Strategic Highway Research Program Pothole Repair Materials and Procedures

THOMAS P. WILSON

As funding for rehabilitation of pavements becomes more scarce, the ability of maintenance agencies to extend pavement service life with patching and other maintenance techniques becomes more critical. The Strategic Highway Research Program has conducted a study of the effectiveness of several pothole patching materials and methods. Eight test sites were installed throughout the United States and Canada, and the performance of the patches was monitored at those sites. The ability to identify good-quality patching materials for use by highway agencies will benefit many agencies, from state departments of transportation to county, city, and municipal streets and roads departments. If agencies can reduce the amount of patch material purchased, as well as the manpower required by increasing the life expectancy of patches, the potential exists to save millions of dollars each year on patching operations. The "patchability" of an area is determined by a number of factors beyond the control of the average maintenance crew—traffic, underlying support, drainage, climate and so on. However, the quality of patching materials and methods used does appear to affect the durability of patches placed. Certain materials will work better than others under different conditions and have the potential to provide significant cost savings to agencies responsible for the maintenance of asphalt-surfaced pavements.

The Strategic Highway Research Program (SHRP) H-106 pothole repair project includes eight test sites distributed across four climatic regions: wet-freeze, dry-freeze, wet-nonfreeze, and dry-nonfreeze. Table 1 gives the different sites along with characteristics of each. As this information indicates, the sites in Ontario and Oregon were installed during colder "winter" conditions (average temperatures between −12 and 4°C), as opposed to the other six sites, which were installed during warmer conditions (average temperatures between 7 and 24°C).

Monitoring of the test sites started immediately after construction, was performed throughout the project, and will continue until all of the sites have been overlaid or rehabilitated. Several documents have been generated to help disseminate the information gained during the initial portion of this experiment. These documents include

- Innovative Pothole Repair Materials and Procedures for Asphalt Surfaced Pavements—Final Report,
- Pothole Repair Materials and Procedures—Manual of Practice, and
- Pothole Repair Materials and Procedure—Training and Implementation Package.

ERES Consultants, Inc., Eight Dunlap Court, Savoy, Ill. 61874.

TEST SITE INSTALLATION

The first step in the installation process consisted of removing existing pothole patches along a stretch of pavement to "create" potholes for the experiment. This avoided a situation in which a participating agency would have had to leave open potholes before installing the test sites. A reasonably short test section was desired—in an attempt to minimize the differences in traffic, pavement cross section, drainage, subgrade type and support—for each patch. When wet conditions were not present as the patches were placed, water was added to the created potholes and allowed to sit in the holes until the patch materials were placed. All patching operations were intended to model as closely as possible the conditions, equipment, and productivity that would be experienced during a typical, nonexperimental patching operation.

The installation process produced a series of experimental and control patches placed in each section of roadway. Two experimental material types were alternated with one set of control patches. The resulting placement order is as follows:

E1, C, E2, E2, C, E1, E1, C, E2, E2, C, E1, . . .

where

E1 = first experimental material-procedure combination,
C = control material-procedure combination, and
E2 = second experimental material-procedure combination.

The installation procedure continued until all of the desired combinations and corresponding control patches had been placed at each site. Information about the patch location, patch size, manpower and equipment requirements, and rates of production for the various patching operations was also collected during the installation procedure.

MATERIALS

The materials included in the H-106 pothole project are both proprietary and state-specified materials, all of which received favorable reviews from a previous SHRP project, H-105 (*1*). Table 2 gives the materials and procedures used during each of the installations. The UPM High Performance Cold Mix, QPR 2000, and Perma-Patch are proprietary cold-mix materials intended to be stockpiled and used throughout a patch-

TABLE 1 Locations of Pothole Repair Test Sites

Test Site	Route	No. of Lanes	2-dir. ADT (vpd)	Annual Precipitation[a]	Annual Days < 32 °F [a]	Installation Dates	Total Patches Placed
Alturas, CA	US 395	2	1,000	14 in (0.36 m)	190	5/6- 5/9/91	140
Vandalia, IL	I-70	4	15,000	38 in (0.96 m)	100	4/1-4/4/91	150
Las Vegas, NM	Rte 518	2	1,700	14 in (0.36 m)	120	4/8-4/11/91 and 5/21/91	140
Modoc Point, OR	US 97	2	5,400	16 in (0.41 m)	180	2/5-2/9/91	200
Greenville, TX	FM 1570	2	7,500	40 in (1.02 m)	50	3/25-3/29/91 and 4/30/91	150
Draper, UT	I-15 Frontage	2	1,500	16 in (0.41 m)	180	4/22-4/25/91	140
Bradford, VT	Rte 25	2	2,100	37 in (0.94 m)	160	5/13-5/16/91	140
Prescott, ON	Rte 2	2	4,500	32 in (0.81 m)	140	1/6-1/8/92 and 2/25-2/26/92	190

[a] Historical averages from the *Climatic Atlas of the United States*, 1968.
°C = (°F - 32) ÷ 1.8.
ON = Ontario

ing season. The PennDOT 485, PennDOT 486, and modified HFMS-2 are cold mixes that are produced according to the specifications of state departments of transportation and are also intended to be stockpiled and used as needed throughout a patching season. Besides these materials, each agency provided some of their "everyday" cold mix material so that a direct comparison could be made between the H-106 materials and the types of material being used on a daily basis by different agencies across the country.

Besides the different cold-mix materials used at each site, sets of experimental patches were also placed using spray injection patching devices. The spray injection devices were provided by Duraco Industries Inc. (the Durapatcher), Road-Patch Services Inc. (the RoadPatcher), and the Illinois and Oregon departments of transportation (Rosco Asphalite 200). These devices carry virgin aggregate and asphaltic materials (generally emulsion, heated to about 80°C) to the site of the pothole, blow out any water or debris that may be present, and then shoot both the aggregate and the asphalt into the hole, creating a patch. The pothole is filled with the material and can be immediately opened to traffic, as can all of the repair types included in this project.

TABLE 2 Material and Procedure Combinations

Patch Type	Material	Procedure	Sites Installed: CA	IL	NM	ON	OR	TX	UT	VT
A[a]	UPM High-Performance Cold Mix	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
B		Edge seal	✓	✓	✓		✓	✓	✓	✓
C		Semipermanent	✓	✓	✓	✓	✓	✓	✓	✓
D	PennDOT 485	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
E	PennDOT 486	Throw-and-roll	✓	✓	✓		✓	✓	✓	✓
F	Local material	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
G	HFMS-2 w/Styrelf®	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
H	Perma-Patch	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
I	QPR 2000	Throw-and-roll	✓	✓	✓	✓	✓	✓	✓	✓
J	Spray injection	Spray injection	✓	✓	✓	✓		✓	✓	✓
K	QPR 2000	Edge seal					✓			
L		Semipermanent				✓	✓			
M	PennDOT 485	Edge seal					✓			
N		Semipermanent				✓	✓			
X	Local material	Surface seal		✓						
X	Local material	Propane torch					✓			

[a] Control patch type for all sites.

REPAIR METHODS

The methods used for the installation of the H-106 patches are referred to as throw-and-roll, edge seal, semipermanent, and spray injection. For this project, the throw-and-roll procedure consisted of placing material into an unprepared pothole, backing the tires of the material truck over the patch between four and eight times, and then moving on to the next location. In most cases the potholes were still full of the water that had been added, so that the patching material displaced the water as it was installed. No additional effort was required after the truck had compacted the patch other than to add more material if the compacted patch appeared to be low. A minimal crown was left in the compacted patches to allow for further compaction by traffic.

The edge seal procedure was performed only with the throw-and-roll repairs. The procedure consisted of placing a swath of asphaltic material (generally an emulsion or cutback) on the pavement surface using a brush or a broom. The seal was placed around the perimeter of the patch and then covered with sand to prevent tracking by passing vehicles. The edge seal was generally placed 1 day after patch installation to allow water on the surface of both the patch and pavement to dry, providing better adhesion. The edge seal patch procedure was included to evaluate the potential for inhibiting the intrusion of moisture at the patch-pavement interface.

The semipermanent procedure included saw-cutting or jackhammering the edges of the pavement around the pothole to achieve straight, sound sides for the patch; removing the water and debris from the pothole; placing the material (in lifts, where pothole depths were excessive); and compacting the patches using a device other than the truck tires. No tack material was used for these repairs. The compaction devices used in the project included a single-drum vibratory roller, a vibratory plate compactor, dual steel-wheeled rollers, and rubber-tired rollers, depending on what each agency had available. The procedure requires additional manpower and equipment but has produced more durable patches in previous studies when compared to throw-and-go repairs (*2*).

The Duraco and Rosco spray injection devices used in this project consisted of trailer units, which housed a heated asphalt tank and the aggregate and asphalt delivery systems. The trucks towing the trailers were outfitted with a chute for feeding aggregate from the truck into the aggregate delivery system on the trailer. The Roadpatcher device includes the same components as the others but contains the aggregate and asphalt in a single vehicle rather than a truck-trailer setup.

In addition to these procedures, each participating agency was able to add one repair type. The crews in Illinois and Oregon requested that more repairs be placed using their everyday patching procedures. In Illinois this procedure consisted of placing throw-and-roll patches and returning the next day to place a surface seal over the entire patch. The surface seal consisted of bituminous material covered with sand—like the edge seal except that it was placed over the entire patch surface rather than just the edges.

In Oregon the everyday procedure included placing an emulsified asphalt as a tack material, heating the tack with a propane torch to accelerate "breaking," and then placing the cold mix. As the cold mix is placed, it too is heated with the propane torch.

RESULTS

The currently available results of the H-106 pothole repair project include the following:

- Complete productivity information from all test site installations;
- Five rounds of performance evaluations for Texas, Illinois, New Mexico, Utah, California, and Vermont (approximately 18 months);
- Four rounds of performance evaluations for Ontario and Oregon (approximately 10 months);
- Laboratory data quantifying the material characteristics for a majority of the materials included in the project; and
- Statistical analysis of significant differences between patch survival (for the latest round of evaluations).

Field Installation

As the field installation procedures were taking place, data were collected on various aspects of the patching process that could be used to determine the productivity of the various materials and procedures used. Data on the size of the patches, the time required to place and compact the material, the number of workers needed to perform the procedure efficiently, and the type of equipment used in the operation were collected at each site for each repair. The time required to prepare the potholes for the semipermanent procedure and the time required to place the edge seal material around those patches where it was required were recorded for their respective patch types. The time required to remove the existing patches before the placement of the experimental and control patches was not noted.

The test sites were installed using workers from eight agencies in eight different areas of the United States and Canada, yet the times for placing and compacting the throw-and-roll and edge seal patches were similar at all sites. Slightly more time was required in Illinois, which is partly because the site is on a heavily traveled Interstate and the workers had to use more caution while they worked. Table 3 gives the average times for the different repair methods at each test site.

One of the effects of using a backhoe to create the potholes was that the size and shape of the potholes were to some degree determined by the equipment being used. Table 4 gives a summary of the volumes of the potholes for each of the repairs at each site. The average volumes for each site show that the last two sites installed, Ontario and Oregon, had average volumes less than the others. This is due to the shallower depths of patches at these two sites.

When the approximate volumes are combined with the times required to fill the holes, the productivity of the operation can be determined as follows:

$$\text{RATE} = \text{DENS} \times (V_{\text{avg}}/T_{\text{avg}}) \times (1\ \text{ton}/2{,}000\ \text{lb}) \times (60\ \text{min}/1\ \text{hr}) \qquad (1)$$

where

RATE = productivity (tons per hour),
DENS = compacted density of material placed in hole (lb/ft^3),

TABLE 3 Summary of Patching Times for All Sites

Procedure	Activity	Test Site (min)								Average (min)
		CA	IL	NM	OR	TX	UT	VT	ON	
Throw-and-Roll	Placement	2.0	3.1	2.4	1.2	2.2	1.5	1.5	1.3	
	Compaction	1.0	1.9	0.8	0.3	0.7	0.5	0.3	0.4	
	Total	**3.0**	**5.0**	**3.2**	**1.5**	**2.9**	**2.0**	**1.8**	**1.7**	**2.6**
Edge Seal	Placement	1.4	2.9	2.1	1.2	2.0	1.1	1.2	N/A	
	Compaction	1.0	1.5	0.7	0.4	0.5	0.4	0.4	N/A	
	Placing seal	1.0	1.0	1.0	1.0	1.0	1.0	1.0	N/A	
	Total	**3.4**	**5.4**	**3.8**	**2.6**	**3.5**	**2.5**	**2.6**	**N/A**	**3.2**
Semipermanent	Preparation	2.8	15.2	0.9	24.3	12.1	5.4	4.1	2.0	
	Placement	1.6	3.9	2.5	1.4	4.8	2.7	1.2	1.1	
	Compaction	2.6	2.5	1.0	1.3	1.1	1.0	1.0	1.1	
	Total	**7.0**	**21.6**	**4.4**	**27.0**	**18.0**	**9.1**	**6.3**	**4.2**	**13.3**
Spray Injection	Placement	1.9	2.4	2.7	N/A	2.0	3.9	2.3	4.6	
	Total	**1.9**	**2.4**	**2.7**	**N/A**	**2.0**	**3.9**	**2.3**	**4.6**	**2.8**

V_{avg} = average volume of potholes (ft^3), and
T_{avg} = average time for filling potholes (min).

Using this equation for the each of the repair methods, the productivity figures found in Table 5 can be calculated.

The semipermanent operation generally required more equipment than the throw-and-roll, such as a jackhammer or pavement saw, compressor, compaction device, and usually an extra vehicle for transporting equipment. The added equipment and labor costs, along with reduced productivity, indicate that the performance of the semipermanent patches would need to be significantly better than the throw-and-go performance to make the extra effort of the installation procedure cost-effective.

Field Performance

Field evaluations of the H-106 pothole locations were performed at all sites at approximately 1, 3, 6, 12, and 18 months after the installation. The field evaluations were performed to note the number of patches still performing well in the field, as well as to document any distresses that became apparent before the patch failure. For this project, a patch is considered failed if the local maintenance crew determines it is necessary to make a repair at the location of a previously placed experimental or control patch. In most instances, failures have occurred as a result of material raveling out of the hole, thereby creating a new hole to be patched.

As of the latest performance evaluations, 355 of the original 1,250 patches (28 percent) have failed at the test sites, as is shown by Table 6. Another 49 repairs have been lost to overlay (4 percent), leaving 866 patches surviving (69 percent). As can be seen from this table, the highest failure rate is at the test site in Ontario, where the patches were placed in an older asphalt-concrete pavement in freezing weather, subjected to snow and subsequent deicing salts 2 days after installation was completed and then hit with rain and freezing rain for most of the first 3 months after installation. The climatic conditions experienced at the other sites did not provide nearly that amount of stress to the patches, and as Figure 1 shows, the percentage of patches still performing at the Ontario site is decreasing much more rapidly than at any of the other sites.

When comparing the survival results of one set of patches against another, the most basic level of comparison is between the different repairs placed in the sets of 20 or 30 patches. Within these sets, there is the least amount of variability due to site-specific factors, which provide the most meaningful comparison. The analysis to identify differences in survival among the different patch types was carried out using a one-on-one comparison between each set of experimental patches

TABLE 4 Summary of Pothole Volumes for All Sites

Procedure	Test Site (ft^3)								Average (ft^3)
	CA	IL	NM	OR	TX	UT	VT	ON	
Throw-and-roll	1.7	1.4	1.1	0.5	2.0	1.3	1.0	0.3	**1.1**
Edge seal	1.9	2.3	0.8	0.4	1.5	1.2	1.6	N/A	**1.2**
Semi-permanent	1.8	2.2	0.9	0.8	3.7	1.5	1.5	0.5	**1.2**
Spray injection	1.4	1.1	1.2	N/A	1.9	1.6	1.3	0.4	**1.3**

1 ft^3 = 28.3 L

TABLE 5 Summary of Productivity for All Procedures

Procedure	Average Productivity (tons/hr)	Laborers Recommended	Average Productivity (tons/person-day)
Throw-and-roll	1.6	2	3.2
Edge seal	1.4	2	2.8
Semi-permanent	0.3	4	0.3
Spray injection	1.7	2	3.4

1 ton = 907 kg

TABLE 6 Summary of Patch Survival for All Sites

Test Site	Number of repairs			Percent surviving	
	Surviving	Lost	Failed	By Site*	By Region
CA	114	2	24	83	94 (Dry-freeze)
UT	137	0	3	98	
OR	196	0	4	98	
NM	110	0	30	79	79 (Dry-nonfreeze)
IL	66	1	83	44	49 (Wet-freeze)
VT	92	0	48	66	
ON	74	2	114	39	
TX	77	34	39	66	66 (Wet-nonfreeze)

* Percentages do not include "Lost" patches.
All values based on latest observations.

and the corresponding control patches. The analysis provided 80 comparisons at the eight test sites, of which four were significantly different ($\alpha = 0.05$). All four of these significant comparisons involved local materials performing worse than the control patches. Subsequent data collection will yield more significant differences as this project continues.

Laboratory Results

Laboratory testing was conducted on patch samples in order to provide material characteristics that could be compared with the performance observed in the field. Tests conducted included modified Marshall stability and flow, bulk and maximum specific gravities, gradation, asphalt binder content, Pennsylvania Transportation Institute workability, and modified resilient modulus. Tests performed on the recovered binders include penetration, ductility, softening point, and viscosity. Since the Marshall tests and the resilient modulus tests were intended to be run on hot-mix asphalt concrete materials rather than on stockpiled cold-mix materials, the cold-mix samples were put through an "aging" process consisting of heating overnight at 135°C.

The results of the gradation testing indicate that the majority of the materials have very few fines and a fairly open gradation. For all of the experimental and control materials, crushed, angular aggregate was used to provide better edge-to-edge interlock and therefore better stability. The "local" materials in Utah, Illinois, Vermont, and Oregon used rounded gravel as a coarse aggregate.

The data from the laboratory testing were intended to provide a means of identifying material properties that would correlate to performance observed in the field. Because of the lack of differentiation among the various patch types in the field, attempts to identify material property–field performance correlations have not yielded many results. More field performance data collection should provide information that will lead to more meaningful analysis results.

COST-EFFECTIVENESS

Perhaps the most important aspect of the H-106 pothole repair project is the determination of the cost-effectiveness of the different materials that have been included. For a new patch material to be selected for use by an agency, the overall amount

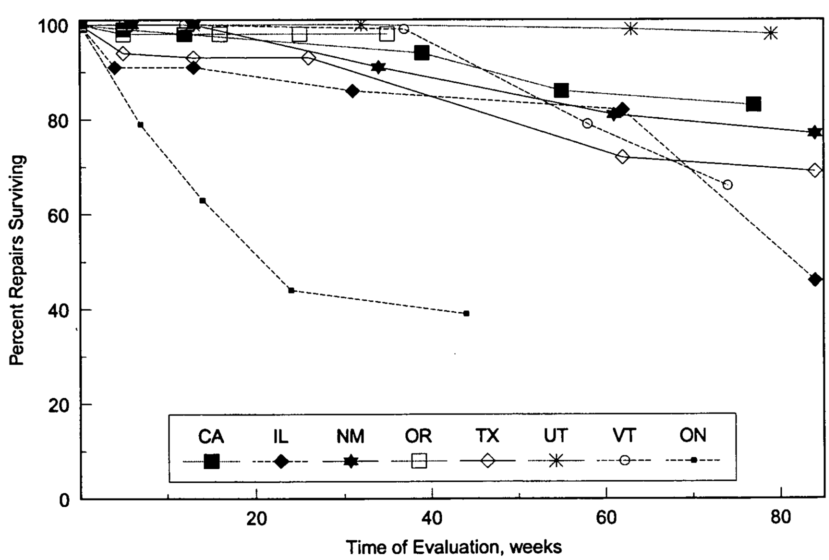

FIGURE 1 Patch survival over time for all sites.

of money spent on the total patching operation must be reduced from what is currently being spent. This total patching amount includes the cost of material delivered to a stockpile area, the manpower costs associated with the pothole patching operation, the equipment costs associated with the patching operation, and the number of times a single area will need to be patched before overlay or rehabilitation of the pavement. Of all the factors, the last may be the most important. Whereas the costs of increased travel time and vehicle repairs as a result of rough roads are also important, many agencies do not consider these costs when determining the most cost-effective patching operation. The increasing number of lawsuits by drivers against maintenance agencies may force the consideration of user costs into the overall cost-effectiveness calculation.

At several of the test sites, inexpensive materials were compared with better-quality patch materials. The cost of the better material was as much as four times that of the less expensive 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. In situations where traffic control is necessary to shut down lanes while repairs are being made, the manpower and equipment costs are an even larger portion of the total patching costs. Since the major cost of pothole repair appears to be labor, equipment, and traffic control, significant savings can be obtained by using more effective materials and methods.

SUMMARY

The pothole patches placed as part of the H-106 project have performed well, with an overall survival rate of 69 percent as of the latest evaluation. At the Texas, Illinois, Vermont, and Oregon sites, the poor performance of the local materials has provided a good indication that there are better materials and methods available for pothole repair.

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