Field and Laboratory Evaluation of Winter Season Pavement Patching Materials in Tennessee

Qiao Dong, Ph.D.
Postdoctoral Research Associate
Department of Civil and Environmental Engineering
The University of Tennessee
Knoxville, TN 37996
Ph: (865)974-2608
Fax: (865)974-2608
E-mail: qdong2@utk.edu

Baoshan Huang, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
The University of Tennessee
Knoxville, TN 37996
Ph: (865)974-7713
Fax: (865)974-2669
E-mail: bhuang@utk.edu

Word Count: Abstract: 228
Text: 5108
Figures: 7 (250 ea)
Tables: 1 (250 ea)
Total: 7108
ABSTRACT

Field survey and laboratory tests were conducted to evaluate the performance of four patching materials used in winter season pothole repair in Tennessee. The adhesiveness, cohesion, moisture susceptibility and loaded wheel test were conducted to investigate the bonding, freeze-thaw resistance and rutting resistance of the patching materials. Statistical analysis on the six month field survey showed that edge disintegration and missing patch are the mainly distress of “throw and roll” patching in winter season. Severe freeze condition, high traffic level and vehicle speed accelerated the deterioration of patching. Patchings with lower depth and larger size especially longer longitudinal length deteriorated faster. Both field and adhesiveness test showed that the cold dump mix had high potential to edge disintegration and missing patch, which is probably caused by the insufficient binder content or an excessive stiff binder. One cold bag mix showed high potential to deformation and low strength performance, mainly due to its single size gradation and weak aggregate skeleton. Cohesion test conducted at different temperature and compaction times presented consistent ranking of materials. 25°C and 15 blows were recommended to evaluate the cohesion of materials at moderate temperature. Two cold mixes did not withstand the 60°C water bath in the freeze-thaw cycling due to the high air voids and 25°C was suggested instead. Reduced wheel load is recommended to improve the effectiveness of loaded wheel test for cold patching mixtures.

Keywords: Pothole; Patching; Cold mix; Adhesiveness; Cohesion; Moisture susceptibility; Loaded wheel test.
INTRODUCTION

Background

Potholes are usually bowl-shaped holes frequently encountered on the surface of flexible pavement. Low severity potholes are less than 1 in. deep, moderate-severity from 1 to 2 in. deep and high-severity potholes are deeper than 2 in. (1). Some potholes can penetrate through the HMA layer to the base layer. Unlike raveling, potholes usually have sharp edges and vertical sides at the top. Potholes greatly reduce the pavement performance level and service life, and are the most aggravating pavement distresses for traffic safety. Generally, potholes are the result of alligator cracking, which is a type of severe fatigue failure of the pavement surface. As alligator cracking becomes more severe, the interconnected cracks cause the pavement surface break into small pieces. The broken pieces are then pulled up by travelling wheels and a pothole forms. Freeze-thaw cycles accelerate the formation of potholes. The water inside the pavement expands when it freezes to ice, forcing higher stress on an already cracked pavement.

Pothole repair is one of the most commonly performed maintenance operations for many highway agencies, especially in areas where cold winters and warm, wet springs. Pothole repair methods include various combinations of materials and procedures. Patching materials include hot mixed asphalt (HMA) mixture and cold mixed asphalt using either emulsified asphalt or cut-back asphalt. Patching procedure generally includes placing and compacting asphalt mixtures in the potholes, and sometimes cleaning and cutting before patching and sealing edge after patching. The most widely used patching procedures include throw and roll and semi-permanent. Throw and roll includes placing material and compacting with truck tires. Semi-permanent usually includes cut sides, cleaning debris and compacting with specific compactors (2). Other commonly used procedures include spraying edge sealing to seal the patch and heating the old pavement using an infra-red heater. Many highway agencies use throw and roll procedure in winter for temporary repairs while conduct semi-permanent patching in summer as permanent repair (2).

Previous Studies

There have been several studies conducted to evaluate the performance and effectiveness of various patching techniques through field survey and laboratory tests. Thomas and Anderson investigated the longevity and cost-effectiveness of different pothole repair methods in the northern states based on field observations (3). They pointed out that material cost is a small percentage of the total cost for pothole repair, and thus innovative or more expensive materials that can provide longer repair longevity will be cost-effective. From 1991 to 1996, the Strategic Highway Research Program (SHRP) conducted the most extensive field experiment, the SHRP H-106 project, to determine the most cost-effective combinations of materials and patching procedures for pothole repair (2)(4)(5)(6). Different repair methods were investigated through test sites installed at eight locations in the United States and Canada under the SHRP and LTPP programs. It was found that throw-and-roll technique was as effective as the semi-permanent procedure and was more cost-effectiveness because of the lower labor and equipment.
Various laboratory tests have been developed to evaluate the performance of different pothole patching materials \((7)(8)(9)\). Virginia Department of Transportation (DOT) evaluated the performance of different cold-mix patching materials through coating test, stripping test, drain down test, cohesion test, workability test and adhesion test \((7)\). In addition to the traditional Marshall Stability and resilient modulus test, New Jersey DOT conducted blade resistance and rolling sieve test to evaluate the workability and cohesion of patching materials by simulating field operation \((8)\). Texas conducted wheel tracking test and indirect tensile strength test to evaluate the stability and strength of cold mixes and developed a slump-based laboratory workability test \((9)(10)\).

In addition to the wheel tracking test, accelerated tests on simulated potholes were also proposed to evaluate the performance of pothole under analogue traffic and environment conditions. Texas developed an accelerated pavement test to evaluate the rutting of potholes installed on field by applying an accelerated wheel loading using a mobile load simulator \((10)\). Fragachan \((11)\) evaluated the performance of patching by applying an accelerated wheel load on potholes constructed in concrete blocks. The distresses observed in the manufactured potholes were very similar to field distresses reported in the literature. The accelerated testing was successful in differentiating the performance of emulsion and asphalt binder mixes.

Objectives and Scope

The objectives of the present study is to investigate the performance of frequently used pothole patching materials used in winter season in Tennessee through both field survey and laboratory tests. Pothole patchings using different materials were installed on highways of Tennessee in winter for long term field survey. According to the distress observed on the field patchings, laboratory tests were designed and conducted to evaluate the field performance of patching materials.

FIELD PERFORMANCE SURVEY

Installation of Pothole Patching

Tennessee Department of Transportation (TDOT) generally uses throw and roll procedure for temporary pothole repairs in winter. The patching materials used for winter repair include a hot mixed asphalt (HMA) mixture, a cold dump mix and two cold bag mixes (A and B). HMA is a plant mixed mixture and pave with a heater truck. The cold dump mix is a stockpile cold mixed asphalt mixture produced with slow curing cutback asphalt. The two cold bag mixes use single size fine aggregate and rapid curing cutback asphalt.

65 pothole patchings were installed on six highway sections in east and middle Tennessee, including I75, I640, SR111, SR96, SR71 and SR33. The number of patchings using HMA, cold dump, cold bag A and B were 21, 11, 28 and 5, respectively. The length, width and depth of each patching was measured and recorded. The latitude and longitude coordinates of the field spots were recorded by a GPS for the following survey. Photos inventory was also set up for each patching. The average depth of patching ranged
from 1 to 3 in. The area of potholes ranged from 0.1 to 50 ft². Large area pothole was usually originated from longitudinal cracking.

**Distress of Patching**

The most commonly encountered distress for pothole patching includes bleeding, dishing, edge disintegration, missing patch, raveling, pushing/shoving and alligator cracking (7)(9). The descriptions and causes of those distresses are summarized as follows:

- **Bleeding** is the flushing of asphalt to the surface of the patch. It is usually caused by insufficient voids or excessive binder in the mix.
- **Dishing and Pushing/shoving** is the bowl shape and vertical/horizontal movement the patch and usually results from instability of mixture and inadequate compaction during construction.
- **Edge disintegration and missing patch** occurs when the patch material loses its adhesion to the pavement underneath or sides of the pothole. The lose materials can be easily pulled off by traffic. They are the most commonly distress for “throw and roll” method and are usually caused by insufficient compaction, poor cohesion, debonding and alligator cracking.
- **Raveling** is the loss of aggregate from the surface of the patch. Raveling is caused by stripping, poor cohesion, excessive fine aggregates and poor aggregate interlock of the patch material.
- **Alligator Cracking** is the “bottom-up” cracking caused by the freeze thaw cycles and is a typical distress of pothole patching during winter.

The pothole patchings were visually rated in terms of different distress by following the procedure recommended by Virginia DOT (7). The ratings ranged from 1 to 4, with 4 indicated the best condition and 1 indicated the poorest distress condition. Usually, an overall rating is determined in order of the importance and weighting factors of different distress. The overall rating of a patching can be determined by equation (1).

The weighting factors were determined based on discussions with pavement maintenance engineers of Tennessee DOT. The weighting factors of edge disintegration and missing patching are higher since they are the two main distress for throw and roll patching in winter season.

$$\text{Performance rating} = 0.05 \times \text{Bleeding} + 0.075 \times \text{Dishing} + 0.0625 \times \text{Pushing} + 0.175 \times \text{Edge disintegration} + 0.3375 \times \text{Missing patch} + 0.125 \times \text{Raveling} + 0.175 \times \text{Alligator cracking}$$ (1)

**Performance of Pothole Patching**

Field performance surveys were performed 1, 3 and 6 weeks, 3 and 6 months after the installation. Figure 1 shows the typical deterioration of a “throw and roll” pothole patch. It can be seen that the patching deteriorated fast due to the freeze-thaw cycles, missing patching was the major distress. According to the 3 month field performance survey, missing patch and alligator cracking due to deboning and freeze-thaw cycles are the most commonly encountered distress of potholes in winter season.
Figure 2 summarized the number of distress before and after patching. It can be seen that about half of the potholes were caused by various cracking, especially alligator cracking. According to the field performance survey, missing patch and alligator cracking due to deboning and freeze-thaw cycles are the most commonly encountered distress of potholes in winter season.
Influence of factors on Patching Performance

Multiple linear regression method, as shown in equation (2) was used to analyze the influence of different factors (X_i) on the performance ratings (Y) of potholes. Analyzed factors include service time, material, the length, width and depth of potholes, annual average daily traffic (AADT), speed limit and freeze times. The freeze times are the number of days when the temperature was lower than the freezing point. The daily temperatures recorded by the weather stations within 5 miles of the pothole locations were collected from the National Climatic Data Center (NCDC) (12). The responses of the regression model include performance ratings in terms of dishing, edge disintegration and missing patch and the overall rating.

\[ Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_i X_i + \cdots + \beta_k X_k + \varepsilon \]  

Where, \( \beta_i \) = Parameters estimate of factor \( X_i \), is the magnitude and direction change in response with each one-unit increase in predictor \( i \). 
\[ \varepsilon = \text{random error term.} \]

The ordinal least square method was used to estimate the parameters. Table 1 shows the p-value of the F-test, which indicates the significance of each predictor by testing the significant increase in explained variation by adding that predictor to the reduced model. Factors with p-values lower than 0.05 were regarded as significant; indicating the probability of getting this result by chance is less than 5%. It can be seen that the most of the factors are significant except for the width for missing patch. The p-value of time for missing patch is slightly larger than 0.05 and was regarded as marginal significant.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Dishing</th>
<th>Edge disintegration</th>
<th>Missing patch</th>
<th>Overall rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (Weeks)</td>
<td>0.0364</td>
<td>&lt;.0001</td>
<td>0.0998</td>
<td>0.0181</td>
</tr>
<tr>
<td>Material</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>0.0007</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Longitudinal length (ft)</td>
<td>&lt;.0001</td>
<td>0.0192</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Transverse width (ft)</td>
<td>0.001</td>
<td>0.0261</td>
<td>0.3652</td>
<td>0.0158</td>
</tr>
<tr>
<td>Depth (in.)</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>AADT</td>
<td>0.0155</td>
<td>&lt;.0001</td>
<td>0.0014</td>
<td>0.0006</td>
</tr>
<tr>
<td>Speed limit (mile/h)</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Freeze time</td>
<td>0.0153</td>
<td>0.0013</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

Figure 3 shows the influence of each predictor on the response. The middle lines within the plots show how the response changes when changing the current value of an individual factor. The dotted curve surrounding the prediction trace (for continuous variables) and the context of an error bar (for categorical variables) show the 95% confidence interval for the predicted values. It can be seen from Figure 5 that, severe weather, indicated as freeze times, accelerated the failure of patchings. Vehicle speed and traffic level also accelerated the deterioration of patching, which is mainly caused by the
higher abrasion, pushing and pulling effect of traveling wheels. In addition, potholes with higher length or width and lower depth deteriorated faster. The rating of dishing indicated the resistance to permanent deformation of materials. HMA had the highest stability, followed by cold dump mix, cold bag A and B. The two cold bag mixes use fine aggregate so that they could be used as cracking filling materials. However, the resistance to deformation is compromised due to the weak aggregate skeleton. The resistance to edge disintegration and missing patching were mainly determined by the cohesion and adhesiveness of patching material. It can be seen that HMA and Cold bag A had higher resistance to debonding while cold dump mix performed the worst. Since edge disintegration and missing patching have high weighting factors in the overall rating, the material rank in terms of the overall rating was similar with that of the missing patch.

![FIGURE 3 Influence of different factors on patching distress](image)

**LABORATORY TESTS**

The quality of material is of great importance for a successful pothole repair. Some of the desired properties of patching materials include workability, adhesiveness, cohesion, durability, freeze-thaw resistance and storageability (7). The distresses observed in the field performance survey include missing patch, edge disintegration, alligator cracking and dishing. To investigate the resistance of patching materials to those distresses, four laboratory tests were performed. Adhesiveness and cohesion tests were conducted to evaluate the materials’ adhesiveness to original pavement and inner cohesion. Moisture susceptibility including a freeze-thaw cycle was conducted to evaluate the freeze-thaw resistance of patching materials. Loaded wheel test was tried to evaluate the resistance of mixture to permanent deformation.
Adhesiveness Test

Adhesiveness is the bond between patching mixture, the underlying pavement, and the sides of the pothole. Loss of adhesion usually causes edge disintegration and missing patch, which were the two main distresses observed in the field survey. For the traditional “throw-and-roll” pothole repair procedures, no tack coat is applied before patching. The adhesiveness of the patching materials plays a vital role in the bond between patching material and original pavement. It is important to test the adhesiveness of different patching materials become very important.

Several laboratory tests have been tried in an effort to produce a suitable procedure to evaluate the adhesiveness of patching materials. Shear test was conducted to evaluate the bonding strength of patching materials with old pavement but the results were inconclusive (13)(7). In this study, a test procedure used by Virginia DOT for quality control of cold patching material was adopted (7). 500 g lose mixtures were placed in a 100-mm diameter Marshall mold on top of a 75-mm sample of compacted HMA and compacted with 10 blows of a standard Marshall hammer. The compacted sample is extruded and the sample is inverted. The adhesion of the mixture is measured by the amount of time it takes for the specimen to drop from the substrate asphalt. Two groups of materials were tested, the original and oven-aged at 60°C for 4 hr. The test was conducted at room temperature (25°C). Figure 2 shows the testing procedure.

Cohesion Test

Cohesion test, also named rolling sieve test, measures the cohesion or the bonding inside the materials. It was developed by the Ontario Ministry of Transportation to evaluate the cohesion and durability of stockpiled patching materials and then revised by AASHTO TP-44-94 (7)(8)(14). In this study, sealed loose cold mixes and the Marshall mold were put in a refrigerator at 4°C for 12 hours. 1000 g cold-mix was then put in the mold and compacted 5 times on each side with the Marshall hammer. The extruded sample was placed in a 30.5 cm diameter full height sieve with 25.4 mm (1 in.) openings. A cover was placed on the sieve and the sieve is rolled back and forth on its side approximately 550 mm (22 in) for 20 cycles. Recommended test times for this test is approximately 20 seconds (Tam and Lynch 1987). The sieve remained in this position for ten seconds to let the lose material drop down. Then, the material loss is calculated by weighing the material retained on the sieve. The percentage of materials retained on the sieve was calculated as a measure of cohesion of the mixture. A higher percentage indicates a more cohesive material. The Ontario Ministry of Transportation recommended a minimum percentage retained of 60% for adequate cohesion in a cold-mix. One limitation of this test is that it only indicates the cohesion at low temperature. The pavement surface temperature could be much higher than 4°C direct sunlight even in winter. Thus, the test was performed at room temperature (25°C) with different compaction times to investigate the cohesion at moderate temperature.
Moisture Susceptibility Test

For all the patching materials used in the winter season pothole repair, freeze-thaw cycling is the main cause of many distresses including alligator cracking missing patch and edge-disintegration. Field survey indicated that the potholes at mountain area deteriorated much faster due to the more severe freeze-thaw condition. Freeze-thaw resistance, which is the capability of the patching mixture to withstand the expansion of ice resulting from freeze-thaw cycles, plays a vital role in the durability of patching mixture.

According to ASTM D4867, moisture susceptibility test with a freeze-thaw cycling was conducted to evaluate the freeze-thaw resistance of patching materials. The fresh loose cold mix using cutback asphalt could not be compacted into specimens. In order to add stability to the mixture and simulate field conditions after several months of traffic, the cold mixtures were cured and aged before compaction in an oven at 60°C for 96 hours (9). After curing, the cold and hot mixes were heated to 100°C and 135°C respectively to prepare 100-mm diameter Marshall specimens. For moisture susceptibility test, specimens are usually compacted to a void content between 6 to 8%. However, due to the lack of fine aggregate in the cold mix materials, the void content of cold bag A and cold dump could not be controlled at 6% to 8% even with more compaction times. Previous studies found that some cold mix patching material can have 10% air content even with 200 gyration times (9). To simulate the actual compaction of repeated wheel loads in the field, specimens were all compacted for 50 blows on each side. The air content of cold dump, cold bag A, cold bag B and HMA are 10.5%, 13.5%, 4.1%, and 0.95%, respectively. The saturations were controlled between 70% and 80% as recommended by ASTM D4867.

The partially saturated specimens were then wrapped with two layers of plastic film, sealed into a leak-proof plastic bag, placed into a freezer at −7°C for 20 h and then eventually immersed in a water bath at 60°C for 24 h. During the test, the cold dump and cold bag A specimens could not withstand the 60 °C water bath and collapsed after being submerged in the hot water for 10 minutes. The low high temperature stability was probably caused by the high air void and low viscosity. The air voids of cold dump and Cold bag A were 10.5% and 13.5%m respectively, much higher than those of cold bag B and HMA. At similar saturation level, specimens with higher air voids had higher void pressure generated by the expansion of water in the freeze-thaw cycle. Even after curing at 60°C for 96 hours, the viscosity of these cutback asphalt cold mixes might be still lower than that of the traditional HMA and the low viscosity and cohesion caused insufficient strength of the specimen. It seemed the traditional 60°C did not apply for these cold patching mixtures. In addition, the pavement surface temperature in winter season in Tennessee is not likely to be as high as 60 °C. In the revised procedure, the water bath was changed to 25°C.

A MTS machine was utilized to test the indirect tensile strength (IDT) of both dry and conditioned specimens. The indirect tensile strength (IDT) and tensile strength ratio (TSR) can be calculated by using equation (1) and (2).

\[ S_i = \frac{2P}{\pi D} (\psi i) \]
Where, $S_t$ = tensile strength (psi);
$P$ = maximum load (lbf);
t = specimen height immediately before tensile test (in.);
$D$ = specimen diameter (in.).

$$TSR = (S_{tm} / S_{td})100$$  \hspace{1cm} (4)

Where, TSR = tensile strength ratio (%);
$S_{tm}$ = average tensile strength of the moisture conditioned subset (psi);
$S_{td}$ = average tensile strength of the dry subset (psi).

**Loaded Wheel Test**

In this study, Asphalt Pavement Analyzer (APA), a widely used loaded wheel tester, was utilized to test the rutting resistance of mixture. As shown in Figure 4, the Hamburg test procedure was adopted. A simulated pothole was made by putting two 150mm (6in.) diameter and 38mm (1.5 in.) thick concrete pills at the bottom of the mold. The concrete pill was fabricated by pouring 1.72 kg concrete into the 150mm (6in.) diameter and 300mm (12 in.) The rough surface of the pills faced up to simulate the actual rough pothole bottom. Since the stiffness of the concrete base is much higher than that of asphalt mixture, it doesn’t influence measured rutting depth. The volume for the asphalt mixture left in the mold is around 828cm³. Loose were cured in an oven at 60°C for 96 hours first. After curing, 1800 g materials was heated to 100 °C, placed into the mold and compacted with 30 blows of a standard Marshall hammer on each side. The estimated air voids of the mixture were around 10%. The Hamburg wheel (8”in. diameter and 1.85” in. width) was used in this test. The vertical load on each wheel was 158 lbs. The test frequency was 1 Hz (one cycle per second) and test temperature was 25°C.

![Figure 4 Loaded wheel test device and simulated pothole](image)
DISCUSSION OF LABORATORY TEST RESULTS

Adhesiveness Test

Figure 5 shows the adhesion time and weight of remnant of the adhesiveness test. HMA had much higher adhesion time than cold mixes even with only one blow. Increasing compaction greatly improved the adhesiveness of materials. Cured cold mixes had much higher adhesiveness than the original cold mixes, since high temperature accelerated the volatilization of the dilution in the mixture. High weight of remnant also indicates high adhesiveness or inner-bonding of the material. For cured cold mixes, the ranking in terms of the weight of remnant is the same with that of the adhesion time.

Previous researchers recommended 5 to 30 seconds as the optimum adhesion time for cured cold mix (7). They pointed out that times less than 5 seconds may indicate excessive binder contents; and times in excess of 30 seconds may indicate insufficient binder content or an excessive stiff binder. The adhesion time of cured cold bag mixes were between 20 to 30 seconds whereas that of cured cold dump mix was around 50 seconds. The cold dump seemed have insufficient binder content or excessive stiff binder, which probably caused its poor performance regarding the edge integration and missing patch in the field.

![Figure 5 Results of adhesiveness test](image)

Cohesion Test

Figure 6 shows the cohesion test results, the percent of materials retained on the 25mm size sieve. Generally, cold bag B had the highest percent of material retained, followed by cold bag A and cold dump. At the standard test condition (4°C and 5 blows), the percent of materials retained of the three cold mixes were all higher than the recommended 60%, indicating sufficient cohesion. At 25°C test temperature, the cohesion increased as the increase of compaction times.

The tested specimens can be classified into good, moderate and poor conditions. The good specimen had little materials loss. The moderate specimen had moderate material loss but still maintain its geometry shape. The poor specimen totally fell apart...
during the test and usually had percent of material retained lower than 60%. During the test, cold dump and cold bag A specimens tested at 25°C and 5 blows were classified as poor after testing. The test generating poor specimens could not differentiate different materials if more than one group of material was in poor condition. A practical test procedure should avoid having poor tested specimens. The 25°C with 15 blows test conditions is recommended as an alternative to evaluate the cohesion of mixtures at moderate temperature.

Moisture Susceptibility Test

Figure 7 shows the indirect tensile strength of mixtures before and after the freeze-thaw cycle and the TSR. HMA had highest indirect tensile strength among the three cold mixed, followed by cold bag A, cold dump and cold bag B, which generally agreed with the ranking of field performance rating for dishing distress. The low strength stability of cold bag B is the main cause of its poor resistance to permanent deformation in the field. The strength level of HMA was at least 4 times higher than those cold mixes, indicating that it has the best stability with sufficient compaction. Although cold bag B had lowest tensile strength, its TSR was higher than 1. HMA had TSR higher than 80%. The TSR of cold dump and cold bag A were lower than 80%, which was mainly caused by the high air voids of the specimen.
Loaded Wheel Test

During the loaded wheel test, the rutting depth of cold bag B reached 14 mm after around 200 load cycles and the test stopped. Tested specimens were shown in Figure 4. Because of coarser gradation and tight aggregate interlock, the cold dump mixture exhibited better rutting resistance. However, its rutting depth was still very high at such a low load cycles comparing with traditional HMA mixture. Chatterje et al. also acknowledged that the Hamburg stability testing was unstable for uncured materials or at temperatures greater than 25 °C (77°F) regardless of the curing time (9). There are mainly two reasons for the high deformation. Firstly, the laboratory compaction of the simulated pothole is insufficient to simulate the tire compaction on the field. Secondly, the gradation of cold bag B is very fine and does not provide a good skeleton for deformation resistance. Both the two cold bag mixes use single size fine aggregate so that they can also be used as cracking filling materials. However, their resistance to permanent deformation is highly compromised. The traditional loaded wheel test doesn’t apply for such cold mixes. Reduced wheel load is recommended for future study.

CONCLUSIONS AND FUTURE RESEARCH

This study evaluated the performance of patching materials used in winter season in Tennessee through field survey and laboratory tests. The laboratory tests were conducted to characterize the material properties that are critical for the desired field performance. Based on findings of field survey and laboratory tests, some conclusions can be summarized as follows:

1. Six month field survey indicated that edge disintegration and missing patch were the two main distresses of throw and roll patchings in winter season. In addition to service time and material, freeze condition, vehicle speed, traffic level, and the size and depth of potholes are significant for the performance of patching. Severe freeze condition, high traffic level and vehicle speed accelerated the deterioration of patching. Patchings with lower depth and larger size especially longer longitudinal length deteriorated faster due to the increased abrasion.

2. In terms of the overall rating in the field, HMA performed the best followed by the two cold bag mixes and the cold dump. The cold dump mix showed high potential to edge disintegration and missing patch, which is probably due to the insufficient binder content or an excessive stiff binder, as indicated in the laboratory adhesiveness test. The cold bag mixes exhibited weak resistance to permanent deformation, which is caused the weak aggregate skeleton and low strength performance as indicated in the laboratory indirect tensile strength test.

3. Laboratory tests showed that HMA mixture had higher adhesiveness and strength than all the three cold mixes. Improve compaction could greatly increase both adhesiveness and cohesion of patching mixes.

4. Cohesion test conducted at different temperature and compaction times presented consistent ranking of materials. 25°C and 15 blows was recommended to evaluate the cohesion of materials at moderate temperature.
5. The cold dump and cold bag A did not withstand the 60°C water bath in the freeze-thaw cycling due to the high air void in the specimen. 25°C was recommended instead of 60°C water bath in the freeze-thaw cycling for moisture susceptibility test. The TSR of cold dump and cold bag A were between 60% and 80% which were mainly caused by the high air voids. The air voids of cold dump and cold bag were higher than 10% with regular compaction effort because their aggregate were of single size and could not form a dense gradation.

6. Loaded wheel test results showed that the cold bag mix using fine aggregate exhibited high dishing and pushing potential due to the weak aggregate skeleton. Traditional loaded wheel test procedure does not apply to the cold patching material. Reduced wheel load and improved compacted specimens are recommended to improve the effectiveness of the test.

Future research will primarily focus on improving the effectiveness of loaded wheel test on differentiate the fine grade cold mixes. It is recommended to modify the test method to evaluate the rutting resistance of cold mix, including reducing the wheel load level and improving the compaction of specimens. With more field survey data collected, long-term cost-effectiveness will be investigated by including the cost factor into performance evaluation.

ACKNOWLEDGEMENT

The funding of this study was supported by the Tennessee Department of Transportation (TDOT). The TDOT maintenance engineers are acknowledged for their assistance on field patching installation. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the TDOT, nor do the contents constitute a standard, specification, or regulation.

REFERENCE


