REPORT NO. CDOH-DTP-R-80-16

PAVEMENT PATCHING DEMONSTRATION AND EVALUATION DOT-FH-11-8188

Herbert N. Swanson
Denis Donnelly
Colorado Department of Highways
4201 East Arkansas Avenue
Denver, Colorado 80222

Final Report
December 1980

Prepared in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Implementation Division
Office of Development

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDH-DPT-R-80-16		

4. Title and Subtitle	5. Report Date
Pavement Patching Demonstration and Evaluation DOT-FH-H-8188	December 1980
	6. Performing Organization Code: 1497 A N
7. Author(s): Herbert N. Swanson, Denis E. Donnelly	8. Performing Organization Report No.: CDH-DPT-R-80-16
9. Performing Organization Name and Address: Colorado Department of Highways, Division of Transportation Planning, 4201 East Arkansas Avenue, Denver, Colorado 80222	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.: DOT-FH-11-8188
12. Sponsoring Agency Name and Address: Colorado Department of Highways, 4201 East Arkansas Avenue, Denver, Colorado 80222	13. Type of Report and Period Covered: Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U. S. Department of Transportation, Federal Highway Administration

16. Abstract

This report describes the selection, laboratory, and field testing of experimental patching materials. The most promising of laboratory tested materials were field tested to patch potholes during the winter of 1979-80. Five concrete materials were tested, two of which are recommended for continued use by state forces. Nine materials were tested for pothole patching of bituminous roadways. Evaluations and recommendations were made which do not encourage the use of most of the experimental materials which were used in this study.

17. Key Words	18. Distribution Statement
Pothole Patching Concrete Asphalt	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	43	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

CONVERSION FACTORS
English to Metric System (SI) of Measurement

Quantity	English unit	Multiply by	To get metric equivalent
Length	inches (in) or (")	2.54×10^{1}	millimetres (mm)
		2.54×10^{-2}	metres (m)
	feet (ft) or (')	3.048×10^{-1}	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in^2)	6.452×10^{-4}	square metres (m^2)
	square feet (ft^2)	9.29×10^{-2}	square metres (m^2)
	acres	4.047×10^{-1}	hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft^3)	2.832×10^{-2}	cubic metres (m^3)
	cubic yards (yd^3)	7.646×10^{-1}	cubic metres (m^3)
Volume/Time (Flow)	cubic feet per second (ft^3/s)	2.832×10^{1}	litres per second (l/s)
	gallons per minute (gal/min)	6.309×10^{-2}	litres per second (l/s)
Mass	pounds (lb)	4.536×10^{-1}	kilograms (kg)
	ounces (oz)	2.835×10^{1}	grams (g)
Velocity	miles per hour (mph)	4.47×10^{-1}	metres per second (m/s)
	feet per second (fps)	3.048×10^{-1}	metres per second (m/s)
Weight/Density	pounds per cubic foot (lb/ft^3)	1.602×10^{1}	kilograms per cubic metre (kg/m^3)
Force	pounds (lbs)	4.448	newtons (N)
	kips (1000 lbs)	4.448×10^{3}	newtons (N)
Pressure	pounds per square inch (psi)	6.895×10^{3}	pascals (Pa)
	pounds per square foot (psf)	4.788×10^{1}	pascals (Pa)
Temperature	degrees fahrenheit (F)	$\frac{^{o}F - 32}{1.8} = {}^{o}C$	degrees celsius (^{o}C)

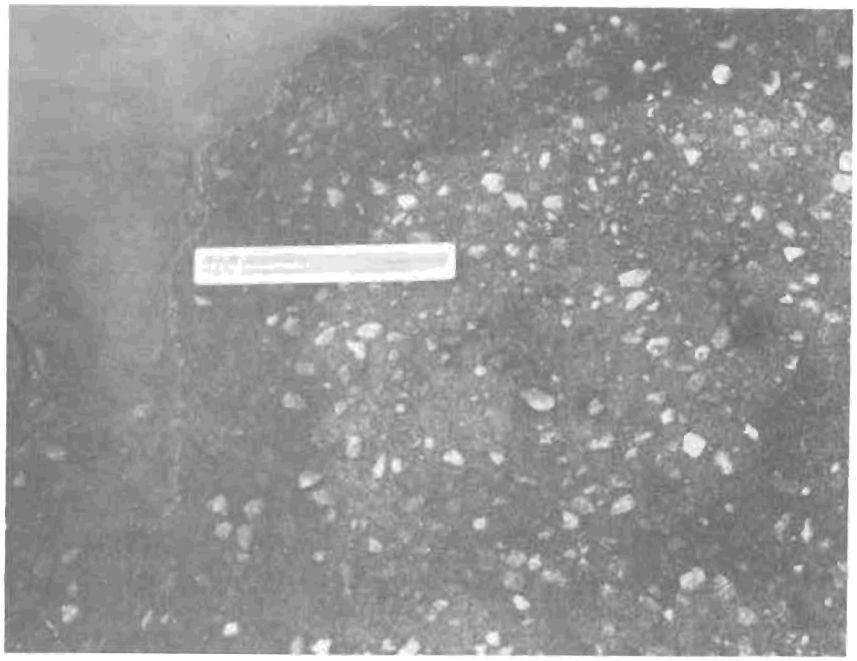
INTRODUCTION

In response to degradation of the nation's highway system due to increased demands for highway transportation and severe weather conditions, the Federal Highway Administration's Implementation Division, Office of Development requested participant State Highway Departments to study alternative materials and methods of pothole patching. Colorado Department of Highways was selected by Region 15 to conduct tests and evaluate patching materials which may improve the pothole problem.

BACKGROUND

Multiple freeze/thaw cycles along with drainage water are the major cause of the localized failure "the pothole." There are usually more than a hundred freeze/thaw cycles produced per year by Colorado's and other northern states' variable climate. The strained economy of the country and the availability of Federal funds has forced agencies to postpone reconstruction and rehabilitation projects; thus, older pavements are more prevalent. These older pavements, being more brittle and cracked, are more susceptible to heavy traffic, infiltration of water, freezing, thawing, and failure.

Potholes require immediate attention to prevent even more rapid deterioration of both surfacing and subsurface materials, and to avoid safety hazards to the traveling public.



Water is the worst enemy of the maintenance man and the pavement.

The water-softened pavement is easily raveled and spalled by traffic making small potholes larger.

Note the spalling around the edges of this pothole.

MATERIALS SURVEY AND SELECTION

Following approval to begin work on this project a search was begun to select candidate pavement patching materials for evaluation. A number of materials had previously been submitted to the Central Materials Laboratory by sales representatives from various companies. Other materials or formulations were suggested by staff employees of the Colorado Division of Highways and a few more were added by a review of an HRIS search on the subject. Some of these materials were eliminated on the basis of previous experience or obvious incompatability for use as a pavement patch. This preliminary survey and selection process resulted in two lists of materials to be tested in the Central Materials Laboratory. The following materials were tested for possible use as patching materials for concrete and asphaltic pavements, respectively:

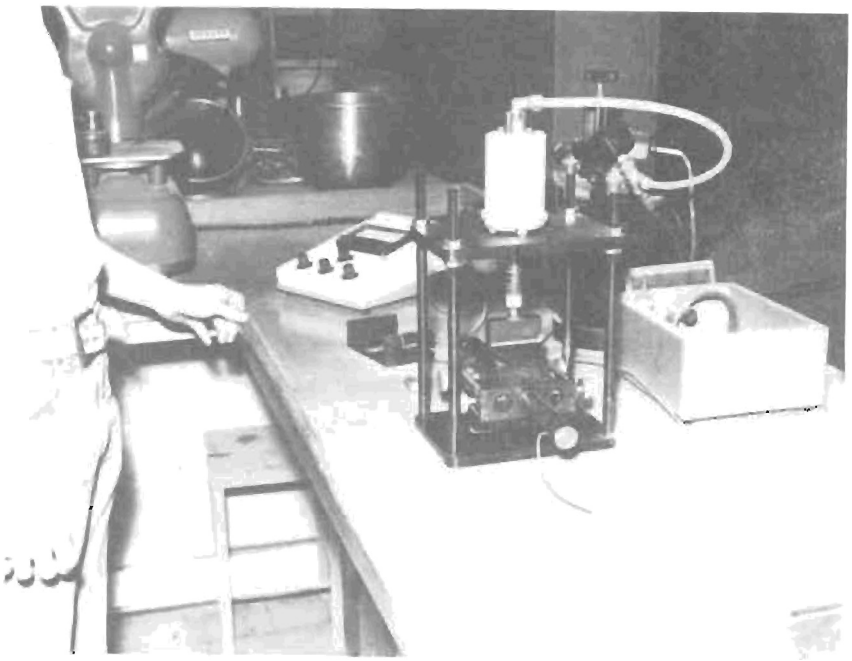
Concrete Patching Material Tested in the Laboratory	Asphalt Patching Materials Tested in the Laboratory
*1. Duracal	1. Sylvax W/Hercules Fibers
*2. Speed Crete W/Sticky Stuff	*2. Foamed Asphalt (6% AC)
*3. Set - 45	*3. Sta-Fil
4. Tapecrete	*4. Sylvax
5. Proflow - 30	*5. Cold Mix W/Hercules Fibers
6. Bonderment	*6. Cold Mix (MC-800)
*7. Supreme Grout	7. Emulsion (CSS—1h)
*8. Pro Set	*8. Rubberized Emulsion (Pavon)
9. Swindress 210	*9. MC-800 with Anti-Stripping
	10. AC-5 with Anti-Strip (Foamed)
	*11. Sulfur Additives (Sulphex)
	*12. Hot Mix (CDOH Standard)
	*13. Cold Mix (MC-70)

*Selected for Field Testing

These materials, the manufacture address, and their physical composition are listed in Appendix A.

LABORATORY TESTING

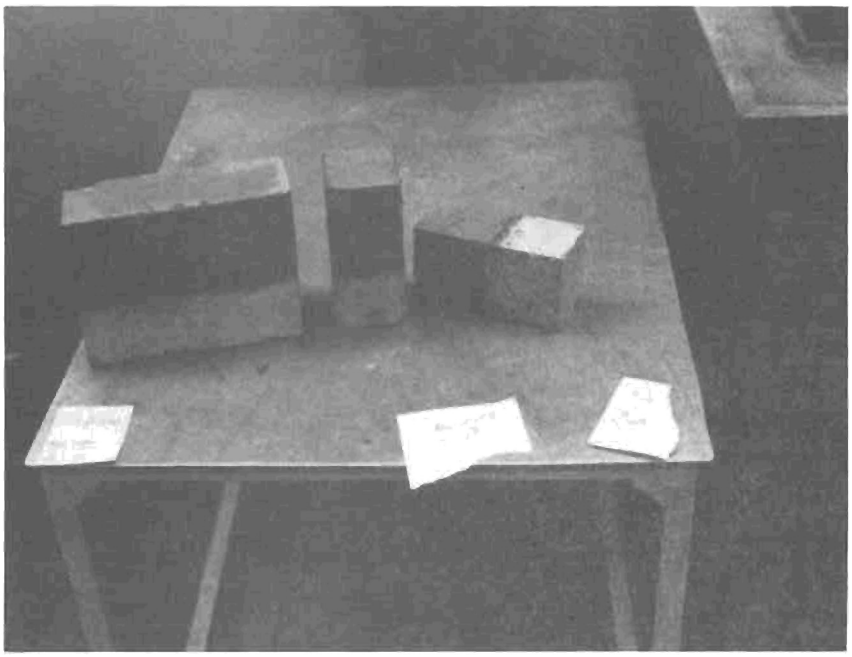
Patching materials were ordered and received from respective industry outlets and laboratory testing began. The tests used for the asphalt patching materials included aggregate gradation, resilient modulus, stability, immersion/compression, and cohesiometer. The tests performed on the concrete patching materials included shear strength (4-5 hours and 3 days), percent bond failure, compressive strength (4 hours, 3 days and 7 days), and pot life in minutes. Tables A and B show the results of the laboratory tests. All tests were performed according to Colorado's Central Laboratory Test Procedural Manual. From these results, ten asphaltic materials and five concrete patching materials were selected for field testing.



A sample of an experimantal bitumin and aggregate is undergoing tests to determine its Resilient Modulus.

CONCRETE PATCH DEMONSTRATION STUDY

CONCRETE PATCH SHEAR/BOND TEST



Test slab with patch material (top) molded to Concrete slab. Slab cut into three specimens for Shear/Bond test.

TABLE A

COLORADO

ASPHALT PATCH DEMONSTRATION PROJECT

LABORATORY RESULTS

PRODUCT	% BITUMIN	IMMERSION-COMPRESSION PSI WET	DRY	INDEX	STABILITY	COHESION	R MODULUS (X1000)
Foamed Asphalt	6.0	87	210	41	45	295	
Sta-Fil	5.5	107	160	67	43	130	41
Sylvax	5.4	33	64	51	29	27	21
CDH Cold Mix W/Fibers	4.5	129	228	56	44	124	197
CDH Cold Mix (MC-800)	5.5	134	176	76	42	202	208
CSS-1h	4.0	119	399	30	47	608	191
CDH Cold Mix W/Anti-Stripping	5.5	303	236	129	38	195	167
Sulphlex	6.0	-	-	-	48	312	814
CDH Hot Mix (AC-10)	6.0	346	399	87	45	295	473
CDH Cold Mix (MC-70)	6.0	49	84	58	46	91	58
Rubberized Emulsion (Pavon)	6.0	-	-	-	38	416	108

Aggregates Used in All Asphalt Mixes
with the exception of Pavon, Sta-Fill, and Sylvax

AGGREGATE SIZE	GRADATION USED PERCENT PASSING
1/2	100%
#4	65
#50	21
#200	10

TABLE B

COLORADO

CONCRETE PATCH DEMONSTRATION PROJECT

LABORATORY RESULTS

PRODUCT	SHEAR STRENGTH PSI		% BOND	COMPRESSIVE STRENGTH PSI			POT LIFE Min.
	4-5 hrs	3 days	FAILURE	4 hrs	3 days	7 days	
Duracal & Sand 50:50	-	345	100	1800	5000	-	25
Speed Crete w/ss	350	300	100	170	2250	-	15
Set 45	430	-	90	7880	8800	11080	10
Set 45 & Pea Gravel 63:37	537	-	90	6370	7285	6905	10
Tapecrete	-	-	100	-	2650	-	10
Proflow - 30	145	-	-	49	3630	4655	-
Bonderment	87	-	100	120	1550 (24 hr)	3990 (28 day)	4
Supreme Grout	384	-	-	255	1625	6470	10
ProSet	189	-	-	3650	4710	5320	3
Swindress 110							

SITE SELECTION

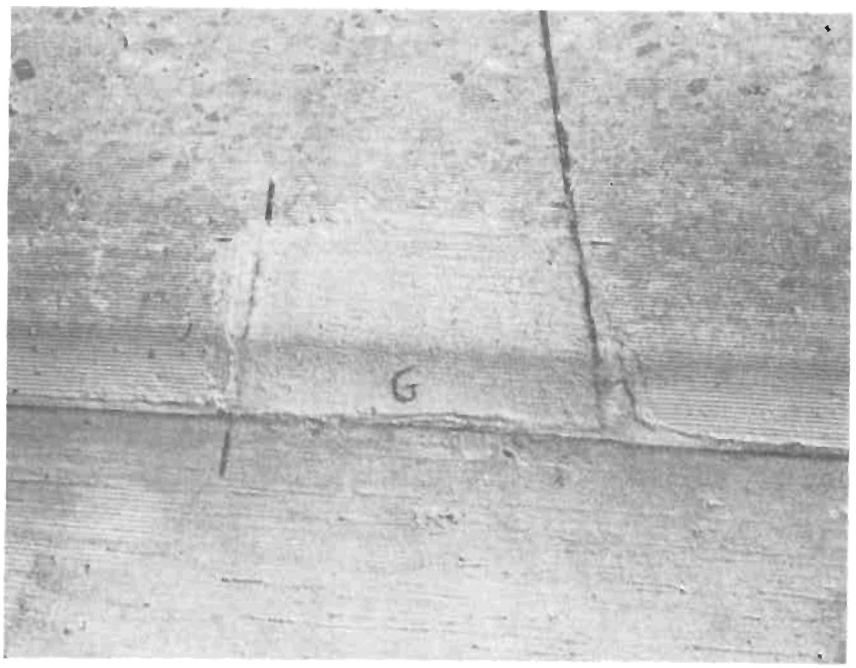
Inquiries were made of maintenance and engineering personnel to suggest sites for field testing a number of pothole patching materials. There was no difficulty in finding enough potholes in asphalt concrete pavements; therefore, it was easy to select locations in the Denver Metro area where the Average Daily Traffic (ADT) was 10,000 or greater.

South Sheridan Boulevard (SH 95) has an average of 35,000 Vehicles Per Day (VPD) on four lanes and 9,625 VPD in the driving lane. Kipling Street (SH 319) has an average VPD of 27,200 on four lanes and 7,485 VPD in the driving lane. The bituminous patches were placed in the driving lanes of these two streets for this evaluation. Some of the surplus bituminous materials were placed in large transverse shoulder cracks on SH 76 near Brush, Colorado. These shoulders are not exposed to continuous traffic but are a continuing problem where thermal expansion results in the one-inch to six-inch wide by 10-feet cracks.

Site selection for concrete patching experimentation was more difficult. The high traffic prerequisite limited the area to the urban areas, and Colorado does not have a high percentage of Portland Cement concrete highways which have not been overlaid with hot bituminous pavement. The remaining concrete surfacing is in relatively good condition regarding small potholes which need repair. Some such potholes were located but they were scattered, and it was felt that a good comparison could not be made using widely scattered tests with different materials.

A section of Interstate 70 was under construction which included adding lanes and grinding and repairing the old concrete surface. Cracked and spalled chips at the junctions of transverse and longitudinal joints existed which were generally less than one square foot in area. The contractor was given the responsibility of cutting, cleaning, and patching these small cracked areas with Duracal. Arrangements were made for the contractor to prepare but leave open 25 of these areas so that the Research Section could field-test the selected five concrete patching materials.

This section of I 70 has a high traffic volume (25,800 ADT for three westbound lanes), but the patches had to be placed near the left edge of the left driving lane. Only a small percentage of the traffic actually rides over these patches. A traffic counter was installed to count the actual vehicles which traveled over the patches. The results were less than 100 VPD. Even though this is a low traffic volume the speed is 55 MPH and all other factors are equal for a good comparison. The evaluations described alter in this report show that the patches received considerable wear and some failures resulted.



A typical concrete patch which repaired a spalled area at the junction of expansion joints.

SITE PREPARATION AND PATCH INSTALLATION

Concrete Products

On November 5, 1979, members of the Research Section and the Central Laboratory arrived at the project to place the concrete experimental products. The pavement and air temperaure was 49°F by mid-morning when mixing the placement of the patching materials were started.

The materials were all mixed by hand in small tubs on the site. They were mixed with water or the liquid provided by the manufacturer and according to the directions provided. Five patches of each of the five selected materials were completed by mid-afternoon. Code letters were painted on the median jersey barrier adjacent to each patch for future identification.

Table C lists the code letters, materials placed (in the order placed), mixing, and cleaning ease and a field evaluation of a setting time which was felt that the material could have been opened to traffic.

TABLE C

COLORADO

CONCRETE PAVEMENT PATCHING RESEARCH

I 70 WADSWORTH TO KIPLING - WESTBOUND

CODE LETTERS	MATERIAL	NUMBER OF PATCHES	MIXING EASE	CLEANING EASE	SET TIME FOR OPENING TRAFFIC
G	Supreme Grout	5	Good	Good	4 Hours
45	Set 45	5	Fair	Good	1.5 Hours
P	ProSet*	5	Difficult	Fair	1 Hour
S/SS	Speedcrete W/SS	3	Very Difficult	Difficult	1.5 Hours
S	Speedcrete	2	Difficult	Difficult	1.5 Hours
D	Duracal & Sand	5	Good	Good	1 Hour

*Requires Component Mixing On Job

Asphalt Products

The site preparations and installations for bituminous materials were done by a maintenance section in the Denver area. Bituminous patching materials were installed over a four-month period from January through May of 1980.

The following discussion of the present methods used by Colorado Department of Highways is presented to allow the reader to understand the standard procedures which have been practiced for several years. The common practice of Colorado's maintenance is to patch potholes with an MC-70 cold mix as soon as possible after a storm and potholes appear. This is usually in adverse conditions of weather with snow, slush, or water present. A minimum of preparation is done such as clean snow, surface water, and other foreign material from the hole. Cold mix is put in the hole and rolled with the truck wheels. These cold patches are intended to be temporary and are replaced within a few days with hot bituminous pavement which is more permanent. This usually works well in Colorado's climate in which warm, dry weather usually exists between snowstorms.

The cold patches, or what remains of them, are removed during the better weather. The holes are squared with a jackhammer, cleaned, the edges primed with MC-70, and the holes filled with hot mix. These patches are then rolled hot and then rerolled 15 to 30 minutes later resulting in a permanent repair.

Preparation of potholes for the experimental materials and installation of these materials was done in the same manner as the preparation for hot mix patches with a few exceptions, as follows:

(1) CDH Cold Mix (MC-70) as listed in Table A is Colorado's standard cold mix and the hole preparation was as stated above.

(2) Some of the holes patched with Pavon were primed with MC-70 and others with Pavon liquid. Two holes were patched with Pavon liquid and aggregate, only. Others were diluted with one-third water. The manufacturer recommended either method. A sand blotter was used over the patch until curing was complete.

(3) A coating of MC-70 was painted over the surface of the foamed asphalt patch as this mix looks and works very dry. A sand blotter was placed over the MC-70.

(4) Sylvax was not field-tested since it was not available in Denver. In previous years the city and county mixed and stockpiled large quantities of Sylvax mix for patching, but they discontinued the use of it since regular hot mix is available and can be adjusted for any given condition. Also the Sylvax liquid is nearly twice as costly as asphalt.

(5) Sulphlex was used in the same manner as hot mix. Since this had to be mixed in a small quantity (250 pounds), the field mixing was difficult, time consuming, and inconvenient.

Small amounts of the leftover experimental materials were placed in wide cracks in bituminous shoulders on I 76 near Brush, Colorado. These included Foamed Asphalt, Sta-Fil, MC-800 Cold Mix with fibers, MC-800 Cold Mix with anti-stripping agent, MC-800 Cold Mix and Pavon. Concrete patching materials were also placed in the driving lanes near Brush. Set 45, Duracal, Speedcrete, and ProSet were used.

Standard Cold Mix
(MC-70) Patch
(4 Days Old)

These patches were placed under adverse conditions and intended to be temporary.

The thin patch over the concrete pan line has spalled off but the thick part of the patch is still in service. It will be replaced with hot mix when time permits.

Preparation for a hot mix patch includes removal of old cold mix, squaring the hole, and priming the edges.

EVALUATION

The bituminous patches were inspected daily for the first few days and then weekly until failure. A patch was considered to have failed when it was raveled, shoved or otherwise depressed more than three-fourths of an inch below the pavement. At this point the maintenance crew would replace the patch.

Figures 1a and 1b are graphical representations of the longevity of the bituminous patches in the field. From the experience gained and observation of these graphs, it is apparent that hot bituminous pavement mix is the only permanent patch of the group tested.

One factor which caused early failure of some of the experimental bituminous patches was probably insufficient compaction. Compaction by the use of truck tires provides only the force equal to the tire pressure (65 to 100 psi). Small vibratory rollers are used when and if available. Hot Mix patches are more permanent, however, even when compacted by the truck tires.

ASPHALT PATCH LONGEVITY

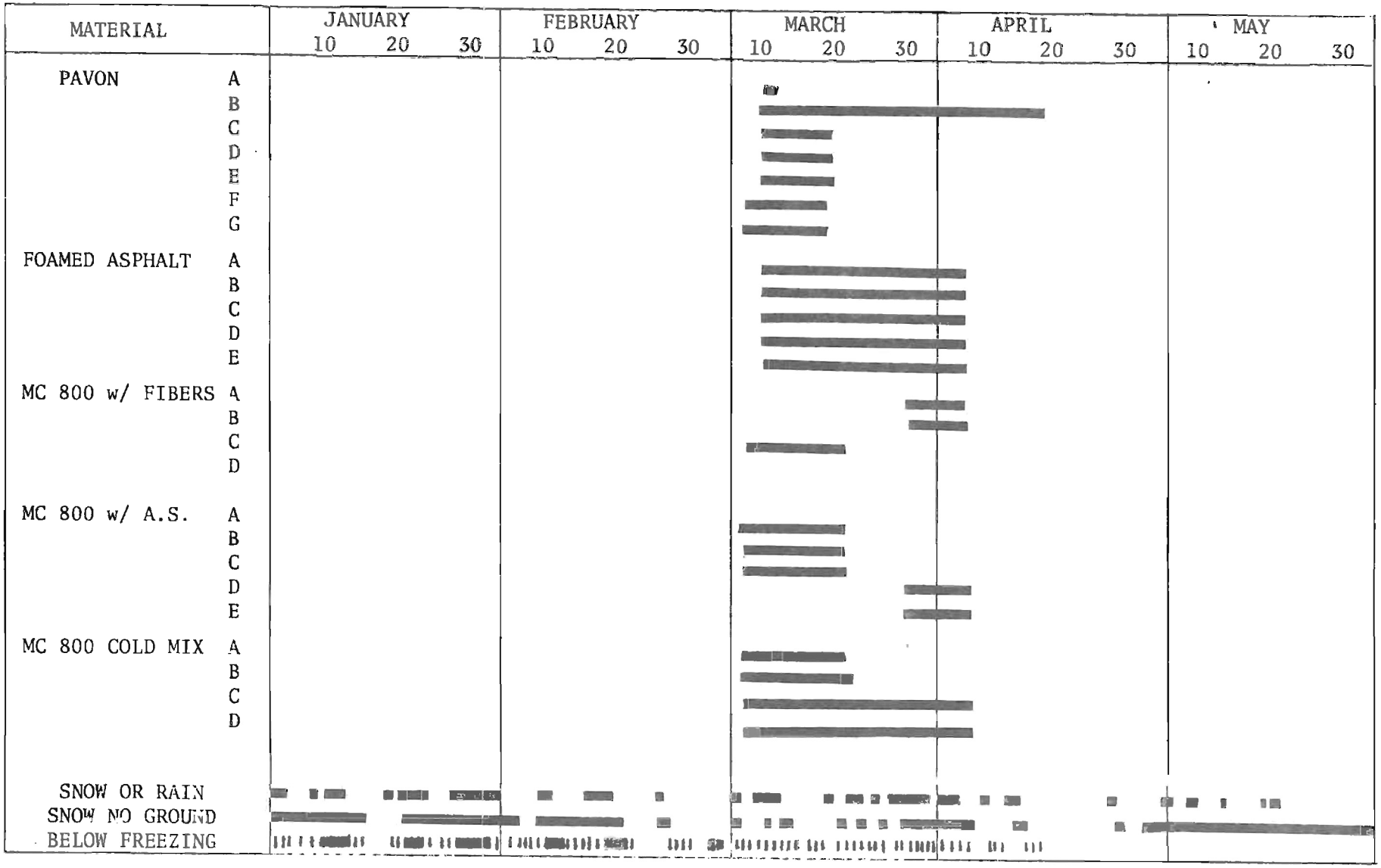
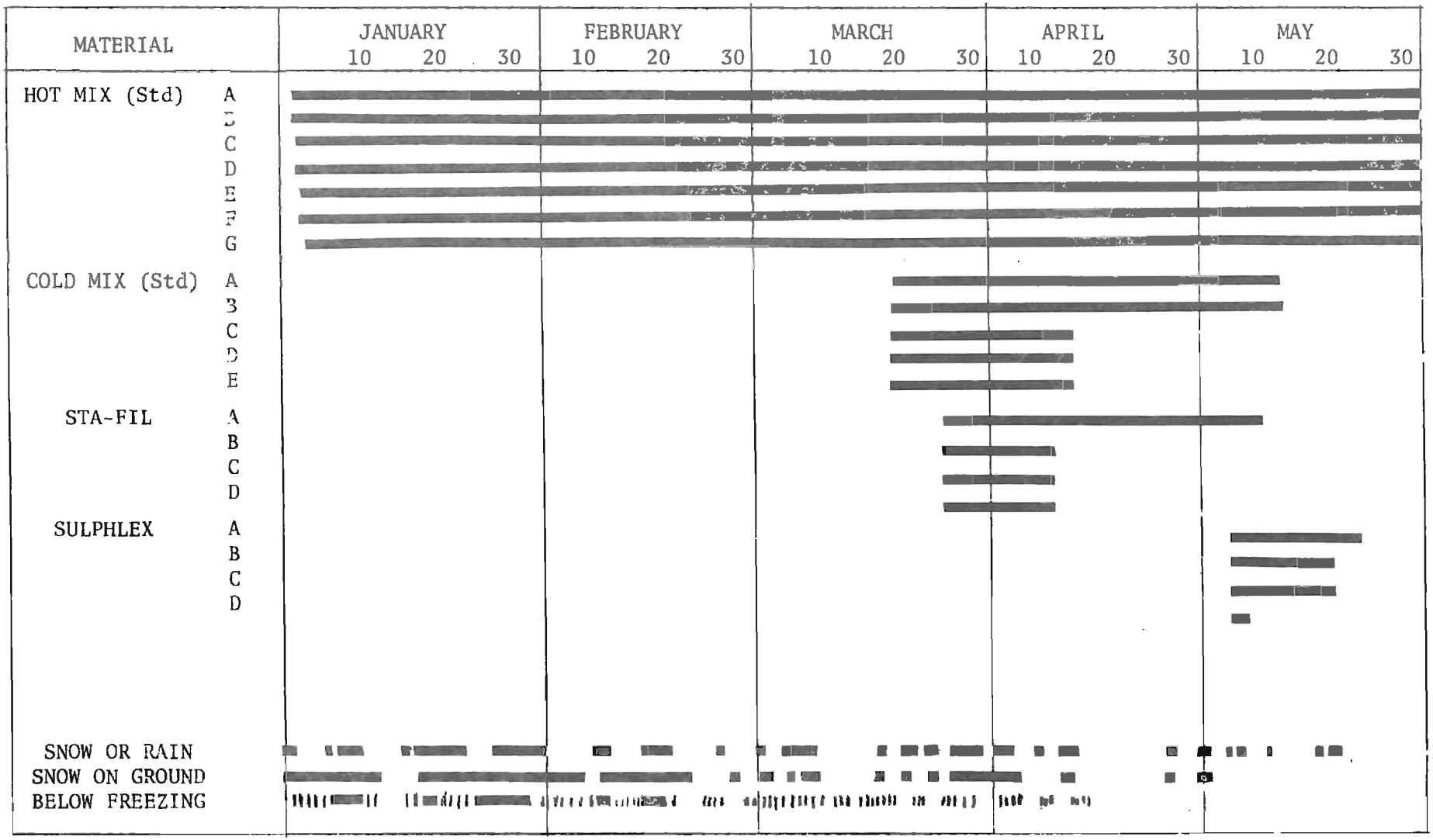


Figure 1a

ASPHALT PATCH LONGEVITY



Note: The HOT MIX patches above are still in place (11/18/80) and are considered to be permanent.

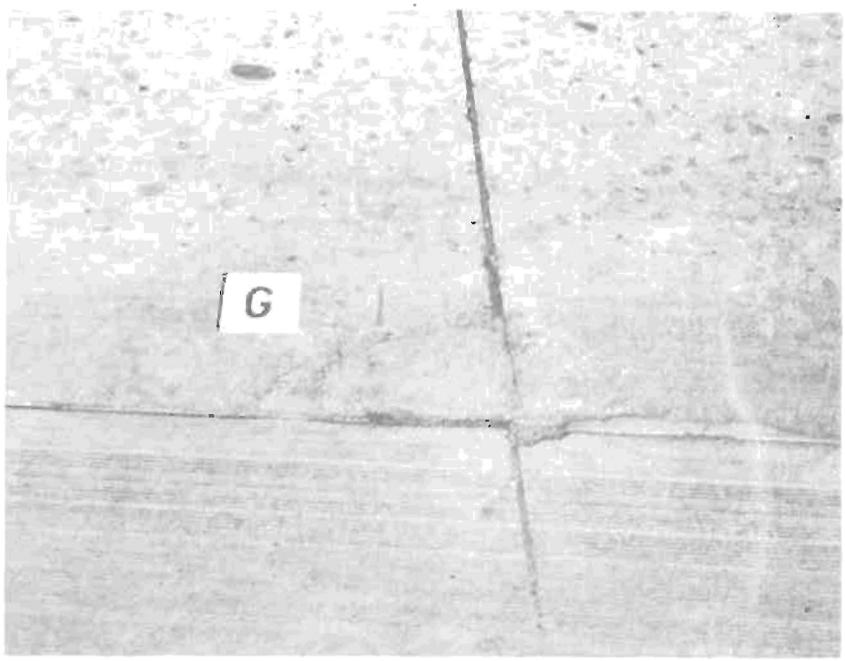
Figure 1b

A Pavon patch raveled out to about an inch below the driving surface. This patch was removed and replaced with a permanent hot mix patch.

An MC-70 with Hercules fibers has failed because of raveling and shoving.

This material came completely lose during the following storm.

A Speed Crete patch (center) is still in place and at the same level as the driving surface, but it has caused the surrounding concrete to pop out. Differential expansion and contraction is suspected to be the cause of this problem.



Supreme Grout is in good condition after one year.

The concrete cement type patches were inspected once a month. Similar to the asphalt materials, a patch was considered to have failed when a substantial portion eroded to about three-fourths inch below the pavement. Figures 2a and 2b show the longevity of the concrete materials tested. The climate is also portrayed in graphical form in Figures 1 and 2. A brief study of the graphs in Figure 2a and 2b indicates that Set 45 and Speed Crete should be eliminated from further use based on durability. Speed Crete demonstrated another peculiar disavantage in that it caused the surrounding concrete to pop out. Apparently, it is very strong but has different expansion-contraction characteristics than normal concrete.

Part of the field evaluation included considerations of cost of materials, cost of placement, stability, durability, and general condition or acceptability. Table D shows the results of these evaluations. The costs, except for the standard hot and cold mixes, can not be used in estimates for larger or continued use of given materials since they represent only enough material and labor to install five pothole patches each. Other subjective ratings were made on the premise that a long lasting patch was desired.

CONCRETE PATCH LONGEVITY

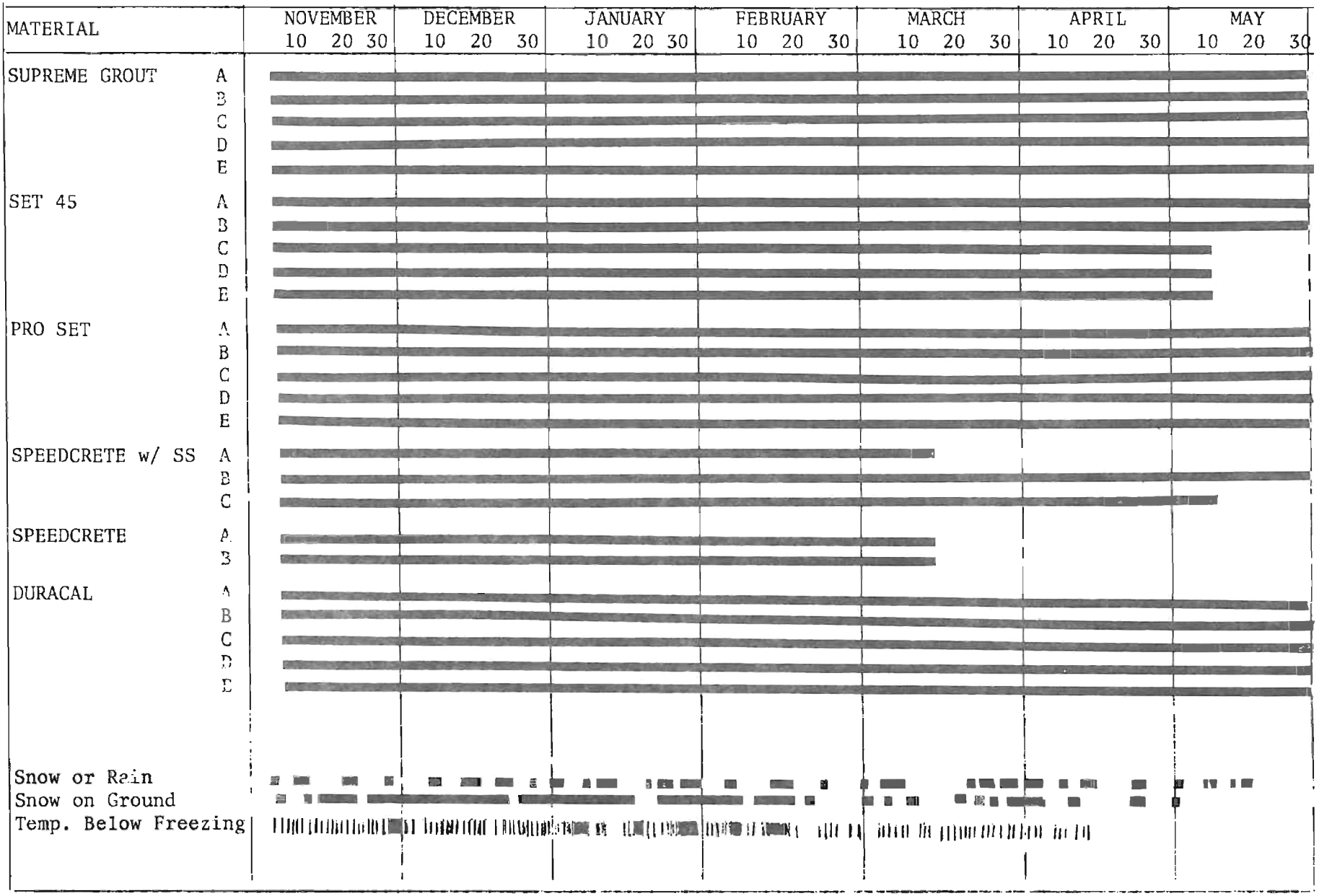


Figure 2a

CONCRETE PATCH LONGEVITY

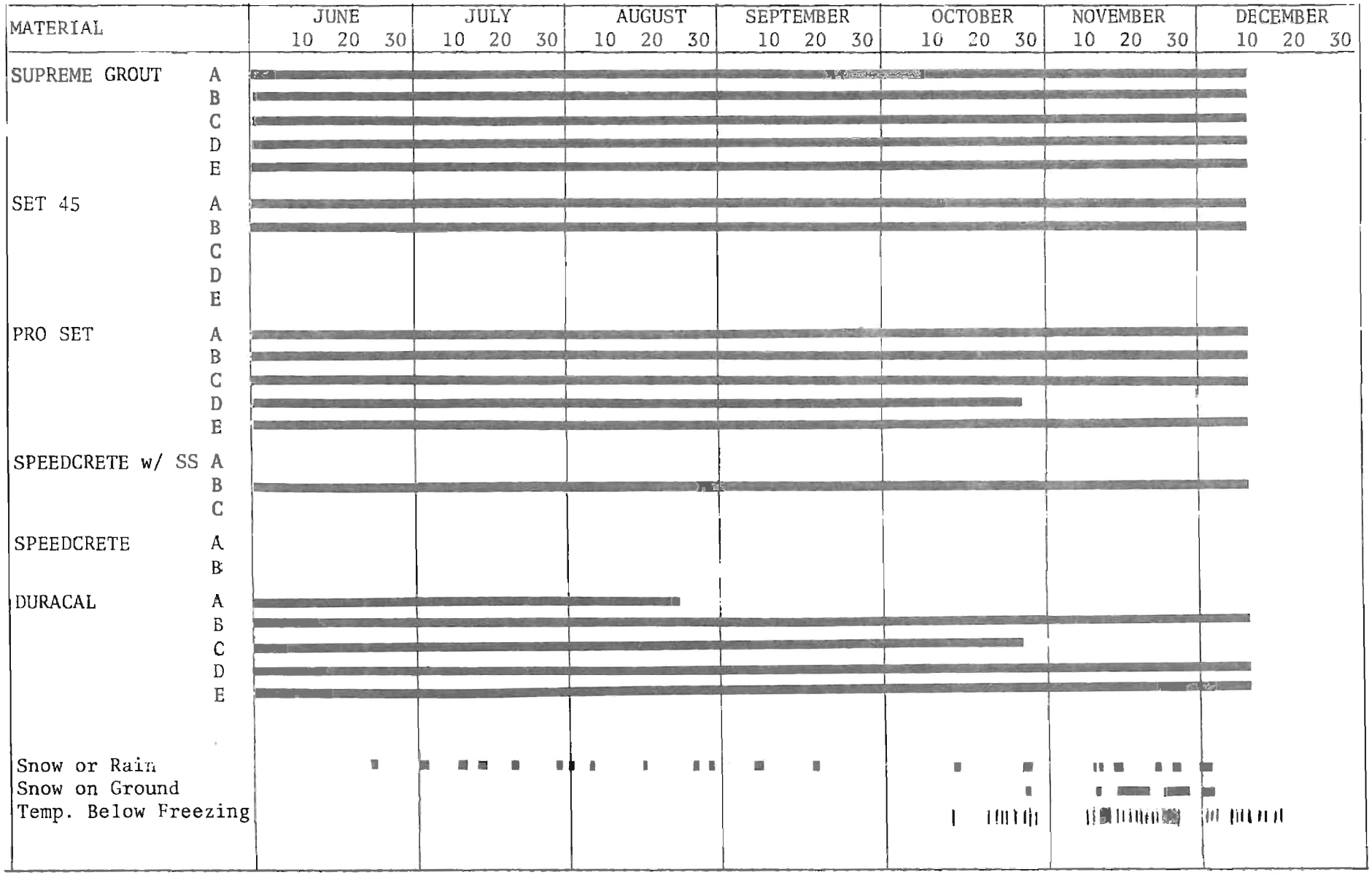


Figure 2b

TABLE D

FIELD DATA SUMMARY

	Approximate Cost*		Field Evaluations		
MATERIAL	MATERIAL	PLACEMENT	STABILITY	DURABILITY	GENERAL COND. ACCEPTABILITY
Supreme Grout	2.20	20	good	good	good
Set 45	5.60	20	poor	poor	poor
PRO SET	6.40	20	good	good	good
Speedcrete	5.20	20	poor	good	poor
Duracal	1.90	20	good	good	good
Foamed Asphalt	0.25	15	fair-poor	poor	poor
STA-FIL	11.80	12	good	good	fair
Sylvax	50.00	12	---	---	---
MC 800 W/Fibers	0.70	12	fair	fair	poor
MC 800	0.70	12	fair	poor	poor
MC 800 W/Anti-Strip	0.70	12	fair	fair	poor
Pavon	8.80	15	fair	fair	poor
Sulflex	10.00	60	fair	poor	poor
Hot Mix	0.40	12	excellent	excellent	excellent
Cold Mix (MC-70)	0.35	8	good	fair	fair

Note: * - Cost in dollars per patch, 1 ft sq x 4 in deep.

CONCLUSIONS

From the preceeding evaluation, it is apparent that the hot mix bituminous patch is the only one which is permanent. Since hot bituminous pavement is mixed daily, on demand, in the Denver area, there is no reason to use any of the others. Since standard cold mix using MC-70 asphalt is also readily available and economical it should continue to be used as a temporary patch until the weather and time permits the placement of a hot patch. An anti-stripping additive has a high Benefit/Cost ratio and improved cold mix more than enough to compensate for its relatively small cost. Some additional compaction with the use of a jackhammer attachment or other economical means could increase the longivity of cold mix patches in rural areas where hot mix is not as easily available. Better ridability will be a benefit of better compaction.

Concrete patching is and has been performed in Colorado using Duracal with good results. Supreme Grout and ProSet have performed about as well as Duracal in this evaluation. Since ProSet is more expensive and somewhat difficult to work with, it cannot be recommended. Supreme Grout appears to be competitive with Duracal in cost and performance.

In summary, the repair and maintenance of asphalt pavement potholes is strongly correlated with the methods used. The need for the potholes to be clean and primed, in addition to using hot, well compacted material, has been well documented in the literature. Apparently, the use of substitute materials does not replace these procedures or requirements. Regarding cementitious patches for PCC pavements, there are, on the market, durable materials that will provide a patch that meets the requirements of maintenance personnel and the motoring public.

APPENDIX A

Field Notes

CONCRETE

PAVEMENT PATCHING RESEARCH
I 70 WADSWORTH TO KIPLING
WESTBOUND

November 5, 1979

This section of Interstate 70 is under construction which includes adding lanes and grinding and repairing the old concrete surface. There were some cracked and spalled chips at the junctions of transverse and longitudinal joints. These are generally less than one square foot in area. The contractor was given the responsibility of cutting, cleaning and patching these small cracked areas with Duracal. Arrangements were made for the contractor to prepare but leave open twenty-five of these areas so that the Research Section could field test five concrete patching materials.

On November 5, 1979, members of the Research Section and the Central Laboratory arrived at the project to place the experimental products. The pavement and air temperature was 36°F at 9:00 AM. The 17 holes which had been prepared by the contractor were partly filled with mud and trash and were wet in the bottom. The team spent two hours cleaning the holes. Some of the concrete was easily removed from the bottom of the holes. This was probably cracked and loosened by the jackhammers when the surface concrete was removed.

About 11:00 AM the contractor supplied a compressor to blow out the holes and prepare additional holes. By 11:15 AM the air surface temperature was 49°F, and the Supreme Grout was mixed. The mix temperature was 54°F. Motar was brushed on the third and fourth hole. The temperatures reached 50°F by noon and remained that throughout the afternoon.

Five patches of each of Set 45, ProSet, Speedcrete, and Duracal were placed following Supreme Grout from east to west on lane three on westbound I 70. Code letters were painted on the median jersey barrier adjacent to each patch for future identification.

Supreme Grout is sacked dry mix which looks like sand and cement. It mixes easily with water and works very similar to cement. Cleaning of equipment is rather easy, also similar to a cement mix. The setting time is somewhat longer than desired for work which must be opened to traffic each day.

Set 45 is a dry mix delivered in bags which is fairly easy to mix with water. It has a dark gray, dirty appearance but is easy to work with. Tool cleaning is easy and the material sets very hard in a reasonably short time.

ProSet is a two part component job mix. It is received in cans and appears to be sand and a powdered cementatious material. The catalyst was received as a liquid. When mixed these materials become an epoxy resin. The consistency is similar to a dry pack with no slump. It has to be packed into the hole but becomes very hard in less than an hour. Cleaning of equipment is fairly easy if done immediately.

Speedcrete is a dry mix which looks like cement but is very difficult to mix with water. While mixing it was lumpy and had the appearance of a poorly made gravy. After thorough mixing with water another compound called Sticky Stuff compounded the problem of mixing making the material even more unmanageable. It stuck to everything and was very difficult to keep in the hole without sticking to finishing tools. Sticky Stuff looks, smells and acts like white glue. The final batch of Speedcrete was prepared without Sticky Stuff. Mixing and cleanup were still difficult but not as bad as the previous. Both batches had set sufficiently within an hour and a half.

Duracal is a dry cement like material which can be used alone or mixed 50/50 with sand. Either way it mixed readily with water. Workability and cleaning is relatively easy and similar to any cement mixture. These patches of 50/50 Duracal-sand were sufficiently set within an hour.

March 11, 1980

On March 11, 1980, members of the Research Section went to Wadsworth Boulevard at I 70 to observe how the concrete patches looked after four months. The following is a summary of our findings on the condition of the patches. Pictures were taken.

1.	Supreme Grout (5 patches)	-	Looked real good. Color blends well with existing pavement. Patches show no sign of deterioration.
2.	Set 45 (5 Patches)	-	Color of patches contrast with pavement. Surface is starting to wearout unevenly.
3.	ProSet (5 Patches)	-	All patches were doing well. Color blends with pavement. No signs of patches unraveling.
4.	Speedcrete w/SS (3 Patches)	-	One patch is totally out. Two patches are intact.
5.	Speedcrete (2 Patches)	-	One patch crumbled. The other patch is starting to crumble.
6.	Duracal (5 Patches)	-	All patches were holding on good.

July 9, 1980

The concrete patches that failed to have been replaced with regular concrete patching material. Speedcrete with Sticky Stuff patch and the plain Speedcrete patch failed about March 11, 1980.

ASPHALT

PAVEMENT PATCHING MATERIALS

December 27, 1979

Members of the Research Section received 35 bags of aggregates from Brannan Sand and Gravel Company to be used for mixing asphalt materials. The reason the aggregates were taken from one source is to insure that all the aggregates to be used in this project will be the same quality. Because the aggregates were frozen, it was necessary to heat them in the Central Laboratory ovens to dry them ready to be mixed with various asphaltic additives. The mixing was done in the Garage at Holly Street. A concrete mixer was used to mix the aggregates.

Three different kinds of mixes were prepared:

1. 250 lbs. of aggregate with 2 gallons of MC-800 and 0.5 lbs. of Hercules Polypropylene fibers.
2. 250 lbs. of aggregates with 2 gallons of MC-800 (Normal Cold Mix).
3. 250 lbs. of aggregate with 2 gallons of MC-800 and 2 ounces anti-stripping material.

All these mixes were put in bags, labeled and stored in the Maintenance Yard of District 6. We will be notified when District 6 Maintenance is ready to use these patching materials so that the procedures will be monitored.

January 18, 1980

In January 1980, members of the Research Section were present to observe and take notes on the repair of potholes on South Sheridan near Ohio Street. Maintenance forces were placing hot mix asphalt which was

made with AC-10 in some potholes near the curb line. The air temperature was near 50°F on this and the previous three days, between snowstorms. Snow on adjacent lots was melting and both the surface and subsurface were saturated. The following are some quotes from the lead maintenance man: "Water is our worst enemy." Under worse conditions "when we use cold mix and the ground is cold and wet, we are trying to get cold mix to stay overnight or a few days until we can get back and redo it with hot mix." "Poor or no sweeping can cause dirt and other debris to force the runoff water out from the gutter into the travel lanes. Traffic then ravels and works and softened pavement causing small potholes to continue spalling to create bigger and bigger potholes."

The potholes were dug to an average depth of about 5" and shaped into rectangular holes with all the sides squared. The holes were cleaned up and patched with hot mix.

March 6, 1980

On March 6, 1980, members of the Research Section were present to observe and take notes on the repair of potholes on South Sheridan Boulevard near Center Avenue.

The first pothole to be filled was dug out using a jackhammer and then cleaned using compression air. All corners were squared and the depth of the hole was approximately one inch on the concrete over the curb, and approximately four inches outside of the curb line. The first hole was very large and required four sacks of MC-800 with polypropylene fibers on the north end and an additional two sacks of standard cold mix (MC-800) on the south portion.

The MC-800 with fibers looked rich and was very active. The MC-800 (Standard Mix) was very dry looking having numerous 1/2 - 3/4" aggregate with no coating, and the mix contained numerous clay balls up to 2" in

diameter. Following compaction by rolling with the sign truck, the MC-800 with fibers compacted and the standard cold mix showed little compaction or adhesion to itself or the existing pavement.

Several holes were then filled with Standard Cold Mix and then with MC-800 with an anti-stripping agent.

Again, the standard cold mix was very lean with numerous clay balls (5 sacks in all).

The MC-800 with the anti-stripping agent mix was somewhat caked up, but went in the holes well and looked good following compaction.

Two holes were filled using PAVON and the aggregate supplied, (resembled Class 6). No water was available so the PAVON liquid was not diluted. The first hole was dug out with the jackhammer and blown clean using compression air. The sides were then covered with PAVON liquid and then layers of aggregate were then placed and covered with the liquid. The top of the hole was then covered with a layer of Masons Sand.

March 6, 1980

The second hole was cleaned by blowing debris out with compression air. Then Masons Sand and PAVON liquid were layered into the hole.

Both of these holes were then compacted using the Sign Truck. Some bleeding was noted on the large hole with none noticed on the smaller hole.

Patching will continue tomorrow, weather permitting.

March 7, 1980

On the morning of March 7, 1980, the potholes patched the previous day were revisited to determine their performance after one day. The weather, starting in the afternoon of March 6, had been rain mixed with snow and

temperatures in the 20's. These conditions persisted into March 7, and at the time of this inspection the temperature was 25°F with snow and approximately one inch of water draining along the curb.

Overnight the condition of the patches were as follows:

MC-800 with polypropylene fibers - Patch depressed about 1½" with raveling on the top.

MC-800 with Anti-Stripping Agend - Patches depressed approximately 1 inch with some raveling on surface.

PAVON-W/Class 6 - 1/3 of patch held up well - lower ent of patch raveled out to 2½ inch depth.

PAVON-W/Masons Sand - Patch completely raveled out.

Pictures were taken of each patch.

The hot mix patches placed in January were also inspected and photographed. Most are slightly depressed, but holding up well.

March 10, 1980

Members of the Research Section inspected asphalt patching jobs done on potholes along Sheridan Boulevard between Center Avenue and Ohio Avenue. Pictures were taken. Condition of patches was the same as was reported in a report dated March 7, 1980.

March 14, 1980

HOLE NO. 1 PAVON

Pothole was squared with the use of a jackhammer. The final size of the pothole was 2' X 2' X 3" deep. The pothole was then primed all around and the bottom with PAVON. The maintenance crew then mixed the aggregate

(1/3 part water with 2/3 part PAVON) inside the hole. More mix was made and added to fill up the pothole. The patch was then covered with sand. A pickup truck rolled over patch about tem times. After 30 minutes the patch was still soft. After one hour the lane was opened to traffic. Later the patch was checked and was still soft and most of it had been shoved out of pothole by traffic. It was dug out and replaced with MC-70 mix.

HOLES NO. 2, 5, and 6 PAVON

The same steps were done in preparing to patch the hole as was done in Hole No. 1. The difference was in actual patching of potholes. In Hole No. 2 the aggregate was poured in the hole and tamped by foot. PAVON emulsion was then poured over the tamped aggregate, more aggregate was spread over PAVON up to level of street. More PAVON emulsion was poured over aggregate, sand was poured over emulsion and sand was leveled with a broom.

HOLE NO. 4 PAVON

The same proceure as in Hole No. 2 was done except PAVON emulsion was poured only once.

HOLES NO. 3, 7, 8, 9, 10 FOAMED ASPHALT

All holes were squared with a jackhammer. The edges and bottom were primed with MC-70. Foamed asphalt was poured in all holes, and rolled over with a pickup truck until compacted. MC-70 was poured over the foamed asphalt and finally aggregate was poured over the MC-70.

March 17, 1980

On March 17, 1980, members of the Research Section went out to observe the asphalt patching job on South Sheridan near Center Avenue. The following are notes on the condition of the different patches after eleven days:

1. MC-800 with Fibers

   The patch is depressed one inch but otherwise is holding on to pothole.

2. MC-800 with Anti-Stripping

   One patch is about 3/4" depressed and the other two patches are totally out.

3. PAVON

   The patch is starting to ravel out.

March 18, 1980

The patches are three days old today. Members of the Research Section went back to observe and take pictures of the different patches. The following is a report on the different patches:

PAVON

One patch came out satisfactory, but the other PAVON patches in this project failed.

FOAMED ASPHALT

All the foamed asphalt patches turned out satisfactory. Although some of the patches tend to spread out of the hole, the patches still seem to stick to the pothole. The spreading out of the patching material could be the need for a more thorough tamping with a good tamping machine. In two potholes there was no spreading out of the patching material.

March 25, 1980

1. Sheridan Near Ohio Street

   Patch Nos. 4 and 5 failed and were replaced with regular patching material.

2. Patch No. 2 failed. No. 3 was replaced with regular patching material. Nos. 4, 6, 7, 8, 9, and 10 seem to be holding on. Hole No. 5, the center part was replaced with cold mix.

3. Sheridan Near Center Avenue

Patch Nos. 1, 2, 3, 4, 6, and 7 were replaced with regular patch. Portion of No. 5 is totally out and replaced by regular patch. The other portion of No. 5 is holding on.

April 1, 1980

On March 27, 1980, a Research Section representative went with members of the Maintenance Section of District VI to Kipling Street near 14th Street to check and put in more experimental patches in potholes. Some of the patches put in previously were starting to ravel and some were starting to settle lower than the street level. Some of the patches were replaced with Sta-Fil, a patching material that is being put in for the first time. New potholes were prepared to take in more patch materials. This time the maintenance people brought a roller with them to insure better compaction of the materials. Each of the patches were rolled over at least 10 times. Of all the new materials put in, it looks like the Sta-Fil patching material is the better material than all the other patching materials previously put in. Photographs will be taken later to find out how the patches are holding on.

April 4, 1980

On April 4, 1980, a representative of the Research Section took pictures and notes on the condition fo patches on Kipling Street near 13th Avenue and South Sheridan near Center Avenue. The following are descriptions of the different patches:

PAVON

All Pavon patches are starting to ravel. Holes are starting to appear on the patches. Patches are 20 days old and three snowstorms occurred during that period.

STA-FIL

STA-FIL patches look good although some are about one inch below roadway surface. Patches are seven days old and two snowstorms occurred since installation.

MC-800 WITH ANTI-STRIPPING

Portions of each patch are completely out. Patches are seven days old and two snowstorms occurred during that period.

FOAMED ASPHALT

One patch is completely out. The other patch has one corner completely out. Patches are 20 days old and three snowstorms occurred during that period.

MC-800 WITH FIBERS

Corners of patches are out and patches settled one inch below the road level. Patches are seven days old and two snowstorms occurred during that period.

MC-800 COLD MIX

One corner of each patch is completely out and patches settled down one inch below road level. Patches are seven days old and two snowstorms occurred since installation.

SHERIDAN NEAR CENTER

All the patches are intact except the portion on top of the pan line which is being washed away by the flowing water.

SHERIDAN NEAR OHIO AVENUE

Out of seven patches, only three are intact. The rest are gone.

Sta-Fil - All looks good. (Holes #1, 5, 9, and 10)

MC-800 with Fibers - One corner of one patch is gone. The other patch settled about one inch below the pavement. (Holes #3, and 15)

Pavon - The surface of one patch is eroding in one corner and the other patch is gone. (Holes #4 and 6)

Foamed Asphalt - One patch is out. One corner of one patch is gone. (Holes #7 and 8)

MC-800 With Anti-Stripping - All patches are eroding badly. (Holes #11 and 12)

Cold Mix - All patches settled about one inch. (Holes #13 and 14)

April 14, 1980

On April 14, 1980, a representative of the Research Section went to Kipling Street near 13th Avenue to check and take pictures of the pavement patching materials installed there on March 13, 1980. The following is a report on the condition of the patches:

Hole No. 1 (STA-FIL)

Patch is intact except for one corner which is starting to crack. Patch is 18 days old.

Hole No. 2 (PAVON)

Patch is 30 days old and looks good.

Hole No. 3 (MC-800 WITH FIBERS)

Patch is 18 days old. One corner of the patch is out; the rest of the patch is still performing well.

Hole No. 4 (PAVON)

Corner of patch is reveling. Patch is 30 days old.

Hole No. 5 (STAFIL)

Patch still looks good. Patch is 8 days old.

Hole No. 6 (PAVON)

One half of patch is gone. Patch is 30 days old.

Hole No. 7 (FOAMED ASPHALT)

Patch is 30 Days old. Patch is out.

Hole No. 8 (FOAMED ASPHALT)

30 days old. One corner of patch is out.

Hole No. 9 (STA-FIL)

18 days old. One corner of patch is out.

Hole No. 10 (STA-FIL)

18 days old. Patch is intact. (dishing out).

Hole No. 11 (MC-800 W/ANTI-STRIPPING)

18 days old. Patch looks good. (dishing out).

Hole No 12 (MC-800 W/ ANTI-STRIPPING)

18 days old. Patch looks good. (dishing out).

Hole No. 13 (MC-800 COLD MIX)

18 days old. Patch looks good.

Hole No. 14 (MC-800 COLD MIX)

18 days old. Patch looks good.

Hole No. 15 (MC-800 W/ FIBERS)

18 days old. Patch starting to fail in one corner.

May 6, 1980

On May 6, 1980, members of the Research Section supervised and participated in patching potholes using Sulphlex Binders. 250 lbs. of aggregate was preheated in an oven turned to 310^{o}F. Sulphlex has heated to

250° at the site. When Sulphlex was getting close to 250°F, the heated aggregate was brought from the Central Lab oven to the job site where the aggregate and the Sulphlex were mixed in an improvised mixer drum. To mix the aggregate with Sulphlex in the drum, the drum is rolled on the street a few times. The resulting mixture seems to be adequately mixed because the color is uniformly the same. The first batch seemed lacking in Sulphlex Binder to that for the next batch we added 2% more Sulphlex Binder. The resulting mixture looked just about right. Four potholes were patched with these Sulphlex mixtures and then rolled with the roller. One thing that caught our attention is when the old STA-FIL patch was being dug out the bottom part of the patch was wet so that it crumbled easily. Adjacent to these Sulphlex patches, four potholes were patched with hot mix patches the same day the Sulphlex patches were placed. With the same number of vehicles going over these patches, a good comparison between a hot mix patch and Sulphlex patch will then be available.

On May 7, 1980, pictures of the patches were taken -- one day after patches were placed. All the patches (Sulphlex and Hot Mix) are still intact.

May 9, 1980

Sulphlex, Kipling Near 10th

One out of the four Sulphlex patches failed. The rest didn't work too well compared to the Hot Mix patches that were placed the same day. Maintenance replaced the Sulphlex patch that failed with Hot Mix.

May 12, 1980

Sulphlex, Kipling

Patches starting to erode on the surface. One patch is about half an inch below the level of the street. In comparison with Hot Mix put in the same day, the Hot Mix patches look better.

July 9, 1980

On July 9, 1980, a member of the Research Section went to investigate the conditions of the different experimental patches being tested. All the asphalt patching materials except for Sulphlex have been replaced with regular CDOH hot mix patching material. The Sulphlex patches are stripping and have raveled one inch below the pavement level. According to the maintenance foreman, the Sulphlex patches will be replaced as soon as their equipment is available.

APPENDIX B

Manufacturers and Physical Characteristics of Materials

APPENDIX B

EXPERIMENTAL MATERIALS

MATERIAL	MANUFACTURERS' NAME AND ADDRESS	BRIEF PHYSICAL CHARACTERISTICS
CONCRETE		
TAPE CRETE	FRC COMPOSITES LTS. 1993 Leslie St., Don Mills Ontario, Canada	Waterbased cementitious materials
SPEED CRETE	STRUCTURAL COATING SUPPLY 4770 Fox Street Denver, Colorado 80216	N/A
STICKY STUFF	GSI SUPPLY, INC. 5775 W. 52nd Avenue Denver, Colorado 80212	Liquid White Glue
SWINDRESS BOND	PULLMAN SWINDELL 441 Smithfield St. Pittsburgh, Pennsylvania 12522	Inorganic-Polymer Cement
BONDURMENT	PLAINS MANUFACTURING CO. P. O. Box 611 Sidney, Nebraska 69162	Grout
PROFLOW 30	1331 West Evans Avenue Denver, Colorado 80223	Sand & Liquid Catalyst
SET 45	SET PRODUCTS, INC. 8501 Freeway Drive Macedonia, Ohio 44050	Magnesium Phosphate Cement
DURACAL	U. S. GYPSUM CO. Chicago, Illinois	Calcium Sulfate with Portland Cement
SUPREME GROUT	MPM CONSTRUCTION P. O. Box 5183, T.A. Denver, Colorado 80217	N/A

APPENDIX B

MATERIAL	MANUFACTURERS' NAME AND ADDRESS	BRIEF PHYSICAL CHARACTERISTICS
ASPHALT		
STA-FIL	REVERE CHEMICAL CORP. 30877 Carter Street Solon, Ohio 44139	Pre-Mix Bituminous material
PAVON	CARGEL SYSTEMS INC. 3001 Merriam Lane Kansas City, Kansas 66106 Tel - (913)236-6667	Rubberized Emulsion
SYLVAX	SYLVAX CHEM. CORP. Station Plaza East Great Neck, New York 11021	N/A
FOAMED ASPHALT & HOT MIX AC-10	SINCLAIR OIL CO. Sinclair, Wyoming	Asphaltic Cement
MC 800	SINCLAIR OIL CO. Sinclair, Wyoming	Liquid Asphalt
CSS-1h	COLORADO BITUMULS CO. 5301 N. Bannock Street Denver, Colorado	Liquid Emulsion
ANTI-STRIP Acra	NO STRIP CHEMICAL WORKS INC. P. O. Box 9 Commerce City, Colo. 80037	Waxy Base Liquid
SULFLEX	SOUTHWEST RESEARCH INST. San Antonio, Texas	Plasticized Sulfur Binders
MC-70	SINCLAIR OIL CO. Sinclair, Wyoming	Liquid Asphalt
HERCULES FIBERS	HERCULES INCORPORATED Wilmington, Delaware 19899	15 Denier Herculon Staple