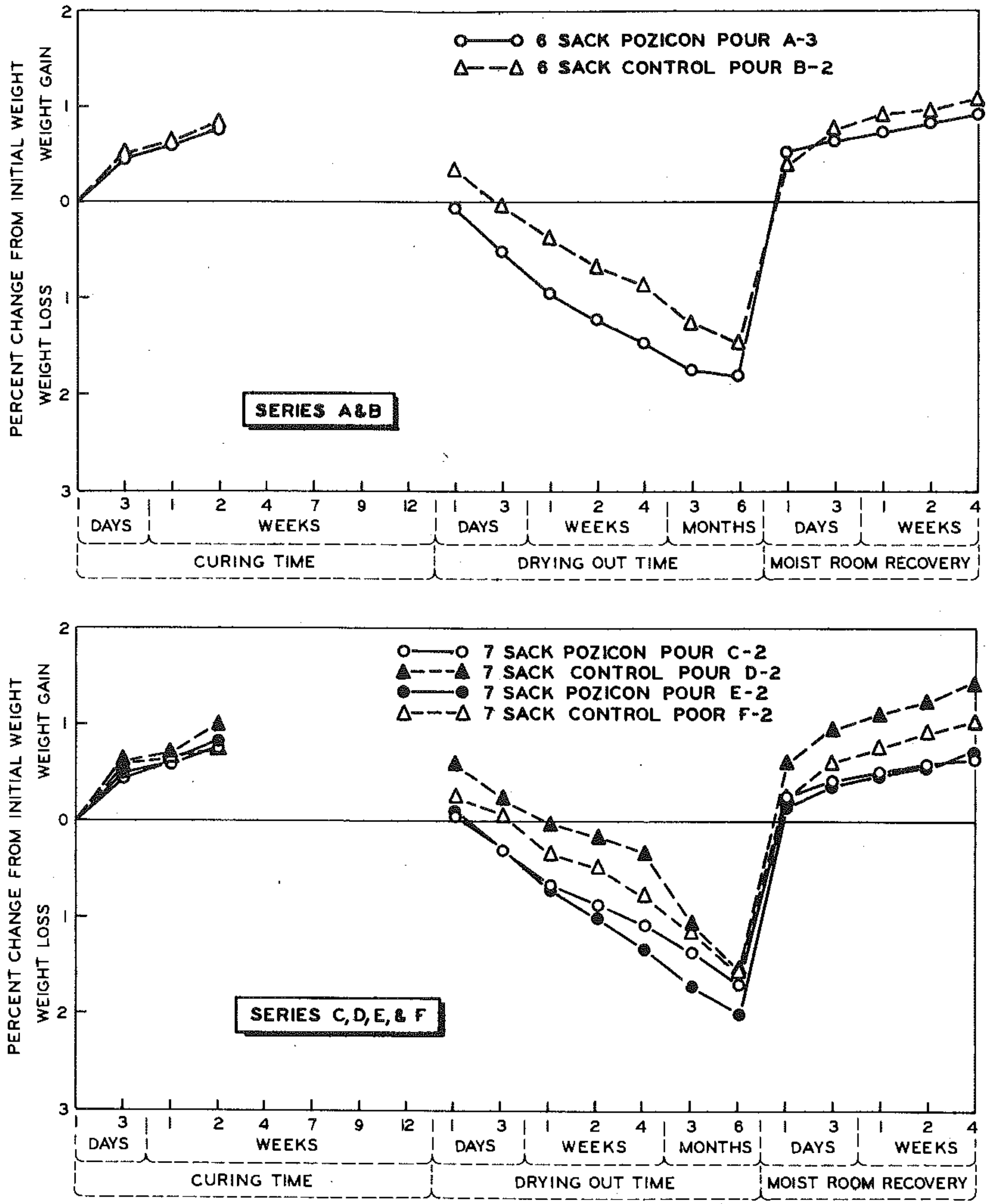


Figure A-12. Shrinkage prism weight variation of first stage 14 day cure prisms.

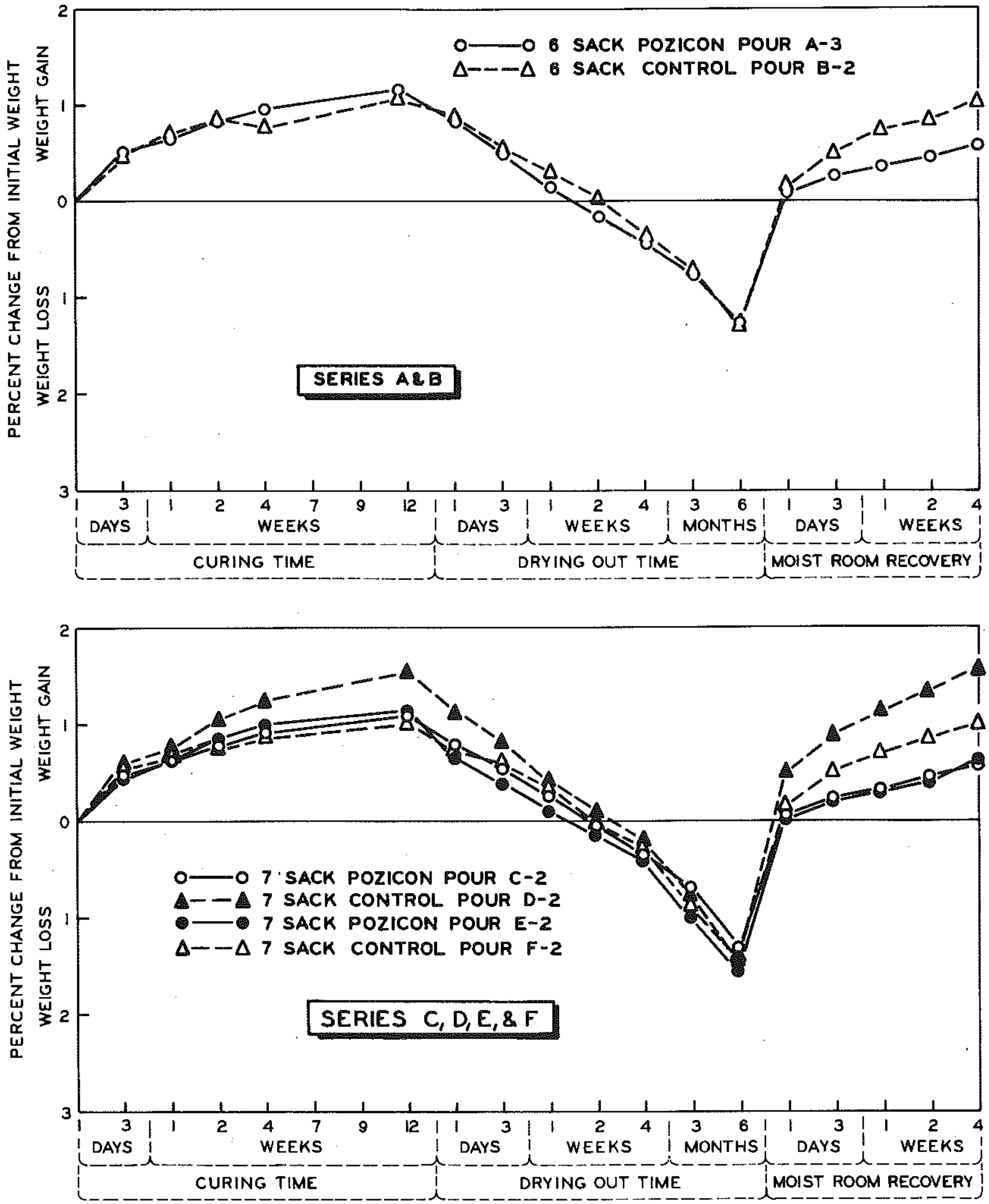


Figure A-13. Shrinkage prism weight variation of first stage 12 week cure prisms.

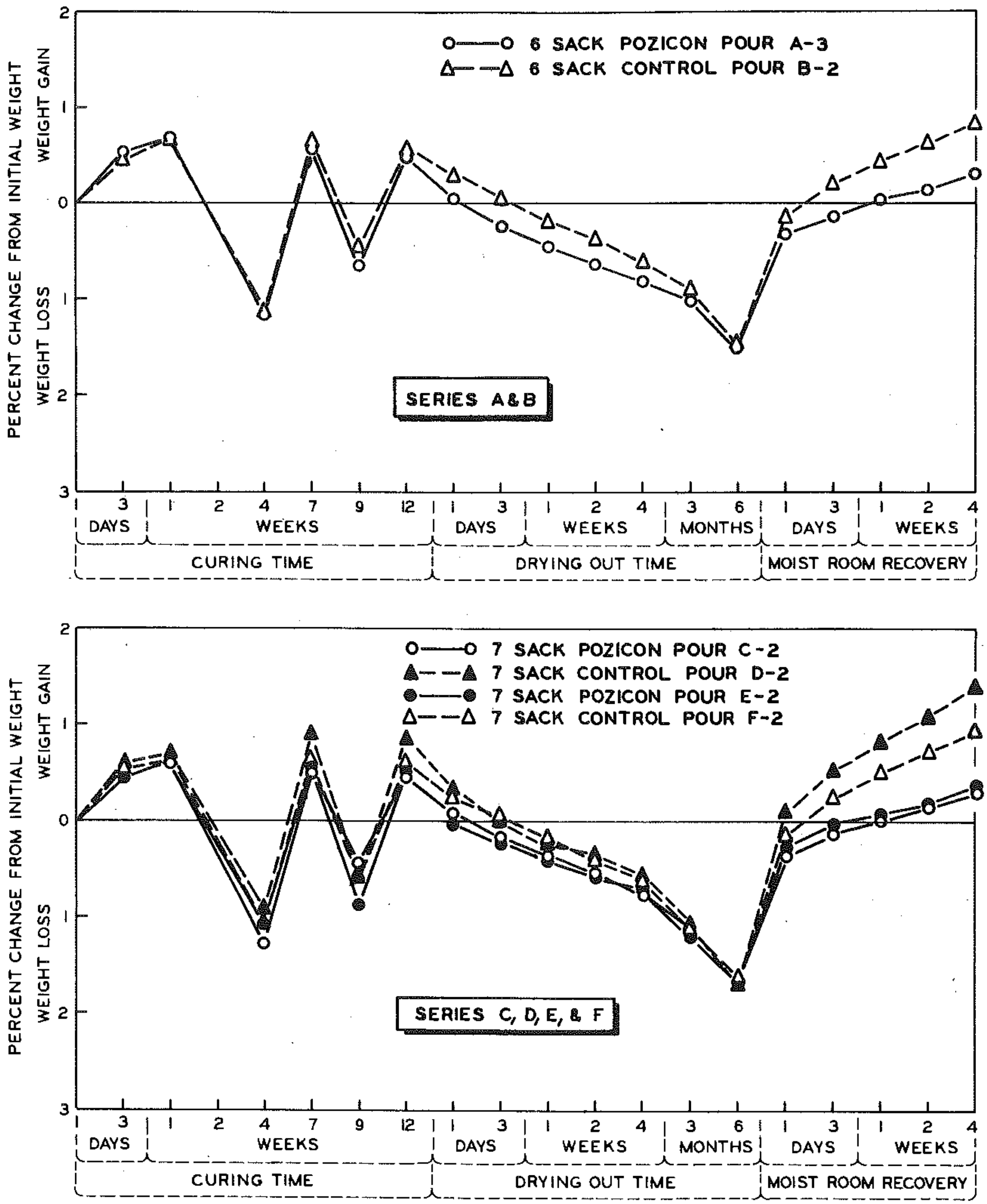


Figure A-14. Shrinkage prism weight variation of first stage SBDC prisms.

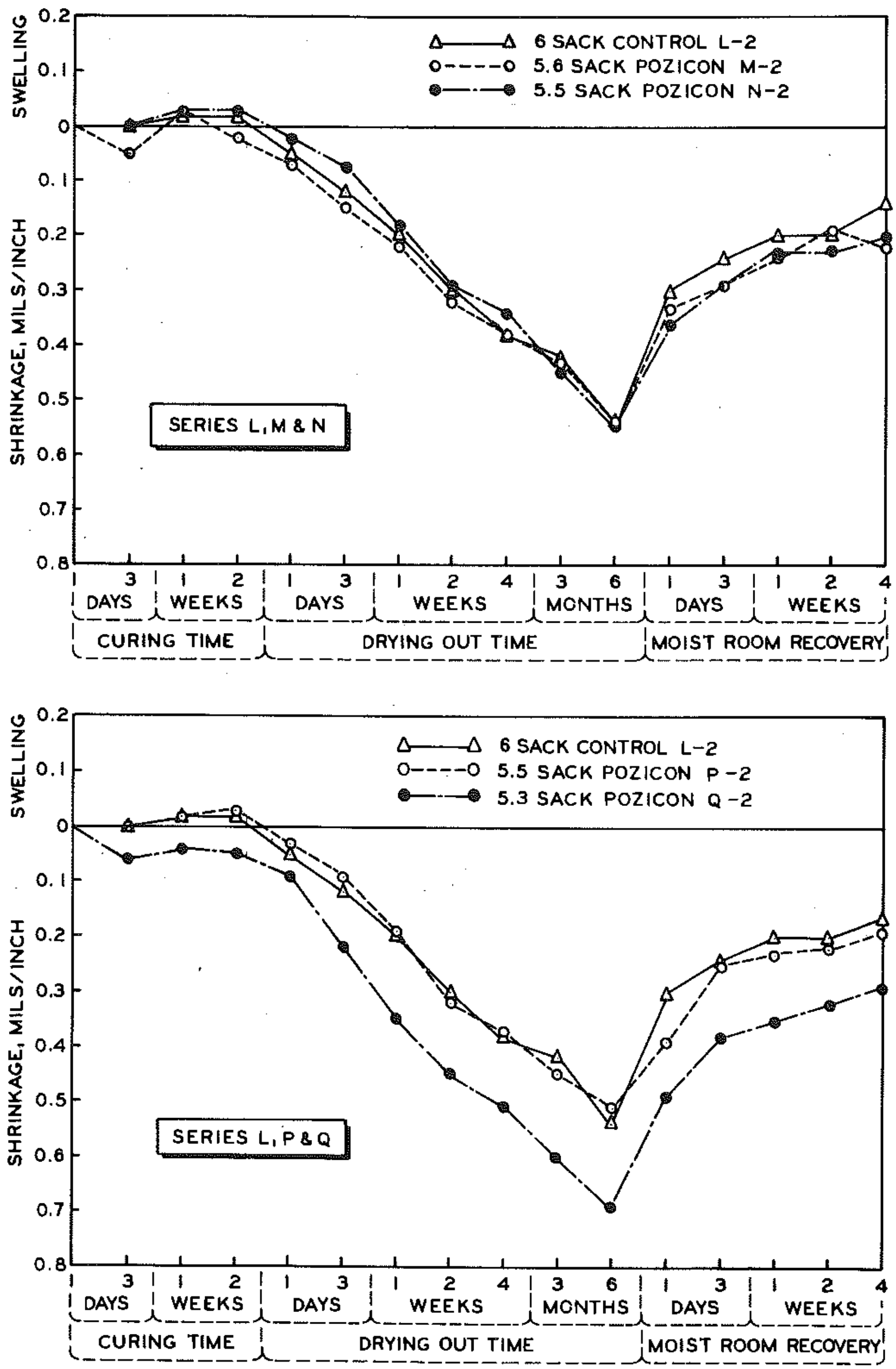
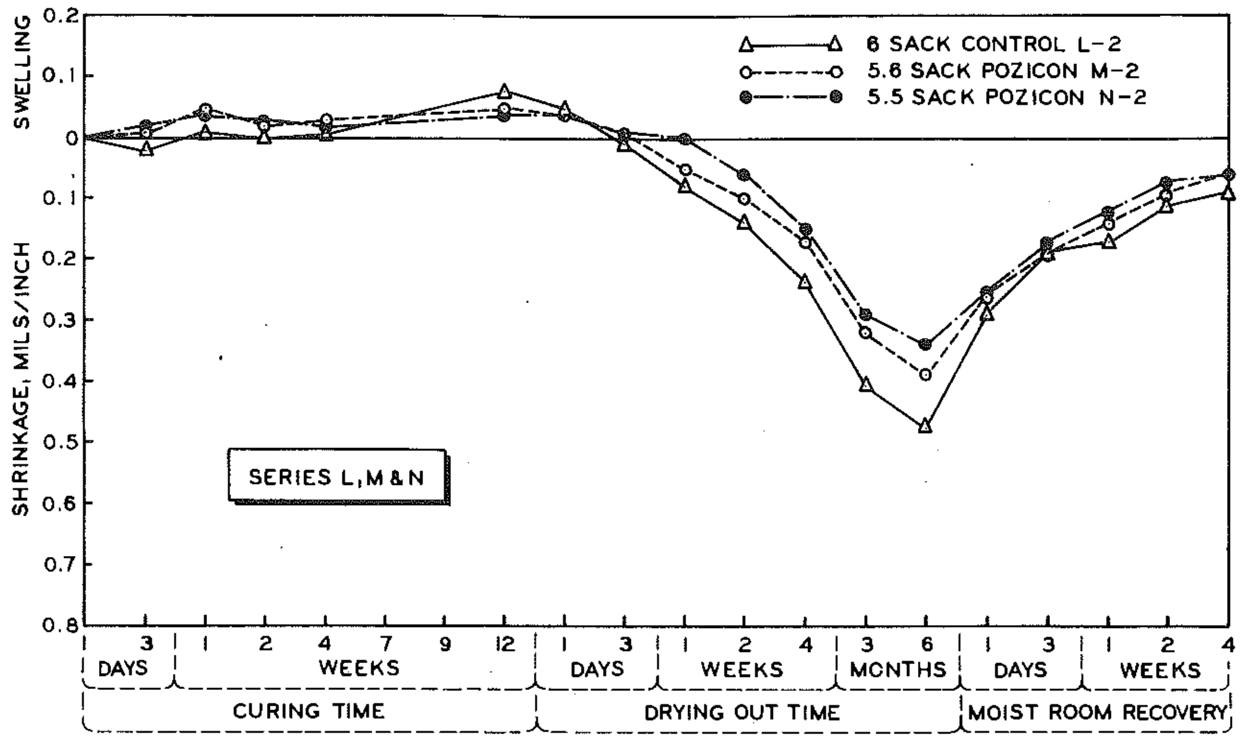


Figure A-15. Shrinkage prism length variation of second stage 14 day cure prisms.



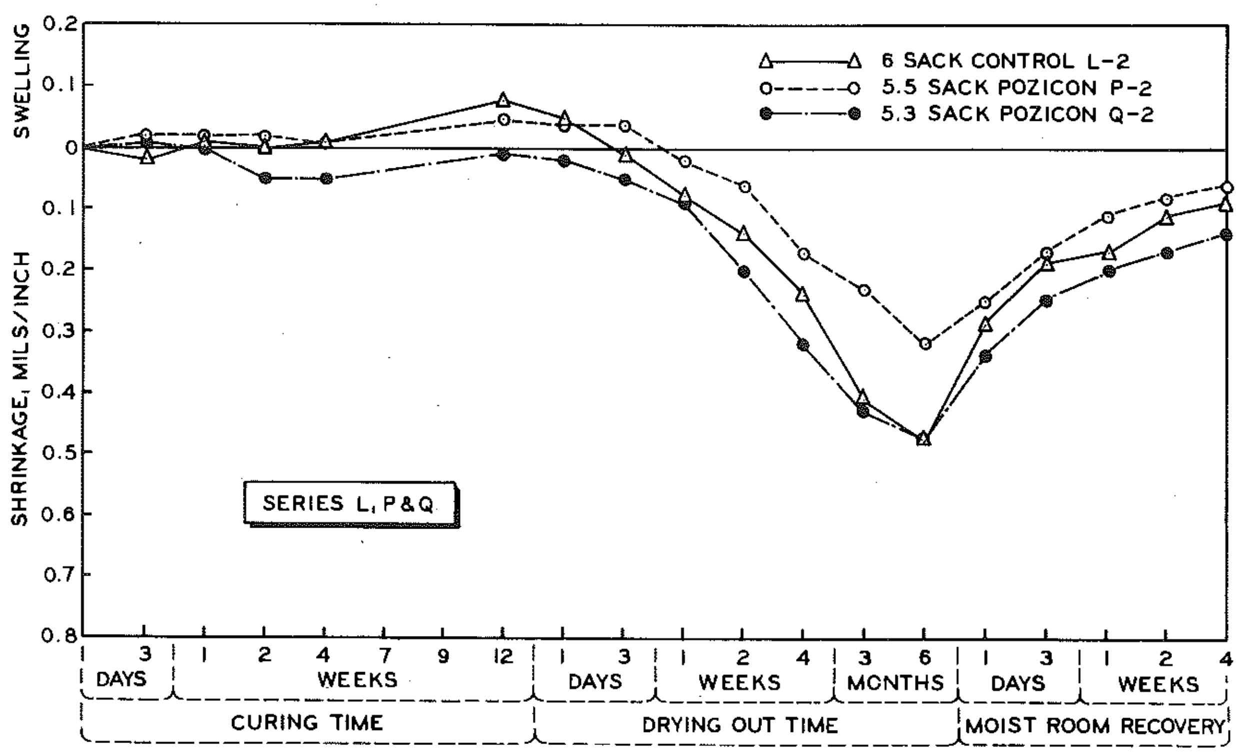


Figure A-16. Shrinkage prism length variation of second stage 12 week cure prisms.

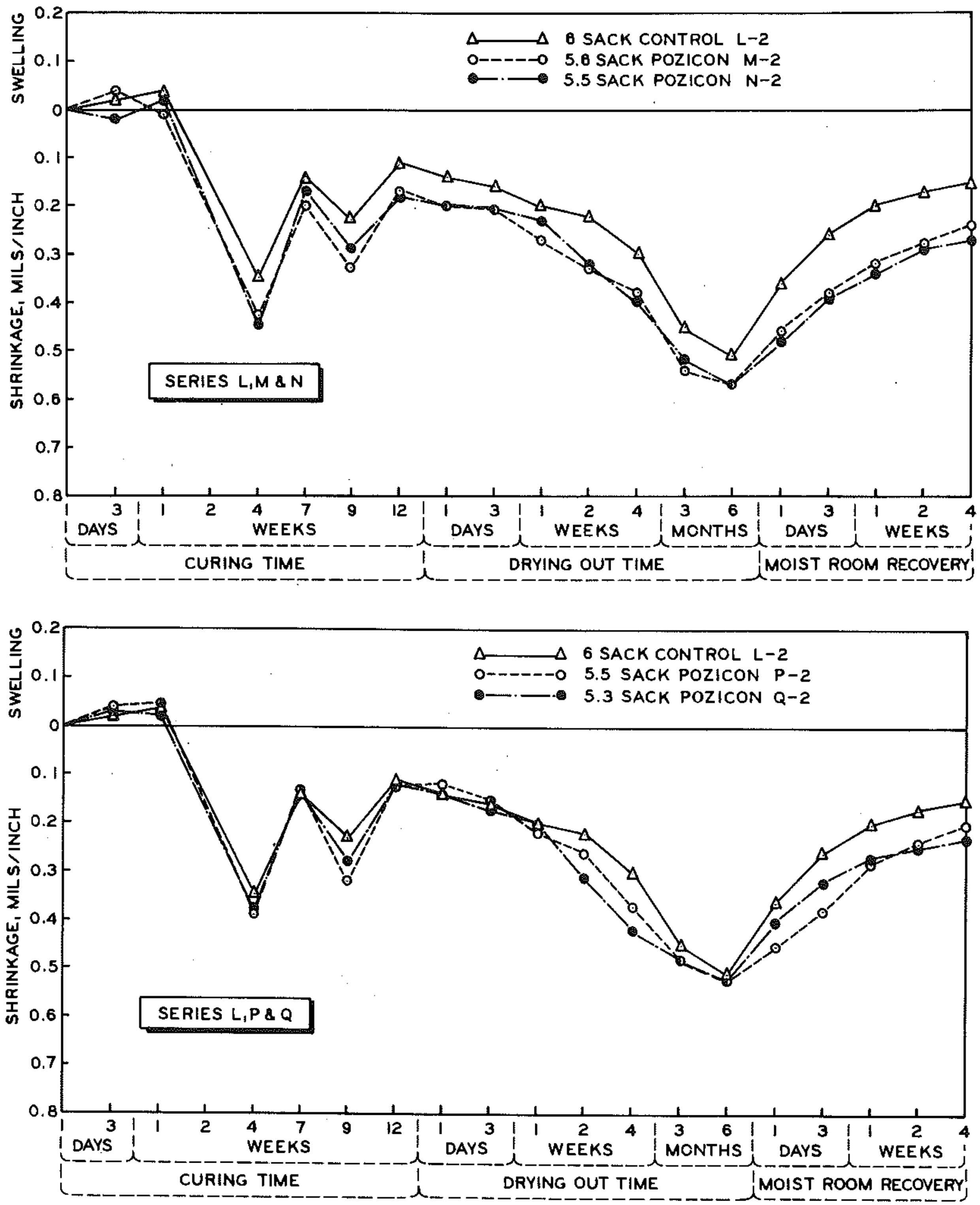


Figure A-17. Shrinkage prism length variation of second stage SBDC prisms.

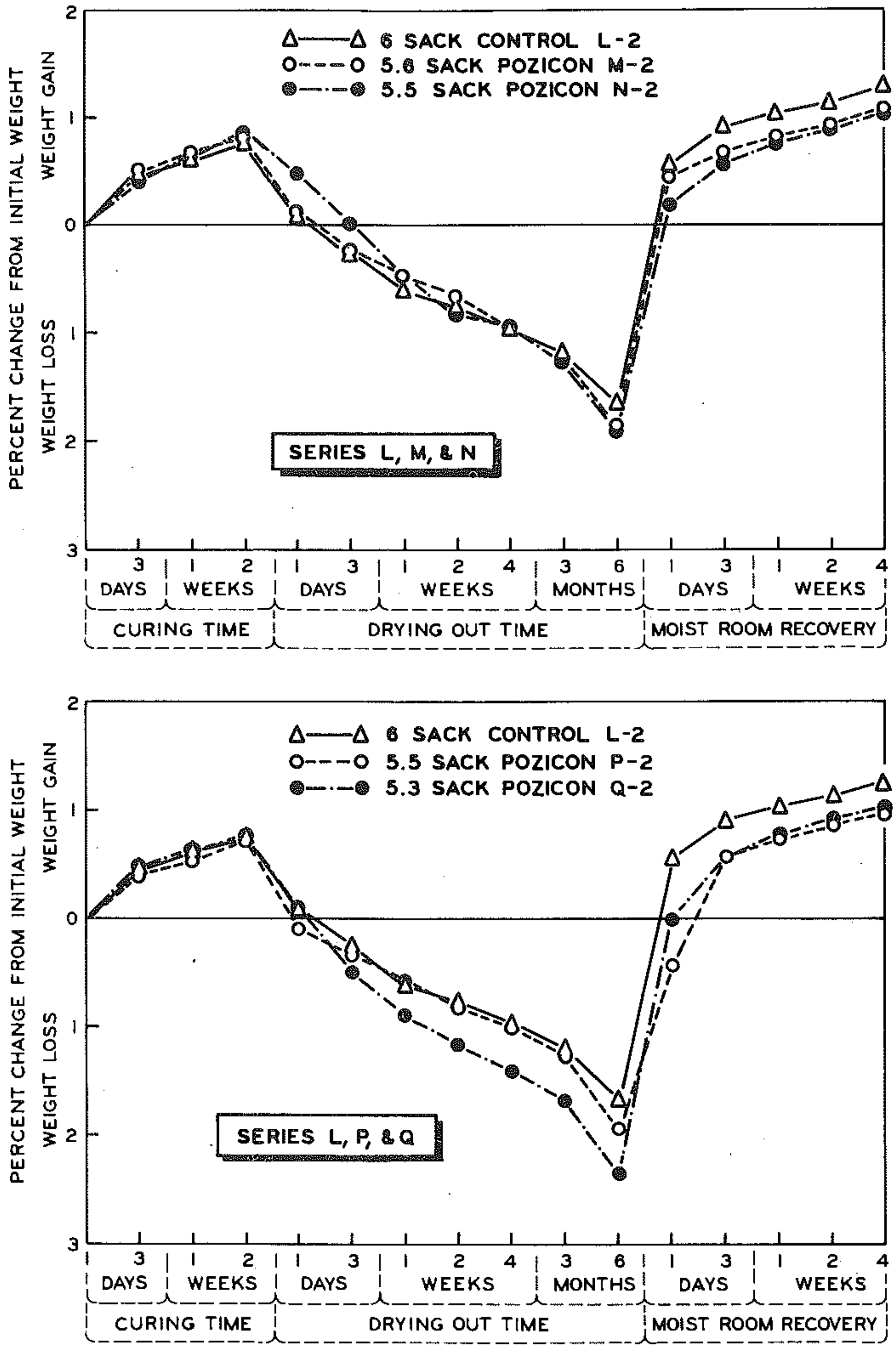
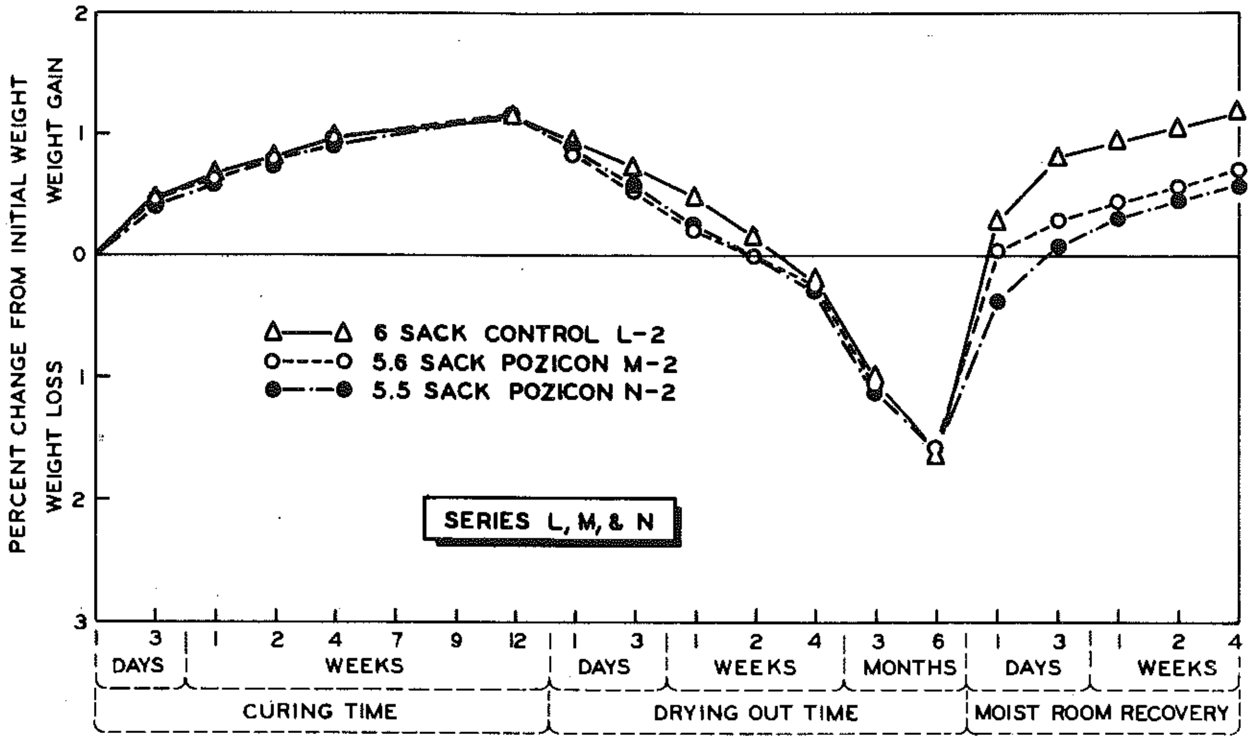


Figure A-18. Shrinkage prism weight variation of second stage 14 day cure prisms.



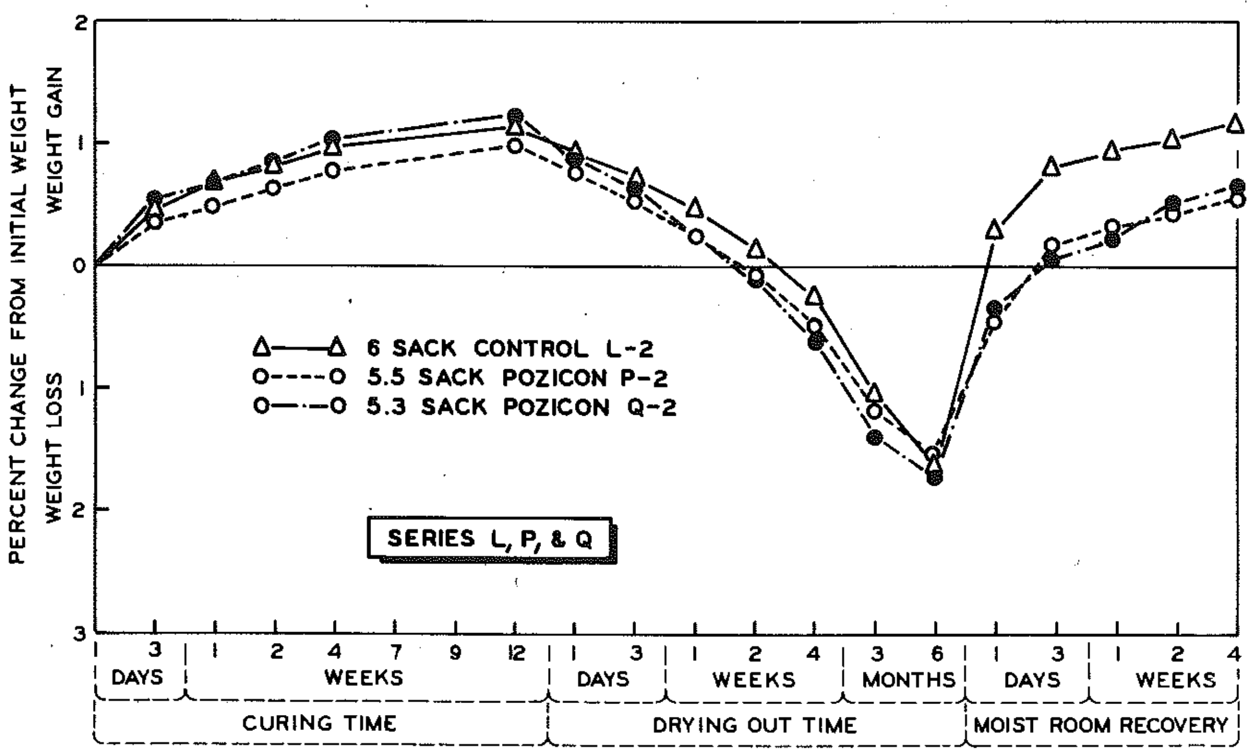


Figure A-19. Shrinkage prism weight variation of second stage 12 week cure prisms.

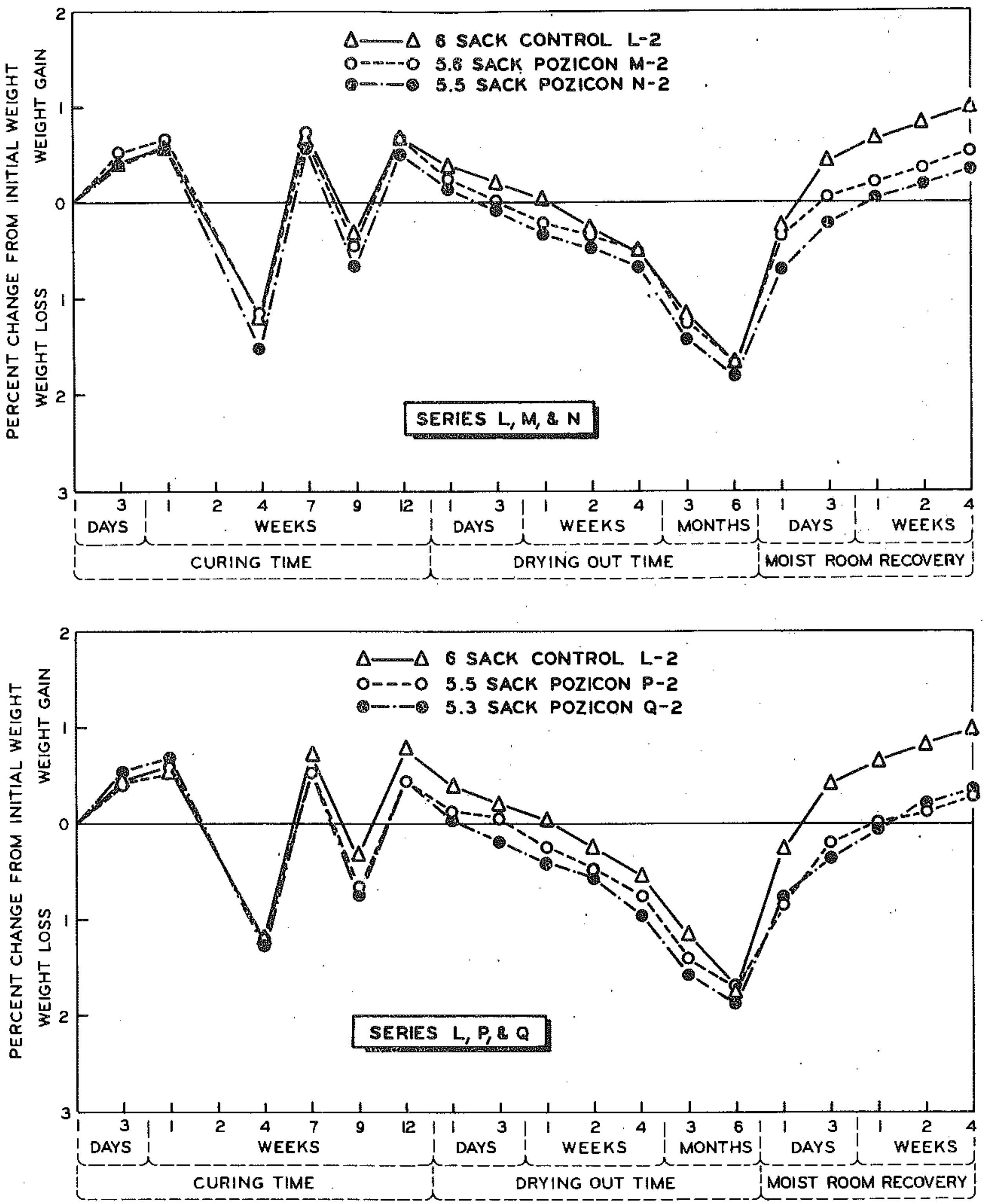


Figure A-20. Shrinkage prism weight variation of second stage SBDC prisms.

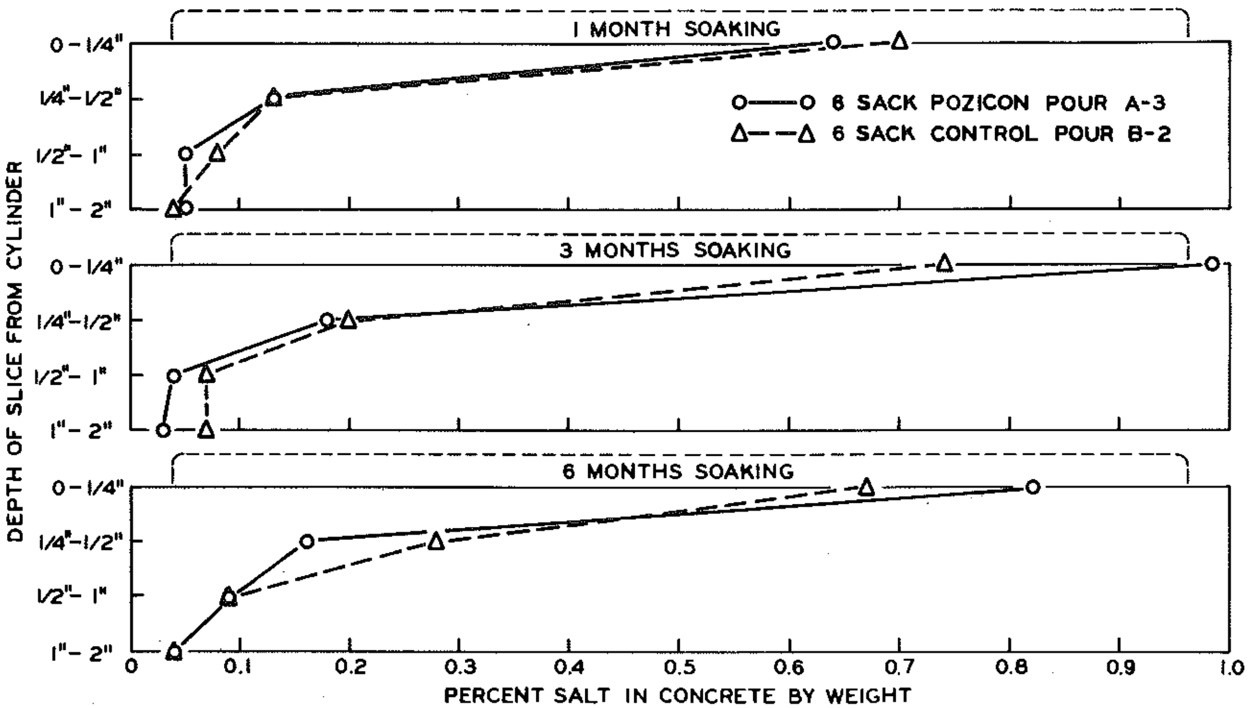


Figure A-21. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series A and B having had 7 days curing.

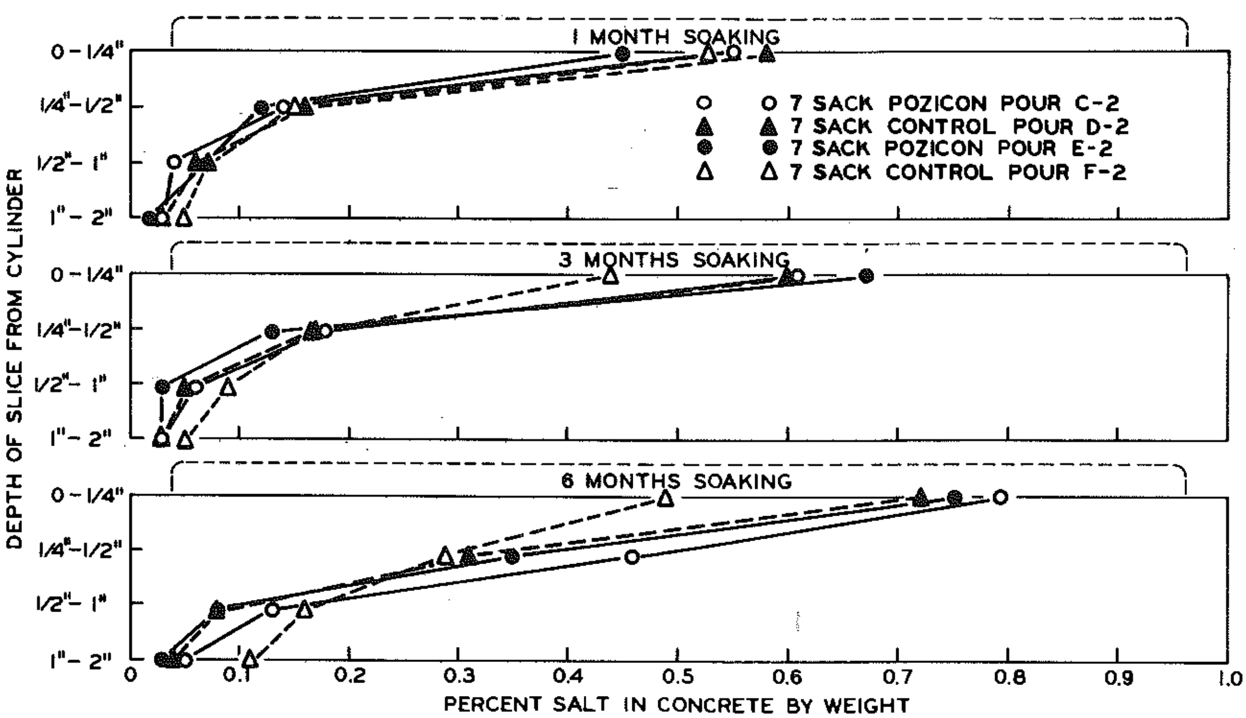


Figure A-22. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series C, D, E, and F having had 7 days curing.

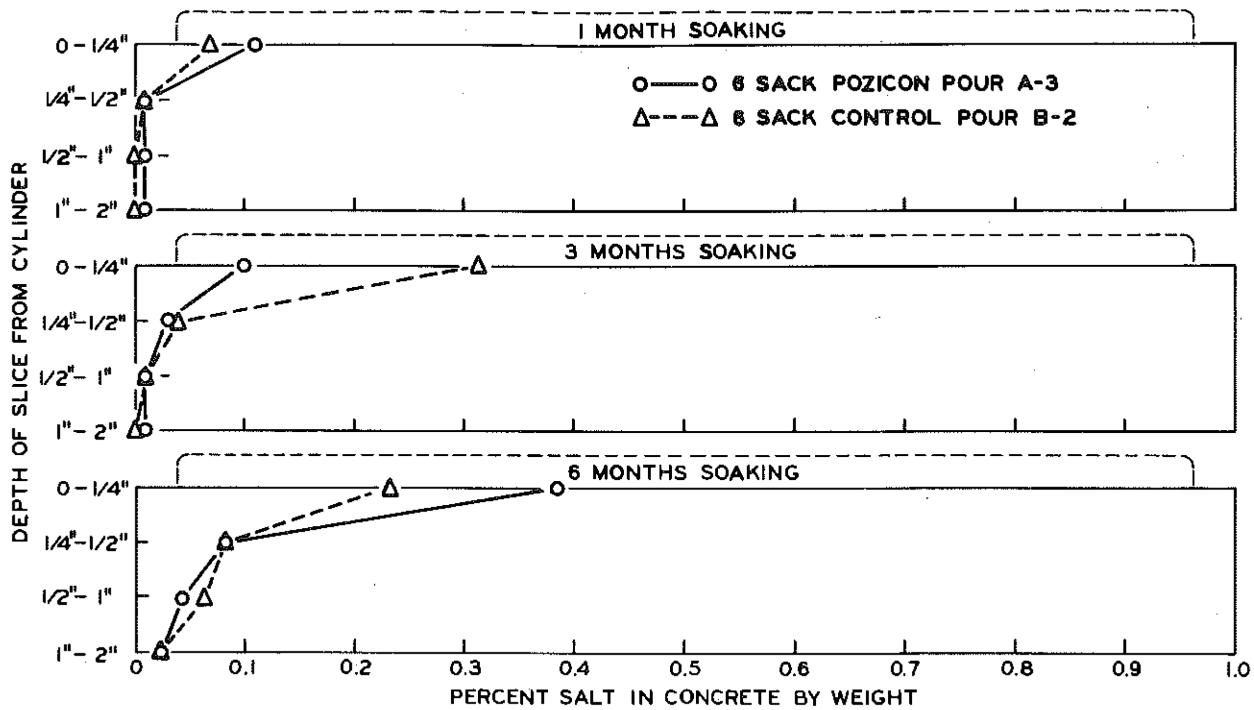


Figure A-23. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series A and B having had 12 weeks curing.

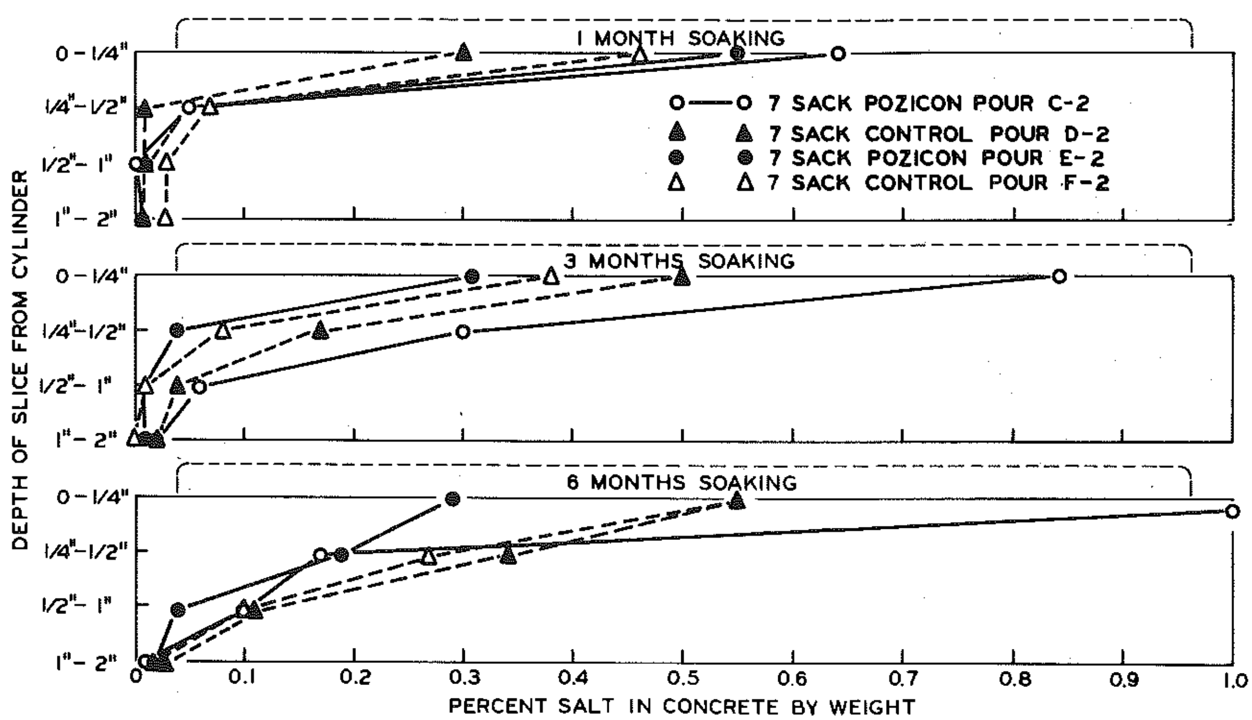


Figure A-24. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series C, D, E, and F having had 12 weeks curing.

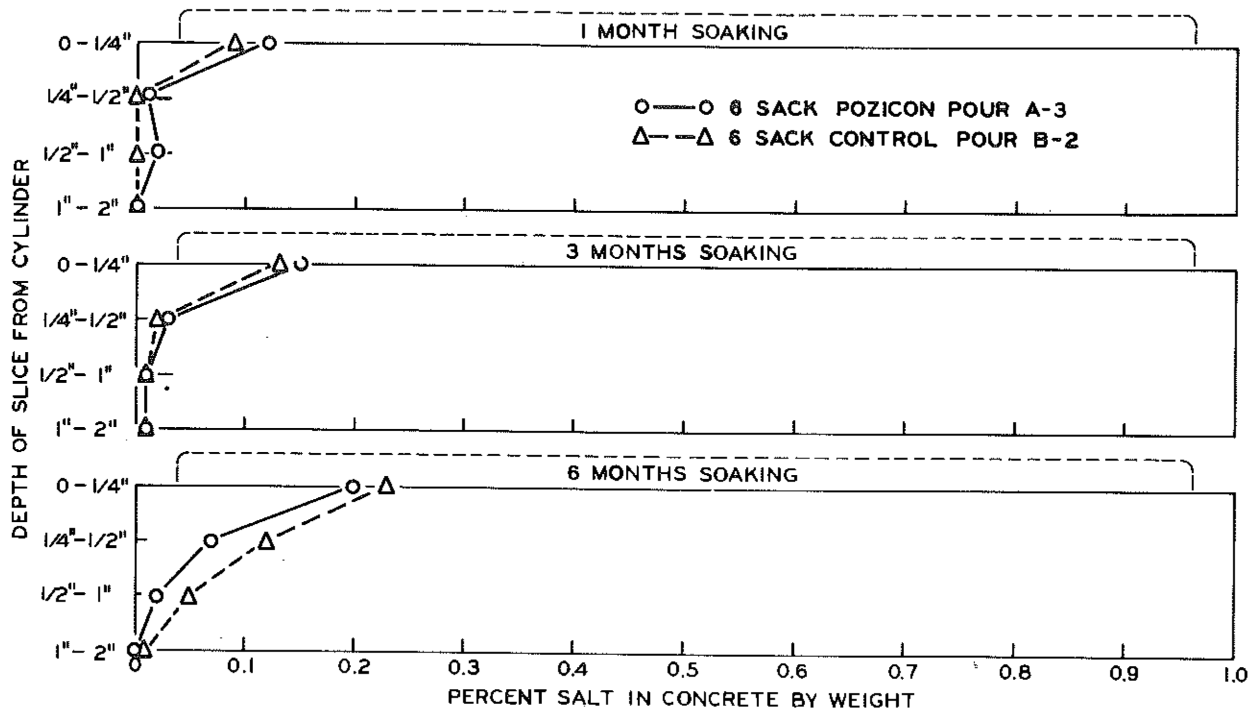


Figure A-25. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series A and B having had the SBDC.

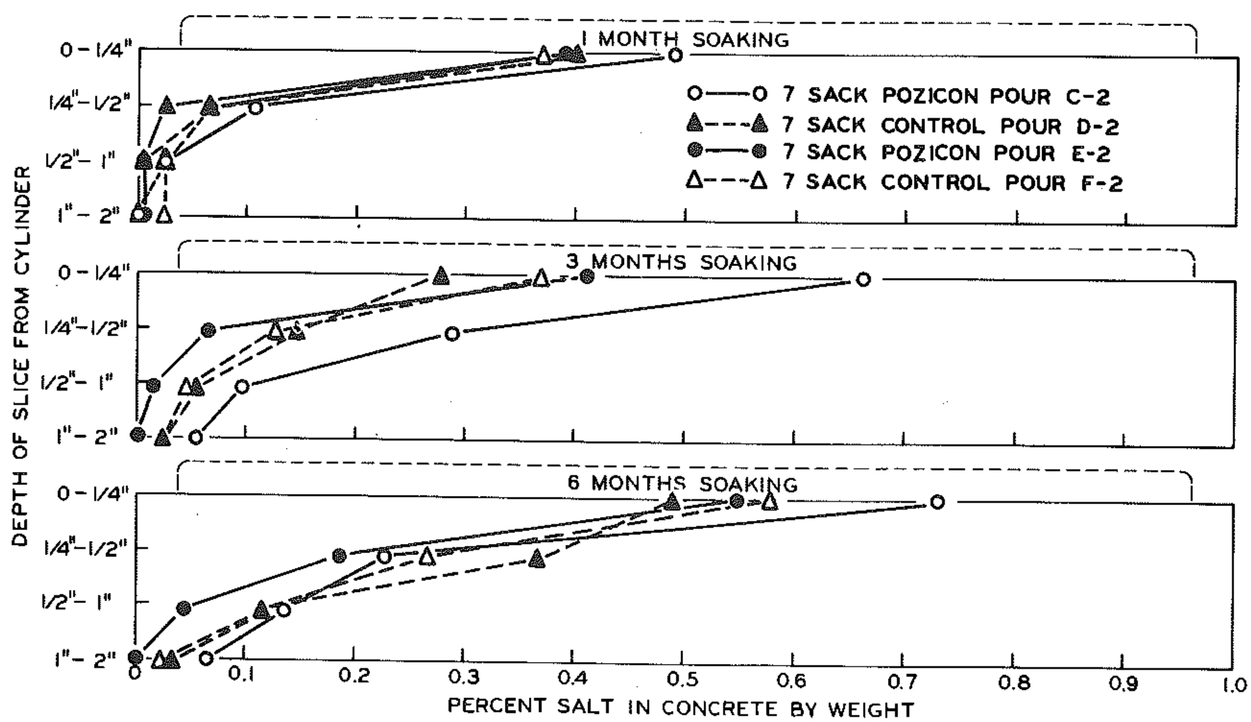


Figure A-26. Penetration of 4 percent NaCl solution into 3 by 6 in. concrete cylinders of first stage series C, D, E, and F having had the SBDC.

TABLE A-1
COMPRESSIVE STRENGTH SUMMARY
4 by 8 in. Cylinders
(Cured in Moist Curing Room)

Stage	Mix Description	Series No.	Compressive Strength (Avg. of 3), psi 3 Day	7 Day	28 Day	12 Week	SBDC
First Stage	6 Sack Pozicon	A-1	3,330	4,020	4,050	6,180	6,330
	6 Sack Control	B-1	3,260	4,130	4,800	4,730	4,790
	7 Sack Pozicon	C-1	2,580	2,930	4,540	5,650	5,510
	7 Sack Control	D-1	2,920	3,710	4,550	4,790	5,060
	7 Sack Pozicon	E-1	2,890	3,280	4,520	5,330	5,340
	7 Sack Control	F-1	3,810	4,230	4,680	4,940	5,680
Second Stage	Control Series L	L-1	2,850	4,030	5,660	5,940	6,000
	Pozicon Series M	M-1	2,010	2,990	4,610	4,680	4,730
	Pozicon Series N	N-1	2,290	3,100	3,860	5,140	5,210
	Pozicon Series P	P-1	2,250	2,990	4,680	5,420	5,120
	Pozicon Series Q	Q-3	2,290	2,860	3,840	5,220	4,720

TABLE A-2
FLEXURAL STRENGTH SUMMARY
3 by 4 by 16 in. Beams
(Cured in Moist Curing Room)

Stage	Mix Description	Series No.	Flexural Strength (Avg. of 3), psi 3 Day	7 Day	28 Day	12 Week	SBDC
First Stage	6 Sack Pozicon	A-1	580	640	740	---	---
		A-2	---	---	---	750	750
	6 Sack Control	B-1	570	660	740	---	---
		B-3	---	---	---	900	790
	7 Sack Pozicon	C-1	490	610	680	---	---
		C-3	---	---	---	860	850
	7 Sack Control	D-1	490	580	760	---	---
		D-3	---	---	---	760	800
	7 Sack Pozicon	E-1	520	570	780	---	---
		E-3	---	---	---	790	840
	7 Sack Control	F-1	610	720	800	---	---
		F-3	---	---	---	780	790
Second Stage	Control Series L	L-1	590	700	830	---	---
		L-3	---	---	---	960	930
	Pozicon Series M	M-3	510	570	720	---	---
		M-4	---	---	---	790	790
	Pozicon Series N	N-1	440	560	730	---	---
		N-3	---	---	---	870	840
	Pozicon Series P	P-1	510	620	760	---	---
		P-3	---	---	---	880	850
	Pozicon Series Q	Q-1	490	600	740	---	---
		Q-4	---	---	---	810	860

TABLE A-3
FLEXURAL STRENGTH AFTER FREEZE-THAW TEST

Stage	Mix Description	Series No.	Strength After 336 Freeze-Thaw Cycles, psi: 14 Day Cure in Moist Room	Strength After 336 Freeze-Thaw Cycles, psi: SBDC
First Stage	6 Sack Pozicon	A-2	400	---
		A-3	---	280
	6 Sack Control	B-2	680	---
		B-3	---	190
	7 Sack Pozicon	C-2	590	---
		C-3	---	640
	7 Sack Control	D-2	520	---
		D-3	---	470
	7 Sack Pozicon	E-2	610	---
		E-3	---	560
	7 Sack Control	F-2	550	---
		F-3	---	410
Second Stage	Control Series L	L-2	600	330
	Pozicon Series M	M-1	400	320
	Pozicon Series N	N-2	510	240
	Pozicon Series P	P-2	450	220
	Pozicon Series Q	Q-3	370	320

TABLE A-4
ABSORPTION CHARACTERISTICS IN 4 PERCENT NaCl
3 by 6 in. Cylinder
(7 Day Cure)

Stage	Mix Description	Mix No.	Net Absorption (percent)[1]				Dry Out Reduction (percent)[1]			
			6 Hr	24 Hr	3 Day	7 Day	6 Hr	24 Hr	3 Day	7 Day
First Stage	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
Second Stage	Control Series L	L-1	1.1	1.4	1.5	1.6	1.5	1.2	0.9	0.6
	Pozicon Series M	M-3	1.3	1.5	1.6	1.7	1.4	1.2	0.9	0.7
	Pozicon Series N	N-2	1.2	1.5	1.7	1.8	1.5	1.2	1.0	0.7
	Pozicon Series P	P-2	1.3	1.6	1.7	1.8	1.5	1.2	1.0	0.8
	Pozicon Series Q	Q-1	1.4	1.7	1.9	2.0	1.6	1.4	1.1	0.9

[1] Percent absorption over pretest moisture content.

TABLE A-5
ABSORPTION CHARACTERISTICS IN 4 PERCENT NaCl
3 by 6 in. Cylinder
(12 Week Cure)

Stage	Mix Description	Mix No.	Net Absorption (percent)[1] 6 Hr	24 Hr	3 Day	7 Day	Dry Out Reduction (percent)[1] 6 Hr	24 Hr	3 Day	7 Day
First Stage	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
Second Stage	Control Series L	L-1	0.4	0.5	0.5	0.6	0.5	0.5	0.3	0.2
	Pozicon Series M	M-3	0.3	0.5	0.5	0.5	0.4	0.4	0.2	0.1
	Pozicon Series N	N-2	0.3	0.4	0.5	0.5	0.4	0.4	0.2	0
	Pozicon Series P	P-2	0.3	0.4	0.5	0.5	0.4	0.3	0.2	0
	Pozicon Series Q	Q-1	0.3	0.5	0.5	0.5	0.4	0.4	0.2	0

[1]Percent absorption over pretest moisture content.

TABLE A-6
ABSORPTION CHARACTERISTICS IN 4 PERCENT NaCl
3 by 6 in. Cylinder
(SBDC)

Stage	Mix Description	Mix No.	Net Absorption (percent)[1] 6 Hr	24 Hr	3 Day	7 Day	Dry Out Reduction (percent)[1] 6 Hr	24 Hr	3 Day	7 Day
First Stage	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	0.6	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
Second Stage	Control Series L	L-1	0.3	0.5	0.6	0.7	0.6	0.5	0.4	0.2
	Pozicon Series M	M-3	0.6	0.7	0.8	0.9	0.7	0.6	0.4	0.2
	Pozicon Series N	N-2	0.4	0.6	0.7	0.8	0.6	0.5	0.3	0.2
	Pozicon Series P	P-2	0.3	0.5	0.7	0.8	0.6	0.5	0.3	0.1
	Pozicon Series Q	Q-1	0.4	0.7	0.8	0.9	0.7	0.6	0.4	0.2

[1]Percent absorption over pretest moisture content.