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Pavement maintenance procedures with and without milling materials

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Abstract

This study evaluates maintenance treatment followed by different Districts of New Mexico Department of Transportation (NMDOT). In addition, two case studies on the use of old pavement materials, called the "millings", in maintenance projects are reported. Based on this study, it is observed that none of the Districts have a written procedure for maintenance work. Rather Districts rely on the experience of the maintenance crew for conducting maintenance projects. All Districts prefer to use chip seal for maintenance irrespective of distress conditions of the pavements. Patching and crack sealing are usually done before chip sealing to extend the life of the chip seals. Sand seal, scrub seal, and slurry seal projects are not done by District maintenance crews but by outside contractors. It is also observed that all Districts are interested in using millings in maintenance projects and most have already used millings in at least one maintenance project with some success and failure. Most of the Districts have used coarse fraction of millings in chip seal projects successfully. However, they failed to find a proper way to process the fine fractions of millings. Case Study I shows that fine millings can be used to construct thin overlay when mixed with emulsion in pug mill or hot drums. Case Study II concludes that fine millings can be used as fine/sand seal successfully following the same procedure and using the same equipment as chip seal.

Keywords: Millings; Maintenance; Emulsion; Rutting; Pug-mill

1. Introduction

Maintaining a pavement costs millions of dollars and may be a total waste if proper maintenance type is not applied [1–3]. If pavements are constructed following standard specifications but they are not maintained following any uniform standard or procedure, performance will be jeopardized. In New Mexico, it is not known whether any of the New Mexico Department of Transportation (NMDOT) Districts follow the same procedure for maintenance work, because the NMDOT specification book does not include any maintenance procedure. Therefore, it can be assumed that NDMOT Districts conduct maintenance work based on the experience of their crew. If all the maintenance is done based on experience only, it is possible that the procedure can be lost after retirement of an expert crew or personnel. Also, different District crews might be doing a specific maintenance work (say, chip seal) differently. Therefore, documentation of the maintenance procedures of different Districts across New Mexico and identifying similarities and dissimilarities among District maintenance procedures for a specific type of maintenance treatment is important (maintenance procedure, maintenance method, and maintenance treatment are synonymous and they are used interchangeably in this study). If different Districts perform maintenance work differently, some may use less manpower and money and

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come up with a higher service life. The opposite is also possible. Therefore, a comparative study may reveal the best maintenance procedure that is less expensive and more effective. For example, if one District finds a specific type of emulsion or binder does not work with a certain type of aggregate and/or maintenance treatment, that information can be very useful to other Districts if there is supporting documentation. In such cases, a face to face interview or survey of District crew can be very useful, which is what has been done in this study.

Use of millings in maintenance projects can save on maintenance costs. Asphalt "millings" are defined as the "old asphalt materials" that are produced due to removal and recycling of an existing asphalt pavement layer to correct and restore the surface to a specified profile. Cost effectiveness, sustainability, and environmental friendliness are the primary reasons for using milling materials. Although NMDOT Districts have used asphalt millings over the years, it is not known which Districts have used millings in what type of maintenance projects, nor it is known whether a specific maintenance procedure (say, chip seal) differs when using virgin aggregates versus millings. It is also not known whether millings are preferable to virgin rock or vice versa. There is a need for determining the optimum use of millings specific to a maintenance method considering the practices, materials, traffic, and environmental conditions in New Mexico. To this end, an attempt is made in this study to examine some of these issues and options of milling in maintenance projects through conducting District interviews. In addition, case studies on the trial use of millings are included herein to assess current state-of-the-practice used in New Mexico regarding millings in maintenance treatments.

2. Objectives

The objectives of this study are to investigate

- The maintenance procedure followed by different NMDOT Districts with/without using millings.
- The effectiveness of the use of millings in maintenance. Two case studies are presented to discuss effective ways of using millings.

3. Maintenance treatments

Six different types of maintenance treatments are used by different Districts of NMDOT. They are described below.

3.1. Chip seal

This type of maintenance work consists of single or multiple applications of asphalt and aggregate over a weathered surface or a prepared base course as the original surface. The thickness of such applications is generally limited to 25 mm (1 in.) maximum. Chip seal is done for the maintenance work of block cracking, over polished aggregate, raveling and weathering and bleeding (with less binder). Chip seal does not expect to provide structural capacity.

Arizona DOT collects the pavement distress data before applying chip seal [4]. Montana DOT (MDT) and California DOT (Caltrans) follow their own manual to construct chip seal [5,6]. These manuals contain detailed procedures as well as specification limit. MDT starts chip sealing on 1st May and continues until August 20th, although the pavement temperature has to be greater than 16 °C (65 F). Caltrans described specific limits of different distresses for which chip seal is to be used. Chip seal should not be used for pavement with Annual Average Daily Traffic (AADT) > 40,000. Caltrans uses equations to determine chip and emulsion application rates and preforms ball penetrometer and sand path test on finished surface to check its quality. National Cooperative Highway Research Program (NCHRP) performed an extensive study on chip seal and published "Chip Seal Best Practices" which contains detailed procedures and specification. Only 18% of US roads are chip sealed using some method/equation. The rest of the pavements are chip sealed using experience only [7].

3.2. Sand/fine seal

The procedure for sand sealing is similar to chip sealing except sand or fine material is used instead of stone chips. Sand seal is often used where a flexible pavement has raveled to the extent that there is significant fine aggregate missing from the surface. It is also used as a pavement preparation treatment to provide a uniform surface before constructing a chip seal and to seal low severity fatigue cracks before constructing an overlay. The maximum thickness of a sand seal is about 4.75 mm (3/16 in.). There is no ASTM or AASHTO standard available for a sand seal mix design. In fact, very few studies are available on sand seal. FHWA described a very short procedure [8]. According to FHWA manual, the binder application rate varies from 0.68 to 0.90 l/m^2 (0.15–0.20 gallon per square yard, gsy) and sand application rate is in between 5.4 and 8 kg/m^2 (10–15 pound per square yard, psy). Sand or fine material sizes used by Washington DOT (WSDOT) vary between 6.4 mm and 9.5 mm (1/4 in. and 3/8 in.) [9].

3.3. Scrub seal

This is placed in situations very similar to that of sand or chip seals. Scrub seals can be applied when the distress level is greater than what would normally be used as a criterion for the application of a sand seal. The major difference in sand seal and scrub seal is, for scrub seal an initial sweeping is done over the applied emulsion before application of the sand or aggregate. After application of the sand or aggregate another sweeping is done, forcing the sand into the emulsion filled cracks and voids. The scrub seal method can fill cracks up to 12.5 mm (0.5 in.) wide that would normally fill by crack sealing. The benefit of scrub seal is that no crack seal is required before scrub seal, as crack seal is done sometimes before chip seal. The equipment required for chip seal is the same as scrub seal. There is no ASTM or AASHTO standard available for scrub seal mix design. MDT and Utah DOT (UDOT) use their own manual for scrub seal [10,11]. The emulsion application rate varies between 1 and 2 l/m^2 (0.22–0.45 gsy), cost varies between 1.07 and 1.26 \$/m^2 (0.9 and 1.05 \$/square yard).

3.4. Slurry seal

A slurry seal is a homogeneous mixture of emulsified asphalt, water, well-graded fine aggregate or sand and mineral filler which has a creamy, fluid-like appearance when mixed in proper proportions. The layer thickness is approximately equal to the maximum aggregate size. Generally, slurry seal used for the distress types block cracking, raveling and weathering on polished aggregate [12].

Several agencies and DOTs have developed standard procedures for slurry seal. The International Slurry Seal Association (ISSA) developed a manual consisting of detailed procedures and specification limits [13]. ISSA has proposed three gradations with maximum aggregate size 6.25 mm (1/4 in.), residual asphalt content varies from 6.5% to 16% and the application rate varies from 4.3 to 16.2 kg/m^2 (8–30 psy). Pavement temperature must be higher than 10 °C (50 F) for successful slurry sealing. Virginia, California and Arizona DOTs follow their own procedures for slurry sealing [14]. All these procedures are very similar to ISSA procedure and all of them have three types of slurry seal as in the ISSA.

3.5. Thin overlay

According to Caltrans, if a maintenance overlay is thinner than 38 mm (1.5 in.), it is known as thin overlay [6]. This is the traditional treatment method for protecting a deteriorating pavement, reducing roughness, restoring skid resistance, on alligator cracking, on block cracking, and improving reliability of a flexible pavement. Thin overlay is not suitable for structural strengthening and when there are issues on the de-bonding between the existing pavement layers. Another issue with the overlay is the propagating of reflective cracking through the overlays. The bottom of the overlay experiences additional horizontal strain due to the expansion of crack tip that is present in the existing pavements. This horizontal strain initiates bottom-up cracks in the overlays; bottom-up cracks are known as reflective cracks. Typical life of thin overlay is 4–6 years. Iowa DOT uses PG 76–34 for thin overlay [15]. If crack opening is more than 6.25 mm (1/4 in.), pavement should be crack sealed before overlay [16].

3.6. Patching

Patching is one of the most common methods for repairing localized areas of intensive cracking, whether the cracking is load associated (alligator) or environmental or construction related (transverse or longitudinal). Patching can be either partial or full-depth. Partial depth repairs usually involve removing the surface layer and replacing it with mix prepared with emulsified asphalt. Full-depth repair involves removal of the complete pavement down to the subgrade or to an intact intermediate subbase layer. Full-depth patching is the most common procedure used for the repair of localized alligator cracking and potholes. Emergency repairs of potholes frequently involve the use of cold-mix materials under severe environmental conditions. It is one of the expensive pavement maintenance procedures. Hot mix, cold mix, and bag mix are used for patching [6].

3.7. Use of millings in maintenance projects

Millings can be used as an aggregate substitute and asphalt cement supplement in recycled asphalt paving (hot or cold mix), as a granular base or subbase, stabilized base aggregate, or as an embankment or fill material [17–19]. Most of these usages, other than millings in HMA, do not take full advantage of the monetary values of this product. Milling materials used in pavement construction works show several advantages such as cost effectiveness, sustainability, and environmental friendliness, etc. [20], although, there are some drawbacks of using 100% milling as it has low bearing capacity and high creep [15]. Researchers have tried to improve the quality of millings using emulsion or cement or other materials and used it in pavement maintenance work [21].

Currently, in New Mexico, more maintenance work is done compared to pavement reconstruction or new construction, due to an ever shrinking state budget. NMDOT wants to use millings in the most effective way and that is in maintenance treatments. Therefore, it is necessary to determine if millings are suitable for pavement maintenance or not. Very few literatures are available on the use of millings in maintenance projects. Whether they can be used directly, or after mixing with emulsion, or as sand or chip seal is not known and therefore needs to be evaluated.

4. Research methodology

As a first step, based on the practices currently followed by different US states, governing factors for each maintenance type were identified and classified in seven categories: (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. As a second step, a survey questionnaire was developed for each of these categories. Information gathered from these interviews and documents collected from all five Districts were compiled and compared for each category.

As per the case study, two maintenance projects where 100% millings were used are documented in this study. In the first project, millings were mixed in hot drums or pugmill and compacted as overlay. Millings were mixed emulsion at different percentages to determine the optimum emulsion content. In the second project, fine millings were used as fine seal. Different binder application rates and fine spreading rates were tried to find a suitable match.

5. Synthesis of interview responses

5.1. Chip seal

NMDOT has six Districts of which one District does not use any millings in maintenance projects. Therefore, that District was not interviewed. All five Districts were asked if they have some documents on chip seal: any written procedure or specification. Only one District, District 4 possesses a written procedure which is followed during chip sealing.

Each District was asked how they determine which roads are to be chip sealed or maintained in a specific year. All of them answered that each year the field patrol recommends which pavements are to be chip sealed or maintained. Selection of candidate pavements to be chip sealed depends on different distresses: their extent and severity. None of the Districts measures severity and extent of the distresses. Recommendation depends on field patrol's visual inspection only. Table 1 summarizes the different distresses each District prefers to chip seal. For cracking and moisture infiltration, all Districts use chip seal. For bleeding, only District 4 uses chip seal.

Each District was asked about the characteristics of chips (sizes, tests for quality control, application rate, etc.) they use. From the interview or survey, it was revealed that the size of the chips or chip aggregates used by different NMDOT Districts varies between 9.5 mm and 12.5 mm (3/8 in. and 1/2 in.). District 1, District 2, and District 4 use 9.5 mm (3/8 in.) chips whereas District 5 and District 6 use both sizes, but mostly 12.5 mm (1/2 in.) chips. Chips are cleaned using 9.5 mm (3/8 in.) sieve so that no fines are present and damped by spraying water. Small chips are expensive but required less in quantity. Therefore, District 1 has less application rate (9.8 kg/m^2) compared to District 6 (15.2 kg/m^2). District 2 and District 4's chip application rate is as low as 8 kg/m^2. Chip application rate in the field depends on the existing field conditions, available chip quality and type, and is determined by trial and error. All Districts dampen their chips before spreading to control dust. Reduction of dust also helps better bonding between chips and emulsion. None of the Districts pre-coat the chips as it may cause a bleeding problem. Laboratory testing for chip quality is mainly performed by contractors according to the price agreement. District officials only perform gradation to cross check the chip size.

Table 1
Selection criteria for chip seal.

Distress type	Districts
Cracking	D1, D2, D4, D5, D6
Oxidation	D1, D2, D6
Rutting	D2, D4
Wearing surface	D1, D6
Skid resistance	D1, D2, D4, D6
Bleeding	D4
Raveling	D2, D4, D5
Moisture infiltration	D1, D2, D4, D5, D6
Moisture damage	D1, D5

To find out information about emulsions, each District was asked about the type, application rate of emulsion they use. It was observed that polymer modified high float emulsion (HFE-100P) is used for chip seal by all five Districts. HFE 100P is an anionic medium to rapid setting emulsion. Use of polymers in emulsion performs well when fines are more than 2%. Application rate varies between 1.6 and 2.1 l/m^2 (0.35–0.46 gsy). The application rate is adjusted in the field depending on the pavement condition and weather. District 2 uses more emulsion for virgin chips compared to millings. District 6 stated that use of millings does not influence the application rate as the binder coating the chips is aged and hardened.

Each District was asked if they check the site condition before chip sealing. Investigation of the pavement temperature as well as weather forecast during the day and the following day of construction is very important for a successful chip sealing. If temperature is too low or wind speed is too high, surface binder may become harder while leaving unbroken emulsion inside. This may result in bad bonding between chips and emulsion and results in premature failure in chip sealing which was observed in some pavements in New Mexico. Therefore, in New Mexico, chip sealing starts in late spring and continues to early winter, typically May to August. Mountainous regions have a narrow range whereas the flat plains have a wider range. As rain water may wash out the emulsion, chip sealing should not be constructed during rain or if there is rain forecasted on the following day. Freezing temperature during the night of construction may also affect the chip performance.

Each District was asked if they prepare the surface before chip sealing. All of the Districts clean the surface for dust and debris by broom and sometimes tack coat is applied. The edges are cleaned for vegetation by District 6. If crack is more than 6.25 mm (1/4 in.) wide, crack sealing is done. District 6 does crack sealing at least one year before chip sealing to give enough time to cure. District 2 crack seals three months prior to chip seal. If other distresses are present, District 1 does a blade patch six months prior to chip sealing. All surface preparation before chip seal is conducted by field patrol.

Table 2 summarizes the field condition and preparation techniques followed by different NMDOT Districts. It is observed that none of the Districts construct chip seals if the pavement temperature is below 16 °C (60 F). All Districts except District 2 do a test strip to determine chips and emulsion application rate before constructing chip seal. The test strip is chosen on the actual pavement to be chip sealed, as adjustment made on other pavements may not work for the pavement to be chip sealed.

All Districts were asked to provide information on construction procedures starting from traffic control to final brooming. During construction, all Districts use the Manual on Uniform Traffic Control Devices (MUTCD) with little or no modification for traffic control. Emulsion is distributed at a lower rate. If the pavement surface looks uniform after emulsion spraying, the rate is set. Otherwise, nozzle height, pressure and shot rate are adjusted. All Districts except District 5, verify the application rate by dividing total emulsion by area sprayed. Chips are sprayed at a lower rate using a chip box. If bleeding is not observed, that rate is selected. All Districts except District 4, use pneumatic tire roller for compaction. District 4 uses a steel wheel roller in addition to a pneumatic tire roller. Steel roller is not preferred as it may crush the chips and pressure is not uniform if the surface of the pavement is not uniform. This may cause uneven compaction. On the other hand, pneumatic tires are flexible and can compact uniformly even though the pavement surface is not uniform. The number of passes is an important parameter that controls the quality of the finished surface. A lower number of passes may result in higher chip loss and inadequate bonding; more compaction may result in damage of the seal. Therefore, the optimum number of passes needs to be determined. This is done by the chip seal crews' visual inspection of the chip seal after each pass. The number of passes for all Districts varies between three and four passes. Brooming for loose chips is done on the following day to give the chip adequate time to set. Table 3 describes the construction sequence and configuration of the different Districts.

QA/QC is important for any successful project and each District was questioned on their procedure. For QC, all Districts measure the chip application rate. Districts 1 and 6 measure the embedment depth, which has to be more than 50% immediately after construction. Embedment depth is measured by picking up a chip from the chip seal. The embedment depth is supposed to be more than 70% some days after the pavement is opened for traffic. Chip loss also needs to be measured to control broken windshields as well as to reduce chip cost. Districts 1 and 6 do it by visual inspection. None of the Districts performs field testing to check the quality of the finished surface. Districts 1, 5 and 6 fog seal the chip seal, if needed. District 1 fog seals only if millings are used and they look oxidized. Districts 5 and 6 fog seal if chip loss is higher or chips are loose.

Districts were questioned on the typical thickness, life and cost of the chip seal. Maximum thickness of chip seal varies between 9.5 mm (3/8 in.) and 25 mm (1 in.), depending on the chip size and layer of chips. For single layer chip application, chip seal thickness is equal to the chip size. For double layer chip application, chip seal size is double of the chip size. The life of chip seal is around 7 years. Different types of maintenance may be done on the chip seal during this time. District 1 is able to chip seal 5 km (3 miles) of pavement in a day, whereas District 6 can construct 13 km (8 miles) in a day. Other Districts can construct 8 km (5 lane miles) of chip seal in a day. All Districts are capable of doing more chip seal in a day. However, due to the higher price of emulsion (which is only bought with state money), use of more than 5 tankers of emulsion in a day is not possible.

5.2. Sand/fine seal and scrub seal

Each District was questioned if they use sand seal or scrub seal for maintenance and if they have any information available. None of the Districts prefer to use sand seal as they don't have the manpower and equipment required for sand seal. Districts 1 and 4 tried to use sand seal by using chip box and chip seal procedures. They used millings fines as sand. HFE-90 is used by District 1 for sand seal as it works better with dust.

Districts 1 and 2 do not use scrub seal. District 4 once used scrub seal on NM219 MP15-0 (here, NM stands for New Mexico and MP stands for mile post) and District 6 did scrub seal on NM371. Both of them were constructed

Table 2
Site condition and preparation.

Season	D1 April–September	D2 May–August	D4 May–September	D5 May–September	D6 May–August
Temperature	65F+	60F+	65F+	60F+	60F+
Test strip (ft)	250	n	200	y	y
Calibration	y	y	y	n	y
Brooming	y	y	y	y	y
Crack seal	y	y	n	y	y
Tack coat	s	s	s	s	s
Patching	y	y	y	y	y
Fog seal	y	n	n	n	n
Blade patch	n	n	n	n	y
Shoulder clean	n	n	n	n	y

y = yes, n = no and s = sometimes.

Table 3
Construction of chip seal.

Steps	D1	D2	D4	D5	D6
Traffic control	MUTCD	MUTCD	MUTCD	Own	MUTCD
Roller type	3 tire	3 tire	3 tire + 1 steel	3 tire	3–4 tire
Roller speed	5 mph	5 mph	Not known	Not known	5 mph
Pressure (psi)	90–120	Not known	Not known	Not known	Not known
No. of passes	3–4	3	3	Not known	4
Brooming	y	y	y	y	y

by contractors and did not perform well. For District 5, maximum aggregate size was 9.5 mm (3/8 in.) and application rate was 10.8 kg/m^2 (20 psy). HFE-90P emulsion was used at a rate of 0.9–1.1 l/m^2 (0.2–0.25 gsy).

5.3. Patching

Districts were asked about their procedure of how they select a pavement to be patched. As they said, field patrols investigate the roads in each District and determine the road sections to be patched. The selection criteria of a pavement for patching depend on the distress type of the pavement which varies from District to District. All Districts use patching for potholes, rutting and edge damage. District 1 uses patching for additional distresses like cracking, oxidation, moisture infiltration and moisture damage. Table 4 shows the selection criteria of a pavement to be patched.

Districts were asked about the type of patching and the materials they use for patching. All NMDOT Districts use three types of patching: emergency patching or pothole patching, dig-out patching and blade patching. District 6 always uses dig-out patching within a few days after pothole patching. District 6 has three small milling devices which can be attached to a skid steer to mill down the pavement. For pothole patching, Districts 1 and 6 use QPR and others use UPN brand. During winter, District 2 stores the bag inside to keep it workable. During summer time, HOT Mix Cold Lay (HMCL) is used by all Districts. Every District except District 5 uses millings to produce HMCL. The mixing job is performed by the contractors. The main benefit of HMCL is that it can be stockpiled for a long time (as long as six months for millings and 8 months for virgin materials). HMA is used for blade patch by all Districts and they mainly buy it instead of mixing, as they only require a small quantity of HMA.

Table 4
Selection criteria for patching.

Distresses	Districts
Cracking	D1, D5, D6
Oxidation	D1
Rutting	D1, D2, D4, D5, D6
Skid resistance	D1
Potholes	D1, D2, D4, D5, D6
Edge damage	D2, D4, D6
Base damage	D6
Moisture infiltration	D1, D5, D6
Moisture damage	D1, D6

Each District was asked to provide information about the construction procedures they follow. For pothole patching, none of the Districts use 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 a roller. The construction truck and hand compactor should be enough. For blade patching, District 1 uses a pneumatic tire and steel roller for compaction whereas District 2, District 4 and District 6 use steel roller only. For steel roller, water is sprayed on the roller continuously during compaction so that the 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 District 2, the crown height ranges from 6.25 mm to 25 mm (1/4 in.–1 in.). District 4 does not have an exact value for crown height. It may range from 3.1 mm to 6.25 mm (1/8 in.–1/4 in.). District 6 does not keep any crown height if the compaction is done by roller.

Each District was asked about the life of their patching. According to District 1, the life of patching ranges from 2 to 4 years. According to District 2, pothole patches last around 3 months whereas blade patch lasts around 3 years. District 3 states their pothole patch has almost no life and blade patch lasts about a year. District 6 indicates that their pothole patch last around three days, dig-out patch lasts about 1.5 years and blade patch lasts 3–5 years.

6. Case Study I: use of millings as thin overlays

This case study examines the applicability of coarse and fine millings as thin overlay while mixed with emulsion in a hot drum or pugmill.

6.1. Materials

Two types of milling materials were used: coarse and fine. Both of the millings were collected from US550.

6.1.1. Coarse millings

Fig. 1(a) shows the stock pile of the millings. The milling has the NMDOT's base coarse gradation.

6.1.2. Fine millings

The constituent material is Nova chips of 6.25 mm (¼ in.) maximum size. Fig. 1(b) shows the stock pile of the fine millings. This milling is dark, which indicates that the particles are also coated with enough binders.

6.2. Procedure and outcome

6.2.1. Thin overlay by coarse millings

6.2.1.1. Trial 1: 100% millings with no emulsion added. As millings already have binder coating on each particle, crush millings were used to see if it could be used as an overlay without adding any additional binder. The millings were warmed to a temperature around 77 °C (170 F) and compacted without any addition of binder. It is observed that the millings do not show any bonding. Although the millings look dark because of asphalt coating, they show a rough texture rather than a glossy texture. That means that the millings binder content is less than the amount of binder required to bond particles together. Thus, 100% milling without any addition of binder cannot be used in the field as overlay.

6.2.1.2. Trial 2: 100% millings with 1% emulsion added. As 100% millings with no added binder did not work, 1% emulsion was added to the millings. During this time millings temperature was 77 °C (170 F), emulsion temperature was 100 °C (212 F), and after mixing, the temperature was recorded as 62 °C (144 F). Initially the mix was tested on a hand palm by hand squeezing as shown in Fig. 2. It was observed that the millings now showed some kind of bonding between them. HFE-300 emulsion was used.

After initial investigation of bonding, the millings were used as overlay on a driving lane of NMDOT field patrol of District 6. On a compacted base, a thin layer of CSS-1H emulsion was sprayed as tack coat. The millings were transported to the site by a hauling truck. By the time the millings were transported to the site, the temperature decreased and the lay down temperature was 43 °C (110 F). The millings were distributed over the base using a leveler vehicle. As the leveler was manually operated, it was expected that the millings were not distributed to a uniform thickness. The millings were then compacted using a 15 ton pneumatic tire roller for two passes and a 3 ton steel roller for one pass. The overlay thickness was about 64 mm (2.5 in.).

6.2.2. Thin overlay by fine millings

A thin overlay by fine millings was applied on the thin overlay by coarse millings. For the 1st trial 1% emulsion was used. However, it was observed that the bonding between particles was not good. A lot of cracks were visible all over the surface as shown in Fig. 3(a). It was expected, because fine millings are composed of small particles with more surface area compared to coarse mills, therefore, they require more emulsion. The second trial was to use 2% emulsion. This time the surface looked good without any visible cracks as shown in Fig. 3(b). The compacted fine millings layer was about 19 mm (3/4 in.) thick. Some observation should have been made after opening to traffic, however, because of the distance; it was not possible to make a trip to the test site.

7. Case Study II: use of fine millings as fine seal

This case study examines the applicability of fine millings as fine seal to repair an aged pavement with minor cracks. The procedure, similar to chip seal, was followed and the same equipment was used.

7.1. Existing pavement condition

The last maintenance on this pavement was done around 8 years ago by a layer of Open Graded Friction Coarse or OGFC. It was observed that the pavement had severely aged and OGFC was popping out in several locations. Few wide open cracks were also visible. The pavement condition is shown in Fig. 4.

7.2. Materials

HFE-100P was used as emulsion which is the popular emulsion for chip sealing in New Mexico. The maximum size of the fine millings was 6.25 mm (1/4 in.). These millings looked gray instead of dark which indicates that the millings were aged and contain a lot of uncoated particles. Fig. 5 shows the millings used for this project. The millings were damped before using by spraying water on it.

(a) Coarse millings (b) Fine millings

Fig. 1. Stock pile of millings.

Fig. 2. 100% millings after adding 1% emulsion.

(a) Crushed chips with 1% emulsion (b) Crushed chips with 2% emulsion

Fig. 3. Use of fine millings as thin overlay.

(a) Aged with popped out OGFC (b) Some wide open cracks

Fig. 4. Existing pavement condition.

7.3. Operations and observations

The initial shot rate for the emulsion was set to 0.73 l/m^2 (0.16 gsy), as the pavement does not have severe cracks. At this low shot rate, a significant portion of the pavement was not covered by emulsion as shown in Fig. 6(a). Shot rate was increased to 0.91 l/m^2 (0.20 gsy) and the problem still existed. Finally, the shot rate was increased to 1.1 l/m^2 (0.24 gsy). This time, due to the overlapping of nozzles, some areas had higher volume of emulsion compared to other areas as shown in Fig. 6(b). This happened because the distributor was used for chip seal and worked perfect for the shot rate as low as 1.6 l/m^2 (0.35 gsy). To eliminate the overlapping of nozzles, alternate nozzles were turned off and the pressure and height of the nozzles were increased.

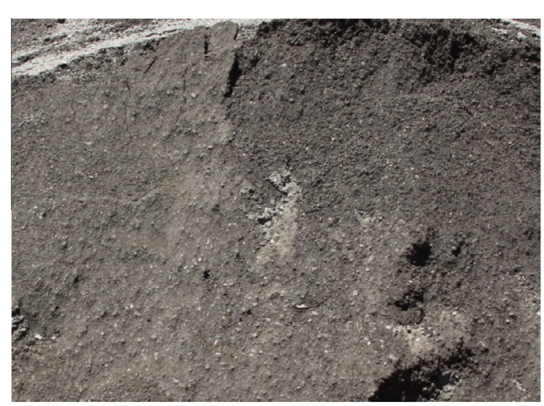
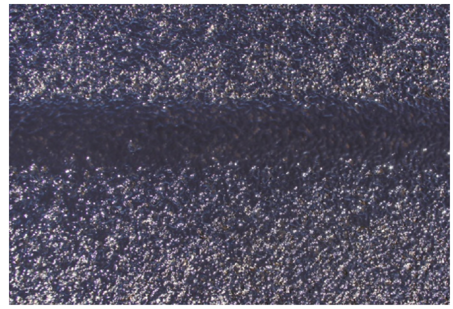


Fig. 5. Fine millings used for the fine seal.

(a) Very low shot rate



(b) Emulsion overlapped

(c) Chip box spreading the fine millings

(b) Bleeding due to low fines spreading rate

Fig. 6. Emulsion shot rate adjustment.

Fig. 7. Compacted fine seal.

During this time, the emulsion sprayed on the pavement was almost uniform and covered the whole pavement. The shot rate during this time was 1.28 l/m^2 (0.28 gsy). Finally, this shot rate was used throughout the project.

A chip box was used to spray the millings as shown in Fig. 6(c). Initially, the spread rate was 7 kg/m^2 (13 psy). After compaction, bleeding was visible as shown in Fig. 6 (d). To stop bleeding, shot rate was increased to 9.2 kg/m^2 (17 psy). There was no bleeding; therefore, this rate was used throughout the project. After spreading, fine seal was compacted using a pneumatic tire roller by 3–4 passes. At the end, a steel wheel roller was used to create a smooth surface. Fig. 7 shows the compacted fine seal.

8. Conclusions

This study revealed that no documents are available for any maintenance activities by different NMDOT Districts. Rather, maintenance activities are run by the experience of each District maintenance crew. As a result, a non-uniform maintenance procedure exits among the Districts. All of them prefer to do chip sealing over any other type of maintenance as they have experienced manpower and equipment for chip sealing. Crack seal and patching is done a few months prior to the chip seal.

As millings are scattered all over the state, all the Districts like to use it for their maintenance projects but do not know beyond using them in chip seal projects.

Case Study I shows how District 6 tried to use both fine and coarse millings as thin overlay by mixing them with emulsion in a hot drum or pugmill. Coarse millings with 1% HFE-300 shows good bonding between the milling particles hence it was compacted as an overlay on a driveway of the NMDOT field office. Fine millings require 2% emulsion to get bonding between the particles. Depending on the millings fineness, the percentage may differ. However, this case study gives an idea of the percentage of emulsion to start with as a trial for milling materials.

Case Study II explores how fine millings are used as a fine seal by District 4. It is observed that an emulsion shot rate of 1.27 l/m^2 (0.28 gsy) and fine millings spread rate of 9.2 kg/m^2 (17 psy) work well for that specific pavement. Depending on the pavement condition and millings type, the rate may differ. Again, this case study gives an idea of which shot or spread rate one should start fine sealing while using millings.

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