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EVALUATION OF SIX COMMERCIAL FAST-SETTING HYDRAULIC PATCHING MORTARS, A LATEX BONDING AGENT, AND AN EPOXY EMULSION ADMIXTURE

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INTRODUCTION

Initiation of Research

The following commercial fast-setting hydraulic patching mortars or cements were presented to the New Materials Committee for consideration and possible adoption for use on Michigan highways. The names of the materials, their new materials project numbers, and the dates they were presented to the committee are as follows:

"Fast-Krete"	(69 NM-226) February 21, 1969
"Mari-Crete"	(69 NM-239) July 1, 1969
"Rev-Crete"	(69 NM-240) July 1, 1969
"Regulated-Set Portland Cement"	(69 NM-251) November 18, 1969
"Duracal A Cement"	(71 NM-290) June 26, 1971
"Quick Set"	(71 NM-306) December 28, 1971

In addition to the mortars and cements listed above, a patching mortar bonding agent called "Bonding Blend" (71 NM-288) was presented to the Committee on May 7, 1971; also, an admixture called "Epi-Top PC-10" (71 NM-299) on July 21, 1971. The New Materials Committee referred all of these to the Research Laboratory for evaluation.

In this report, frequent reference is made to an earlier mortar evaluation report, "Evaluation of Five Commercial Fast-Setting Patching Mortars" (Research Report No. R-715, October 1969); hereafter, this report shall be referred to as "Report R-715."

MATERIALS TESTED

Fast-Setting Hydraulic Mortar

These mortars comprise the six listed above that are the subject materials of this report, as well as a control material, "Embeco LL-411A," which is produced by the Master Builders Company.

Conventional Hydraulic Mortars

These conventional mortars all contain commercial admixtures which are designed for use with Type-I portland cement.

1) Epi-Top PC-10 - This admixture is an epoxy which, after the two liquid components are combined, is added to an equal weight of water to form an emulsion. This emulsion, along with additional mix water, is then added to the cement-sand mixture to form a patching mortar. This material is produced by Celanese Coatings Company.

2) Dow Modifier B - This admixture is a latex emulsion that is produced by the Dow Chemical Company. It is an emulsion of saran (75 percent) and styrene-butadiene (25 percent) in water which, like Dow Modifier A (formerly SM-100), imparts superior bonding properties to portland cement mortars.

3) Meta Bond L - This admixture is a polyvinyl acetate emulsion in water which is produced by the American Metaseal Co. It was produced as an alternate product to Dow Modifier A.

Bonding Agent for Hydraulic Mortars

This material, Bonding Blend, is included in this report because it is a patching mortar related material. It is a latex emulsion in water that the manufacturer (M. P. S., Inc.) states should be mixed with portland cement to form a slurry which is brushed into the concrete substrate of a patch area.

TESTING PROGRAM

Test Specimens

The mortar specimens, test intervals, and testing procedures employed for each material were as follows:

1) Compressive Strength - Twenty-four 2-in. cubes, conforming to ASTM C 109-63, "Compressive Strength of Hydraulic Cement Mortars," were used to evaluate the patching mortar's compressive strength. These were tested in groups of three at 8 and 24 hr, and at 3, 7, and 28 days; and after 50, 100, and 200 freeze-thaw cycles following a 28-day cure. The freeze-thaw cycles conformed to ASTM C 291-61T, "Resistance of Concrete Specimens to Rapid Freezing in Air and Thawing in Water." A 14-day test was substituted for the 8-hr test for the slower setting comparison mortars.

2) Tensile Strength - To evaluate the tensile strength, 15 briquets were tested in groups of three at 8 and 24 hr, and at 3, 7, and 28 days. With these, as well, a 14-day test was substituted for the 8-hr test in the case of slow setting mortars. The briquets conformed to ASTM C 190-63, "Tensile Strength of Hydraulic Cement Mortars."

3) Shear Bond Strength - To determine the bond strength in shear, 24 shear bond blocks were tested. These test specimens consisted of a 1-in. mortar cap cast on the 3 by 4-in. sawed face of a 3 by 4 by 3-in. concrete block. The bonding surface was ground with carborundum to a flat surface which was free of saw striation and all foreign materials. In testing, the blocks were clamped on their side in a testing apparatus and loaded until the mortar cap sheared off. These blocks were tested in groups of three at the same time intervals and freeze-thaw cycle intervals as the mortar cubes. No ASTM standard currently covers this shear bond test.

4) Shrinkage - To determine the shrinkage characteristics of the patching mortars, four 1 by 1 by 11-1/4-in. prisms of 10-in. effective gage length were used. These prisms are described in ASTM C 151-63, "Autoclave Expansion of Portland Cement." All of the shrinkage prisms were cured the first seven days in a sealed polyethylene bag and then removed to air dry in the laboratory through six months. Measurements of weight and length were taken at 8 and 24 hr, at 3, 7, 14, and 28 days, and at three and six months. Following the six-month measurements, the prisms were placed in the moist curing room to measure weight and length recovery. Recovery measurements were made at 1, 3, 7, and 14 days.

MORTAR PREPARATION

Each mortar mix was given a one-minute mix time in a Hobart Model N50 Laboratory mixer. Figure 1 shows the various steps in mortar mixing and placement.

Fast-Set Hydraulic Patching Mortars

Table 1 shows the mix proportions, and cost per cubic ft of these mortars. Because their fast-setting nature limited the form-placement time to 10 minutes, the ASTM standard tamping procedure for mortar was discarded in favor of mechanical vibration. This means of consolidation was very rapid and permitted all forms to be struck-off before the mortar set.

Fast-Krete - The producer never supplied a sample of this material, therefore no testing was done.

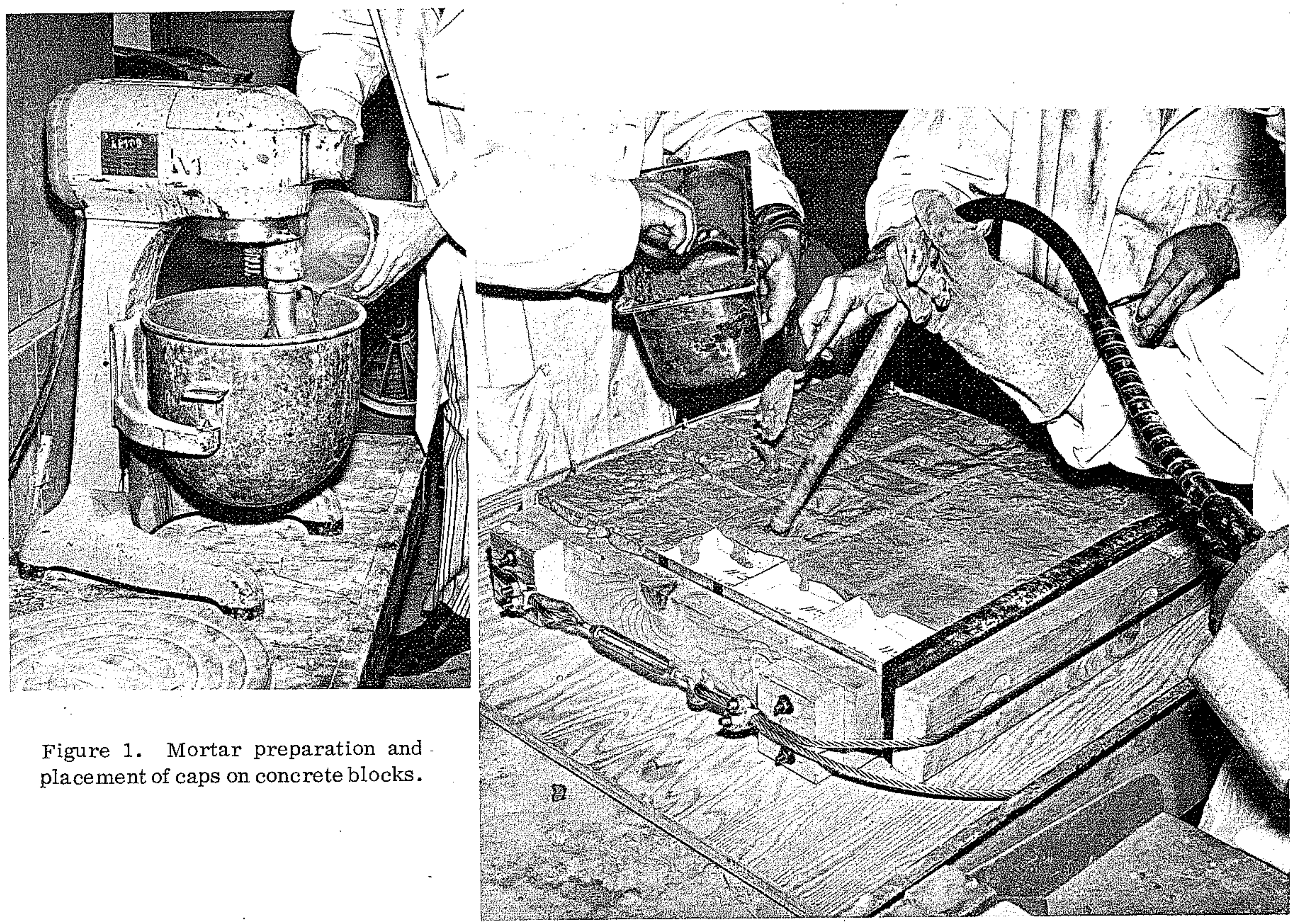


Figure 1. Mortar preparation and placement of caps on concrete blocks.

TABLE 1

FAST-SET HYDRAULIC MORTARS

Component Weights and Cost of One cu ft of Patching Mortar

Mortar	Packaged Material, lb	Mixing Fluid, lb	Cement lb	2 NS Sand, lb	Aggregate/ Cement Ratio	Water, lb	Water/ Cement Ratio	Admixtures		cost/ cu ft
								AE (Darex)	Other lb	
Fast Krete	(Material not tested in Laboratory)									
Mari-Crete	(Material not tested in Laboratory)									
Rev-Crete	131.4	19.9								$38.00
Regulated-Set			44.6	111.2	2.49	19.0	0.43	447 ml	Hardener 0.4	2.50
Duracal A			46.0	92.0	2.00	14.0	0.30			3.53
Quick Set	114.6	25.8								3.45
Embeco LL-411A	146.5					14.9				16.88

Mari-Crete - The producer supplied a 9-oz sample of this mortar which permitted a chemical analysis. Since the mortar very closely resembled the composition of Speed-Crete, no additional amounts were requested.

Rev-Crete - The producer supplied a 15-lb sample of cement and a proportional amount of mixing fluid. This sample was sufficient for a chemical analysis and a limited amount of laboratory work. Upon mixing the white "mixing fluid" (a modified vinyl polymer emulsion) with the cement, a strong and unusual odor was given off indicating a volatile fluid evaporating rapidly. Within four minutes the mortar had dried out (not set) as if the water had been absorbed and the vinyl polymer solids were sticking the mortar together. When the mortar was placed in the molds it could not be consolidated, resulting in specimens that were badly honeycombed; therefore, no meaningful test results could be obtained. It was concluded that this material was useless as a patching mortar, and no further testing was initiated.

Regulated-Set Portland Cement - During the Huron Cement Company's development of their present cement, two preliminary cements were submitted for evaluation. The first was found to shrink excessively, while the second developed strength too slowly. The producer rectified the latter problem with the addition of a hardner, sodium sulfate, which is added at the rate of 1 percent of the weight of the cement. The mortar made with this hardened cement is the one described in this report. One ounce per sack of cement of air-entraining agent (Darex) was added to the mix water before mixing. To improve the bonding characteristics, the shear bond block surfaces were moistened with water, and a slurry of Regulated-Set portland cement plus hardener was brushed on the surface.

Duracal A - Preliminary work was done with an earlier formulation, before a sample of Duracal A was received. Duracal A contained a retarder and required a lower water content than the initial sample. The producer recommended one part cement to two parts sand and a water-cement ratio of 0.36. The first mortar mix at this ratio resulted in a mortar which was too fluid; additional work produced a lower water-cement ratio.

To improve the bond of the shear bond blocks, the bonding surface was moistened with water and a Duracal cement slurry brushed on prior to placement of the mortar cap.

Embeco LL-411A - This material is a complete premixed product which contains cement, admixtures, fine aggregate and a pea gravel sized coarse aggregate.

The mix proportions were 500 parts Embeco LL-411A to 51 parts water by weight. The shear bond blocks were moistened with water and brushed with a slurry of Embeco (passing a No. 8 sieve) and water, prior to placement of the mortar.

Quick-Set - This material is a complete premixed product which contains a high magnesia cement, a manufactured dolomite sand, and a mixing fluid (phosphate solution). The producer recommends that the mortar be mixed at a ratio of 77.5 percent cement and sand to 22.5 percent mixing fluid. No water was recommended to be used with the mixing fluid. When the mortar was placed in the molds it was found to be sticky and would not flow when vibrated therefore the mortar was hand tamped in the molds. Upon removing the specimens from the molds a strong ammonia odor was present, and it was found upon examination that the formed surfaces of this specimen were full of small circular voids that apparently were formed by the ammonia gas being liberated. The shear bond block surfaces were moistened with water prior to placement of the mortar caps.

Bonding Blend - Since this material is simply a bonding agent for patching mortars and not a mortar itself, a Type-I portland cement mortar was used for the shear bond caps. The producer recommended that Bonding Blend be mixed with portland cement to form a slurry of medium consistency. It was determined in the laboratory that a "medium consistency" was obtained when 1-part of Bonding Blend was combined with 2.5-parts of portland cement by weight. This slurry was brushed onto the moistened surface of the shear bond blocks prior to placement of the mortar.

Conventional Hydraulic Patching Mortars

Table 2 shows the mix proportions, and the cost per cu ft of the mortars containing selected admixtures. In order to maintain a uniformity with the fast-setting mortars, they were vibrated in the same manner, cured seven days in a polyethylene bag, and 21 days in laboratory air.

Portland Cement Type-I with Epi-Top PC-10 - Two mortar mixes were developed using this material; one utilized the PC-10 admixture at 10 percent of the weight of cement, the other at 20 percent. The epoxy is mixed 100 parts A and 35 parts B, by weight. After combining the two components, the epoxy mix is immediately added to an equal weight of water to form an emulsion. The pot life of the epoxy is 1 hr and 15 min.

The shear-bond blocks were brushed with straight epoxy to improve the bonding of the mortar to the concrete.

Portland Cement, Type-I with Dow Modifier B - The producer states that this material is a saran and styrene-butadiene emulsion blend composed

TABLE 2

CONVENTIONAL HYDRAULIC PATCHING MORTARS, WITH ADMIXTURES

Mix Proportions, Component Weights, and Cost of One cu ft of Patching Mortar

Admixture Material	Sand, lb	Cement, lb	Aggregate/ Cement Ratio	Mix[1] Water, lb	Water Cement Ratio	Admixture, lb			Cost/ cu ft
Dow Mod B	90.9	36.4	2.50	6.1	0.33	Solids 5.5		Water 5.9	$6.85
PC 10 - 20%	81.4	32.6	2.50	4.9	0.35	Part A 4.8	Part B 1.7	Water 6.5	4.76
PC 10 - 10%	83.6	33.4	2.50	9.7	0.39	Part A 2.5	Part B 0.9	Water 3.3	2.91
Meta Bond L	86.0	34.3	2.50	7.7	0.40	Solids 5.2		Water 6.0	----

[1] Does not include water in admixtures.

of 48 percent solids and 52 percent water by weight. When mixed with a portland cement mortar it imparts a fluidity characteristic that permits a reduction in the required mix water. This reduction of mix water produces higher tensile and bond strengths and reduces shrinkage as the mortar sets. It was recommended by the producer that the Modifier B admixture be added such that the weight of the solids component be 15 percent of the weight of cement. The shear-bond blocks were moistened with water and some of the mortar was brushed into the surface prior to placement. This material has a fairly short shelf life of 90 days.

Portland Cement Type-I with Meta Bond L - This polyvinyl acetate emulsion in water was mixed according to the producers directions. The shear bond blocks were moistened with water and brushed with straight Meta Bond L prior to placement of mortar.

TEST RESULTS

As each patching mortar was tested in compression, tension, shear bond, and shrinkage, the values were recorded and unit strengths calculated. The entire data are presented in graphical form. Figures 2 through 6 show the following mortar properties: compression strength (Fig. 2); tensile strength (Fig. 3); bond strength in shear (Fig. 4); shrinkage prisms length variation (Fig. 5); and shrinkage prism weight variation (Fig. 6). Each figure is divided into three graphs. Two graphs present data on the fast-setting hydraulic mortars: Regulated-Set, Duracal, Quick-Set, and Embeco LL-411A. The third graph gives data on the conventional hydraulic mortars. The shear bond strength of the Bonding Blend material is included with the fast-setting mortar.

Results of Fast-Setting Hydraulic Mortar Tests

Table 3 gives the composition of each of the fast-setting hydraulic mortars. The analysis was obtained by sieving out the aggregate portion of the mortar (when required) and chemically analyzing the cementing portion.

No test results are given for Fast-Krete, Mari-Crete, and Rev-Crete, as explained in the "Mortar Preparation" section of this report.

Regulated-Set Portland Cement - Initial testing of this mortar during the 7-day cure in the polyethylene bag yielded encouraging results. When the test specimens were placed in laboratory air, however, the shrinkage prisms recorded excessive shrinkage; no corresponding strength reduction was evident from tests run on the shear bond blocks.

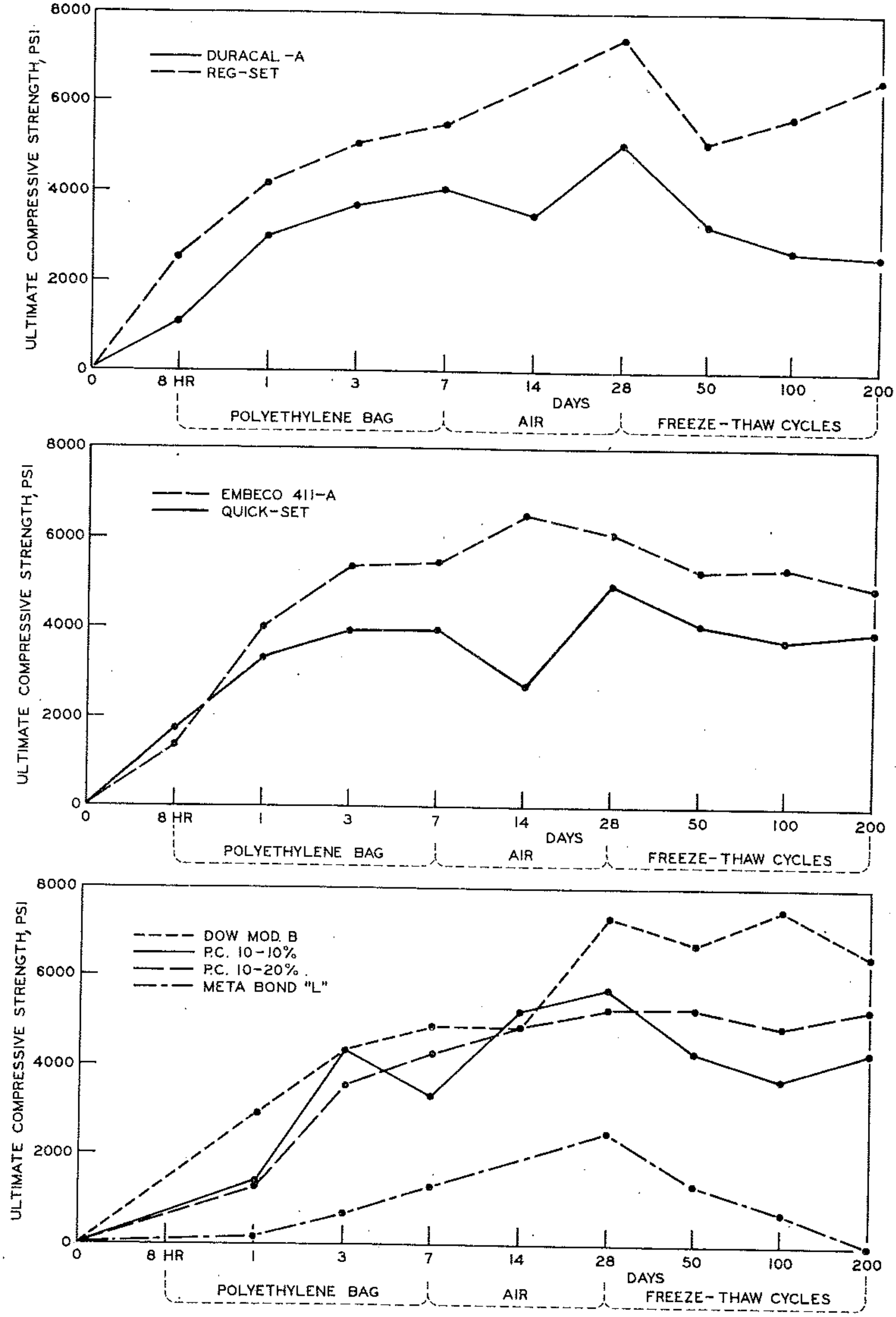


Figure 2. Compressive strength of patching mortars.

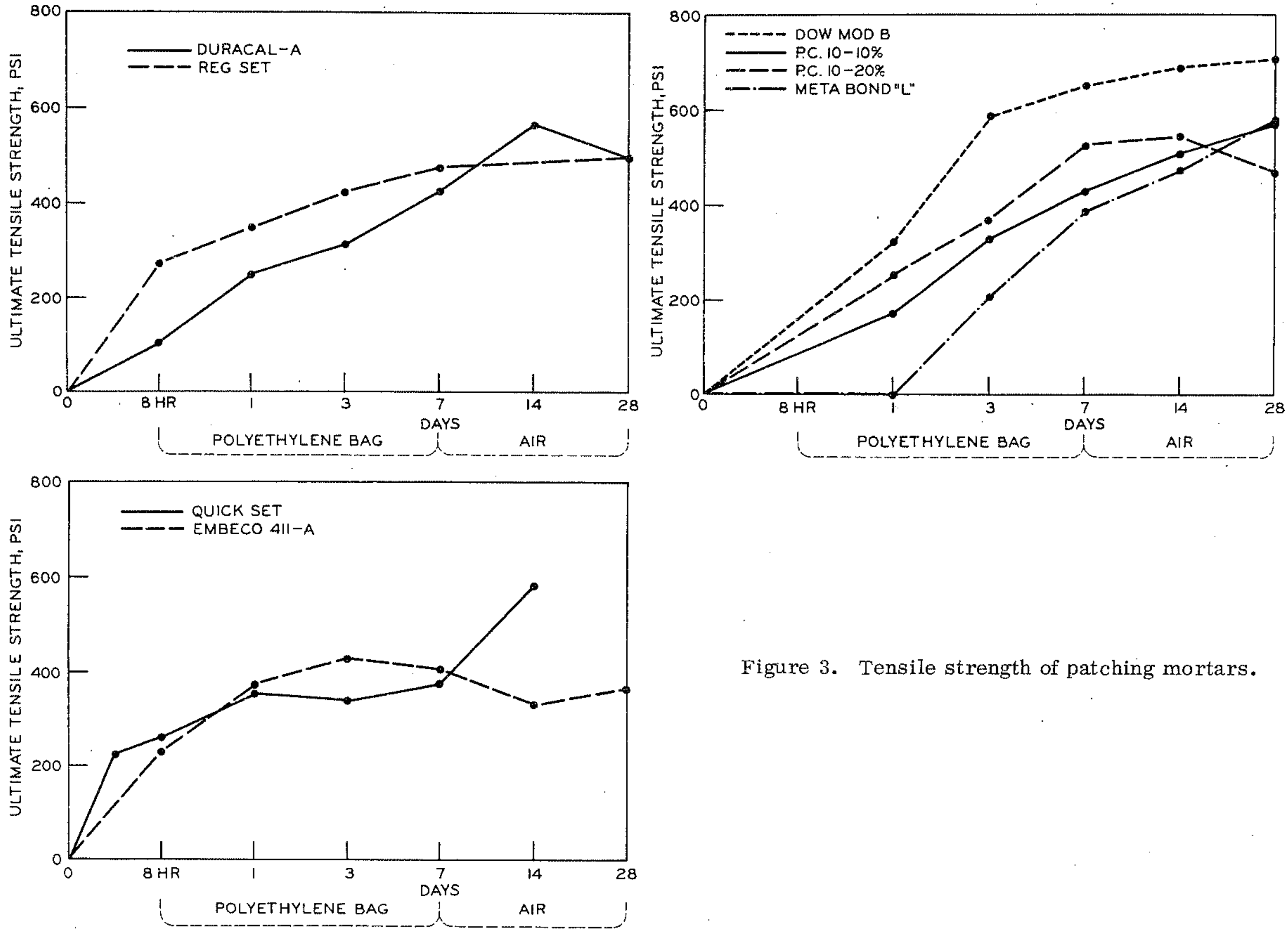
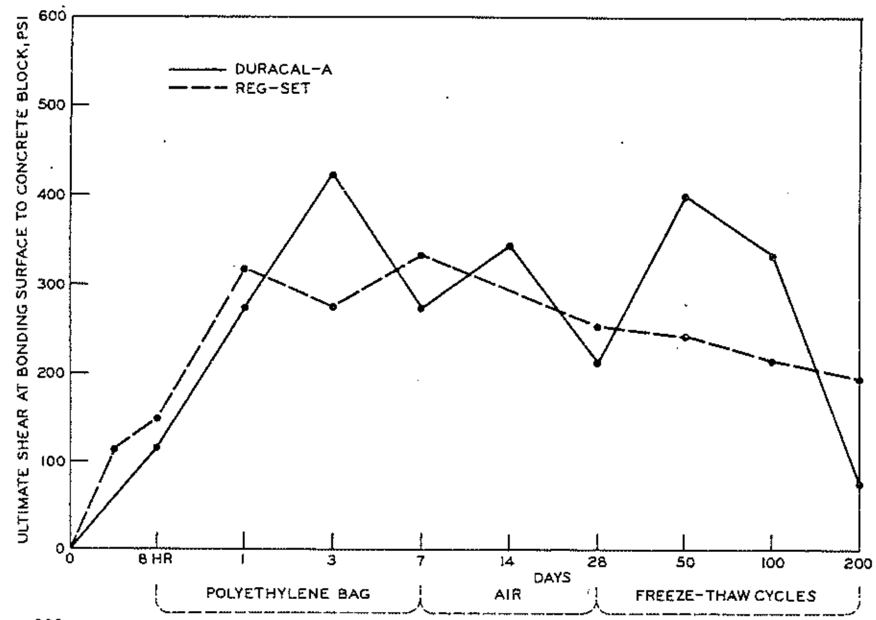
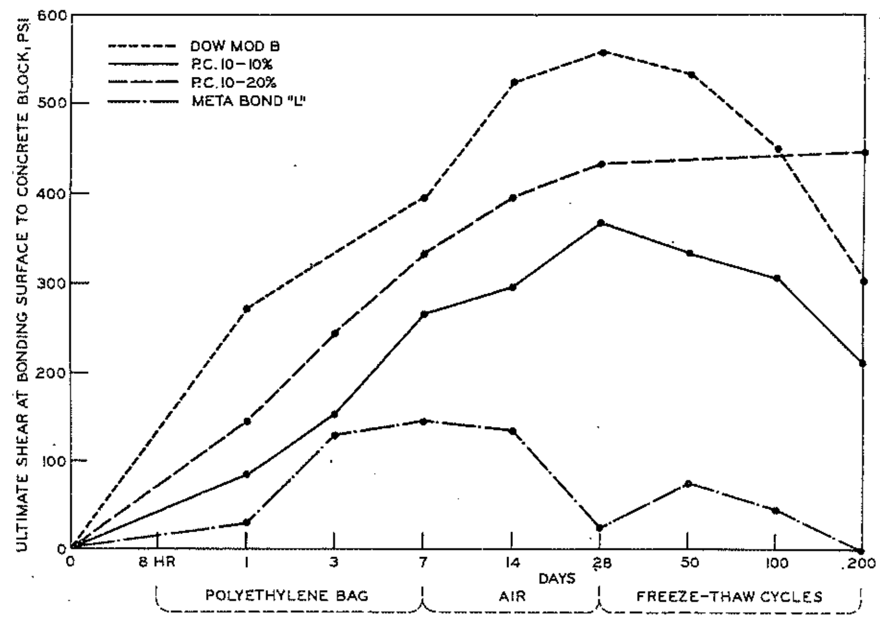


Figure 3. Tensile strength of patching mortars.





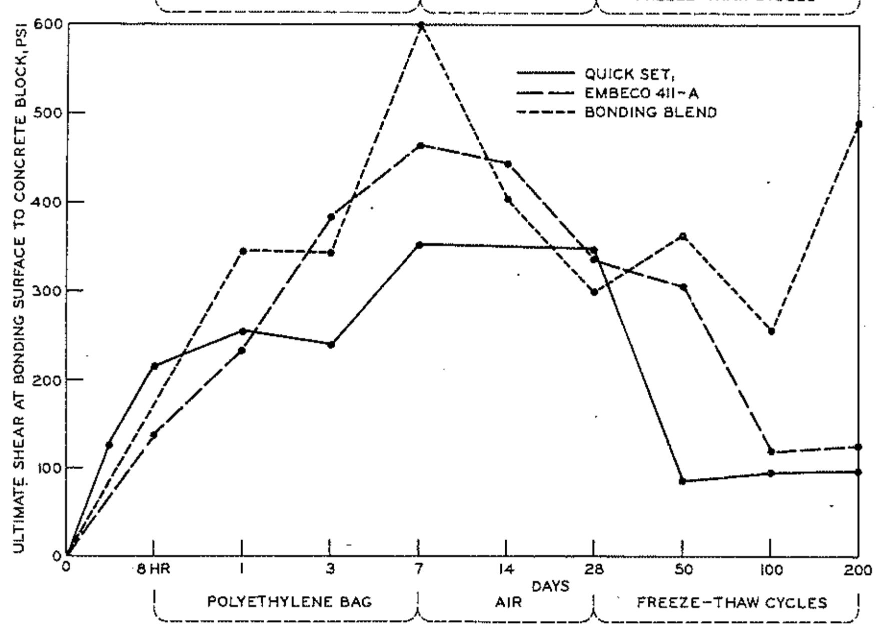


Figure 4. Shear bond strength of patching mortars.

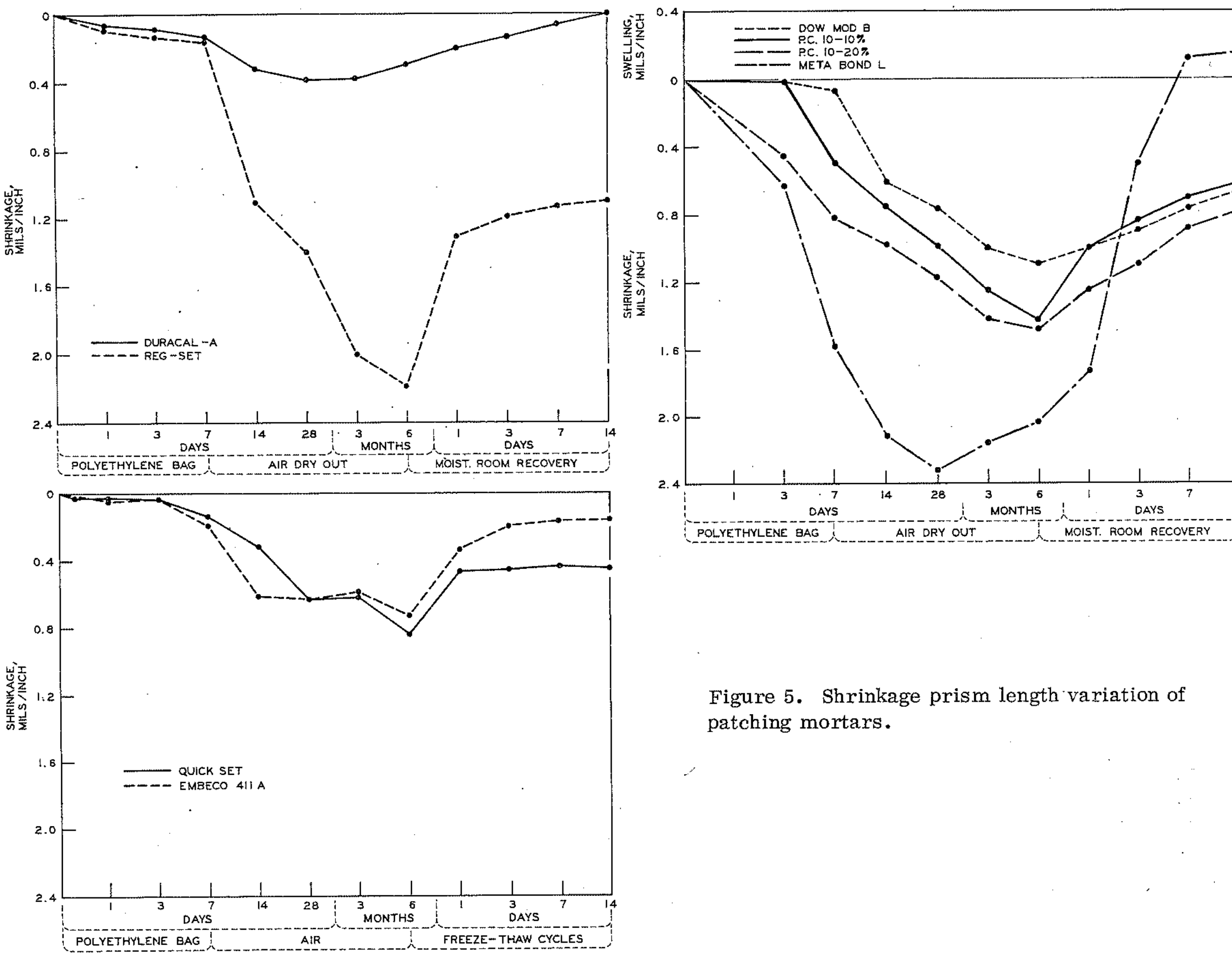


Figure 5. Shrinkage prism length variation of patching mortars.

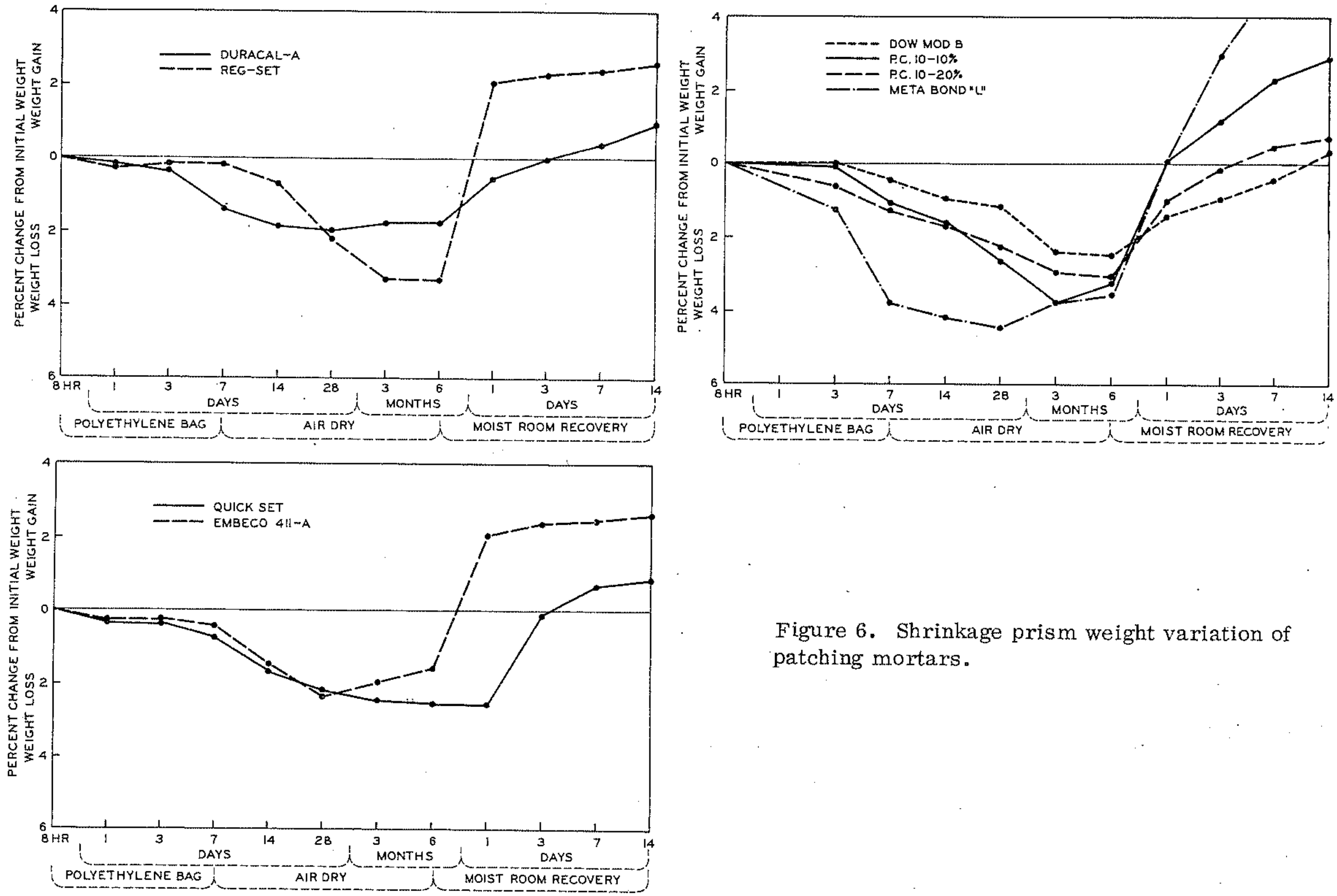


Figure 6. Shrinkage prism weight variation of patching mortars.

TABLE 3

APPROXIMATE COMPOSITION AS DETERMINED BY SIEVE AND CHEMICAL ANALYSES

(percent by weight)

		Mari-Crete	Reg-Set	Rev-Crete	Duracal A	Quick Set		Embeco LL-411A
						Mortar	Liquid	
	Fraction retained by No. 100 sieve (agg.)	25%	---	65%	---	79%	---	76%
	Fraction passing No. 100 sieve (cement)	75	100	35	100	21	---	24
Chemical Composition on Cementing Portion only	Calcium oxide	42.2	58.2	42.3	49.7	4.0	---	60.2
	Magnesium oxide	3.7	2.2	3.9	1.9	83.4	---	5.4
	Sulfur trioxide	7.6	5.7	1.8	30.6	---	---	2.4
	Soluble silica	12.3	15.1	13.5	11.7	5.1	---	21.6
	Iron and Aluminum oxide	5.0	13.2	1.3	4.5	6.0	---	7.9
	Iron filings	---	---	6.2	---	---	---	---
	Loss on ignition	2.5	4.2	2.9	1.7	0.4	---	2.4
	Insoluble silica (powder)	27.5	1.7	28.7	---	---	---	---
	Ammonium phosphate	---	---	---	---	---	64%	---
	Water	---	---	---	---	---	36%	---

Duracal A - This mortar showed the best resistance to shrinkage of all the mortars tested, but the compressive strength and shear bond strengths declined after 50 cycles of freeze-thaw. This would indicate the mortar is somewhat vulnerable to freeze-thaw destruction.

Quick-Set - The shear bond strengths of this mortar decreased greatly after starting freeze-thaw testing. This would indicate that the bonding properties are vulnerable to freeze-thaw destruction.

Embeco LL-411A - Although more than half of the bond strength was lost after 50 cycles of freeze-thaw testing, this mortar showed the best performance during testing of all the fast-setting mortars.

Results of Conventional Hydraulic Patching Mortar Tests

Portland Cement Type-I with Dow Modifier B Admixture - This mortar, with its emulsified liquid admixture, seemed to retard the initial rate of strength gain; after 24 hours, however, its strength equaled or surpassed any of the other mortars tested. This mortar also survived 200 freeze-thaw cycles with very little damage.

Epi-Top PC-10 (20 percent) - The PC-10 admixture emulsion retarded the initial rate of strength gain through the 24-hour test; after three days, though, it competed favorably with the other mortars tested. The shrinkage prisms recorded excessive shrinkage, but no corresponding strength reduction was evident from tests run on the shear bond blocks. Compared with the portland cement Type-I control, tested in Report R-715, this epoxy modified mortar developed lower compressive strengths throughout the test, developed comparable bond strengths in the early test intervals and superior bond strength in the latter intervals, and shrank about 20 percent more.

Epi-Top PC-10 (10 percent) - This mortar performed quite like the PC-10, 20 percent except that it developed lower bond strength in shear.

Bonding Blend - Since Bonding Blend is simply a bonding agent, only shear bond tests were run. Results are shown in Figure 4.

Meta Bond L - This material performed very poorly in all testing. Within three hours from pouring it was noted that significant shrinkage was occurring; cubes, briquets and shrinkage prisms all shrank away from their forms. After six months the shrinkage prisms were placed in the moist curing room. One week later it was discovered that they had swelled, cracked, and bowed. Apparently this swelling was caused by the re-emulsification of the polyvinyl acetate because a white sticky substance was being secreted from the cracks.

EVALUATION OF THE TEST MORTARS

Evaluation System

The system used to evaluate the properties of the various patching mortars was based upon laboratory test data and mortar cost. The properties evaluated are shown in Figure 7 (A through F), along with the rating points assigned to them. Included are the mortars' shear bond, compressive and tensile strengths, shrinkage characteristics, material cost per cu ft of mixed mortar, and a special rating called "Weather Resistance Factor," which is based on the mortars' resistance to freeze-thaw damage.

Of the 100 points provided for performance, 36 were allotted to shear bond strength because of its critical importance to the effectiveness of the patch. In the rating intervals of the shear bond strength, greatest and equal emphasis were given to the strength developed at eight hours and strengths retained after 100 and 200 freeze-thaw cycles. Lesser emphasis was given to ratings at 24 hours, 28 days, and 50 freeze-thaw cycles.

Twenty of the 100 performance points were allotted to compressive strength. Intervals rated were at 8 and 24 hours, 3 days, and 200 freeze-thaw cycles. Greatest emphasis was given to the strength retention following 200 freeze-thaw cycles.

Shrinkage was allotted 17 points of the performance rating with the greatest emphasis placed on the three-month measurement.

Weather resistance factor and tensile strength were allotted 15 and 12 points, respectively.

Figure 7 shows that the 50 rating points allotted for material costs have been assigned in a manner such that they are inversely proportional to the mortars' cost in dollars per cubic ft, as given in Tables 1 and 2.

Table 4 contains a tabulation and total of all of the performance rating points. It shows how each of the 9 mortars performed for each of the rating intervals given in Figure 7. The data for this table were taken from the graphs in Figures 2 through 5. From the graphs, the magnitude of the test values for each mortar were noted for the intervals being rated; they were then compared with the strength range in Figure 7, and the corresponding rating value was selected and entered in Table 4.

The weather resistance factor values shown in Table 4 were selected by observing the vulnerability of mortar to freeze-thaw damage.

A. Shear Bond Strength

Strength Range, psi	Time Interval			Freeze-thaw Cycles		
	8 hr	24 hr	28 day	50	100	200
0-10	0	0	0	0	0	0
10-100	2	0	0	0	0	0
100-200	4	1	1	1	2	2
200-300	6	2	2	2	4	4
300-400	8	3	3	3	6	6
400-500	8	4	4	4	8	8

B. Compression Strength

Strength Range, psi	Time Interval			200 Freeze-thaw Cycles
	8 hr	24 hr	3 day	
0-100	0	0	0	0
100-1000	1	0	0	0
1000-2000	2	1	0	0
2000-3000	3	2	1	3
3000-4000	4	3	2	6
4000-5000	4	4	3	9

C. Shrinkage

Shrinkage Range (mils/inch)	Time Interval		
	7 day	28 day	3 mon.
1.6-1.2	0	0	0
1.2-0.8	0	2	3
0.8-0.4	1	4	6
0.4-0.0	2	6	9
any swelling	2	6	9

D. Tensile Strength

Strength Range, psi	Time Interval		
	8 hr	24 hr	3 day
0-10	0	0	0
10-100	1	0	0
100-200	2	1	1
200-300	3	2	2
300-400	4	3	3
400-500	4	4	4

E. Weather Resistence Factor

Excellent - 15
Good - 10
Fair - 5
Poor - 0

F. Cost Factor

Mixed Mortar Cost ($/cu ft)	
0-2	50
2-4	47
4-6	44
6-8	41
8-10	38
10-12	35
12-14	32
14-16	29
16-18	26
18-20	23
20-22	20
22-24	17
24-26	14
26-28	11
28-30	8
30-32	5
32-34	2
34-36	0

Figure 7. Evaluation System (rating point tables).

TABLE 4
EVALUATION SYSTEM RATING OF PERFORMANCE

	Mortar	Shear Bond Strength						Compression Strength				Weather Resist. Factor	Tensile Strength			Shrinkage			Rating Point total
		8 hr	24 hr	28 Day	F-T Cycles 50	F-T Cycles 100	F-T Cycles 200	8 hr	24 hr	3 Day	200 F-T Cycle		8 hr	24 hr	3 Day	7 Day	28 Day	3 Mo	
Fast-Setting	"Ideal" Patching Mortar	8	4	4	4	8	8	4	4	3	9	15	4	4	4	2	6	9	100
	Embeco LL-411A	4	2	3	3	2	2	2	3	3	9	15	3	3	4	2	4	6	70
	Reg-Set	4	3	2	2	4	2	3	4	3	9	15	3	3	4	2	0	0	63
	Duracal A	4	2	2	4	6	0	2	3	2	3	10	2	2	3	2	6	9	62
	Quick Set	6	2	3	0	0	0	2	3	2	6	10	3	3	3	2	4	6	55
Conventional	Dow Mod B	0	2	4	4	8	6	0	2	3	9	15	0	3	4	2	4	3	69
	PC 10 - 20%	0	1	4	4	8	8	0	1	2	9	15	0	2	3	0	2	0	59
	PC 10 - 10%	0	0	3	3	6	4	0	1	3	9	15	0	1	3	1	2	0	51
	Meta Bond L	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Bonding Agent	Bonding Blend	0	3	3	3	4	8												

The mortars in Table 4 are divided into two groups the fast-setting patching mortars and the conventional hydraulic patching mortars. The mortars in each group are arranged in descending order of their rating point total.

Table 5 combines the performance rating total of Table 4 with the cost factors shown in Figure 7. The combined rating represents a compromise between the mortars' performance and the mortars' material cost. The cost of labor for mixing and placing the mortar is not considered since it is approximately the same for all of the mortars. As in Table 4, the mortars are divided into two groups and arranged in descending order of their rating point total.

TABLE 5
EVALUATION SYSTEM RATING OF PERFORMANCE AND COST

	Mortar	Performance Rating Point Total	Cost Factor	Combined Rating Point Total	Combined Perferential Order of Mortars
Fast-Setting	"Ideal" Patching Mortar	100	50	150	-
	Embeco LL-411A	70	26	96	7
	Reg-Set	63	47	110	1&2
	Duracal A	62	47	109	3
	Quick Set	55	47	102	5
Conventional	Dow Mod B	69	41	110	1&2
	PC 10 - 20%	59	44	103	4
	PC 10 - 10%	51	47	98	6
	Meta Bond L	2	--	<50	8

The intent of this report was to test and evaluate the fast-setting hydraulic patching mortars. By testing these mortars along with other control mortars, it was hoped that a mortar approaching the "ideal" patching mortar could be found.

Patching Mortar Performance

Fast-Setting Hydraulic Mortars - As the rating in Table 4 shows, Embeco LL-411A is the best in this group, followed by Regulated-Set and Duracal A. Embeco LL-411A was significantly aided by the coarse aggregate it contained which partially restrained it from shrinking. Regulated-Set exhibited some good properties in shear bond, compression, and tension, but seemed to shrink excessively. Duracal A had excellent shrinkage properties but failed to develop high strengths in either compression or tension. Quick-Set, which was rated last in the group, developed the highest initial strength but seemed to lose its bond during freeze-thaw testing. A white fluid was noted to be secreting from the Quick-Set mortar at the 200 freeze-thaw cycle test.

Conventional Hydraulic Control Mortars - Table 4 shows that all of these mortars were handicapped by not having any developed strength for the 8-hr test. It also shows that of the five conventional hydraulic mortars, Dow Modifier B received the highest rating point total for testing performance, 69 points of a possible 100. It exceeded or equaled the performance rating of the other four mortars in all categories except shear bond. The PC-10 (20 percent) showed good resistance to freeze-thaw destruction, but gained strength slowly and shrank excessively.

Bonding Agent for Hydraulic Mortar - Table 4 indicates that the bonding agent, Bonding Blend, performed well in bonding the portland cement control cap to the shear bond block. Compared with the shear bond performance of the portland cement Type-I mortar of Report R-715, it outperformed the control during the first seven days of curing by over 100 psi. During the critical air drying time after seven days, the portland control bond strength quickly dropped below 100 psi, whereas Bonding Blend's strength never dropped below 300 psi.

The Bonding Blend's performance cannot be compatibly compared with that of the Dow admixture mortar because the latter shrank less than the portland control.

The cost of Bonding Blend is currently $9.00 per gallon. The cost of the slurry for a unit area of application is 19 cents per sq ft; this figure includes only the cost of the material and not the cost of application.

CONCLUSIONS

Performance Consideration

In general the fast-setting hydraulic mortars of this report were much superior to those tested previously (Research Report No. R-715). From these laboratory tests, it appears that the Embeco LL-411A mortar would be suitable for use in the field and possibly also the Regulated-Set and Duracal A cements; none of these materials, however, should be specified for general use until their performance is observed in the recent field test application which is described in the "Recommendation" section of this report.

The portland cement Type-I with Dow Modifier B mortar performed the best of any of the conventional mortars and appears to have slightly outperformed both the Atlas Lumnite and portland cement Type-I with SM-100 of Research Report No. R-715. It also appears to be suitable for field use, but Dow Chemical states that the chloride composition of the saran component could increase the possibility of corrosion if it contacts reinforcing bars.

Combined Performance and Material Considerations

As in Research Report No. R-715, the performance rating of the mortar was combined with a cost factor. This was intended to temper the performance rating point total of Table 4 with some degree of economic feasibility. The results of this combination are shown in Table 5. Embeco LL 411A, the best performing "mortar," was severely handicapped by its excessive cost. The "Combined Preferential Order" column in Table 5 ranks the conventional hydraulic mortar portland cement Type-I with Dow Modifier Admixture, and the fast-setting mortar Regulated-Set, as being tied for first place among all the mortars. Duracal A, a fast-setting mortar, closely followed in third place. All other mortars were less impressive and followed in the order shown in the table.

RECOMMENDATIONS

This mortar report is being printed simultaneously with the construction report of the patching concrete application which is Research Report No. R-871 and is entitled, "Experimental Patching Concrete Field Application on Test Bridge S01 of 33035A (WB M 36/US 127)." This latter report describes the field application of four of the materials which are included in this report; they are: Duracal A, Embeco 411A (the commercial version of the experimental product Embeco LL-411A), Regulated-Set Cement, and Portland Cement Type-I with Dow Modifier B admixture. Although no firm recommendation concerning these materials can be made at the present time, it does appear that Regulated-Set and Embeco 411A are superior to any other fast-setting mortars or concretes that are presently available for patching use. Because of its excessive cost, however, the pre-packaged Embeco 411A product must be restricted to small patching jobs where it would not be economical to supply the materials and equipment required for the use of a less expensive mortar or concrete.