MnROAD [Safer, Smarter, Sustainable Pavements through Innovative Research] September 2011

TPF-5(134) PAVEMENT SURFACE CHARACTERISTICS REHABILITATION (INNOVATIVE DIAMOND GRINDING)

Participating Agencies	**Contract Duration**	**Funding**
Minnesota (Lead State), Texas, FHWA	Start – March 2007 End – November 2012	Total Funds $315,000
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Abstract

The Efforts at the Herrick Laboratory in Purdue University preceded a full scale experimentation of grinding configurations at the MnROAD research facility. This culminated in development of a quiet grinding configuration. This configuration was subsequently pre-deployed on Highway 94 near St Cloud Minnesota in 2009. Finally this quiet grinding was fully deployed and implemented in a mega project on Interstate 35 in Duluth Minnesota in 2010. Rolling Resistance measurements were conducted in summer 2011. Mankato State University and HDR are separate consultants retained for some defined tasks. Participating States Include MnDOT, TxDOT and FHWA.

Preliminary Laboratory Development

The International Grinding and Grooving Association (IGGA), American Concrete Paving Association (ACPA) and Purdue University initiated laboratory studies towards a diamond grinding texture with improved noise characteristics. IGGA developed grinding head was used to grind the various textures and is shown in FIGURE1. The process did not create or use a parallel laboratory equivalent for friction measurement neither did it simulate actual OBSI speeds and linear motion. Noise testing, using Sound Intensity (SI) techniques could only be conducted to 30 mph in the laboratory although field evaluations are typically conducted at 60 mph. A pooled fund study TPF 5-134 (MnDOT, TXDOT & FHWA) was set up to study the development and deployment of the grinding configuration.

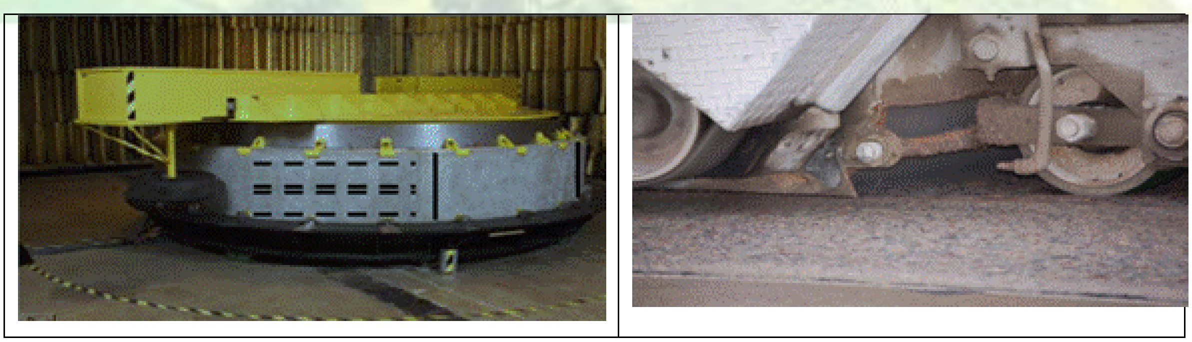


FIGURE1. Purdue SQDH Laboratory Test Wheel & Diamond Grinding Equipment.

Summer 2007 Constructability Evaluation

Diamond grinding was performed with large equipment (FIGURE1) that consists of a large rotary drum with diamond-tipped cutters, a large water receptacle for wet grinding and a delivery pipe for the slurry produced. Although it was not a full width grinding, the process created four test strips. TS1 was a flush grind and groove in one pass, TS2 was the flush grind and groove in 2 passes, TS3 was the conventional grind of 0.125X 0.125 X 0.066 inch grove width, land width and depth, and TS4 was the original non-uniform transverse tine. Mn/DOT measured Ride quality, Friction, and Texture before and after grinding. Subsequent OBSI were measured by Mn/DOT every season after summer 2007 and data is available in the MnROAD data base. Additionally the surfaces were evaluated for mean profile depth, friction and ride quality. Due to the width of the strips (18 inches wide and 2 ft. apart) pavement smoothness and friction measurements with the light weight profiler and friction measurements with the lock wheel skid tester were challenging in the test strips but easily achieved in the subsequent full width grind discussed in a later section.

Pavement noise, mean profile depth and international roughness are measured at each stage of the grinding development. Ribbed tire and smooth tire friction were also measured. However, sound intensity test procedure is discussed here. Tire-pavement noise was evaluated with the on board sound intensity (OBSI) test according to the AASHTO TP 79-08 (11) procedure. Pavement noise response from the microphones was condensed into a third octave frequency band and averaged for the leading edge and trailing edge. The OBSI parameter is the average of the logarithmic sum of the sound intensity in 12 frequencies (400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, and 5000 Hz) computed for the two microphones as follows:
Where SIi (i=1, 2, 3,… 12) are sound intensities in dB at each of the frequencies. The OBSI analysis is based on the AASHTO TP 76-09 protocol.

$$\text{OBSI} = 10 * \log_{10} \sum_{i=1}^{12} 10^{\{SI_1/SI_0\}} \qquad \text{(Equation 1)}$$

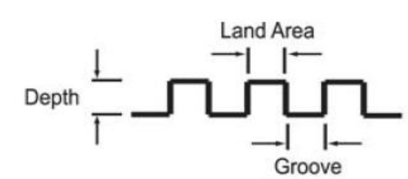
Where SI_i (i=1, 2, 3, …, 12) are sound intensities in dB at each the twelve 3rd octave frequencies.

SI_0 = SI at threshold of human hearing = 10^{-12} Watts/m^2

The same scope and set of testing was repeated in the subsequent stages of grinding configuration.

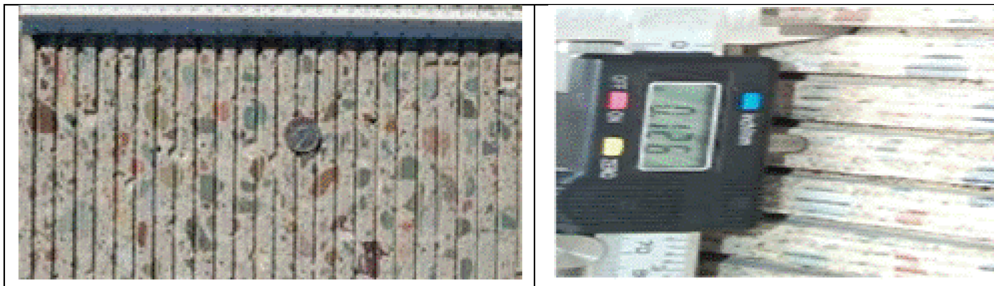
Full Width Grind Autumn 2007

Mainline Cells 7 and 8 the conventional grind grinding was done between 10/18/07 and 10/20/07 and the respective testing for post grind friction texture ride and noise followed shortly after. Cell 7 (innovative grind) received the innovative grind while cell 8 the conventional grinding. The secondary grind for cell 7 was the innovative diamond grinding configuration that is the subject of this study. Conventional configuration (MnROAD Cell 8) consists of groove and landing similar to the square box car configuration with equal land and groove area but the depth is 1/20th of an inch. Innovative grind in cell 7 consisted of groove and landing similar to the box car configuration with unequal land and groove area but the depth is 1/16 of an inch. Land is much wider than groove for quiet pavement enhancement. Results showed that ribbed tire friction for the ranging from 47 to 59. The disparity between ribbed and smooth tire friction was less than 5 in the innovative configurations.
At 98.5 dB (A) the innovative grind was much quieter than the conventional grind where OBSI was 102.7 dB (A) and quieter than the un-ground tine where measured OBSI was104 dB (A).



a) General Configuration

Conventional Grind Cell 8



c)Innovative Grind Cell 7 | d)Ultimate Grind Cell 9

FIGURE 2: Grinding Configuration of Conventional and Innovative Grinding.

Grind Improvements (Fall 2008) For Acoustics and Frictions

To improve friction in the innovative grind another configuration was performed on another cell in 2008. A configuration was then conceived that had approximately the same aspect ratio as the innovative grind but in addition had some corrugations on the land area. This led to the grinding configuration that came to be known as the ultimate grind. A difference between the ultimate grind and the innovative grind was the width of landing (0.375 inch former versus 0.5 inch latter) and corrugated landing. The configurations were ground in cell 9 in fall 2008. It was evident that though cell 9 was not as quiet as cell 7 there was a remarkable improvement in friction. The next improvement was in a predeployment as part of concrete rehabilitation project on Interstate 94 from Monticello to St. Cloud. The project included surface restoration through diamond grinding.

TABLE 1: Summary OF Full Width Grind (2007) and Grind Improvement Timeline

	Cell 37 Multiple Strips 2007	Cell 7 Innovative 2007	Cell 8 Conv. (2007)	Cell 9 Trans tine Pre-grind (2008)	Cell 9 Ultimate (2008)	Pre-deployment (2009)	Duluth Ultimate (2010)
	Inch	Inch	Inch	Inch	Inch	Inch	Inch
Mean Land Width	0.375	0.375	0.125	0.5	0.502	0.375	0.375
Groove Depth	0.1	0.120	0.125	0.15	0.309	0.309	0.309
Groove Width	0.125	0.125	0.125	0.15	0.129	0.129	0.129
MPD ASTM E-2157	0.047	0.035	0.047	0.035	0.057	0.07	0.07
OBSI (dBA) AASHTO TP	99.0	99	102.7	104.0	101.0	98.7	98.7
Ribbed Tire Friction ASTM E-274	Not Feasible	52	68	50	51	52	52
Smooth Tire Friction ASTME-274	Not Feasible	45	55	30	46	47	51
Corrugated Landing 1/32” X 1/32”	-	-	-	-	Yes	Yes	Yes

Predeployment on Mile Post 175 Interstate 94 near St. Cloud

In 2009, a rehabilitation project performed conventional diamond grinding on 1000-ft of a 4-lane divided highway that was originally textured with burlap drag in 1980. Over the years, with a traffic volume of 14000AADT and an ADTT of 1700, most of the texture was worn out. However the texture wear also resulted in some degree of aggregate exposure. The condition of the joints in the 27-ft dowelled skew jointed panels ranged from good to poor. The joints that were considered fair to poor were repaired before grinding. Some extensively damaged panels were ether partial depth repaired or full depth repaired.

In the rehab project a 1000-ft segment was isolated and ground to a different configuration. The chosen segment had joints in good condition and needed no rehab prior to grinding. The configuration used was an improvement over the 2008 grind of cell 9 MnROAD and obtained from Izevbekhai's (2) phenomenological model. It maintained the same width of groove and the same inter-groove spacing of 2007 cell 7 but utilized the additional corrugation of the 2008 Cell 9 initiative. The actual configuration is elucidated in table 1 provided improved friction and acoustic properties. Mn/DOT Retained HDR consultants to perform statistical pass-by evaluation of the innovative grind on TH 94 as well as MnROAD. The report (4) validated the quietness effect of the pavement on overall noise but identified certain truck noises of lower frequency than OBSI would capture.

Full Deployment TH 35 Duluth

The I-35 Duluth "Mega Project" contained two areas of concrete pavement rehabilitation (CPR). Mn/DOT's District 1 – Duluth Office was determined to grind these two areas to enhance the ride and friction, but also sought to implement the new configuration to rehabilitate the existing 1990 vintage transversely tined concrete pavement. Initial attempt to achieve an IRI of 60 inches/ mile were not realized. Subsequently the 2 stage grinding provided the solution and facilitated IRI of less than 60 inches per mile. Friction and OBSI measurements as well as MPD were measured and results summarized in table 1 shows that the 2010 Duluth grind was not only quiet but met the requirements for sufficient friction comparable to common network values as well as significant IRI improvement. The total length ground in this project was 20 lane miles.

FIGURE 3: Project Area in Three Segments

The first stage grinding included the conventional grind utilized to remove bumps and dips. A 2-stage grind with the conventional grind as flush grind provided corrugated landing for the ultimate grind. To facilitate monitoring of the Duluth grind, the configuration was replicated in the MnROAD test cells.

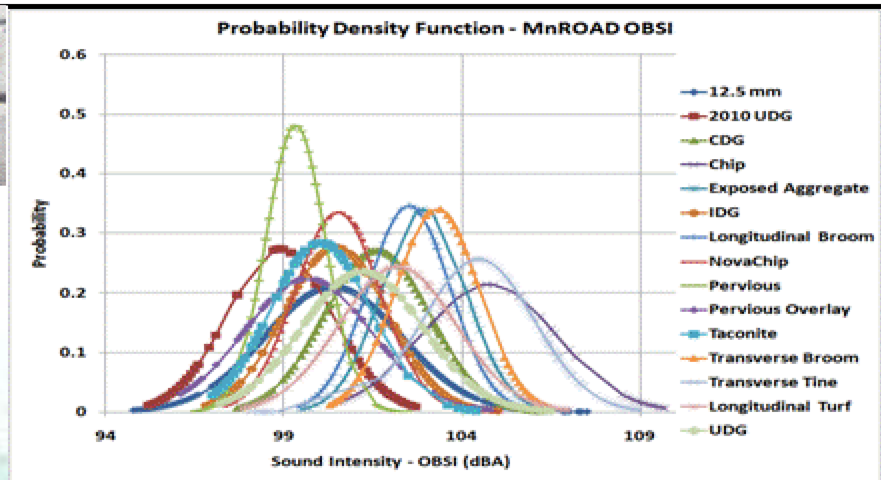
In 2010, a fifth strip was ground on cell 37 and the driving lane of cell 71 was ground with the Duluth configuration (FIGURE 4 inset). The passing lane of cell 71 was ground with the conventional grinding configuration. For an acoustic evaluation of the various grinding configurations in comparison to the other surface textures, a statistical analysis using a quasi- probability-density-function (fitted normal distribution) was chosen and used (FIGURE 4).

Acoustic Evaluation

FIGURE 4 shows a representation of OBSI data since 2007 for all MNROAD textures. Evidently, the 2010 ultimate grind has the lowest mean and is therefore by that definition the quietest surface in the MnROAD facility. It is also evident that the probability that this surface is louder than 100dBA is only 20 % with a mean OBSI of 98.7dBA. To compare this with transverse tining in the same figure, the mean is 105 dBA and the probability of being quieter than 100dBA is zero. The innovative grind shows a 50% likelihood of being quieter than 100dBA. The pervious concrete surfaces exhibit a mean of 99.5 but the full depth pervious cells are much less tailed than the pervious overlay cell. It is also evident that the traditional grind shows a mean of102.5 dBA and a 25% likelihood of being quieter than 100dBA. The quietest asphalt surface at MnROAD is the 4.75 mm taconite cell as shown in the fitted normal distribution. It exhibits a mean of 100dBA, The 2010 ultimate grinding (2010 UDG) is not only therefore fulfilling the requirement of a quiet pavement but appears to be the quietest surface at MnROAD.


Original Transverse Tine Texture


Final Grind (UDG)



Representation of UDG Configuration in Prespective

FIGURE 4: PDF of All Pavement Types at MnROAD.

Conclusion

This study chronicled the stepwise field improvement of noise and friction of the conventional grind, through the 2007 innovative grind, 2008 Ultimate grind, the 2009 pre-deployment and the 2010 (Duluth) Ultimate grind. The frictional benefits derived from transverse brooming appear to supersede the noise demerits obtained.

Both frictional and acoustic benefits have been derived from the diamond grinding improvements at MnROAD. The final configuration is the quietest pavement at MnROAD facility based on a probability density function representation of entire database and maintains high friction properties comparable to surfaces in the network with acceptable friction numbers.

The initiative to improve diamond grinding configuration for quietness without a forfeiture of frictional resistance has been successfully achieved.

References

1) Scofield L. (2011) Next Generation Concrete Surface. Final Report. ACPA Skokie IL

2) Izevbekhai, B.I., Wilde, W.J. (2011) Innovative Diamond Grinding on MnROAD Cells 7, 8, 9 and 37 (December 2010) Minnesota Department of Transportation. Report Number: 2011-05 URL Report/Product: http://www.lrrb.org/pdf/201105.pdf Assessed 1/21/2011

3) Izevbekhai B.I. (2011) Tire Pavement Interaction Noise of Concrete Pavements. Dissertation for Doctor of Philosophy in Civil Engineering. Department of Civil Engineering University of Minnesota.

4) Dick E.B., Izevbekhai, B.I., Casey T. (2010) Influence of Pavement on Traffic Noise – Statistical Pass-By Measurements of Traffic on Several Interstate Pavements MN/RC 2010-40 http://www.lrrb.org/pdf/2010-40.pdf Assessed 1/21/2011.

Additional Info

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