EVALUATION OF FIVE COMMERCIAL FAST-SETTING PATCHING MORTARS

MICHIGAN

RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

EVALUATION OF FIVE COMMERCIAL FAST-SETTING PATCHING MORTARS

K. H. Laaninen

Research Laboratory Section
Testing and Research Division
Research Projects: 73 NM-360, 73 NM-374,
73 NM-382, 74 NM-396, and 74 NM-407
Research Report No. R-1057

Lansing, March 1977

INTRODUCTION

Initiation of Research

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

"Octocrete" [1]	73 NM-360 (April 2, 1973)
"Set-Instant Concrete Repair" [1]	73 NM-374 (August 9, 1973)
"Darex 240 Concrete" [2]	73 NM-382 (December 7, 1973)
"Set 45" [2]	74 NM-396 (April 29, 1974)
"Bostik 275" [2]	74 NM-407 (July 15, 1974)

Proposed Uses for Patching Mortars

Patching mortars are used by the Department to repair spalled bridge decks, particularly in high traffic areas. There has been a continuing interest in fast-setting mixtures which could be opened to traffic in one to four hours and still have good durability. This report is the fourth in a series on patching mortars; the previous reports being R-715, "Evaluation of Five Commercial Fast-Setting Hydraulic Patching Mortars" (October 1969); R-872, "Evaluation of Six Commercial Fast-Setting Hydraulic Patching Mortars" (July 1973); and R-871, "Experimental Patching Concrete Field Application on Test Bridge S01 of 33035A," (July 1973). Reference will be made to these three previous reports throughout this text by report number.

The 'Ideal' Patching Mortar

In order to more clearly explain the criteria for evaluating these types of mortars the following description of the properties of an 'ideal' patching mortar is presented (initially described in Report R-715).

When setting, the ideal patching mortar would develop a strong bond to the original concrete so that it could carry any transferred horizontal shear or tensile stresses. It develops the high compressive strength required by the composite design, and it develops sufficient tensile strength

---

[1] Commercial fast-setting hydraulic patching mortars.

[2] Commercial fast-setting mortars containing MgO cement.

to cope with the positive-to-negative moment reversals caused by moving loads. It does all of this immediately after placement so that the bridge can be opened to traffic as quickly as possible. The ideal patching mortar also does not shrink, neither during nor after cure, and has a thermal coefficient of expansion equal to that of the concrete so these properties do not cause it to break bond with the concrete. The ideal patching mortar is also unaffected by the destructive action of deicing chemicals during freezing and thawing conditions. Finally, the ideal patching mortar should be cheap, easy to mix, easy to place, and require no special application equipment.

TESTING PROGRAM

Test Specimens

The ideal patching mortar described in the Introduction does not exist, but its properties provide a basis for evaluating the properties of existing patching mortars. Using this concept, the test procedures, intervals, and specimens employed in the evaluation of each material are as follows:

1) Compressive Strength - Two-inch cubes, conforming to ASTM C109-70T, "Compressive Strength of Hydraulic Cement Mortars," were used to evaluate the patching mortars' compressive strengths during and after a special cure and freeze-thaw exposure. The number of compressive cubes and the test intervals used for each material are given in Table 1.

TABLE 1
COMPRESSIVE STRENGTH SPECIMENS
(2-in. cubes)

Material	Age at Test						Freeze-Thaw Cycles			Total
	2 hr	8 hr	24 hr	3 day	7 day	28 day	50	100	200	
Octocrete	0	3	3	3	3	3	3	3	3	24
Set-Instant Repair	3	3	3	3	0	3	0	0	3	18
Darex 240	3	3	3	3	0	3	0	0	3	18
Set 45	3	3	3	0	3	3	0	0	3	18
Bostik 275	0	0	0	0	0	0	0	0	0	0

The special cure used on all materials consisted of 7 days in polyethylene bags to prevent early drying out, followed by 21 days in laboratory air. In actual field use, a spray coat of curing membrane would probably be used. This special cure was followed by 200 cycles of freezing and thawing. These cycles corresponded to ASTM C666-73, Procedure B, which describes rapid freezing in air and thawing in water.

2) Tensile Strength - To evaluate the tensile strength of the patching mortars, briquets conforming to ASTM C190-70, "Tensile Strength of Hydraulic Cement Mortars," were employed.

The tensile briquets were tested in groups of three at various ages during the special cure; Octocrete and Set 45 were tested after 8 and 24 hours, 3, 7, and 28 days; Set-Instant Repair was tested after 8 and 24 hours, 2 and 7 days; Darex 240 was tested after 8 hours, 2, 3, and 7 days.

3) Shear Bond Strength - A laboratory developed single-shear test was used to evaluate the patching mortars' bond strength. A 4 by 4-in. sawed face of a 4 by 4 by 3-in. air-entrained concrete block containing limestone coarse aggregate was ground with a flat steel plate and No. 36 grit to ensure surface uniformity. A 1-in. thick cap of the patching mortar was cast on this 4 by 4-in. ground face.

The capped shear blocks were tested in groups of three at the same ages during the special cure and freeze-thaw exposure as were the compression cubes; except Set 45 mortar was tested in groups of two. Set-Instant Repair and Darex 240 mortars had additional tests after 50 and 100 freeze-thaw cycles.

Testing was performed by clamping the shear block so the bonding face was vertical and loading the edge of the mortar cap until the cap sheared from the concrete block. There is currently no ASTM standard covering this shear test for bond strength.

4) Shrinkage - To evaluate the shrinkage characteristics of the patching mortars, shrinkage prisms of 1 by 1 by 11-1/4-in. conforming to ASTM C490-74, "Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete," were employed. Four prisms were cast of the Octocrete, Set-Instant Repair, Darex 240, and Set 45 mortars. The prisms were weighed and measured after 2, 8, and 24 hours, 3, 7, and 28 days during the special cure; after 3 and 6 months of drying in laboratory air; and after 1, 3, 7, and 14 days of moist room recovery following the 6 month dry out. The prisms of Octocrete mortar were measured and weighed initially at 8 hours due to its low early strength. No shrinkage prisms were cast of the Bostik 275 mortar.

5) Surface Scaling During Freeze-Thaw Testing - To determine the resistance of the patching mortars to surface scaling during freeze-thaw testing, slabs of 6-in. diameter by 1/2-in. thickness were employed. A dike, created by placing 1-1/2-in. metallic tape around the perimeter of the slab, was used to retain ponded solutions on the surface of the slab.

Three slabs were cast of each mortar and were given the 28 day special cure; the tape dikes were then placed, and the slabs soaked in fresh water for 24 hours. Freeze-thaw cycling was then conducted with the slabs positioned in the rapid freeze-thaw machine so that their bottoms intruded 3/4-in. into the thaw cycle water. The cycles of freezing and thawing corresponded to ASTM C666-73, Procedure B, except for the positioning and ponding of the slabs as previously described.

The slabs were ponded with fresh water during the initial 12 cycles of freezing and thawing. A solution of 3 percent sodium chloride replaced the fresh water after 12 cycles. Fresh water was alternated with the 3 percent sodium chloride throughout the test; the changes in solution being made after 12, 36, 54, 78, 96, 120, 138, 162, and 180 cycles of freezing and thawing.

Care was taken during the changing of the ponded solution to retain any loose scale on the slabs; this scale was collected after 36, 78, 120, 162, and 204 cycles of freezing and thawing. The scale was oven dried and cumulative totals of scale weight were kept for each slab.

After completion of the freeze-thaw exposure the dry bulk density was determined for each slab.

A numerical value for the rate of surface scaling was determined by the following formula:

$$\text{Rate of Scaling} = \frac{\text{Dry Weight of Scale (gm)}}{\text{Dry Bulk Sp. Gr. x Ponded Area (cm}^2\text{)}} = (\text{cm}^3/\text{cm}^2)$$

All slabs were subjected to 204 cycles of freezing and thawing except that the Octocrete and Darex 240 mortars were subject to 162 cycles of freezing and thawing. No slabs were cast of the Bostik 275 mortar.

Method of Curing

The fast-setting hydraulic cement mortars and MgO cement mortars were given the "special cure," which was designed to simulate field curing. This consisted of seven days in polyethylene bags followed by 21 days in laboratory air. This laboratory does not have constant humidity and temperature control so the laboratory air humidity varies according to the season of the year. This has some effect on the long-term rate of shrinkage and weight loss of the shrinkage prisms.

MORTAR PREPARATION

Each of the patching mortars was mixed two minutes in a Hobart Model N50 laboratory mixer. Due to the rapid setting nature of these mortars, the ASTM standard hand tamping was discarded in favor of a probe type mechanical vibrator to hasten consolidation; the lone exception being Darex 240 which did not consolidate well and which had to be hand tamped into the molds. Table 2 shows the mix component weights and cost for each cubic foot of patching mortar.

TABLE 2
COMPONENT WEIGHTS AND MATERIAL COST
FOR ONE CUBIC FOOT OF PATCHING MORTAR

Material	Weight, lb	Water, lb	Liquid Admixture, lb*	Darex, ml	Cost, per cu ft	Date of Price Quotation
Octocrete	111.2	22.7	--	20.2	11.70	3-19-73
Set-Instant Repair	115.2	17.4	--	--	11.30	2-20-75
Darex 240	126.5	--	29.7	--	32.90	8-26-74
Set 45	132.7	11.1	--	--	27.90	2-20-75
Bostik 275	112.5	--	29.4	--	27.50	1975

* Ammonium phosphate solution weighing 11.75 lb/gal.

The preparation of, and general information regarding each patching mortar follows.

Fast-Setting Hydraulic Mortars

Octocrete - The producer, Penn-Crete Products Co., Inc., Philadelphia, PA., supplied two samples with different setting times; one of nine minutes and the other of 30 minutes. The slower setting material showed a water reduction of 2 percent and generally higher strengths than the faster setting material. The Octocrete mortar of 30 minutes setting time was, therefore, selected as a subject material of this report. It was recommended that five quarts of mix water be used for a 50-lb bag.

An acrylic-polymer emulsion admixture called "Octoblen" was also supplied which is claimed to improve workability and bond strength in feather edging when used with Octocrete. Testing showed slightly greater compressive and tensile strengths and improved resistance to surface scaling during freezing and thawing, but also showed reduced shear bond strength and no improvement in rate of shrinkage. Octoblen costs $3.50 per gallon. The manufacturer recommends one gallon of Octoblen be added to 100 lb of Octocrete. Octoblen is not considered in the remainder of this report as its effect of producing a reduction of shear bond strength was considered detrimental.

The shear bond blocks were brushed with water prior to placement of the mortar. Darex air-entraining agent was added at the rate of 0.25 fl oz/ 50-lb sack of Octocrete.

<u>Set-Instant Concrete Repair</u> - The producer, Set Products, Inc., Macedonia, OH, modifies Regulated Set cement from the Huron Cement Co. for use in this product. Water was added at the rate of 7.25 pints per 50-lb sack which produced a mix of good consistency; the manufacturer had recommended 7.5 pints per sack.

Shear bond blocks were brushed with water prior to placement of the mortar. No Darex air-entraining agent was added as a small trial batch using Darex showed an excessive amount of entrained air.

The time of setting was too rapid to allow placement at 70 F but was reduced to 12 minutes with a mix component temperature of 60 F.

<u>Mortars Containing MgO Cement</u>

<u>Darex 240 Concrete</u> - This material is produced by W. R. Grace and Co., Chicago, IL, under license to Republic Steel and is similar to their formulation for Quick Set mortar. The latter material has been studied earlier under Research Project 71 NM-306.

Two samples, each with a different time of setting; one of seven minutes and the other of 20 minutes were received. The slower setting material showed slow strength gain in the initial 24 hours. The Darex 240 mortar of seven minute time of setting was therefore selected as a subject material of this report. This latter material is the one currently supplied as Darex 240, by W. R. Grace.

One gallon of ammonium phosphate liquid (11.75 lb) was provided with each 50-lb sack of dry mix and was added at that rate to produce about 0.42 cu ft of mix.

The mortar was sticky and did not flow well when vibrated, necessitating hand tamping to achieve consolidation. A strong odor of ammonia was noted during mixing and circular voids were noted on the formed surfaces upon stripping which indicated that this gas was liberated in the material prior to setting.

The shear bond blocks were brushed with water and then with ammonium phosphate liquid prior to placing the mortar.

Set 45 Minute Concrete - This material, produced by Set Products, Inc., is a mixture of silica sand, an MgO cement, and a dry form of ammonium phosphate to which only water need be added.

Water was added at the rate recommended by the manufacturer (0.5 gallon to a 50-lb bag). This material was not sticky but did not flow easily when vibrated. Placing the probe type mechanical vibrator against the forms helped in consolidating the material. A moderate odor of ammonia was present when mixing the material.

Upon setting, the mortar showed strong bond to the metal forms causing two shrinkage prisms to fracture on stripping at two hours age. Circular voids were noted on the formed surfaces and a slight odor of ammonia indicated that this gas was liberated in the material prior to setting. Time of setting appeared to be 16 minutes. The temperature of the mortar rose to 140 F while setting.

The shear bond blocks were brushed with water and then with a slurry of one part water to seven parts Set 45 prior to placing the mortar.

Bostik 275 - This material is produced by Upco Chemical Division of USM Corp., Cleveland, OH, under license to Republic Steel and is similar to their formulation for Quick Set mortar.

A trial batch hardened so rapidly that no forms could be filled and the hard mortar had to be chipped out of the mixing bowl. As the time of setting was too rapid to permit any field placement no further testing was performed on this material. A 45-lb bag of MgO Cement and aggregate mixed with one gallon of ammonium phosphate solution yields about 0.40 cu ft of mix.

TEST RESULTS

Table 3 shows the percentage of the mortar passing the No. 200 or No. 140 sieve and also the chemical analysis of that portion, considered to be the cement fraction. Note that data previously obtained on Quick Set mortar (71 NM-306) are given for Darex 240 and Bostik 275. These three products are all similar in formulation and are made by licenses to Republic Steel Corporation.

TABLE 3
CHEMICAL CONSTITUENTS OF THE CEMENTING FRACTION OF SUBJECT MORTARS

Percent Passing a No. 200 or No. 140 Sieve	Octocrete (No. 200) 50 Percent	Set-Instant Repair (No. 200) 33 Percent	Darex 240[1] and Bostik 275 (No. 140) 26 Percent	Set 45 (No. 140) 22 Percent
CaO	59.2	40.2	(Quick Set) 4.0	4.4
MgO	4.1	2.3	83.4	29.2
SiO_2	22.5	23.8	5.1	13.0
SO_3	2.5	4.9	0.0	0.0
R_2O_3[2]	7.2	25.0	6.0	27.6
PO_4	--	--	0.0	14.7
Loss on Ignition	5.5	3.6	0.4	12.8
Total	101.0	99.8	98.9	101.7

[1] Analysis of Republic Steel's "Quick Set" mortar. See "Mortar Preparation - Darex 240."

[2] R_2O_3 constitutes all metallic oxides (Al_2O_3, Fe_2O_3).

The results of each of the five tests performed on the hardened mortars are presented in the following tables: Compressive Strength (Table 4), Tensile Strength (Table 5), Shear Bond Strength (Table 6), Shrinkage Prism Length Variation (Table 7), Shrinkage Prism Weight Variation (Table 8), and Rate of Surface Scaling (Table 9).

TABLE 4
COMPRESSIVE STRENGTH (psi)
2-in. Cubes (ASTM C109-70T)

Material	Age of Mortar						Cycles of Freezing and Thawing		
	Polyethylene Bag					Air Dry			
	2 hr	8 hr	24 hr	3 day	7 day	28 day	50	100	200
Octocrete	---	530	3,290	4,070	4,970	6,320	5,720	5,020	6,080
Set-Instant Repair	790	1,010	2,420	3,840	---	5,880	---	---	4,170
Darex 240	3,480	3,730	3,640	4,120	---	6,890	---	---	6,620
Set 45	3,830	5,890	6,540	---	7,550	9,320	---	---	6,130

TABLE 5
TENSILE STRENGTH (psi)
Briquets, 1-in. square tensile face (ASTM C190-70)

Material	Age of Mortar					
	Polyethylene Bag					Air Dry
	8 hr	24 hr	2 day	3 day	7 day	28 day
Octocrete	140	360	---	390	560	500
Set-Instant Repair	180	260	290	---	260	---
Darex 240	320	---	380	390	350	---
Set 45	260	280	---	300	300	440

TABLE 6
SHEAR BOND STRENGTH (psi)
4 by 4 by 1-in. Mortar Cap Bonded to a 4 by 4 by 3-in. Concrete Block

Material	Age of Mortar						Cycles of Freezing and Thawing		
	Polyethylene Bag					Air Dry			
	2 hr	8 hr	24 hr	3 day	7 day	28 day	50	100	200
Octocrete	---	50	230	210	250	70	170	40	170
Set-Instant Repair	50	50	130	180	---	60	0	0	30
Darex 240	260	420	300	340	---	400	90	0	0
Set 45	300	315	200	---	250	250	---	0	90

TABLE 7
SHRINKAGE PRISM LENGTH VARIATION (mil/in.)
1 by 1 by 11-1/4-in. Prisms (ASTM C157)

Material	Age of Mortar								Moist Room Recovery			
	Polyethylene Bag				Air Dry							
	8 hour	1 day	3 day	7 day	14 day	28 day	3 month	6 month	1 day	3 day	7 day	14 day
Octocrete	-0.25	-0.36	-0.21	-0.10	0.68	2.04	3.07	3.61	2.46	2.08	2.00	1.91
Set-Instant Repair	0.02	0.12	0.43	0.73	0.92	3.31	3.14	3.24	2.83	2.77	2.75	2.72
Darex 240	0.01	0.02	-0.01	0.05	0.11	0.41	0.52	0.62	0.46	0.38	0.34	0.37
Set 45	-0.02	-0.01	---	0.08	0.24	0.30	0.38	0.58	0.20	0.11	0.11	0.07

TABLE 8
SHRINKAGE PRISM WEIGHT VARIATION (PERCENT FROM INITIAL)
1 by 1 by 11-1/4-in. Prisms (ASTM C157)

Material	Age of Mortar								Moist Room Recovery			
	Polyethylene Bag				Air Dry							
	8 hour	1 day	3 day	7 day	14 day	28 day	3 month	6 month	1 day	3 day	7 day	14 day
Octocrete	----	-0.4	-0.8	-0.8	-2.5	-4.2	-6.2	-6.7	+0.2	+2.1	+2.2	+2.9
Set-Instant Repair	-0.1	-0.1	-0.2	-0.4	-2.8	-3.7	-4.2	-3.7	+1.9	+2.4	+2.5	+2.8
Darex 240	-0.2	-0.4	-0.6	-0.9	-1.9	-2.3	-2.5	-2.6	-0.9	0.0	+0.4	+0.7
Set 45	-0.1	-0.1	--	-0.5	-1.0	-1.7	-1.9	-1.8	-0.1	-0.1	-0.1	-0.2

TABLE 9
RATE OF SURFACE SCALING (cm^3/cm^2)
6-in. Diameter by 1/2-in. Thick Slabs

Material	Cycles of Freezing and Thawing				
	36	78	120	162	204
Octocrete	0.000	0.015	0.030	0.036	---
Set-Instant Repair	0.028	0.050	0.063	0.081	0.110
Darex 240	0.002	0.019	0.048	0.150	Term
Set 45	0.001	0.002	0.004	0.010	0.033

Results of Fast-Setting Hydraulic Mortars

Octocrete - This material gained strength slowly in the initial 8 hours. After removal from the polyethylene bag at seven days age the shear bond strength decreased due to a high rate of shrinkage which caused cracks to appear at the bond surface. The high rate of drying shrinkage was accompanied by a large loss in weight. Octocrete held up well in the surface scaling test and was no doubt helped in this by the additional air-entrainment provided by the MBVR added to the mix. Tensile strength was good.

Set-Instant Concrete Repair - This material also gained strength slowly in the initial eight hours partly because it had to be poured at 60 F to slow down its rapid time of setting. After removal from the polyethylene bag after seven days, the shear bond strength decreased due to the high rate of drying shrinkage. No cracks were visible at the bond surface, however. The shear bond strength decreased to zero after 50 cycles of freezing and thawing. The surface scaling slabs showed a moderate amount of surface scaling after 204 freeze-thaw cycles. This material was low in tensile strength.

Results of Mortars Containing MgO Cement

Darex 240 Concrete - This material gained strength rapidly in the initial two hours. Excellent shear bond strength was maintained during the dry cure due to the low rate of shrinkage. Freezing and thawing conditions were very destructive causing loss of all bond after 100 cycles and disintegration of the surface scaling slabs after 162 cycles of exposure. Tensile strength was good.

A. Compression Strength

Strength Range, psi	Time Interval 8 hr	24 hr	3 day	200 Freeze-Thaw Cycles
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	4	4	3	9

B. 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	4	4	4

C. 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	8	4	4	4	8	8

D. Shrinkage

Shrinkage Range (mils/in.)	Time Interval 7 day	28 day	3 mo
> 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

E. Rate of Surface Scaling

Scaling, (cm^3/cm^2)	204 Freeze-Thaw Cycles
> 0.20	0
0.10-0.20	5
0.05-0.10	10
0-0.05	15

F. Cost Factor

Cost per cubic foot	
>34	0
32-34	2
30-32	5
28-30	8
26-28	11
24-26	14
22-24	17
20-22	20
18-20	23
16-18	26
14-16	29
12-14	32
10-12	35
8-10	38
6-8	41
4-6	44
2-4	47
0-2	50

Figure 1. Rating System.

Set 45 Minute Concrete - This material also gained strength rapidly in the initial two hours and continued a marked strength gain through eight hours. Fair shear bond strength was exhibited during the dry cure due to the low rate of shrinkage. Freezing and thawing conditions were moderately destructive causing low shear bond strength after 200 cycles and a slight scaling of the surface scaling slabs after 200 cycles of exposure. Tensile strength was good.

Bostik 275 - No strength or shrinkage tests were run on this material due to its four-minute setting time.

EVALUATION

Evaluation System

The system used to evaluate the potential of the subject patching mortars was based on the results of the laboratory tests and the mortar cost. The evaluated properties and cost are shown in Figure 1 (A through F), along with the rating points assigned them. Included are the mortars' shear bond, compressive, and tensile strengths; shrinkage; rate of surface scaling; and mortar cost per cu ft. An 'ideal' mortar as described in the Introduction would receive a total of 100 points for performance and 50 points for material cost for a total rating of 150 points.

The rating system used is the same as used in Research Reports R-715 and R-872 except that the 15 points previously alloted to the 'Weather Resistance Factor' are now alloted to 'Rate of Surface Scaling.'

Table 10 is an itemization of the performance rating points earned by each patching mortar. These rating points were obtained by taking the performance values from Tables 4 through 9 and entering these in the performance rating tables in Figure 1.

Table 11 combined the performance rating point total of each mortar, taken from Table 10, and the cost factor derived from Figure 1. The cost factor includes only the mortar cost, F.O.B. from the manufacturer, when purchased in truckload (500 sack) quantity and does not include labor or equipment needed to place the material.

Patching Mortar Performance

Fast-Setting Hydraulic Mortars - Both of these mortars were slow in developing compressive and shear bond strengths and shrank excessively

TABLE 10
RATING OF PERFORMANCE

Material	Compressive Strength				Tensile Strength			Shear Bond Strength						Shrinkage			Rate of Surface Scaling	Rating Point Total
	8 hr	24 hr	3 day	200 Freeze-Thaw Cycles	8 hr	24 hr	3 day	8 hr	24 hr	28 day	Freeze-Thaw Cycles 50	Freeze-Thaw Cycles 100	Freeze-Thaw Cycles 200	7 day	28 day	3 mn		
	(4)	(4)	(3)	(9)	(4)	(4)	(4)	(8)	(4)	(4)	(4)	(8)	(8)	(2)	(6)	(9)	(15)	(100)
Octocrete	1	3	3	9	2	3	3	2	2	0	1	0	2	2	0	0	15	48
Set-Instant Repair	2	2	2	9	2	2	2	2	1	0	0	0	0	1	0	0	5	30
Darex 240	4	3	3	9	4	3	3	8	3	4	0	0	0	2	4	6	0	56
Set 45	4	4	3	9	3	2	3	8	1	2	2	2	0	2	6	9	15	76

TABLE 11
COMBINED RATING OF PERFORMANCE AND COST

Material	Performance Rating Point Total (100)	Cost Factor (50)	Combined Rating Point Total (150)	Combined Preferential Order ---
Set 45	76	11	87	1
Octocrete	48	35	83	2
Set-Instant Repair	30	35	65	3
Darex 240	56	2	58	4

during the dry cure. Octocrete showed good resistance to surface scaling during freezing and thawing sequences with the help of additional MBVR air entraining agent, while Set-Instant Concrete Repair showed only fair resistance. Both mortars showed poor shear bond strength during freezing and thaw cycles.

Mortars Containing MgO Cement - Both of the tested mortars gained compressive, tensile, and shear bond strength rapidly and showed a low rate of shrinkage. Darex 240 was vulnerable to surface scaling during freezing and thawing conditions while Set 45 was only moderately affected. Both of the tested mortars set in 16 minutes or less at room temperature and were difficult to consolidate which may cause problems in field application, except in cold weather use. Both tested mortars showed average to poor shear bond strength during freezing and thawing conditions.

CONCLUSIONS AND RECOMMENDATIONS

Performance Considerations

The only mortar that came close to the performance of an 'ideal' mortar was Set 45.

Both Octocrete and Set-Instant Concrete Repair gained strength slowly and showed too much shrinkage to be effective for bridge deck patching.

Darex 240 mortar was too vulnerable to freeze-thaw destruction to allow it to be used on pavements or bridge decks in its present form.

Bostik 275 set too fast to allow placement but is expected to perform the same as Darex 240 since it is based on the same recipe under license with Republic Steel.

Combined Performance and Material Cost Considerations

As noted previously, a maximum rating of 50 points was allowed for material cost considerations to integrate the 100 point performance rating with the economic feasibility of the mortars. Table 11 shows the combined preferential order of the mortars.

Set 45, which was the only mortar that showed acceptable performance, is quite costly and this hindered its overall rating, although it still retained first place among the mortars.

Recommendation Based on Laboratory Test Results

Traffic should be removed from a bridge deck while a patching mortar is setting to avoid stresses and vibrations which may destroy the developing bond.

If a bridge must be opened to traffic in three hours, our testing indicates Set 45 is the only mortar that would be adequate in strength and durability. Set 45 mortar is costly, however, and limitations must be made on the quantity to be used.

If a bridge can be closed overnight, richer Type I-A cement mixes such as used on the Blue Water Bridge in 1976 (B04 of 77111) can be used and will give good results with low cost. These mixes used an 11 sack mortar or nine or ten sack concrete with 17A or 25A aggregate.

Required Field Confirmation

Before this laboratory recommendation is incorporated into permanent specifications a field test of the recommended patching mortar should be made and observed to confirm the laboratory results.

Set 45 was the only mortar which we felt would warrant an experimental field application. The Concrete and Surface Treatment Sub-Unit of the Materials Research Unit was involved with numerous projects during the summer and fall of 1976 and was unable to perform the necessary experimental patching. In lieu of this experimental bridge deck patching the following field applications by MDSHT, Wayne County Road Commission, and the Ohio DOT are listed.

a) Field Application by MDSHT - During the fall of 1976, the Experimental Field Studies Sub-Unit continued their experimental patching of pavement joints under Research Project 75 G-217, "Maintenance of Neoprene Sealed Concrete Pavement." J. E. Simonsen, Sub-Unit head, agreed to use Set 45 mortar as an experimental material in some of these patches.

A total of 63 patches of Set 45 were placed during September and October, 1976. An inspection of the patches in November, 1976 disclosed four of the Set 45 patches had failed in bond. These failures occurred where the mortar was feather edged. Feather edging is not recommended nor desired in concrete patching.

An inspection of the patches in February, 1977 disclosed an additional six of the Set 45 patches showing bond failure; one of these patches had failed completely. The patch that failed completely had been placed after the

Set 45 had begun to harden; moreover, the pavement had not been adequately saturated prior to patch placement. The other five patch failures discovered in the February inspection were determined to be caused by feather edging or inadequate wetting of the pavement prior to placement.

It was determined that none of the failures were due to any inherent deficiency in the Set 45 mortar.

b) Field Applications by the Wayne County Road Commission - During August 1975 the Wayne County Road Commission used Set 45 as an experimental bridge deck patching material.

A total of 19 patches were placed on S01 of 82081, M 153 over M 39. The only lane that was patched with Set 45 was the center lane on the westbound deck. Tom Voyles, Assistant Bridge Maintenance Engineer, Wayne County Road Commission, reported that as of the fall of 1976 these patches were in good condition.

c) Field Applications by Ohio Department of Transportation - The Ohio DOT Bridge Maintenance crews have been using Set 45 for bridge deck patching for the past three years. George Maki, District 12 Bridge Maintenance Engineer, Ohio DOT, reports their experience has been with patches ranging from shallow-depth, up to and including full-depth repairs. They generally use 100 lb of peastone aggregate per three bags of Set 45.

The District 12 (Cleveland) bridge crews have placed Set 45 in 20 F temperature by heating the peastone and water and using blow torches to heat the deck and patch.

They report that at 70 F temperature traffic can be allowed on the patches one hour after placement.

Hot weather placement of Set 45 is made quickly with no cooling of ingredients.

The only failure they noted involved the patching of a bituminous concrete overlay on an open grid deck. In this case the aggregate was dusty and this is thought to be the cause of the failure.

Recommendation Based on Field Applications

The laboratory test results combined with the favorable results of field applications performed by several agencies indicate Set 45 is a suitable material for bridge deck repairs where the time for deck closure to traffic is critical.

It is recommended that Set 45 be approved for the use stated. If approved on this basis, we would suggest that a record be kept by the District Maintenance repair crews of the time, location, quantity, etc., of use so that we can follow subsequent performance of the patches. Initially, it might be more feasible to have only some of the Maintenance repair crews in the lower part of the state use the Set 45 if technical assistance from the Research Laboratory is needed.