RAPID SETTING CEMENT MORTARS FOR CONCRETE REPAIR - FIELD TRIALS

Final Report

by

D. L. O'Connor
Supervising Chemical Engineer

Materials and Tests Division
Texas Highway Department

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ABSTRACT

The field performance of three rapid setting cement mortars developed by the Materials and Tests Division of the Texas Highway Department was evaluated. The mortars were used to patch spalled joints on concrete pavement. After 27 months under heavy traffic, all patches placed with one of the formulations are still in good condition.

A specification for this mortar was prepared and trial amounts purchased for use by four Districts of the Texas Highway Department. Obtaining good performance with the mortar is dependent upon mixing and placement techniques and using only the minimum mixing water necessary. Use of additional aggregate, such as pea gravel, with the mortar has not proved successful.

Although the durability of this material is not as good as conventional concrete, it is believed that its overall performance equals or exceeds that of the various rapid setting mortar materials currently offered for highway use.

SUMMARY

Three rapid setting cement mortar formulations developed by the Materials and Tests Division of the Texas Highway Department were used to patch spalled joints of concrete pavement on I-10 in the city of Houston. The patching was done by a Highway Department Maintenance crew. The performance of the various patches was monitored for 27 months. After 27 months under heavy traffic, all patches placed with one of the three formulations are still in good condition. This mortar consists of Type II portland cement, high strength gypsum, fine sand, powdered saponified vinsol resin air entraining agent, water reducer and plaster retarder.

A specification for this formulation was prepared and trial amounts purchased for use by four Districts of the Texas Highway Department. Based on placement of the field trial patches and subsequent use of the material, it was found that mixing and placement techniques are quite important. Use of a mechanical mixer, preferably a plaster mixer, is recommended. A more uniform mix can be obtained in less time than by hand mixing. Also, less mixing water can be used. If more than the minimum mixing water necessary to obtain a workable mix is used, the strength development and durability of the mortar will be adversely affected. The addition of extra aggregate, such as pea gravel, to the mortar did not prove successful.

Some of the patches placed in the field trial were coated with a fast drying curing membrane and some covered with wet mats until just prior to opening to traffic. No significant difference in performance attributed to curing has been noted. Experience has indicated that if the humidity is high and the pavement temperature is below 90 F, no curing is needed.

Characteristics of this mortar, particularly the set times, will vary from batch to batch of the portland cement used, so evaluation of laboratory blends prior to production is necessary to be sure the desired properties are obtained. It was also found that the properties of the mortar change if the dry mix is stored for a period of time prior to use. The most significant change is a slowing of the set times.

Although the durability of this material is not as good as conventional concrete, it is believed that its overall performance equals or exceeds that of the various rapid setting mortars currently available for highway use.

IMPLEMENTATION

A specification has been prepared for the mortar exhibiting the best performance in the field trial. The material has been designated as Rapid Setting Mortar RS-1. It appears to perform as well or bette· than proprietary patching mortars currently being purchased by various Districts of the Highway Department. It is recommended that this specification be used for purchase of rapid setting patching mortar by the Districts until such time that developments in this field result in materials which offer better performance.

Since work with this mortar indicates that its properties change in storage, no more material should be purchased than can be used in six months from date of manufacture.

The Materials and Tests Division can supply use instructions and information to any of the Districts desiring to use the material.

I. SUBJECT

Rapid setting cement mortars for concrete repair - field trials.

II. PURPOSE

The purpose of this project was to evaluate the performance in the field of rapid setting cement mortars which, based on the work presented in Research Report 3-09-71-020 (reported June 1971) showed promise as repair materials for concrete bridge decks and roadway.

III. CONCLUSIONS

This investigation has shown that rapid setting mortars developed by work previously reported will give good performance for at least two years. After 27 months under heavy traffic, three patches placed with one of these formulations are still in good condition. This mortar consists of Type II portland cement, high strength gypsum, fine sand, powdered saponified vinsol resin air entraining agent, water reducer and plaster retarder.

A specification for this formulation was prepared and the material designated as Rapid Setting Patching Mortar RS-1. A copy of the specification is included in the Appendix. It is believed that this formulation offers the best overall performance that can be obtained with rapid setting materials based on combinations of portland cement and gypsum. The durability of these materials is not as good as conventional concrete and this fact should be considered when planning repairs with the rapid setting mortar.

The following specific conclusions regarding Rapid Setting Mortar RS-1

were reached based on the field trials in District 12 and subsequent purchase and use of some of the material by various Districts.

1) In order to obtain good performance, mixing and placing should be done as rapidly as possible and the amount of mixing water should be held to the minimum necessary to obtain a workable mix. To achieve this, a mechanical mixer such as a plaster mixer should be used rather than mixing by hand. Hand mixing is slower and there is a tendency to add too much mix water.

2) No difference was noted in performance of patches coated with a quick drying curing membrane and those covered with wet mats removed just prior to opening to traffic. Experience indicates that no curing is required if the humidity is high and the pavement temperature is below 90 F.

3) The use of aggregate other than a small amount of fine sand has proved unsuccessful. The durability of patches containing concrete sand and pea gravel was poor. The use of aggregate requires additional mixing water to obtain workability. Since these formulations are quite sensitive to the amount of mixing water used, this is probably one factor in the poor durability.

4) Production of this material on a commercial scale emphasized the necessity to evaluate a laboratory blend of samples taken from the actual batches of raw materials proposed for use in the mortar. The characteristics of the finished product, particularly the set times, will vary from batch to batch of a given portland cement.

5) Laboratory tests and use of this material in the field show that properties of the mix change if the dry mix has been stored for a period of time prior to use. Comparison of the initial properties with those after six months in storage showed that the most pronounced change was a slowing of the set times.

IV. MATERIALS

The specific materials used in the patching cement prepared for field trials are listed in Table I below.

Table I

Identification of Raw Materials

Material	Manufacturer
Portland Cement, Type II	Lone Star Cement Corp. (Maryneal)
No. 1 Molding Plaster	U. S. Gypsum
Hydrostone (High strength pressure calcined gypsum)	U. S. Gypsum
Aggregate (No. 4 sandblast sand)	Clemtex, Ltd.
Aggregate (No. 1 Fine Aggregate, THD Std. Spec. Item 421)	Longhorn Sand & Gravel Co., Austin, Tex.
Lomar LS water reducer	Nopco Chemical Div. of Diamond-Shamrock
Red Top Retarder	U. S. Gypsum
Vinsol NVX air entraining agent	Hercules Powder Co.
Pea Gravel (Grade No. 4 aggregate, THD Std. Spec. Item 421)	Unknown

V. TEST METHODS

The tests used in laboratory evaluation of the rapid setting mortar mixes and the raw materials used therein were as follows:

1) Physical testing of Gypsum Plasters and Concrete
(ASTM Designation: C 472)

2) Acid Insoluble Residue for Fine Aggregate
(Test Method Tex-612-J)

3) Moisture in Mineral Aggregate for Use on Built-Up Roofs
(ASTM Designation: D 1864)

4) Sieve Analysis of Fine and Coarse Aggregate
(Test Method Tex-401-A)

5) Air Content of Hydraulic Cement Mortars
(ASTM Designation: C 185)

6) Time of Setting of Hydraulic Cement by Gillmore Needles
(ASTM Designation: C 266)

7) Compressive Strength of Hydraulic Cement Mortars (Using 2 Inch Cube Specimens)
(ASTM Designation: C 109)

VI. PROCEDURE

After completion of the work covered in Research Report 3-09-71-020 dated June 1971 (Rapid Setting Cement Mortars for Concrete Repair) the decision was made to place some of the more promising formulations in the field to obtain information on mixing, handling and performance characteristics under actual conditions. Three mixes were selected for trial, the composition of which are shown below. Mix 1 is the same as Formulation IX discussed in the previous report. Mix 2 is the same as Formulation X except that the Lomar LS content was increased.

Additional test data on Formulation X was obtained with regard to expansion in air and shrinkage in water after the original report was written. This data is included in Table I-A of the Appendix, along with the data available on Formulation X at the time of publication.

The only difference between Mix 2 and 3 was the aggregate used.

	Mix 1	Mix 2	Mix 3
Lone Star (Maryneal) Type II Portland Cement, g	79	79	79
U. S. Gypsum No. 1 Molding Plaster, g	21	-	-
U. S. Gypsum Hydrostone, g	-	21	21
Clemtex No. 4 sandblast sand, g	50	50	-
No. 1 Fine aggregate, g	-	-	100
Red Top Retarder, g	0.04	-	-
Vinsol NVX Air Entraining Agent, g	0.01	0.005	0.005
Lomar LS Water Reducer, g	-	0.5	0.5

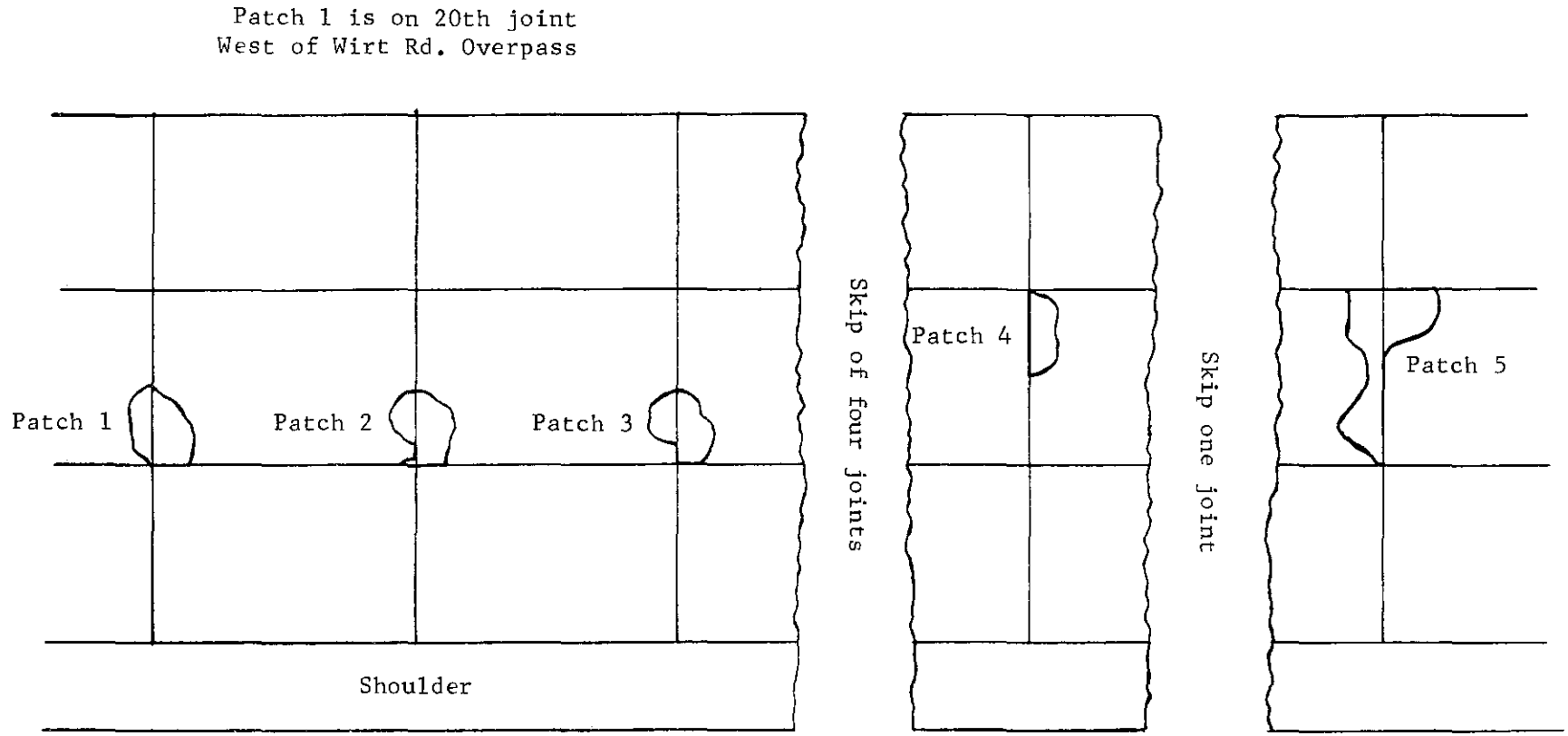
The dry mixes for the field trial were blended in a mortar mixer and bagged. Approximately 1500 pounds of Mix 1, 1400 pounds of Mix 2 and 900 pounds of Mix 3 were prepared. Samples were taken for each mix and tested in the laboratory. The results obtained are shown in Table II.

Table II

Properties of Mixes Prepared for Field Trial

Property	Mix 1	Mix 2	Mix 3
Mixing water added per 100 g dry mix, ml	22	19	15
Initial set, minutes	24	30	19
Final set, minutes	35	41	32
Compressive strength, psi			
2 Hours	300	378	325
1 Day	3395	4048	2888
14 Days	6225	8438	5563

All of this material was placed by District 12 Maintenance forces on August 18 and 19, 1971. It was used in repair of spalled concrete pavement joints on Westbound I-10 near Wirt and Campbell Roads in the city of Houston. The traffic count on this section of roadway was approximately 55,000 vehicles per day. All patches were located on the median or center traffic lanes of the Westbound section and were designated as Patches 1 through 12 as shown in Figures 1 and 2 on the following pages. Patches 1 through 5 were placed on August 18th and Patches 6 through 12 on August 19th. Detailed information on mixing, placing and curing of material for Patches 1 through 5 is shown in Tables III and IV. This information for Patches 6 through 12 is presented in Tables V and VI.



I-10 West bound

Figure 1

Location of Patches 1 through 5

Patch 6 is located just West of Campbell Road
Overpass one joint East of "Merging Traffic" sign.

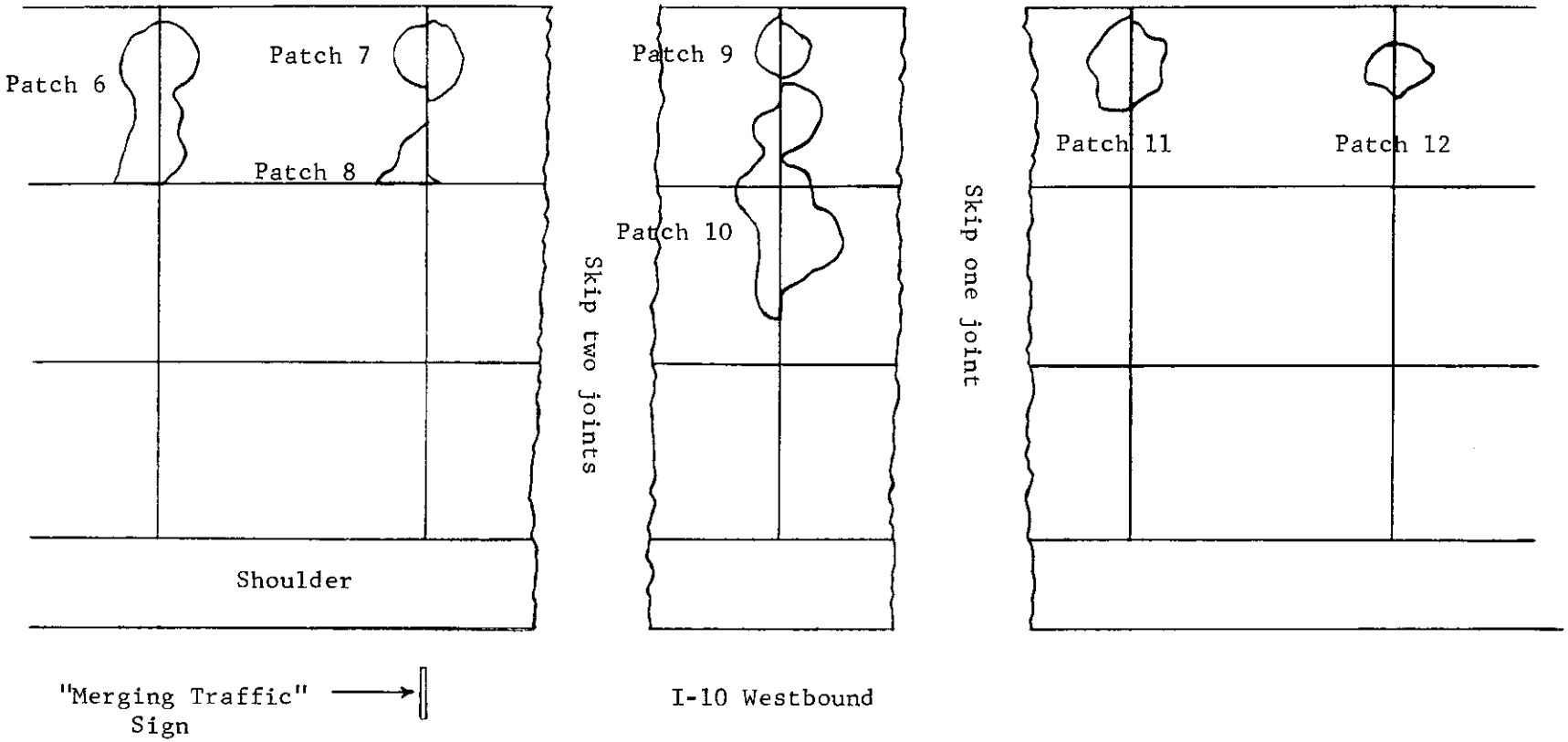


Figure 2

Location of Patches 6 through 12

Table III

Data on Patches 1 Through 5

Patch No.	Formulation Used	Batches Used	Curing	Approx. Time From Placement to Traffic	Ambient Temp. During Placement, F	Approx. Pavement Temp, F	Relative Humidity
1	No. 1	1 & part of 2	Wet Mat Placed @ 12:00 Removed at 1:15	1 hr. 55 min.	92	100	50%
2	No. 1	Portion of 2 & Portion of 3	Same as Patch 1	1 hr. 50 min.	92	100	50%
3	No. 2 Except for Small Amount of No. 1	Portion of 3, 4 & 5	Same as Patch 1	1 hr. 40 min.	93	100	50%
4	No. 2	6 & Portion of 7	Sealer Applied at 12:10	1 hr. 30 min.	95	102	50%
5	No. 2	8, 9 & 10	Sealer Applied at 12:30	1 hr. 15 min.	95	102	50%

Table IV

Data on Batches Used in Patches 1 Through 5

Batch No.	Form No.	Pounds Dry Mix	Gallons Water	Time Mixing Initiated	Mixing Time Minutes	Time Req. to Place & Finish, Min.	Mix Temp. F
1	1	200	5-3/4	11:27	1-1/2	5	92
2	1	200	5-3/4	11:31	1-1/2	4	92
3	1	176	5-1/4	11:37	1-1/2	4	92
4	2	200	5	11:42	1-1/4	4	93
5	2	100	2-3/4	11:47	1-1/4	4	93
6	2	200	5-1/4	11:49	1-1/2	8	92
7	2	200	5-1/4	12:01	2	6	92
8	2	200	5-1/4	12:04	2	5	92
9	2	200	5-1/4	12:09	2-1/4	5	92
10	2	210	5-1/4	12:13	2-1/4	5	92

Table V

Data on Patches 6 Through 12

Patch No.	Formulation Used	Batches Used	Curing	Approx. Time From Placement to Traffic	Ambient Temp. During Placement, F	Approx. Pavement Temp, F	Relative Humidity
6	3 + Pea Gravel	11 & 12	Wet Mats Placed @ 12:00 Removed 1:20	2 hr. 20 min.	90	90	65%
7	3 + Pea Gravel	13 & Part of 14	Same as Above	2 hr. 10 min.	90	90	60%
8	3 + Pea Gravel	Part of 14	Same as Above	2 hr. 5 min.	90	90	60%
9	3 + Pea Gravel & Sand out of 2 + Pea Gravel	Part of 14 & Part of 15	Same as Above	1 hr. 55 min.	90	90	60%
10	2 + Pea Gravel & 1 + Pea Gravel	Part of 15 & Part of 16	Wet Mats Placed @ 12:30 Removed @ 1:20	1 hr. 45 min.	92	95	60%
11	No. 1 & No. 1 + Pea Gravel	17 & 18	Sealer Applied @ 1:00	1 hr. 30 min.	93	95	60%
12	No. 1	19	Same as Above	1 hr. 20 min.	93	95	60%

Table VI

Data on Batches Used in Patches 6 Through 12

Batch No.	Formulation No.	Pounds Form.	Pounds Pea Gravel	Gallons Water	Time Mixing Initiated	Mixing Time, Minutes	Time Req. to Place & Finish, Min.	Mix Temp., F	Notes
11	3	200	150	4-3/4	11:22	1	4	84	Used Ice Water for Mixing - this Batch was too wet.
12	3	200	150	4-1/4	11:25	2	5	85	Used ice water for mixing - consistency O.K.
13	3	200	150	4-1/2	11:35	1-1/2	4	84	Used ice water for mixing.
14	3	200	150	4-1/2	11:37	2	5	83	Same as above.
15	2 & 3	100	150	4-3/4	11:47	2	4	85	Same as above.
16	1	300	150	7	11:55	2	6	92	Mix was too stiff.
17	1	200	0	5-1/2	12:10	2	4	92	
18	1	200	75	5-3/4	12:14	2	4	90	
19	1	200	0	5-3/4	12:20	2-1/2	4	93	

On August 18th, the weather was partly cloudy with temperature in the low to middle 90's and relative humidity 50%. Clean-out of spalled areas was begun at 9:45 A.M. Cleaning consisted of breaking out deteriorated concrete with an air hammer and then blowing dust and debris out of the hole with compressed air.

The holes were dampened with water prior to placing the mortar. On Patch 5, some of the mortar was scrubbed against the old concrete faces with a broom just prior to placing to see if this might result in a better bond. All of the mortar mixed on Wednesday handled well and developed its initial set at the time expected. Where the patches spanned a joint, the material was grooved along the joint line to create a plane of weakness. When the surface of the mortar took on a dry appearance, wet mats were placed on Patches 1, 2 and 3. Patches 4 and 5 received a brush coat of a fast drying curing membrane. This material was essentially on unpigmented fast drying traffic paint. The surface of the patches coated with curing compound hardened up faster than those cured with wet mats and the mortar got quite hot. The temperature was estimated to be 120 to 130 F. The patches cured with wet mats reached an estimated temperature of 105 to 110 F. Traffic was turned onto Patches 1 through 5 at 1:25 P.M. No immediate wear or damage to the patches occurred.

The weather on the 19th was cloudy to partly cloudy, temperature approximately 90 F and relative humidity 60%. Clean-out of areas 6 through 12 was begun at 9:35 A.M. Areas 7, 8, 11 and 12 were all quite clean prior to placing the mortar. Areas 6, 9 and 10 previously had been patched with hot mix and spots of asphaltic concrete remained in the holes after

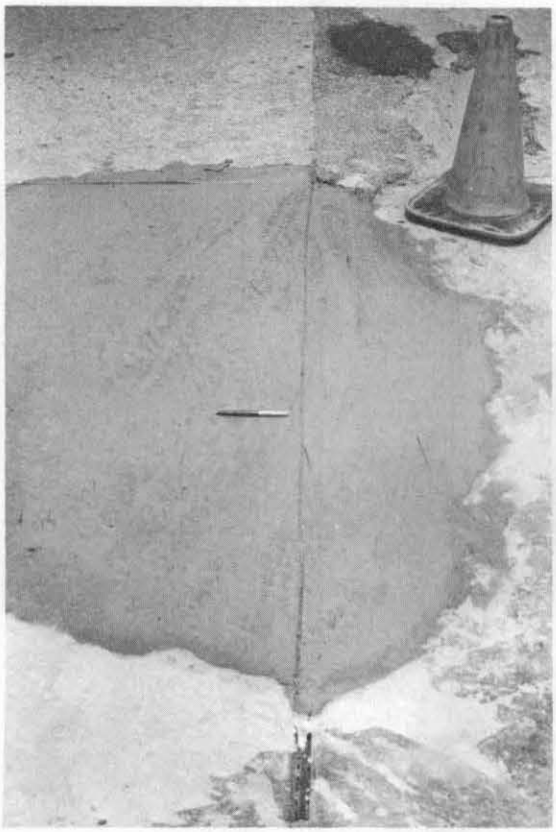
cleaning. All of the holes were dampened with water prior to placing the mortar. The mixing and placing of mortar for Patches 6 through 12 did not go as smoothly as it did for Patches 1 through 5.

Formulation 3, which was intended for use with pea gravel handled fairly well. Because the total amount of material required to patch the areas cleaned out by the maintenance personnel was somewhat greater than anticipated, pea gravel was also added to some of the No. 1 and No. 2 formulations. Formulation 1 in combination with pea gravel was hard to handle. It began to develop its initial set before placement was complete. The patches spanning joints were grooved along the joint line. In the case of Patch 8, the joint was maintained by placing a section of 1/2 inch thick asphalt board in the existing joint prior to placing the mortar. Patches 6 through 10 were covered with wet mats while Patches 11 and 12 were coated with the curing compound. The patches were examined just prior to opening to traffic. The surface of the patches coated with curing compound was fairly hard, but those covered with wet mats still had a rather soft surface. The area was opened to traffic at 1:45 P.M. About 15 minutes later, it began to rain. Examination of the patches from a distance after about one hour of traffic showed that some surface wear was already occurring.

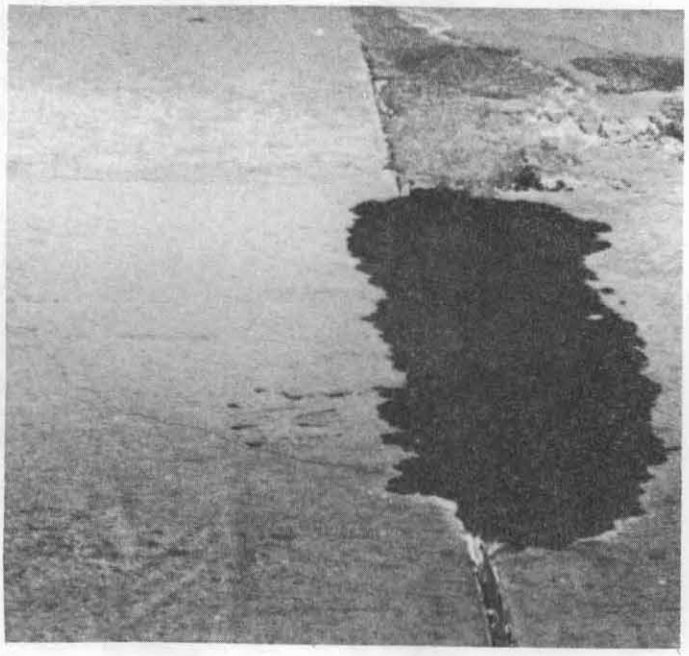
VII. FIELD TRIAL RESULTS

Photographs of each patch taken immediately following placement and at the six month inspection are presented on the following pages along with a performance summary.

Patch 1



Appearance immediately after placement

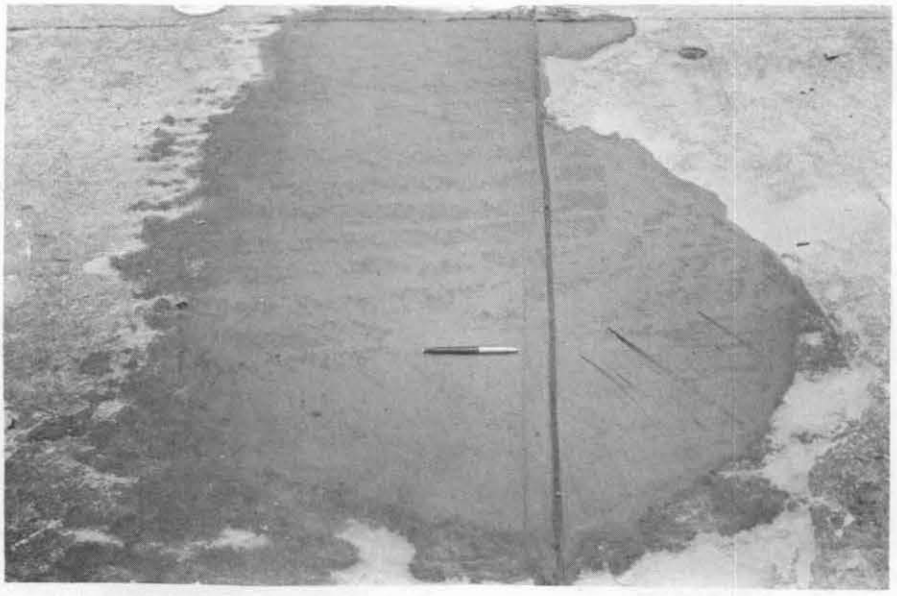


After six months service

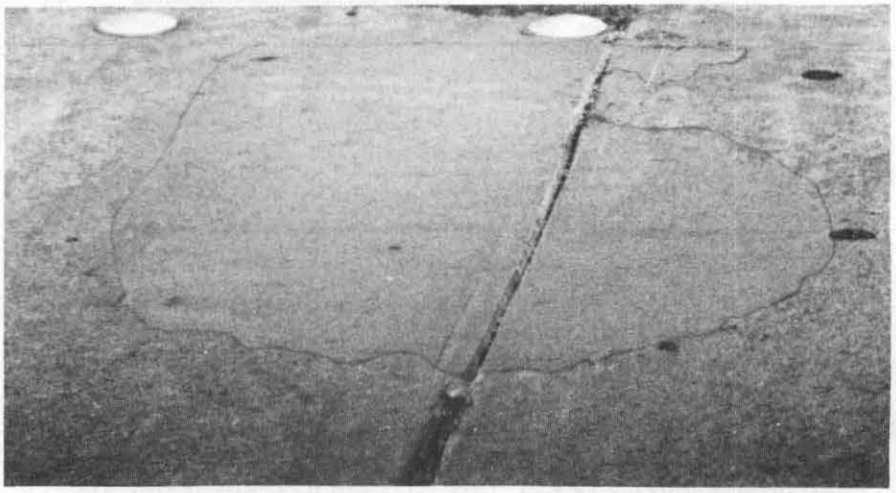
East

Portion of patch on East side of joint (about six inch width) failed prior to the six month inspection and was replaced with hot mix. No further change was noted until the 21 month inspection indicated a crack had developed in that portion on West side of joint. At 27 month inspection, several cracks were noted. This patch will probably fail completely in the near future.

Patch 2



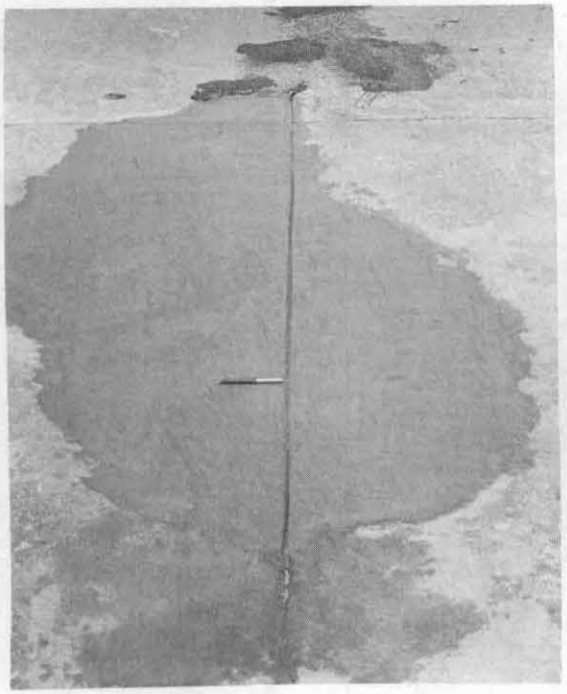
Appearance immediately after placement

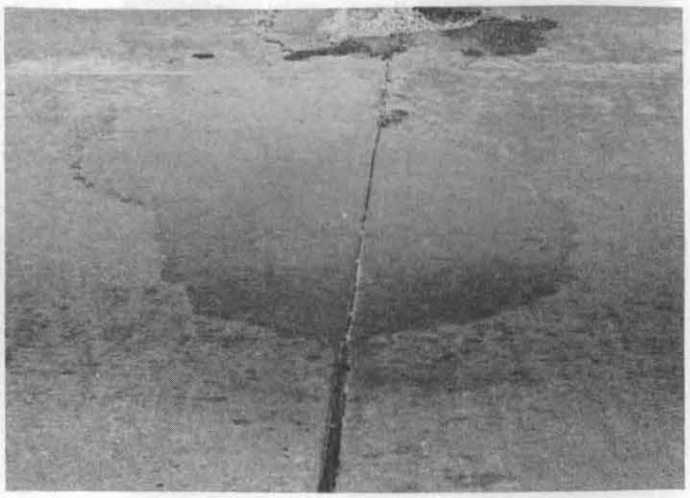


After six months service

This patch is in excellent condition after 27 months service. There is no noticeable deterioration or wear.

Patch 3





Appearance immediately after placement ← West After six months service

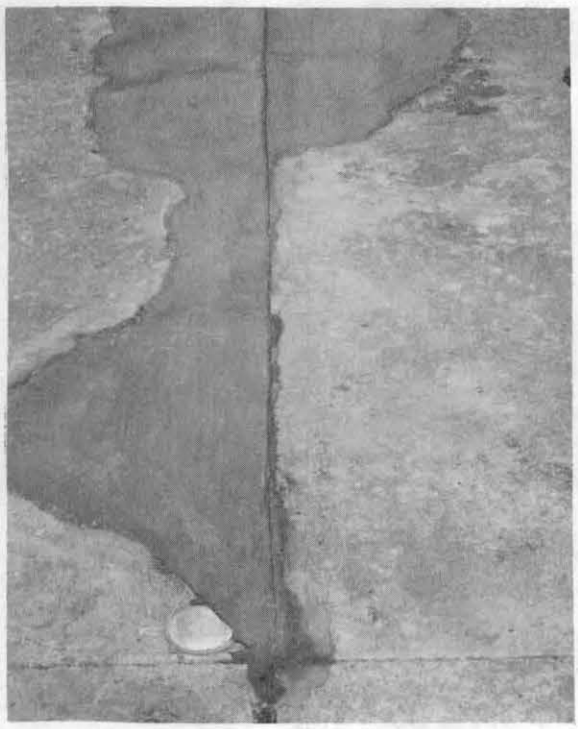
A small spall on the west side was noted on the 21 month inspection. This spall had increased some in size at the 27 month inspection. Otherwise the patch is performing quite well.

Patch 4

Appearance immediately following placement → East After six months service

Minor spalling was noted on East side of joint at 21 months. After 27 months service, this patch is still in good condition.

Patch 5



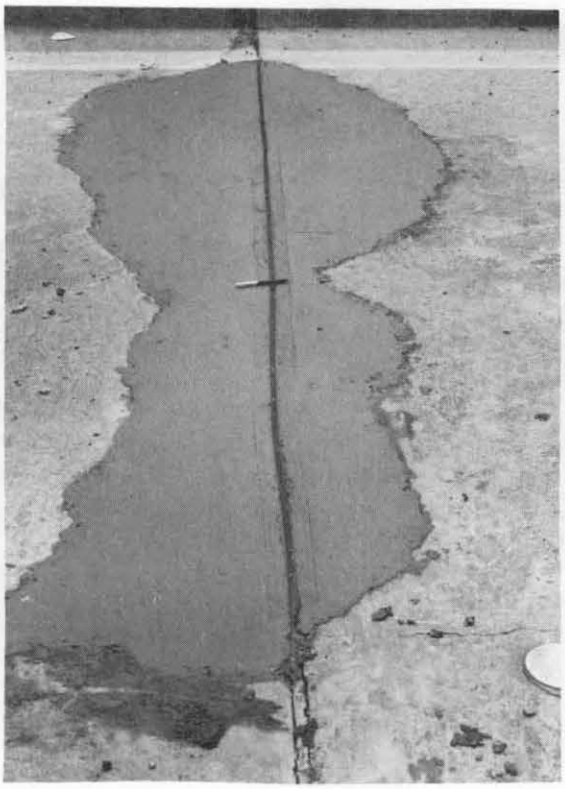
Patch immediately following placement.

North ↓

After six months service.

A small spall at the joint line on the North edge of the patch was noted at 3 months. There was no change noted until the 21 month inspection. A small spall had developed on tip of patch adjacent to the median lane. Slight enlargement of this spall was noted on the 27 month inspection. Overall, the patch is performing quite well after 27 months service.

Patch 6

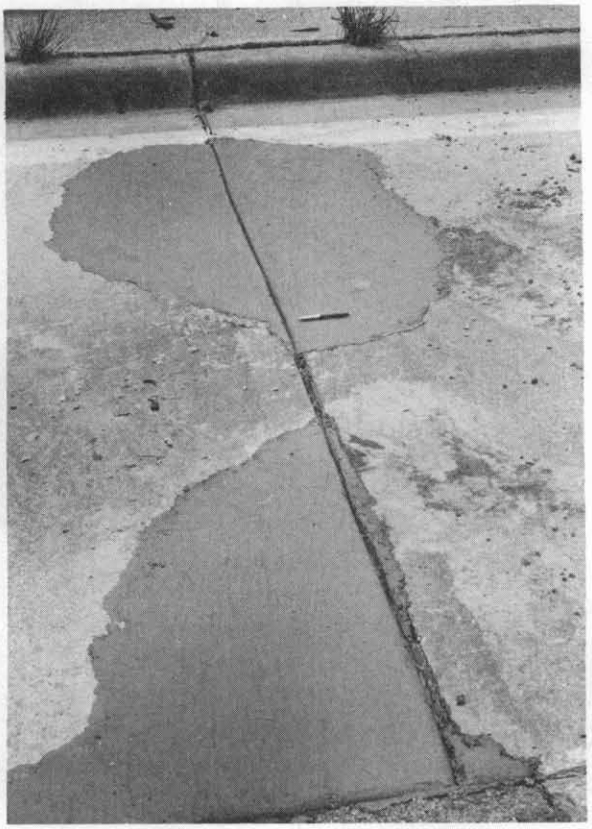


Patch immediately after placement

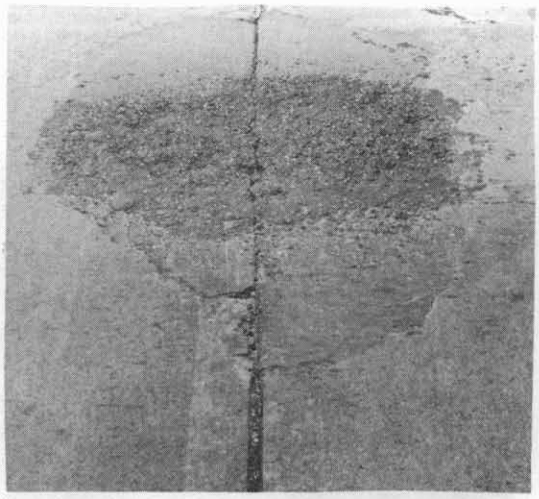
After six months service

Prior to three month inspection, a hot mix skin patch had been placed on an approximately 2 foot wide portion adjacent to the median. Extensive surface wear was evident in the right wheel path. No additional change was noted until the 21 month inspection. Additional hot mix had been placed in the right wheel path. At 27 month inspection additional hot mix had been placed adjacent to right wheel path. Only center portion of original patch is still intact.

Patches 7 and 8



Patches immediately after placement. No. 7 is background and No. 8 in foreground.



No. 7 after six months service. Note worn area in center.

No. 8 after six months service. Surface wear is evident in wheelpath.

Patch 7. Prior to three month inspection, District had attempted to place a hot mix skin patch in left wheel path. Hot mix had raveled out leaving 1/2 to 3/4 inch deep worn area. Remainder of patch was in fair condition. No further change noted until 9 month inspection. Hot mix had been replaced in left wheel path area - appeared over half of original patch had been replaced with hot mix. At 12 month inspection, it was noted that patch had essentially been completely replaced with hot mix.

Patch 8. At three month inspection, patch was intact, but exhibited considerable surface wear. Some additional wear was noticeable at the six month inspection. Prior to the 9 month inspection, the patch failed and was replaced with hot mix.

Patch 9

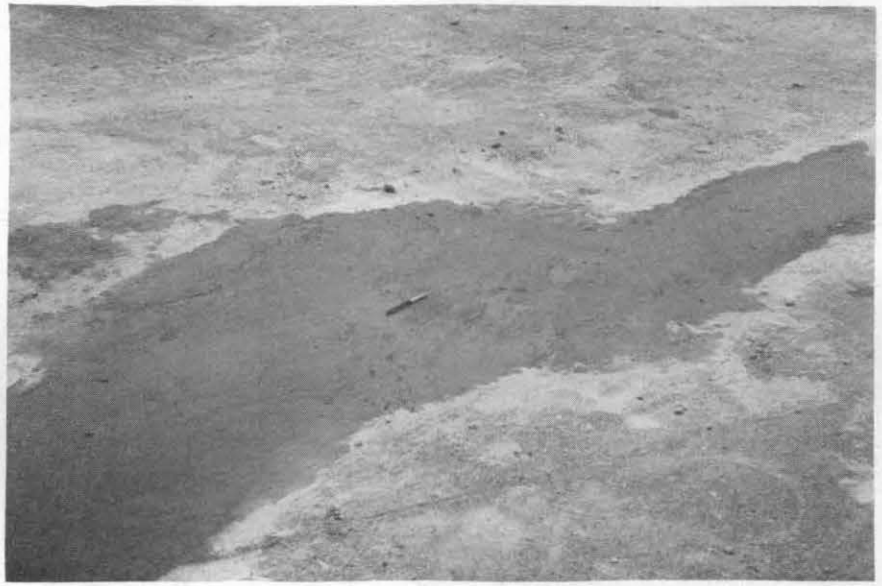
Patch immediately after placement

After six months service

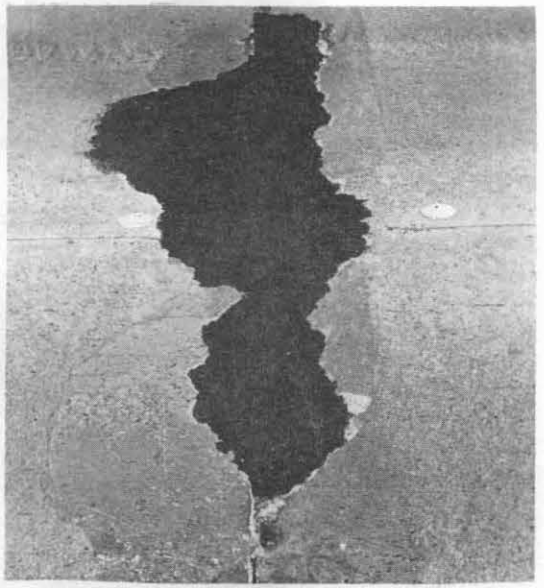
Prior to three month inspection, hot mix patch had been placed in wheel path. At time of six month inspection, additional hot mix was placed that morning. Approximately one-half of the patch had been covered or replaced with hot mix. Prior to the 12 month inspection, the entire patch was replaced with hot mix.

Patch 10

Portion of No. 10 in median lane immediately after placement.



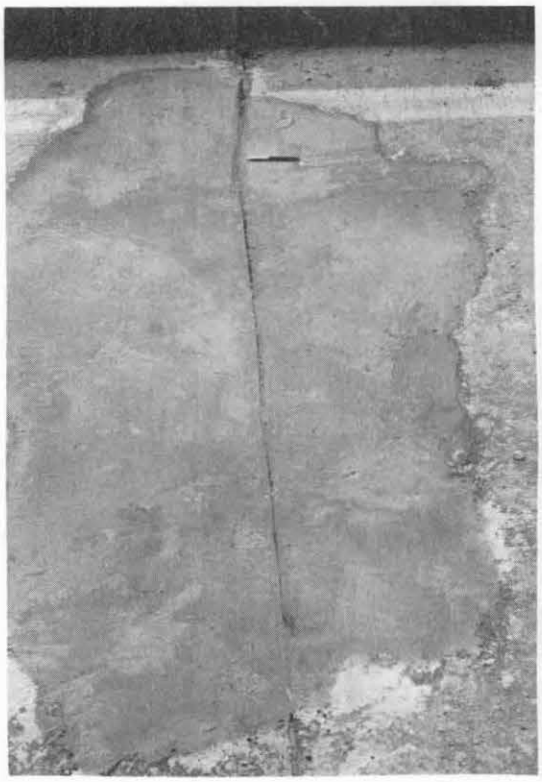
Portion of No. 10 in center lane immediately after placement.



Appearance of No. 10 at 6 month inspection.

At three month inspection, extensive wear was evident in wheel paths. Hot mix skin patch had been placed in left wheel path area of the center traffic lane. Prior to six month inspection, essentially all of the patch had failed. All but a small portion in the median lane had been replaced with hot mix on day of inspection.

Patch 11



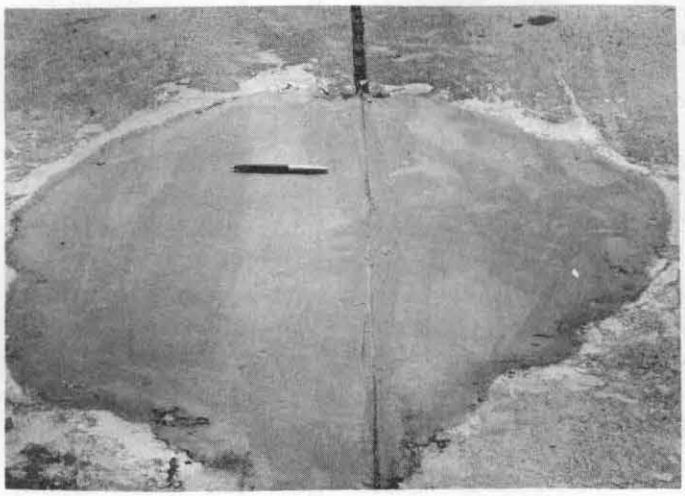
Patch immediately after placement.

After six months service.

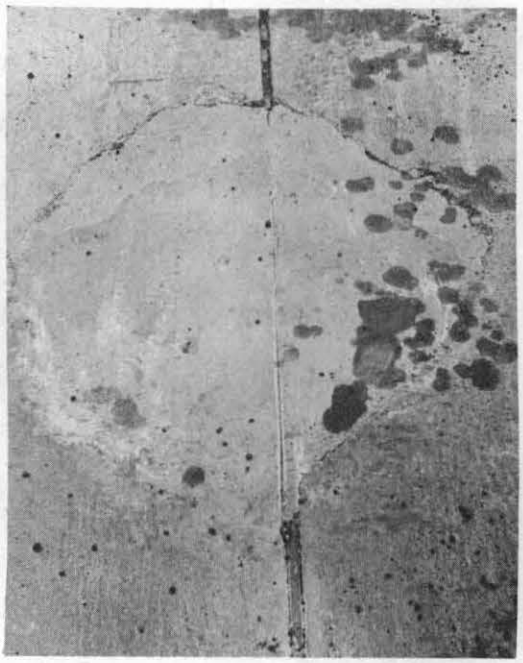
← East

At three month inspection, patch was intact, but evidenced some wear in the wheel paths. Prior to the six month inspection, the patch had cracked along the joint and portion in the right wheel path (about one-fourth of entire patch) had been replaced with hot mix. No further change was noted until 21 month inspection. A crack had developed in portion of patch still intact on East side of joint along with a spall at joint on East side. There was no great change noted on 27 month inspection except some increase in size of crack and spall. Intact portion of patch will probably fail in near future.

Patch 12



Appearance immediately after placement



After six months service

At three month inspection, the patch was in good condition except for some surface wear and slight spalling on median edge of the patch. Prior to the six month inspection, a hairline crack had developed along the joint line. There has been no further change in this patch. It is still performing satisfactorily after 27 months service.

VIII. DISCUSSION

After 27 months of service, all three patches placed using formulation No. 2 (Patches 3, 4 and 5) are performing satisfactorily. Two of the three patches placed using Formulation 1 (Patches 2 and 12) are still giving good service after 27 months. All of the patching done with Formulations 1, 2 and 3 with pea gravel added had failed prior to the 15 month inspection with the exception of about half of Patch 6 and 3/4 of Patch 11 which are still in service. Patch 6 was placed with Formulation No. 3 plus pea gravel and Patch 11 with Formulation 1 plus pea gravel. The condition of Patch 11 indicates that the remaining portion will probably fail in the near future.

Based on the field trial results up to this point, it appears that both Formulations 1 and 2 should give reasonably good performance if properly mixed and placed. Since none of the patches placed with Formulation 2 have failed, it would be the most desirable material.

No significant difference in the two types of curing used is apparent at this point. If wet mats are used, they must be removed sufficiently ahead of opening to traffic to allow the surface to dry and harden or excessive surface wear will occur. From experience with placement of these patches and subsequent use of these materials, no curing is required under certain weather conditions. Since loss of water from the patch is a function of windspeed, humidity and temperature, it is difficult to establish a definite breakpoint between curing and not curing. As a general guide, if the pavement temperature is below 90 F and the relative humidity is 60 percent or greater, no curing is needed.

The use of aggregate other than small amounts of fine sand in quick setting mortars of this type has not proved successful. The surface wear which occurred on the field trial patches placed with mortar containing aggregate could be attributed to the rain which occurred soon after placement. However, this should not have caused the early complete failure of these patches which occurred. Addition of extra aggregate requires an increase in the water-active ingredient ratio which seems to adversely affect performance of the material.

Since Formulation 2 was giving the best overall performance in the field trial, a specification was prepared for this material, which was designated Rapid Setting Patching Mortar RS-1. A copy of the specification is included in the Appendix. It was decided that it would be desirable to make a pilot purchase of the material to determine what problems, if any, might be encountered in producing the material and also to give some of the Districts more experience in working with it. Districts 2, 12, 18 and 20 each agreed to purchase five tons of the material. It was manufactured in April of 1973. The initial set time of some of this material was too fast. Also, the initial strength development was slightly slow. This experience points out the necessity of making sure that the actual batch of portland cement proposed for use in the mortar will give the desired properties, since the results obtained will vary from batch to batch with the same brand and type cement. Characteristics of the material immediately after manufacture and after six months in storage are shown in Table VII.

Table VII

Properties of Rapid Setting Mortar RS-1
Manufactured Commercially on April 3 and 4, 1973

The mix used was 2000 grams dry mix and 370 Ml. mixing water.

	Tests Initiated April 5, 1973		Tests Initiated October 4, 1973
	Batch 4	Batch 9	Batch 22
Flow, percent	88.5	89.5	84.0
Set times, minutes			
Initial	12	16	22
Final	17	22	33
Compressive strength, psi, after cure time indicated			
2 Hours	249	247	427
24 Hours	4148	4158	3833
14 Days	6376	6432	5840

The results from these samples and previous samples of this type of material show that the set time becomes slower with age. In this case, the early strength development improved.

Information on use of some of the RS-1 by Districts 2 and 18 is presented in the Appendix. Two important observations based on their

use of the material are as follows:

1. It is difficult to properly mix the mortar by hand in the time available. Use of a mortar mixer gives better results.

2. There is a tendency to add too much mixing water. This is especially true if the mortar is being mixed by hand. Use of excessive mixing water will slow the strength development and result in a lower quality mortar, expecially with regard to durability.

APPENDIX

Table I-A

Properties of Rapid Setting Mortar Formulation X

Initial Set, Minutes - 15

Final Set, Minutes - 27

Compressive Strength, psi
2 Hours - 308

1 Day - 3800

14 Days - 6819

Percent Expansion in Water

Elapsed Time	A+ 73.4°F	A+ 120°F
7 Days		0.043
14 Days		0.100
28 Days		0.137
8 Weeks	0.129	0.219
11 Weeks		0.240
16 Weeks	0.186	
32 Weeks	0.260	
64 Weeks	0.380	

Percent Shrinkage in Air

5 Days - 0.013

7 Days - 0.041

14 Days - 0.097

21 Days - 0.112

28 Days - 0.123

8 Weeks - 0.150

16 Weeks - 0.152

40 Weeks - 0.193

64 Weeks - 0.201

First Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Don O'Connor and Charles Dumas on November 11, 1971. To prevent blocking the heavy traffic, the patches were examined from the shoulder with binoculars. Condition of the individual patches was as follows:

Patch #1 - In good condition except for minor spalling on leading edge where outer and center traffic lanes meet.

Patch #2 - In excellent condition.

Patch #3 - In excellent condition.

Patch #4 - In excellent condition.

Patch #5 - Small hole about 1" diameter, 3/8 to 1/2" deep near center of patch. 2" x 3/4" spall on left side of joint approximately 8" from outer traffic lane. Otherwise in good condition.

Patch #6 - Two foot width adjacent to median had raveled out so badly that a hot mix skin patch had been placed on this portion. The remainder of patch was in fair condition. There is extensive surface wear evident in right wheel path.

Patch #7 - Portion of patch in left wheel path has apparently had hot mix placed on surface because of bad wear problem - hot mix has worn away, leaving 1/2 to 3/4 inch deep area. Rest of patch is in fair condition.

Patch #8 - Patch still intact but badly worn in wheel path.

Patch #9 - Appears that hot mix had been placed on area of extensive wear, which is primarily in the wheel path. Rest of patch O.K.

Patch #10 - Shows spalling along leading edge in wheel path. Extensive wear in wheel paths. Has had hot mix skin patch in left wheel path area of center lane.

Patch #11 - Intact, but shows wear in wheel path - wear is not nearly as bad as patches 6 through 10. Some spalling on leading edge of patch in wheel path and also at joint in right wheel path.

Patch #12 - Patch intact - some wear on surface and slight spalling on left edge of patch.

Discussion with District 12 Maintenance personnel revealed that most of the wear and shelling out on patches 6 through 10 occurred in the first few days after placement.

Second Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 & 19, 1971, were inspected by Don O'Connor and Charles Dumas on February 10, 1971. Photographs of each patch were made. Condition of the individual patches was as follows:

Patch #1 - That portion of patch (about six inch width) on traffic side of the joint had been replaced with hot mix. Rest of patch in good condition.

Patch #2 - Excellent condition - no change since last inspection.

Patch #3 - Ditto

Patch #4 - Ditto

Patch #5 - Good condition - no change since first inspection.

Patch #6 - No change since first inspection.

Patch #7 - Ditto

Patch #8 - Some additional wear in wheel path since first inspection.

Patch #9 - Additional deterioration - approximately 1/2 of patch had been covered or replaced with hot mix that morning.

Patch #10 - Essentially all of patch had failed. All but small portion in the median lane was replaced with hot mix that morning.

Patch #11 - Cracked along joint - that portion of the patch in the right wheel path has been replaced with hot mix.

Patch #12 - Cracked along joing - otherwise no noticeable change since first inspection.

The maintenance foreman in charge of the patching crew stated that on the large scale failures, such as Patch #10, the patch appears to lose adhesion and then "blow-up" - i.e., it appears as if the material had expanded or at least failed as a result of compressive stresses.

Third Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Don O'Connor on May 18, 1972. Condition of the individual patches was as follows:

Patch #1 - No noticeable change since last inspection. That portion of patch (about six inch width) on traffic side of the joint had been replaced with hot mix prior to our second inspection. Rest of patch has remained in good condition.

Patch #2 - Excellent condition - no change since last inspection.

Patch #3 - Ditto

Patch #4 - Ditto

Patch #5 - Ditto

Patch #6 - No change since last inspection.

Patch #7 - Hot mix patch placed prior to first inspection has been replaced - appears to cover a larger portion of the patch area - over half of the original mortar has been replaced with hot mix.

Patch #8 - All of patch has been replaced with hot mix.

Patch #9 - No change since last inspection.

Patch #10 - All of patch has been replaced with hot mix.

Patch #11 - No change since last inspection.

Patch #12 - No change since last inspection. Patch is performing satisfactorily.

Fourth Inspection of Rapid Setting Cement Mortar Field Trail Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Don O'Connor on August 22, 1972. Condition of the individual patches was as follows:

Patch #1 - No noticeable change since last inspection. Portion on west side of joint still performing well.

Patch #2 - No noticeable change since last inspection - in good condition.

Patch #3 - Ditto

Patch #4 - Ditto

Patch #5 - Ditto

Patch #6 - No noticeable change since last inspection.

Patch #7 - Almost completely replaced with hot mix - doesn't look any different than previously.

Patch #8 - Previously replaced with hot mix.

Patch #9 - Almost all of patch has been replaced with hot mix.

Patch #10 - All of patch has been replaced with hot mix.

Patch #11 - No noticeable change - patch is still performing OK except for about 1/4 of total area which is in right wheel path that has been replaced with hot mix.

Patch #12 - No noticeable change - patch is still in good condition.

Fifth Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Don O'Connor on November 21, 1972. Condition of the individual patches was as follows:

Patch #1 - No noticeable change since last inspection. There is slight surface wear in the wheel path.

Patch #2 - No noticeable change since last inspection - in good condition.

Patch #3 - Ditto

Patch #4 - Ditto

Patch #5 - Ditto

Patch #6 - No noticeable change since last inspection.

Patch #7 - No change - had already failed and been replaced with hot mix.

Patch #8 - Ditto

Patch #9 - Patch had previously failed and been replaced with hot mix.

Patch #10 - Ditto

Patch #11 - No noticeable change - 3/4 of patch is still intact.

Patch #12 - No noticeable change - patch still in good condition.

Sixth Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Charles Dumas on May 2, 1973. Condition of the individual patches was as follows:

Patch #1 - Appears that a crack has developed in portion on West side of joint which previously had been in good condition.

Patch #2 - No change - in good condition.

Patch #3 - In good condition except for small spall on West side of joint.

Patch #4 - Ditto

Patch #5 - In good condition except for small spall which has developed on tip of patch adjacent to median lane.

Patch #6 - Some additional hot mix has been placed in the right wheel path.

Patch #7 - Had previously failed and been replaced with hot mix.

Patch #8 - Ditto

Patch #9 - Ditto

Patch #10 - Ditto

Patch #11 - Large crack has developed in portion of patch still intact on East side of joint. Spall has also appeared at joint on East side. Considerable wear is evident in left wheel path.

Patch #12 - No noticeable change - in good condition.

Seventh Inspection of Rapid Setting Cement Mortar Field Trial Patches

The 12 patches placed on IH 10 West on August 18 and 19, 1971, were inspected by Don O'Connor on November 13, 1973. Condition of the individual patches was as follows:

Patch #1 - Remaining portion of patch on West side of joint now has four large cracks. Patch will probably fail in near future.

Patch #2 - In good condition - no noticeable change.

Patch #3 - In good condition - only change is some enlargement of spall on West side of joint. Now about 1/2 inch deep, 2-3 inches in width and about 8 inches in length.

Patch #4 - No change - in excellent condition.

Patch #5 - Good condition - no change except slight enlargement of spall on West side of joint adjacent to median - about 1/4 inch deep, 5 inches wide and 5 inches long.

Patch #6 - Additional hot mix placed in right wheel path. All of patch has been replaced with hot mix except portion in center (about 1/4 of original patch remains).

Patch #7 - Had previously failed and been replaced with hot mix.

Patch #8 - Ditto

Patch #9 - Ditto

Patch #10 - Ditto

Patch #11 - No major change other than possible increase in size of crack and spall on Eastside of joint. Although approximately 3/4 of patch is still intact, it will probably fail in near future.

Patch #12 - No change - still performing satisfactorily.

Specification for Texas Highway Department Rapid Setting Patching Mortar RS-1

The following specification item governs the basic materials and the composition, manufacture and testing of the finished product for Rapid Setting Patching Mortar RS-1. This material requires only the addition of mixing water to prepare a mortar for repair of portland cement concrete roadway or structures which will attain sufficient strength in 1-1/2 to 2 hours to bear traffic.

Raw Materials

The basic raw materials to be incorporated in this mortar are listed on the following pages along with the specific requirements for each material. Prior to manufacture of the mortar, the formulator shall inform the Highway Department as to the exact brands of raw materials which he proposes to use. The final decision as to equality of materials shall be made by the Highway Department. After the Highway Department has approved the brand names of raw materials proposed by the contractor, no substitution will be allowed during the manufacture without prior approval.

Portland Cement

The cement used shall be a Type II portland cement complying with the requirements of Item 421, Concrete for Structures, T.H.D. 1972 Standard Specifications.

NOTE: Experience has shown that some cements meeting the above specification are unsuitable for use in this formulation. Some cements will produce an extremely rapid setting material which will not comply with the set time requirements on the finished product. To determine suitability of the cement, the formulator should perform preliminary tests on laboratory blends of mortar containing cement from the actual batch proposed for use.

Gypsum Cement

The gypsum cement shall be Hydro-Stone, manufactured by United States Gypsum, or equivalent. Detailed requirements for this material are as follows:

Time of setting, minutes - 15 Minimum
25 Maximum

Compressive Strength, psi minimum - 10,000

These qualities shall be determined by ASTM Designation C 472, Physical Testing of Gypsum Plasters and Concrete.

Sand

The sand used shall be a clean, hard, angular silica sand, free of injurious amounts of salt, alkali, vegetable matter or other objectionable material. It shall comply with the following specific requirements:

Acid Insoluble Residue,
Percent by Weight, Minimum - 95

Moisture Content, Percent by Weight, Maximum - 0.2
Gradation:

U. S. Std. Sieve No.	Percent Retained Cumulative
20	0
30	0 to 3
60	75 to 90
100	95 to 100

Test Methods to be used in determining these qualities are listed below:

1. Acid Insoluble Residue - Acid Insoluble Residue for Fine Aggregate (Test Method Tex-612-J)

2. Moisture Content - Moisture in Mineral Aggregate for use on Built-Up Roofs (ASTM Designation D 1864)

3. Sieve Analysis - Sieve Analysis of Fine and Coarse Aggregate (Test Method Tex-401-A)

Water Reducer

The water reducer shall be Lomar LS, powdered sulfonated naphthalene condensate manufactured by Nopco Chemical Division of the Diamond-Shamrock Corporation.

Air Entraining Agent

The air entraining agent shall be Vinsol NVX, powdered saponified vinsol resin, manufactured by Pine and Paper Chemicals Dept. of Hercules, Incorporated.

Set Retarder

The set retarder shall be Red Top Retarder, manufactured by United States Gypsum Company.

Compounding of Rapid Setting Patching Mortar RS-1

The mortar shall be compounded from the materials previously specified according to the following formula. The method of mixing shall be at the manufacturer's discretion, so long as no contaminants are introduced into the mix and a uniform material free of lumps is obtained.

The ratio of raw materials is as follows:

94 pounds portland cement
25 pounds gypsum cement
60 pounds sand
0.6 pound water reducer
0.005 pound (2.7 grams) air entraining agent
*0 to 0.06 pound (27.0 grams) set retarder

*The amount of set retarder used may be varied within the limits shown to obtain the desired initial and final set times.

Packaging

The formulated mortar mix shall be packaged in multiwall bags constructed of three plies of paper and one ply of polyethylene as a minimum. Each bag shall contain 50 pounds of material. The method of closing the filled bags must provide an effective seal against moisture.

Labeling

The bags shall be labeled as follows:

Texas Highway Department
Rapid Setting Patching Mortar RS-1
Batch Number
Order Number
Date of Manufacture
Name of Manufacturer

For detailed use instructions, see D-9 pamphlet entitled Instructions Regarding Use of Rapid Setting Patching Mortar RS-1.

Physical Requirements for Rapid Setting Patching Mortar RS-1

For all of the following tests, the amount of mixing water used with the dry mix shall be sufficient to obtain a flow of 80 to 95, determined as

specified in ASTM Designation: C 185.

Set Times (ASTM Designation: C 266)

Initial - 15 Minutes Minimum
Final - 40 Minutes Maximum

Compressive Strength (ASTM Designation: C 109 Mod.)

Cure Time	Minimum Strength, psi
2 Hours	300
24 Hours	3000
14 Days	6000

Sampling and Testing

A. Materials to be tested. The rapid setting patching mortar purchased by the Highway Department under this specification shall be tested for conformance to said specification.

B. Agency. All tests on finished products and raw materials, as well as inspection during manufacture will be made by the Texas Highway Department, or by a commercial laboratory designated by the Highway Department.

C. Inspection and Testing Expenses. The cost of inspection and testing of this material will be borne by the Highway Department. The manufacturer will be expected to bear the actual cost of the materials and finished mortar taken as samples at the time of manufacture. The size of samples taken will be no larger than is absolutely necessary for testing purposes.

D. Sequence of Inspection.

1. Immediately after the contract has been awarded, the supplier will contact the Materials and Tests Engineer, Texas Highway Department, Austin, Texas, regarding brand names and characteristics of all raw materials which the contractor proposes to use; and to make arrangements for inspection during production.

2. Manufacture shall be witnessed in whole or in part, depending upon the discretion of the testing agency. Production shall not begin prior to the arrival of the Highway Department Inspector unless prior specific approval for such starting has been obtained. Samples of raw materials actually used in production and samples of the

mortar shall be taken during production. The manufacturer shall afford the inspector free access to those parts of the plant wherein the mortar is being manufactured or raw materials are being stored, and in all other ways shall facilitate the inspection and sampling process. Any questions regarding the inspection or testing shall be addressed to the Materials and Tests Engineer, Texas Highway Department, Austin, Texas.

Use of Rapid Setting Patching Mortar RS-1 by District 2

District 2 maintenance personnel placed all of the RS-1 they received during the latter part of April and the early part of May, 1973. For the first patches placed, aggregate was added to the RS-1. These patches all failed or began to show distress soon after placement. All additional work was done using no added aggregate. According to the maintenance foreman, one gallon of water was used with each 50 pound bag of mix. The mixing was done manually in a wheelbarrow. He stated that the mix had good handling characteristics. Some of the patches placed using only RS-1 and mixing water were inspected by D-9 personnel on July 24, 1973. All of these patches were in the city of Ft. Worth. Location and condition of the patches were as follows:

Location	Comments
Santa Fe R.R. Overpass I-820 Westbound	Four patches had been placed on the outside lane near lane stripe. All of the patches appeared to be in good condition except what appeared to be a small hairline crack in one of the patches.
I-35 W Southbound, just past Jessamine St. Overpass.	This is a large patch (about 6' x 15') located in the outer traffic lane of the concrete pavement. It was in good condition.
Westbound structure of I-20 over Camp Bowie Boulevard	This structure has many patches on the deck and District 2 maintenance personnel were not certain about the material used in some of them. However three patches known to have been placed with the RS-1 were examined. Two of them were in good condition. The traffic edge of the third patch was beginning to crack and the mortar evidenced distress several inches back from the edge.

Use of Rapid Setting Patching Mortar RS-1 by District 18

The initial use of RS-1 by the Dallas District was on July 23, 1973. The material was used to patch delaminated areas on the Zion Road Overpass. This structure crosses IH 30 about 7 miles N.E. of the District Office and carries very little traffic. The delaminated areas go down to the level of the top steel. The delaminated areas were delineated by cutting with a concrete saw. This resulted in all patches being rectangular. The depth of the patches was approximately 2 inches. There was considerable corrosion of the reinforcing steel in some spots. The corrosion was not removed prior to placing the RS-1. Four patches were placed while D-9 personnel were present. Data on the installation is as follows:

Weather Conditions	Patches 1 - 3	Patch 4 & Following
Air Temperature	93°F	95°F
Deck Temperature	105°F	115 to 120°F
Relative Humidity	55 to 60%	45 to 50%

Amount of mixing water used - 1-1/4 gallons per sack in most cases. Some of the batches were too wet.

Mixing was done manually in a wheelbarrow. One batch consisted of one sack of mix + water. Mixing time was approximately 2 minutes. Each batch was placed within 5 minutes of initiation of mixing.

Curing: Patch No. 1 - Wet tow sacks.

Patch No. 2 - Coated with rapid drying curing compound about 30 minutes after placement (curing compound did not harden very fast - either placed too soon or put on too thick).

Patch No. 3 - No special curing.

Patch No. 4 - Wet tow sacks for about 30 minutes, then left open.

The mix handled satisfactorily. The patch areas were soaked with water and the excess water blown out prior to placing any mortar. The material seemed slow in setting and developing strength. Patch No. 1 was still rather soft on the surface at 1:00 P.M., which was about 4 hours after initiation of mixing. Ice was added to the first batch of mortar used in Patch No. 3. The temperature dropped to 82 F. Adding ice directly to the mix did not work well because it caused the workmen to misjudge the amount of mixing water required. The first batch used in Patch No. 3 was too wet. The ice was then added to the barrel of water being used for mixing to cool it. Temperature of the mix without any ice at all was about 85 F which should be satisfactory.

District 18 maintenance personnel indicated that all patches looked good after four months service.