ASPHALT CONCRETE PATCHING MATERIAL EVALUATION

Interim Report

SR 548

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by

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16. Abstract

There are a great number of proprietary pothole patching products available on the market that claim to be the "perfect" fix to repair asphalt concrete highway potholes. These products are difficult to evaluate. Without actually placing the products in a test deck, it is difficult to determine the quality of a product by looking at the product literature.

The objective of this study was to evaluate new patching materials to determine their viability. Issues such as uniformity, availability, handling, stockpiling impacts, compatibility with common roadway materials, and field performance were investigated. A literature review of laboratory, field, and pothole patching material ranking was performed.

Both a laboratory and field verification component were included. The laboratory component included a series of material tests with pass-fail criteria. The field portion of the study included manufactured potholes and natural potholes. All fieldwork performed was done with standard maintenance procedures. Following placement, pothole test patches were monitored and will continue to be monitored for an additional year.

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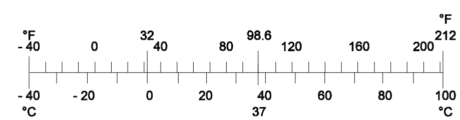
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
In	inches	25.4	millimeters	mm
Ft	feet	0.305	meters	m
Yd	yards	0.914	meters	m
Mi	miles	1.61	kilometers	km
		AREA		
In^2	square inches	645.2	millimeters squared	mm^2
Ft^2	square feet	0.093	meters squared	m^2
Yd^2	square yards	0.836	meters squared	m^2
Ac	acres	0.405	hectares	ha
Mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
Fl oz	fluid ounces	29.57	milliliters	mL
Gal	gallons	3.785	liters	L
Ft^3	cubic feet	0.028	meters cubed	m^3
Yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8C + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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ASPHALT CONCRETE PATCHING MATERIAL EVALUATION

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1.0 INTRODUCTION

Many proprietary products are on the market that claim to be the "perfect" fix to repair asphalt concrete pavement potholes. These products are difficult to evaluate. Without actually placing the products in a test deck, it is difficult to determine the quality of a product by looking at the product literature. In addition, some of the products may cause problems in the future when the pavement is overlaid because of incompatibility with the new asphalt. Finally, few test procedures exist to fairly compare performance and/or liability of pothole patching materials (PPMs). The tests are generally only useful in identifying PPMs that are blatant failures.

In order to determine the best patching materials for ODOT maintenance, a study was set up to objectively evaluate a range of materials. Issues such as uniformity, availability, handling, stockpiling, environmental impacts, compatibility with common roadway materials, and field performance were investigated.

Both a laboratory and field verification component were included. The laboratory component included tests based on AASHTO Provisional Test Procedures. The field portion of the study included constructing and patching test potholes as well as filling natural potholes. All fieldwork was done with routine maintenance procedures.

1.1 ODOT STUDY MATERIALS

The ODOT New Products Coordinator supplied a list of cold mix patching material vendors. Each vendor on the list was asked to participate in the ODOT study by supplying five 5-gallon (18.9-liter) buckets of their materials. The five buckets of each material were to be applied as shown in Table 1.1.

Table 1.1: Material application

Number of Buckets	Application
1	Laboratory testing.
1	Manufactured pothole in open-graded mix.
1	Manufactured pothole in dense-graded mix.
1	Natural pothole in open-graded mix.
1	Natural pothole in dense-graded mix.

Nine proprietary materials were donated and are listed in Table 1.2. One material – Polypatch HFMS-2SP/HFE-300S – was obtained from the Albany ODOT Maintenance Yard stockpile and was used for control patches at the test sites.

Table 1.2: Materials evaluated

Product Name	Manufacturer	Binder Type
Bond-X	Seaboard Asphalt Products	Cutback
Elasti-Patch	Koch Materials	Cutback
HFMS-2SP/HFE-300S (control)[1]	Albina Asphalt	Emulsion
Instant Road Repair	Safety Lights Company	N/A
King Patch	Pacific Asphalt Marketing	Natural Tar Sands
Optimix Cold Patch	Optimix	Cutback
Perma Patch	National Paving & Contracting	Cutback
QPR 2000[2]	Quality Pavement Repair	Cutback
Tag 8000	Infratech Polymer	Emulsion
UPM High-Performance[3]	United Paving Materials	Cutback

[1]Polypatch is the little used brand by Albina for this product.
[2]Currently being used by Bend and Lakeview ODOT maintenance crews.
[3]Currently being used by Salem and Portland ODOT maintenance crews.

2.0 LITERATURE REVIEW

A literature review was performed to identify studies on cold mix pothole patching materials. Investigations have been conducted on patching material evaluation criteria, laboratory testing, material properties, cost effectiveness, application techniques, field performance and climatic factors. A summary of the results, findings, and observations found in these studies is elaborated below.

2.1 POTHOLE ORIGIN

Potholes are caused when the pavement or the base can't support the traffic loads. Two factors are almost always present in pothole failures: water and traffic. Heavy traffic or other factors may create cracks, which allow water to seep into the pavement base and soften it. The pounding of traffic causes the weak base to migrate, leaving nothing to support the pavement above it. Further traffic impact eventually causes the unsupported pavement to break up.

Traffic that is too heavy for the pavement design can also cause fatigue failures. As the weak pavement breaks apart, potholes form.

Potholes may also be created in freeze/thaw situations. When water in the pavement or base freezes, it expands and pushes the pavement above it up. The swelling expansion forces can cause a pavement to weaken, resulting in potholes (*APWA 1983*).

2.2 POTHOLE REPAIR CONSIDERATIONS

A highway agency must consider ride-ability and safety problems that could result from unrepaired potholes. The agency must repair hazardous potholes as soon as it becomes aware of them. Many pothole repairs cannot wait for optimum patching conditions. Two main elements of quality pothole patching are material selection and repair procedures. Parameters that affect cost-effectiveness of patching operations are materials, labor, and equipment (*FHWA 1999*).

The "throw and roll" cold mix patching technique is a standard maintenance process preferred during the winter pothole season (*Wilson 1993; Prowell and Franklin 1996*). The throw and roll procedure consists of placing patching material into a virtually unprepared pothole (sometimes filled with water), and backing the tires of the maintenance truck over the patch between four and eight wheel passes. It is generally recommended to slightly overfill the pothole with PPM to allow for material compaction that will inevitably result. If a depression is present after rolling, additional material should be added and rolled to bring the patch surface above surrounding pavement level. Throw and roll is the common cold mix patching procedure for highway maintenance crews in Oregon (*FHWA 1998*).

Installation techniques are varied between maintenance crews. Activities such as cleaning the pothole prior to patching and the removal of soft degraded pavement surrounding the pothole can greatly improve patching success (*Thomas 1981 and 1986*).

Hot-mix asphalt patching is preferred over cold-mix patching (*Randolph and Anderson 1986*). Hot mix, however, requires fair weather and labor intensive application.

Patch longevity is a variable that is crucial to determining the cost/benefit of a certain patching operation. Most pothole repairs made during the winter months are short lived. It has been reported that the same potholes have been repaired by an agency as many as 15 times in a year. If the same pothole needs frequent repair, the cost to keep the pothole in a patched condition goes up (*Public Technology, Inc. 1976*).

By using more expensive proprietary cold mixes, a cost benefit can be realized due to increased longevity of pothole patches (*Better Roads 1999; Anderson, et al. 1988*). The increase in performance more than offsets the additional cost of proprietary mixes (*Outcalt 1993*).

2.3 COLD MIX PATCHING MATERIAL GROUPS

Cold mix patching materials are typically classified in three groups: “everyday” cold mix, state specified, and proprietary (*Wilson 1993; HITEC 1995; FHWA 1999*). Everyday or locally produced mixes may include materials that are prepared with no specifications or quality control. State specified mixes are generally well designed and tested to assure adherence to state specifications. Proprietary pothole patch materials typically use a brand name and are produced by the manufacturer to adhere to proprietary specifications. Proprietary materials are often referred to as high-performance cold mix (*Better Roads 1996*).

2.4 COLD MIX PATCHING MATERIALS SELECTION

Material costs are a small percentage of the total cost for pothole patching (*Randolph and Anderson 1986*). Certain materials work better than others under different conditions (*Wilson 1993*).

All-weather workability is of prime concern in maintenance operations. Patching material should be soft and pliable for easy handling. Patch material stockpiles should be workable after several months of storage (*Sequeira, et al. 1991; Texas DOT 1999*). In addition, since winter pothole repair can occur at freezing temperatures, the mix needs to be workable at the temperatures at which it is handled and applied. A mix that is suitable at freezing temperatures may not be suitable at warm spring temperatures when pavements thaw (*Estakhri and Button 1997*).

Draindown potential should also be considered. Draindown occurs when the asphalt cement drains from the coated aggregate and becomes concentrated in the bottom of the stockpile. Draindown is caused by warm storage temperatures (*Kandhal and Mellot 1981*). Draindown indicates loss of coating and creates storage problems for material at the bottom of a stockpile (*FHWA 1999*).

Many cold mix materials are suitable for placement under wet conditions. Materials used in wet weather conditions need to have exceptional anti-stripping properties – resistance to water induced degradation (*Sequeira, et al. 1991; Texas DOT 1999*).

2.5 POTHOLE PATCHING MATERIAL PRINCIPLES

A difficulty in designing a stockpile patching mixture is that material properties required in stockpiling and durability are contradictory. For example, patching material needs to be able to be removed easily from a stockpile and loaded on to a maintenance truck. Once out in the field, material needs to be able to be shoveled, placed, and spread into a pothole with ease. Materials meeting these requirements, however, are generally less durable under traffic. A summary of these contradictions is presented in Table 2.1.

Table 2.1: Pavement patching material characteristics (*Kandhal and Mellot 1981*)

Property	Parameter	Workability	Durability
Gradation	Open Gradation	Good	Poor
	Dense Gradation	Poor	Good
Aggregate Shape	Angular	Poor Workability	Good Durability
	Round	Good Workability	Poor Durability
Binder Viscosity	Low Viscosity	Good (Good storageability)	Poor
	High Viscosity	Poor	Good
Aggregate Size	Larger Gradation	Poor	Good with ideal conditions
	Finer Mix P#4 & retained on #16	Good	Good if depth < 76 mm (3”)
Gradation	One Size	Good (Effective Cure)	
Antistrip			Good if compatible

In view of the challenges of pothole patch mix design, the characteristics discussed below are desired for a satisfactory mix (*Kandhal and Mellot 1981*).

Finer and predominately one sized gradation. Typically, a finer gradation will not have good workability. However, if a fine mix is made predominately of one sized aggregate mostly retained on the 1.18 mm (no. 16) sieve, the workability and curing of the mix improves.
A gradation consisting of 100% passing the 9.5 mm (⅜ ”) or 4.75 mm (no. 4) sieve has the following advantages:

1. The mix is pliable and workable.
2. Due to increased surface area, more binder can be incorporated into the mix to improve the durability.
3. The mix remains pliable for a prolonged period of time and increases in density under traffic and continues to adapt to pavement expansion and contraction.

Clean Aggregate: In order to preserve tackiness of the mix, it is important to keep dust or material passing the 0.075 µm (#200) sieve to a minimum.

Low Absorption Aggregate: Highly absorbent aggregates should be avoided. The aggregate water absorption should be limited to approximately one percent.

Angular Shape: Angular aggregate shape is desired for better stability.

Adequate Binder Content: PPMs need to have thick binder films on the aggregate for stickiness and durability. Too much binder can lead to draindown problems while stockpiling. The binder needs to completely cover more than 90% of aggregate particles.

Anti-stripping Agents: Anti-stripping agents and additives are placed in binder formulas to keep the aggregate coated during stockpiling and after compaction in the pothole.

2.6 EVALUATION OF COLD MIX PATCHING MATERIALS

A strong need exists for performance-based tests that ensure cold mix patching material quality. Many specifications list ASTM tests regarding asphalt viscosity, binder distillation, aggregate gradation and other physical measurements that many inferior patching products can meet. Current bid specifications do not guarantee good patching performance and can allow unsatisfactory materials (*Roads and Bridges 1997*).

The major mechanisms responsible for early cold mix failure are: drainage of binder from aggregate, poor workability, stripping, inadequate stability under traffic, and inability of the mix to adhere to the pothole (*Anderson, et al. 1988*).

Laboratory evaluations are important in the development and quality control of patch materials. Tests or performance requirements should reflect the underlying failure mechanisms (*Anderson, et al. 1988*). An agency involved in pothole patching can usually perform testing that falls into one of two categories: compatibility or acceptance. Compatibility testing includes checking new combinations of asphalt and aggregate to be used in production of cold mix materials. The information can be used to develop a mix design. Acceptance testing is for new cold mix materials produced by proprietary sources to spot blatant failures (*FHWA 1999*).

2.7 PERFORMANCE AND TESTING REQUIREMENTS

A Strategic Highway Research Program (SHRP) study performed several cold mix tests that were similar to those designed for hot mix asphalt concrete materials. To compensate for the different properties of cold mixes, samples were aged in an oven to stabilize them for testing. The following tests were performed on the samples:

- Resilient Modulus
- Marshall Stability and Flow

- Maximum and Bulk Specific Gravity
- Extraction and Binder Content
- Viscosity (recovered binder)
- Ductility (recovered binder)
- Softening Point (recovered binder)

No correlation between the hot mix laboratory test results and cold mix field performance was found (*FHWA 1998; SHRP 1993*).

Suitable cold mix patching evaluations include tests for draindown, workability, cohesion and stripping potential. Draindown resistance is necessary for stockpile storage during hot summer days. This requirement can be tested by placing the mix on a plate and observing the amount of binder that drains to the plate surface at a specified time and temperature (*Anderson, et al. 1988; FHWA 1999*).

Workability is required during handling and repair operations. The mix must be workable over the specified climatic temperature range. Workability can be simulated by cooling a sample to a winter temperature and working a small quantity by hand with a spatula. Quantifying workability can be achieved by measuring penetration resistance of a specified probe (*Anderson, et al. 1988; FHWA 1999*).

Cohesion is the ability of the coated aggregate to hold together after compaction. Cohesion can be demonstrated by preparing a compacted molded cylinder of cold mix at near freezing temperatures and rolling the cold mix cylinder in a 25 mm (1 in) sieve under specified conditions. The percentage of compacted cold mix retained on the screen is a measure of cohesiveness (*FHWA 1999*).

Stripping is the phenomenon of the coating being washed away from the aggregate due to exposure to water. Stripping can be indicative of asphalt/aggregate incompatibility. Stripping can be observed in the laboratory by cooking a sample overnight in water and judging the acceptability of the coating. The coating needs to cover >90% of the aggregate before and after the water exposure (*FHWA 1999*).

The most in-depth descriptions of these methods can be found in the June 1998 Edition of the AASHTO Provisional Standards. (See also *Section 5.0: Laboratory Testing* for test method numbers and titles.)

3.0 FIELD PERFORMANCE EVALUATIONS BY OTHERS

Several patching material studies were identified in the literature review. Pertinent features of the studies were incorporated into the ODOT study. The two most extensive studies identified are described below.

3.1 STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) H-106 POTHOLE REPAIR EXPERIMENT

The H-106 experiment was part of the most extensive field experiment of its kind ever undertaken. Data were collected on the performance and cost effectiveness of various cold mix materials and procedures for repairing potholes in asphalt concrete (AC) surfaced pavements (*Wilson 1998*).

The objective of H-106 was to determine which combinations of material and patching procedures provided the most cost-effective repair of potholes in AC. Cost effectiveness was a function of many variables, including material cost, labor cost, equipment cost, productivity, traffic delays, safety, and repair performance.

Beginning in March 1991 and ending February 1992, 1250 pothole patches were placed at eight test sites located throughout the United States and Canada. Naturally occurring potholes were prepared by removing in-place patching materials to allow placement of experimental materials. Experimental materials included UPM, PennDOT485, PennDOT486, Perma Patch, QPR2000, HFMS-2 with Styrelf, and various locally obtained materials. Adverse moisture conditions were created by filling the holes with water.

The analysis was concentrated on differences within the eight test sites because of variability in performance observed from one set of control patches to the other. The percentage surviving after 198 weeks varied from 30 to 80% even though the materials, placement procedure and compaction were the same.

Table 3.1 ranks materials based on last observations at each of the eight sites. The ranking used raw data that did not take into account factors such as traffic, pavement structure, and climate. All proprietary pothole patching materials performed better than the locally produced nonproprietary materials.

Table 3.1: Percent patch failure

Rank	Material Type	% Failed
1	Spray Injection	22
2	Penn DOT 485	22
3	Perma Patch	23
4	QPR2000	31
5	UPM	38
6	PennDOT486	41
7	HFMS-2	44
8	Local	65

3.1.1 SHRP H-106 Findings and Recommendations

The final report, *Long-Term Monitoring of Pavement Maintenance Materials Test Sites* (FHWA-RD-98-73) makes several observations and recommendations (*Wilson 1998*).

- Survival rates for dry freeze sites are significantly higher than for wet freeze sites.
- The throw-and-roll technique is more cost effective than the semi-permanent procedure in most situations, if quality materials are used.
- Cold mix materials and throw-and-roll procedures can provide long-term repairs that last more than four years, half of the time.
- Correlations between laboratory characteristics and field performance have been difficult to identify.
- Differences in performance between materials are most apparent before the patches had cured.
- The cost of proprietary materials is as much as four times that of the less expensive patching material, yet the overall cost of the patching operation per cubic foot is almost five times less for the better quality material as a result of the longer service life of the patches.

The following recommendations were made as a result of the study.

- Use high productivity, "throw and roll" operations in adverse weather.
- Use the best materials available for repatching.
- Consider safety and user delay costs.
- Testing should be performed to ensure compatibility of aggregate and binder when producing a cold mix pothole patching material.

3.2 VIRGINIA DEPARTMENT OF TRANSPORTATION'S WINTER POTHOLE REPAIR EVALUATION

New patching materials are constantly being supplied to the Virginia DOT (VDOT) Materials Division for approval (*Prowell and Franklin 1996*). Field test sections are costly to set up and time-consuming to monitor. Laboratory tests alone were considered insufficient for screening potential cold mixes but were considered valuable for design and control. In order to evaluate mixes for inclusion as a qualified product, VDOT initiated a research study to determine which of the submitted materials were of the same caliber as previously approved materials.

The VDOT evaluated 13 proprietary cold mix pothole patching materials, four of which are currently approved under VDOT's Special Provision for High Quality Cold Patching Materials. Three highway test sections were placed to evaluate the materials' performance. Standardized evaluation forms and performance models were developed to rank materials. The field performance results were compared with laboratory test results, in an effort to develop laboratory-screening tests. Design and quality control procedures were identified. These procedures were used to design a patching material mix using Bond-X binder.

3.2.1 Field Evaluations

Potholes were evaluated for bleeding, dishing, debonding, raveling, and shoving. Three test sites were used including manufactured holes 75 mm (3 in) deep by 380 mm (15 in) in diameter with flat bottoms; manufactured holes 51 mm (2 in) deep by 380 mm (15 in) in diameter with the addition of a liter of water; and natural potholes.

All proprietary test patches survived 12 months, until the last evaluation period. Shoving was difficult to differentiate from dishing in 380 mm diameter holes. The vertical sides of the manufactured holes probably slowed edge disintegration. The primary forms of distress were dishing, raveling, and bleeding. None of the holes in which water was introduced debonded.

The 75 mm (3 in) deep manufactured test patches had more dishing than the 51 mm (2 in) test sections. The study recommended that filling of potholes with depths greater than 51 mm (2 in) in two lifts should be considered to alleviate dishing in deep holes. (Note: Kandhal and Mellot also recommend patching in layers for potholes greater than 76 mm (3 in) deep (*Kandhal and Mellot 1981*).)

A statistical performance model was developed that combined ratings data for bleeding, dishing, edge disintegration, pushing, shoving, raveling, and workability. Each of these distress types was assigned factors based on a survey of 25 Virginia DOT engineers. From this model the researchers developed rankings for each patching material. The factors assigned to each distress type can determine which patching products are approved or not recommended. Table 3.2 shows the VDOT products evaluated and the products' approval status. The approved products were recommended for addition to VDOT's Special Provision for High Quality Cold Patching Materials.

Table 3.2: Proprietary Cold Mixes Evaluated For Virginia DOT Approval (*Prowell and Franklin 1996*)

Product Name	Company	Approved for Use?
Sakrete	American Stone Mix	Yes
MacPatch CM-300	Suit-Kote S.E., Inc.	Yes
Optimix	Optimix Cold Patch	No
Tough Patch	Tough Patch USA	
Sylcrete EV	Sylcrete Corp. (Flinn Paving)	Yes
HEI-WAY	Heilman Pavement Specialties	Yes
Bond-X	Seaboard Asphalt Products	Yes
Perma Patch	National Paving and Con.	Yes
UPM	Unique Paving Materials	Yes
QPR-2000	US Pro-Tec	Yes

4.0 FIELD EVALUATION

The field evaluation portion of the research study compared the performance of pothole patching materials in two types of asphalt pavement roadways: dense and open graded. Manufactured holes were constructed at Century Drive in Albany, Oregon (a dense graded pavement) and at Wallace Road near Salem, Oregon (an open graded pavement). In addition, several *natural* potholes were filled with PPMs.

4.1 MANUFACTURED POTHOLES

Some of the difficulties of studying pothole patching include finding sections of roadway with sufficient concentrations of potholes to make reasonable performance comparisons between PPMs. There are many types of potholes, and PPM performance comparisons can be difficult to make when comparing patches of different size, type, and traffic conditions.

To eliminate some of the variables, all potholes were manufactured with a jackhammer. Spacing and material placement locations were selected using a random number table. All hole locations were marked on the pavement within 0.9 m (3 ft) of the skip stripe (approximately the outside wheel track). The diameter of the holes was 0.41 m (16 in).

The test potholes were patched using common throw-and-roll procedures. PPM was poured from a bucket or shoveled into a pothole. The material was tamped with the back of a shovel and the amount of PPM adjusted to allow a slight crown after compaction by a few passes of a maintenance vehicle.

Construction notes and detailed monitoring data for the manufactured potholes are included in Appendix A.

4.1.1 Century Drive Manufactured Potholes

Century Drive is a frontage road located in Albany that parallels Interstate 5. All the holes were manufactured in the southbound lane. Mean temperatures in the area range from a maximum 27 °C (81 °F) in the summer to a minimum 1 °C (34 °F) in the winter with annual rainfall levels of 1.08 m (42.7 in) (OSU Climate Service). The ADT for the section is less than 500 vehicles.

Figures 4.1 and 4.2 show the jackhammering and the resulting hole. The materials tested, installation order, spacing, depth and final shape are shown in Table 4.1. The cold mix used for the control (obtained from the ODOT's Albany Maintenance office) was Polypatch (HFMS-2SP/HFE-300S) from Albina Asphalt Company.

Figure 4.1: Manufacturing a pothole at Century Drive

Figure 4.2: Manufactured pothole at Century Drive

Table 4.1: Century Drive manufactured pothole data

Number	Material Name	Distance to next hole, ft (m)	Depth, in (mm)	Installed Shape, in (mm)
1	Control	39 (11.9)	2 (51)	Flush
2	Bond-X	21 (6.4)	1.5 (38)	+0.25 (+6.4)
3	Elasti-Patch	42 (12.8)	1.5 (38)	+0.25 (+6.4)
4	Elasti-Patch	39 (11.9)	2 (51)	+0.25 (+6.4)
5	Cold Mix	49 (14.9)	2 (51)	-0.125 (-3.2)
6	UPM	42 (12.8)	1.75 (44)	-0
7	UPM	23 (7.0)	2.25 (57)	+0.125 (+3.2) S, -0.125 -(3.2) N
8	Tag8000	27 (8.2)	2.25 (57)	+0.25 (+6.4)
9	Instant Road Repair	26 (7.9)	2 (51)	-0.125 (-3.2) SE, +0.125 (+3.2) NW
10	Control	32 (9.8)	1.75 (44)	0
11	Bond-X	23 (7.0)	2.5 (64)	+0.0625 (+1.6)
12	Tag8000	48 (14.6)	2 (51)	+0.125 (+3.2)
13	Cold Mix	44 (13.4)	2 (51)	0
14	Instant Road Repair	31 (9.5)	2.5 (64)	+0.125 (+3.2)
15	QPR2000	33 (10.1)	2.5 (64)	+0.125 (+3.2)
16	QPR2000		2.5 (64)	+0.125 (+3.2)

4.1.2 Wallace Road Manufactured Potholes

The section of Wallace Road used for test potholes was located north of Salem on Oregon Route 221 (State Hwy. 150) near milepost 13. All holes were manufactured in the southbound lane. Mean temperatures in this area range from a maximum 28 °C (82 °F) in the summer to minimum of 1 °C (33 °F) in the winter with annual rainfall levels of 0.996 m (39.2 in) per year. The ADT for the section is about 6,500 vehicles.

Figure 4.3 shows material placement with the general pavement condition. Figure 4.4 shows the completed holes looking south. The materials tested, installation order, depth and final shape are shown in Table 4.2. The cold mix used as the control mix (obtained from the ODOT's Salem Maintenance office) was UPM purchased from Porter Yett Co., Portland, OR.

Figure 4.3: Wallace Road pothole manufacturing

Figure 4.4: Wallace Road manufactured potholes, looking south

Table 4.2: Wallace Road manufactured pothole data

Number	Material Name	Distance to next hole, ft (m)	Depth, in (mm)	Installed Shape
1	Perma Patch	31 (9.5)	2 ½ (64)	¼" (6 mm) crown
2	Bond-X	40 (12.2)	2 (51)	¼" (6 mm) crown
3	Control	23 (7.0)	2 (51)	Flush
4	Control	46 (14.0)	2 (51)	Slight dishing on edges
5	Perma Patch	26 (7.9)	1 ⅞ (48)	Slight crown
6	Instant Road Repair	24 (7.3)	2 ⅛ (54)	Flush
7	Elasti-Patch	48 (14.6)	2 ¼ (57)	¼" (6 mm) crown
8	QPR 2000	33 (10.1)	2 ⅜ (60)	⅜" (10 mm) crown
9	Instant Road Repair	48 (14.6)	2 (51)	Slight crown
10	UPM	39 (11.9)	2 ⅛ (54)	Flush
11	QPR 2000	48 (14.6)	2 (51)	⅜" (10 mm) crown
12	TAG 8000	44 (13.4)	2 ½ (64)	Slight crown
13	UPM	44 (13.4)	2 ¼ (57)	Flush
14	TAG 8000	49 (14.9)	2 ⅛ (54)	¼" (6 mm) crown
15	Control	21 (6.4)	2 ¼ (57)	Slight crown
16	Bond-X	35 (10.7)	2 (51)	Flush
17	Control	49 (14.9)	2 (51)	Flush
18	Elasti-Patch		2 ⅛ (54)	Slight Crown

4.2 NATURAL POTHOLES

Naturally formed potholes were patched in several locations. Table 4.3 lists the materials placed in these locations. The majority of the potholes filled on Century Drive on February 25, 2000 were north of the manufactured holes. Natural potholes were filled on Oregon Route 226 (State Hwy. 211) between Lyons and Scio on May 17, 2000, and at Ona Beach Park on U.S. Route 101 (State Hwy. 9) ten miles south of Newport. Both Century Drive and Oregon Route 226 are dense graded pavements, and U.S. Route 101 at Ona Beach is an open graded pavement.

Table 4.3: Materials used

Product	No. of Patches at Century Drive	No. of Patches at OR Route 226	No. of Patches at Ona Beach (US 101)	No. of Patches at Corvallis Bypass (OR Route 34)
Bond-X	0	3		
Elasti-Patch	1	2		
HFMS-2SP	2	7	1	
Instant Road Repair	3	4	1	
King Patch	1			
Optimix	0	0	1	
Perma Patch	0	6		
QPR 2000	0	3	2	1
Tag 8000	1	1		
UPM	2	2	2 (Salem Stockpile)	1

Potholes were patched using common throw-and-roll procedures. Like the manufactured potholes, PPM was poured from a bucket or shoveled into a pothole (Figure 4.5). PPM was tamped with the back of a shovel, and the amount of PPM was adjusted to provide for a slight crown after compaction by a few passes of a maintenance vehicle (Figure 4.6). Two metal signal plates were patched on the Corvallis Bypass at Oregon Route 34 (Figures 4.7 and 4.8). Construction notes and detailed monitoring data for the natural potholes are included in Appendix B.

Figure 4.5: Installing TAG 8000 into a pothole with standing water at Century Drive

Figure 4.6: Using a truck for compaction

Figure 4.7: Metal signal plate prior to patching

Figure 4.8: QPR2000 metal signal plate patch

4.3 MONITORING

Both manufactured and naturally located pothole patches were checked several times for a period of six months. Most of the natural pothole test patches were successful. Some failures were observed in which the patch material was partly or completely removed from the pothole.

Of the ten natural potholes patched on Century Drive in wet weather, four had failed when inspected a week later – two Albany Maintenance Yard stockpile material patches, an Instant Road Repair patch, and the King Patch:

- One of the Albany mix potholes was a partial failure (Figure 4.9), which could have been caused by not rolling over the whole 457-mm (18-in) wide patch. This partial failure changed little over five months of monitoring. The other Albany mix patch was a complete failure (Figure 4.10).
- The Instant Road Repair patch failure resulted from the center portion wearing away (Figure 4.11).
- The King Patch product was a complete failure in less than a week.

Figure 4.9: Albany mix partial failure

Figure 4.10: Albany Mix complete failure

Figure 4.11: Instant Road Repair failure after one week

Each time the potholes were checked the relative height of the patch to the surrounding pavement was noted since dishing and crowning can affect pavement ride and be an indicator of patch performance. Instant Road Repair and UPM products seemed to compact more than the other products.

In order to evaluate PPMs, it is necessary to monitor test patches for an extended period of time, including both the wet winter months and the hot summer months. Monitoring will continue in order to provide additional information on how well the PPM products perform.

5.0 LABORATORY TESTING

Laboratory testing was conducted to correlate field performance with test results. Since field trials are expensive and time consuming, the goal is for laboratory testing to provide a reliable evaluation of new products. In this study gradation, workability, mix cohesion, and binder coating were investigated. The laboratory testing followed procedures from *Materials and Procedures for Repair of Potholes in Asphalt-Surfaced Pavements – Manual of Practice*, Report No. FHWA-RD-99-168 and the American Association of State Highway and Transportation Officials (AASHTO) Provisional Standards – June 1998 Edition.

5.1 GRADATION

Gradations were determined for each of the mixes for comparison. Cold mix samples were ignited using AASHTO method TP53-95 and a Troxler ignition oven. The aggregate obtained by TP53-95 was used for gradation analysis according to AASHTO T30. The FHWA recommendation is that the P#200 fines be less than five percent. Table 5.1 summarizes the gradations of the pothole patching materials (PPMs) evaluated.

Table 5.1: Patching material gradations (percent passing)

Screen Size	Albany Control mix	Bond X	Elasti-Patch	Instant RR	King Patch	Opti-mix	Perma Patch	Qpr 2000	Tag 8000	UPM
¾ in	99.8	100	100	100	100	100	100	92.0	99.4	100
½”	99.8	100	100	100	100	100	100	92.0	98.9	99.6
⅜”	99.8	100	99.8	99.9	100	100	100	68.3	97.9	98.6
¼”	96.6	100	99.3	93.3	99.7	76.4	99.9	24.2	44.2	86.8
#4	55.4	93.3	89.8	81.6	99.7	47.1	88.9	17.2	13.0	59.2
#8	8.8	23.0	21.4	41.0	99.1	8.0	23.0	10.8	3.5	15.4
#16	5.3	4.7	10.6	26.5	98.5	4.6	9.1	8.2	3.2	7.5
#50	3.8	2.7	5.6	12.0	70.4	3.7	6.2	6.1	2.6	4.5
#200	3.0	2.7	3.4	5.4	16.3	3.1	3.0	3.8	1.7	2.9
P200	2.8	1.5	2.9	5.0	12.9	2.9	2.5	3.1	1.5	2.6

Note: Shaded cells indicate predominant aggregate size for the mix.

The coarsest material tested was QPR 2000 with more than 75% of the material greater than 6 mm (¼ in), and the finest material tested was King Patch with more that 98% of the material passing the 1.18 mm (#16) screen. The King Patch P200 content exceeded the recommended 5% maximum with a percent passing of 12%.

Fine mixes are suitable for shallow holes, since they can be laid thin to help prevent raveling around a pothole’s edges. A coarse mix can provide extra durability for deep patches. Many patching material vendors are willing to consider designing a mix with the preferred gradation of a state agency.

5.2 WORKABILITY

Standard test method AASHTO TP43-94 was used to determine relative penetrometer values of various PPMs. The test uses a soil penetrometer with a specially manufactured adapter that measures the relative workability of the mix. Material is placed in a metal box at 4 °C (39.2 °F). The probe is then inserted through a hole in the side of the box and the relative resistance measured. Figure 5.1 shows the box, probe and adapter.

Figure 5.1: Workability box and penetrometer with adapter

Averaged workability readings between three and four would be considered marginal, and a value greater than four should be rejected. Values of three or less are acceptable and the materials should be workable in the field. Table 5.2 summarizes the workability values for the submitted PPMs.

Table 5.2: Workability data

Product	Workability #
Albany Mix (Control)	2.5
Bond X	0.5
Elasti-Patch	0.75
Instant Road Repair	<=0.5
King Patch	>4.5
Optimix	1.0
Perma Patch	0.75
QPR2000	1.0
TAG8000	0.5
UPM	2.0

5.3 COHESION

The cohesion test includes compacting a cooled sample in a 101.6 mm (4 in) cylinder; extruding it and rolling it in a sieve with 25.4 mm (1 in) openings. The purpose of the test is to determine how well the sample sticks together. The amount of material that falls through the sieve openings after rolling is measured and used as an indication of cohesiveness.

The test method (FHWA-RD-99-168, Test A.2.2 and AASHTO TP44-94) specifies using 1200 g (2.65 lb) samples. Compacting a 1200 g cold mix sample in a standard Marshall mold would result in a sample cylinder about 100 mm (4 in) high. The Marshall mold that ODOT uses has a height of 75 mm (3 in). The 305 mm (12 in) sieve with 25.4 mm (1 in) openings accommodates an extruded sample with a 51 mm (2 in) height. For this reason, the test was done using ~600 g (1.3 lb) samples that compact to a height of 51 mm (2 in).

To maintain the sample at 4 °C (39.2 °F), the mold was cooled in a freezer prior to sample compaction. The cooler was used to maintain several samples at 4 °C.

The test method specifies laying the sieve against the edge of a table for ten seconds. This was interpreted to mean that the sieve is to be laid flat on a table top after rolling. The ten-second "rest period" following sample rolling is critical to the precision of this test. If too high or thick of a molded sample is used, passing material in the pan can accumulate and support loosely retained material.

Table 5.3 summarizes the cohesion test data. The FHWA recommends that averaged cohesion values for PPMs be greater than or equal to 60%. Figure 5.2 shows the test equipment.

Table 5.3: Cohesion test data

Product	% Retention on 1" screen	Average
Control Mix*	99.7	99.6
Control Mix*	99.5	
Bond-X	58.2	66.5
Bond-X	74.7	
Elasti-Patch	72.4	72.4
Instant Road Repair	99.7	99.7
King Patch	7.6	12.7
King Patch	17.7	
Optimix	87.2	87.2
Perma Patch	78.6	66.6
Perma Patch	54.5	
QPR2000	100.0	100.0
Tag 8000	96.6	96.6
UPM	100.0	99.9
UPM	99.7	

*Albany cold mix was soaked in water and drained prior to compaction

Figure 5.2: Rolling sieve and Marshall Hammer

The Perma Patch and UPM sales literature says that the surface material gets hard while material underneath remains semi-fluid, acting as an expansion joint. The manner in which a PPM cures could affect laboratory results such as the AASHTO TP44-94 cohesion test. Mixes that are not designed to have a perfectly solid cure may have lower cohesion values than mixes with other cure mechanisms.

5.4 COATING

The amount of binder material coating the rock, or percent coating, was observed using test method AASHTO TP40-94 on received materials. The test method is based on a visual inspection. The FHWA Pothole Manual recommends a 90% minimum coating specification. Table 5.4 shows the percent coating observed.

Table 5.4: Percent coating data

Material	Percent Coating
Albany Control	99
Bond-X	97
Elasti-Patch	99
Instant Road Repair	99
King Patch	95
Optimix	100
Perma Patch	99
QPR2000	95
Tag8000	100
UPM	99

5.5 DISCUSSION

All of the materials tested except King Patch passed the criteria for workability, cohesion, and coating. King Patch is a naturally occurring tar sand, unlike the other patching materials, which are designed mixtures. King Patch had a workability number of 4.5, which exceeded the FHWA recommended specification of 4.0. King Patch's average cohesion value was 12.7%, well below the FHWA recommended minimum specification of 60%. The laboratory data collected will be used for field performance comparisons.

6.0 MATERIAL COSTS

There are three ways to purchase pothole patching material:

1) purchasing from an asphalt concrete supplier;
2) contracting with an asphalt concrete manufacturer to mix the product; and
3) manufacturing the product in-house.

Manufacturing PPM in-house is the least costly. Contracting with an asphalt concrete supplier can be cheaper than purchasing by the dump truck load.

Many proprietary PPMs can be produced using mostly locally available materials. In the case of Optimix, only ~3% of the binder containing the adhesive and anti-strip additives have to be obtained from Optimix. Optimix recommends mixing a minimum of 360 Mg (400 t) of mix at a time. Some of the other suppliers, like QPR, can ship tankers of liquid binder.

Many highway maintenance yards produce their own PPMs in their yard. A pug mill is the only mandatory piece of equipment required for production. Some operations may require access to a laboratory to assure quality and access to a mixing tank for stirring binder. The Bend and Lakeview ODOT Maintenance yards have produced their own QPR2000 patch material stockpiles and will again be using QPR2000 for the upcoming 2000/2001 winter season.

Table 6.1 summarizes costs of pothole patching materials studied for this research project. Many of the materials have not been used in Oregon on a maintenance stockpile scale before (Bond-X, Elasti-Patch, Optimix, Perma Patch, and Tag 8000). Since 360 to 450 Mg (400 to 500 t) stockpiles of patching mix are made from a 27 Mg (~30 t) load of proprietary liquid binder, it is difficult to get exact costs until all deliverables have been priced.

Table 6.1: Pothole patching material costs

Material	Mix, Cost/ton	Binder, Cost/ton
Perma Patch	$75?	
Instant Road Repair	$350 (in buckets)	
Tag 8000	$152 -186	
Elasti-Patch		$550
Bond X	$55	$370
QPR2000	$38 (mixed at maintenance yard)	
UPM	$55 -68	
Optimix	$55	
HFMS-2SP	$55 - 68	$325
HFMS-2S		$249
Hot Mix	$30	

ODOT currently has contracts that include price agreements for UPM, HFMS-2S, MC 250 and HFMS-2SP. The American Society for Testing and Materials (ASTM) uses the designation HFMS-2S for emulsified asphalts that are used in stockpiled maintenance mixes (*ASTM D3628-1997*). The designation HFMS-2SP denotes that the emulsion is polymer modified. Old designations HFE-300 and HFE-300S correspond with HFMS-2S and HFMS-2SP respectively. The old designations can be found in current ODOT contracts. Current ODOT contracts can be found on the Oregon Department of Administrative Services' (DAS) website at: http://pub.das.state.or.us/purchasing/. Contacts for the above materials can be found in Appendix C.

7.0 SUMMARY, DISCUSSION AND RECOMMENDATIONS

7.1 SUMMARY

Table 7.1 presents the results of the laboratory testing and field evaluation by mix type. The majority of mixes performed well with the exception of King Patch, which failed the workability and cohesion test and did not stay in the natural pothole at Century Drive. Instant Road Repair was also noted to dish in the potholes at Century Drive and OR Route 226.

7.2 DISCUSSION

Cold mix pothole patching materials are useful for patching road pavement in any type of weather, whereas hot mix is generally applied during fair weather. Cold mix patching has advantages over other patching materials, such as hot mix. Cold mix can be stockpiled in a highway maintenance yard for several months at a time, making it convenient and accessible to patching crews. Crews can load needed amounts of material and return unused portions to a stockpile. Although hot mix material costs can be a fourth of the cost of a cold mix, hot mix patching has greater equipment and labor costs.

Earlier research has shown that cold mix pothole patches can provide permanent throw and roll repairs that last longer than four years, greater than 70% of the time (*FHWA 1998*). In the current study additional monitoring is needed to definitively prove the performance of one proprietary PPM over another. Results to date show that all of the manufactured potholes and most of the natural pothole test areas have performed satisfactorily. The natural pothole patch test areas on Oregon Route 226 and Century Drive experienced some proprietary pothole patching material failures over the past few months. On Century Drive, the two Albany Maintenance Yard stockpile material patches (control mixes) failed after one week, while several of the proprietary patch materials have lasted more than five months. Laboratory tests have been unable to differentiate the performance of various PPM products.

One objective of this study was to see if some proprietary mixes perform better on dense and open graded asphalt concrete pavements. Natural and manufactured potholes were constructed in both open and dense graded pavements. The low incidence of failures after six months of monitoring, makes it difficult to identify trends or draw conclusions about patching materials between the two types of asphalt concrete roadways.

The natural and manufactured potholes will be monitored for the next two years to evaluate long-term performance. In the interim, based on published literature, it is apparent that proprietary patching materials can provide superior performance. Determining which is more superior than the next in Oregon will only be determined through time.

Table 7.1: Summary of material performance

Product	Quantity & Location	M or N[1]	D or O[2]	Performance	**Laboratory Test Results** (acceptable limits in parentheses) Predominant Size % retained/size	Workability (< 4)	Cohesion (>= 60%)	Coating (>= 95%)	Comments
Bond-X	2-Century Drive	M	D	Good	60.3 / 2.36 mm (#8)	0.5	66.5%	97%	
	2-Wallace Rd	M	O	Good					
	3-Route 226	N	D	Good					Dishing observed on Hwy 226
Elasti-Patch	1-Century Drive	N	D	Good	68.4 / 2.36 mm (#8)	0.75	72.4	99	
	2-Route 226	N	D	Good					
	2-Century Drive	M	D	Good					
	2-Wallace Rd	M	O	Good					
HFMS-2SP	2-Century Drive	M	D	Good	41.2 / 4.75 mm (#4)	2.5	99.6	99	Natural patches installed in water filled holes on Century Drive failed.
	2-Century Drive	N	D	Poor					
	7-Route 226	N	D	Good					
	3-Ona Beach	N	O	Good					
Instant Road Repair	2-Century Drive	M	D	Good	40.6 / 2.36 mm (#8)	< 0.5	99.7	99	Tended to dish.
	2-Wallace Rd	M	O	Good					
	3-Century Drive	N	D	1x Fair, 2x Poor					
	4-Route 226	N	D	3x Good, 1x Fair					
	1-Ona Beach	N	O	Good					
King Patch	1-Century Drive	N	D	Poor	54.1 / 75µm (#200)	>4.5	12.7	95	Did not stay in hole.
Optimix	1-Ona Beach	N	O	Good	29.3 / 4.75 mm (#4)	1.0	87.2	100	
Perma Patch	2-Wallace Rd	M	O	Good	65.9 / 2.36 mm (#8)	0.75	66.6	99	Tended to dish.
	6-Route 226	N	D	4x Good, 2x Fair					
QPR 2000	2-Century Drive	M	D	Good	44.1 / 6.3 mm (¼")	1.0	100	95	Large aggregate size may inhibit dishing
	2-Wallace Rd	M	O	Good					
	1-CorvallisBypass	N	O	Good					
	3-Route 226	N	D	Good					
	2-Ona Beach	N	O	Good					
Tag 8000	1-Century Drive	N	D	Good	53.7 / 6.3 mm (¼")	0.5	96.6	100	Large aggregate size may inhibit dishing
	1-Route 226	N	D	Good					
	2-Century Drive	M	D	Good					
	2-Wallace Rd	M	O	Good					
UPM	2-Century Drive	M	D	Good	43.8 / 2.36 mm (#8)	2.0	99.9	99	Dishing observed on Hwy 226
	2-Wallace Rd	M	O	Good					
	2-Century Drive	N	D	Good					
	2-Route 226	N	D	1x Good, 1x Fair					
	1-Ona Beach	N	O	Good					
	1-CorvallisBypass	N		Good					

[1] M = Manufactured Pothole; N = Natural Pothole
[2] D Original pavement is dense graded; O = Original pavement is open graded.

7.3 RECOMMENDATIONS

The following recommendations are based on the literature review, laboratory investigation and preliminary field investigation.

1. ODOT maintenance crews should pursue the use of proprietary patching materials at least for potholes that are difficult to keep patched.

2. Proprietary mixes submitted for use should be evaluated at a minimum for:

   - Gradation with an allowable P#200 of less than 5%;
   - Workability with a workability number less than 4 as determined by AASHTO TP43-94;
   - Coating with a minimum coating of 90% as determined by AASHTO TP40-94.

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APPENDICES

APPENDIX A:

POTHOLE PATCH CONSTRUCTION DATA

(MANUFACTURED HOLES)

MANUFACTURED POTHOLES

Century Drive – Dense Graded Pavement

On March 3, 2000 Liz Hunt, the Albany Maintenance Crew, and Marcus Berlin created 16 potholes with a jack hammer and filled them with a variety of pothole patching materials. The holes were concave in shape with tapered edges, 51 mm (2 in) minimum deep in the center and 406 mm (16 in) in diameter. A 406 mm (16 in) round template and spray paint was used to mark areas for uniform jackhammering.

The maintenance crew consisted of two flaggers and three laborers. Temperatures were around 49 °F with a pavement temperature of 51 °F. The humidity was 59%. The sky was overcast with some sun.

This test site is just north of a curved section. Pavement condition can be described as poor to fair condition with few patches and some alligator cracking.

The following is the table of materials to fill each pothole. Efforts were used to randomize the order of placement of the specific materials. All holes were placed within 3 ft (0.915 m) of the skip stripe.
These test patches were overlaid in September, 2000, but will be monitored for compatibility.

Table A.1 lists the order and shape of patches for the Century Drive manufactured holes.

Table A.1: Century Drive manufactured pothole patches

Material Name	Number	Depth, in (mm)	Installed Shape
Cold Mix	1MS	2 (51)	Flush
Bond-X	1MP	1 ½ (38)	+¼ ” (+6 mm)
Elasti-Patch	2MP	1 ½ (38)	+¼ ” (+6 mm)
Elasti-Patch	3MP	2 (51)	+¼ ” (+6 mm)
Cold Mix	2MS	2 (51)	–⅛ ” (-3 mm)
UPM	4MP	1 ¾ (44)	–0
UPM	5MP	2 ¼ (57)	+⅛ ” (+3 mm) S, –⅛ ” (+3 mm) N
Tag8000	6MP	2 ¼ (57)	+¼ ” (+6 mm)
Instant Road Repair	7MP	2 (51)	–⅛ ” (-3 mm) SE, +⅛ ” (+3 mm) NW
Cold Mix	3MS	1 ¾ (44)	0
Bond-X	8MP	2 ½ (64)	+1/16 ” (+1.6 mm)
Tag8000	9MP	2 (51)	+⅛ ” (+3 mm)
Cold Mix	4MS	2 (51)	0
Instant Road Repair	10MP	2 ½ (64)	+⅛ ” (+3 mm)
QPR2000	11MP	2.5 (64)	+⅛ ” (+3 mm)
QPR2000	12MP	2.5 (64)	+⅛ ” (+3 mm)

Wallace Road – Open Graded Pavement

Andrew Griffith and Liz Hunt coordinated the installation of patching materials on Wallace Road on March 7, 2000 between 8:30 and 11:30 am. The installation was done by the Salem Bridge Crew (six workers) who provided traffic control, labor for jack hammering and material installation. The weather was dry with overcast skies. The temperature varied from 46 °F at 9:50 AM to 48 °F at 10:35 AM. Pavement temperatures were near 50 °F. The pavement condition is rated as fair.

Andrew and Liz initially marked out the location for 18 holes including 14 for seven different proprietary mixes (two potholes/mix) and four for Salem Maintenance cold mix. The holes were located in the southbound lane of Wallace Road near MP 13, in the left wheel track (about two feet off of the skip stripe). The order of the holes and the distances between them were determined by using a random number table. Variable distances between holes were established to avoid periodicity.

The cold mix was obtained from Porter Yett. One of the workers reported that the cold mix used by Salem had been working well and appeared to conform to the holes well as compared to materials from previous years.

Following the marking of the holes, the Bridge Crew set up traffic control and potholes were created using a jackhammer. The holes were about 381 mm (15 in) in diameter with measured depths near 51 mm (2 in). Photographs were taken of the empty holes just prior to filling. All photographs were taken facing north.

The holes were filled by either pouring material out of the buckets or by shoveling the material out. Most of the materials were poured out with little difficulty. The materials were then moved around with a shovel and tamped a few times for initial compaction. Final compaction was done with the Salem Maintenance truck filled with cold mix. About six passes were made over each patch to insure compaction.

After final compaction, final measurements were taken to determine if the patch was bowl shaped, crowned or flush with the existing pavement. Photographs were then taken of the finished patch for future reference.

Table A.2 lists the order and shape of patches for the Wallace Road manufactured holes.

Table A.2: Wallace Road manufactured pothole patches

Material Name	Number	Depth, in (mm)	Final Shape
Perma Patch	1WP	2 ½ (64)	¼" (6 mm) crown
Bond-X	2WP	2 (51)	¼" (6 mm) crown
Cold Mix	1WS	2 (51)	Flush
Cold Mix	2WS	2 (51)	Slight dishing on edges
Perma Patch	3WP	1 ⅞ (48)	Slight crown
Instant Road Repair	4WP	2 ⅛ (54)	Flush
Elasti-Patch	5WP	2 ¼ (57)	¼" (6 mm) crown
QPR 2000	6WP	2 ⅜ (60)	⅜" (10 mm) crown
Instant Road Repair	7WP	2 (51)	Slight crown
UPM	8WP	2 ⅛ (54)	Flush
QPR 2000	9WP	2 (51)	⅜" (10 mm) crown
TAG 8000	10WP	2 ½ (64)	Slight crown
UPM	11WP	2 ¼ (57)	Flush
TAG 8000	12WP	2 ⅛ (54)	¼" (6 mm) crown
Cold Mix	3WS	2 ¼ (57)	Slight crown
Bond-X	13WP	2 (51)	Flush
Cold Mix	4WS	2 (51)	Flush
Elasti-Patch	14WP	2 ⅛ (54)	Slight Crown

Material handling characteristics (workability) were discussed for each of the materials. The results are included in Table A.3.

Table A.3: Material workability

Material	Workability
Bond-X	Easily poured out of bucket.
Elasti-Patch	Stiffer than Bond-X, Instant Road Repair and Perma Patch. Coarser material. Moderate workability.
Instant Road Repair	Easily shoveled out of bucket. Slightly stiffer than Bond-X and Perma Patch. Finer mix.
Perma Patch	Easily poured out of bucket.
QPR 2000	Poured out of bucket. Coarser aggregate requires more work. Moderate workability.
TAG 8000	Poured out of bucket. Coarser aggregate. Stiff-moderate workability.
UPM	Tough to open bucket; get material out of bag. Stiffer, fine material with some clumps. Moderate workability.

Century Drive Manufactured Holes Monitoring Data

Pothole material height relative to the surrounding pavement was measured since filled pothole shape can affect pavement ride and overall patch performance. Negative values indicated some dishing and positive values indicate a crown or possibly some shoving. Table A.4 summarizes pothole height monitoring data for the manufactured pothole patches on Century Drive. As noted earlier, the Century Drive manufactured potholes were overlaid in September 2000.

Table A.4: Century Drive manufactured pothole monitoring data

Material Name	Number	Shape 3/3	Shape 3/17	Shape 5/4	Shape 6/15	Shape 8/24
Cold Mix	1MS	0	-1/4”	-0	-3/8	-5/16
Bond-X	1MP	+3/8	+3/8	+0	+1/8	+3/16
Elasti-Patch	2MP	+1/4	+3/8	+0	0	+1/8
Elasti-Patch	3MP	+1/4	+1/4”	0	0	+1/8
Cold Mix	2MS	-1/8	-1/4	-3/8	-3/8	-5/16
UPM	4MP	0	+1/4	-3/8	-3/8	-5/16
UPM	5MP	+1/8 N, -1/8 S	-0	-1/4	-1/4	-3/16
TAG 8000	6MP	+1/4	-1/8	0	0	-1/8
Instant Road Repair	7MP	+1/8 N, -1/8 S	-1/4	-7/16	-1/4	-3/8
Cold Mix	3MS	0	+0	-3/16	-1/8	-1/4
Bond-X	8MP	+1/16	+0	0	0	-1/8
TAG 8000	9MP	+1/8	+0	-0	0	-1/8
Cold Mix	4MS	0	+1/4	-1/4	-1/8	-3/16
Instant Road Repair	10MP	+1/8	+3/16	0	0	-5/16
QPR 2000	11MP	+1/8	0	0	0	0
QPR 2000	12MP	+1/8	+3/16	0	0	-1/8

Wallace Road Manufactured Holes Monitoring Data

Table A.5 summarizes pothole patch height data for the Wallace Road test site.

Table A.5: Wallace Road manufactured pothole monitoring data

Material	Number	Height 3/7	Height 3/17	Height 5/5	Height 6/15	Height 8/25
Perma Patch	**1WP**	+1/4”	+0	+0	0	+1/8”
Bond-X	2WP	+1/4	+0	+0	0	-1/8
Cold Mix	1WS	0	+0	+0	-1/16	-1/8
Cold Mix	2WS	0 slight dishing on edges	-5/16”	-3/8”	-1/8	-3/8
Perma Patch	3WP	+0	-0	+0	0	-1/8
Instant Road Repair	4WP	0	-1/4	-5/16	-1/4	-3/8
Elasti-Patch	5WP	+1/4	+0	+0	+1/8	+1/16
QPR 2000	6WP	+3/8	+0	+0	+1/8	+3/16
Instant Road Repair	7WP	+0	-3/16 CL side +1/8 center	-5/16	-1/4	-3/8
UPM	8WP	0	+1/4	-7/16	-3/8	-3/8
QPR 2000	9WP	+3/8	0	+0	0	+1/8
TAG 8000	10WP	+0	+1/8	-0/+0	-1/8	-1/8, +1/8
UPM	11WP	0	-1/4	-1/4	-3/8	-3/8
TAG 8000	12WP	+1/4	+0	+0	0	-0/+0
Cold Mix	3WS	+0	+3/8	-5/16	-1/8	-3/8
Bond-X	13WP	0	-1/4	-5/16	-1/8	-3/8
Cold Mix	4WS	0	-3/8	-1/4	-1/8	-1/4, +1/8
Elasti-Patch	14WP	+0	Shoved to shoulder	0	-1/8	-1/4

APPENDIX B:

NATURAL POTHOLE PATCH INSTALLATION DATA

Century Drive (Dense Graded Pavement) Natural Pothole Patch Construction Notes

Potholes were filled with proprietary patching materials at Century Drive in Albany, February 25, 2000, between 10 AM and 12 PM. Century Drive is a two-lane country road that parallels the I-5 freeway on the east side for about two miles in the Millersburg area just North of Albany. It's an old road with a 25 mm (1 in) dense mix overlay that has been failing for some time. Evidence of previous patching occurs along the entire roadway, along with severe alligator cracking. Traffic includes heavy dump trucks from an aggregate yard. Traffic volume is low.

Liz Hunt, and Terry, Ron, and Earl of the ODOT Albany Maintenance crew, and Marcus Berlin patched nine potholes with ODOT cold mix and four proprietary cold mix patching materials.

The weather was cold and wet, with a 10 AM temperature of 47 °F and a 12 PM temperature of 51 °F. The relative humidity was 50%. The rain drizzled off and on.

The operation included two pickup trucks. The ODOT Albany Maintenance pickup was equipped with shovels, brooms and ODOT cold patching mix. The second pickup carried four buckets of proprietary cold patching mix. Each bucket contained a different patching product.

We started looking for potholes toward the north end of Century Drive, near the gravel yard turnoff. Most of the potholes appeared to be the result of alligator cracking and overlay delamination. Potholes in the wheel path were selected.

The loose material in the pothole was picked with a shovel. Loose material and water was swept out of the holes as much as possible. Often times some water remained in the hole. Patching material was pored from a bucket or shoveled into the hole. The back of a flathead shovel was used for immediate compaction. The maintenance truck was used to run over the filled holes and wheel passes were counted. On occasion a passing truck would oblige by running over a newly filled hole.

Potholes were marked and identified as the ODOT "standard" cold mix or a "proprietary" cold mix. Potholes were numbered in order of patching. Pothole "1P" was the first hole to be patched with a proprietary mix and pothole "1S" was the first hole to be patched with the standard mix.

Silver spray paint was used to mark the circumference and the ID designation was painted on the outer edge of the fog line. A "Pothole Installation Form" was used to document each hole.

Standard cold mix was used to fill two holes and the four different proprietary mixes were used to fill seven holes. Table B.1 includes details collected during placement.

Table B.1: Summary of natural pothole installations on Century Drive

ID	Product	Location: Century Dr., Albany	Pothole Condition	Workability	Installation Compaction
1P	TAG8000	N bound lane Off skip stripe Near "37949 Jefferson Fire Dist." sign	2" d, 18"dia delamination old mix removed, wet	Easy	7 wheel passes 2 workers hole swept
2P	UPM	S bound lane Driver wheel path 8' S of S bound site post 20'S of "Emergency Parking Only" sign	1"d, 18"L x 11"W, next to old patch on skip line	Tough getting out of bag, a little harder to work than 1P	½ bag 7 wheel passes
3P	Instant Road Repair	S bound lane R wheel path Next to "Emergency Parking Only" sign	5'L x 3'W 1"d, very shallow delamination with underlying pavement alligator cracked	Harder than 1P and 2P, dry mix, not as sticky as 1P & 2P	Used 2 buckets, Extra sweep care, tamped edges, 8 wheel passes, 3 workers, only 85% covered
4P	KOCH	SB lane, R wheel path, just S of concrete wall at paper mill, 5th fence post north from end	1"d- 3' x 1.5' Delamination, alligator cracking underneath	Most workable, "too easy"	Easy to compact, will it set 6 wheel passes
5P	UPM	NB R wheel path 2nd fence post from S end just across from electrical pole at paper mill concrete structure	Filled with water 2"d	"	3 wheel passes with dump truck
6P	Instant Road Repair	SB down hill, L wheel path, east of "Viewcrest I5" sign Just S of creek bridge	12" x 11" x 1.5" rough bottom with some water	"	8 wheel passes High Traffic
7P	Instant Road Repair	Next to 6P, NB lane, L wheel path	3' x 12" x 1" uneven bottom	"	
1S	Standard Mix	NB, skip stripe to wheel path 12'N of site marker	4' x 18" x 1"d delam. Alligator bottom		Swept out water 8 wheel passes
2S	Standard Mix	Next to 6P, SB lane, L wheel path	3.5' x 2' 2" deep S end 1" deep N end water in hole delam		

On May 8th a natural pothole about 64 mm (2.5 in) deep at the south end of the manufactured pothole section of the Century Drive evaluation test area was filled with King Patch pothole patch material, a naturally occurring tar sand with a sandy aggregate sized gradation. Conditions were rainy with water in the pothole. The throw and roll technique was used. This hole was checked on May 14th, no evidence that the hole had been patched a week earlier could be found. The King Patch material failed to stay in the pothole one week.

Highway 226 (Dense Graded Pavement) Natural Pothole Patch Construction Notes

On May 17, 2000, Ron Gress and Terry of the ODOT Maintenance crew, and Marcus Berlin patched 28 potholes on Highway 226, between Scio and Lyons. We started patching holes just north of Scio and worked our way north to Lyons. The weather was cloudy, 55 °F, and dry.

Proprietary products were randomly selected and placed in potholes. Nine of the holes were patched with locally produced cold mix to serve as a control. Patches had silver circles spray painted around them. Proprietary products were numbered from 1 to 18 in order of installation, on the edge of the road near the fog line. The potholes patched with the standard mix were marked with an S.

The table below describes location of the naturally occurring potholes that were patched. NB and SB designate which lane the pothole can be found. Driver and passenger columns designate which wheel path the pothole is located. The MP column is the location relative to mile posts.

Table B.2: Pothole locations on Highway 226

ID	Product	NB	SB	Driver	Pass.	MP	Notes:
1	Instant Road Repair	X		X		12.9	Delamination
1S	Standard Mix	X		X		12.9	Delamination
2S	Standard Mix	X		X		12.9	Delamination
2	Bond-X		X		X	13.1	Delamination
3	Perma Patch		X	X		13.15	
3S	Standard Mix	X			X	13.17	
4S	Standard Mix		X	X		Power line	
4	QPR 2000	X			X	13.2	Delamination
5	UPM		X		X	14.4	
6	Elasti-Patch	X			X	14.5	
7	Perma Patch	X		X		15.0	
7a	Perma Patch		X		X	15.3	Small
8	Tag 8000		X	X		15.3 Big/thin	Delamination
9	QPR2000	X		X		15.8	Repatch
S	QPR2000	X		X		15.8	Repatch
10	Bond-X		X	X		16.5	
11	Perma Patch	X		X		17.9	Delamination
S		X		X		17.9	
S			X	X		18.0	
12	QPR 2000	X			X	18.0	
S		X			X	18.5	
13	Elasti-Patch	X			X	Thomas Cr. Rd.	
14	Perma Patch					Echo hill	Small
15	Instant Road Repair					19.4	
16	UPM	X			X	19.8	
17	Bond-X	X			X	20.4	
18	Perma Patch	X		X		20.9	Wet, hilltop
S			X	X		21.1	

Corvallis Bypass at Highway 34 (Open Graded Pavement) Natural Pothole Patch Construction Notes

On May 31, 2000 Michelle Baldwin and Marcus Berlin patched two holes on the Highway 34 Bypass near the Hwy 34 intersection. The weather was sunny, warm and dry. These holes were caused by overlay failure over metal signal plates. The road and pothole edges were open graded. Both these holes were in the left wheel path of the right turn lane onto westbound Highway 34.

One hole was patched with UPM and the other with QPR 2000. Patches were about 19 mm (¾ in) thick.

As of July 31, 2000, both of these patches were in good condition.

Route 9 at Ona Beach State Park (Hwy 101) Construction Notes

On July 27, 2000 at 10 AM, Andrew Baldwin of the Newport ODOT Maintenance crew, Dave Horton, Marcus Berlin and two flaggers patched 6 potholes on a curve on Highway 101, across from the entrance to Ona Beach State Park. The weather was sunny, 55 °F, and dry. Patches were placed under dry conditions.

The open graded pavement was in near new condition. The test site was damaged by a large piece of equipment that had tipped over. The damaged potholes included both 51 mm (2 in) deep gouges and 25 mm (1 in) scratches. The six patches are congregated around the left wheel path of the northbound lane. Patches one through three are in the wheel path, patches four and five are just outside of the wheel path towards the center of the northbound lane. Patch six is in the southbound lane in between the centerline and the left wheel path.

Table B.3. Summary of patching repair notes for Hwy 101 at Ona Beach.

Patch ID #	Material Brand	Depth	Wheel Passes	Description
1	Optimix	1 ⅜ ”	2	~30” L * 2”w scratch
2	Albina, Albany Maintenance Stockpile	1”	1	~30” L scratch
3	UPM, Salem Maintenance Stockpile	2 ¼” & 1”	3	12*18”oval & 6”round (2 patches)
4	Instant Road Repair	1 ½” & ½”	5	2*4’ L shaped scratch 2” wide
5	QPR 2000	1 ¾” & ½”	4	3 ½’ * 3”w scratch + 2 gouges
6	Instant Road Repair	1”	0	6’L * 2”W scratch

The figures below show the repair site prior to patching and three of the patches prior to compaction.

Figure B.1: Hwy101 at Ona Beach State Park prior to patching

Figure B.2: Three Ona Beach patches prior to compaction

Century Drive Natural Pothole Monitoring

The table below summarizes observations made during field monitoring. Some of the overlays were large and may not have been placed over the patching materials due to poor product performance.

Table B.4: Century Drive natural pothole monitoring

Material Name	ID	3/17 Inspection	5/4 Inspection	6/15 inspection	8/24 inspection
TAG 8000	1P	Some raveling around edges	15% repatched, some spalling and dishing	Patched over Large overlay	overlaid
UPM	2P	Loss of mix in center	Looks good, no spalling	level	flush
Instant Road Repair	3P	Some spalling	10% loss at patch center	overlaid	Overlaid (will be monitored for compatibility)
Elasti-Patch	4P	Looks good	Looks good	level	flush
UPM	5P	Breaking away on edges	Looks good	-¼ ”	95% patched, a little spalling
Instant Road Repair	6P	Low in hole	¾” dishing	Level, some spalling	1 ⅛ ” dish
Instant Road Repair	7P	Low in hole	-	-⅜ ”	7/16” dish
Standard Mix	1S	Raveled out	60% loss	Level 60% gone	~55% gone
Standard Mix	2S	Repatched?	failed	repatched	repatched

Highway 226 Natural Pothole Monitoring

The table below summarizes location and condition of potholes on 5/19 and 8/24. The patching materials performed well, staying in the naturally occurring potholes. Figures B.3 through B.5 show the patches. The figures show how a Perma Patch repair compares to an Albany Maintenance Yard stockpile material. The Perma Patch material had the fewest failures of any of the proprietary materials tested in the large SHRP H-106 pothole patching material study. The ODOT Perma Patch repair was on curve in the wheel path next to an Albany Maintenance stockpile patch that is still intact.

Table B.5: Pothole monitoring on Highway 226

ID	Product	5/19 Inspection	8/24 Inspection
1	Instant Road Repair	-6 mm (-¼")	-6 mm (-¼")
1S	Instant Road Repair	-13 mm (-½")	-8 mm (-5/16")
2S	Instant Road Repair	-10 mm (-⅜")	-13 mm (-½")
2	Bond-X	-10 mm (-⅜")	-11 mm (-7/16"), -6 mm (-¼")
3	Perma Patch	-11 mm (-7/16")	-6 mm (-¼")
3S	Standard Mix	+0 mm (+0 ")	+3 mm (+⅛")
4S	Standard Mix	-10 mm (-⅜")	-3 mm (-⅛")
4	QPR 2000	+6 mm (+¼")	+6 mm (+¼")
5	UPM	-10 mm (-⅜")	-8 mm (-5/16")
6	Elasti-Patch	0 mm (0 ")	0 mm (0 ")
7	Perma Patch	+0 mm (+0 ")	0, -3 mm (-⅛") shove forward
7a	Perma Patch	+0 mm (+0 ")	0, -3 mm (-⅛") shove forward
8	Tag 8000	-10 mm (-⅜")	-8 mm (-5/16")
9	QPR2000	-13 mm (-½")	0 mm (0 ")
S	Cold Mix	-19 mm (-¾")	-6 mm (-¼")
10	Bond-X	-13 mm (-½")	-13 mm (-½"), -6 mm (-¼"), -6 mm (-¼")
11	Perma Patch	-6 mm (-¼") failed on south end	20% spalled out
S		-6 mm (-¼")	-3 mm (-⅛"), +3 mm (+⅛")
S		+6 mm (+¼")	0 mm (0 ")
12	QPR 2000	+6 mm (+¼")	+6 mm (+¼"), -3 mm (-⅛")
S	Cold Mix	+6 mm (+¼") missing material on south end	-0 mm (-0 ")
13	Elasti-Patch	0 mm (0 ")	0 mm (0 ")
14	Perma Patch	+8 mm (+5/16")	0 mm (0 ")
15	Instant Road Repair	+13 mm (+½")	0 mm (0 "), -8 mm (-5/16")
16	UPM	+13 mm (+½")	-13 mm (-½")
17	Bond-X	-16 mm (-⅝")	-8 mm (-5/16")
18	Perma Patch	-6 mm (-¼")	-13 mm (-½")
S		+0 mm (+0 ")	-6 mm (-¼") shoving

Figure B.3: Perma Patch failure on Hwy 226

Figure B.5: Albany material performed well

Figure B.4: Close-up of Perma Patch failure

Corvallis Bypass

Michelle Baldwin and Marcus Berlin patched two holes on the Highway 34 Bypass near the Highway 34 intersection on May 31, 2000. These holes were caused by delamination of the overlay over metal signal plates. One patch was UPM and the other QPR 2000. The patches were about 19 mm (¾ ") thick. Conditions were sunny and dry.

Both of these patches have adhered well to the metal signal plates. These patched performed well over the three summer months. A drive-by inspection in September found no failures.

APPENDIX C:

POTHOLE PATCHING MATERIAL MANUFACTURERS

Pothole Patching Material Manufacturers

Bond-X
Seaboard Asphalt Products
Shawn Campbell
3601 Fairfield Rd
Baltimore, MD 21226
800-536-0332 410-355-0330
410-355-0330fax
[sales@seaboardasphalt.com]

Elasti-Patch
Koch Materials
Steve Vandebogart
Spokane, WA
509-487-4560ext11
509-995-1924cell
[VanDeboS@kochind.com]

HFMS-2SP/HFE-300S
Albina Asphalt
John Gunter
3246 NE Broadway
Portland, OR 97232
503-281-1161
503-362-6180fax
503-329-6104cell
800-888-5048
www.albina.com

Instant Road Repair
Safety Lights Co.
Jeff Parson
2324 SE Umatilla
Portland, OR 97202
503-235-8531

Optimix Cold Patch
Jeff Axel
555 Broad Hallow Rd., Ste 216
Melville, NY 11747
516-293-6300
516-293-6317fax
Optimix, Inc. [optmx@erols.com]

Perma Patch
National Paving & Contracting
Robert Storrs
4200 Menlo Dr.
Baltimore, MD 21215
410-764-7117
410-764-7137fax
http://www.permapatch.net/

QPR 2000
Quality Pavement Repair
Tony Fargnoli 800-388-4338,
716-924-2116,
US Pro-Tec Inc.
23611-101 Chargrin Blvd.
Beachwood, Ohio 44122
1-800-263-7511

TAG 8000
Infratech Polymer
Roger Johnson
#4 - 19747 Telegraph Trail
Langley, BC U3A 4P8
800-567-4888
604-888-8191fax
604-290-4320 mobile

UPM High-Performance
Unique Paving Materials
Jeff Bucell
3993 East 93rd St.
Cleveland, Ohio 44105
800-441-4880
216-441-0148fax

UPM
Porter W Yett Co.
Steve Yett
Portland, OR
503-282-3251