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Trends in Use of Millings in Pavement Maintenance

Rafiqul Tarefder, Mohiuddin Ahmad, Mohammad Hossain

***Abstract*—**While millings materials from old pavement surface can be an important component of cost effective maintenance operation, their use in maintenance projects are not uniform and well documented. This study documents the different maintenance practices followed by four transportation districts of New Mexico Department of Transportation (NMDOT) in an attempt to find whether millings are being used in maintenance projects by those districts. Based on existing literature, a questionnaire was developed related to six common maintenance practices. NMDOT district personal were interviewed face to face to discuss and get answers to that questionnaire. It revealed that NMDOT districts mainly use chip seal and patching. Other maintenance procedures such as sand seal, scrub seal, slurry seal, and thin overlay have limited use. Two out of four participating districts do not have any documents on chip sealing; rather they employ the experiences of the chip seal crew. All districts use polymer modified high float emulsion (HFE100P) for chip seal with an application rate ranging from 0.4 to 0.56 gallons per square yard. Chip application rate varies from 15 to 40 lb/ square yard. State wide, the thickness of chip seal varies from 3/8" to 1" and life varies from 3 to 10 years. NMDOT districts mainly use three type of patching: pothole, dig-out and blade patch. Pothole patches are used for small potholes and during emergency, dig-out patches are used for all type of potholes sometimes after pothole patching, and blade patch is used when a significant portion of the pavement is damaged. Pothole patches last as low as three days whereas, blade patch lasts as long as 3 years. It was observed that all participating districts use millings in maintenance projects.

***Keywords*—**Chip seal, sand seal, scrub seal, slurry seal, overlay, patching, millings.

I. Introduction

NMDOT has specification on pavement construction, however it does not describe the procedure for maintenance like, chip seal, sand seal, patching and so on. Maintaining a pavement may be a difficult job rather than construction. As the weather condition, binder and aggregate type may vary at different region, a specific standard of maintenance procedure is not possible to be follow by a large geographic region. Therefore, different districts of NMDOT adopted their own procedure for maintenance. It is logical if they are doing the maintenance projects solely based on experience, they may lose it after the retirement of the expert crew or personals. Therefore, it is necessary to document the procedure before the expertise is gone or retired.

Rafiqul Tarefder is with the Department of Civil Engineering, University of New Mexico, MSC01 1070, Albuquerque, New Mexico 87131-0001, USA (e-mail: tarefder@unm.edu).

Mohiuddin Ahmad is with the Department of Civil Engineering, University of New Mexico, MSC01 1070, Albuquerque, New Mexico 87131-0001, USA (corresponding author e-mail: mahmad@unm.edu).

Mohammad Hossain is with the Department of Civil Engineering, Bradley University, 1501 W. Bradley Avenue, Peoria, IL 61625 (e-mail: mihossain@fsmail.bradley.edu).

Each district is doing different type of maintenance by its own way, therefore they are not uniform. One may use higher application rate with more cost and less design life and vice-versa. Therefore, a comparative study may reveal a procedure and application rate that is less expensive and has higher design life.

All the NMDOT districts started using millings for maintenance works, as all of them have hundreds of tons of millings stockpiled all over the state. It is necessary to use millings for sustainable environment. In addition, use of millings reduces the cost of construction by reducing material cost (both aggregate and binder). Therefore, the current trend of use of millings by different districts needs to be evaluated.

II. Current Practices

Different states of USA prefer to use six type of maintenance: chip seal, sand seal, scrub seal, slurry seal, thin overlay and patching. Arizona collects quantitative distress data on cracking and rutting of their pavements before applying any maintenance [1]. Chip seal is a surface treatment constructed by applying one or multiple layer of stone chips over asphaltic emulsions. Montana and California DOT have well written document on chip sealing including the detailed procedure and specification limits [2], [3]. MDT does chip sealing in between May 01-August 20 when the air temperature is more than 65°F. Caltrans described the different distress conditions for which a pavement should be chip sealed. Chip sealing should not be done on roads with AADT > 40000. Caltrans uses equation to determine chip and binder application rate. They use “ball penetrometer test” to test for punching strength and “sand patch test” to determine the texture depth of the seal. In 2005, NCHRP released “Chip Seal Best Practices” which includes procedure and specifications of chip seal. According to this report, only 18% chip seal in USA is constructed using some kind of method/ equations and the rest 82% is constructed using experience only [4].

If sand is used instead of stone chips, it is known as sand seal. On sand seal, FHWA has specification limits; however they didn’t described any procedure or method [5]. Binder application rate varies from 0.15 to 0.20 gsy and sand application rate is in between 10 to 15 psy. Sand size varies from 1/4" to 3/8" [6].

If scrub broom is used after emulsion spray and chip spreading, it is known as scrub seal. Montana and Utah have documents on scrub seal specifying limits and procedure [7], [8]. Aggregate size for scrub seal is similar to sand seal or chip seal. Application rate of emulsion varies from 0.22 to 0.45 gallons per square yard. Cost varies from $0.9 to 1.05 per square yard and expected life is 4 to 10 years.

If sand and emulsion are mixed before spraying on the pavement, it is known as slurry seal. International Slurry Surfacing Association (ISSA) has guidelines for slurry seal construction [9]. They proposed three gradations with maximum aggregate size 1/4" and the residual asphalt content vary from 6.5% to 16%. The application rate varies from 8-30 psy. Slurry seal should not be used if the pavement temperature is below 50°F and no freeze in 24 hours. Virginia, California and Arizona also use slurry seal and have specification on it [10], [13]. Caltrans, ADOT and VDOT specification are very much similar to the ISSA procedure with three types of gradation and other properties.

If a maintenance overlay is constructed less than 1.5" thick, it is known as thin overlay. The life of thin overlay varies from 4 to 6 years. Iowa uses PG 76-34 binder for their overlay construction [11]. Crack greater than 0.25" should be crack sealed before thin overlay [12].

One of the most expensive maintenance is patching. It is used for potholes, cracks and edge damages. Hot Mix Asphalt (HMA), cold mix and granular base materials are used for patching.

III. Objectives and Methodology

The main objective of this study is to evaluate the trend of use of millings in maintenance work by different NMDOT districts. One of the goals of this study is to document and compare different maintenance procedures followed by different NMDOT districts.

In this study, a literature review has been conducted mainly to find out the trends in different pavement maintenance works in USA. Based on the literature, key factors governing each maintenance procedures are identified and classified in seven distinct categories. They are: i) documents, ii) selection of pavement to maintain, iii) materials, iv) site condition and preparation, v) construction, vi) QA/QC, and vii) life and cost. Survey questions on these seven categories were developed. Authors met the maintenance engineers and supervisors from each district individually to gather the answers to these questions. Data collected from each district is compiled and analyzed.

IV. Results and Discussions

A. Chip Seal

Each district was asked whether they have anything written about chip sealing. They were also asked about the use and documents on millings. It is observed that only two out of 4 participating districts have documents on chip sealing. All the districts use millings for chip sealing, although they started it very recently and they do not know if they will be performing well or not.

All districts follow the same procedure to identify the pavements to be chip sealed. They divided their district in several continuous sectors. Each year, the maintenance patrol roams around the sector and identifies the pavements that have distress levels suitable for the chip seal. That is, pavements of a district are chip sealed in cyclic order. Each district has its own choice of distresses for chip sealing. Table I shows the distresses for which different district do chip sealing. For cracking (any kind of), skid resistance and water infiltration, all districts prefer to use chip seal. For bleeding, only district-4 (D4) uses chip seal. For moisture damage, only district-1(D1) uses chip seal. Most of the districts don't follow a severity and extent level for which the pavement should be chip sealed. They select the pavement solely based on experience.

TABLE I
Distress for Which Chip Seal Is Used

Distress Type	D1	D2	D4	D6
Cracking	y	y	y	y
Oxidation	y	y	n	y
Rutting	n	y	y	n
Wearing Surface	y	n	n	y
Skid resistance	y	y	y	y
Bleeding	n	n	y	n
Raveling	n	y	y	n
Moisture infiltration	y	y	y	y
Moisture damage	y	n	n	n

y = yes and n = no

Chip sizes vary district to district as D1, D2 and D4 use 3/8" chips and D6 uses 1/2" chips. The application rate ranges from 15 to 40 lb per sq. yard (psy). D1 uses only 18 psy, D2 uses 15-20 psy, D4 uses 15-40 psy, and D6 uses 28 psy. All districts determine the application rate based on experience and trial rate in the field. They damp the aggregate before or during the day of construction to control the dust and enhance better bonding between chips and emulsion. None of the district pre-coats the chips. None of the districts do laboratory testing for quality assurance of the chips. They completely rely on the test results provided by the contractors. Sometimes they do sieve analysis to cross check the chip size.

All districts use polymer modified high float emulsion (HFE100P). Application rate is determined based on experience. Emulsion is distributed on the road at a certain rate. If the emulsion is not distributed uniformly, they adjust the height and pressure of the nozzle. The typical rate ranges from 0.4 to 0.56 gallons per square yard (gsy) depending on the pavement condition as shown in Table II. Pavement with more cracks/distress requires more emulsion. Some of the districts started using milling as chip seal. D6 stated that use of millings doesn't have significant effect on binder application.

TABLE II
Description of Emulsion

Districts	D1	D2	D4	D6
Type	HFE100P	HFE100P	HFE100P	HFE100P
Application rate (gal/sq.yd)	0.42-0.56	0.45M-0.5V	0.35-0.5	0.45-0.51

Investigation of the pavement condition before construction is very important for a successful chip sealing. Especially the temperature during the day of construction and the following day is very significant. If temperature is below 60°F, it will take a long for the binder to cure. Surface binder may become

harder while leaving unbroken emulsion inside. This may cause a bad bonding between chips and emulsion and results in premature failure in chip sealing which was observed in some pavements in New Mexico. Therefore, chip sealing is done during late spring and summer, typical May to August. Depending on the territory, some of the districts may start earlier or end later months. For example, D1 start chip sealing as early as in April and continue as late as September. Chip sealing should not be done if there is forecast for rain during and after several days of construction. It may wash out the chips before firmly boded. If there is freezing temperature warning during or the following day of construction, the crew should not proceed for chip sealing. The surface is broomed properly and sometimes tack coat is applied. The edges are cleaned of for vegetation if there is any. Sometimes, crack sealing is done if it is open more than 1/4". D6 does the crack sealing at least one year before the chip sealing to give enough time to cure. D2 wait about three months after crack sealing before chip seal. If other distresses as for example ravelling, rutting, moisture damage and bleeding, they use blade patch at least one month prior to chip seal. District 1 waits about 6 months after blade patch and before chip seal. If there are potholes, pothole patching is performed prior to chip seal. All these surface preparation is performed by field maintenance patrol. They make the surface ready to chip seal for chip seal crew. Table III summarizes the field condition and preparation techniques followed by different NMDOT districts.

TABLE III
SURFACE CONDITION AND PREPARATION

Districts	D1	D2	D4	D6
Season	April-September	May-August	May-September	May-August
Temperature	65F+	60F+	65F+	60F+
Test strip (ft)	250	n	200	y
Calibration	y	y	y	y
Brooming	y	y	y	y
Crack seal	y	y	n	y
Patching	y	y	y	y
Fog seal	y	n	n	n
Blade patch	n	n	n	y
Shoulder clean	n	n	n	y

Table IV shows a summary of the work done during construction phase. The steps followed by all districts for chip sealing are similar. Traffic control plan is prepared based on the traffic condition of the pavement and number of lane and other characteristics. Usually all districts follow Manual on Uniform Traffic Control Devices (MUTCD) with little or no modification. Chips and emulsion application rate is determined and calibrated on the site by using a test strip. Initially binder is distributed at a lower rate. If it is uniformly distributed and covers all the area, this rate is selected. Otherwise the nozzle height, pressure and rate are adjusted. After selecting a rate for the emulsion, the rate is verified by dividing the total gallons sprayed by the area sprayed. Chips are sprayed on the pavement at a rate as low as 15 psy. If bleeding is observed, rate is increased. If the chips are loose, binder rate in increased. After several trial and error, chip and emulsion application rate are adjusted. All districts except district 4 uses pneumatic tire roller only. District 4 uses 1 steel roller in addition to 3 pneumatic tire rollers. Steel tire roller is not preferred as they can crash the chips. On the other hand, if the pavement surface is not uniform, steel tire will create an inhomogeneous pressure under the wheel and the compaction will not be uniform. Pneumatic tires are flexible and can compact uniformly even though the pavement surface is not uniform. Although compaction densifies the chip seals, more compaction may damage the chip seal. Therefore, an optimum number of passes is required to set. It is mainly done by visual inspection of the crew. D1 uses 6-8 passes where D2 and D4 use only 3 passes for compaction. Brooming is performed in the following day so that chip seal is hard enough and chips will not be picked up by the broom.

TABLE IV
CONSTRUCTION OF CHIP SEAL

Districts	D1	D2	D4	D6
Traffic control	MUTCD	MUTCD	MUTCD	MUTCD
Calibration	y	n	y	y
Roller type	3 tire	3 tire	3tire+1steel	3-4tire
Roller speed	5mph	5mph		5mph
Pressure(psi)	90-120			
No. of passes	6-8	3	3	4
Brooming	y	y	y	y

TABLE V
QA/QC

Criteria	D1	D2	D4	D6
Check application rate	y	y	y	y
Embedment depth	>50%	n	n	>50%
Measure chip loss	<3%	No specific	No specific	No specific
Field tests	n	n	n	n
Fog seal	y	n	n	

Table V shows the list of jobs performed for QA/QC. As described before, chips and emulsion application rate is adjusted and checked with computer rate of the distributor of chip box. All districts check the application rate by manually measuring it. It is necessary to calibrate the rate every time before the chip seal, as the computer may show wrong rate (e.g. when pump pressure is too high, it is possible that some of the emulsion return to the tank instead of going out through the nozzles). The embedment depth must be checked. If it is not sufficient, more compaction is required. D6 check the embedment depth at three stages. Immediately after spreading, it should be around 30-40%. After compaction it is supposed to be around 50-60%. Several days after opened to traffic, the embedment depth should be more than 70%. D1 check the embedment depth immediately after construction and it should be greater than 50%. Embedment depth is checked by pulling out a chip from the pavement and visually inspecting it. D2 and D4 do not check the embedment depth by pulling out a chip. They just do it by visual inspection. Chip loss also needs to be measured to control broken windshield as well as to reduce chips cost. None of the districts performs any field test to evaluate the characteristics of the chip seal. D1 fog seal the

chip seal only if milling is used as it is already oxidized. Other districts do not fog seal the chip seal.

State-wide, the thickness of chip seal varies from 3/8" to 1". The minimum thickness of chip seal for D1 is about 3/8" whereas for D4 it is 1". Life of chip seal varies from 3-10 years. As discussed before, chip sealing is done in a cyclic manner. Therefore, the time period for the cycle equal to the life of chip seal for some of the districts. Some of the districts, e.g. D1, they do chip sealing if the pavement condition is bad regardless the cycle. The cost of chip sealing increased in last few years as emulsion price increased a lot. Now it takes as much as $25000 to chip seal a lane mile while it was only $10000 few years back. Number of field crew involved in chip seal and the lane miles that can be completed in a day is important for cost analysis. D2 has 15 people whereas D4 has 23 people involved in chip seal. Both of districts can finish 5 lane miles in a day. D4 is capable of chip sealing more than 5 lane miles in a day. Because of the budget issue, they cannot use more 5 emulsion tankers in a day by which only five lane miles is possible to chip seal. Table VI summarizes the information about the thickness, life and cost.

TABLE VI
THICKNESS, COST AND LIFE

	D1	D2	D4	D6
Thickness	3/8"	1/2"	1"	1/2"
Life (yrs)	3-5	6-7	5-11	7-10
Cost ($/sq.yd)	2.63	2.84-3.55	I	1.99
No. of crew	21	15	23	17
Lane mile/day	3	5	5	8

B. Sand/Fine Seal and Scrub Seal

All of the NMDOT districts do not like to use sand seal because of the instrument and manpower issue. Few sand seals were constructed by contractors. Recently D1 and D4 did some fine sealing using milling materials. They used the chip box to spread the fines. None of the district has any written documents or standards for fine seal. D1 has some information on emulsion and fines application rate they used. HFE90P is usually used for sand seal. This emulsion performs betters in presence of dust. Typical application rate is around 0.4 gsy which is determined based on experience and experiment on the site by a test strip.

D1 and D2 don't use scrub seal and don't have any information on scrub seal. In D4, NM219 MP15-0 was scrub sealed by contractors. But no information on that project is available. D6 once did scrub seal on NM371 by contractors and some of the information on that project is available. The maximum aggregate size for scrub seal is 3/8" and application rate is around 20 psy. HFE90P emulsion is used at a rate around 0.2-0.25 gsy rate.

C. Patching

Like chip seal, patching is widely used by NMDOT districts. They do it based on experience. All districts sometimes use millings for patching. As discussed before, each district has their own maintenance patrol who roams around to find pavements to be patched. Table VII shows the distress types for which different district prefer to use patching. For rutting, pothole and edge damage, almost all districts prefer to patch the road. D2 uses patching for these three reasons only. D1 like to use patching for other distresses/conditions such as cracking, oxidation, moisture infiltration and moisture damage.

TABLE VII
SELECTION CRITERIA FOR PATCHING

Distresses	D1	D2	D4	D6
Cracking	y	n	n	y
Oxidation	y	n	n	n
Rutting	y	y	y	y
Skid resistance	y	n	n	n
Potholes	y	y	y	y
Edge damage	n	y	y	y
Base damage	n	n	y	n
Moisture infiltration	y	n	n	y
Moisture damage	y	n	n	y

NMDOT districts use three types of patching: pothole patch, dig-out patch, and blade patch depending on the pavement condition. D1 uses a thin blade patch which is known as skin patch. If small potholes exist pothole patch is used. It is an emergency type of patching and lasts for very short time (as low as three days). If the pothole condition is very bad that is pothole continued to sub-base and subgrade, dig-out patch is used sometimes. For dig-out patch the pothole is made square and dug out up to the subgrade. D6 always use dig-out patches within few days after pothole patching. D6 has three small milling devices which can be attached to a bob CAT to mill down the pavement. For pothole patching ready mix bag material is used. Several brand of bag mix are available in the market such as QPR and UPN. D1 and D6 use QPR and others use UPN. During winter, bags are stored inside room to keep it workable (D2 does it). Dig-out patching is mainly constructed using Hot Mix Cold Lay (HMCL) material. The mixing is mainly done by contractors. Contractors collect the millings from the districts and mix it in hot drums and supply it to districts. Brasier Asphalt is preferred by D1 and D6 and Mesa Verde is preferred by D2. The main benefit of this mix is that it can be stockpiled for a long time (as long as six months for millings and 8 months for virgin materials). For larger area with distresses, blade patch is used. For blade patch, hot mix or HMCL is used. Hot mix requires a lot of materials to be mixed. That's why districts buy HMA from contractors instead of mixing.

Table VIII describes the site condition and preparation for patching. Pothole patching has to be done all over the year to meet the emergency need. If it is raining, it is not possible to clean the hole. If it is dry holes are cleaned for any debris and vegetation. D6 sometimes uses geo-grid or geotextile on the base to increase capacity. Cold mix is normally used in summer season. D1 uses blade patch from March to October and D2 does it from March to August. All districts do brooming, crack sealing and tack coating before blade patching.

TABLE VIII
SITE CONDITION AND PREPARATION FOR PATCHING

Districts	D1	D2	D4	D6
Season for pothole	Year round	Year round	Year round	Year round
Cold mix				Summer season
Blade patch	March-October	March to August	Year round	
Pothole cleaning	y	y	y	y
Surface Brooming	y	y		y
Crack seal	y	n	n	n
Tack coat	y	y	n	y

Before construction, traffic control should be planned. For pothole patching, none of the district uses any traffic control plan. For blade patch a traffic control plan is required. It includes flagger control, signs and pilot vehicles. For pothole patching, there is no need for roller. The construction truck and hand compactor should be enough. For blade patching, D1 uses pneumatic tire and steel roller for compaction whereas D2, D4 and D6 use steel roller only. For steel roller, water is sprayed on it continuously during compaction so that HMA does not stick to the roller. All districts keep a crown height to provide the patch enough room for compaction by moving traffic. For D2, the crown height ranges from 1/4" to 1". D4 doesn't have any exact value for crown height. It may range from 1/8" to 1/4". D6 doesn't keep any crown height if the compaction is done by roller.

The design life of patching varies from as low as 3 days to as much as 3 years depending on patching type, weather condition and traffic volume. According to D1, the life of patching ranges from 2 to 4 years. According to D2, pothole patches lasts around 3 months whereas blade patch lasts around 3 years. D3 says that their pothole patch has almost no life and blade patch lasts about a year. D6 says that their pothole patch last around three days, dig-out patch lasts about 1.5 years and blade patch last 3-5 years. It was not possible to estimate a cost for any of the district for patching. as pothole or blade patch size and thickness varies over a wide range.

V. CONCLUSIONS AND FUTURE WORK

The following conclusions can be made from this study;

- All districts use millings for the maintenance purpose. They are at initial stage and have not been investigated yet for performance and cost effectiveness
- Although very few documents are available on maintenance work in New Mexico, none of the document clearly specifies any design procedure for the maintenance job. All the works are done based on experience.
- Chip seal and patching are the popular maintenance procedures in New Mexico. Chip size varies from 3/8" to 1/2" and single layer of chip seal is used. All districts use HFE-100P as binder for chip sealing. Life of chip seal in New Mexico varies between 3 to 10 years
- Pothole, dig-out and blade patch are preferred by all districts. Life of pothole patch is as low as 3 day whereas blade patch may last for 3 years.

The authors have plan to investigate millings project to evaluate its performance, life expectancy and cost

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