Use of Millings in Flexible Pavement Maintenance

Rafiqul A Tarefder and Mohiuddin Ahmad
Department of Civil Engineering, University of New Mexico, New Mexico, USA
Email: {tarefder, mahmad}@unm.edu

Mohammad Hossain
Department of Civil Engineering, Bradley University, USA
Email: mihossain@fsmail.bradley.edu

***Abstract*— Use of milling materials in pavement maintenance can help to achieve sustainability through conservation of new aggregates. However, specific guidelines are not available to state Department of Transportation (DOTs) for using millings in maintenance projects. Two case studies are presented herein. One is about use of milling in thin overlay and the other is use of milling in fine seal treatment. For overlay maintenance, two millings materials were considered: coarse millings and fine millings. Trials were made in the field to mix 100% coarse millings without any emulsion and with 1% emulsion. It is observed that 100% coarse millings without any emulsion do not show enough cohesion. Rather, 100% millings with 1% emulsion showed better cohesion and integrity. 100% fine millings were tried with 1% and 2% emulsions. It was observed that fine millings with 2% emulsion worked better compared to the with 1% emulsion. It can be concluded that 100% millings can only be used as thin overlay if emulsion is used in the mix. For fine sealing, fine millings were used to repair an aged pavement with minor cracks. The procedure similar to chip seal was followed and same equipment as chip seal were used. It is observed that fine millings show a better bonding with emulsion if used as sand seal.**

***Index Terms*—chip sealing, emulsion, millings, sand sealing**

I. Introduction

A. Millings

Asphalt milling is defined as the material collected from the milled asphalt concrete pavement. According to New Jersey Department of Environmental Protection, asphalt milling is defined as fine particles, generally ranging in size from dust to less than 1 in., of bitumen and inorganic material that are produced by the mechanical grinding of bituminous concrete surface [1].

B. Use of Millings in Pavement Construction

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 [2]-[4]. Most of these usages, other than millings in asphalt concrete, do not take full advantage of the monetary values of this product. Millings materials used in pavement construction works show several advantages such as cost effectiveness, sustainability, and environmental friendliness, etc. [5]. Although there are some drawbacks of using 100% milling as it has low bearing capacity and high creep [6]. Researchers tried to improve the quality of millings using emulsion or cement or other materials and use in pavement maintenance work [7].

C. Use of Millings in Pavement Maintenance

Now-a-days, in New Mexico, more maintenance works are done compared to pavement reconstruction or new construction, due to ever shrinking state budget. The New Mexico Department of Transportation (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 needed to be evaluated. Two case studies are conducted during this study to determine the effective way of using millings in maintenance projects.

D. Use of Millings as Thin Overlay

Thin overlay is defined as a nonstructural maintenance layer which is less than 1.5 in. in thickness and placed over the old pavement [8]-[11]. Typically Hot Mix Asphalt (HMA) or Warm Mix Asphalt is used for overlay construction. Three types of gradation are used by California: Dense graded, gap graded and open graded. Nominal Maximum Aggregate Size (NMAS) is limited to ½ in. or smaller and the lift thickness is 3 to 5 times of the NMAS (12). Thin overlay is normally used to improve skid resistance and to decrease bleeding, raveling, oxidation etc.

Use of millings in maintenance reduces the construction cost. According to NCAT, use of 25% millings reduces the

Manuscript received March 4, 2015; revised July 10, 2015.

doi: 10.18178/ijscer.4.2.206-211

cost about 12.5% [12]. Therefore, most of the contractors and DOTs started using reclaimed materials as much as 20% in their mix. Caltrans uses up to 15% millings in their HMA for thin overlay [8]. Initially, researchers suspected that use of high percentage of reclaimed materials may affect the quality and performance of the mix. However, further research proved this statement wrong. Even, mixes with high percentage of reclaimed materials (up to 55%) shows better performance in rutting and moisture damage [12]. Reclaimed materials must be clean and screened. Sometimes mill and fill is used to overlay construction, however, none of the agencies or DOTs tried to use 100% millings for overlay construction using pugmill.

E. Use of Millings as Fine Seal

Sand seal is a bituminous-sand application to an existing pavement surface to seal the surface and function as light wearing course. The maximum thickness of sand seal is about 3/16 in. There is no ASTM or AASHTO standard available for san seal. None f the DOTs or organization tried to use 100% millings as fine seal.

II. Objectives

The objective of this study is to find out the applicability of millings as thin overlay or fine seal. If millings are used as thin overlay, what percentage of HFE300 emulsion would be used and if millings are used as fine seal, what would be the emulsion and millings application rate- are the two main concerns of this study.

III. Case Study I: Use of Millings as Thin Overlay

Coarse and fine millings were collected from United State- 550 (US550). The millings were mixed in pugmill with different percentage of HFE300 emulsion to determine the minimum percentage of emulsion that gives a better bonding between particles.

Figure. 1. Stock pile of coarse millings.

TABLE I. Gradation of Coarse Millings

Sieve Size	%Passing
1.0 in	100
3/4 in	90
No. 4	45
No. 10	32
No. 200	6

A. Coarse Millings

The milling has the NMDOT base coarse gradation as shown in Table I. Fig. 1 shows the stock pile of the coarse millings. It is observed that the crushed millings are black therefore coated with asphalt that are not aged too much.

B. Fine Millings

The maximum aggregate size fine millings are ¼ in. Fig. 2 shows the stock pile of the fine millings. The color of this milling is also dark, which indicates that the particles are also coated with enough binders. As small particles have more surface compared to coarse particles, fine millings contains more binders compared to coarse millings.

Figure. 2. Stock pile of fine millings.

C. Procedure and Outcome

1) Thin overlay by coarse millings

a) Trial 1- 100% millings with no emulsion added

As millings are coated with binder 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 heated to a temperature around 170 ℉ and compacted without any addition of binder. It is observed that the aggregates don't show any bonding between them. That is, the millings binder content is less than the amount of binder required to bond particles together. Therefore, 100% milling without any addition of binder cannot be used in the field as overlay.

b) Trial 2- 100% millings with 1% emulsion added

As 100% millings with no added binder didn't show any bonding, 1% emulsion was added to the millings. During this time millings temperature was maintained 170 ℉, emulsion temperature was 212 ° F and after mixing, the temperature was recorded as 144 ℉. To see quickly if the millings are showing any bonding, the mix was tested on a hand palm by hand squeezing as shown in Fig. 3. It is observed that the particles are now showing some kind of bonding between them.

After initial investigation of bonding between particles, the millings were used as overlay on a driving lane of NMDOT field patrol of District-6. A thin layer of CSS-1H emulsion was sprayed as tack coat on the existing pavement. Fig. 4(a) and 4(b) show the pavement before and after the application of emulsion respectively. The emulsion looks brown when applied but become dark with time as emulsion starts breaking (water evaporates from it). During hot and dry season, emulsion dries out in about 10

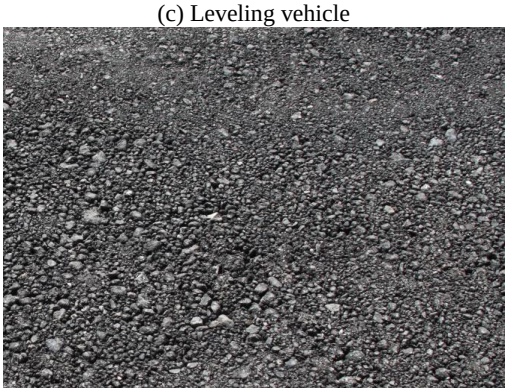
minutes. However, this study was conducted during winter and more time (around 30 minutes) was needed to break the emulsion. The millings were transported to the site by a hauling truck. By the time the millings were transported to the site, its temperature went down to 110 ℉. The millings are distributed over the base using a leveler vehicle. As the leveler is manually operated, it is expected that the millings are not distributed to a uniform thickness. Fig. 4(c) shows the leveling car. The millings are 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 2.5 in. Fig. 4(d) shows the compacted overlay.

Figure. 3. 100% millings after adding 1% emulsion

(a) Existing pavement before tack coating

(b) Emulsion sprayed on existing pavement

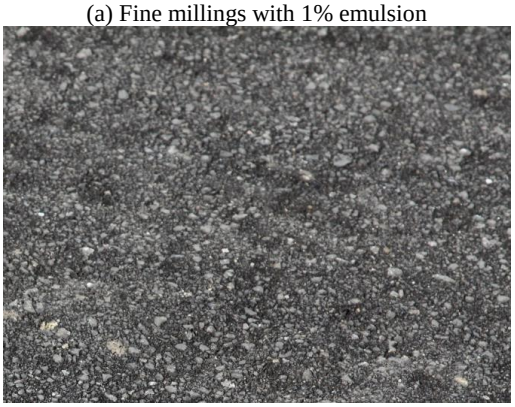
(c) Leveling vehicle



(d) Compacted overlay

Figure. 4. Different stages of using millings as overlay

(a) Fine millings with 1% emulsion



(b) Crushed chips with 2% emulsion

Figure. 5. Use of fine millings as thin overlay.

2) Fine millings as thin overlay

Initially, 1% emulsion was used with the fine millings, as it worked for coarse millings. It is observed that the bonding between particles were not good. Lots of cracks were visible all over the surface as shown in Fig. 5(a). It is expected, because fine millings are composed of small

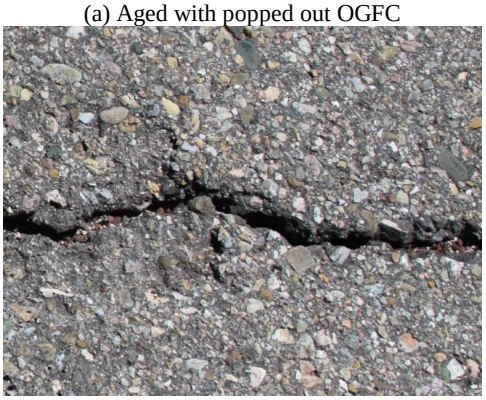
particles with more surface area compared to coarse mills, therefore, requires more emulsion. For next trial, 2% emulsion was used with the millings. This time the surface looked good without any visible cracks as shown in Fig. 5(b). The compacted layer of fine millings was about 3/4" thick.

IV. Case Study II: Use of Fine Millings as Fine Seal

A. Existing Pavement Condition

The last maintenance on this pavement was done around 8 years ago by a layer of Open Graded Friction Coarse (OGFC). It was observed that the pavement is severely aged (gray to white color) and OGFC is popping out in several locations. Some wide open cracks were also visible. The pavement condition is shown in Fig. 6.

(a) Aged with popped out OGFC



(b) Some wide open cracks

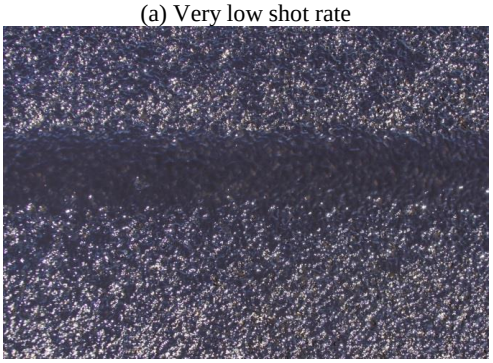
Figure. 6. Existing pavement condition.

Figure. 7. Fine millings used for the fine seal.

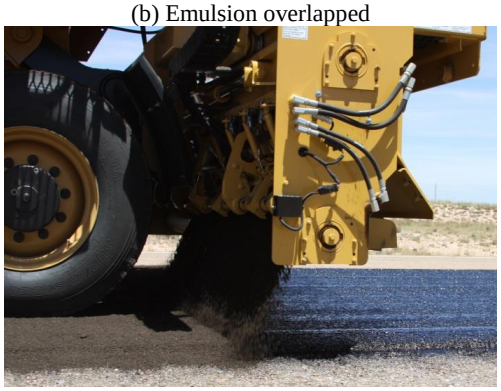
B. Materials

HFE100P was used as emulsion (which is the popular emulsion for chip sealing in New Mexico). The maximum size of the fine millings was 1/4". Unlike the previous project, these millings looked gray instead of dark. This indicates that the millings are aged and contains lots of uncoated particles. Fig. 7 shows the millings used for this project. The millings were damped before using.

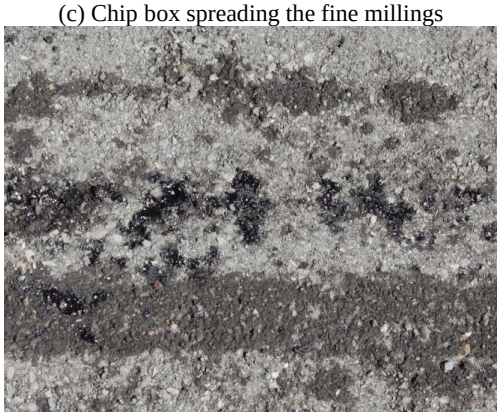
(a) Very low shot rate



(b) Emulsion overlapped



(c) Chip box spreading the fine millings



(d) Bleeding due to low fines spreading rate

Figure. 8. Emulsion shot rate adjustment.

C. Operation and Observation

The initial shot rate for the emulsion was set to 0.16 gallon per square yard (gsy), as the pavement doesn't have

severe cracks. However, at this low shot rate, a significant portion of the pavement is not covered by emulsion as shown in Fig. 8 (a). Shot rate is increased to 0.20 gsy and still the problem existed. Finally, the shot rate is increased to 0.24 gsy. This time, due to the overlapping of nozzles, some area had higher volume of emulsion compared to other as shown in Fig. 8 (b). This happened because the distributor is used for chip seal and worked perfect for shot rate as low as 0.35 gsy. To eliminate the overlapping of nozzles, alternate nozzles were turned off and the pressure and height of the nozzles were increased. This time, the emulsion sprayed on the pavement was almost uniform and covered the whole pavement. The shot rate during this time was 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. 8 (c). Initially, the spread rate was 13 pound per square yard (psy). After compaction, bleeding was visible as shown in Fig. 8(d). To stop bleeding, shoot rate was increased to 17 psy. There was no bleeding; therefore, this rate was used throughout the project.

After spreading, fine seal was compacted using pneumatic tire roller. Number of passes was 3 to 4. A steel wheel roller was used at the end to create a smooth surface. Fig. 9(a) shows the compacted fine seal. The surface was broomed on the following day. Fig. 9 (b) shows the finished fine seal constructed using fine millings. The surface looks good and performing well.

Figure. 9. Surface condition after compaction.

V. Conclusions

As millings are scattered all over the state, all the Districts are thinking to use it for their maintenance projects. All NMDOT Districts have already started using millings for their maintenance works.

Case study I shows how District-6 tried to use both fine and coarse millings as thin overlay by mixing them with emulsion in hot drum or pugmill. Coarse millings with 1% HFE 300 added showed bonding between the particles hence compacted as an overlay on a driveway of NMDOT field office. Fine millings required 2% emulsion to get bonding between the particles. Depending on the millings type, the percentage may be different. However, this study gives an idea at which percentage of emulsion to be used for trial mixes.

Case study II describes how fine millings were used as fine seal by District-4. It is observed that an emulsion shot rate of 0.28 gsy and fine millings spread rate of 17 psy worked well for that specific pavement. Depending on the pavement condition and millings type, the rate may be different. However, this study gives an idea at which shot or spread rate one should start fine sealing while using millings.

Acknowledgements

This project is funded by the NMDOT. The authors would like to express their gratitude to Lisa Vega for being the Advocate of this project and Michelle Langehennig for being Project manager. Special thanks to Romero from District 4 and Lisa Vega from District 6 and for inviting to visit the maintenance projects.

References

[1] Asphalt Millings Guidance Document, New Jersey Department of Environmental Protection, New Jersey, 2001.
[2] D. T. Murphy and J. J. Emery, "Modified Cold In-Place Asphalt Recycling," *Transportation Research Record*, pp. 143-150, 2007.
[3] A. M. Bleakley and P. J. Cosentino, "Improving properties of reclaimed asphalt pavement for roadway base applications through blending and chemical stabilization," *Journal of the Transportation Research Board*, no. 2335, pp. 20–28, 2013.
[4] R. L. Carvalho, H. Shirazi, M. Ayres, Jr., and O. Selezneva, "Performance of recycled hot-mix asphalt overlays in rehabilitation of flexible pavements," *Journal of the Transportation Research Board*, no. 2155, pp. 55–62, 2010.
[5] Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method: Guidelines, NCHRP Research Result Digest, 2001.
[6] IowaDOT, Developmental Specifications for Hot Mix Asphalt Thin Lift Overlay, Iowa, USA, 2014.
[7] N. H. Tran, G. Julian, A. J. Taylor, R. Willis, and D. Hunt, "Effect of geosynthetic material in reclaimed asphalt pavement on performance properties of asphalt mixtures," *Journal of the Transportation Research Board*, no. 2294, pp. 26–33, 2012.
[8] State of California Department of Transportation, Maintenance Technical Advisory Guide: Volume I – Flexible Pavement Preservation, Second Edition. California, USA, 2008.
[9] Thin Asphalt Overlays for Pavement Preservation. National Asphalt Pavement Association, Information Series 135, Lanham, MD, 2009.
[10] Thin Asphalt Overlays for Pavement Preservation. Mid-Year Asphalt Pavement Technical Seminar Sponsored by Flexible Pavements of Ohio, 2012.
[11] Thin Hot Mix Asphalt Overlay. Martin Asphalt Company, South Houston, TX, 2007.
[12] E. R. Brown and M. Heitzman, "Thin HMA overlays for pavement preservation and low volume asphalt roads," NCAT Report No. 13-05, Washington, D.C., 2013.

Rafiqul A Tarefder is one of the prominent researchers in the field of pavement engineering and geomechanics. He obtained his Bachelor degree in Civil Engineering from Bangladesh University of Engineering and Technology, Masters from He has more than 200 publications including journals, conference proceeding, book chapter and reports. He is Editor-in-Chief, editorial board member of different peer reviewed journals. He is serving as member and organizer in different committees in different organizations like TRB and NSF.

Mohiuddin Ahmad is a young researcher in the field of pavement engineering. He has more than 15 publications including 8 papers in peer reviewed journals like ASCE, TRB, ASTM, IJPE, IJP etc. He completed one project on pavement permeability and moisture damage and now working on pavement maintenance with millings.

Mohammad I Hossain is another young pioneer researcher in the field of pavements. Before joining to Bradley University as Assistant Professor, he served as Research Assistant, Teaching Assistant, Assistant Engineer, Entrepreneur, CAD Engineer in different organizations. He has more than 25 publications including journals, conference proceedings and presentation.