THE EVALUATION OF PAVEMENT PATCHING MATERIALS IN OREGON

Final Report

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16. Abstract

This report describes the installation and evaluation of trial pavement patching materials in Oregon. The patches were placed in portland cement concrete and bituminous concrete pavements and evaluated for periods ranging from four to twelve months.

Of the five products used in patching the portland cement concrete pavement, the epoxy concrete and the acrylic polymer concrete materials were found to have greater durability than the other products tested. Their costs were considered high at between $1350 to $1675 per cubic yard.

The evaluation of patching materials for bituminous concrete pavements was limited to cold-mixed, cold-applied products. Of the four materials examined, Sta-Fil was rated superior. Its cost at $450/ton was a major disadvantage.

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The Evaluation of Pavement Patching

Materials in Oregon

This is the final report on a study entitled "The Evaluation of Pavement Patching Materials", conducted by the Oregon State Highway Division. The study was sponsored by the Federal Highway Administration's Office of Implementation in an attempt to provide better information on effective pavement patching materials for permanent repair. In the study, materials for patching both portland cement concrete and bituminous concrete pavements were examined.

The scope of the study included the selection, installation, and performance appraisal of proprietary and non-proprietary patching materials. The materials were evaluated for properties such as storageability, workability, stability, durability, ease of placement, and material cost. Because the requirements and properties of the bituminous concrete and portland cement concrete patching materials differed, the project was divided in two segments.

Initially, a literature search was conducted to find suitable materials for field trials. The search did not produce an adequate list of candidate materials but instead pointed out just how serious the pavement patching problem had become. Much of the problem was attributed to a lack of durable and dependable patching materials.

After conducting the literature search, a questionnaire was sent to each of Oregon's 16 district maintenance engineers requesting their aid in choosing candidate products. In addition, the state highway departments in Washington, Idaho, California, and Colorado were polled for their suggestions. The response from each state and most of Oregon's engineers was basically the same. They could not suggest any commercial product that was entirely successful, but they did recommend some materials they thought were better than others. After scrutinizing the recommendations, a group of patching materials was chosen for the project.

Portland Cement Concrete Patching Materials

The primary problem in patching portland cement concrete pavement has been the prohibition of prolonged closure of traffic lanes on high volume highways. On low volume highways, where adequate curing periods can be provided, patching with high early cement concrete has been very satisfactory. Many durable patches have been placed using this system. The need to keep traffic lanes open during peak hours has led to the commercial development of a number of quick setting, high early strength patching materials; each claiming to be durable. The performance of many of these materials has been inconsistent and often unsatisfactory.

The five materials that were selected for field evaluation for patching portland cement concrete were:

(1) Set 45,
(2) Embeco 411-A,
(3) Plexicrete,
(4) Niklepoxy Epoxy Cement Product No. 4,
(5) and a non-proprietary polyester styrene polymer concrete.

In addition to these materials, which were purchased with contract funds, two other polymer concrete products were supplied free of charge by DuPont and Adhesive Engineering for field testing. These products were Crylcon and Concresive 2010-2020 respectively. A sufficient amount of material was purchased to repair approximately 20 cubic feet (0.57 m^3) of potholes, and each of the donated materials provided for 6 cubic feet (0.17 m^3) of repairs. Since there were not a significant number of potholes in any one geographic location, all of the portland cement concrete repairs were concentrated on damaged pavement joints. A section was selected on Interstate Highway 5 (I-5) beginning at milepost 241.09 and proceeding south for about four miles (6.44 km).

The preparation of the damaged area was a critical function in the patching operation. Taking advantage of past experience, care was exercised to place the new patching materials against a clean solid substrate. Several days before the actual patching began, the test areas were selected and delineated. At that time a concrete saw with a diamond tipped blade was used to cut around the periphery of the defective area to a depth of 2.5 inches (63 mm).

On the day of the patching, traffic was diverted from the lane to be repaired and the removal of the defective concrete was started. A pneumatic pavement breaker with a 2.5 inch (63 mm) diameter tip was employed to fracture the concrete within the removal area. Because of the extent of the cracking and spalling, all patches were made 9 inches (229 mm) deep; 1 inch (25.4 mm) deeper than the pavement thickness. Additional jackhammering was needed to remove the concrete from around dowels and reinforcing steel and to loosen some rubble. Although five maintenance men worked on the concrete removal, this activity required the major portion of the repair time. When all of the fractured and loose concrete had been removed from the hole, the entire area was cleaned by high pressure air.

A description and evaluation of the PCC patching materials follows:

Set 45 is a one component, magnesium phosphate mortar that is packaged in 50 pound (22.6 kg) sacks. Water is added to produce a workable mortar. The mix may be extended by adding up to 30 pounds (13.6 kg) of 3/8" (9.5 mm) pea gravel per sack. Using the precise amount of mixing water is a critical factor in attaining the desired strength of the material.

The advantages of using Set 45 are:

(1) High early strength, one hour cure.
(2) It is easy to mix, place, and finish.
(3) The material cost was moderate at \$864/cu yd (\$1129/m^3).
(4) Water is used for clean up.
(5) The aggregate and substrate can be wet.

The disadvantages of Set 45 are:

(1) Short work time, about ten minutes, which limits the size of the patch.
(2) There is a small amount of shrinkage during curing which results in cracking around the patch.
(3) A mortar mixer is recommended for mixing the material.
(4) The amount of mixing water is extremely critical.
(5) After one year in service, three patches were satisfactory while two failed due to cracking and spalling.

Embeco 411-A is a one component system containing high early cement, pea stone, metallic aggregate, an air entraining agent, a water reducer, and an oxidizing catalyst. No additional aggregate is added to the mix. Like Set 45, the amount of mixing water is a critical factor in determining strength.

The advantages of Embeco 411-A are:

(1) It is easy to mix, place, and finish.
(2) It has an allowable work time of about 15 minutes at 80 F (27 C).
(3) The material cost was moderate at \$1130/cu yd (\$1477/m^3).
(4) Water is used for clean up.
(5) The aggregate and substrate can be wet.
(6) It can be mixed in a conventional mixer.

The disadvantages of Embeco 411-A are:

(1) A slow curing time of 3.5 hours before traffic can be placed on the patch, even at high temperatures.
(2) There were some small shrinkage cracks around the edges of the patches.
(3) The amount of mixing water is very critical.
(4) After one year, one Embeco 411-A patch is satisfactory while five have failed due to cracking and spalling.

Niklepoxy Epoxy Cement Product No. 4 is a two component epoxy formulation that is blended at the job site by weight or volume and combined with aggregates to produce an epoxy concrete. The proportioning and mixing of the two components is critical. Dry aggregate is required to produce a durable concrete. The recommended gradation required the mixing of three different size aggregates for the tests in Oregon. The amount of resin used was approximately 12.5 percent by weight of the aggregate. Bleeding of the resin binder was prominent in several of the patches, as a result of overworking the concrete during placement. The complexity of batching the appropriate quantities of epoxy with the correct gradation of aggregate and the difficulty of clean up with chemicals such as methyl ethyl ketone or xylene requires special training and instruction for the users of Niklepoxy Epoxy Cement Product No. 4.

The advantages of Niklepoxy Epoxy Cement Product No. 4 are:

(1) Moderately fast cure time of 2.5 hours at 80 F (27 C).
(2) A conventional mixer is used for mixing.
(3) No shrinkage.
(4) Adequate work time of 15 minutes at 80 F (27 C).
(5) The durability of six patches has been excellent after one year of service.

The disadvantages of Niklepoxy Epoxy Cement Product No. 4 are:

(1) High material cost at \$1620/cu yd (\$2117/m^3).
(2) Requires training in the handling, mixing, and finishing.
(3) Requires special equipment such as rubber gloves, goggles, etc.
(4) Requires special solvents for clean up.
(5) Requires dry aggregate.
(6) Requires a dry substrate.
(7) Bleeding results in a slick surface.

Plexicrete is a two component acrylic mortar used to produce a polymer concrete. The system is prepared by blending a low viscosity resin with a special powder composed of fine grained inert and reactive fillers. Only a dry aggregate can be used in producing a durable polymer concrete. The recommended batching procedure is to place the aggregate into a conventional drum mixer with sufficient resin to wet the stones. The remaining liquid and the powder is then added for a two-minutes mix cycle. A special resin tack coat is applied to the dry substrate in order to ensure good bonding.

The Crylcon and Concresive 2010-2020 polymer concretes are similar to Plexicrete in every noticeable respect.

The advantages of Plexicrete, Crylcon, and Concresive 2010-2020 are:

(1) Fast cure time of 1.5 hours.
(2) Easy to mix, place, and finish.
(3) No shrinkage.
(4) Adequate allowable work time of 20 minutes at 80 F (27 C).
(5) The one year performance of the polymer concrete patches has been very good. The two Crylcon and four Concresive 2010-2020 patches have performed very well while two of the four Plexicrete patches were unsatisfactory. The substrate material failed in both instances causing the patches to lose bond.

The disadvantages of Plexicrete, Crylcon, and Concresive 2010-2020 are:

(1) High material cost of $1350 to $1675/cu yd ($1765 to $2190/m³).
(2) Requires dry aggregate.
(3) Requires special equipment like rubber gloves, goggles, etc.
(4) Unpleasant odor.
(5) Requires a dry substrate.
(6) Requires a solvent for clean up.

The non-proprietary polyester styrene polymer concrete used in this project was designed by the Oregon State Highway Division. It was prepared by blending a casting resin, MR11044 (USS Chemical), with dry aggregate. An initiator and promoter are mixed with the resin to cause polymerization. By carefully proportioning the initiator and promoter, the allowable work time and time to cure were controlled for different ambient temperatures. Although a 12 percent resin loading was used, the material was difficult to finish. The overall handling characteristics and performance of the polyester styrene polymer concrete was considered unsatisfactory.

The advantages of the polyester styrene polymer concrete are:

(1) Relatively low material cost at $450/cu yd ($588/m^3).
(2) Moderately fast setting time of two hours.
(3) Ability to alter the allowable work time and cure time.

The disadvantages of the polyester styrene polymer concrete are:

(1) Requires trained personnel to proportion and mix chemicals.
(2) Requires special equipment like rubber gloves, goggles, etc.
(3) The resin has an unpleasant odor.
(4) The material is difficult to finish and requires extra effort for consolidation.
(5) After one year, one patch failed completely and was replaced and the other four have disbonded and are considered unsatisfactory.

Table A rates each of the PCC patching materials for workability, durability and material cost. Since the time required to prepare and repair the damaged areas was a function of the size of the hole and not of the type of materials used, the labor and equipment costs were calculated at $266 per repair. To permit some measure of the relationship between the costs for labor and equipment and the cost of materials, the average repair required four cubic feet (0.11 m^3) of material. Table B presents climatological data for the testing period.

Summary of PCC Patching Materials

On highways where a minimum curing time of 6 to 8 hours can be provided, patching of portland cement concrete pavements with low slump, high early strength concrete has been very satisfactory. In comparison with proprietary concrete patching products, the high early strength concrete has a very low materials cost.

Table A
PCC Patching Material Ratings

Test Material	Workability	Durability	Material Cost
Set 45	4	3	$ 864/cy
Embeco 411-A	4	1	$1130/cy
Niklepoxy Epoxy Cement Product No. 4	3	5	$1620/cy
Polyester Styrene Polymer Concrete	2	1	$ 450/cy
Plexicrete	4	4	$1675/cy
Crylcon	4	5	$1350/cy
Concresive 2010-2020	4	5	$1350/cy
High Early Strength Concrete	4	4	$ 60/cy

Rating Legend
1 - Very Poor
2 - Poor
3 - Average
4 - Good
5 - Very Good

Table B
Climatological Data

Month/Year	Days With Precipitation	Number of Freeze-Thaw Cycles
September 1979	10	0
October 1979	15	0
November 1979	17	8
December 1979	25	4
January 1980	17	21
February 1980	19	10
March 1980	21	4
April 1980	15	4
May 1980	12	0

Of the proprietary products evaluated during this study, the best performance, as measured by durability, was found for Niklepoxy Epoxy Cement Product No. 4, Crylcon, and Concresive 2010-2020. All of the patches made with these three products performed without failure during a one year evaluation period. Of four patches made with Plexicrete, a polymer concrete that appears to be the same material as Crylcon and Concresive 2010-2020, two were satisfactory and two unsatisfactory because of substrate failure. Dry aggregate and a dry substrate are required for the epoxy concrete and the three proprietary polymer concretes. Cost is very high for all four products; ranging from $1350 to $1675/cu yd ($1765 to $2190/m). Proportioning and clean up is easier for the polymer concretes than for the epoxy concrete although solvents are needed for all of them.

Three of the five patches made with Set 45 performed satisfactorily during the one-year observation period. Thus, performance was not as good as that for the epoxy concrete and the Crylcon and Concresive 2010-2020 discussed above. A principal advantage of Set 45 is that the aggregate and substrate concrete can be wet, enabling patching under conditions unsatisfactory for the use of epoxy and polymer products. The material cost for Set 45 is approximately 60 percent of that for the epoxy and proprietary polymer products. Set 45 has a shorter work time than the other products, which limits the amount that can be mixed at a given time. Clean up can be accomplished with water.

The patches made with Embeco 411-A and a polyester styrene polymer concrete did not have satisfactory durability on this project. Only one of six Embeco 411-R patches and none of the five polyester styrene mix patches were judged satisfactory after one year.

<u>Bituminous Concrete Patching Materials</u>

The patching of bituminous concrete pavement in Oregon has been satisfactory when favorable weather conditions exist. The application of a tack coat to a dry, stable substrate followed by the placing and proper compaction of a hot-mix patch has produced excellent results. Unfortunately, potholes and other roadway surface defects occur in bituminous pavements most often during periods of cold, wet weather when conventional hot-mix patching is not available or when its use is not feasible because of water in the holes and surrounding pavement. The inability to place permanent patches under adverse weather conditions remains a serious problem in Oregon.

Although the testing of ten different bituminous patching materials was authorized for this study, only four different products were chosen for field evaluation. These materials were Sylvax, Spec 200, Spec 200 with polyester fibers, and Sta-Fil. The Sylvax and Spec 200 were each purchased from two different asphalt concrete producers to permit comparison. All are cold-mix products.

The selection of installation sites was made using two criteria. First, a high traffic volume of over 10,000 ADT was considered desirable and secondly, a section containing suitable pavement problems such as potholes, excessive cracking and base failures. After some investigation a portion of I-5 northbound between milepost 244 and 258 and a one mile (1.61 km) section of Highway 99E between milepost 46.5 and 47.5 were chosen for the experimental patching.

The highway section crew normally responsible for maintenance patching in the district was assigned the task of placing all of the trial installations. The standard method of cold-mix patching was used during this project. It consisted of loading the patching materials from local stockpiles onto two one-ton trucks at the beginning of each day. The trucks then proceeded to cruise the highways in tandem in search of pavement defects. When a defect was located, the lead truck stopped at the site while the trailing truck detoured traffic into adjacent lanes by means of a flashing arrow board. The method of repair was similar for all patching materials. No attempt was made to dry the hole and no tack material was used for bonding purposes. Some minor preparation was made with a pick and shovel if loose material was present in the hole. After the hole was made ready, the patching material was hand-shoveled from the truck and consolidated in the hole by a vibrating plate compactor. The entire patching operation at each defect was completed in a matter of a few minutes. All of the experimental patching was accomplished in two days. The weather conditions preceding and during the installation were moderately severe. Temperatures were in the low 30's and some rain had fallen recently.

The lack of adequate site preparation may have contributed to the failure of some of the patches, but since all of the materials were treated equally, their performance can be compared objectively.

A description and evaluation of the bituminous patching materials after an in-service period for four months follows:

Sylvax is a patching compound composed of aggregate, a cut back asphalt (medium cure grade MC3000), and a chemical additive supplied by the Sylvax Chemical Corporation. It was purchased from two different asphalt concrete producers. The aggregate gradations were similar but the residual asphalt content was 0.8 percent greater in one mix than the other. Table C presents the aggregate gradation and asphalt content of the various bituminous patching materials.

The performance of Sylvax was not consistent. Seven of the twelve patches made with material from Producer A were satisfactory and four of seven patches made with material from Producer B were considered acceptable. In general, the Sylvax material had good workability after a one month storage period. The material was slightly less durable than the other products tested because of early stability problems. The patches that failed remained slightly unstable for several hours after installation. These patches either popped out or were badly displaced. The average material cost of Sylvax was $47/ton ($51.82/t). A summary of the bituminous patching material ratings is shown in Table D.

Table C
Aggregate Gradation for Bituminous Patching Mixes

Material	Spec 200	Spec 200	Spec 200 w/fibers*	Sylvax	Sylvax
Producer	A	C	D	A	B
Sieve Size			% Passing		
1/2	100.0	98.0	99.0	100.0	100.0
3/8	100.0	62.0	89.0	100.0	100.0
1/4	100.0	22.0	57.0	100.0	100.0
4	79.0	12.0	37.0	29.0	44.0
10	3.0	5.0	7.0	7.0	7.0
40	0.4	5.0	2.0	2.0	3.0
200	0.3	1.5	1.7	1.3	2.3
Residual Asphalt Content %	4.3	4.7	6.3	3.9	4.7

* Polyester fibers were added at a rate of 0.25% by weight of the aggregate.

Table D
Evaluation of Asphalt Concrete Patching Materials

Patching Material	Producer	Total No. of Patches	S[1]	U[2]	Rating of Properties: Storageability	Workability	Stability	Durability	Material Cost/ton
Sylvax (UPM)	A	12	7	5	3	3	3	3	$ 46
	B	7	4	3	3	3	3	3	$ 48
Spec 200	A	2	2	0	3	3	3	4	$ 23
	C	2	2	0	3	3	3	4	$ 23
Sta-Fil	E	6	6	0	5	4	5	5	$450
Spec 200 w/polyester fibers	D	6	4	2	3	2	4	3	$ 25

[1] Satisfactory
[2] Unsatisfactory

Rating Legend

1 - Very Poor
2 - Poor
3 - Average
4 - Good
5 - Very Good

Sta-Fil is a proprietary patching material produced by the Revere Chemical Corporation of Ohio. It is composed of a carefully graded aggregate and coated with a special emulsified asphalt. The manufacturer's literature indicates the product has a built-in primer that is chemically inactive until compaction of the patching material in a hole initiates the necessary reaction. The material is sold in 55 gallon (208.20 l) drums.

The performance of Sta-Fil in Oregon has been excellent. Because the material is very expensive, \$450/ton (\$496/t), it is only used in critical loacations. Patching foremen indicated they only used Sta-Fil where all other patching material has failed and repeated repatching is not tolerable because of traffic conditions. All six patches placed under this study have performed satisfactorily. In the past, Sta-Fil has remained very useable after an 18 month storage period.

Spec 200 is a patching material which derives its name from the special Chevron cationic emulsified asphalt from which it is made. The patching material is composed of a 1/2" (13 mm) minus aggregate with an eight percent emulsified asphalt content. The specifications for the emulsified asphalt are given in Table E. Spec 200 has been used with varying degrees of success in Oregon for two years. The material used in this study was acquired from two asphalt concrete producers. In addition to the conventional Spec 200, polyester fibers were added to a one-ton batch of Spec 200 that was produced by the Oregon State Highway Division. The fibers were added at a rate of 1/4 percent by total weight of the aggregate.

The performance of Spec 200 appeared to be slightly better than that of Sylvax but not as good as Sta-Fil. Although only four Spec 200 patches were placed, the performance of all of them was satisfactory. Spec 200 had adequate workability and was relatively stable and durable after it was consolidated into cracks and potholes. The Spec 200 mixes were used after only a one-month storage period during this study; however, the material has been stored in stockpiles for as long as three months without problems. A report from a district maintenance engineer who had previously tried Spec 200 purchased from the two commercial sources examined in this study, indicated his general satisfaction with the product. Not all Spec 200 patches have been satisfactory but it has out-performed the conventional cold-mix patching materials.

There was a significant difference in the aggregate gradation between the Spec 200 mix purchased from Producer A and Producer C as shown in Table C. The residual asphalt content was 0.4 percent different, also. Although different in gradation and asphalt content, the characteristics of workability, stability, and durability were rated the same for both mixes. The average cost of the commercial Spec 200 was \$23/ton (\$25.30/t). Spec 200 with polyester fibers did not perform quite as well as the material without fibers. Only four of the six patches were considered satisfactory. In spite of a higher asphalt content, the mix was slightly stiffer than the material without fibers and workability was somewhat reduced. Because it was more difficult to place and compact, the durability declined. The cost to produce Spec 200 by state forces was approximately \$20/ton (\$22/t). The

Table E
Specification for Cationic
Stockpile Emulsion (Spec 200)

Test	Test Method	Specification Limits
Sieve, 20 mesh, % retained	ASTM D244	0.1 Max.
Viscosity @ 122 F, SFS	ASTM D88	50-200
Water, % by volume	ASTM D244	30 Max.
Oil Distillate, % by volume	ASTM D244	10 Max.
Residue, % by weight	ASTM D244	63 Min.
Viscosity of Residue @ 210 F, cSt	ASTM D2170	200-500
Viscosity of Residue @ 275 F, cSt	ASTM D2170	50-100
Solubility in Trichloro-ethylene, Residue	ASTM D2042	97.5 Min.

addition of the polyester fibers increased the production cost to $25/ton ($27.50/t).

Summary of Asphalt Pavement Patching Materials

When weather conditions are warm and dry, the patching of bituminous pavements with hot-mix asphalt concrete has been very satisfactory. However, since the prevalent need for patching occurs during wet weather, cold-mix patching products were investigated during this study. Not included in the study, but to be evaluated during the winter of 1980-81, is an insulated hot-box that permits using a hot-mix asphalt concrete for patching potholes during cold and wet weather.

The performance of Sta-Fil was rated superior to the other products evaluated. Of six patches made with this material, all were still satisfactory at the end of the four month evaluation period. The only disadvantage of the product is its cost. At $450 per ton, the material is from 9 to 20 times more expensive than the other asphalt pavement patching materials evaluated during this project.

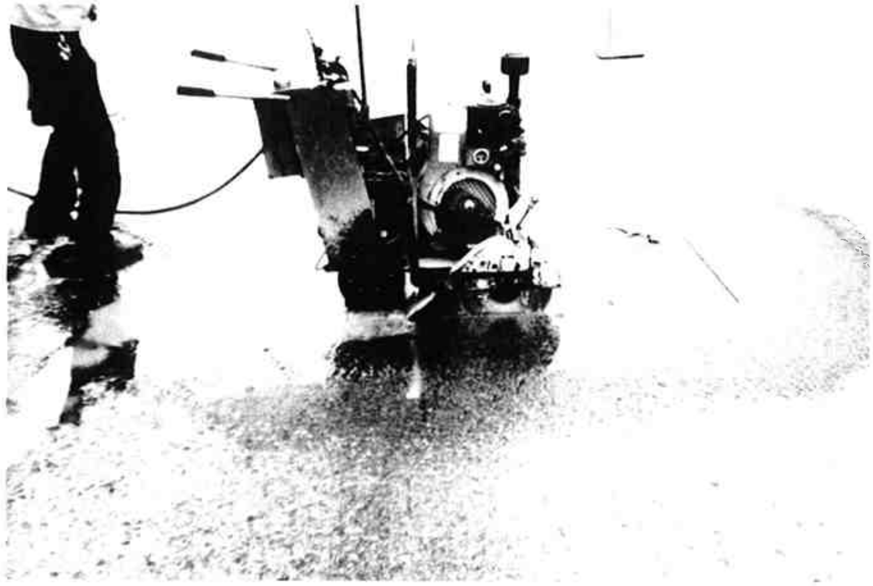
Two mixes utilizing Spec 200 cationic stockpile emulsion were included in the study. However, only two patches from each mix were observed for performance. All of the patches were rated as satisfactory at the end of the four month evaluation period. The material cost was low at $23/ton ($25.30/t).

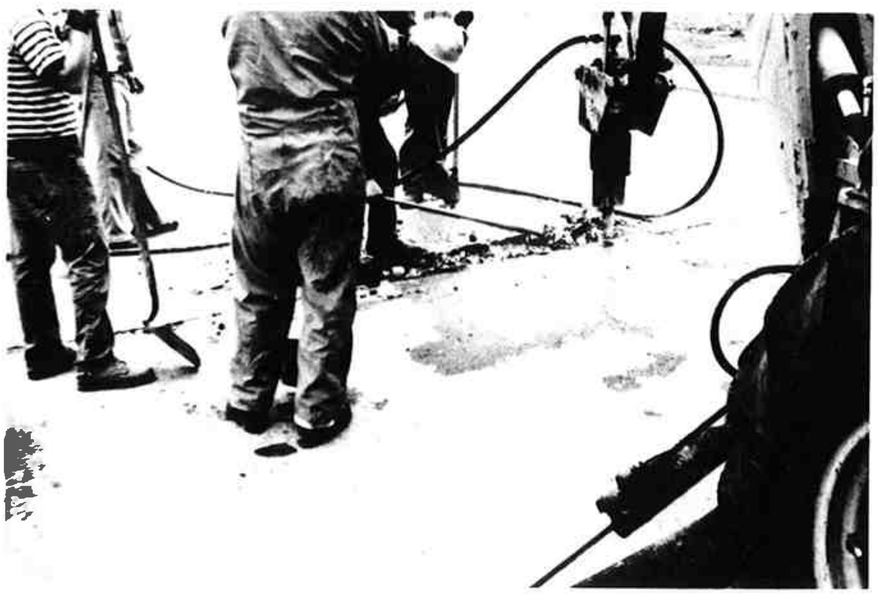
Polyester fibers were added to a third Spec 200 mix produced by state forces. The fibers made the material more difficult to place and compact and only four of the six patches were rated satisfactory.

Two Sylvax mixes, purchased from different producers, were included in the study. This material was about twice as expensive as Spec 200 and it did not perform as well in this evaluation. About 58 percent of the patches were considered satisfactory at the conclusion of the evaluation period.

PORTLAND CEMENT CONCRETE PATCHING

Saw cutting around pavement defect.





Pavement breaker used during removal.

Weighing patching materials.

PORTLAND CEMENT CONCRETE
PATCHING

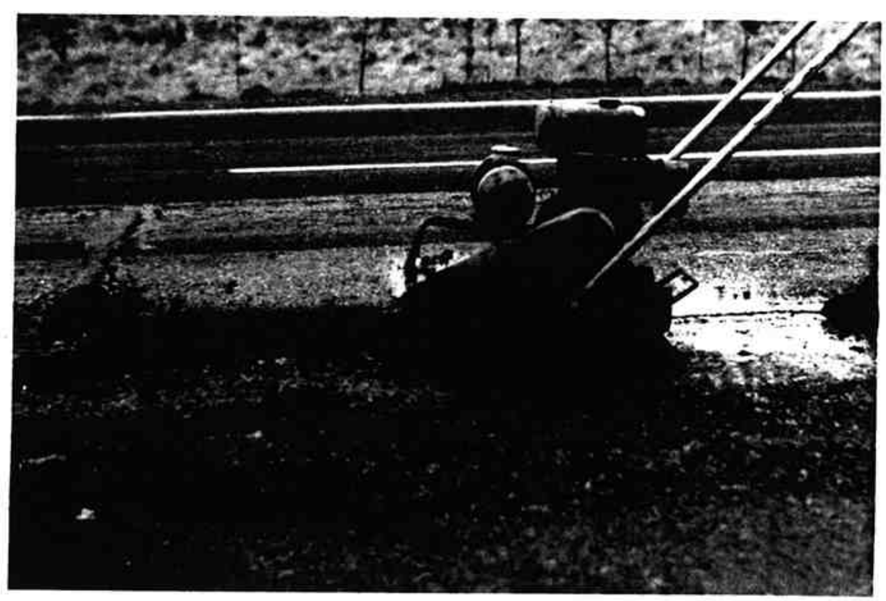
Depositing patching material in hole.

Finishing patch with trowel.

BITUMINOUS CONCRETE PATCHING

Bituminous concrete patching material on truck at site.

Patching material applied to pothole.



Consolidation of patching material.