INVESTIGATION OF RETARDING ADMIXTURES FOR PORTLAND CEMENT CONCRETE

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VERMONT DEPARTMENT OF HIGHWAYS

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STATE OF VERMONT

DEPARTMENT OF HIGHWAYS

MATERIALS DIVISION

INVESTIGATION OF RETARDING ADMIXTURES FOR PORTLAND CEMENT CONCRETE

INTERIM REPORT NO. 1

BY

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RETARDING ADMIXTURE INVESTIGATION

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FIGURES

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APPENDIX

A. INTRODUCTION

One characteristic of concrete that makes it especially valuable as a construction material is its ability to remain plastic for a period of time before it stiffens and starts to develop strength. This delay in set provides time for the constructor to place, consolidate, and finish the concrete before it hardens.

The length of time that concrete remains plastic varies from a few minutes to many hours, depending on the type and brand of cement used and the temperature and weather conditions prevailing at the time the concrete is placed. High temperatures reduce the setting times considerably and often on hot days there will be insufficient time to properly place concrete on certain types of construction.

One type of construction that often requires more retardation of set is bridge decks. If the concrete above a pier hardens before all of the dead load deflection has developed in the deck, more and more stress will be applied to the hardened concrete as the placing continues until the concrete over the pier fails in flexure and a crack is formed. One solution to this problem is to divide the bridge deck into sections and place the areas immediately above the piers last. In this manner the dead load deflection will have developed in the deck before the concrete over the piers has hardened. However, this method of construction requires the use of a considerable amount of additional labor and the installation of numerous headers, which often results in a rough riding surface.

Another solution to the problem would be to produce concrete that would not stiffen and get hard until all sections of the deck had been placed. In this manner placing of the concrete could begin at one end of a deck and continue uninterrupted to the other end. This method allows for the efficient use of mechanical finishing machines - thus providing a smoother riding surface.

The factors affecting the setting time of concrete have been discussed in many reports but none deal with the combinations of admixtures and local materials used in Vermont Highway construction.

The purpose of this investigation is to examine through testing all retarding admixtures currently being used on State of Vermont highway projects.

This series of laboratory tests were performed in accordance with AASHO M 194 with some modifications due to limited facilities and equipment.

B. MATERIALS

In conducting this investigation, it was intended to test the retarding admixtures in combination with the cement and aggregate used in actual field conditions. Most of the materials used for this report were obtained from local producers.

(a) Aggregates:

The aggregate sources were chosen due to their geographical location as well as to their geological composition. For this reason, six locations were sampled representing a good cross-section of the aggregates produced for Vermont consumption. All aggregates were tested for gradation and mineral composition. Tests were conducted concerning thin and elongated piece count and fractured face count of coarse aggregates, as well as organic impurities in sand. The results of these tests are recorded in the individual Retarder Test Reports in the Appendix. Following is listed the aggregate sources used:

Lebanon Crushed Stone	-	W. Lebanon, N. H.	Test	Report	A
* J. P. Carrara & Sons	-	N. Clarendon, Vt.	"	"	B
* Calkins Construction	-	Coventry, Vt.	"	"	C
Lucien Demers - Winooski & S. T. Griswold	-	Williston	"	"	D
* W. E. Dailey & Sons	-	South Shaftsbury, Vt.	"	"	E_1&E_2
Kelley Construction	-	Websterville, Vt.	"	"	F

*Crushed gravel

(b) Cement;

All of the cement currently used in the Vermont Highway program is supplied by three producers. It is continually being tested by the Highway Materials Laboratory for its physical properties which must conform to AASHO M 85 and/or M 134. Since the Department allows both Type I and Type II cements, it was decided that both Types should be included in this program. The individual Retarder Test Reports indicate the brand and type of cement used in conjunction with each aggregate source. Most of the cement in these tests was sampled directly from the silos of the various ready-mix producers. Following is listed the cement manufacturers:

Glens Falls Portland Cement Co.	-	Glens Falls, N. Y.
Universal Atlas Cement Co.	-	Hudson, N. Y.
North East Cement Co. Inc.	-	Syracuse, N. Y.

(c) Retarders;

The retarders investigated in this program represent those brands currently used in Vermont. They represent three general chemical types: lignosulonic acids, hydroxylated carboxylic acids, and carbohydrates. No effort was made to perform chemical tests upon these products. Most samples were obtained directly from the ready-mix producers stock. Again, they were used in the same combinations as in actual field application.

Following is listed the suppliers and the brand names:

Grace Construction Materials	-	Cambridge, Mass.	Daratard & Daratard H.C.
Sika Chemical Corporation	-	Passaic, N. J.	Plastiment
Masterbuilders	-	Cleveland, Ohio	Pozzolith 100 XR & MBHC

(d) Air Entraining Admixtures;

The use of non-air entrained cement necessitated the addition of an admixture to obtain the desired air content. Vermont Specifications require an air content to range from 5% to 8% of the concrete volume. Several commercial products are available but the brand most commonly used by Vermont ready-mix producers is Grace Chemicals' "Darex". This was used in all test mixtures with but one exception. Master Builders Vinsol Resin was used in conjunction with their retarders since this practice prevails in the field.

C. PROCEDURES

The procedures used in mixing throughout this investigation followed as closely as possible that which is required by AASHO T 126 and every effort was made in controlling uniformity of detail.

These tests were performed using Vermont's Standard Class AA ($6\frac{1}{2}$ bags/cy) concrete. Three batches of retarded concrete were compared with three batches of reference or non-retarded concrete for each test as required in AASHO M 194, et. al. Seven tests were performed in order to best represent the majority of combinations common throughout Vermont.

The ingredients were combined in the sequence prescribed in AASHO T 126 with adjustments being made for a slump of 2 to 3 inches. All concrete was blended in a $1\frac{1}{2}$ cu. ft. Sears Roebuck Revolving Drum Type Mixer.

After the concrete was removed from the mixer, the following tests were performed:

1. Slump of Portland Cement Concrete (AASHO T 119).
2. Air content of freshly mixed concrete by Chase Indicator (AASHO T 199).
3. Air content of freshly mixed concrete by Pressure Method (AASHO T 152).
4. Weight per cubic foot & yield of concrete (AASHO T 121).
5. Time of setting of concrete mixtures by penetration resistance (AASHO T 197).
6. Making & curing concrete compression test specimens in the Laboratory (AASHO T 126).

The air content was tested using the Chase Air Indicator with occasional checks using the Pressure Meter Method. When the latter was used, the weight per cu. ft. and yield were also determined.

Penetration tests were performed in accordance with AASHO T 197 using an "Acme" Penetrometer. A six inch cube of mortar was screened from each batch. A mechanical sieve shaker and standard eight inch #4 sieves were used to remove the mortar from the concrete. The steel molds were covered upon being filled in order to keep the mortar from surface drying prematurely. Temperature of the mixes and the laboratory facilities were maintained at 73.4°F ± 3°F.

Due to a limited supply of standard laboratory steel cylinder molds, it was felt that it would be possible to make a study comparing the compressive strength of cylinders cast in various types of commercial molds. To this end, steel, plastic, and paraffined cardboard molds were utilized. Three 6" x 12" cylinders were cast from each batch of concrete. These cylinders were broken at ages of three, seven, and twenty-eight days.

Freeze-thaw tests comparing the durability of retarded and non-retarded concretes were run in cooperation with the State of New Hampshire. Space was shared in their testing cabinet resulting in a limited number of specimens to be compared. Thus, only two aggregate sources were chosen - one being crushed rock, the other being crushed gravel. These tests were made in addition to the before mentioned tests and in accordance with AASHO T 161 - Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water. Specimens were cast in 3" x 2 3/4" x 15" steel molds, then cured for fourteen days prior to being shipped to New Hampshire.

A note of explanation from New Hampshire:

> Four groups of 3 beams each were received from Vermont to be placed in New Hampshire's freeze-thaw cabinet. All the samples were weighed and a sonic fundamental transverse frequency was determined on each. Two beams from each set were placed in the freeze-thaw cabinet and the third one was placed in the moisture room to compare with the others after 300 cycles were completed. After every 50 cycles or so the samples were removed from the cabinet and reweighed and a new frequency measured.

After 300 cycles the samples were broken in midpoint flexure and the two remaining halves were capped and broken for compressive strength.

The concrete mix design and all results may be found in "Discussion of Tests" (f. Durability).

D. DISCUSSION OF TESTS

In conducting these tests, it was sought to determine if the retarding admixtures as used in actual practice conformed to the Vermont Department of Highways specifications. Therefore, each series of batches comparing the retarded concrete and its reference concrete are separate tests and the comparison of one brand of retarder to that of another should be avoided. Although the graphs, etc. show the collective results of the complete series, each test should be considered singularly.

(a) Consistency:

Although every effort was made to maintain a slump of 2" to 3", there was an occasional batch slightly less than two inches. No attempt was made to readjust those mixtures once the slump test was performed. However, no mixtures were allowed having a slump in excess of three inches. It was found that the minor variations within this range had a negligible effect on the setting time of any of the concrete. The stiffer mixtures proved to be much more difficult to screen for the penetration test. The results of the slump tests for each batch are listed in the Appendix.

(b) Water Content:

The addition of the retarder caused wide variations in water content from that of the reference concrete. With one exception, the retarders decreased the amount of water necessary to produce the desired consistency. In test reports E_1 and E_2 (See Appendix) the change in water content was negligible. This was possibly caused by the cement which displayed the properties of "false set" in the reference mixes. Further tests regarding these retarders should be conducted prior to forming definite conclusions.

Claims of the various manufacturers about their products water reducing capabilities were, in some cases, exaggerated but most met the minimum requirements. The lignosulfonate (Daratard) proved to be the most capable water reducer of all the chemical types.

The minimum water reduction caused by retarders is specified to be 5%. The before mentioned tests (E_1 & E_2) failed to meet this requirement and Test Report "C" also failed by 0.4%. It should be mentioned that under actual field conditions, the percentage of water reduction will vary with changes in temperature. According to a report submitted by the State of Nebraska, the mixing water requirements of all retarders was increased at 100°F.

No attempt was made to measure the amount of bleeding water from the penetration test specimens. It was noted that most retarded mixes had slightly more bleeding than the reference mix.

Your attention is directed to Figure I which shows the effect of retarders on mixing water requirements.

(c) <u>Air Entrainment</u>:

There are many factors that effect the air content of Portland Cement Concrete. Among them may be the difference in cement fineness, temperature, water content, and aggregates. The addition of retarders also effects the air volume depending on its interaction with the other ingredients. In these tests, all retarders tended to entrain varying amounts of air. Thus, the air entraining agents had to be adjusted to obtain the proper air contents within the limits desired. The lignosulfonic retarder entrained considerably more air than did the other types. Several comparisons were made between the Chase Air Indicator and the Pressure Meter method of testing entrained air. With one exception, all results compared within 0.5%, which helps to confirm the reliability of the Vermont modified version of the Chase Air Indicator.

(d) Retardation:

The retarding admixtures were added in the quantity recommended to cause an increase from 50 to 60 percent in the setting time of the retarded concrete as compared to the setting time of the reference concrete. This requirement is currently specified by the State of Vermont. However, AASHO specifications do not include this requirement but specify instead a maximum increase in setting time of three hours. The two specifications are, in many instances, not compatible.

Furthermore, none of the tests in this program met both specifications. No attempt was made to rerun any test using an adjusted quantity of retarder. The reason for accepting the obtained results was due to the difficulty in acquiring the necessary amount of concrete ingredients, as well as the fact that each brand of cement and type of aggregate affected the setting time of the mixes differently. This was proven in the reference mixes as well as those mixes using the same retarder. Your attention is directed to Figure 2-A (Time of Set of Concrete Mixtures).

The initial set (500 psi - penetration resistance) is the standard measure showing the hardening rate of concrete, but it should be noted that this point is well past the time when finishing or working of the mix can be easily performed. Figure 2-B shows the curves of both the reference and retarder mixes as plotted from the results of the Penetration Resistance Tests.

(e) Compressive Strengths:

Vermont Specifications require a compressive strength of one-hundred and ten percent when using a retarded mixture relative to that of its reference mixture. This specification refers to all retarders whether they are classed as water-reducing retarders or not. AASHO requires this increase in strength for water-reducing retarders only, while those classed simply as retarders are required to have a relative strength of ninety percent. As shown in Figure 3-F, an increase in compressive strength due to retardation was realized in every test, although some did not surpass the Vermont minimum requirement at all test ages.

The many factors affecting compressive strengths of cylinders include variations in air content, cement content, water-cement ratios, handling, curing, and even the materials from which the molds are constructed. While increased air entrainment usually reduces strength, it was observed, as previously noted, that retarding admixtures generally increased strength. Also, the steel and plastic molds generally produce higher strength cylinders than those cast in paraffin treated cardboard molds. Exceptions were noted at all ages and are indicated in Figure 3-A. Your attention is directed to Figures 3-B through 3-E, which graphically show the comparative cylinder strengths relative to the type of molds. Note that this comparison was performed on three and seven day specimens only due to limited equipment and higher early sensitivity. The twenty-eight day tests were all cast in treated cardboard molds.

Conclusive proof of the desirability of one mold in preference to another is difficult to establish from this series of tests. A factor such as a three percent variation in air content may have profound influence on strength.

(f) Durability:

Vermont and AASHO specifications require that a minimum Relative Durability Factor of 80 must be obtained when comparing a retarded concrete to a reference concrete through Freeze-thaw testing. The results obtained show that all samples tested were well above this minimum.

All information concerning properties of the concrete mixtures used in freeze-thaw testing are shown in Figure 4A

The results obtained from New Hampshire were calculated according to AASHO T-161 which determined the Relative Durability Factor. As indicated in Figures 4B and 4C, the resulting Factor was 100.6 for batch 1 as compared to 2 and 97.3 for batch 4 as compared to 3. This illustrates that the retarders used have no significant effect upon the durability of these mixes.

The samples which were subjected to freeze-thaw testing completed 300 cycles with relatively little weight loss and no physical damage was detectable.

The samples were all physically broken in flexure and then in compression. Results of the actual compressive tests are all less than those computed from the sonic testing.

Figure 4D shows the results of all strength tests performed by the New Hampshire Materials Division. For further details concerning these tests, the complete report is available in the files of the Materials Division.

E. SUMMARY & CONCLUSIONS

1. Strength of cylinders increased in all cases when a retarding admixture was introduced. This increase did not always meet minimum specifications.
2. The addition of retarding admixtures caused no significant adverse effect on the durability of concrete.
3. Retarding admixtures tested, in most cases, reduced the water content of the concrete for any given consistency. The one exception to this statement was possibly caused by false set of cement - not the retarder.
4. Strength of cylinders varied considerably when comparisons were made using steel, plastic, and cardboard molds. With few exceptions, the steel and plastic molds produced the highest strengths while cylinders made in cardboard molds usually broke lower.

5. The retarders in many cases did not meet the requirements specified due to the use of too many variables.
6. Retarder dosages recommended by their manufacturers resulted in higher quantities than necessary when applied under laboratory conditions.
7. Variable amounts of retardation may be expected with various combinations of materials.
8. Minor variations in consistency had a negligable effect on the setting time of the concrete.
9. The amount of air-entraining agent required in the retarded concretes was dependent upon each retarder and the combination of materials that is was used with. Lignosulfonate retarders increased the air content most noticeably.
10. Strength of cylinders varied inversely with the air content of the concrete. As the air-entrainment increased, strength of cylinders decreased.

F. RECOMMENDATIONS

1. The 1964 Vermont Standard Specifications should be revised to conform with AASHO Specifications in cases where there is conflict or disagreement.
2. For acceptance testing, samples of the product to be tested should be obtained from the Supplier as opposed to sampling from Ready-Mix inventories.
3. The testing of any one ingredient in a concrete mixture should be the only variable; all other materials should remain constant.

4. All cylinders should be cast in molds of similar materials in order to minimize their influence on compressive strength.
5. The difference between air contents of both the reference concrete and the retarded concrete should be controlled within 0.5%.
6. The rate of addition of retarding admixture for field conditions should be established through experience and actual field testing.

FIGURES

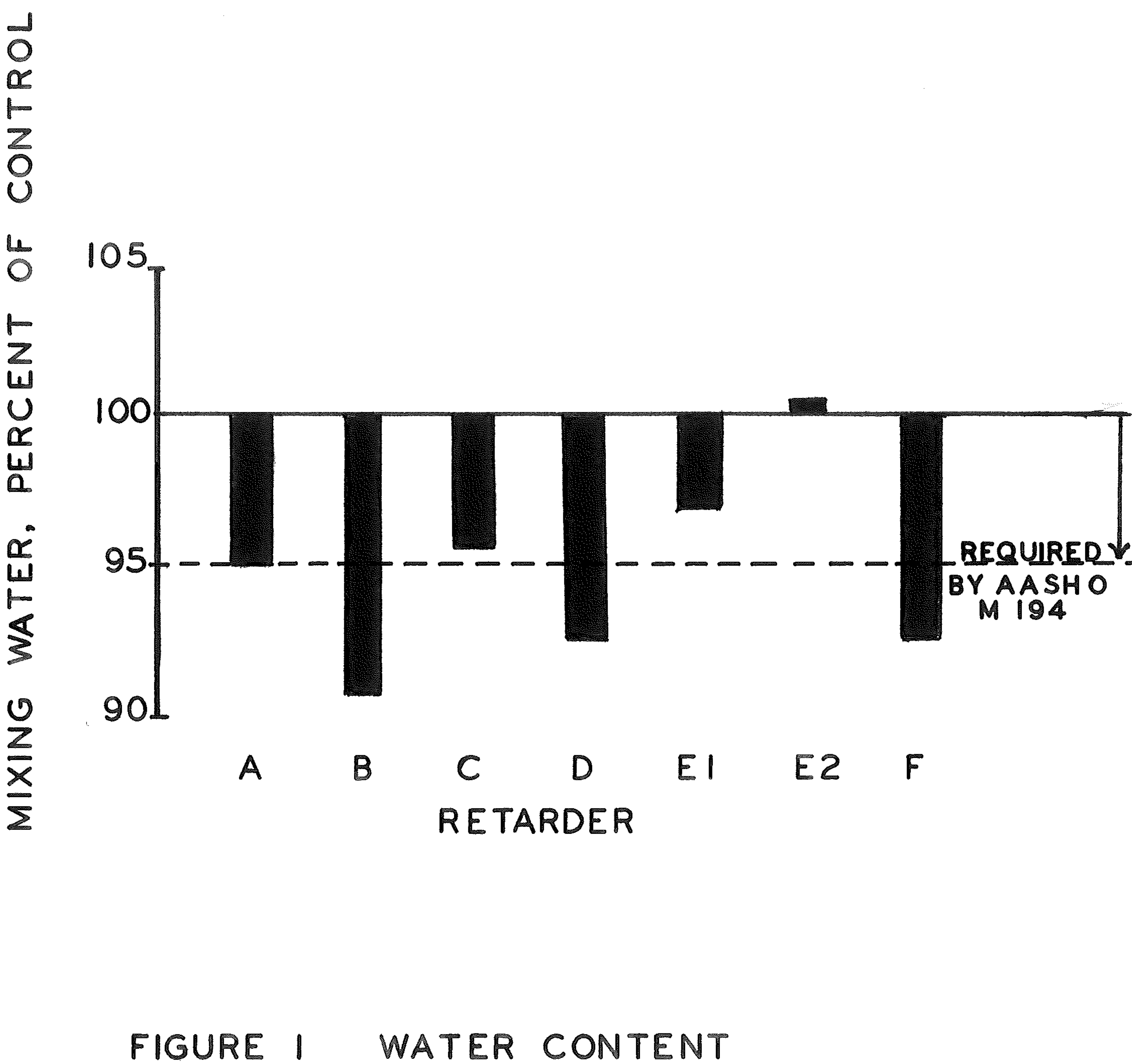

FIGURE 1 WATER CONTENT
AVERAGE PERCENTAGE OF VARIATION DUE TO RETARDER

TEST	INITIAL SET 500 PSI					FINAL SET 4000 PSI			
	REF (TIME IN HOURS)	RET (TIME IN HOURS)	1. PERCENT INCREASE	2. INCREASE IN HOURS		REF (TIME IN HOURS)	RET (TIME IN HOURS)	PERCENT INCREASE	INCREASE IN HOURS
A	4.63	7.69	66	3.06		6.66	9.74	46	3.08
B	6.08	9.39	54	3.31		8.64	12.48	44	3.84
C	6.31	8.98	42	2.67		8.98	11.96	33	2.98
D	5.37	7.77	45	2.40		7.46	9.92	33	2.46
E1	5.67	8.92	57	3.25		7.75	11.21	45	3.46
E2	5.67	10.26	81	4.59		7.75	12.43	60	4.68
F	4.32	8.27	91	3.95		5.71	9.72	70	4.01

1. 1964 VERMONT HIGHWAY SPECIFICATIONS
2. AASHO M 194

FIGURE 2A. TIME OF SET OF CONCRETE MIXTURES

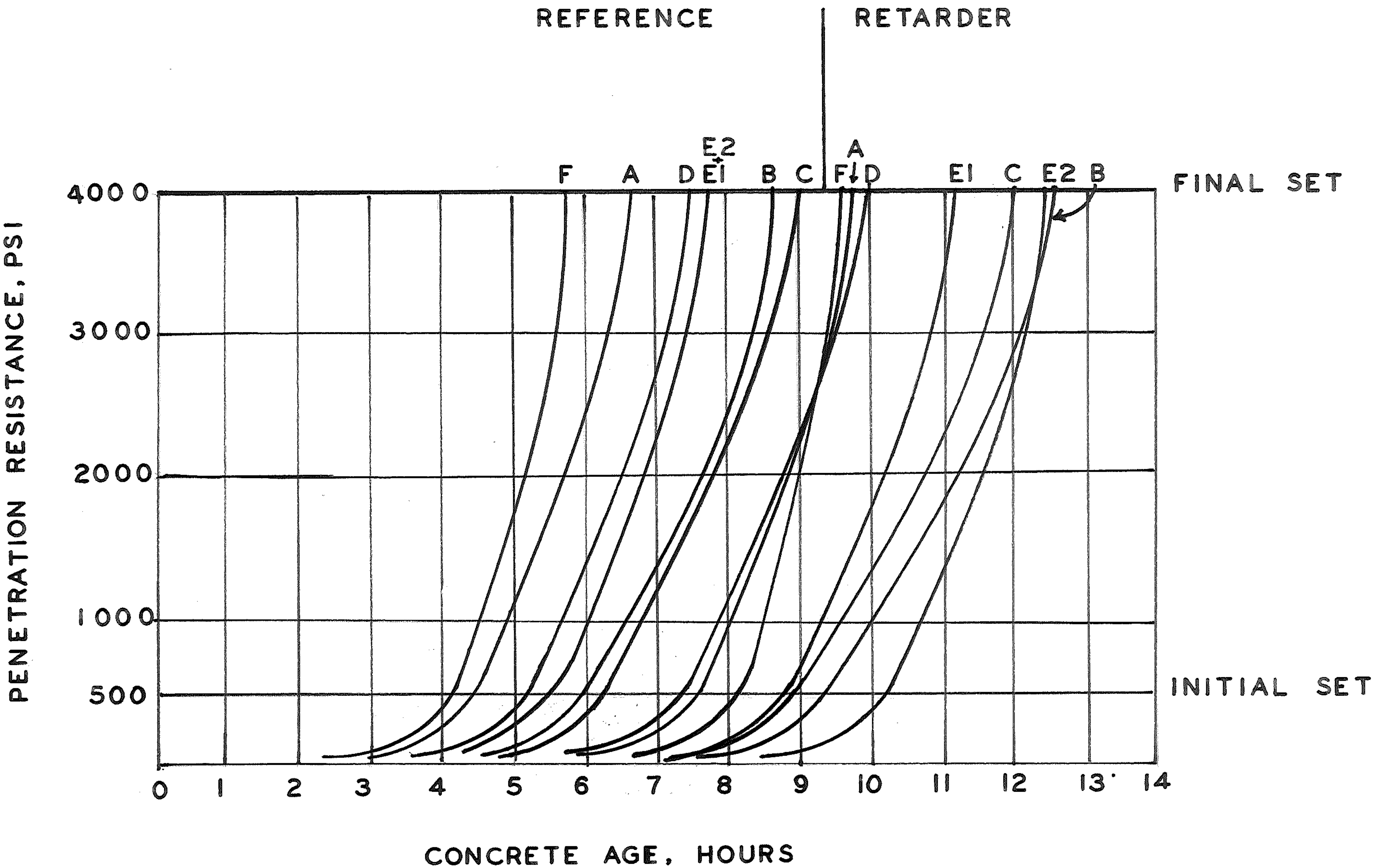

FIGURE 2B TIME OF SET CURVES REFERENCE MIX VS. RETARDER MIX

Retarded Concrete	3 DAY			7 DAY			28 DAY		
Test No.	Steel	Plastic	Cardboard	Steel	Cardboard	Cardboard	Cardboard	Cardboard	Cardboard
A	4041	3855	3767	4616	4403	4244	4297	5535	5429
B	4253	2467	3387	4297	3289	4183	4554	3767	4793
C	3218	3272	2511	4149	3581	3431	4757	4183	5173
D	3440	4899	3749	4138	5217	4863	4227	6048	5394
E1	4740	4439	3961	4757	4722	4704	5474	5801	5341
E2	4191	4014	3643	5305	4536	4439	5474	5456	5252
F	2759	3395	3245	3210	3422	3723	3599	3979	4695
Reference Concrete									
A	2935	3280	2582	3519	3445	3210	4527	4439	4174
B	2953	3334	2785	3793	3599	3652	4403	4793	4359
C	2502	2520	2087	3749	2829	2989	4793	4563	4545
D	2502	3749	2935	4094	3988	3272	4200	4342	4147
E1	4103	3837	3139	4881	3926	3564	4032	5235	4386
E2	4103	3837	3139	4881	3926	3564	4032	5235	4386
F	3192	3148	2440	3820	2918	2661	3882	3882	3564

FIG 3A COMPRESSIVE STRENGTHS OF CYLINDERS

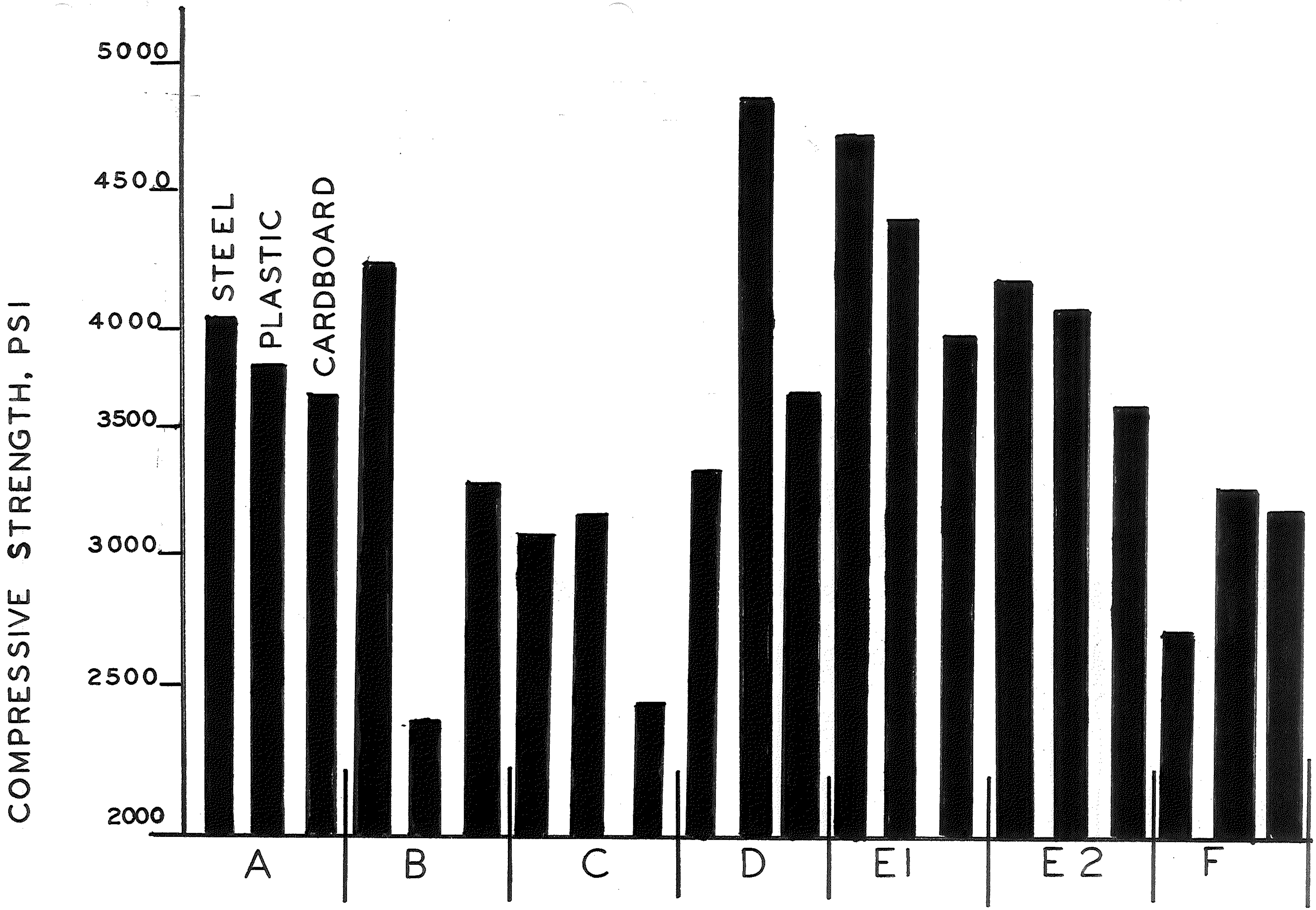

FIGURE 3B 3 DAY COMPRESSIVE STRENGTH TESTS
RETARDED CONCRETES

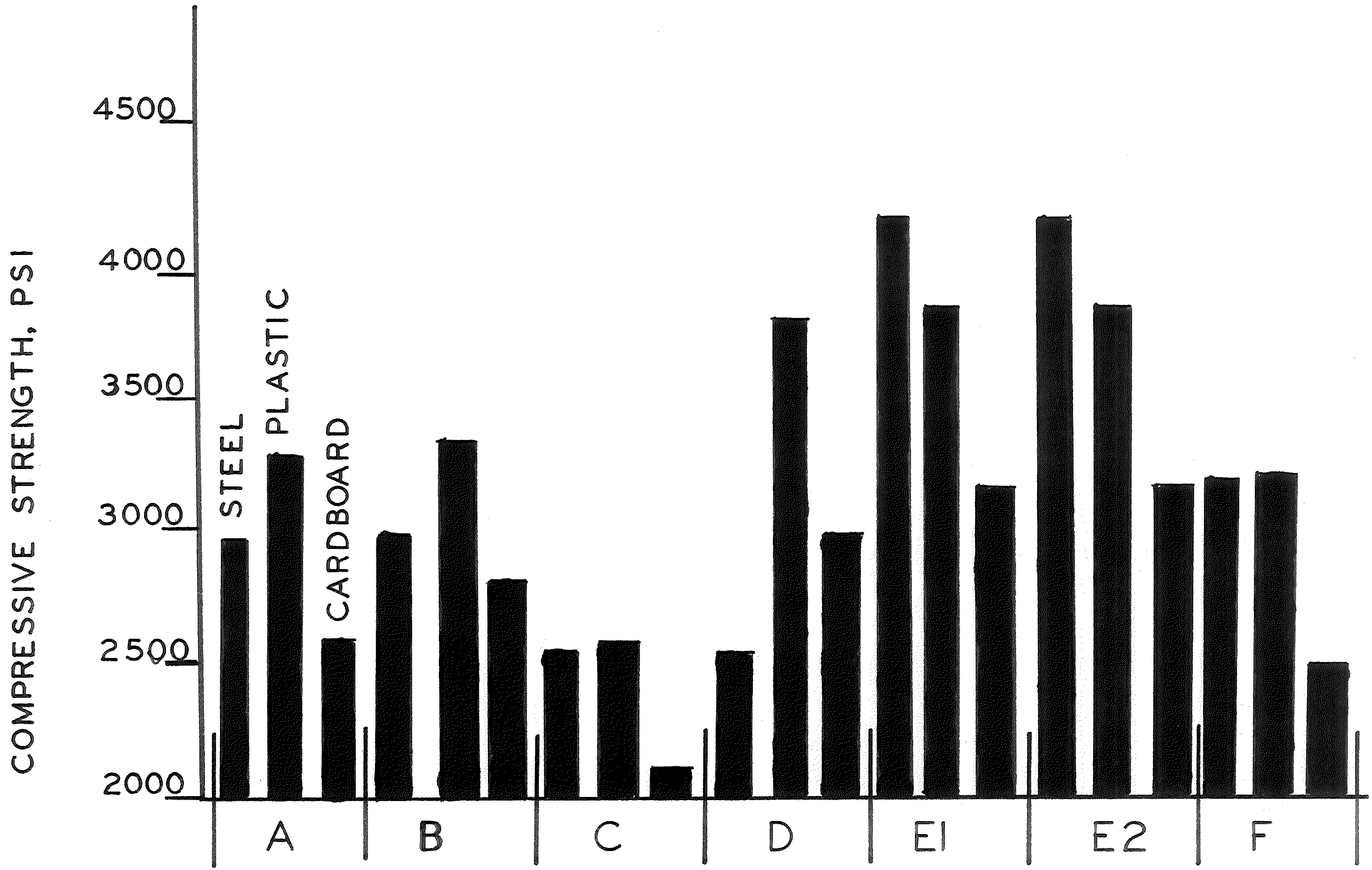

FIGURE 3C 3DAY COMPRESSIVE STRENGTH TESTS
REFERENCE CONCRETES

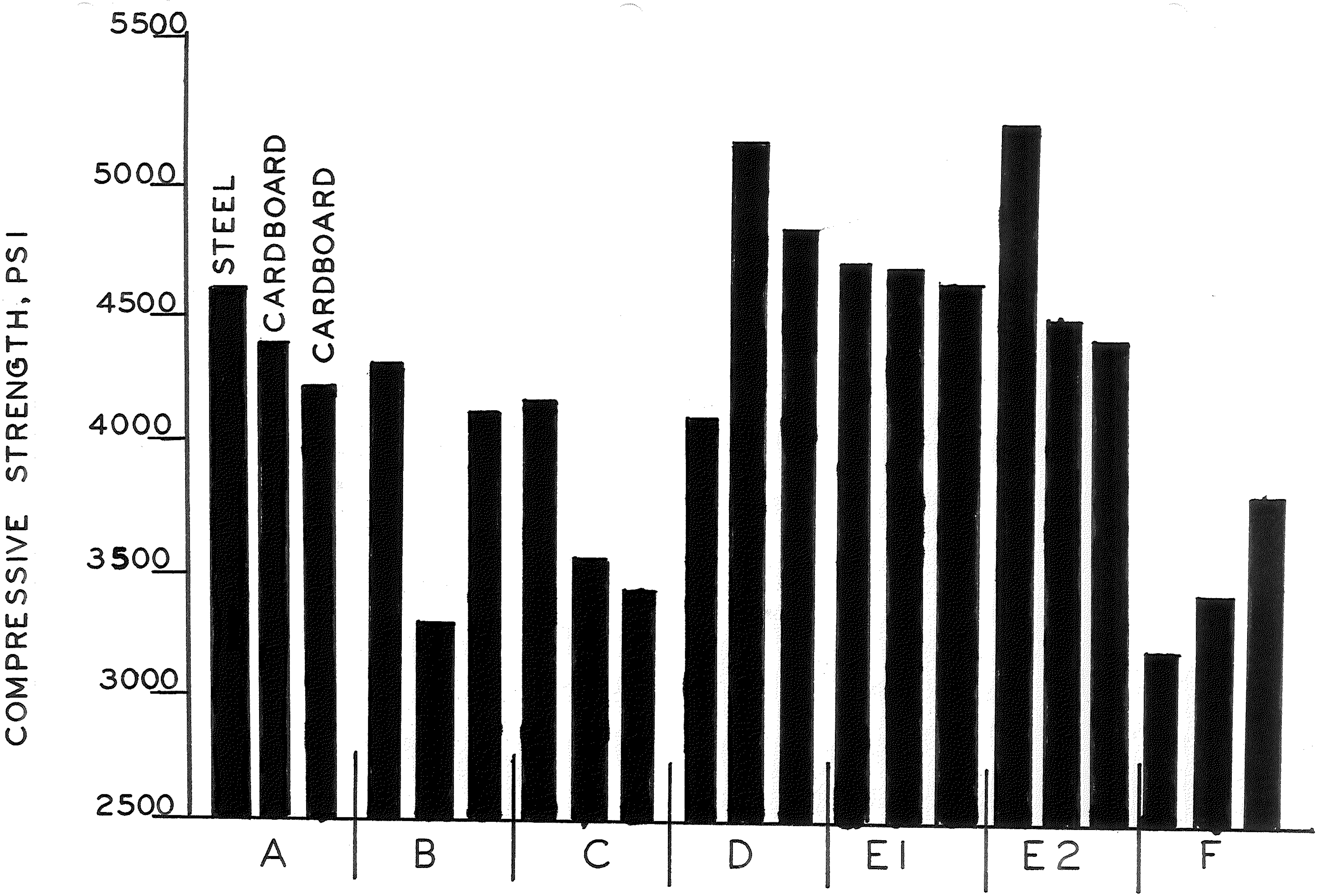

FIGURE 3D 7 DAY COMPRESSIVE STRENGTH TESTS
RETARDED CONCRETES

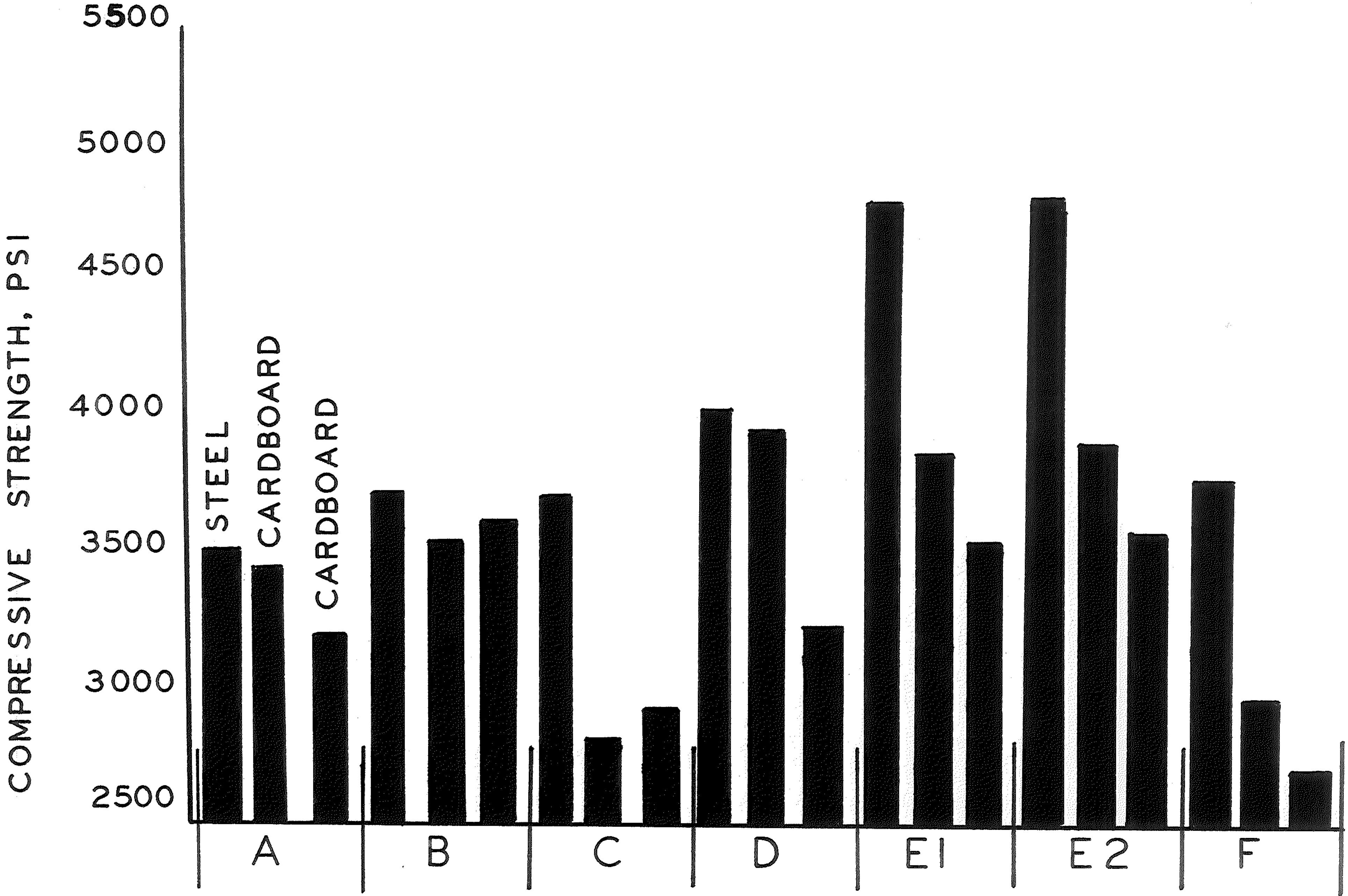

FIGURE 3E 7 DAY COMPRESSIVE STRENGTH TESTS
REFERENCE CONCRETES

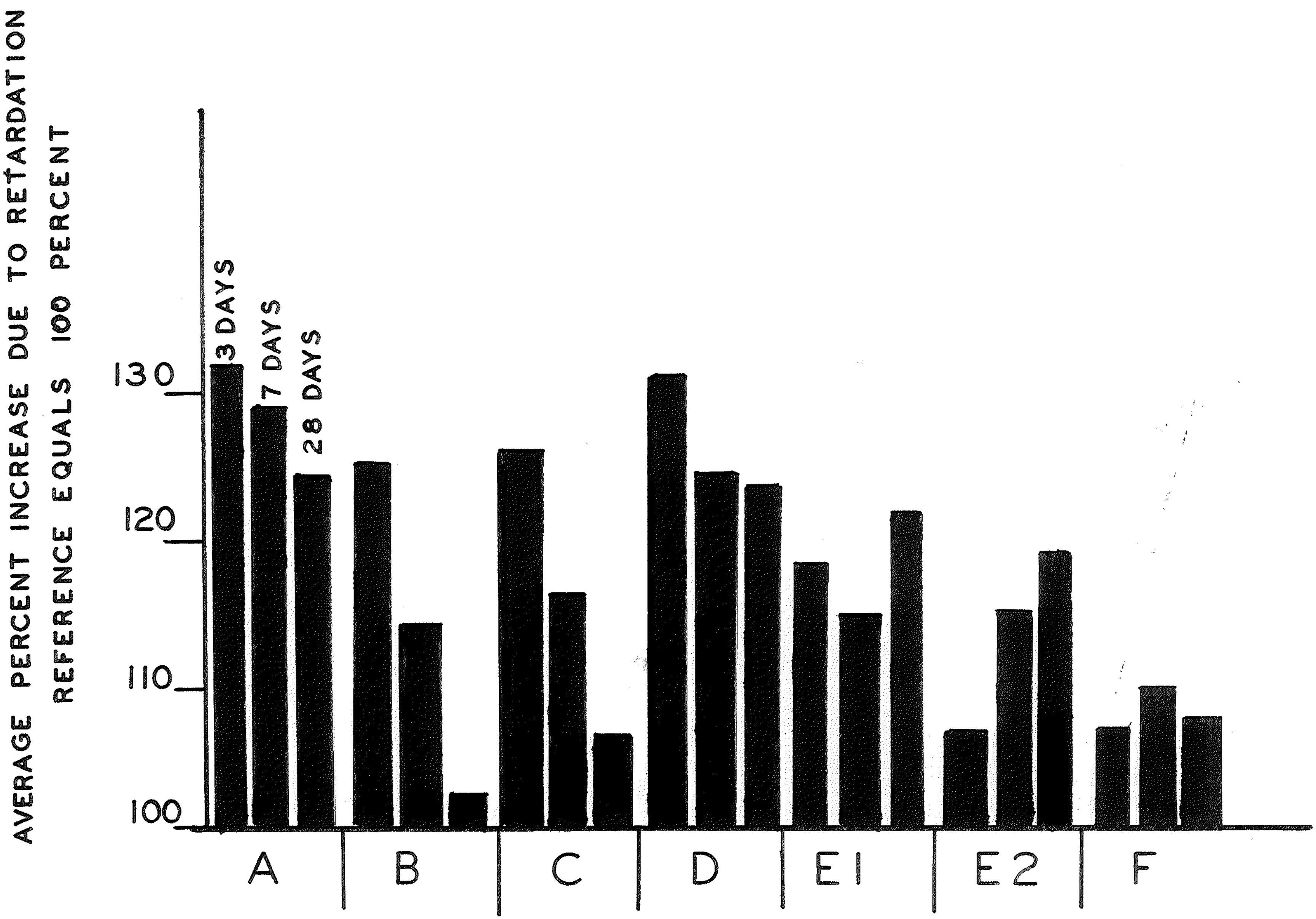

FIGURE 3F AVERAGE INCREASE IN STRENGTH DUE TO RETARDER

These beams were made for the purpose of comparing the durability of retarded concrete with that of non-retarded concrete. Two aggregate sources are used incorporating crushed stone and crushed gravel. Two batches for each aggregate were made using proportions as mixed in the field. Different sources of Type I cement were used for each set of batches. A set of three beams were made for each batch. Batches 1 & 2 are from North Clarendon, Vermont, and are crushed gravel. Batches 3 & 4 are from West Lebanon, New Hampshire, and are crushed stone. All batches are based on our standard mix of 6 1/2 bags/cy. The retarder was added to batches one and four.

Following is a list of information concerning each batch:

	Batch #1	Batch #2	Batch #3	Batch #4
Date	2/6/70	2/9/70	2/10/70	2/11/70
-3/4 Stone	43 lb.-7 oz.	43 lb.-7 oz.	44 lb.-4 oz.	44 lb.-4 oz.
Sand	30 lb.-1 oz.	30 lb.-1 oz.	31 lb.-14 oz.	31 lb.-14 oz.
Cement Brand & Type	Iron Clad Type I	Iron Clad Type I	North East Type I	North East Type I
Cement Quant.	15 lb.-5 oz.	15 lb.-5 oz.	15 lb.-5 oz.	15 lb.-5 oz.
Water (design)	7 lb.-2 oz.	7 lb.-2 oz.	7 lb.-2 oz.	7 lb.-2 oz.
Water (actual)	7 lb.-6 oz.	7 lb.-8 oz.	6 lb.-11 oz.	6 lb.-5 oz.
Darex (Air)	4 grams	5 grams	5 grams	5 grams
Retarder	41.5 ml. (Daratard-9 oz./sack)	None	None	11.5 ml. (Daratard "HC" 2½ oz. sack)
Slump	2 1/4"	1 3/4"	2"	2 1/4"
Air	5%	4 1/2%	5 1/2%	5%
Curing	14 days	14 days	14 days	14 days

Design Dry Weights Per Cubic Yard

	3/4 Stone	Sand	Cement	H_2O
N. Clarendon, Vt.	1728	1196	611	285
W. Lebanon, N. H.	1770	1273	611	285

FIGURE 4A FREEZE THAW TEST INFORMATION

VERMONT MARCH 2, 1970

	BATCH NUMBER	0 CYCLES	300 CYCLES	WEIGHT	FUNDAMENTAL TRANSVERSE FREQUENCY "N"	"N^2"	INDIVIDUAL DURABILITY FACTOR DF	AVERAGE DF	RELATIVE DURABILITY FACTOR
RETARDER	1	A		10.65	1785	3,186,225	98.99	100.1	100.6
	1		A	10.62	1775	3,154,175			
	1	B		10.66	1750	3,062,500	101.15		
	1		B	10.62	1760	3,097,600			
	1	C*		10.70	1820	3,312,400			
	1		C*	10.74	1925	3,705,625			
REFERENCE	2	A*		10.95	1855	3,441,025			
	2		A*	10.98	1935	4,752,400			
	2	B		11.02	1830	3,348,900	101.10	99.5	
	2		B	10.97	1840	3,385,600			
	2	C		10.99	1850	3,422,500	97.85		
	2		C	10.91	1830	3,348,900			

* CONTINUOUSLY MOIST CURED.

FIGURE 4B RELATIVE DURABILITY FACTOR – FREEZE THAW SPECIMENS

BATCHES 1 & 2

	BATCH NUMBER	0 CYCLES	300 CYCLES	WEIGHT	FUNDAMENTAL TRANSVERSE FREQUENCY "N"	"N^2"	INDIVIDUAL DURABILITY FACTOR DF	AVERAGE DF	RELATIVE DURABILITY FACTOR
REFERENCE	3	A		11.26	2005	4,020,025	96.54	96.5	97.3
	3		A	11.19	1970	3,880,900			
	3	B*		11.29	2015	4,060,225			
	3		B*	11.16	2095	4,389,025			
	3	C		11.08	1980	3,920,400	96.50		
	3		C	11.05	1945	3,783,025			
RETARDER	4	A		11.31	2005	4,020,025	94.59	93.9	
	4		A	11.27	1950	3,802,500			
	4	B*		11.13	1980	3,920,400			
	4		B*	11.33	2150	5,856,400			
	4	C		11.39	2015	4,060,225	93.17		
	4		C	11.28	1945	3,783,025			

* CONTINUOUSLY MOIST CURED.

FIGURE 4C RELATIVE DURABILITY FACTOR – FREEZE THAW SPECIMENS
BATCHES 3 & 4

		Sonic PSI			
		At 0 Cycles	At 300 Cycles	Modulus of Rupture PSI	Compressive Strength PSI **
1	A	6700	6600	800	6242
	B	6400	6300	1091	5621
	C*	7200	8600	873	6527
2	A*	7900	12600	1062	6606
	B	7700	7800	960	6467
	C	7900	7600	880	7224
3	A	10400	9800	1135	7685
	B*	10600	11650	1236	7167
	C	9000	9250	1164	8055
4	A	10500	9650	1164	8521
	B*	9850	17100	1033	8328
	C	10550	9550	1164	8545

*Continuously Moist Cured
**Average of both ends of beam broken in compression

FIGURE 4D STRENGTH TEST RESULTS FREEZE THAW SPECIMENS

APPENDIX

RETARDER TEST REPORT

"A"

DATE Feb. 16, 1970

Coarse Agg. Source Lebanon Crushed Stone			
Fine Agg. Source Lebanon Crushed Stone			
Gradation % Passing			
1"	100.0	3/8"	100.0
3/4"	94.5	#4	100.0
3/8"	22.5	#16	67.5
#4	1.7	#30	37.0
#8	0.9	#50	10.0
Flats %	5.1	#100	2.5
Fractures %	100.0	FM 2.92	Color -1
Fine Agg. Sp. Gr.	2.74		
Coarse Agg. Sp. Gr.	2.71		
Predominant Mineral Composition			
Coarse Agg.	Feldspathic Gneiss		
Fine Agg.	Quartz		

Cement Source. Northeast Cement Company			
Type 1			
Retarder Source Grace Construction Products			
Trade Name Daratard H C			
Chemical Type Hydroxylated Carboxylic Acid			
Air Agent Source Grace Construction Products			
Trade Name Darex			
Class AA Mix Design			
Weights	Per Yard	Reference	Retarder
#2 Stone	1770	98Lbs 5oz	98lbs 5oz
Sand	1273	70lbs 12oz	70lbs 12oz
Cement	611	33lbs 15oz	33lbs 15oz
Water	285	15.52lbs Avg	14.75lbs Avg
Retarder	2.5oz/sk		26ml
A.E.A.		11-12g	$10\frac{1}{2}$g
Yield	101.1	100.7	
Unit Weight		144.5lbs	

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	6.85	8.90	$5\frac{1}{4}$	72	$2\frac{3}{4}$	4041	4616	*4297
2	7.82	9.69	$5\frac{1}{4}$	73	$2\frac{1}{2}$	3855	4403	5535
3	8.41	10.62	5	74	$2\frac{3}{4}$	3767	4244	5429
Average	7.69	9.74				3888	4421	5482
Reference								
4	4.74	6.71	5	74	3	2935	3519	4527
5	4.56	6.65	5	75	$2\frac{1}{2}$	3280	3445	4439
6	4.58	6.61	6	74	$2\frac{1}{2}$	2582	3210	4174
Average	4.63	6.66				2932	3391	4380

Water Content (Avg. % of reduction due to Retarder) 5.0

Comp. Strength (Avg. % of increase due to Retarder) 33 3 Days 30 7 Days 25 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 66 Initial 46 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 3.06 Initial 3.08 Final

Notes: *Batch #1 28Day Break Not Included In Averages

RETARDER TEST REPORT

"B"

DATE Feb. 24, 1970

Coarse Agg. Source Carrara No. Clarendon		Cement Source Glens Falls Cement Company	
Fine Agg. Source Carrara No. Clarendon		Type 1	
Gradation % Passing		Retarder Source Grace Construction Products	
1" 100.0	3/8" 100.0	Trade Name Daratard	
3/4" 99.2	#4 99.0	Chemical Type Lignosulfonic Acid	
3/8" 34.9	#16 75.0	Air Agent Source Grace Construction Products	
#4 4.5	#30 44.0	Trade Name Darex	
#8 1.9	#50 15.0	Class AA Mix Design	
Flats % 5.4	#100 5.0		
Fractures % 82.9	FM 2.69 Color -1		
Fine Agg. Sp. Gr. 2.70			
Coarse Agg. Sp. Gr. 2.60			
Predominent Mineral Composition			
Coarse Agg. Quartzite			
Fine Agg. Quartz			

Weights	Per Yard	Reference	Retarder
#2 Stone	1728	96lbs 0oz	96lbs 0oz
Sand	1196	66lbs 8oz	66lbs 8oz
Cement	611	33lbs 15oz	33lbs 15oz
Water	285	16.75lbs Avg	15.17lbs Avg
Retarder	9oz/sk		92ml
A.E.A.		10ml	7-10ml
Yield	100.6		
Unit Weight			

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	8.85	12.50	6½	71	1½	4253	4297	4554
*2	-----	------	8	70	3	2467	3289	3767
3	9.92	12.46	7	70	2½	3387	4138	4793
Average	9.39	12.48				3820	4218	4674
Reference								
4	6.23	8.64	6	68	3	2953	3793	4403
5	5.97	8.79	5½	70	3	3334	3599	4793
6	6.03	8.48	5½	70	2¼	2785	3652	4359
Average	6.08	8.64				3024	3681	4518

Water Content (Avg. % of reduction due to Retarder) 9.4

Comp. Strength (Avg. % of increase due to Retarder) 26 3 Days 15 7 Days 3 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 54 Initial 44 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 3.31 Initial 3.84 Final

Notes: *Batch #2 Not Used In Averages

RETARDER TEST REPORT

"C"

DATE March 3, 1970

Coarse Agg. Source Calkins Coventry			
Fine Agg. Source Calkins Coventry			
Gradation % Passing			
1"	100.0	3/8"	100.0
3/4"	94.0	#4	100.0
3/8"	42.2	#16	72.0
#4	7.0	#30	46.0
#8	2.8	#50	18.0
Flats % 4.4		#100	6.0
Fractures % 86.7		FM 2.62	Color $1\frac{1}{2}$
Fine Agg. Sp. Gr.	2.76		
Coarse Agg. Sp. Gr.	2.78		
Predominent Mineral Composition			
Coarse Agg. Quartz and Labradorite			
Fine Agg. Quartz and Labradorite			

Cement Source. Northeast Cement Company			
Type 2			
Retarder Source Sika Chemical Corporation			
Trade Name Plastiment			
Chemical Type Hydroxylated Carboxylic Acid			
Air Agent Source Grace Construction Products			
Trade Name Darex			
Class AA Mix Design			
Weights	Per Yard	Reference	Retarder
#2 Stone	1891	1051bs 1oz	1051bs 1oz
Sand	1159	641bs 6oz	641bs 6oz
Cement	611	331bs 15oz	331bs 15oz
Water	285	15.751bs Avg	15.061bs Avg
Retarder	2.5oz/sk		26ml
A.E.A.		12-16ml	10-12ml
Yield	101.2	98.5	98.1
Unit Weight		147.91bs	148.41bs

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	9.00	11.73	5	75	3	3218	4149	4757
2	8.95	12.15	$4\frac{1}{2}$	74	$2\frac{1}{2}$	3272	3581	*4183
3	9.00	12.00	$5\frac{1}{2}$	74	$2\frac{1}{2}$	2511	3431	5173
Average	8.98	11.96				3000	3720	4965
Reference								
4	6.00	8.90	$5\frac{1}{2}$	75	$2\frac{3}{4}$	2502	3749	4793
5	6.30	8.78	5	73	$2\frac{1}{2}$	2520	2829	4563
6	6.63	9.25	5	72	$2\frac{3}{4}$	2087	2989	4545
Average	6.31	8.98				2370	3189	4634

Water Content (Avg. % of reduction due to Retarder) 4.6

Comp. Strength (Avg. % of increase due to Retarder) 27 3 Days 17 7 Days 7 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 42 Initial 33 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 2.67 Initial 2.98 Final

Notes: *Batch #2 28Day Break Not Included In Averages

RETARDER TEST REPORT

"D"

DATE March 6, 1970

Coarse Agg. Source Demers Winooski			
Fine Agg. Source Griswold Williston			
Gradation % Passing			
1"	100.0	3/8"	100.0
3/4"	100.0	#4	100.0
3/8"	39.1	#16	64.0
#4	8.9	#30	47.0
#8	2.2	#50	22.0
Flats %	13.1	#100	5.0
Fractures %	100.0	FM 2.79 Color	-1
Fine Agg. Sp. Gr.	2.68		
Coarse Agg. Sp. Gr.	2.79		
Predominent Mineral Composition			
Coarse Agg.	Dolomite		
Fine Agg.	Quartz		

Cement Source. Glens Falls Cement Co.			
Type	1		
Retarder Source	Grace Construction Products		
Trade Name	Daratard		
Chemical Type	Lignosulfonic Acid		
Air Agent Source	Grace Construction Products		
Trade Name	Darex		
Class AA Mix Design			
Weights	Per Yard	Reference	Retarder
#2 Stone	1811	100lbs 10oz	100lbs 10oz
Sand	1260	70lbs 0oz	70lbs 0oz
Cement	611	33lbs 15oz	33lbs 15oz
Water	285	15.73lbs Avg	14.65lbs Avg
Retarder	9oz/sk		92ml
A.E.A.		10-15ml	4-8ml
Yield	101.0	99.3	97.3
Unit Weight		148.0	150.2

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	8.25	10.15	7½	77	2¾	3440	4138	4227
2	7.33	9.85	4¼	75	1¾	4899	5217	6048
3	7.72	9.76	5	76	2¼	3749	4863	5394
Average	7.77	9.92				4029	4739	5223
Reference								
4	5.05	7.10	5	75	2½	2502	4094	4200
5	5.29	7.32	5½	74	2¼	3749	3988	4342
6	5.78	7.97	6	70	3	2935	3272	4147
Average	5.37	7.46				3062	3785	4230

Water Content (Avg. % of reduction due to Retarder) 6.9

Comp. Strength (Avg. % of increase due to Retarder) 32 3 Days 25 7 Days 24 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 45 Initial 33 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 2.40 Initial 2.46 Final

Notes:

RETARDER TEST REPORT

"E1"

DATE March 13, 1970

Coarse Agg. Source Dailey So. Shaftsbury		Cement Source Glens Falls Cement Co.				
Fine Agg. Source Dailey So. Shaftsbury		Type 1				
Gradation % Passing		Retarder Source Master Builders Co.				
1" 100.0	3/8" 100.0	Trade Name MBHC				
3/4" 99.4	#4 100.0	Chemical Type Hydroxylated Carboxylic Acid				
3/8" 35.9	#16 64.0	Air Agent Source Master Builders Co.				
#4 3.5	#30 37.0	Trade Name MBVR				
#8 2.3	#50 16.0	Class AA Mix Design				
Flats % 8.0	#100 6.0	Weights	Per Yard	Reference	Retarder	
Fractures % 70.0	FM 2.88 Color -1	#2 Stone	1800	100lbs 0oz	100lbs 0oz	
Fine Agg. Sp. Gr. 2.76		Sand	1223	67lbs 15oz	67lbs 15oz	
Coarse Agg. Sp. Gr. 2.71		Cement	611	33lbs 15oz	33lbs 15oz	
Predominent Mineral Composition		Water	285	16.40lbs Avg	16.00lbs Avg	
Coarse Agg. **Quartz and Calcite**		Retarder	3oz/sk		31ml	
		A.E.A.		15-18ml	10-12ml	
Fine Agg. **Quartz**		Yield	100.2	100.2	100.0	
		Unit Weight		145.25	145.50	

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	9.30	11.88	4¾	70	2	4740	4757	5474
2	8.77	10.88	5½	70	2	4439	4722	5801
3	8.70	10.88	6	70	2½	3961	4704	5341
Average	8.92	11.21				4380	4728	5539
Reference								
4	5.40	7.48	4½	70	1¾	4103	4881	4032
5	5.50	7.50	4½	72	2¼	3837	3926	5235
6	6.10	8.27	5½	72	2½	3139	3564	4386
Average	5.67	7.75				3693	4124	4551

Water Content (Avg. % of reduction due to Retarder) 2.4

Comp. Strength (Avg. % of increase due to Retarder) 19 3 Days 15 7 Days 22 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 57 Initial 45 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 3.25 Initial 3.46 Final

Notes: Reference Mixes Displayed False Set During 3min. Waiting Period.

RETARDER TEST REPORT

"E2"

DATE March 17, 1970

Coarse Agg. Source Dailey So. Shaftsbury		Cement Source			
Fine Agg. Source		Type			
Gradation % Passing		Retarder Source Master Builders Co.			
1"	3/8"	Trade Name Pozzolith 100XR			
3/4"	#4	Chemical Type Carbohydrate			
3/8"	#16	Air Agent Source			
#4	#30	Trade Name			
#8	#50	Class AA Mix Design			
Flats %	#100	Weights	Per Yard	Reference	Retarder
Fractures %	FM Color	#2 Stone			100 lbs 0 oz.
Fine Agg. Sp. Gr.		Sand			67 lbs 15 oz.
Coarse Agg. Sp. Gr.		Cement			33 lbs 15 oz.
Predominent Mineral Composition		Water			16.44 lbs Avg.
Coarse Agg.		Retarder			31ml
		A.E.A.			12-18ml
Fine Agg.		Yield			100.2
		Unit Weight			145.25 lbs

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	9.60	11.88	4	74	$2\frac{1}{2}$	4191	5305	5474
2	10.67	12.81	$4\frac{3}{4}$	74	$2\frac{1}{2}$	4014	4536	5456
3	10.50	12.61	5	74	$2\frac{1}{2}$	3643	4439	5252
Average	10.26	12.43				3949	4760	5394
Reference								
4								
5								
6								
Average								

Water Content (Avg. % of reduction due to Retarder) "No Reduction" Increased 0.2%

Comp. Strength (Avg. % of increase due to Retarder) 7 3 Days 15 7 Days 19 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 81 Initial 60 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 4.59 Initial 4.68 Final

Notes: Reference Batches Listed on Page 1. Tests Performed On March 13, 1970

RETARDER TEST REPORT

"F"

DATE March 20, 1970

Coarse Agg. Source Kelley Websterville			
Fine Agg. Source Kelley Websterville			
Gradation % Passing			
1"	100.0	3/8"	100.0
3/4"	99.7	#4	100.0
3/8"	45.9	#16	73.5
#4	8.6	#30	50.0
#8	2.5	#50	23.0
Flats %	6.9	#100	5.0
Fractures %	100.0	FM 2.59	Color -1
Fine Agg. Sp. Gr.	2.72		
Coarse Agg. Sp. Gr.	2.60		
Predominent Mineral Composition			
Coarse Agg.	Granodiorite		
Fine Agg.	Quartz		

Cement Source. Universal Atlas Cement			
Type 1			
Retarder Source Grace Construction Products			
Trade Name Daratard			
Chemical Type Lignosulfonic Acid			
Air Agent Source Grace Construction Products			
Trade Name Darex			
Class AA Mix Design			
Weights	Per Yard	Reference	Retarder
#2 Stone	1654	91lbs 14oz	91lbs 14oz
Sand	1253	69lbs 10oz	69lbs 10oz
Cement	611	33lbs 15oz	33lbs 15oz
Water	285	16.15lbs Avg	14.81lbs Avg
Retarder	9oz/sk		92ml
A.E.A.		10-16ml	6-8ml
Yield	99.7	98.2	98.0
Unit Weight		143.75	143.25

CONCRETE TESTS

Batch No.	Proctor Penetration		Air Content	Temp.	Slump	Compressive Strength		
	500 psi	4000 psi	Percent	Degrees	Inches	3 Days	7 Days	28 Days
Retarder	Hrs.	Hrs.						
1	7.90	9.33	7½	70	2½	2759	3210	3599
2	8.50	10.10	6¼	70	2¼	3395	3422	3979
3	8.40	9.73	6	72	2	3245	3723	4695
Average	8.27	9.72				3133	3452	4091
Reference								
4	4.35	5.65	4½	72	2¼	3192	3820	3882
5	4.25	5.70	5	71	2	3148	2918	3882
6	4.35	5.78	5¾	69	2¼	2440	2661	3564
Average	4.32	5.71				2927	3133	3776

Water Content (Avg. % of reduction due to Retarder) 7.1

Comp. Strength (Avg. % of increase due to Retarder) 7 3 Days 10 7 Days 8 28 Days

Time of Setting (Avg. % of Deviation due to Retarder) 91.4 Initial 70.2 Final

Time of Setting (Avg. Increase in Hrs. due to Retarder) 3.95 Initial 4.01 Final

Notes: